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Investing for Equity

USING AN ENVIRONMENTAL JUSTICE APPROACH TO GUIDE TRANSPORTATION & CLIMATE INVESTMENTS

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Transportation systems are crucial for the social and economic wellbeing of our society and our communities, and they are also major sources of environmental burden and inequity. The transportation sector is now the single largest source of climate-change inducing greenhouse gases (GHGs) in the U.S., and it is a major source of noxious and toxic pollution that directly degrades the health and safety of people, especially the most vulnerable amongst us. This study analyzed the distribution of transportation-related burdens (e.g., pollution) and benefits (e.g., transit access) across the six New England states and the relationship of these burdens and benefits to priority populations. The goal is to provide guidance on policy recommendations for transportation investments that promote social and environmental equity and mitigate or prevent disparities and inequities in access to benefits and exposure to burdens.

WHY FOCUS ON TRANSPORTATION?

The most important benefit of a transportation system is the access it provides to opportunity – economic, educational, health care, civic life, and simple freedom of movement.

Transportation systems are also major sources of environmental burden and inequity. The transportation sector is a major source of numerous forms of noxious and toxic pollution that directly degrade the health and safety of people, especially the most vulnerable amongst us.

To ensure that transportation investments promote equity and work to the benefit of communities that are disadvantaged, disproportionately burdened, and vulnerable, it is critical that such communities be systematically identified and assessed using an environmental justice (EJ) framework.

AN EJ APPROACH

This analysis was conducted using an environmental justice lens. As such, we aimed to identify places and populations whose health, safety, and well-being would benefit from targeted investments in a socially and environmentally just transition in our transportation infrastructure and systems. Any new investments in the transportation system should be seen as an opportunity to redress the significant and ongoing harm to communities that live with and are harmed by historic and persistent discrimination and neglect.

METHODS

The objectives of this analysis were to identify the geographic and demographic characteristics of communities that are:

1. overburdened by current transportation-related emissions and related externalities;
2. at increased risk for heat island effects, which is exacerbated by climate change and transportation related air pollution;
3. likely to experience evacuation risks and other transportation-related vulnerabilities resulting from flooding, extreme weather, and other climate stressors, and
4. underserved by current public transit infrastructure or services and overburdened by transportation related costs.

In these analyses, we used only public data that was available for the entire region in order to make the analysis and its conclusions comparable, transparent, and reproducible. Our geographic analyses are done at the census block group level wherever possible to provide the highest level of spatial resolution at which detailed demographic and environmental data are available. To provide consistency across the six New England states, we looked at a common set of demographic characteristics that are standard in environmental justice analysis in both academic research and by the federal government. Where available and relevant, we also used existing state policies defining environmental justice communities. For a detailed description of the methods and data used for each analysis, see the Technical Reports.

KEY FINDINGS

GEOGRAPHIC PATTERNS OF NOTE

Population centers experience high rates and frequencies of all types of burdens. Overall we find pollution exposure, heat risks, and climate risks are primarily found along major roadways (both interstate highways and state roads) as well as around major cities.

Less dense and rural areas experience frequent and significant transportation burdens. Rural and suburban areas experience high transportation cost burdens and have little or no access to alternative modes of transportation, including transit and walkable neighborhoods.

PRIORITY POPULATIONS

Limited English speaking households and people of color are the most affected group across most burden categories and across New England. With very little exception, limited English speaking households and people of color regularly experience the highest levels of exposure or risk for transportation-related emissions, high heat, and risk of flood or storm-related evacuation. People over the age of 64 have the lowest access to transit or walkable neighborhoods. They also experience the highest transportation cost burdens. Those under the age of 18 are most frequently resident in communities with the highest transportation cost burden.

Disparities in exposure continue to exist despite the overall improvement in regional air quality. We find priority populations experience exposure to air pollutants and air quality risks at significantly higher levels than the general population. This is the case regionally and within each state.

WHAT DID WE LOOK AT

We analyzed four measures of transportation adequacy:

- Access to public transit
- Frequency of transit service
- Walkability
- Transportation cost burden

Access to public transit was measured as physical distance from transit stops or routes. Lack of physical access to transit offers a simple measure for areas and people who lack access to public transit, specifically those living in rural areas of New England. The findings here should be met with caution for urban populations. Transit access is likely to appear high in dense urban areas whether or not such service is actually adequate or enables accessibility to desired destinations.

The specific distance threshold for access varied by type of transit option. The distance thresholds are based on widely used measures of access in the transportation literature. Table 1 shows how these were measured. For all states except New Hampshire and Maine, access to public transit was analyzed using publicly available geospatial data for routes and stops as distributed by their respective state GIS agencies. For New Hampshire and most of Maine, geospatial data for local bus routes were manually digitized using online route maps made available by their respective transit agencies.

We also analyzed the geographic distribution of unreasonable access to public transit by priority populations. The purpose of this was to determine the areas where transportation insecure populations do not have reasonable access to public transit.

Table 1: Measures for access to public transit

	Reasonable distance	Unreasonable distance
Bus	≤ ¼ mile (400 m)	≥ 1 mile
Rapid Transit	≤ ½ mile (800 m)	≥ 1 mile
Commuter Rail	≤ 3 miles (4800 m)	≥ 10 miles

Frequency of transit service was measured by headway. Headway describes the time between transit vehicle scheduled arrivals at a transit stop. Frequency of service was analyzed for all states whose data was available via General Transit Feed Specification (GTFS) datasets. GTFS is a common format for the digital dissemination of public transportation schedules and associated geographic information. While coverage was good in most New England states, not all transit agencies make their transit schedule data available via GTFS. For example, HARTransit serving Danbury, Connecticut has not yet made the transition to GTFS, although they are planning to. More problematically, only two out of 12 transit agencies in Maine and none in New Hampshire share data through GTFS. As a result, there are no analyses of frequency of service for these two states.

The analysis of frequency is based on scheduled time between arrivals. It does not take into account delays or situations where overcrowding prevents riders from boarding a vehicle.

Walkability was analyzed using the National Walkability Index, a nationwide geographic data resource produced by the U.S. Environmental Protection Agency. This index ranks census block groups across the country according to their relative walkability using a variety of measures.

Transportation cost burden was analyzed using the Location Affordability Index (LAI). This is a nationwide geographic data resource developed by the U.S. Department of Housing and Urban Development (HUD). The LAI provides an estimate of housing cost and transportation cost (both for public transit as well as personal vehicle) at the census tract level as a percentage of household income based on local cost of living estimates and modeled household types.

In addition, we also conducted case studies of paratransit and similar services in New Hampshire and Maine to understand the structure and distribution of non-fixed route services for certain priority populations in states with limited transit options.

WHO DID WE LOOK AT

We evaluated how these measures varied by priority populations. Priority populations evaluated include:

- Limited English speaking households
- People of color
- Low income persons
- Adults 25 years or older without a high school diploma
- Adults 18 or older living with disabilities
- Households without an available vehicle
- Those under the age of 18
- Children under the age of 5
- Adults over the age of 64

More information about the sources of data and the methods of analysis can be found in the Technical Report for Transportation Options for each state.

VARIATIONS ACROSS THE STATES

GEOGRAPHIC PATTERNS

Access to public transit

The proportion of each state's population with reasonable access to public transit varied significantly across states and modes of service. Bus service is available in all states and reasonable access ranged from 23% of the population in Maine to 55% of the population in Rhode Island. Table 2 shows the variation in bus access across New England.

Table 72 Reasonable access to bus service

	% of state's population
Connecticut	29%
Rhode Island	55%
Massachusetts	48%
Vermont	38%
New Hampshire	24%
Maine	23%

Rural areas uniformly have the least access to any form of public transit. Access to public transit is primarily concentrated in or around the urbanized areas of each state, with the best access in core cities.

Frequency of service

Average headways for bus service are generally quite long, frequently 1.5-2 hours between scheduled stops averaged over the course of a full day (6am – 9pm). They are shortest in the urbanized spaces, especially in major urban centers. Vermont had the longest headways, ranging from 75 minutes to 13 hours with an average of almost 5 hours. Public transit in Massachusetts showed the shortest headways of all states. Notably, rapid transit services had average headways that were considerably shorter than buses (9 minutes versus 96 minutes).

Walkability

Most states in New England have below average walkability scores. The exception is Rhode Island and Massachusetts which both have above average walkability scores.

There is wide variation in walkability within states. Rural areas and other places outside of cities have walkability scores that range from below average to least walkable. This is true even in Massachusetts and Rhode Island. Urbanized areas uniformly show high walkability.

Transportation cost burden

Transportation cost as a percentage of household income is generally high across New England. It is lowest in urban areas and core cities. Transportation cost burden is generally lowest in the southern New England states, which also are the most urbanized.

Five states have areas where the transportation cost burden is greater than the housing cost burden. Connecticut is the only state where this was not the case. Maine experiences the highest transportation cost burdens of all the states in New England. Table 3 summarizes the patterns found.

Table 3: Counts and distribution where transportation cost burden is greater than housing cost burden

	# census tracts	General locations
Connecticut	0	-
Rhode Island	1	Little Compton
Massachusetts	40	Central MA Western MA
Vermont	101	All across the state except the northwest corner from around Burlington north to the Canadian border
New Hampshire	35	Northern NH Western NH
Maine	202	All across the state except the southeast corner south of Brunswick

Priority populations living in rural areas are the most likely to have no reasonable access to transit, have unreasonably low frequency of transit service, live in the least walkable areas, and live in the areas with high transportation cost burdens.

PRIORITY POPULATIONS

Access and frequency

Those over the age of 64 have the least access to all forms of transit in terms of both proximity and frequency of service. Those under 18 are frequently closest to transit, most especially in the northern states. Households without a car frequently experience the longest headways for transit service.

Limited English speaking households generally have the highest access to public transit in terms of proximity and frequency of service. People of color, low income persons, and no car households also have generally high access to and frequency of public transit, although this varied by type of transit and across the states.

Walkability

In all but two states, priority populations live in areas with below average walkability scores. The exceptions are Rhode Island and Massachusetts where, on average, all priority populations live in areas with above average and even, in the case of Rhode Island, most walkable scores.

Those over the age of 64 and under the age of 18 live in areas with the lowest walkability scores. This is also true in Rhode Island and Massachusetts, although scores in these states are still above average.

Limited English speaking households generally live in areas with the highest walkability scores. No car households, low income persons, and people of color also frequently have among the highest scores, although this varies across states.

Transportation cost burden

Across New England, those over 64 frequently reside in communities with the highest cost burden. This is especially the case in Maine where, on average, those over 64 tend to reside in communities where the transportation cost burden would require over 30% of income for a moderate income household. In northern states, adults without a high school diploma and adults living with disabilities often have transportation cost burdens that are at or above average compared to their respective state average.

Limited English speaking households, people of color, and low income persons experience the lowest transportation cost burdens.

The analyses conducted here are most suitable for assessing transportation options in suburban and rural areas. Table 4 summarizes the general pattern of transportation options for priority populations who are most likely to live in those less dense areas.

Table 4: General patterns of transportation options across priority populations likely to live in less dense areas

	Low Income	No HS diploma	<18	<5	>64
CT	☹ rail frequency	☺	☺	☹ rail frequency	☹ bus frequency
RI	☺	☺	☺	☺	☹
MA	☹ rapid transit frequency	☹ rapid transit frequency	No pattern	☹ rapid transit access & frequency	☹ bus & commuter rail frequency
VT	☺	No pattern	☹	☹	☹[1]
NH	☺	☺	☹	☹[2]	No pattern
ME	☹ cost burden	☹[3]	☹	☺	☹

☹ Indicates that the population shows a pattern of lower than average access (either proximity or frequency), lower than average walkability scores, and higher than average transportation cost burdens
☺ Indicates that the population shows a pattern of better than average access (either proximity or frequency), higher than average walkability scores, and lower than average transportation cost burdens

[1] Shorter than average bus frequencies
[2] Better than average access
[3] Higher than average walkability scores

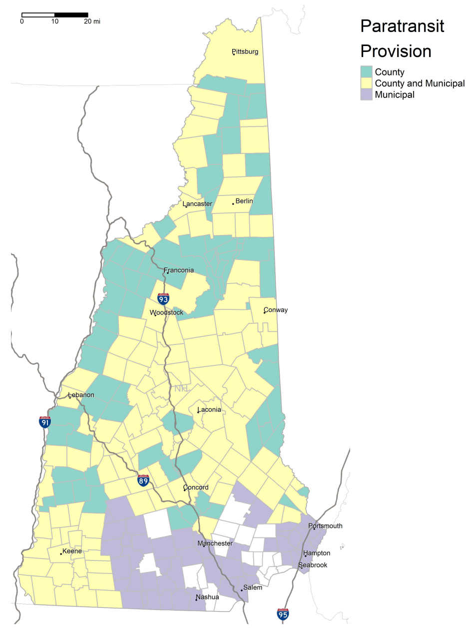
OTHER TRANSIT OPTIONS: ME & NH

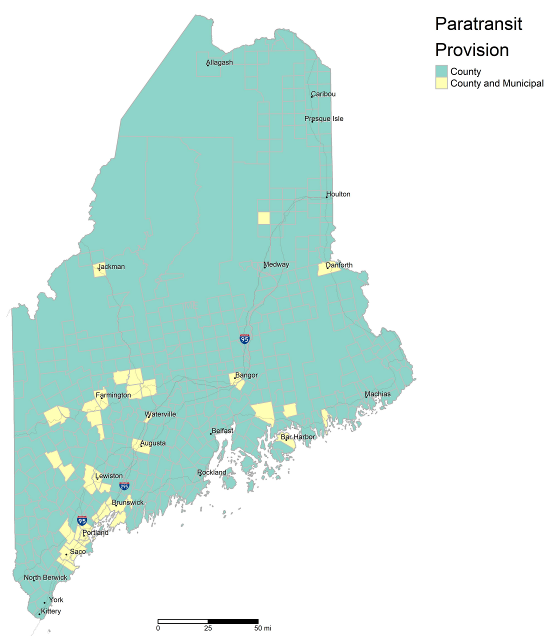
In order to better understand the experience of priority populations in rural states with limited transportation options, we performed case studies of paratransit and similar services for Maine and New Hampshire. These states have the lowest average levels of transit access in New England and the highest average transportation cost burdens. Maine and New Hampshire have very different options available for those who are transportation insecure, but there are two areas of similarity. First, **a significant portion of transit services are owned or operated by non-profit agencies as opposed to public or quasi-public agencies.**

Second, and related, is that **organizations that provide transportation options to those who are transportation insecure are themselves financially vulnerable because they are highly dependent on federal and state funding which has been historically inadequate and declining.** This funding sometimes comes in the form of direct grants as well as contracts from state agencies to serve specific populations. In addition, contributions from municipalities served by the systems or programs comprise an important portion of their budget and will shape which communities are served. Some organizations also rely on foundation grants and contributions from anchor organizations in different communities.

Maine's transportation systems, whether operated by non-profit or public agencies, provide a variety of services to a wide range of populations. Flex route pick-up services are common and primarily provided by non-profit transportation operators. There is wide variation in transportation options offered across municipalities even when operated by the same organization. The variation in services is usually related to the target population or community served. Among paratransit or flex route services offered, disability is frequently the only eligibility criterion in Maine. Although disability is a common characteristic of elderly people, age is infrequently included as a specific eligibility criterion.

Most transportation options in New Hampshire are organized by non-profit and/or religiously affiliated organizations. These are largely structured in one of two ways. The most common structure is transportation services operated as a program within a social service agency and is highly dependent on government or foundation grants as well as typical non-profit fundraising efforts. The other common structure is transportation services operating as a mutual aid effort relying on volunteer drivers, frequently using their own vehicles. These organizations are generally volunteer led with one or two paid staff managing a variety of service programs.





WHAT DID WE LOOK AT?

We looked at seven measures of air emission concentrations and risks:

- Particulate Matter ($PM_{2.5}$)
- Ozone (O_3)
- Diesel Particulate Matter (DPM)
- Air Toxics Cancer Risk
- Respiratory Hazards Risk
- Traffic Proximity and Volume
- On-road Carbon dioxide (CO_2)

These air pollutants and risks are strongly linked to transportation sources and are regarded by the U.S. Environmental Protection Agency (EPA) and environmental health experts as leading environmental threats to human health. With the exception of CO_2, all of the data was downloaded from the EPA's EJSCREEN data tool. The On-road CO_2 data came from the Database of Road Transportation Emissions (DARTE), a product of the NASA Carbon Monitoring System
(CMS).

In addition, we evaluated exposures and risk for the following priority populations:

- Limited English speaking households
- People of color
- Low income persons
- Adults 25 years or older without a high school diploma
- Children under the age of 5
- Adults over the age of 64

These variables are standard measures of populations that either have been historically marginalized and therefore subject to environmental injustice, or are populations sensitive to exposure to air emissions and risks from a public health perspective. The data comes from the Census Bureau's American Community Survey 5-year estimates for the period 2014 – 2018.

More information about the sources of data and the methods of analysis can be found in the Technical Report on Emissions.

NEW ENGLAND

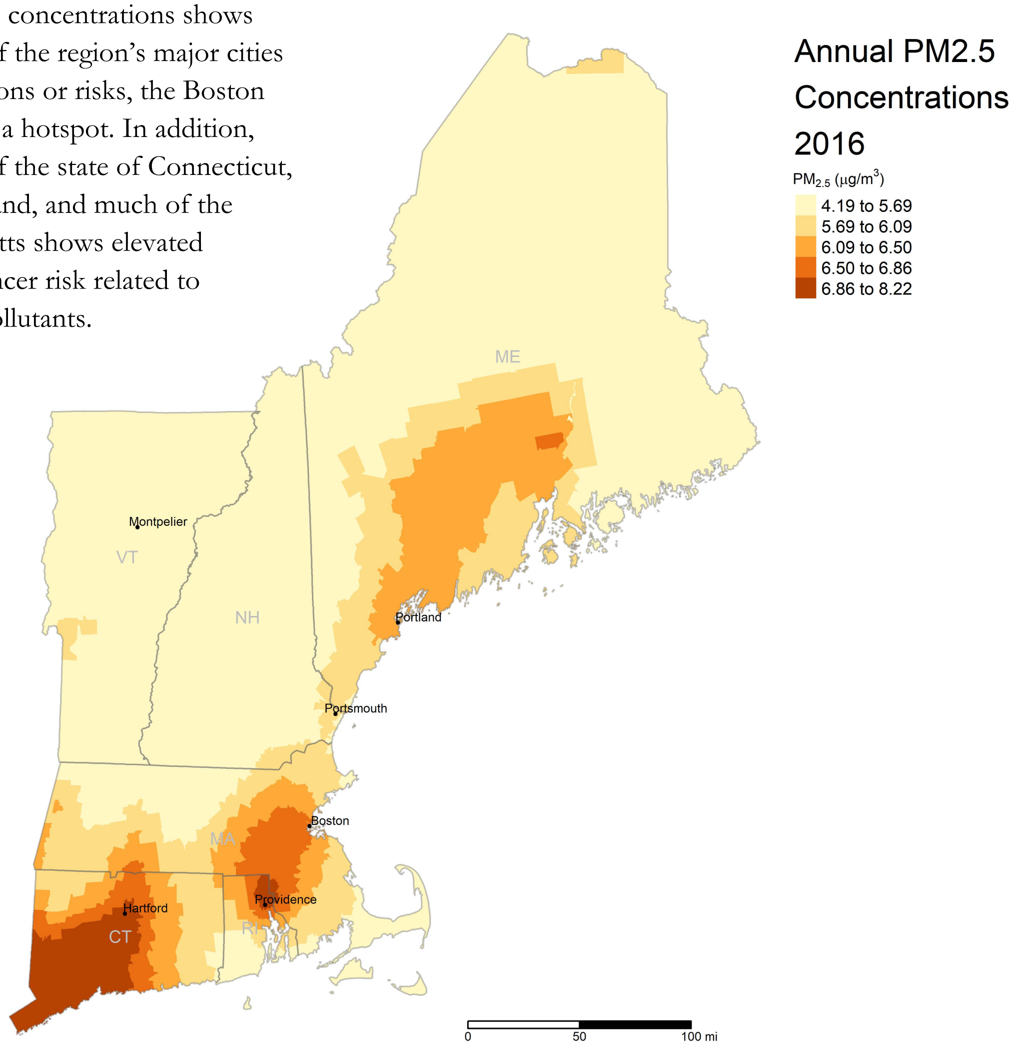
GEOGRAPHIC PATTERNS

With the exception of O_3 exceedances in Connecticut, air pollutant concentrations and risks do not exceed current federal regulatory standards in New England. However, there is significant variation in the geography of exposure and risk. **The highest exposure or risks were found in and around all of the major cities in New England, particularly in southern New England.** $PM_{2.5}$ and O_3 exhibited a clear southwest-to-northeast gradient, starting with high concentrations in southwest Connecticut and then generally decreasing as one travels north and east.

The distribution of DPM, air toxics risk, respiratory hazards risk, and traffic proximity all followed fairly close to major roadways (both interstate highways and state roads) and the major cities in the region. The distribution of On-road CO_2 concentrations shows the same pattern. While all of the region's major cities showed elevated concentrations or risks, the Boston region regularly shows up as a hotspot. In addition, for several measures, most of the state of Connecticut, the entire state of Rhode Island, and much of the southern half of Massachusetts shows elevated exposure to emissions or cancer risk related to exposure to hazardous air pollutants.

PRIORITY POPULATIONS

All priority populations were found to experience elevated levels of exposure or risks when compared to average concentrations or risks across New England. Consistent with the findings in most of the individual states, **limited English speaking households and people of color experienced the greatest exposure to all emissions and risks** analyzed here. Across New England, adults without a high school diploma also frequently experienced elevated rates of exposure or risk. People over the age of 64 almost universally experienced lower than regional average exposure or risk. The one exception to the latter is related to O_3 in which case people over 64 experience exposure that is equal to the region as a whole.



VARIATIONS ACROSS STATES

GEOGRAPHIC PATTERNS

Each state exhibits unique geographic patterns in the concentrations of emissions or risks. However**, most emissions and risks follow major roadways and concentrate around major cities.** Major cities are also where there has been the least change, or improvement, in concentrations of either $PM_{2.5}$ or O_3.

In general, DPM, air toxics cancer risk, respiratory hazard risk, traffic proximity and volume, and On-road CO_2 show very similar geographic patterns. There is some localized variation for individual states but the general geographic pattern is pretty stable across different emissions and risks.

Table 5 shows geographies that show up most frequently for elevated concentrations of emissions or elevated risks.

Table 5: Geographic distribution of elevated emissions and risks

	Most frequent occurrence	Hotspots
CT	Southwest CT Stamford to Hartford along I-95 to I-84	Along I-95 in southern CT from NY border to New Haven Along I-84 from Hartford to NY border
RI	Northeast RI around Providence	Providence
MA	Southern half of MA Within Rt 128 Springfield-Holyoke	Boston New Bedford Springfield/ Holyoke Lowell
VT	Southern half of VT Eastern part of state along I-91 from MA border to Brattleboro Western part of state at NY border along Rt 7 to I-89 Burlington area	Burlington Rutland
NH	Southeast NH along I-93 from Nashua to Concord and I-95 from Seabrook to Portsmouth Southwest corner along VT border south of I-89	Nashua Manchester Concord Portsmouth
ME	Along I-95/I-295 from Kittery to Bangor	Portland Bangor Lewiston Along I-95/I-295 from Kittery to Portland

PRIORITY POPULATIONS

Overall, **limited English speaking households and people of color are the most exposed to elevated emissions and risks.** When compared to their relevant state average, these two groups of people experience exposures 2 to 80 times higher than the lowest exposed groups. Low income persons also frequently show elevated exposures and risk. Those over the age of 64 are the least exposed to elevated emissions and risks.

Exposure to $PM_{2.5}$ and O_3 are distributed across priority populations differently than diesel particulate matter, air toxics risk, respiratory hazard risk, or traffic proximity and volume. For example, in New Hampshire and Maine, adults without a high school diploma and low income households are the least exposed to these emissions. Table 6 summarizes the general patterns of exposures and risks experienced across the region and by state.

Disparities in exposure continue to exist despite the overall improvement in regional air quality. Priority populations experience exposure to air pollutants and air quality risks at significantly higher levels than the general population. Disparities in exposure for limited English speaking households and people of color in particular were found regionally and within each state.

<table>
<tr><th colspan="10">Table 6: General patterns in exposure and risks across New England by population of concern</th></tr>
<tr><th></th><th colspan="2">Limited English HH</th><th colspan="2">People of Color</th><th colspan="2">Low Income</th><th>No HS diploma</th><th><5</th><th>>64</th></tr>
<tr><td>**New England**</td><td colspan="2">+</td><td colspan="2">+</td><td colspan="2">+[1]</td><td>+</td><td>+</td><td>-</td></tr>
<tr><td rowspan="2">**CT**</td><td colspan="2" rowspan="2">+</td><td colspan="2" rowspan="2">+</td><td>**CT**</td><td>**EPA**</td><td rowspan="2">+</td><td rowspan="2">+</td><td rowspan="2">-</td></tr>
<tr><td>+</td><td>+</td></tr>
<tr><td rowspan="2">**RI**</td><td colspan="2" rowspan="2">+</td><td>**RI**</td><td>**EPA**</td><td>**RI**</td><td>**EPA**</td><td rowspan="2">+</td><td rowspan="2">+</td><td rowspan="2">-[1]</td></tr>
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<tr><td rowspan="2">**MA**</td><td>**MA**</td><td>**EPA**</td><td>**MA**</td><td>**EPA**</td><td>**MA**</td><td>**EPA**</td><td rowspan="2">+[2]</td><td rowspan="2">+[3]</td><td rowspan="2">-[1]</td></tr>
<tr><td>+[1]</td><td>+[1]</td><td>+[1]</td><td>+[1]</td><td>No pattern</td><td>+[1,2]</td></tr>
<tr><td>**VT**</td><td colspan="2">+</td><td colspan="2">+</td><td colspan="2">+[1, 2]</td><td>+[1]</td><td>-[4]</td><td>-[4]</td></tr>
<tr><td>**NH**</td><td colspan="2">+</td><td colspan="2">+</td><td colspan="2">+[1, 2]</td><td>+</td><td>+[5]</td><td>-</td></tr>
<tr><td>**ME**</td><td colspan="2">+</td><td colspan="2">+</td><td colspan="2">+[1]</td><td>No pattern</td><td>+</td><td>No pattern</td></tr>
</table>

NOTE: CT, RI, and MA have their own definitions of priority or EJ populations. For those states, we evaluated both the state specific and EPA defined populations wherever relevant.

+ Indicates that the population shows a pattern of higher than regional or state averages in exposure or risk
- Indicates that the population shows a pattern of lower than regional or state averages in exposure or risk
[1] O_3 shows opposite pattern
[2] $PM_{2.5}$ shows opposite pattern
[3] DPM shows opposite pattern
[4] Air toxics risk and Respiratory hazards risk shows opposite pattern
[5] Traffic shows opposite pattern

WHAT DID WE LOOK AT?

We evaluated heat risk based on Land Surface Temperature (LST) data derived from NASA's Moderate-resolution Imaging Spectroradiometer (MODIS) satellite sensor. LST is not the same as ambient air temperature as recorded by a weather station thermometer, but repeated studies have shown that the two are highly correlated. LST is frequently used as a proxy measure of heat risk that allows consistent and simultaneous coverage of large areas at relatively high spatial resolution. We obtained data for an 8-day period from July 28 to August 4, 2019, which was the tail-end of a historically warm month for the region. From this data, we evaluated the following:

- Average day and night LST (11:48 am – 2pm and 12 am – 3:06 am)
- Average daytime LST (11:48 am – 2 pm)
- Average nighttime LST (12 am – 3:06 am)

For each of these measures of temperature, we also analyzed the urban heat island effect; the difference between the local temperature of each block group and the rural average temperature for the region or state.

High air temperatures pose a significant health and safety risk. Heat is the leading cause of weather-related mortality in the U.S. – more than floods, hurricanes, and other forms of severe weather. The risk is particularly acute for people with pre-existing health complications, as well as those unable to avoid exposure or find relief. This risk is expected to increase as the climate warms. As with emissions, we looked at how exposure to heat risk varied by priority populations. We used the same priority populations as found in the emissions analysis.

Because the risk of heat-related illness is a combination of both exposure and vulnerability, it is important to consider where these factors come together. For each LST variable, we identified census block groups that exhibited LSTs and percentages of priority populations in the top quintile (i.e., 80th percentile). In other words, this analysis identified those areas where high percentages of priority populations are living in areas exhibiting the highest temperatures. Maps and tables of this data can be found in the Technical Report for Heat Risk for each state.

NEW ENGLAND

GEOGRAPHIC PATTERNS

Higher temperature areas are regularly found in the urbanized parts of the region. These high heat areas frequently follow the major roadways across New England.

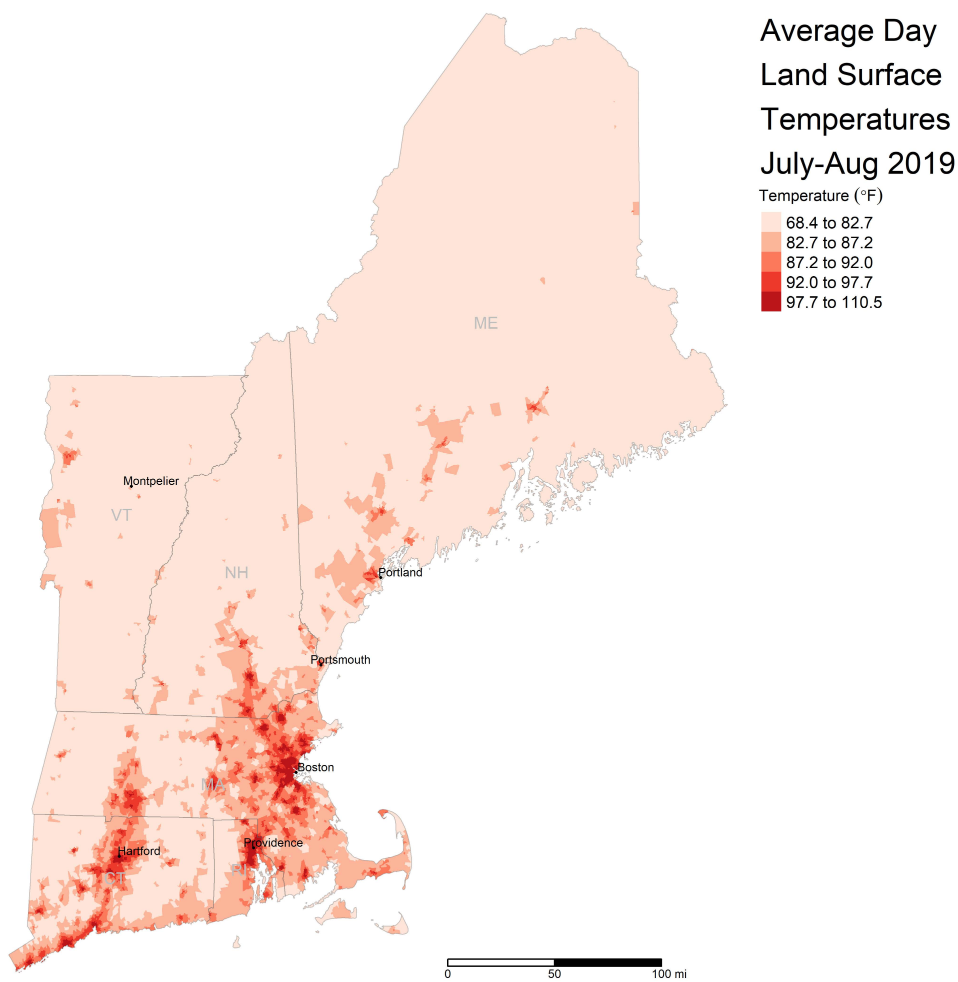
Noteworthy geographic patterns of high heat risk includes the areas:

- Along I-95 from Stamford, CT to New Haven, CT
- Along I-91 from New Haven, CT to Springfield, MA
- Providence, RI
- Boston region
- Southern New Hampshire through Manchester, NH
- Portland, ME

Temperatures are generally highest in southern New England states. Temperatures in Connecticut, Rhode Island, and Massachusetts are significantly higher than in northern New England states. However, there are pockets of high daytime temperatures in less urban areas in Maine.

Most notable is that high nighttime temperatures are found throughout the region, including areas outside the urban core. This includes the Cape Cod area in Massachusetts and northwest Vermont.

The urban heat island effect is most pronounced in Hartford, CT, Providence, RI, and Boston, MA. Southern New Hampshire also exhibits urban heat islands for both daytime and nighttime temperature.



VARIATIONS ACROSS STATES

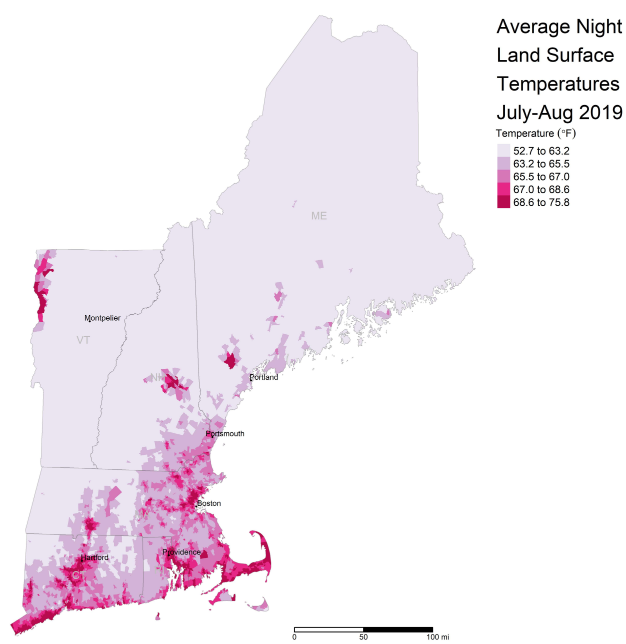
GEOGRAPHIC PATTERNS

Each state exhibits a unique geographic distribution of heat risks. In all states, higher temperatures are found in the major cities and their immediate surrounding regions. Variation in the geographic pattern is found principally with average nighttime temperatures. High average nighttime temperatures are spread more widely in each state and are frequently found in less urban and rural places. This can be seen in Table 7 which compares high temperature outliers by geography for each time period.

Table 7: Geographic distribution of heat risk outliers

	Day-Night	Daytime	Nighttime
CT	Hartford	Hartford Bridgeport	Hartford New Britain
RI	Providence Pawtucket	Providence	Pawtucket
MA	Boston Everett	Boston Everett	Attleboro Boston Malden New Bedford Yarmouth
VT	Burlington	Burlington Rutland South Burlington	Burlington Colchester South Burlington
NH	Manchester Nashua	Manchester Nashua	Gilford Laconia Manchester Moultonborough Tuftenboro Wolfeboro
ME	Lewiston Portland	Lewiston Portland Bangor	Bath Casco Kittery Raymond Saco South Portland Standish Windham

Rhode Island and New Hampshire frequently show the highest urban heat island effects. Average heat island effects are often much greater than what is seen in the larger and more populous states (e.g., Connecticut and Massachusetts). Vermont shows the lowest temperatures and smallest heat island effects.



PRIORITY POPULATIONS

Limited English speaking households and people of color are the groups most exposed to elevated temperatures and urban heat island effects, with only a couple of exceptions. In Connecticut and Rhode Island, low income households are also in the top exposure groups.

Those over the age of 64, with only one minor exception, experience lower than average temperatures compared to the state or regional average. The exception is in Maine where those over 64 experience slightly above state average nighttime temperatures.

Limited English speaking households and people of color also frequently experience urban heat island effects that are twice that experienced by those over 64. In Vermont, limited English speaking households experience nighttime urban heat effects that are almost four times greater than those over 64.

Priority populations who live in areas that experience the most elevated temperatures (i.e., in the top quintile of temperatures) are often a significant proportion of the population in those areas. On average, between 25 to 50% of limited English speaking households or people of color live in the highest temperature block groups.

One notable pattern is that the temperatures experienced by adults without a high school diploma frequently follow low income households. In short, the average temperatures experienced by these two groups are often either the same or vary by less than 1°F.

Table 8 shows the general patterns of heat risk across priority populations in each of the states and New England as a whole.

Table 8: General patterns in heat exposure risks across New England by population of concern

	Limited English HH	People of Color	Low Income	No HS diploma	<5	>64
New England	+	+	+	+	+	-
CT	+	+	CT: + / EPA: +	+	+	-
RI	+	RI: + / EPA: +	RI: + / EPA: +	+	+	-
MA	MA: + / EPA: +	MA: + / EPA: +	MA: + / EPA: +	+	+	-
VT	+	+	+	Same as state average	Same as state average	-
NH	+	+	+	+	+	-
ME	+	+	+[1]	+[1]	+[2]	-[2]

NOTE: CT, RI, and MA have their own definitions of priority or EJ populations. For those states, we evaluated both the state specific and EPA defined populations wherever relevant.

\+ Indicates that the population shows a pattern of higher than regional or state averages in exposure to heat risk
- Indicates that the population shows a pattern of lower than regional or state averages in exposure to heat risk

[1] Shows less than average nighttime temperatures
[2] Shows above average nighttime temperatures

WHAT DID WE LOOK AT?

We looked at two measures of evacuation risks in this analysis: flood hazard exposure risk and hurricane storm surge evacuation or exposure risk.

Flood hazard exposure was based on the Federal Emergency Management Agency's (FEMA) National Flood Hazard Layer (NFHL) which identifies areas subject to floods with an Annual Exceedance Probability (AEP) of 1% (also known as the "100 year" flood) and areas subject to floods with an AEP of 0.2% (also known as the "500 year" flood). Areas within the 0.2% AEP are not currently regulated. These areas are nevertheless subject to flood risk under more extreme storms and are therefore subject to evacuation.

Hurricane evacuation or storm surge risk was based on storm surge modeling by the National Weather Service's National Hurricane Center. This data uses the SLOSH model to simulate storm surge from tropical cyclones. In this analysis, we evaluated hurricane evacuation risks from category 1 and 2 storms (called "Zone A") separately from category 3 and 4 storms (called "Zone B").

It is important to note that flood risk for large portions of Massachusetts, Vermont, New Hampshire, and Maine are not currently mapped through FEMA's NFHL. Consequently, these results should be viewed as conservative estimates of the distribution of evacuation risk from flooding. Similarly, hurricane evacuation risk underestimates the risk from hurricanes since it is based solely on coastal storm surge and does not account for inland flooding due to intense rainfall.

For this analysis, we looked at several priority populations, some of which vary from previous analyses (*indicated by italics*):

- Limited English speaking households
- People of color
- Low income persons
- Adults with less than a high school education
- *Adults 18 or older living with disabilities*
- *Households without an available vehicle*
- *Those under the age of 18*
- Children under the age of 5
- Adults over the age of 64

The additional variables were included as they are related to mobility. Evacuation requires the ability to transport oneself to a safer location. These variables are standard measures of populations that are transit dependent and at risk for being unable to evacuate during an emergency. The data comes from the Census Bureau's American Community Survey 5-year estimates for the period 2014 – 2018.

More information about the sources of data and the methods of analysis can be found in the Technical Report for Evacuation Risk for each state.

NEW ENGLAND

GEOGRAPHIC PATTERNS

Across New England, 3.7% of land area is subject to flood risks, primarily to the 1% AEP. Approximately 6% of the region's population live in areas subject to any flood risk. Flood risks are concentrated in the southern parts of New England, although many rural areas in the northern New England states are also prone to flood risk. Rhode Island has the largest proportion of its population subject to flood evacuation risks (10% of the state's total population).

Areas subject to hurricane evacuation risk account for 1.7% of the land area in New England, primarily to hurricane categories of 2 or lower. Approximately 10% of the population of New England lives in areas subject to hurricane evacuation risk. Massachusetts has the largest proportion of its population subject to hurricane evacuation risks (14% of the state's total population).

Hurricane evacuation zones are found all along the coast of New England from Stamford, Connecticut to Portland, Maine. There are portions of Maine's northern coast that are subject to hurricane evacuation but these areas are not heavily populated.

PRIORITY POPULATIONS

Households without access to a vehicle and limited English speaking households are most exposed to hurricane evacuation risks. These high exposure groups were primarily found in southern New England.

Those under 18 years were the least exposed to evacuation risks. Unlike the previous analyses, those over the age of 64 varied in their risk to evacuation. The proportion of those over 64 at risk for flood evacuation was higher than the regional average, but it was slightly lower than the regional average for hurricane evacuation risks.

VARIATIONS ACROSS THE STATES

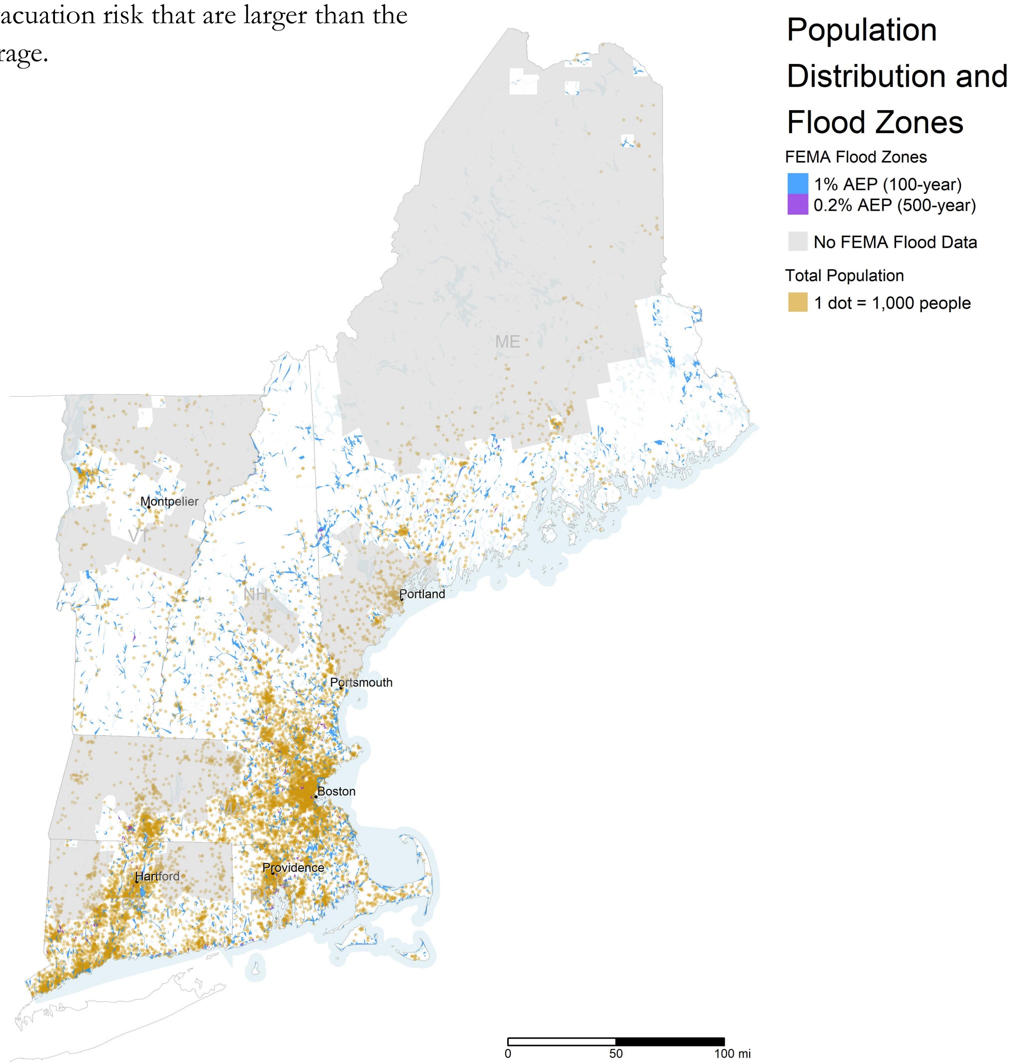
GEOGRAPHIC PATTERNS

In general, the amount of land area subject to flood risk is greater than the land area subject to hurricane evacuation risk. This is expected as hurricane storm surge risks are a coastal phenomenon. Therefore, the relative magnitude of hurricane evacuation risk is largely a function of the extent or length of coastline. New Hampshire has a very small coastline relative to the area of the state, which directly affects the hurricane evacuation risks found there. Vermont does not have a coastline and therefore is not subject to hurricane evacuation risks based on the models used here.

Connecticut, Rhode Island, and New Hampshire show land areas affected by flooding evacuation risk that are larger than the regional average. Connecticut, Rhode Island, and Massachusetts show land areas affected by hurricane evacuation risk that are larger than the regional average.

Although flood risks cover a greater area of land than areas subject to hurricane evacuation risk in states with a coastline, greater proportions of the population are subject to hurricane evacuation risk. The exception to the latter is New Hampshire.

Inland areas are not free of flood or hurricane evacuation risk. Much of the 0.2% AEP flooding is found inland along riverbanks and other inland water bodies. Zone B inundation (i.e., from category 3 and 4 hurricanes) also regularly reaches far inland. This is especially the case in New Hampshire and Maine. For example, there is Zone B inundation risk found near Bangor, Maine which is approximately 50 miles inland from the coast.



PRIORITY POPULATIONS

Households without a vehicle are universally the most at risk for living in an area subject to either flood or hurricane evacuation risks. Those under the age of 18 are regularly the least exposed to evacuation risks.

Adults living with disabilities are also frequently found to have the most elevated exposures to flood evacuation risks relative to their state's population.

Limited English speaking households are frequently disproportionately exposed to hurricane evacuation risks. Those over the age of 64 are also often the least exposed to hurricane evacuation risks with the exception of Rhode Island and New Hampshire where they are the most exposed to hurricane evacuation risks.

Some priority populations do not show a regular pattern of risk between flooding and hurricane evacuation. When this occurs, most often, the population experiences elevated flooding risks and lower than average hurricane evacuation risks.

It should be noted that a large proportion of southern Maine has not been mapped for flooding risk in FEMA's NFHL. This is also the portion of Maine that is the most populated. Consequently, our results are at best conservative assessments of flood risk exposure experienced by priority populations.

Table 9 shows the general patterns of evacuation risk across priority populations in each of the states and New England as a whole

<table>
<tr><th colspan="10">Table 9: General patterns in evacuation risks to flood and hurricane across New England by population of concern</th></tr>
<tr><th>Flood Hazards</th><th>Limited English HH</th><th>People of Color</th><th>Low Income</th><th>No HS diploma</th><th>Disabled</th><th>No Car HH</th><th><18</th><th><5</th><th>>64</th></tr>
<tr><td rowspan="2">New England</td><td rowspan="2">+</td><td rowspan="2">+</td><td rowspan="2">+</td><td rowspan="2">+</td><td>+flood</td><td rowspan="2">+</td><td rowspan="2">-</td><td>same as region</td><td>+flood</td></tr>
<tr><td>-hurricane</td><td>-hurricane</td><td>-hurricane</td></tr>
<tr><td>CT</td><td>+</td><td>+</td><td>+</td><td>+</td><td>+</td><td>+</td><td>-</td><td>+</td><td>-</td></tr>
<tr><td>RI</td><td>-</td><td>-</td><td>-</td><td>-</td><td>+</td><td>+</td><td>-</td><td>-</td><td>+</td></tr>
<tr><td rowspan="2">MA</td><td rowspan="2">+</td><td rowspan="2">+</td><td rowspan="2">+</td><td rowspan="2">+</td><td>+flood</td><td rowspan="2">+</td><td rowspan="2">-</td><td>+flood</td><td>+flood</td></tr>
<tr><td>-hurricane</td><td>-hurricane</td><td>-hurricane</td></tr>
<tr><td>VT</td><td>-</td><td>+</td><td>+</td><td>+</td><td>+</td><td>+</td><td>-</td><td>-</td><td>+</td></tr>
<tr><td rowspan="2">NH</td><td rowspan="2">-</td><td rowspan="2">-</td><td>+flood</td><td>+flood</td><td>+flood</td><td rowspan="2">+</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">+</td></tr>
<tr><td>-hurricane</td><td>-hurricane</td><td>-hurricane</td></tr>
<tr><td rowspan="2">ME</td><td>-flood</td><td>-flood</td><td>+flood</td><td>+flood</td><td rowspan="2">+</td><td rowspan="2">+</td><td>same as region</td><td>same as region</td><td rowspan="2">+</td></tr>
<tr><td>+hurricane</td><td>+hurricane</td><td>-hurricane</td><td>-hurricane</td><td>-hurricane</td><td>-hurricane</td></tr>
<tr><td colspan="10">+ Indicates that the population shows a pattern of higher than regional or state averages in exposure to evacuation risk
- Indicates that the population shows a pattern of lower than regional or state averages in exposure to evacuation risk</td></tr>
</table>

Investing for Equity

Introduction

INTRODUCTION

Transportation systems are crucial for the social and economic wellbeing of our society and our communities, but they are also major sources of environmental burden and inequity. The transportation sector is a major source of numerous forms of noxious and toxic pollution that directly degrade the health and safety of people, especially the most vulnerable amongst us. It is also now the single largest source of climate-change inducing greenhouse gases (GHGs) in the U.S.[1]

The most important benefit of a transportation system is the access it provides to opportunity – economic, educational, health care, civic life, and simple freedom of movement.[2] Lack of adequate access to transportation hinders these opportunities. Accessibility – the ease or difficulty with which people can reach places they want or need to get to – is an important determinant of economic, social, and physical wellbeing. Places (i.e., neighborhoods, municipalities, metropolitan regions) with efficient and diverse options for transportation (i.e., auto, transit, biking, walking) are among the most desirable in the country. And although these places are often also more expensive in terms of housing, the relative cost of transportation is actually lower in places with diverse transportation mode options. Access to good transportation systems supports economic opportunity and better quality of life.

Access to transportation and its benefits is uneven and unequal. Most households in the U.S. have access to a car and rely on a private automobile as the primary mode of transportation. The primacy of the private automobile is reflected in the outsized federal and state investments in transportation infrastructure that subsidizes private vehicle ownership (i.e., roads and highways), as well as the urban and suburban sprawl it supports. Private car ownership favors wealthier households, and it represents a significant cost burden on lower income households, who are less likely to have access to a car and its benefits. This disparity plays out ethnically and racially as well. People of color, particularly Native American, immigrant, and black households, are least likely to have access to a car when compared to white households.[3] Racial and ethnic disparities in car access are due in part to generational wealth gaps as a consequence of economic dispossession and residential segregation, as well as persistent racially discriminatory pricing for auto loans and car insurance that make car ownership more costly.[4] Private automobile dependence for mobility is also problematic for a wide range of individuals who are simply not physically or legally able to drive: adults with a serious disability, the elderly, children or young adults below the legal driving age, and those who do not have a driver's license. Disparities in access to private automobiles – the primary mode of transportation – means that certain communities and populations are systematically disadvantaged, particularly when sprawling development and distance make car access essential for mobility.

Public transit (i.e., bus, rail, and demand-response or paratransit services) provides vital transportation infrastructure which meets the transportation needs of lower income persons, people of color, and individuals without the ability to drive. It also offers alternatives to private auto usage that mitigate road congestion and traffic-related air pollution. Although public transit represents a smaller share of overall transportation usage (approximately 14% of workers in the Northeast use public transit), it nevertheless serves the mobility needs of millions of people every day (over 3.9 million workers in the Northeast).[5] Public transit is particularly important for those who are transit-dependent who rely on transit for access to jobs, school, shopping, health care, and social connection.[6]

However, the accessibility benefits of public transit are uneven, both in terms of physical availability and in the quality of service. Public transit's primary constraint is the low level of funding. It represents a significantly smaller proportion of public investment compared to road and highway spending to support private automobiles. In 2017, public transit expenditures represented 19% of transportation-related government expenditures in the U.S., compared to 63% for highways.[7] The disparity in modal investment is reflected in the inferior accessibility for those who are transit dependent compared to those with private autos – dramatically longer travel times for the same distances and destinations, and access to fewer economic and other opportunities.[8]

Moreover, while private automobile users benefit from generally free or low cost access to unlimited road and highway usage, public transit users must pay for each trip, and transit systems are dependent on rider revenue for significant portions of their often precarious operating and capital budgets.[9] Residents of larger urban areas generally have access to more extensive and frequent public transit, but the quality and accessibility varies significantly by specific mode (e.g., bus versus rapid transit versus rail), and from community to community. Rural transit systems, while representing a smaller share of overall transit trips, are critical for connecting individuals with needed services, especially for the elderly and disabled.

Disparities in our transportation system are particularly apparent in the distribution of transportation-related air pollution and related burdens. People of color and lower income households are disproportionately exposed to transportation-related emissions throughout the Northeast and Mid-Atlantic according to recent work by the Union of Concerned Scientists.[10] This disproportionate exposure is ironic given that these same populations consume less energy and drive less, are less likely to own a car, more likely to rely on public transit, and thus are least responsible for these emissions.[11]

Moreover, these same populations are especially vulnerable to the effects of air pollution. Air pollutants continue to be a significant cause of excess morbidity and mortality.[12] Fine particulate matter ($PM_{2.5}$) has been clearly linked to asthma, which afflicts low income persons and children of color at higher rates than other populations.[13] Disproportionate exposure to transportation-related emissions is related to a history of residential segregation that confined communities of color to dense urban neighborhoods next to high traffic corridors and noxious industry.[14]

In addition to the direct impacts of exposure, however, transportation-related emissions also contribute to the wider scale problem of climate change through emissions of carbon dioxide (CO_2) and other greenhouse gases (GHGs). Transportation emissions account for approximately one-third of all GHG emissions in the U.S. – greater than any other economic sector. While CO_2 emissions do not threaten human health through direct exposure, the effects of climate change do. From increasing air temperatures and heat waves to extreme weather and flooding, the effects of climate change are projected to take their greatest toll on the most vulnerable people globally and domestically. Efforts to mitigate traffic-related pollution and climate change need to account for differential exposures and vulnerabilities and the social inequalities in which these are embedded.

In order to ensure that transportation investments promote equity and work to the benefit of communities that are disadvantaged, disproportionately burdened, and vulnerable, it is critical that such communities be systematically identified and assessed using an environmental justice framework.

AN ENVIRONMENTAL JUSTICE FRAMEWORK

Environmental justice is based on the recognition that specific communities have long been denied two basic rights because of historic and persistent discrimination, marginalization, and disenfranchisement:

- the right to a healthy, safe, and nurturing environment (broadly defined), and
- the right to have a voice in environmental decisions that affect them.

The focus of an environmental justice perspective is on:

- those communities that have been, and continue to be, disproportionately burdened by pollution and other environmental insults,
- those who are especially vulnerable to risks and threats,
- those who have been unfairly excluded from enjoying environmental benefits, and
- those who have been denied a voice in decision making about their environments – where they live, work, and play.[15]

The movement for environmental justice has focused on a variety of issues and burdens ranging from the siting of trash transfer stations to the lack of access to open space. Regardless of the specific focus, the movement, and resulting government policies, have been largely consistent in prioritizing issues confronting communities of color and low-income communities. In response to widespread and growing evidence of persistent and systematic inequalities in exposure to a range of environmental burdens beginning in the early 1980s, primarily along the fault lines of race and class, federal and state governments have promulgated policies to explicitly address the issue of environmental justice.

One of the earliest of these was President Clinton's Executive Order 12898 in 1994 which made addressing disproportionate impacts on people of color and low income persons the responsibility of each federal agency.[16] Although the federal government has not led states or municipalities in developing environmental justice policies, it has nevertheless exerted significant influence as a template for environmental justice policy across the country.[17] The last comprehensive survey of state environmental justice policies, published in 2010 by the Public Law Research Institute and American Bar Association, found some form of environmental justice policy or program in 38 of the 50 states and the District of Columbia.[18] While the ways in which environmental justice was implemented were quite diverse, the most common element was a focus on redressing environmental racism and protecting communities of color and low-income communities.

A more recent study of select states' utilization of environmental justice screening tools found race and income to be explicit criteria in six out of ten states with established policies identifying environmental justice communities.[19] Whether or not these state EJ policies and programs have performed as promised, this focus on race and class is consistent with the founding principles for environmental justice as articulated by the First National People of Color Environmental Leadership Summit held on October 24-27, 1991, in Washington DC.[20]

One of the key tasks of environmental justice research and governance is identifying on whom and where attention should be focused. Experience and research have shown that disproportionate environmental burdens and vulnerabilities tend to align along social fault lines – race, class, education, gender, age, disability, etc.[21] This may because of intentional discrimination in the past or today, but it is almost always embedded within structural forces of racism, discrimination, or inequality that privilege the dominant majority at the expense of other groups. An environmental justice framework is rooted in a contextual understanding of environmental injustice as a legacy and consequence of social and political oppression that continue to operate.

These structural forces include residential segregation which maintains concentrations of both privilege and marginalization. Discrimination in mortgage lending and in renting limits where some groups can live. Discrimination in employment constrains income and economic mobility as well as opportunities for education, both of which are tied to generational wealth inequality. Segregated neighborhoods also place barriers on participation in civic life – a key concern in many environmental justice policies. The cumulative effect of these structural forces includes compromised health as a result of inadequate nutrition over a lifetime, inadequate access to health care, the stresses of poverty and discrimination, and excessive exposure to environmental stressors.

Living in places with disproportionate and cumulative burdens of pollution are certainly one manifestation of these structural inequities. As our understanding of environmental risks, environmental injustice, and their social intersections grow, so does the list of burdens, threats, risks, and insults. What we know now better than ever is that all of these operate through various mechanisms of structural discrimination and inequality.[22]

It is tempting to focus more strictly on identifying the geography of environmental burdens first, apart from any particular group of people that might be affected.[23] The attraction to such an approach is that it seems to offer an objective and de-politicized method to identifying places with the highest environmental health threat. Certainly, we want to identify areas that suffer from excessive or cumulative burdens. However, one practical problem with such an approach is that the possible list of environmental burdens to study is limitless. There is no definitive list of environmental burdens to prioritize.

More importantly, environmental health is not the same as environmental justice. Environmental justice is fundamentally rooted in addressing environmental insults that are part of larger problem of structural inequality and discrimination. If two communities face the same level of environmental burden, it matters if one is wealthier and White and the other is not. Environmental justice is concerned with when and how environmental insults affect socially marginalized groups for two basic reasons: 1) social inequities exacerbate environmental burdens and vice versa; and 2) such environmental insults represent another form of discrimination or oppression. Environmental justice is concerned, among many issues, with environmental health. But it is rooted in concerns of social justice, and therefore it cannot ignore the historical, social, and political context in which certain groups of people are affected.

For these reasons, an environmental justice analysis begins with key demographic characteristics as the lens through which we investigate myriad forms of inequity in the distribution of environmental burdens and benefits, in exposure and vulnerability, and in processes of participation and decision making. A demographics-first environmental justice approach can be applied to any type of environmental issue and it is compatible with cumulative burdens analyses which have drawn increasing attention.

OUR APPROACH

PROJECT GOALS

The goal of this project was to use an environmental justice framework to identify communities or places in New England where investments are warranted in order to address inequitable distributions of transportation-related environmental burdens or risks, as well as inequitable deficiencies in access to transportation-related benefits and infrastructure.

OBJECTIVES

The specific objectives of this analysis were to identify the geographic and demographic characteristics of communities that are:

1. underserved by transportation options or overburdened by transportation costs;
2. overburdened by transportation-related emissions and related externalities;
3. at greater risk for heat island effects, which exacerbates transportation related air pollution; and
4. likely to experience evacuation risks and other transportation-related vulnerabilities due to flooding, extreme weather, and other climate stressors.

The demographic focus of this analysis was on priority populations as compared to the general population in the six New England states: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont. For the purposes of this analysis, priority populations included the following:

- Persons of color (i.e., persons who are of Hispanic ethnicity or racially not White)
- Low income persons
- Limited English speaking households
- Adults 25 years or older without a high school diploma
- Children under the age of 5
- Adults over the age of 64*
- Adults 18 years or older living with disabilities*
- Households without an available vehicle*
- Persons under the age of 18*

These demographic characteristics are standard in analyses of environmental justice or transportation dependency (as indicated by the *) in both academic research and federal and state policy or programs aimed at environmental justice. In addition to using standard measures for each group as defined in federal policy, we also included state specific definitions of "environmental justice community/ group" or "community/ group of concern" wherever relevant. Table 1 in the Appendix identifies demographic characteristics used by the US EPA in its EJSCREEN tool and state governments for identifying environmental justice communities or communities of concern.[24]

RESEARCH QUESTIONS

Appendix A provides the details of data sources and the analytic approach. Additional details can be found in the technical reports.

1. Identify the geographic and demographic characteristics of communities that are underserved by transportation options or overburdened by transportation costs

To identify communities that are underserved by public transit and other transportation options, we analyzed four aspects of transportation adequacy: access to public transit, frequency of transit service, neighborhood walkability, and transportation cost burden.

Access to transit: The most basic assessment of transit access is whether or not people have simple physical access to transit service. A resident is considered to have access if they are within one-quarter mile of a bus stop, one-half mile of a rapid transit (i.e. subway or light rail) station, and up to three miles of a commuter rail station or Park and Ride lot. This geographic definition of access is consistent with FTA Circular 4702.1B Title VI Requirements and Guidelines for Federal Transit Administration Recipients, Chapter IV-14, as well as decades of research on transit behavior, and the judgment of most planners and transit researchers.[25] To be clear, good physical access does not necessarily imply adequate accessibility, since it is not clear if the nearest transit stops offer service to desired destinations. In addition, transit access is likely to appear high in dense urban areas whether or not such service is actually adequate or enables accessibility to employment or other necessary destinations. Nevertheless, without reasonable physical access, transit usage is impossible. Lack of basic physical access to transit offers a simple measure of areas and groups of people who lack access to even the most basic benefits of public transit. As such, this approach is well suited to assess access for less densely populated areas, which provides important information for large parts of New England.

Frequency of Transit Service: For those who have access to transit, the quality of access to public transit can be assessed by the level or frequency of service, which is measured by "headway." Headway describes the time between scheduled transit vehicle arrivals at a transit stop. For example, a bus route with a 15-minute headway would mean that the bus is scheduled to arrive at a given stop four times an hour (its frequency), or once every 15 minutes. Transit headways are affected by the scheduled frequency of service, the number of vehicles on a given route, traffic delays, and dispatch management of vehicle spacing.[26]

Headways are significant because they affect the desirability and useability of transit service.[27] For those who are transit dependent, frequency of service can affect the quality of life and economic opportunities available to transit riders. Headways can affect:

- average wait times
- the amount of planning and preparation needed to use transit and stay on schedule
- the amount of time lost when transit schedules do not directly conform to work, school, or activity schedules
- the time penalty for missing a train or bus
- public use or support of transit

This analysis of frequency of service is based on scheduled time between arrivals. It does not take into account delays or situations where overcrowding prevents riders from boarding a vehicle.

Walkability: More walkable communities are positively associated with a variety of quality of life and public health benefits. Conversely, less walkable communities are associated with a range of public health challenges, including higher rates of cardiovascular disease and diabetes.[28] The walkability of neighborhoods is increasingly regarded as an important component of healthier and more sustainable communities, particularly with regard to reducing motor vehicle travel and promoting alternative modes of transport that are more affordable, accessible, and less polluting.

Transportation cost burden: Transportation is the second-largest expenditure category for American households, approximately 16% of annual expenditures on average between 2015 and 2018.[29] Only housing costs (~32%) exceed those of transportation. The high cost of transportation is due in large part to the costs of dependence on private vehicle ownership, including purchase and financing, insurance, maintenance, and fuel costs. Households without reasonable access to other modes of transportation typically experience higher transportation costs.[30] Transportation costs can be significant economic burdens for moderate and lower income households and for communities where destinations are distant or limited. For many working-class and rural households, the cost of transportation for a moderate income household is greater than the cost of housing as determined by the federal Department of Housing and Urban Development.

2. Identify the geographic and demographic characteristics of communities that are overburdened by transportation-related emissions and related externalities

To identify communities that are overburdened by transportation-related emissions and related externalities, we analyzed the geography of seven transportation-related emissions, concentrations, or exposures: fine particulate matter ($PM_{2.5}$), ground-level ozone (O_3), On-road carbon dioxide (CO_2), diesel particulate matter, air toxics cancer risk, respiratory hazard index, and traffic proximity and volume.

$PM_{2.5}$: $PM_{2.5}$ refers to particulate matter in the air that is 2.5 microns or less in diameter (about 30 times smaller than the width of a human hair). These small particulates pose a threat to human health because they can penetrate deeply into the lungs and even enter the bloodstream. The EPA has documented that exposure to $PM_{2.5}$ is associated with health effects such as elevated risk of premature mortality from cardiovascular diseases or lung cancer, and increased health problems such as asthma attacks.[31] Moreover, the EPA has found that people with pre-existing heart or lung disease, children and older adults, and nonwhite populations are at particular risk.[32]

Sources of $PM_{2.5}$ emissions include power plants and industrial facilities that burn coal or petroleum-based fuels (i.e., oil or natural gas). However, most $PM_{2.5}$ forms in the atmosphere as a result of chemical reactions between gases such as oxides of nitrogen (NO_x) or sulfur dioxide (SO_2), which are pollutants emitted from power plants, industries, and automobiles. $PM_{2.5}$ has been regulated by the US EPA under the National Ambient Air Quality Standards (NAAQS) since 1997. As of April 2020, the EPA's primary (health-based) standard for $PM_{2.5}$ is an annual average of 12μg/m^3 (12 micrograms per cubic meter of air).[33] Research shows that $PM_{2.5}$ continues to have a significant negative impact on mortality at concentrations below the EPA's standard.[34] Former EPA officials and scientists in an Independent Particulate Matter Review Panel have found that the current standard is not protective of public health and recommend that the annual standard be revised to a range of 10μg/m^3 to 8μg/m^3. However, even at the lower end of the range, risk is not reduced to zero.[35]

Ozone (O_3): Ground-level ozone (O_3) is the primary constituent of smog.[36] However, ozone is not usually emitted directly into the air. It is created at ground level by a chemical reaction in the air between oxides of nitrogen (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight. These ozone precursor pollutants are emitted from automobile exhaust, gasoline vapors, industrial boilers, refineries, chemical plants, and other sources. Ozone concentrations tend to be highest during the summer months due to increased sunlight and heat. Ozone can also be carried long distances by wind, affecting areas far from the sources of precursor pollutants.

The EPA has documented an association between exposure to ambient ozone and a variety of health outcomes, including reduction in lung function, increased inflammation and increased hospital admissions and mortality.[37] People most at risk from breathing air containing ozone include people with asthma, children, older adults, and people who are active outdoors, especially outdoor workers. Children are at greatest risk from exposure to ozone because their lungs are still developing and they are more likely to be active outdoors when ozone levels are high, which increases their exposure. Children are also more likely than adults to have asthma.[38]

Ground level ozone has been regulated by the US EPA under the National Ambient Air Quality Standards (NAAQS) since 1971. As of April 2020, the EPA's primary (health-based) standard for ground level ozone is 70 parts per billion (ppb).[39] However, the EPA has acknowledged that clinical and epidemiological evidence has been inconclusive about a possible threshold for ozone-induced health effects. EPA concluded that if a population threshold level exists, it is near the lower limit of ambient ozone concentrations in the United States.[40]

On-road Carbon dioxide (CO_2): Carbon dioxide (CO_2) emissions are the primary driver of human-induced climate change.[41] Direct exposure to CO_2 is not a significant health concern, but its cumulative effects on the climate and global environment are. In addition to risks such as sea level rise, increasing frequency and intensity of extreme weather (e.g., flooding, storms, droughts, heat waves), and economic disruption, climate change is likely to degrade air quality by exacerbating smog formation and other airborne irritants.[42] The single largest source of CO_2 emissions is the transportation sector, especially automobiles. Other sources of CO_2 emissions include the combustion of coal or petroleum-based fuels for electricity production, industry, heating of commercial and residential buildings, agriculture, and land use and forestry.[43]

In 2007, the US Supreme Court ruled that CO_2 is a pollutant under the terms of the Clean Air Act and therefore the EPA has statutory authority to regulate greenhouse gas (GHG) emissions. The EPA and National Highway Traffic Safety Administration (NHTSA) subsequently issued new fuel economy standards which included GHG standards for light-duty vehicles (passenger cars and trucks) for model years 2012 - 2016 and then model years 2017 - 2025. The latter required auto manufacturers to reduce average GHG emissions by approximately 23% by 2026.[44] The Intergovernmental Panel on Climate Change (IPCC), the global authority on climate change science and policy, has warned that the world must bring GHG emissions down to "net zero" as soon as possible in order to avoid catastrophic climate change.[45]

Diesel particulate matter: Diesel Particulate Matter (DPM) refers to particulate matter generated from the combustion of diesel fuel. DPM has historically been used as a surrogate measure of exposure for diesel exhaust more generally. Diesel exhaust is a complex mixture of thousands of gases and fine particles that contains more than 40 toxic air contaminants. These include many known or suspected cancer-causing substances, such as benzene, arsenic, and formaldehyde. It also contains other harmful pollutants, including nitrogen oxides (a component of smog). In addition to long term cancer risk, exposure to diesel exhaust can have immediate health effects. It can irritate the eyes, nose, throat and lungs, and it can cause coughs, headaches, light-headedness and nausea. Exposure to diesel exhaust also causes inflammation in the lungs, which may aggravate chronic respiratory symptoms and increase the frequency or intensity of asthma attacks.[46]

Major sources of diesel exhaust include engines and motorized vehicles that use diesel fuel, such as trucks, buses, trains, ships, and diesel-powered generators. DPM is classified by the EPA as a Hazardous Air Pollutant (HAP). HAPs are pollutants that are known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects. The EPA has not quantified the cancer risk from exposure to DPM. However, it has established a diesel exhaust reference concentration (RfC) for noncancer health effects. The RfC is 5 $\mu g/m^3$ for diesel exhaust measured as diesel particulate matter (DPM). This RfC does not consider allergenic effects such as those associated with asthma, immunologic effects or the potential for cardiac effects.[47]

Air Toxics Cancer Risk: Air toxics, often referred to as hazardous air pollutants (HAPs), are pollutants that are known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects.

Most air toxics originate from transportation and industry, including automobiles, industrial facilities, and power plants. EPA regulates 187 chemicals under its HAP program. Since 1996, the EPA's National Air Toxics Assessment (NATA) program has provided nationwide assessments of outdoor air quality with respect to emissions of air toxics. NATA uses emissions estimates from the National Emissions Inventory (NEI), which is updated every three years. The NEI includes all of the Toxics Release Inventory (TRI) reporting facilities that release hazardous air pollutants, along with many other sources of air pollutants, such as motor vehicles. NATA estimates the cancer risks from breathing these air toxics over a lifetime.[48]

Respiratory hazard index: Respiratory hazard from air toxics refers to non-cancer effects caused by a lifetime of exposure to air toxics listed as Hazardous Air Pollutants (HAPs).[49] EPA's National Air Toxics Assessment (NATA) program calculates a hazard quotient, which is the ratio of ambient air concentration to a chemical's health-based reference concentration (RfC). No adverse health effects are expected from exposure if the hazard quotient is less than one. This hazard quotient represents the cumulative impacts of all the relevant air toxics for which respiratory effects were the key health effect.[50]

Traffic proximity and volume: Proximity to motor vehicle traffic is associated with greater exposure to toxic gases and particulate matter, as well as increased noise. Vehicle-related emissions include ultrafine particulates and other components of $PM_{2.5}$, lead and other metals, air toxics such as benzene, nitrogen oxides (NO_x), hydrocarbons and carbon monoxide (CO), as well as precursors that add to the formation of ground level ozone (O_3) and smog. Research has repeatedly shown that living near highly trafficked roads is related to increased risk of a variety of adverse health outcomes, including asthma, cardiovascular disease, hypertension, stroke, stress, and increased rates of mortality. EPA's 2005 National Air Toxics Assessment (NATA) estimated that mobile emissions accounted for about 30% of average cancer risk from Hazardous Air Pollutants.[51]

3. Identify the geographic and demographic characteristics of communities that are at increased risk for heat island effects, which exacerbates transportation related air pollution

Heat, or hot weather, is the leading weather-related cause of death in the U.S.[52] Between 1999 and 2010, the U.S. Centers for Disease Control recorded over 8,000 heat-related deaths in the U.S.[53] Heat-related hospitalizations or emergency department visits are estimated to be at least 10 times the death rate.[54] Heat exhaustion and heat stroke are the most serious heat-related illnesses. Exposure to excessive heat can directly or indirectly cause some illnesses and can exacerbate many preexisting conditions, such as heart and lung disease. People at greatest risk for heat-related illness include children under 5 years of age, people 65 years of age and older, people who are overweight or have existing medical conditions, such as diabetes and heart disease, people who are socially isolated, and low income individuals.[55]

Risk of exposure to excessive heat tends to be higher for people who work outside (e.g., agriculture, construction, and landscaping), and for those living in densely developed urban areas where there is a dearth of vegetation and an abundance of dense materials such as asphalt and concrete that absorb heat and release it more slowly (i.e., urban heat island effect). However, risk of heat-related illness or death varies within urban environments due to a variety of mitigating factors, especially age, race, and wealth.[56] Exposure to higher temperatures than a population is accustomed to can also make people more vulnerable to heat-related illnesses and death. Although New England experiences a generally cool climate, research has shown that people in this region are actually more sensitive to elevated temperatures than those accustomed to warmer regions of the country.[57]

Climate change is increasing average global temperatures, as well as the frequency, duration, and severity of extreme heat events.[58] In the contiguous U.S., annual average temperatures have increased by 1.2°F (0.7°C) over the last few decades and by 1.8°F (1.0°C) relative to the beginning of the 20th century. These changes are happening more quickly in the Northeast. Average annual temperatures have increased by about 3°F (1.7°C) or more in Massachusetts since 1901. By 2050, average annual temperatures in the Northeast are projected to increase by up to 5.1°F (2.8°C) relative to the period 1975–2005, with several more days of extreme heat occurring throughout the state each year.[59] The combination of rapidly increasing temperatures and higher sensitivity puts people in New England at especially high risk of heat-related illness and death.

Increasing ambient temperatures due to climate change also increase exposure and risk from air pollution. Research has shown that $PM_{2.5}$ and ozone are exacerbated by climate change.[60] The combination of higher heat exposure and exacerbated air pollution have been shown to be significantly associated with risk to pregnancy outcomes in the US.[61] Populations that are sensitive to heat risk or air quality are likely to be at increased risk from this adverse combination of exposures.[62]

Land Surface Temperature (LST): To identify communities that are at increased risk for heat we analyzed Land Surface Temperatures (LST) derived from NASA satellite data.

Urban Heat Island (UHI) effect: The urban heat island (UHI) effect is a phenomenon in which temperatures in urban areas tend to be higher than surrounding non-urban or rural areas. These elevated urban air temperatures are a consequence of the high density of buildings, roads, and other impervious infrastructure in urban areas that absorb heat and release it more slowly. The UHI effect is compounded by the relative absence of vegetation which would otherwise moderate temperatures through evaporative cooling.[63] Higher summer temperatures due to UHI increase the risk of heat-related illnesses, result in increased energy use for air conditioning, and exacerbate air pollution, especially ground-level ozone. As the climate warms, UHI are likely to exacerbate both temperature and air pollution risks.

4. Identify the geographic and demographic characteristics of communities that are likely to experience evacuation risks and other transportation-related vulnerabilities flowing from flooding, extreme weather, and other climate stressors

A significant portion of New England's land area and population are exposed to the risk of flooding from overbanking of inland water bodies (e.g., ponds and rivers) due to heavy precipitation or from coastal storm surge and sea level rise. In the event of significant inland or coastal flooding, evacuation may be required. For individuals and households with limited mobility, either due to inadequate access to transportation options or because of physical limitations, evacuation presents heightened risk. Evacuation may also prove especially difficult for individuals and households due to limited economic resources, difficulty understanding or accessing information, or low trust in official sources of information.

To identify the geographic and demographic characteristics of communities that are likely to experience evacuation risks and other transportation-related vulnerabilities due to flooding, extreme weather, and other climate stressors, we analyzed exposure to two types of flood risk: residence within flood risk zones as defined by the Federal Emergency Management Agency, and residence within areas designated as hurricane evacuation zones or subject to hurricane storm surge as projected by the U.S. Army Corps of Engineers and National Hurricane Center.

FEMA flood zone risk: This analysis focused on identifying populations at risk from floods with a 1% or 0.2% annual exceedance probability. The 1% annual exceedance probability flood, sometimes referred to as a '100-year' flood, is a flood with a 1% chance of being equaled or exceeded in a given year. Areas subject to the 1% flood risk are designated as Special Flood Hazard Areas. Properties within these flood risk zones are required to carry flood insurance in order to participate in the National Flood Insurance Program. The 0.2% exceedance probability flood, sometimes referred to as a '500-year' flood, is a flood with a 0.2% chance of being equaled or exceeded in a given year. There is no federal regulatory requirement for properties within areas subject to 0.2% annual exceedance probability flood risk. While lower risk, these areas are frequently identified as areas subject to flooding under extreme or worst-case scenarios. Note that FEMA flood risk designations do not take into consideration increasing or projected flood risk due to sea level rise, more extreme rainfall events, or other climate change-enhanced risks.[64]

Hurricane evacuation or storm surge risk: New England is subject to hurricane risk. Since 1900, New England has been struck by hurricanes eight times. The most recent hurricane to hit New England directly was Hurricane Bob in 1991,[65] a Category 2 storm when it made landfall on Block Island, Rhode Island, with hurricane-force winds extending to Groton, Connecticut. The storm did its worst damage as it moved northward through Massachusetts as a Category 1 storm, causing over $1 billion in damages, before moving offshore. The storm resulted in 18 deaths, power outages, and over $1.5 billion in damage across the region.[66] In 2011, Hurricane Irene was downgraded to a tropical storm by the time it arrived in New England, but nevertheless caused more than $700 million in damage in Vermont alone due to flooding of streams and rivers from heavy precipitation.[67] Hurricane Sandy in 2012 had also been downgraded to a tropical storm by the time it hit New England. Sandy caused over $360 million in damage along the Connecticut coast,[68] and it left 90,000 people across Maine without power due to high winds.[69] In general, New England is subject to a hurricane return period of between 13 and 50 years, depending on the area.[70]

Hurricane intensity is ranked from 1 to 5 on the Saffir-Simpson scale, which is based on sustained wind speeds. However, the most destructive and deadly aspects of hurricanes are due to storm surge - ocean water pushed inland by the high winds. This coastal storm surge may be combined with intense rainfall which can exacerbate flooding. As a result, coastal evacuation may be necessary as a hurricane approaches

CUMULATIVE SYNTHESIS

For each state, we also identified those areas with the largest proportions of priority populations who experience the highest burden. We did this by first identifying which block groups had any population of concern in the 80th percentile for that group in that state. Those living with disabilities and no car households were not considered in this analysis due to data constraints. We then identified the areas with these highest proportions of populations that were also experiencing the highest concentration or category of burden for any burden. This was defined differently for each type of burden.

We identified highest burdened areas as those areas which have both high levels of any burden and high proportions of any priority population. This yielded four categories of highest burdens (i.e., transportation, emissions, heat, and evacuation). We also identified which of these priority populations experience one or more of these highest burdens and what proportions of each population experienced burdens in the four different burden categories.

Defining highest concentration or category

Top Quintile (80th percentile)

- Transit Access
- Transit Headways
- Transportation Cost Burden
- $PM_{2.5}$
- O_3
- DPM
- Air Toxics Cancer Risk
- Respiratory Hazard Risk
- Heat (average & UHI)

Least Walkable Score

Located in a flood or evacuation zone

INVESTING FOR EQUITY

CONNECTICUT

GEOGRAPHIES AFFECTED

High transportation burdens are found all throughout the state

Low levels of physical access, low frequencies of service, low levels of walkability, and high transportation costs exist all across the state, even in urban areas.

Emissions are particularly high in the southeast and in major population centers

Higher concentrations of emissions and related risks follow major roadways and are regularly found along I-95 from the New York border through New Haven and then north along I-91 to Hartford.

Higher temperatures follow the same patterns as higher emissions and related risks

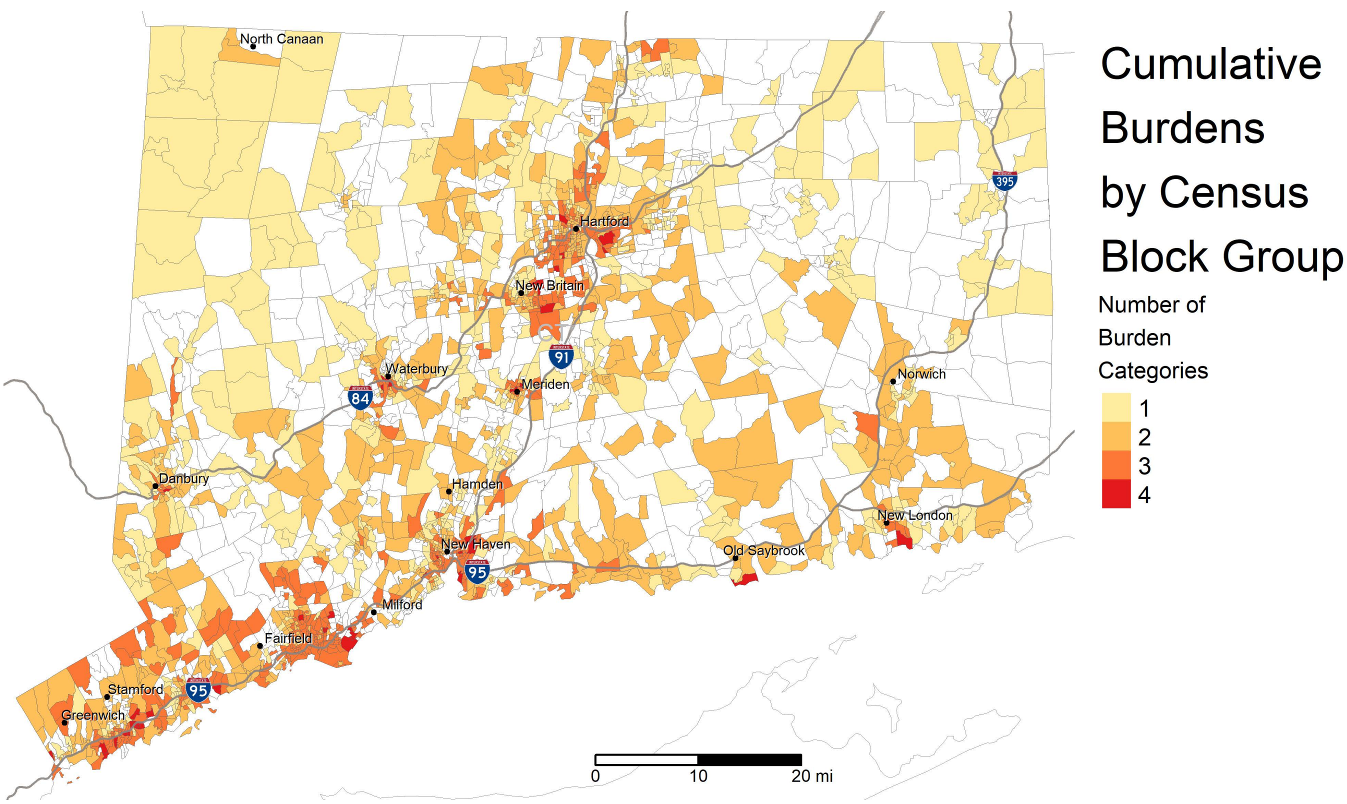
Higher daytime and nighttime temperatures as well as urban heat islands follow major roadways all throughout the state but most particularly the I-95 to I-91 corridor.

Flood and hurricane evacuation risks are found throughout the state

Over 275,000 people are exposed to flood risks and over 342,000 people live in hurricane evacuation zones.[1]

31% of municipalities in Connecticut have block groups that experience three or more categories of highest burdens

The highest burdened places are mostly found along major interstate highways.



[1] It is possible that there are flooding risks in the northwest and northeast portions of Connecticut that are not captured here due to lack of publicly available digital data from FEMA.

PRIORITY POPULATIONS

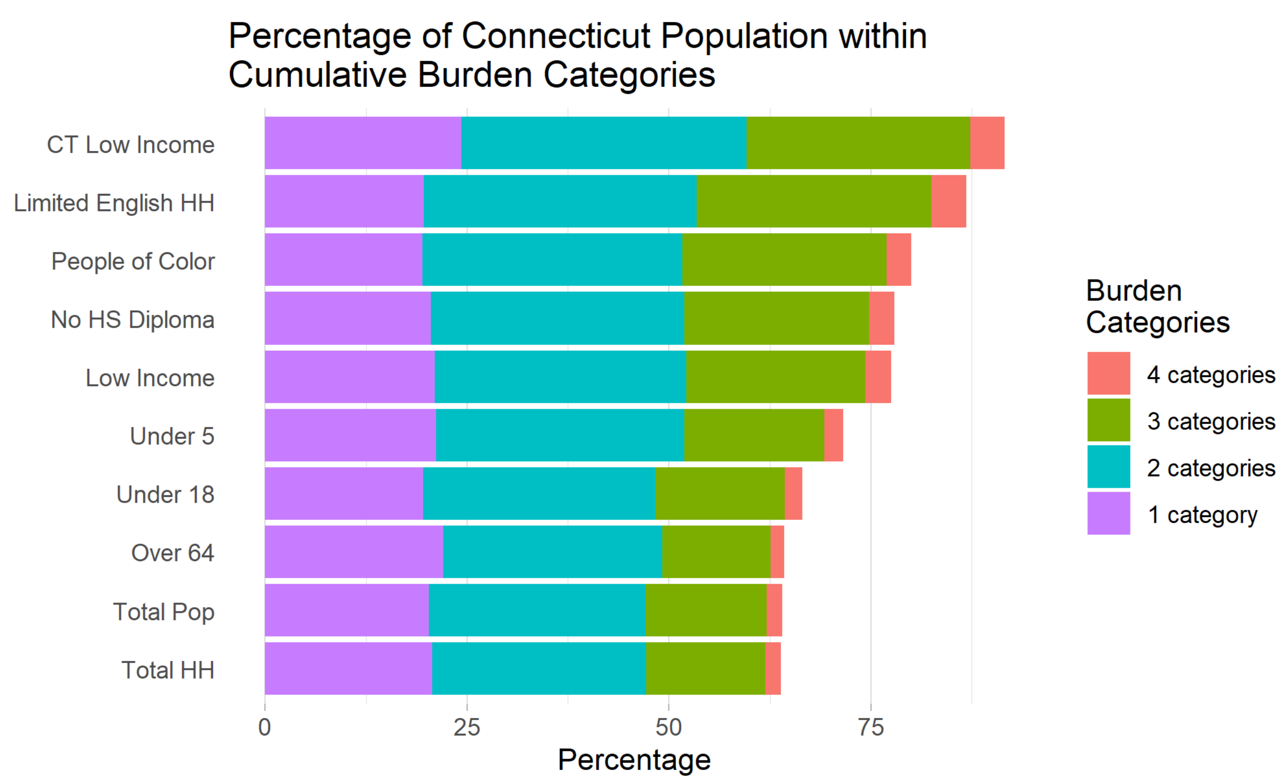
Over 725,000 people in Connecticut live in places that experience at least one highest burden and over 66,000 live with three or more categories of highest burden.

Connecticut's low income EJ block groups, limited English speaking households, and people of color are the most affected groups

Overall, low income block groups (as defined by the Connecticut EJ policy), limited English speaking households, and people of color most frequently experience the greatest number and types of burdens. Cumulatively, Connecticut's low income EJ block groups, and limited English speaking households experience the highest levels of burden. Almost 25% of Connecticut's low income EJ block groups live with at least one type of highest burden and are the most likely to live with all four categories of burden. In addition, 20% of limited English speaking households and 20% of people of color live in areas with at least one type of burden.

Populations affected vary by type of burden. Well over half of Connecticut's low income EJ block groups, limited English speaking households, and people of color experience the highest emissions and evacuation burdens. In addition, over half of limited English speaking households and Connecticut's low income EJ block groups experience the highest heat burdens.

Those over the age of 64 tend to live in areas with the highest transportation burdens. It should be noted, however, that the methods used in the transportation burden analyses are best suited to ascertaining transportation burdens in suburban and rural areas. People over 64 are the dominant population in less dense areas of Connecticut. This transportation burden analysis does not determine whether transit access is adequate or enables accessibility to desired destinations, which may overstate the adequacy of service in dense urban areas.



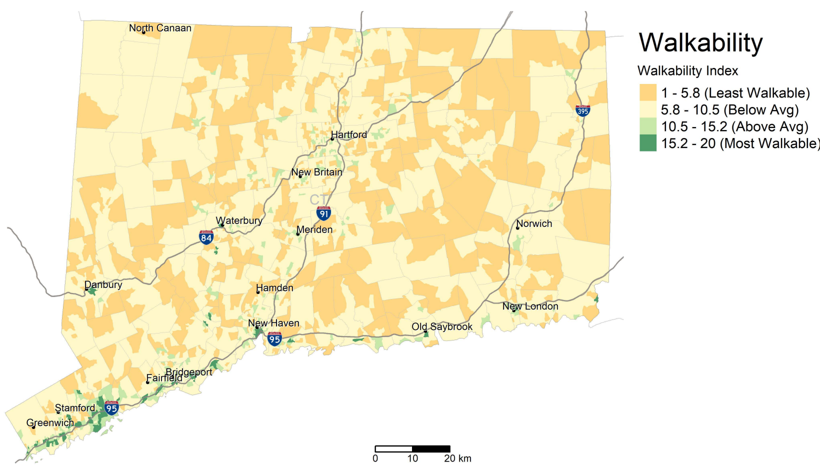
TRANSPORTATION

Connecticut is served by 19 local bus agencies or transit districts, four rail lines, ferries, and two private inter-city bus services. The analysis presented here only considers transit services for which publicly available geospatial data is available, which includes 12 regional public transit agencies and two rail services. We analyzed 257 fixed public transit routes across the state.

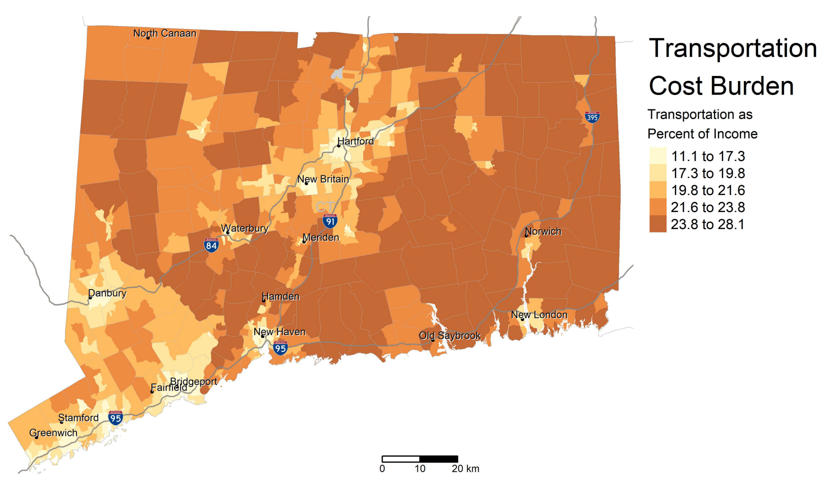
GEOGRAPHIES AFFECTED

Despite the variety of transit services across Connecticut, 45% of the state's residents do not have physical access to any form of public transit. Only 30% of the population lives within a reasonable walking distance of a bus stop. The places that have the least access to public transit, the least frequent service, lower than average walkability, and the highest transportation cost burdens are all the less dense parts of the state. Transit adequacy can also vary dramatically in the densest urban areas. However, the statewide scope of this analysis highlights the rural-urban differences and may mask intra-urban variation in adequacy of access. Frequencies of service are extremely long across all modes of service. The average headway (i.e., times between scheduled arrivals) for busses and commuter rail is well over 2 hours. The shortest headways are found in cities.

Walkability scores across the state are most frequently below average to least walkable. The highest walkability scores are found in the urban areas between Greenwich and New Haven.



Transportation cost burdens for moderate income households are generally high across the state. The lowest transportation cost burden is found in the urban areas along the I-95 corridor between Greenwich and New Haven, as well as in Danbury, Waterbury, New Britain, and Hartford.

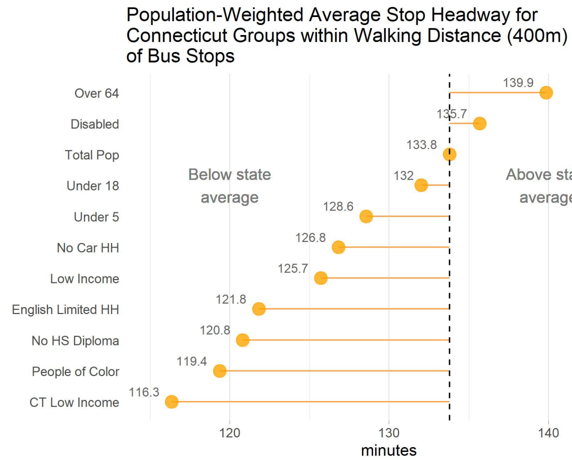


PRIORITY POPULATIONS

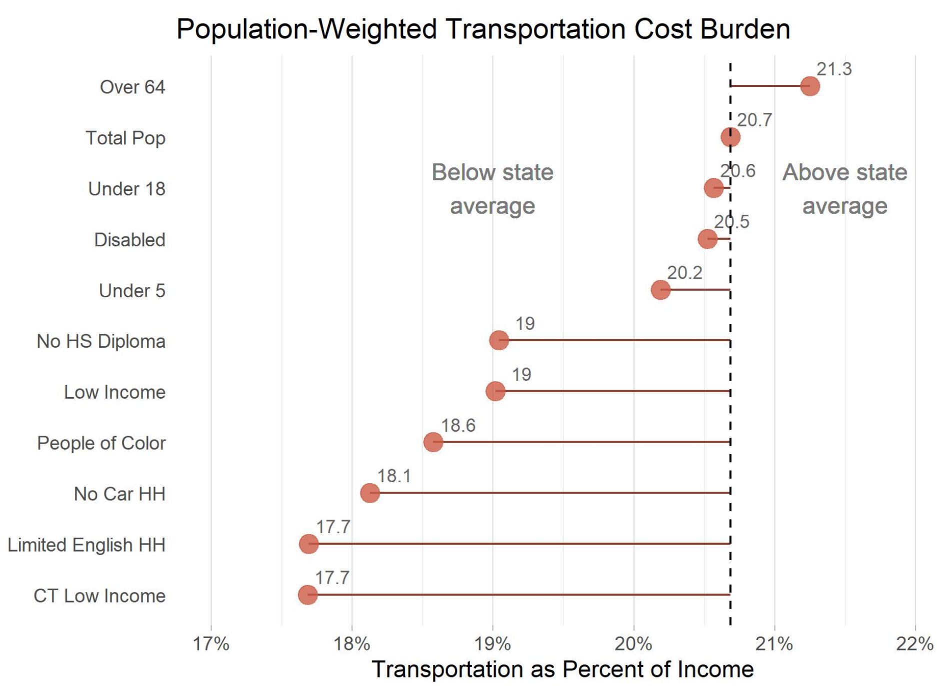
The population with the least access to all forms of public transit and least frequent service are those 64 years old and older. This population also lives in areas with the highest transportation cost burden. This is not surprising given that people over the age of 64 in Connecticut predominantly live in suburban and rural areas, which are the places where these burdens are highest.

It should be noted that, while those over 64 experience the least frequent service, all priority populations experience very long headways. Connecticut's low income EJ block groups, which experience the "best" frequency, still encounter an average 116 minutes between busses. Similar patterns are seen with commuter rail service with frequencies averaging from 106 minutes between trains for those over the age of 64 to 155 minutes for Connecticut's low income EJ block groups.

All priority populations also live in areas with below average walkability scores.



Most priority populations live in areas with transportation cost burdens that are below the state average. However, the transportation cost burdens are still quite high. Connecticut's low income EJ block groups have the lowest cost burden of all priority populations. And yet, it is estimated that this group, on average, spends almost 18% of their household income on transportation. This is higher than the US average of 16%.

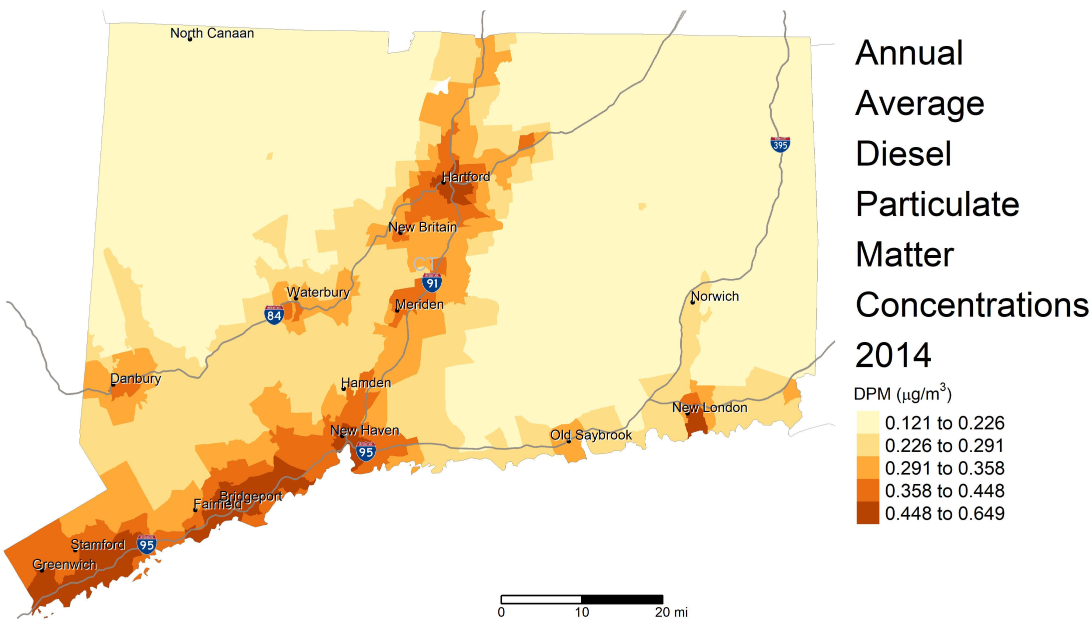


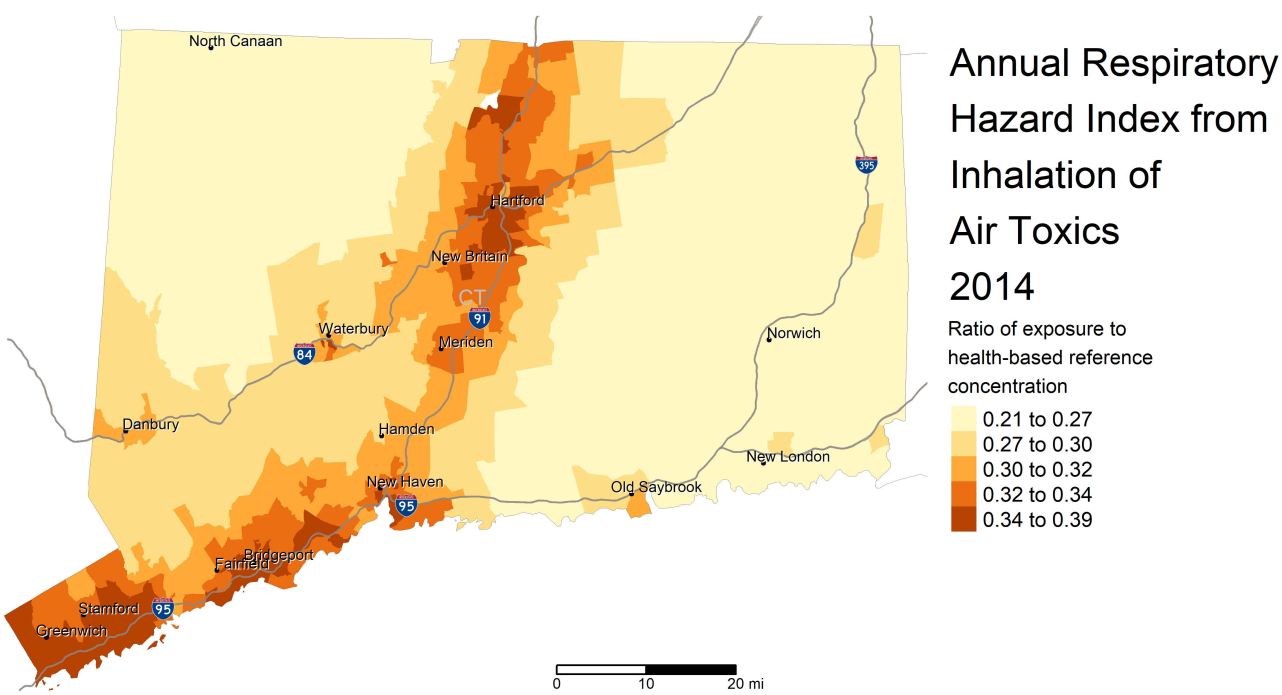
EMISSIONS

Median emissions and related risks in Connecticut are higher than the medians for New England except for CO_2 and traffic proximity and volume. $PM_{2.5}$ emissions in Connecticut have declined almost 23% between 2011 and 2016. Ozone (O_3) emissions have increased 4.8% in the same time span. Median On-road CO_2 emissions and traffic proximity and volume are below the median for New England.

GEOGRAPHIES AFFECTED

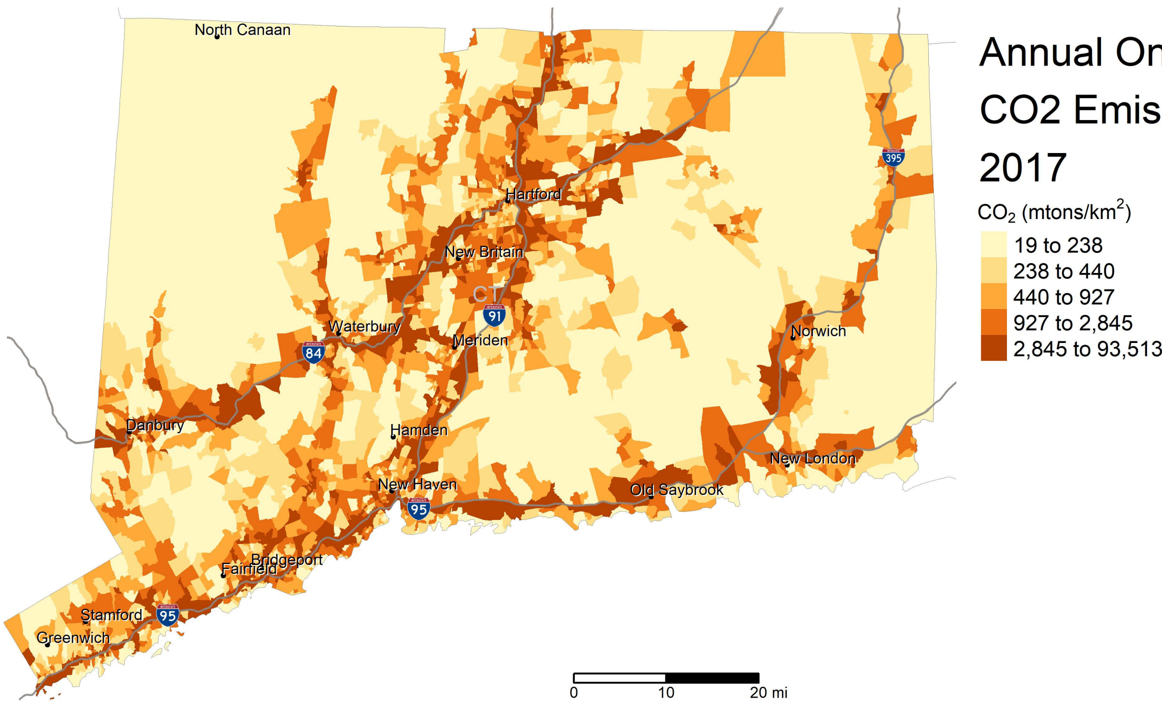
Southwest Connecticut, specifically the corridor along I-95 between Greenwich and New Haven, regularly demonstrates high concentrations for all emissions and high levels of all related risks evaluated here. Outliers are also most frequently found in this area. In addition, the I-91 corridor between New Haven and Hartford also shows high emissions and related risks. High concentrations of diesel particulate matter (DPM) are also found in New London.





On-road CO_2 emissions are high throughout the state with the exception of rural areas. Emissions are higher today than they were in 1990. While there was a decline between approximately 2005 and 2015, there has been a marked rise in CO_2 emissions since 2015.

While emissions have shown a slight downward trend since 2005, emissions growth overall is still higher than population growth.



Annual on-road CO_2 emissions: Change over time

1990 CO_2 (mtons)	2017 CO_2 (mtons)	% change	Per capita 1990 CO_2 (mtons/person)	Per capita 2017 CO_2 (mtons/person)	Per capita % change
13,381,852	15,284,098	14%	4.07	4.27	5%

One area of the state stands out as a frequent hotspot or outlier for emissions and related risks: the I-95 corridor between Greenwich and New Haven. Hotspot areas for on-road CO2 also include the I-84 corridor between Danbury and Hartford.

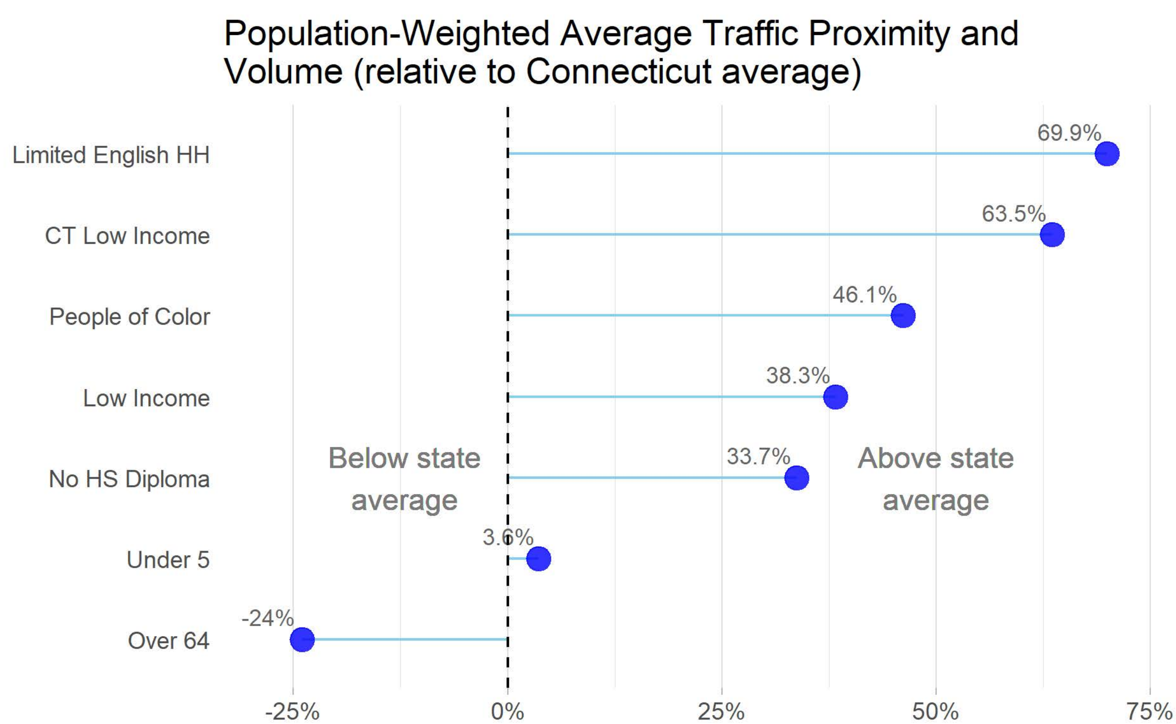
PRIORITY POPULATIONS

Limited English speaking households, people of color, and Connecticut's low income EJ block groups experience the highest exposures to all emissions and related risks evaluated here. They are also the most exposed to the highest levels of emissions. Almost 73,000 limited English speaking households, over 600,000 people in Connecticut's low income EJ block groups, and over 624,000 people of color experience the highest levels of emissions and related risks or are living in closest proximity to high traffic corridors.

Distribution of the highest emissions burdens

	% Emissions Category
Total Pop	32%
CT Low income	61%
People of color	54%
Low income	48%
No HS diploma	48%
Under 5	39%
Under 18	35%
Over 64	29%
Total HH	32%
Limited English HH	60%

Note: Categories are defined as block groups with high proportions of priority populations and are in the top 20% of burdens for emissions. For example, 60% of limited English speaking households are present in areas in the highest burden emissions category. CT's low income EJ block groups are defined in CGS §22a-20a.

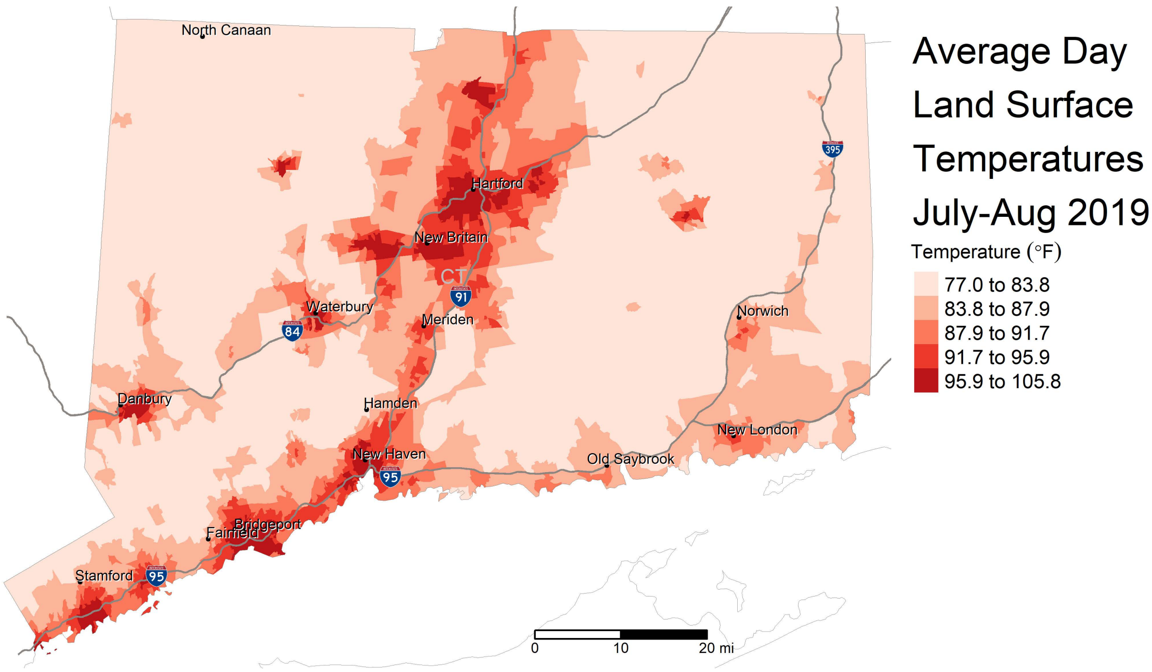


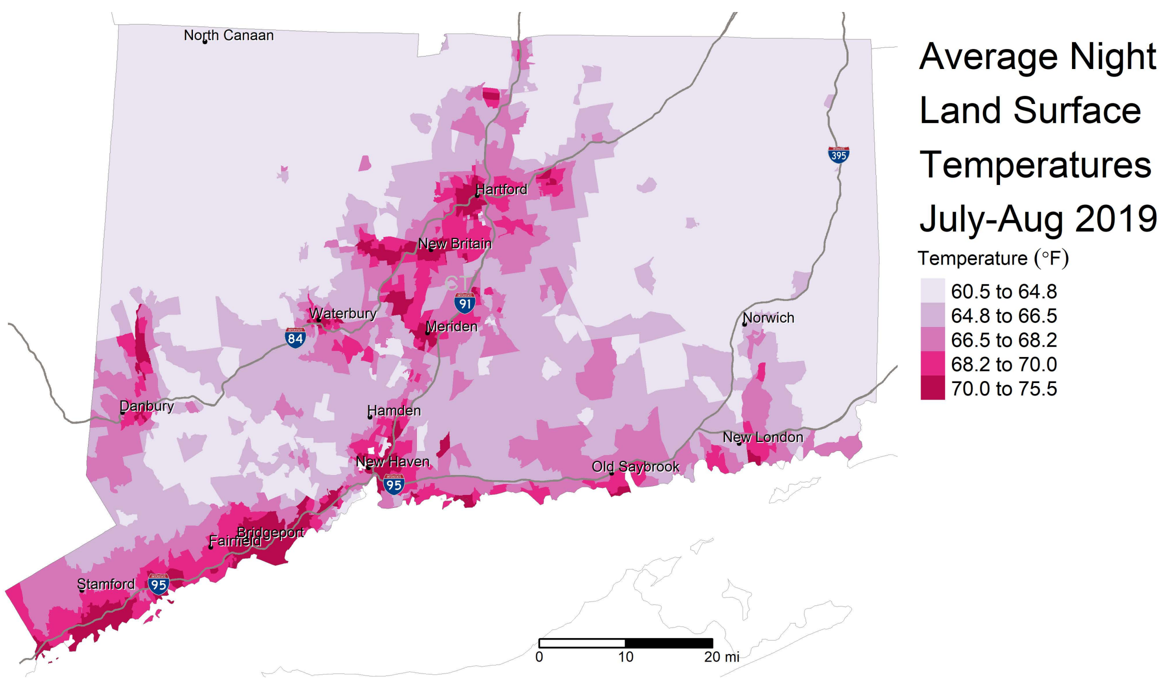
HEAT

Across the day, during the time period studied, average land surface temperatures (LST) ranged from almost 69° to 90°. The highest daytime temperature reached 106° and the highest nighttime temperature reached 76°.

GEOGRAPHIES AFFECTED

Higher temperatures throughout the day and night are found in all urbanized areas of the state and follow the major roadways very closely. This is also true for areas experiencing high levels of urban heat island effect. Higher average nighttime temperatures spread into the less dense areas of Connecticut. Hartford is an outlier in every analysis conducted on heat. In addition, Bridgeport was an outlier for daytime urban heat island effects. New Britain was also an outlier for nighttime temperatures and urban heat island effects.





PRIORITY POPULATIONS

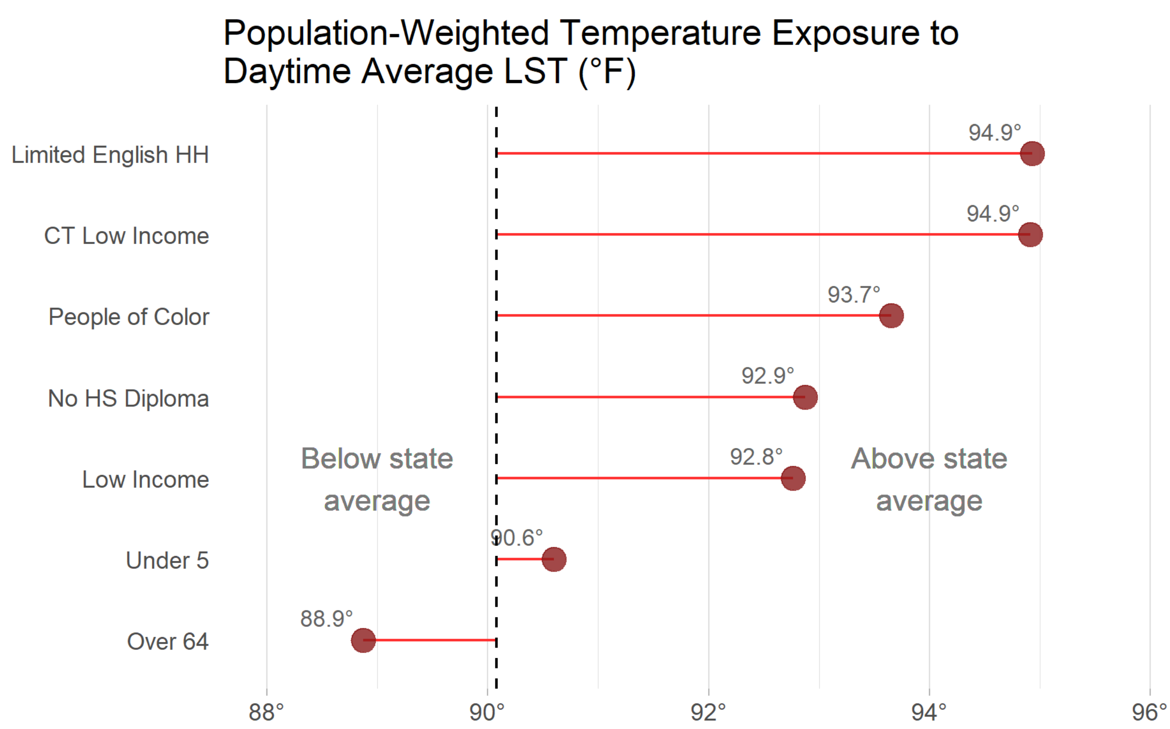
Limited English speaking households and Connecticut's low income EJ block groups are more likely to experience the highest daytime and nighttime temperatures. They also disproportionately experience the highest temperatures. Over 29,000 limited English speaking households and over 345,000 of Connecticut's low income EJ block groups experience the highest daytime temperatures. This is 41% of all limited English speaking households and 35% of people living in Connecticut's low income EJ block groups. Similar numbers and proportions of limited English speaking households and Connecticut's low income EJ block groups experience the highest nighttime temperatures.

In addition, people of color, Connecticut's low income EJ block groups, and those without a high school diploma live in areas that experience the highest burdens of heat.

Distribution of the highest heat burdens

	% Heat Category
Total Pop	22%
CT Low income	53%
People of color	43%
Low income	40%
No HS diploma	40%
Under 5	27%
Under 18	24%
Over 64	17%
Total HH	22%
Limited English HH	54%

Note: Categories are defined as block groups with high proportions of priority populations and are in the top 20% of burdens for temperature. For example, 53% of Connecticut's low income EJ block groups are areas in the highest burden heat category.



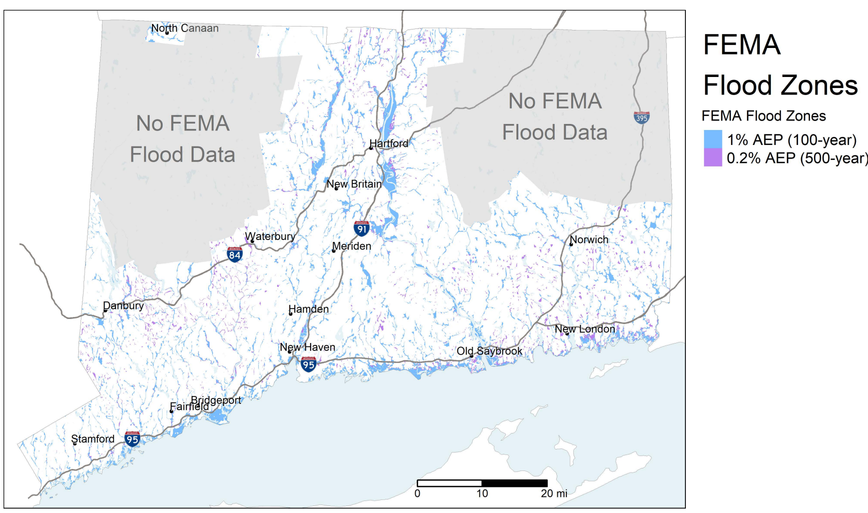
EVACUATION RISKS

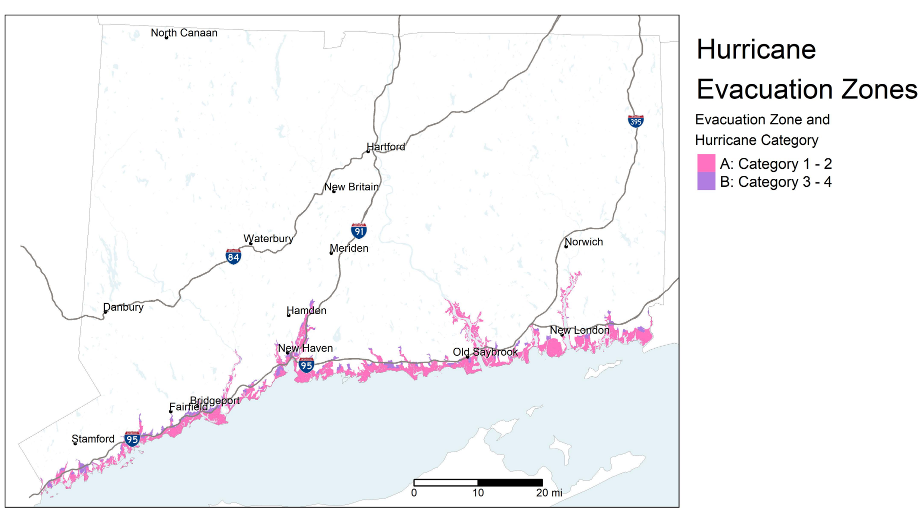
As a humid, coastal state, a significant portion of Connecticut's land area and population are exposed to the risk of flooding from overbanking of inland water bodies (e.g., ponds and rivers) or from coastal storm surge and sea level rise. Connecticut is subject to significant hurricane risk. Since 1900, Connecticut has been struck by hurricanes 5 times, and 3 of those were major hurricanes (i.e., Category 3 or higher). The most recent hurricane to hit Connecticut directly was Hurricane Gloria in 1985, a Category 2 storm. The latter caused over $91 million in damage in Connecticut alone (mostly around Hartford) and left 727,000 people in Connecticut without power. Hurricane Sandy in 2012 did not hit Connecticut directly, but nevertheless resulted in flooding of Connecticut coastal communities. In general, Connecticut is subject to a hurricane return period of approximately 17 years, a level of risk comparable to the Gulf Coast of Texas.[71]

GEOGRAPHIES AFFECTED

Almost 7% of Connecticut's land area falls within FEMA flood zones and over 3% of land falls in a hurricane evacuation zone. Flood zones are found throughout the state. It is important to note that FEMA has not made digital flood data for the northwest and northeast portions of the state publicly available. It is very likely that flood risks are much more widespread than we are able to determine with the public data available.

Hurricane evacuation zones are found along the entire coastline of the state with 3.3% of land area subject to evacuation. There is also significant inland intrusion from hurricane related storm surge through the Quinnipiac River, Connecticut River, and Thames River.





PRIORITY POPULATIONS

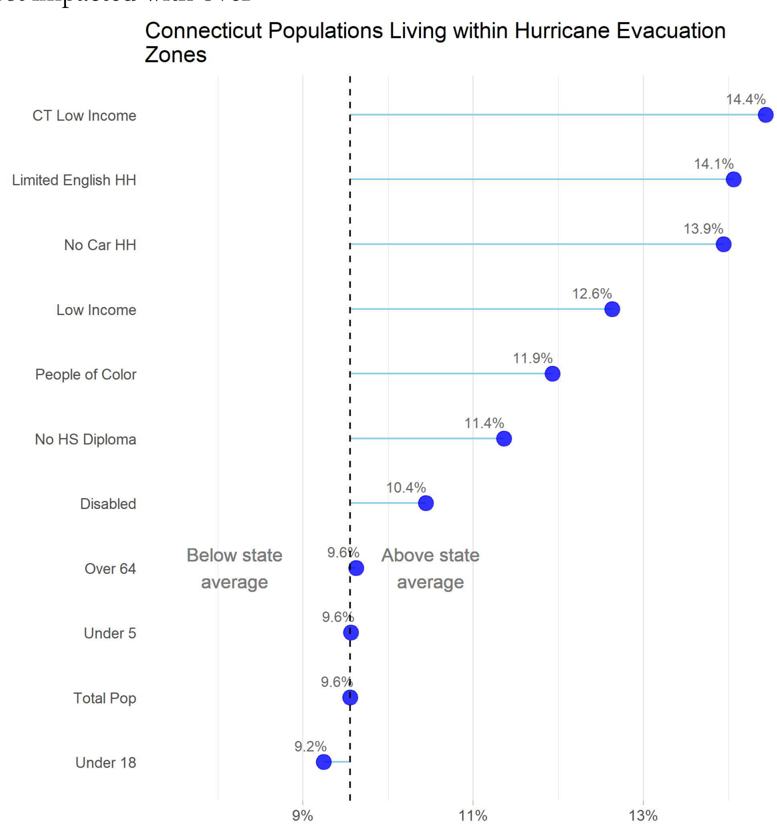
Over 257,000 people live in a flood zone and over 342,000 live in a hurricane evacuation zone. Households without a car and Connecticut's low income EJ block groups most frequently live in both flood and hurricane evacuation zones. In addition, limited English speaking households are also more likely to live in hurricane evacuation zones compared to the general population or other priority populations. Over 10,000 households without a car live in a flood zone and over 17,000 live in a hurricane evacuation zone. Almost 82,000 persons in Connecticut's low income EJ block groups live in a flood zone and over 139,000 live in a hurricane evacuation zone. Almost 10,000 limited English speakers live in a hurricane evacuation zone. In terms of absolute numbers, people of color are the most affected with over 88,000 living in a flood zone and over 139,000 living in a hurricane evacuation zone.

Limited English speaking households and Connecticut's low income EJ block groups are also disproportionately living in areas in the highest burden evacuation categories followed by people of color and those without a high school diploma. In absolute numbers, people of color are the most impacted with over 621,000 people of color living in areas in the highest burden evacuation categories.

Distribution of evacuation burdens

	% Evacuation Category
Total Pop	47%
CT Low income	56%
People of color	53%
No HS diploma	53%
Low income	51%
Under 5	51%
Over 64	49%
Under 18	49%
Total HH	47%
Limited English HH	56%

Note: Categories are defined as block groups with high proportions of priority populations and are in either a flood or hurricane evacuation zone. For example, 53% of people of color are present in areas in the highest burden evacuation category.



INVESTING FOR EQUITY

RHODE ISLAND

GEOGRAPHIES AFFECTED

Moderate to high transportation burdens are found throughout a generally walkable state

Moderately low levels of physical access, low frequencies of service, and high transportation costs exist across the state. While walkability varies, most of the population centers have above average walkability.

Emissions are highest in the northern part of the state

High concentrations of emissions and related risks vary but are regularly found in the Providence metropolitan area generally between Warwick and Pawtucket.

Higher temperatures are most frequently found in the northern part of the state

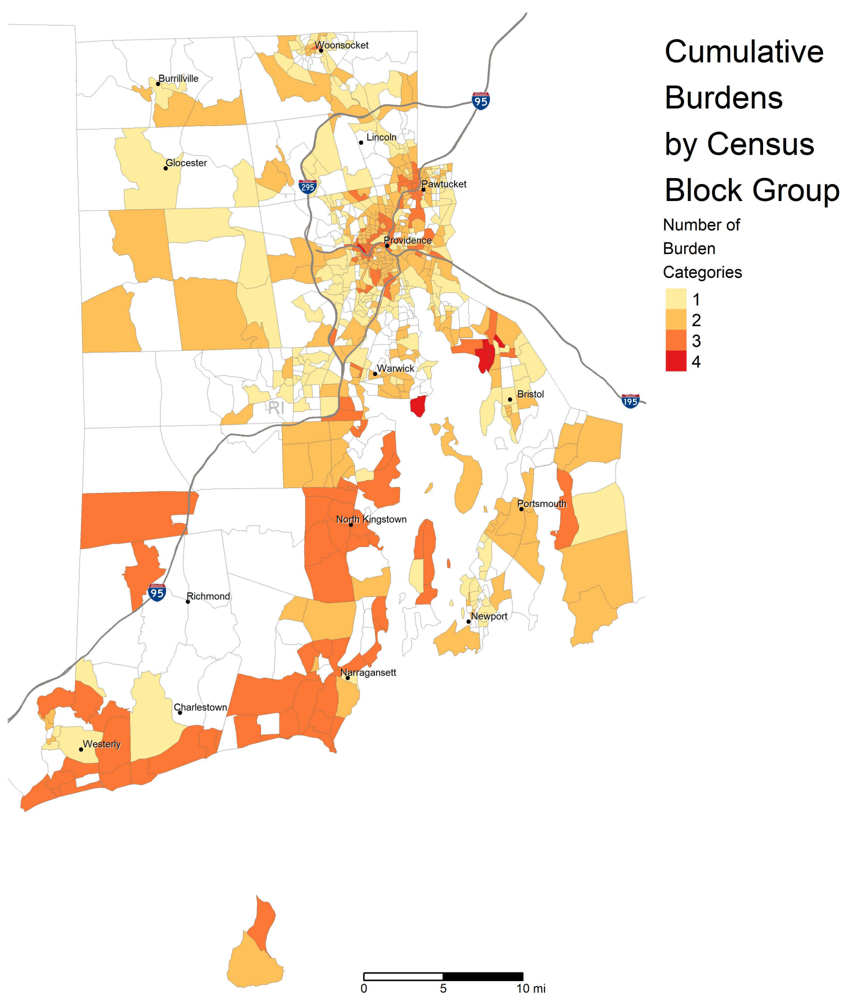
Higher daytime and nighttime temperatures as well as urban heat islands are found in the Providence metropolitan area. Higher nighttime temperatures are found in the northeastern part of the state along the eastern edge of the Narragansett Bay and along the coast.

Flood and hurricane evacuation risks are found throughout the state

Almost 108,000 people are exposed to flood risks. An additional 123,000 people are exposed to hurricane evacuation risks.

59% of municipalities in Rhode Island have block groups that experience three or more categories of highest burdens

The highest burdened places are found in the southeast part of the state along the coast and in the Providence metropolitan area. There are also pockets of higher burdens around the Narragansett Bay.



PRIORITY POPULATIONS

Almost 255,000 people in Rhode Island live in places that experience at least one highest burden and over 134,000 live with three or more categories of highest burden.

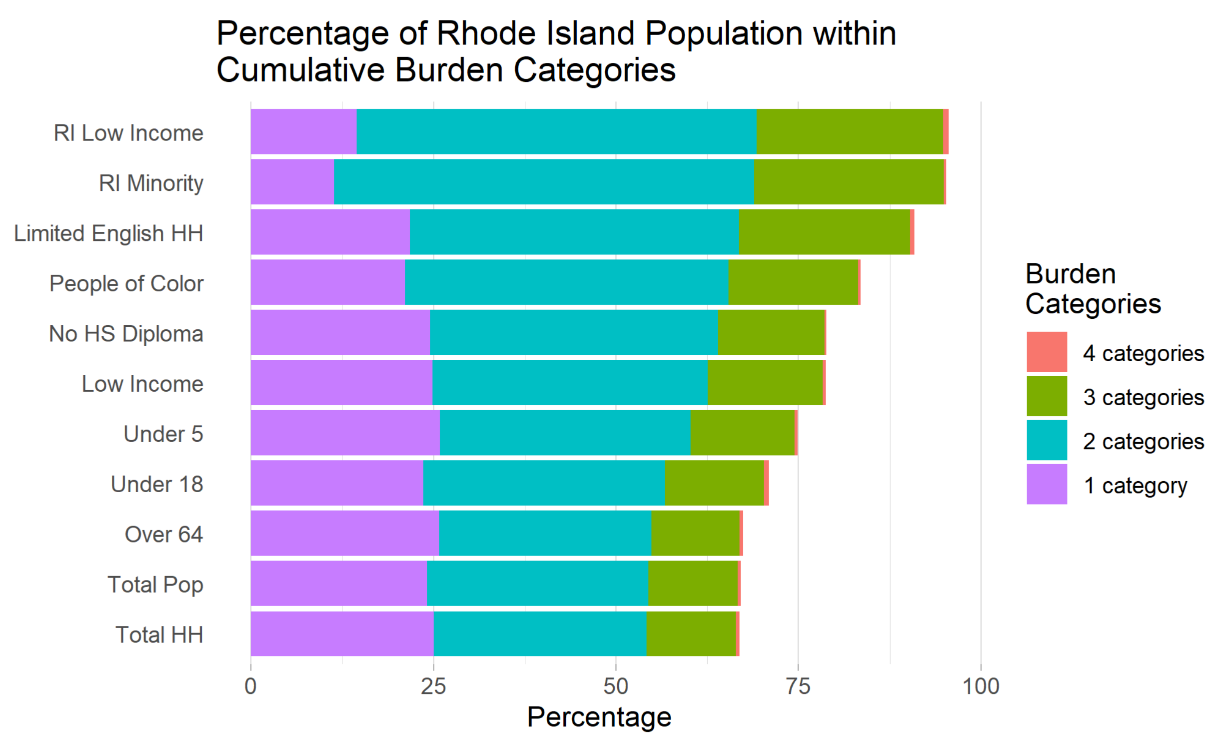
Limited English speaking households, and RI's low income and minority EJ block groups are the most affected by emissions and heat burdens.

Limited English speaking households, and those living in either Rhode Island's low income block groups or Rhode Island's minority block groups (as defined by Rhode Island's EJ policy) most frequently experience higher rates of emissions and heat related burdens. Cumulatively, limited English speaking households, Rhode Island's low income EJ block groups, and Rhode Island's minority EJ block groups experience the highest levels of burden across all types of burdens.

Populations affected vary by type of burden. Well over half of limited English speaking households and those living in Rhode Island's low income EJ block groups experience the highest emissions, heat, and evacuation burdens. In addition, over half of those living in Rhode Island's minority EJ block groups experience the highest emissions and heat burdens.

Those over 64 experience significant transportation and evacuation burdens.

Those over 64 years of age most frequently experience higher rates of transportation and evacuation related burdens. Those over the age of 64 tend to live in areas with the highest transportation burdens. It should be noted, however, that the methods used in the transportation burden analyses are best suited to ascertaining transportation burdens in suburban and rural areas. People over 64 are the dominant population in less dense areas of Rhode Island. This transportation burden analysis does not determine whether transit access is adequate or enables accessibility to desired destinations, which may overstate the adequacy of service in dense urban areas.



TRANSPORTATION

Rhode Island is served primarily by the Rhode Island Public Transit Authority (RIPTA) which is a quasi-public, independent authority. This public transit service system is made up almost entirely by fixed-route bus service, which passes through 36 of Rhode Island's 39 municipalities. We analyzed 59 fixed public bus routes across the state.

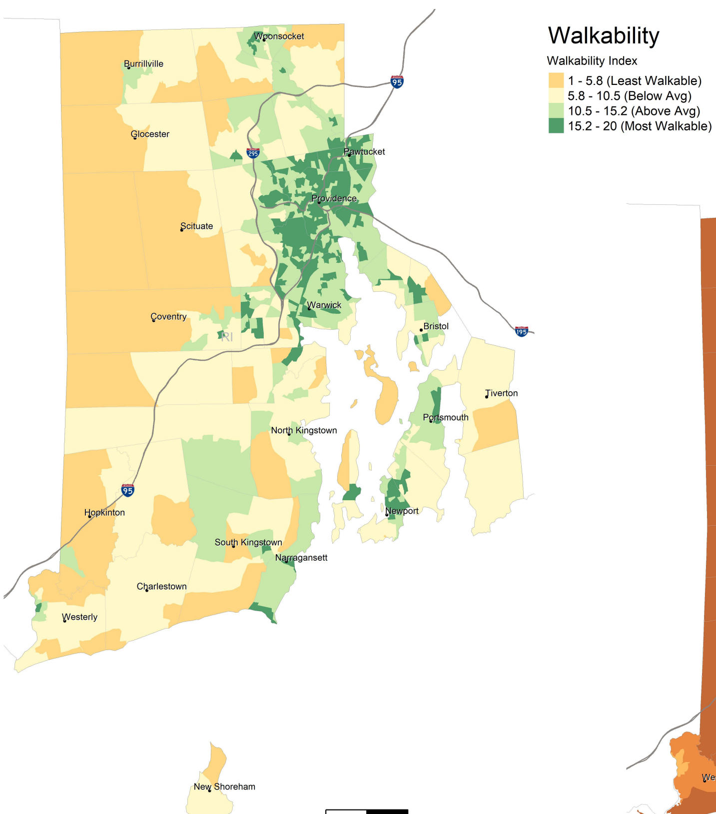
GEOGRAPHIES AFFECTED

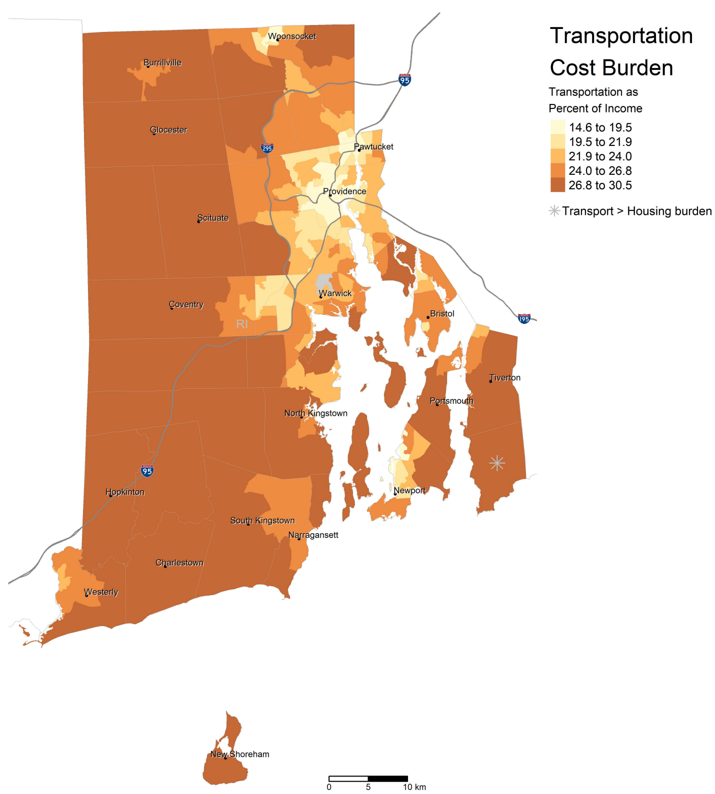
Most of Rhode Island's bus services are concentrated in the northern part of the state, primarily in the Providence metropolitan area. There is significantly less density of bus service in the southern part of the state. Approximately 45% of the state's population does not live within a reasonable distance of a bus stop. Almost 474,000 people in Rhode Island have no physical access to public transit.

The most frequent service is found in the Providence metropolitan area. Municipalities outside this area are generally served by commuter busses with low frequencies of service.

Walkability scores vary but are, in general, above average. The highest walkability scores are found in and around Providence as well as populated areas around Narragansett Bay. The most walkable areas are found in Newport, Providence, and Portsmouth.

Transportation cost burdens for moderate income households vary considerably across the state. They are lowest in and around population centers and highest along the western edge of the state. The average transportation cost burden for moderate income households is 23% of household income, which is 44% higher than the US average. There is only 1 census tract in Little Compton where the transportation cost burdens exceeds housing cost burdens.





PRIORITY POPULATIONS

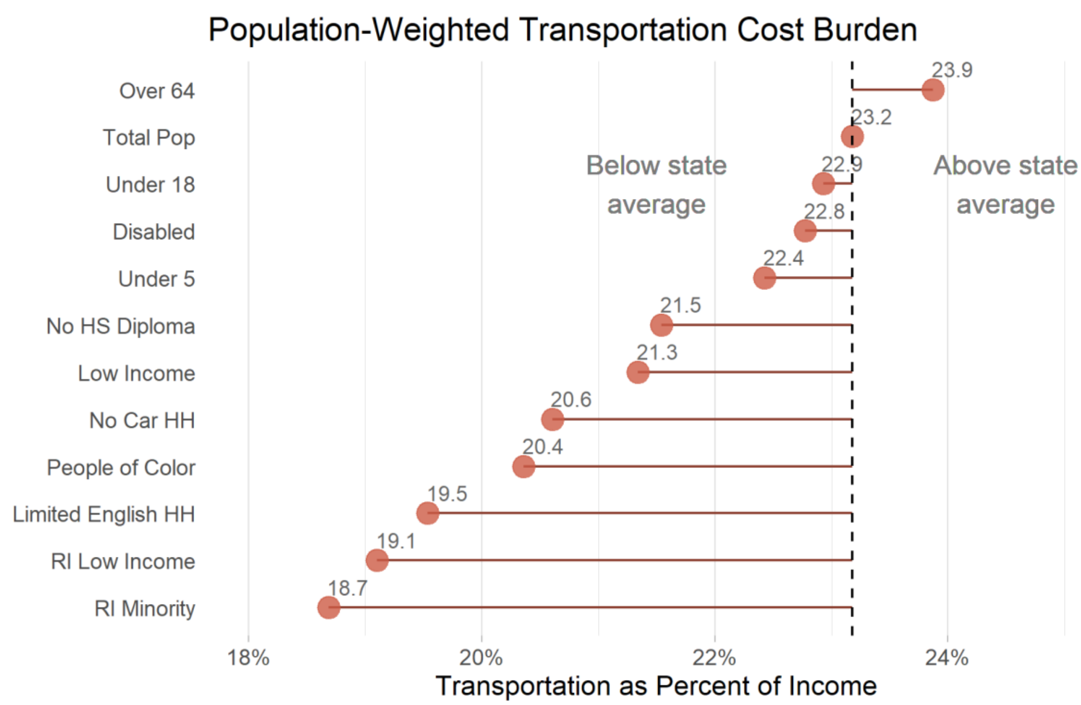
The population with the least access to public transit, experiencing the lowest frequencies of service, living in the least walkable areas, and experiencing the highest transportation cost burden are those over 64 years of age. They are also disproportionately affected by transportation burdens. Over 340,000 people over 64 live in areas in the highest transportation burdens category.

In terms of absolute numbers, low income persons have the least physical access to a bus stop. Almost 86,000 people do not live within a reasonable walking distance of a bus stop.

It should be noted that while those over 64 experience the least frequent service, all priority populations experience long headways. The average headway for busses is over 1.5 hours. Those living in Rhode Island's minority EJ block groups, experience the "best" frequency, and yet still encounter an average 62 minutes between busses.

All priority populations also live in areas with above average walkability scores.

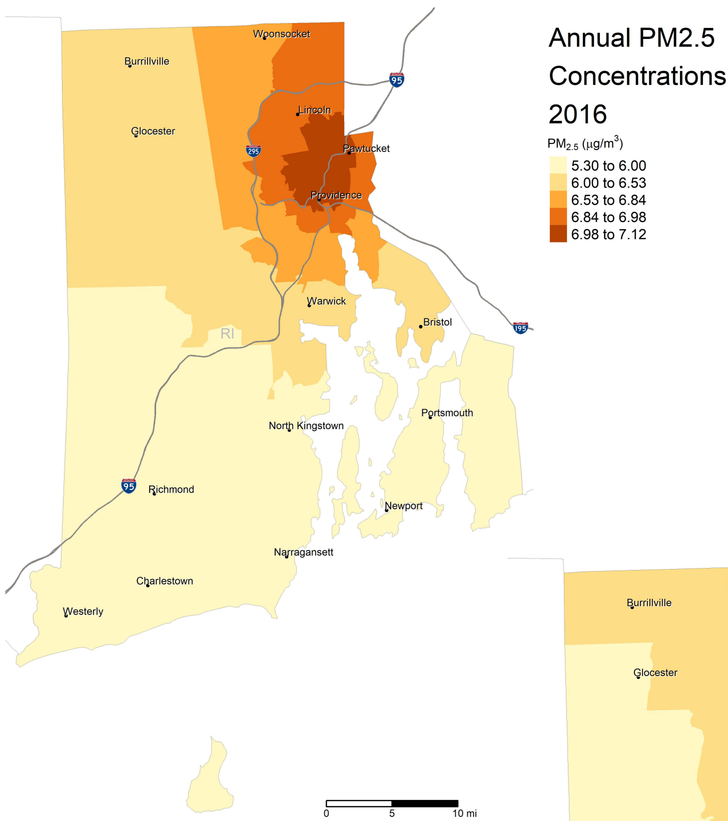
Transportation cost burdens are generally high for all priority populations. Rhode Island's minority EJ block groups demonstrate the lowest cost burden of all priority populations. And yet, moderate income households in this group, on average, spend almost 19% of their household income on transportation. This is higher than the US average of 16%.

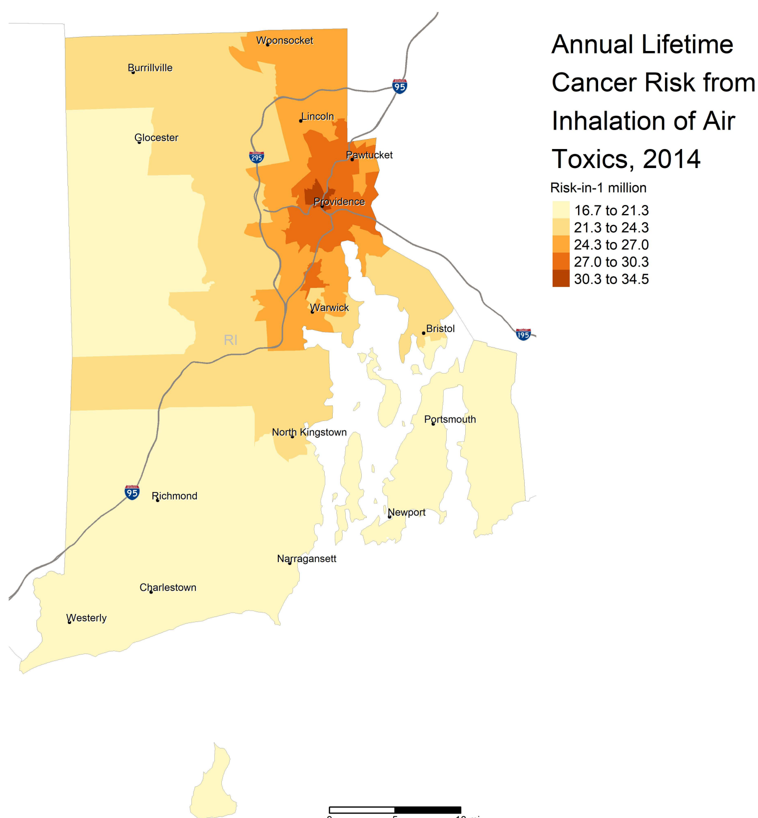


Median emissions and related risks in Rhode Island are higher than the medians for New England with the exception of CO_2. $PM_{2.5}$ emissions have declined almost 25% between 2011 and 2016. Ozone (O_3) emissions have declined 2.6% in the same time span. Median CO_2 emissions are below the median for New England.

GEOGRAPHIES AFFECTED

With the exception of ozone (O_3), higher concentrations for all emissions and higher levels of all related risks evaluated here are found in northern Rhode Island, primarily in the Providence metropolitan area. Higher O_3 concentrations are found in the southwest part of the state and decline going north and east. The most frequent outliers are found in and around Providence. Westerly is an outlier for O_3.

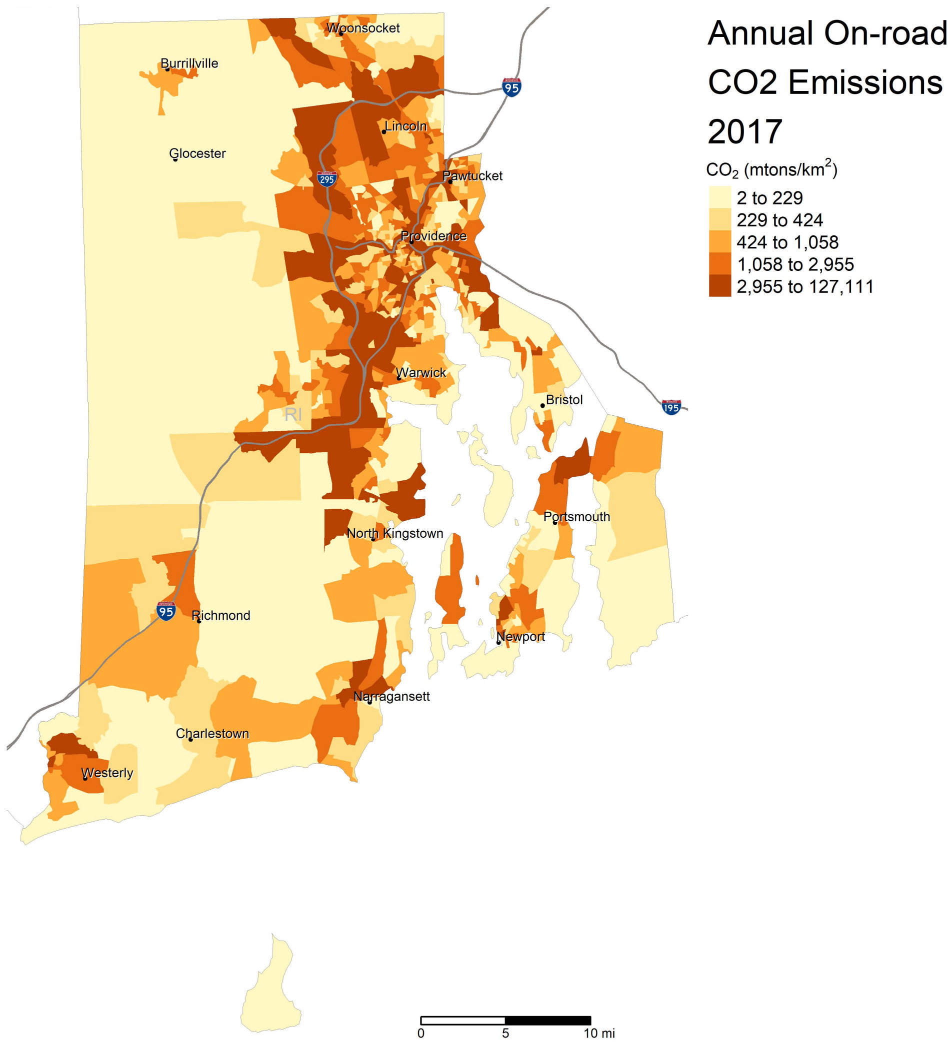




EMISSIONS

On-road CO_2 emissions are found in and near population centers across the state. They are highest from around North Kingstown north and east to the Massachusetts border. Providence is a hotspot for on-road CO2 emissions.

Total emissions have increased since 1990 but there has been a general decline since 2007. Emissions growth is less than population growth.



Annual on-road CO_2 emissions: Change over time

1990 CO_2 (mtons)	2017 CO_2 (mtons)	% change	Per capita 1990 CO_2 (mtons/person)	Per capita 2017 CO_2 (mtons/person)	Per capita % change
3,556,500	3,642,921	2%	3.54	3.45	-3%

PRIORITY POPULATIONS

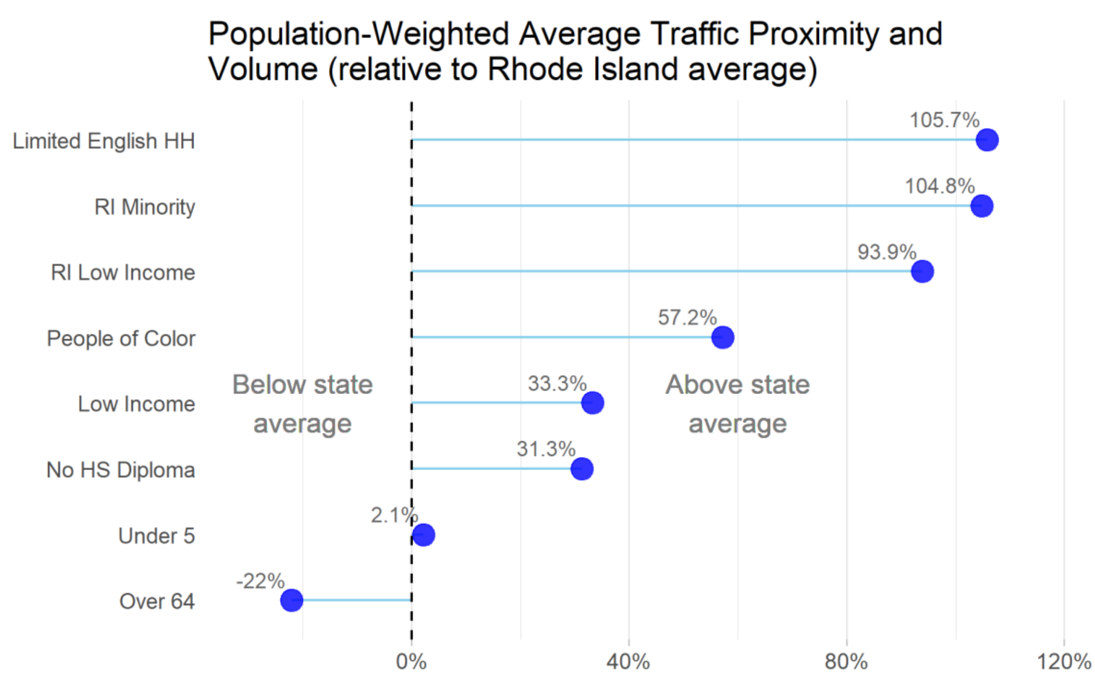
Limited English speaking households, Rhode Island's minority EJ block groups, and Rhode Island's low income EJ block groups experience the highest exposures to all emissions and related risks evaluated here with the exception of O_3.[2]

They are also disproportionately exposed to the highest levels of emissions. Almost 176,000 people living in Rhode Island's minority EJ block groups, over 177,000 people living in Rhode Island's low income block groups, and over 16,000 limited English speaking households experience the highest burdens of emissions.

Distribution of the highest emissions burdens

	% Emissions Category
Total Pop	35%
RI Minority	87%
RI Low income	81%
People of color	61%
Low income	51%
No HS diploma	49%
Under 5	43%
Under 18	40%
Over 64	31%
Total HH	34%
Limited English HH	69%

Note: Categories are defined as block groups with high proportions of priority populations and are in the top 20% of burdens for emissions. For example, 87% of people living in low income block groups as defined by Rhode Island's EJ policy are present in areas in the highest burden emissions category. RI's EJ block groups are defined in R.I. Gen. Laws §250-RICR-140-30-1.4.20.



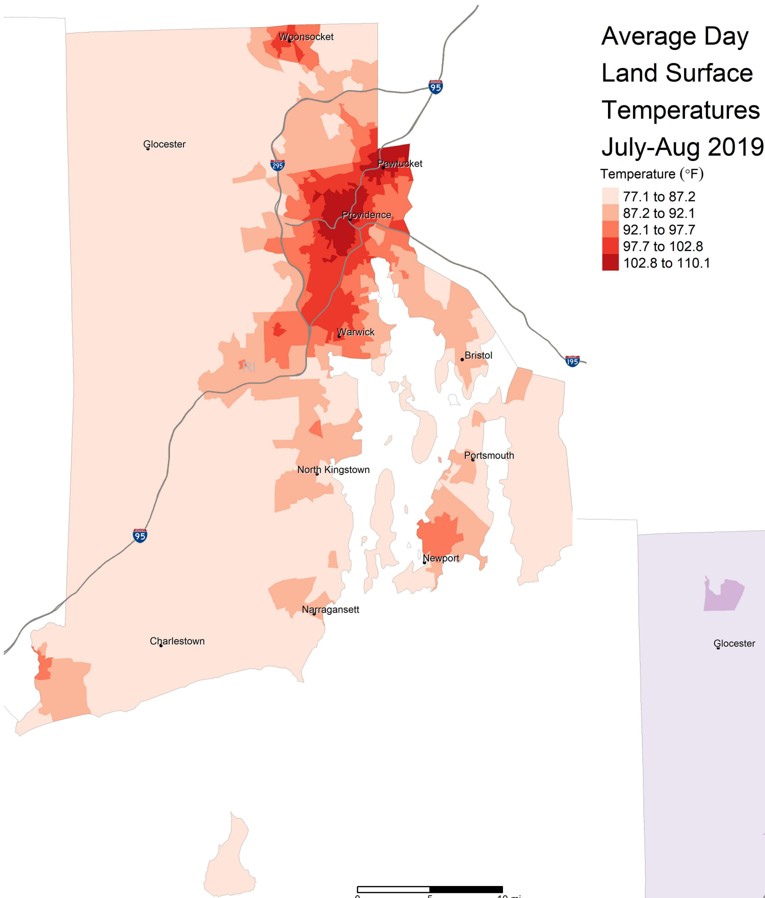
[2] Those over 64 experience the highest exposure to O_3.

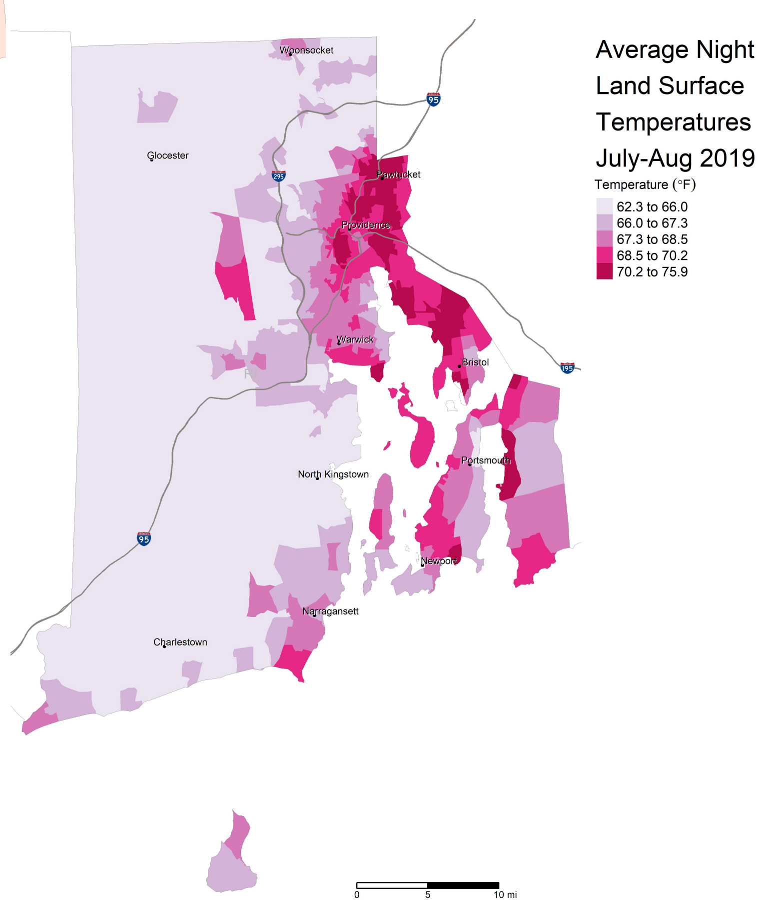
HEAT

Across the day, during the time period studied, average land surface temperatures (LST) ranged from almost 71° to 91°. The highest daytime temperature reached 110° and the highest nighttime temperature reached 76°.

GEOGRAPHIES AFFECTED

Temperatures and urban heat island vary significantly across the state. In general, the Providence metropolitan area experiences the highest daytime temperatures and urban heat island effects. Higher nighttime temperatures are found further south and east with the highest temperatures and urban heat islands around Pawtucket southeast to Bristol. Outliers are found in Providence and Pawtucket.





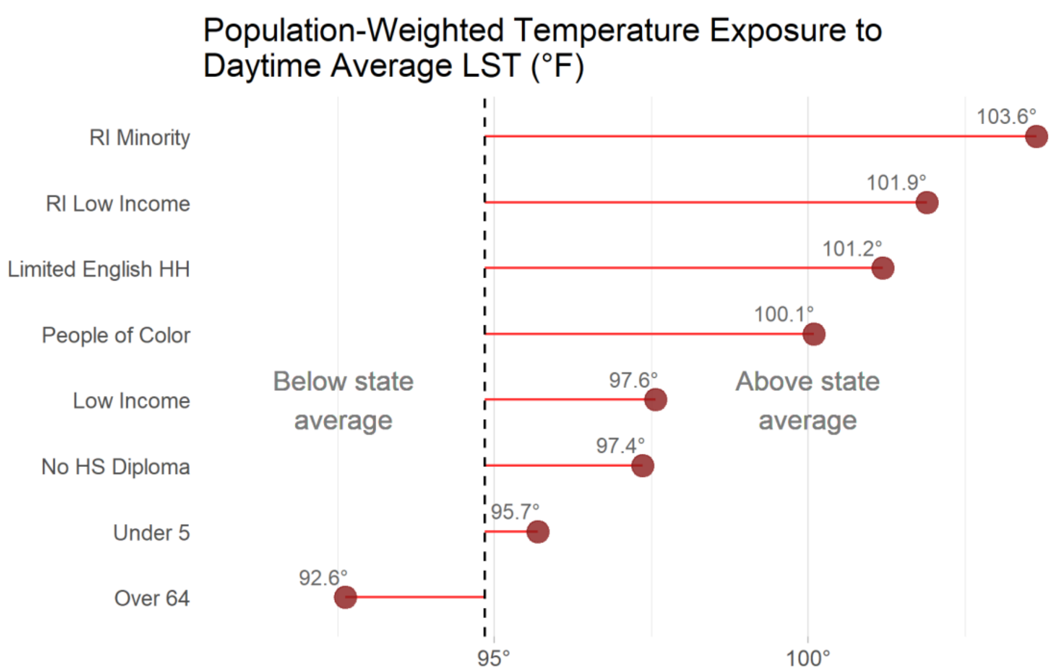
PRIORITY POPULATIONS

Almost 181,000 people live in areas with the highest daytime heat temperatures. Limited English speaking households, Rhode Island's minority EJ block groups, and Rhode Island's low income EJ block groups are more likely to experience the highest daytime and nighttime temperatures compared to the general population or other priority populations. They also disproportionately experience the highest temperatures overall. Over 144,000 people living in Rhode Island's minority EJ block groups, over 137,000 people living in Rhode Island's low income EJ block groups, and almost 1,300 limited English speaking households experience the highest temperatures across the day relative to the state average.

Distribution of the highest heat burdens

	% Heat Category
Total Pop	22%
RI Minority	71%
RI Low income	63%
People of color	49%
No HS diploma	38%
Low income	37%
Under 5	29%
Under 18	27%
Over 64	16%
Total HH	21%
Limited English HH	60%

Note: Categories are defined as block groups with high proportions of priority populations and are in the top 20% of burdens for temperature. For example, 60% of limited English speaking households are present in areas in the highest burden heat category.



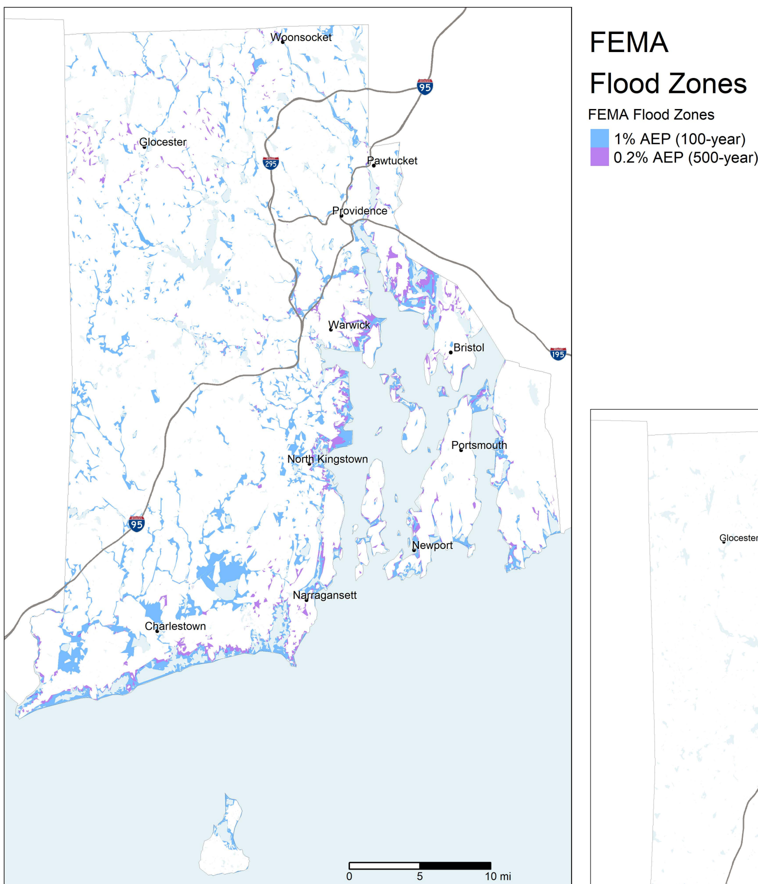
EVACUATION RISKS

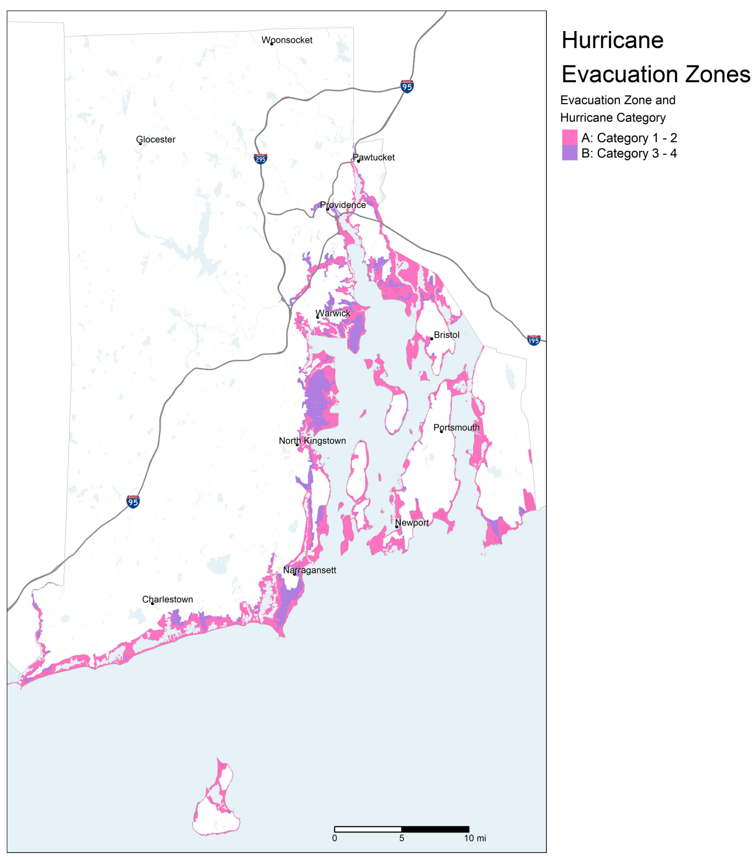
As a relatively flat, coastal plain state, a significant portion of Rhode Island's land area and population are exposed to the risk of flooding from overbanking of inland water bodies (e.g., ponds and rivers) or from coastal storm surge and sea level rise. Rhode Island is subject to significant hurricane risk. Since 1900, Rhode Island has been struck by hurricanes 6 times, and 3 of those were major hurricanes (i.e., Category 3 or higher). The most recent hurricane to hit Rhode Island directly was Hurricane Bob in 1991, a Category 2 storm. The latter caused over $230 million in damage in Rhode Island alone and left 60% of the state's population without power.[2] In general, Rhode Island is subject to a hurricane return period of approximately 17 years, a level of risk comparable to the Gulf Coast of Texas.[72]

GEOGRAPHIES AFFECTED

Approximately 11.6% of land area is found in a flood zone. Flood zones are located all throughout the state.

In addition, 10.3% of land area falls within a hurricane evacuation zone. There is also significant inland intrusion from hurricane related storm surge risk through the Pawtucket River, Seekonk River, and Providence River.





PRIORITY POPULATIONS

Over 108,000 people live in a flood zone. Those over 64 years of age, persons living with disabilities, and households without a car are more likely to live in flood zones compared to the general population or other priority populations. Over 21,000 people over 64, over 15,000 people living with disabilities, and over 4,400 households without a car live in a flood zone. In terms of absolute numbers, low income persons are disproportionately affected; over 25,000 low income persons live in a flood zone.

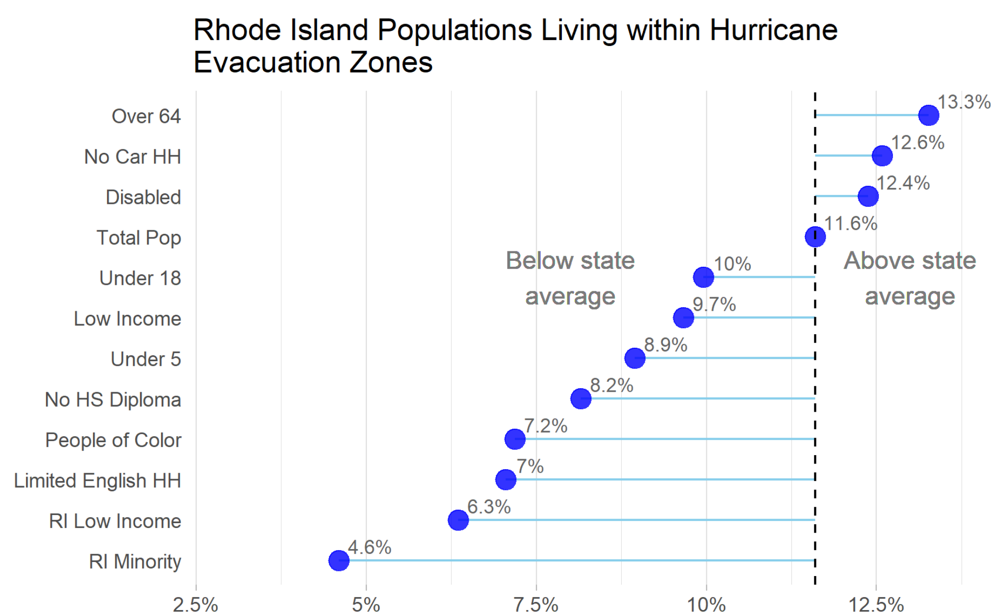
Over 123,000 people live in a hurricane evacuation zone. Those over 64 years of age, households without a car, and persons living with disabilities are more likely to live in a hurricane evacuation zone compared to the general population or other priority populations. Over 23,000 people over 64, almost 5,000 households without a car, and over 16,000 people living with disabilities live in a hurricane evacuation zone. In terms of absolute numbers, low income persons are disproportionately affected; over 28,000 low income persons live in hurricane evacuation zones.

Most priority populations are living in areas in the highest burden evacuation category at rates equal to or higher than the state average. Those over 64 and those living in Rhode Island's low income EJ block groups are disproportionately living in areas with the highest burden evacuation categories. Almost 96,000 people over 64 and almost 117,000 people living in Rhode Island's low income EJ block groups are present in areas in the highest burden evacuation category. In absolute numbers, low income persons are the most impacted; over 149,000 low income persons are living in areas in the highest burden evacuation categories.

Distribution of evacuation burdens

	% Evacuation Category
Total Pop	50%
Over 64	55%
RI Low income	54%
Under 5	53%
Low income	52%
No HS diploma	51%
Under 18	50%
People of color	47%
RI Minority	44%
Total HH	63%
Limited English HH	72%

Note: Categories are defined as block groups with high proportions of priority populations and are in either a flood or hurricane evacuation zone. For example, 53% of those under the age of 5 are present in areas in the highest burden evacuation category.



INVESTING FOR EQUITY

MASSACHUSETTS

GEOGRAPHIES AFFECTED

Less dense areas experience the highest transportation burdens

Low levels of physical access and walkability as well as high transportation cost burden are high in less dense areas.

Distribution of the concentrations of pollutants varies by pollutant

Generally higher in the southern part of the state, around large population centers, and along major roadways.

The eastern half of the state, the Cape, and the area around Springfield/ Holyoke experience the highest heat exposures

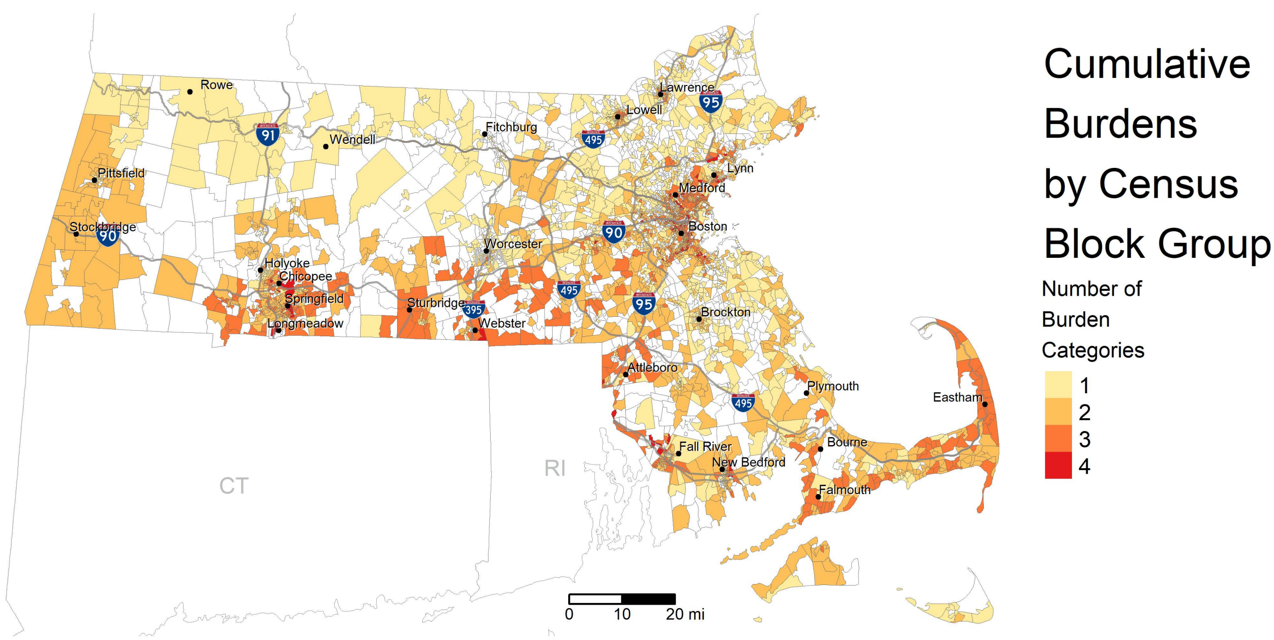
High daytime temperatures and urban heat island effects are concentrated in and around dense, urban areas. The Cape experiences the highest levels of nighttime heat.

Flood and hurricane evacuation risk are spread throughout the state

Over 371,000 people are exposed to flood risk and over 965,000 people live in hurricane evacuation zones.[3]

Over 32% of municipalities in Massachusetts have block groups experiencing three or more categories of highest burden.

The highest burdened geographies in the state are located in the southern and eastern portions of the state.



[3] It is possible that there are flooding risks in the northwest portions of Massachusetts that are not captured here due to lack of publicly available digital data from FEMA.

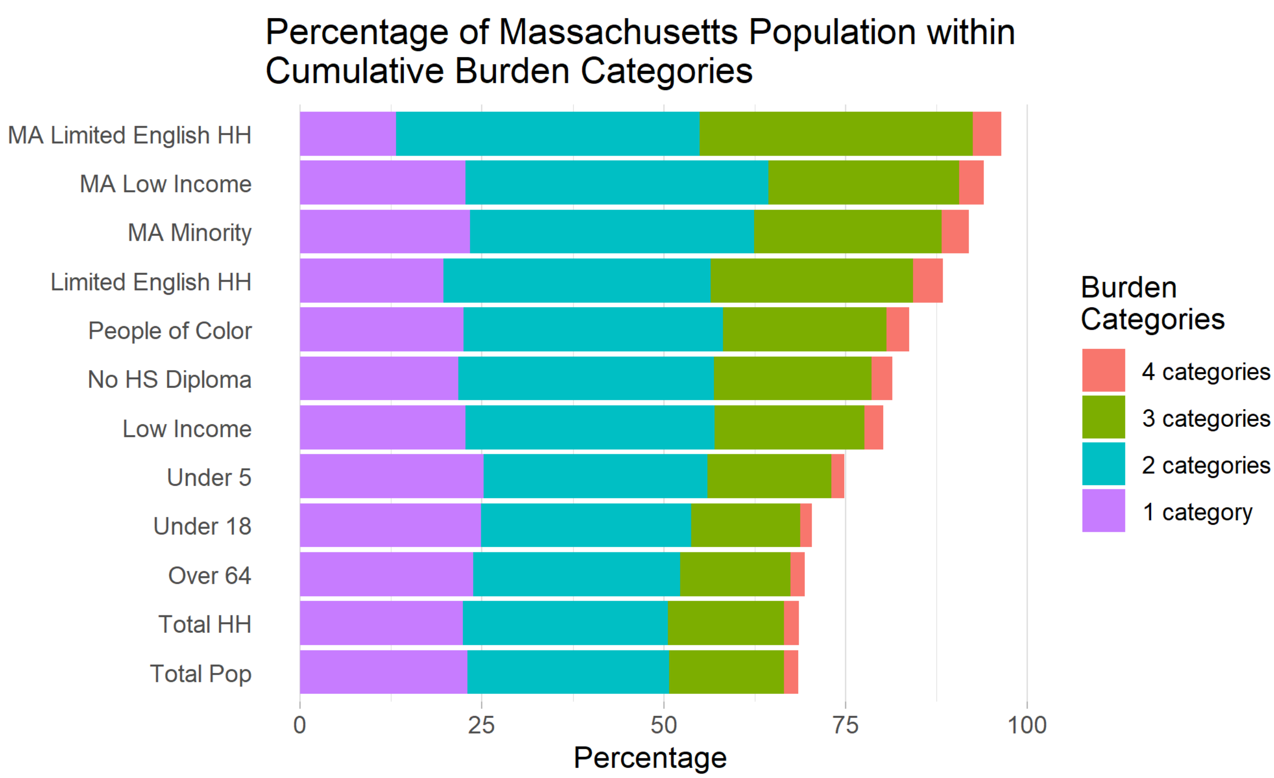
PRIORITY POPULATIONS

Almost 157,000 people in Massachusetts live in places that experience at least one highest burden and almost 121,000 live with three or more categories of highest burden.

Limited English speaking households and people of color are the most affected groups

Overall, limited English speaking households and people of color most frequently experience the greatest number and types of burdens. Cumulatively, a much greater proportion of limited English speaking households and people of color live in places with the highest levels of burdens. Between 88%-96% of limited English speaking households live in block groups with the highest levels of at least one type of burden. They are also the most likely to be areas that experience all four types of burdens. In addition, over 90% of low income persons and people in Massachusetts' minority EJ block groups, live in places with the highest level of burdens.

Populations affected vary by type of burden. Over half of limited English speaking households, people of color, and low income persons experience emissions burdens, heat burdens, and evacuation risks. Those over the age of 64 tend to live in areas with the highest transportation burdens. It should be noted, however, that the methods used in the transportation burden analyses are best suited to ascertaining transportation burdens in suburban and rural areas. People over 64 are the dominant population in less dense areas of Massachusetts. This transportation burden analysis does not determine whether transit access is adequate or enables accessibility to desired destinations, which may overstate the adequacy of service in dense urban areas.



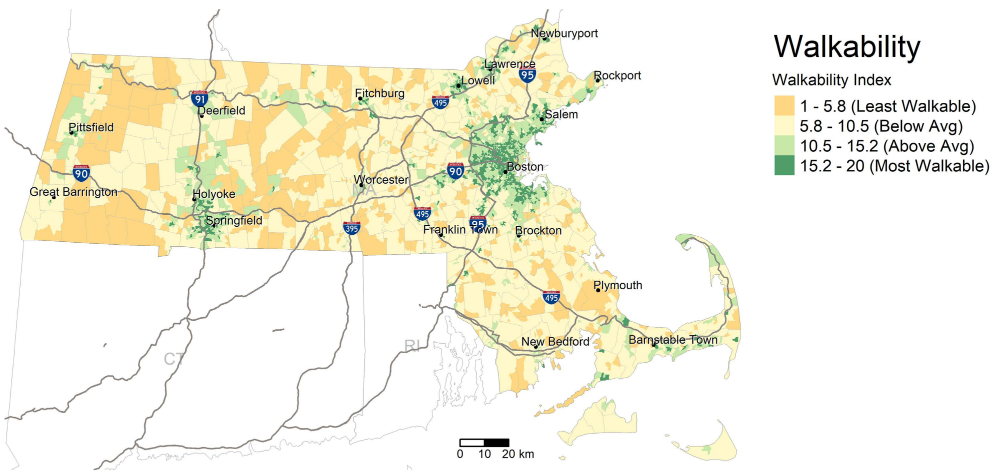
TRANSPORTATION

Massachusetts is served by 15 regional public transit agencies, as well as a number of private operators. These transit services include buses, rapid transit (i.e., subway or light rail), commuter rail, and Park and Ride lots served by public and private buses or shuttles. We analyzed 2,125 fixed public transit routes across the state.

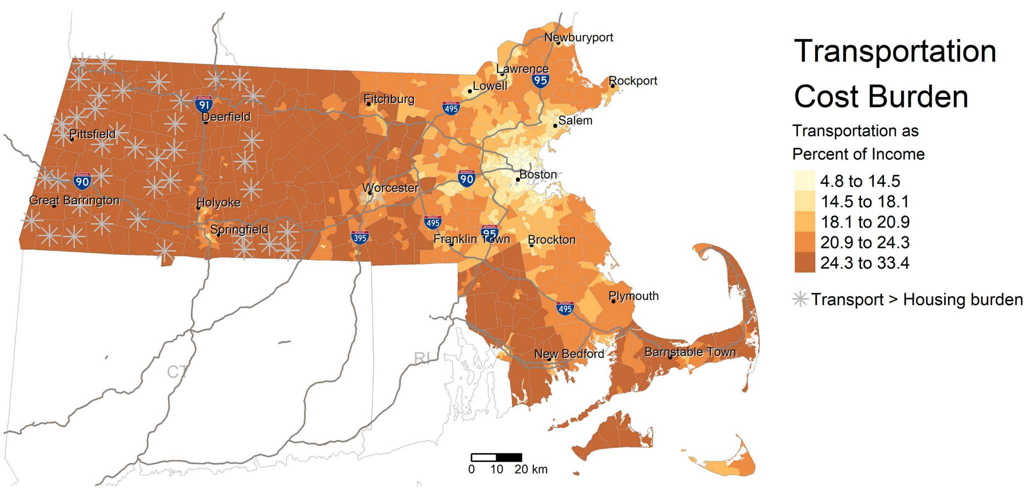
GEOGRAPHIES AFFECTED

Although Massachusetts hosts three modes of public transit, more than any other state in the region, over 25% of the population has no access to any form of public transit. Busses are the most common mode of public transit available and yet over 50% of the state's population do not live within reasonable walking distance of a bus stop. The places that have the least access to public transit, the least frequent service, lower than average walkability, and the highest transportation cost burdens are all the less dense parts of the state. This is not surprising as mass transit has been concentrated in dense urban areas, mostly the Boston region. Transit adequacy can also vary dramatically in the densest urban areas. However, the statewide scope of this analysis highlights the rural-urban differences and may mask intra-urban variation in adequacy of access.

The average walkability score for Massachusetts is above average. This varies geographically, however. Walkability is highest in and around the state's major urban centers, such as the Boston area, Springfield, Holyoke, Lawrence, Lowell, Pittsfield, and urbanized areas of the Cape. Most of the suburban and rural parts of the state show below average and least walkable scores.



There are 40 census tracts, all in central and western Massachusetts, where transportation cost burdens exceed housing cost burdens for a moderate income household. These areas also have the lowest access to any form of public transit or have less frequent service.



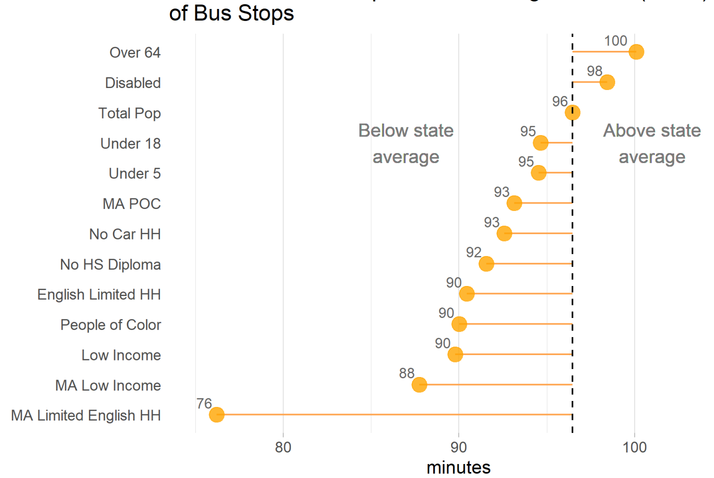
PRIORITY POPULATIONS

Almost 1.8 million people in Massachusetts do not have access to any form of public transit. The population with the least access to all forms of public transit and least frequent service are those over the age of 64 years. This population also lives in areas with the highest transportation cost burden. This is not surprising given that people over the age of 64 in Massachusetts predominantly live in suburban and rural areas, which are the places where these burdens are highest.

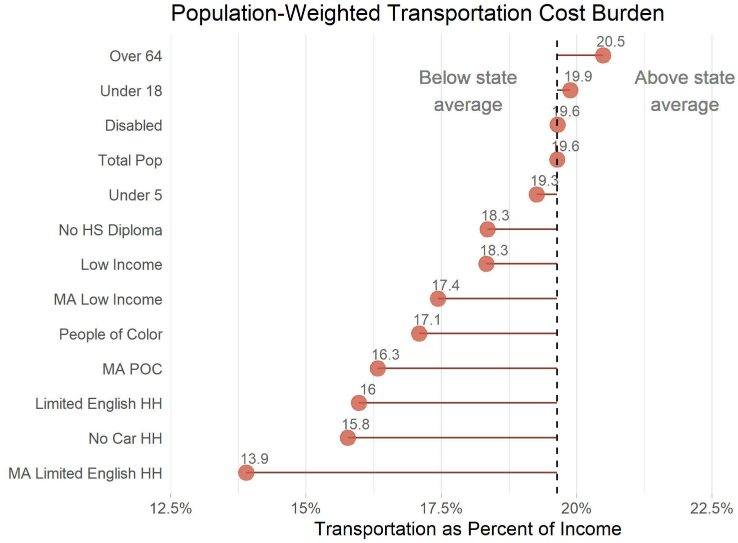
It should be noted that, while those over 64 experience the least frequent service, all priority populations experience very long headways. The average headway for busses is over 1.5 hours. Limited English speaking households (as defined by the Massachusetts EJ policy), which experience the "best" frequency, still encounter an average 76 minutes between busses. Similar patterns are seen with commuter rail service with frequencies averaging from 46 minutes between trains for limited English speaking households (as defined by the Massachusetts EJ policy) to 85 minutes for those over the age of 64.

Rapid transit service shows the least inequities across priority populations. Those without a high school diploma, Massachusetts' minority EJ block groups, those living with disabilities, and households without a car experience the least frequent service. This is a different pattern than found with other transportation focused analyses. However, it is important to note that rapid transit is only available to those living or working in Boston's inner core communities.

Population-Weighted Average Bus Stop Headway for Massachusetts Groups within Walking Distance (400m) of Bus Stops



Population-Weighted Transportation Cost Burden

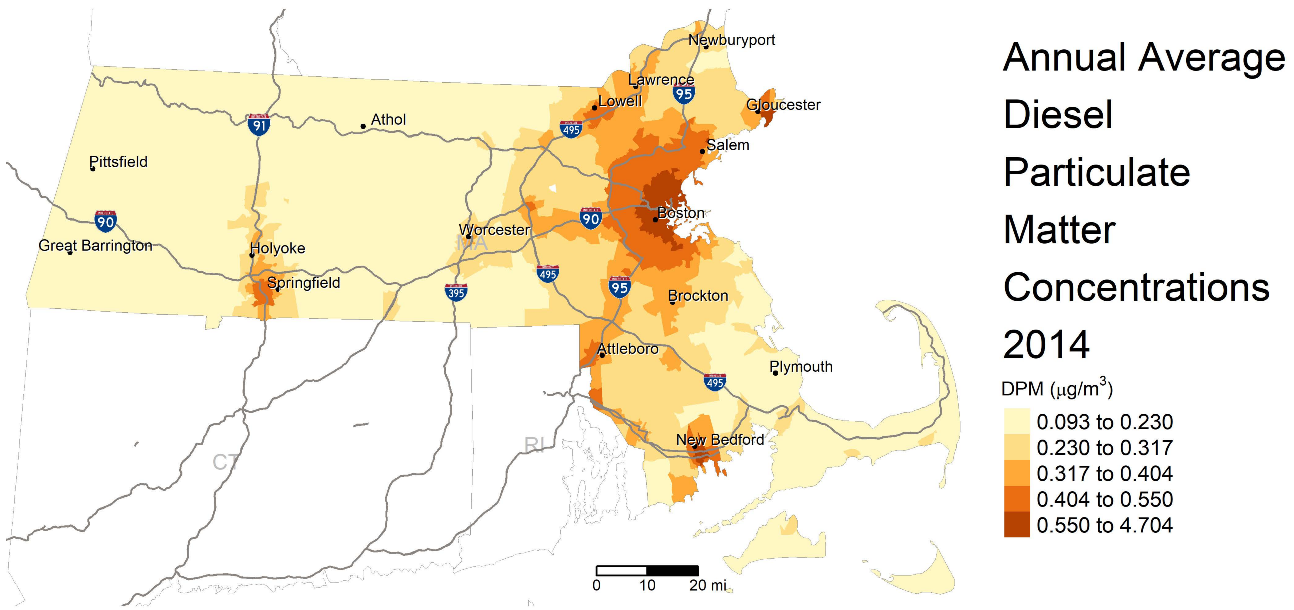


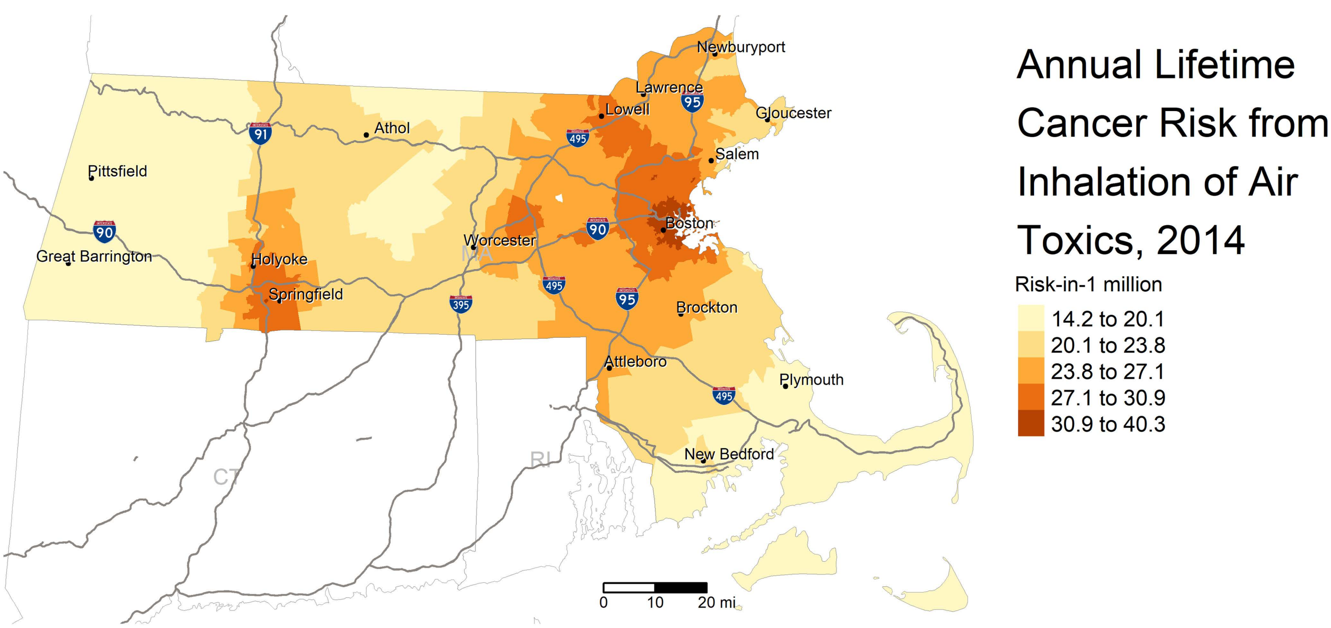
EMISSIONS

Average concentrations for $PM_{2.5}$ and ozone (O_3), as well as median emissions for CO_2 in Massachusetts are below the median for New England. $PM_{2.5}$ concentrations have declined almost 32% between 2011 and 2016. O_3 has increased only 0.7% in the same time span. The medians for diesel particulate matter (DPM), air toxics cancer risk, respiratory hazard index, and traffic proximity and volume are all above the medians for New England.

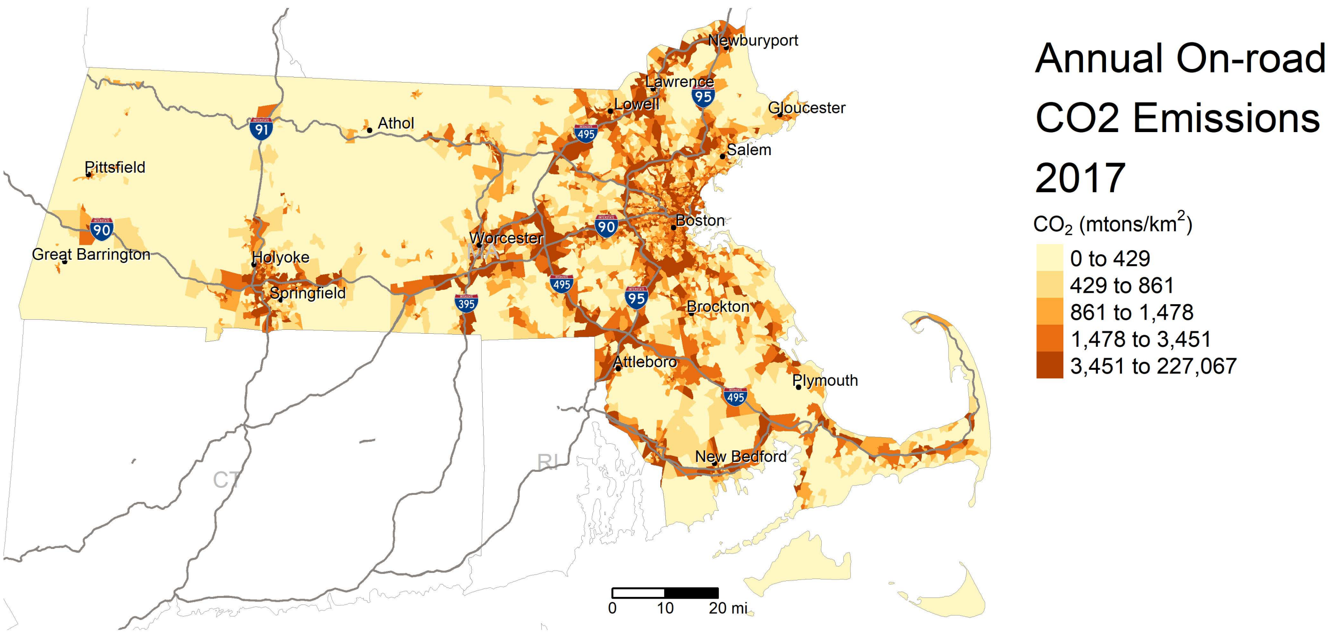
GEOGRAPHIES AFFECTED

Higher concentrations of $PM_{2.5}$, DPM, and air toxics risk are generally found within the inner core communities in eastern Massachusetts (i.e., within the I-495 loop), in southeastern Massachusetts along the Rhode Island Border, and in and around the Springfield/ Holyoke areas. These concentrations follow closely the major roadways in the state.





On-road carbon dioxide (CO_2) emissions are largely concentrated in the eastern half of the state and around the urbanized areas in central and western Massachusetts. Total emissions have increased dramatically since 1990. While emissions have shown a slight downward trend since 2005, emissions growth overall is still higher than population growth.



Annual on-road CO_2 emissions: Change over time

1990 CO_2 (mtons)	2017 CO_2 (mtons)	% change	Per capita 1990 CO_2 (mtons/person)	Per capita 2017 CO_2 (mtons/person)	Per capita % change
22,875,230	27,208,279	19%	3.8	3.98	5%

With the exception of O_3, two parts of the state stand out as frequent outliers with the highest levels of emissions: Boston and surrounding municipalities and the areas around and between Fall River and New Bedford. Springfield and surrounding communities show up as outliers for O_3.

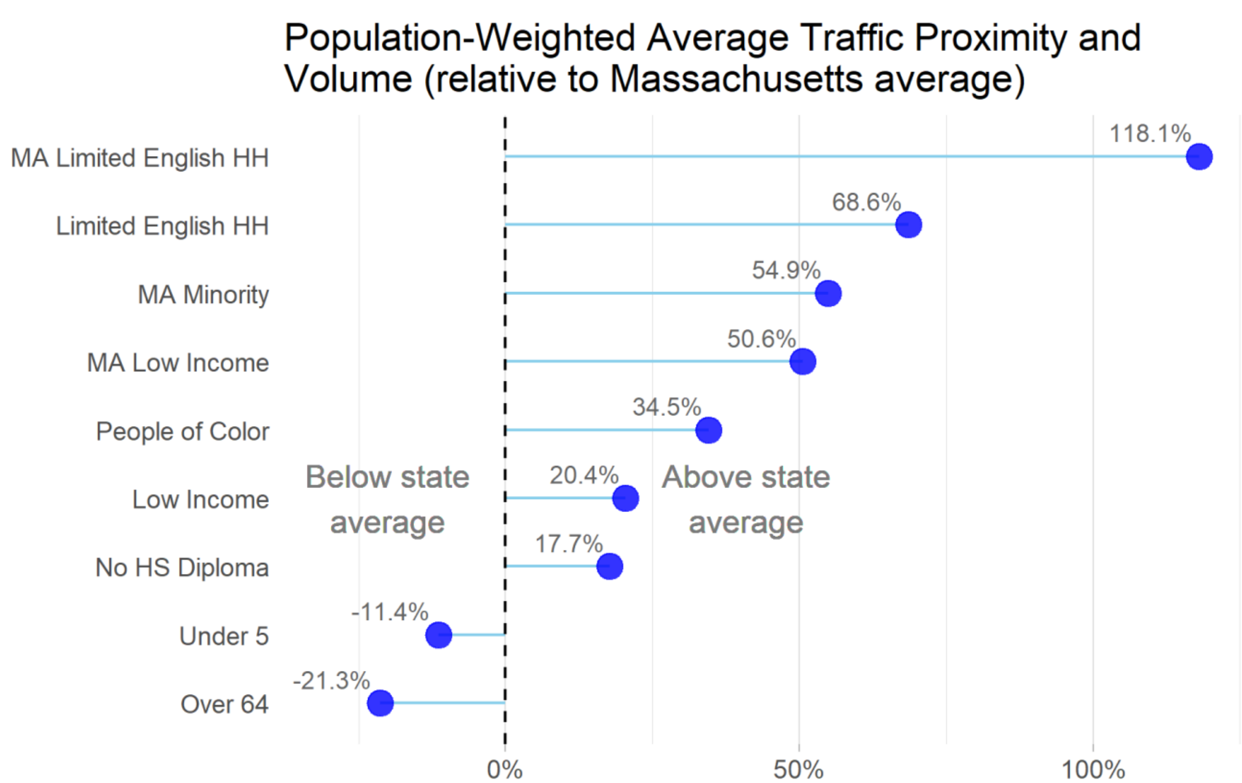
PRIORITY POPULATIONS

Limited English speaking households and people of color, regardless of definition, are by far the most exposed to emissions and the most exposed to high levels of emissions and are living in close proximity to high traffic corridors. Low income persons, as defined by the Massachusetts EJ policy, and individuals without a high school diploma are disproportionately exposed to the highest levels of emissions.

Distribution of the highest emissions burdens

	% Emissions Category
Total Pop	40%
MA Minority	70%
MA Low income	68%
People of color	59%
No HS diploma	55%
Low income	54%
Under 18	40%
Under 5	44%
Over 64	36%
Total HH	41%
MA Limited English HH	78%
Limited English HH	66%

Note: Categories are defined as block groups with high proportions of priority populations and are in the top 20% of burdens for emissions. For example, 70% of people living in MA EJ minority block groups are present in areas in the highest burden emission category. MA's EJ block groups are defined in H.4933.

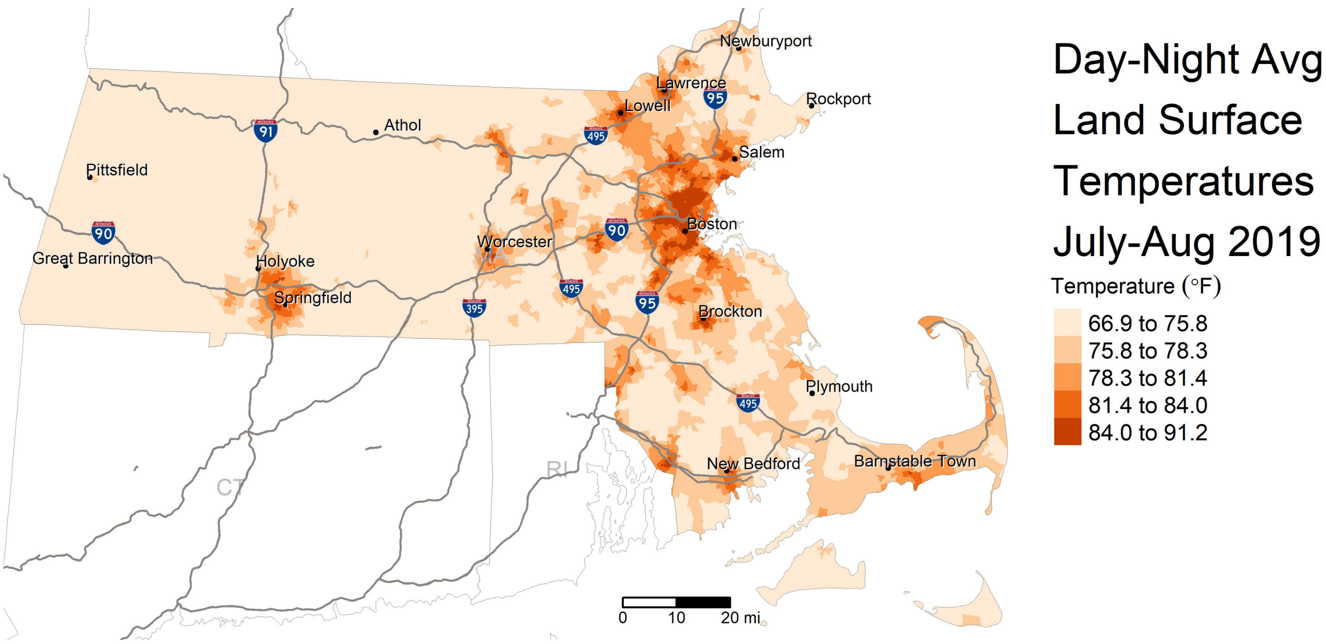


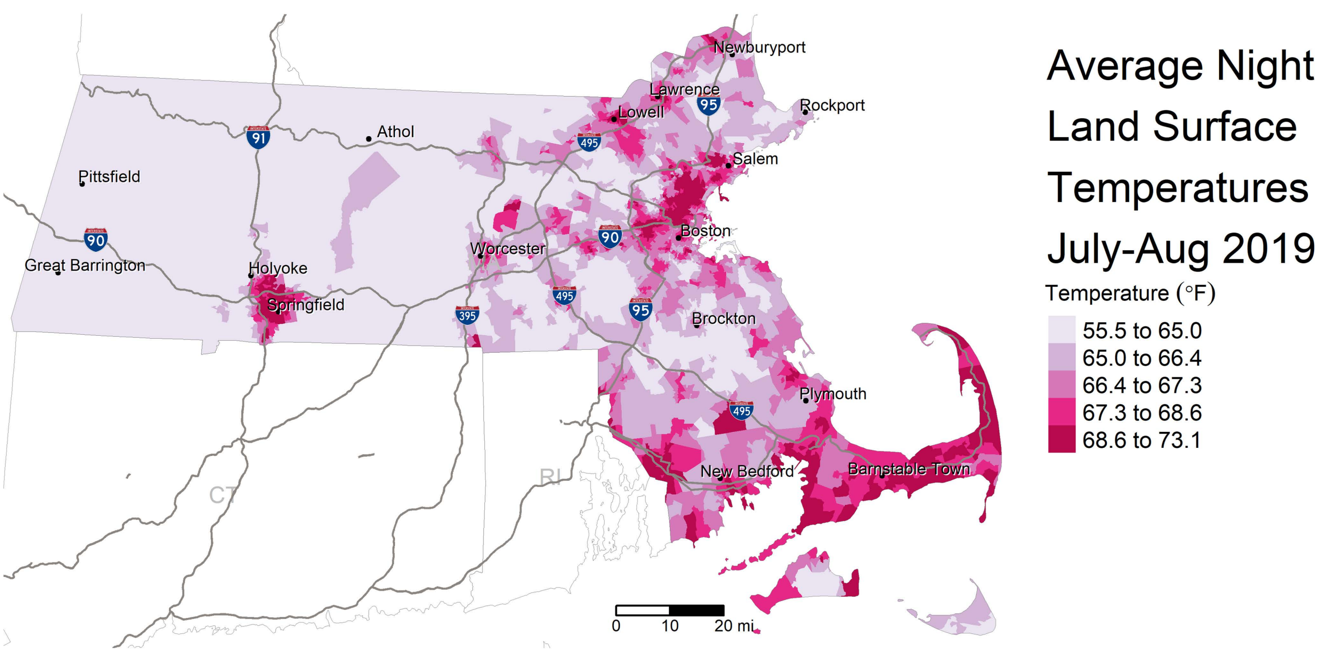
Across the day, during the time period studied, average land surface temperatures (LST) ranged from almost 67° to 91°. The highest daytime temperature reached 112° and the highest nighttime temperature reached 73°.

GEOGRAPHIES AFFECTED

In general, the eastern half of Massachusetts and the Springfield-Holyoke area experience the highest average daytime temperatures. In contrast, the Cape experiences the highest average nighttime temperatures. This same pattern for daytime and nighttime average temperatures is also seen for the urban heat island effect.

Boston and Everett are both outliers for higher daytime temperatures and daytime urban heat island effects. Outliers for higher nighttime temperatures are Boston, Malden, Attleboro, New Bedford, and Yarmouth.





PRIORITY POPULATIONS

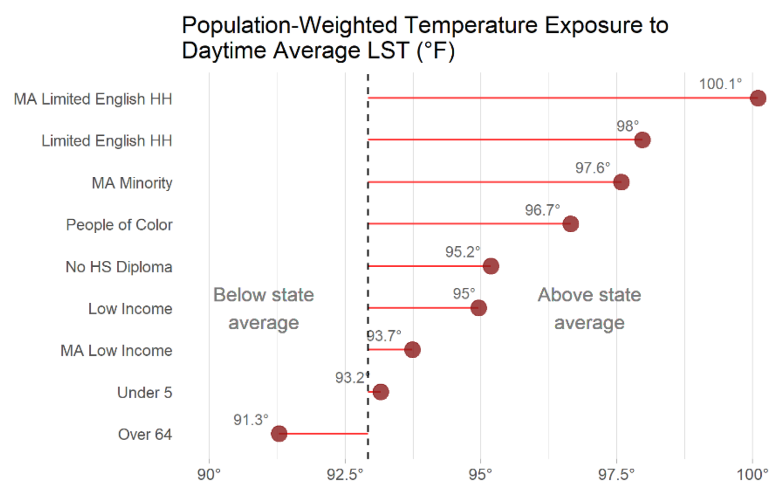
Almost 1.23 million people live in areas with the highest daytime temperatures. Limited English speaking households and people of color (regardless of definition) experience proportionally the highest daytime and nighttime temperatures. They also disproportionately live in areas with the highest temperatures. Over 22,000 limited English speaking households and almost 600,000 of those living in Massachusetts' minority EJ block groups are exposed the highest daytime temperatures. This is 15% of all limited English speaking households and 32% of those living in Massachusetts' minority EJ block groups.

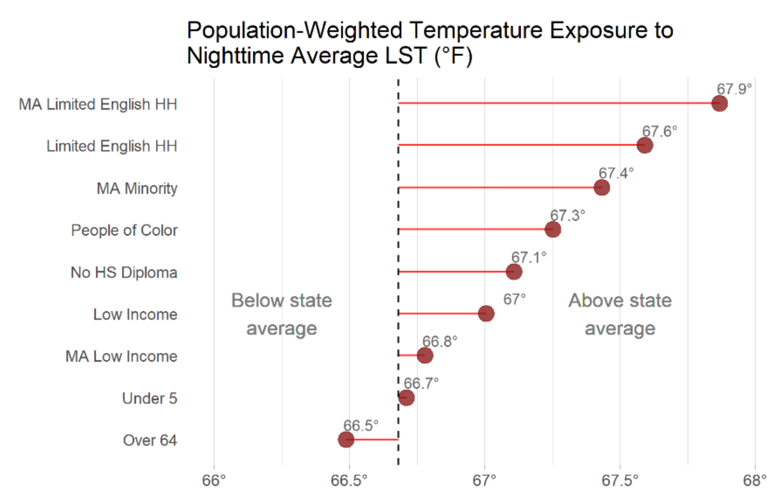
In addition, low income persons (regardless of definition) and those without a high school diploma are also disproportionately exposed to the highest levels of heat.

Distribution of the highest heat burdens

	% Heat Category
Total Pop	25%
MA Minority	53%
MA Low income	52%
No HS diploma	45%
Low income	41%
People of color	40%
Over 64	28%
Under 5	24%
Under 18	22%
Total HH	26%
MA Limited English HH	68%
Limited English HH	52%

Note: Categories are defined as block groups with high proportions of priority populations and are in the top 20% of burdens for temperature. For example, 68% of MA limited English speaking households are present in areas in the highest burden heat category.



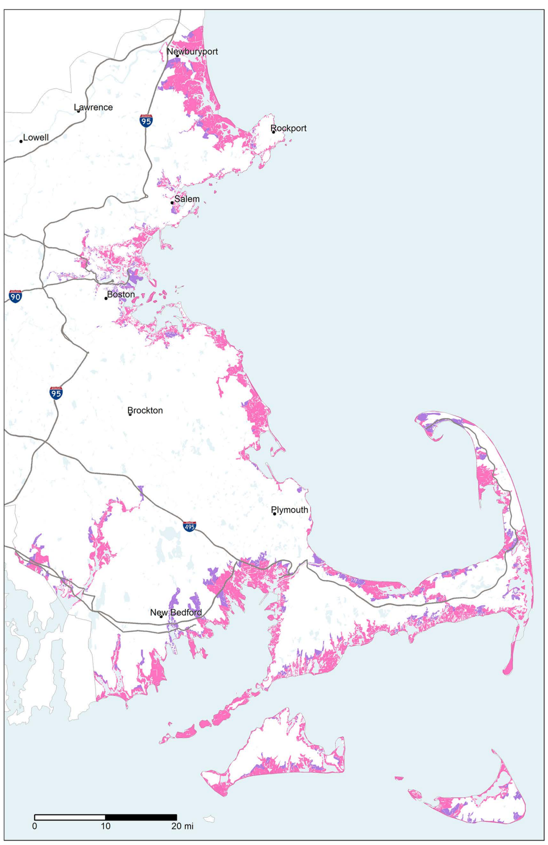


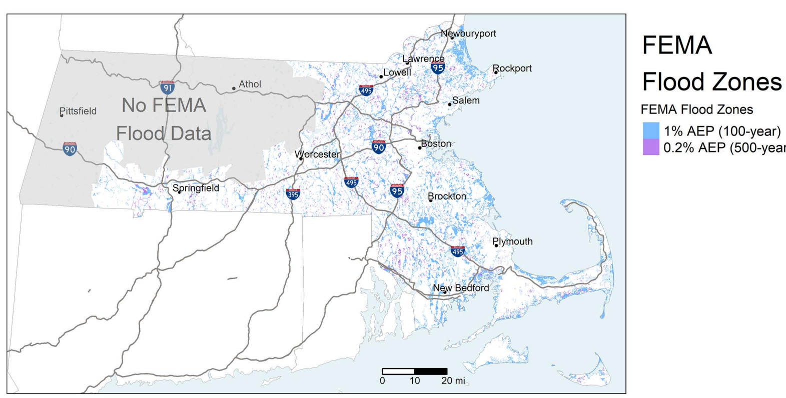
EVACUATION RISKS

As a humid, coastal state, a significant portion of Massachusetts's land area and population are exposed to the risk of flooding from overbanking of inland water bodies (e.g., ponds and rivers) or from coastal storm surge and sea level rise. Massachusetts is also subject to significant hurricane risk. Since 1900, Massachusetts has been struck by hurricanes 8 times, and 3 of those were major hurricanes (i.e., Category 3 or higher). The most recent hurricane to hit Massachusetts directly was Hurricane Bob in 1991, a Category 2 storm when it struck the Cape and Islands and south shore of Massachusetts. The latter caused over $39 million in damage in Massachusetts alone and left 60% of the state without power.[73] Hurricane Sandy in 2012 did not hit Massachusetts directly, but nevertheless resulted in flooding of Massachusetts coastal communities. In general, the Cape and Islands of Massachusetts are subject to a hurricane return period of approximately 13 - 16 years, a level of risk comparable to the Gulf Coast states including Texas, Louisiana, and Florida. Boston Harbor is subject to a hurricane return period of approximately 30 years.[74]

GEOGRAPHIES AFFECTED

Over 9% of Massachusetts' land area falls within FEMA flood zones and over 6% of land falls in a hurricane evacuation zone. Flood zones are found in much of the eastern half of the state as well as in and around Springfield. It is important to note that FEMA has not made digital data for the north, west, and northcentral parts of the state publicly available. It is very likely that flood risks are much more widespread than we are able to determine with the public data available. Hurricane evacuation zones are found along almost the entire coastline of the state. There is also risk of significant inland intrusion from hurricane storm surge in Mt. Hope Bay, Buzzards Bay, the Charles River, the Mystic River, and in the northeast corner of the state.





PRIORITY POPULATIONS

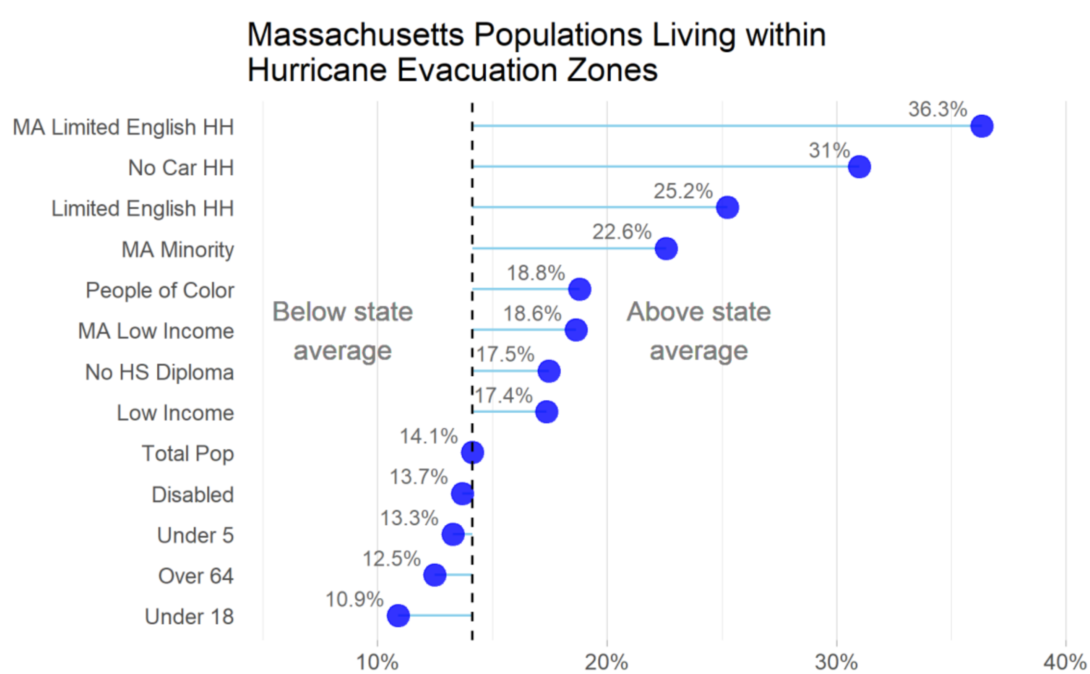
Over 371,000 people live in a flood zone and almost one million live in a hurricane evacuation zone. Limited English speaking households (regardless of how they are defined) and households without a car most frequently live in either a flood or a hurricane evacuation zone. Over 35,000 limited English speaking households live in a flood zone and over 133,000 live in a hurricane evacuation zone. Almost 23,000 households without a vehicle live in flood zones and over 100,000 live in a hurricane evacuation zone. In absolute numbers, those living in Massachusetts' minority EJ block groups are the most affected with over 166,000 living in a flood zone and almost 600,000 living in a hurricane evacuation zone.

Low income persons and those without a high school diploma are also more likely to live in flood zones than the general population. Minorities (regardless of how they are defined) are also more likely to live in a hurricane evacuation zone. While all priority populations live in areas that are subject to flooding or hurricane evacuation, limited English speaking households and people of color (regardless of how they are defined) as well as low income persons disproportionately live in areas with these risks.

Distribution of evacuation burdens

	% Evacuation Category
Total Pop	47%
MA Minority	56%
MA Low income	56%
People of color	54%
Low income	52%
Under 18	52%
No HS diploma	50%
Over 64	49%
Under 5	49%
Total HH	47%
MA Limited English HH	71%
Limited English HH	60%

Note: Categories are defined as block groups with high proportions of priority populations and are in either a flood or hurricane evacuation zone. For example, 56% of MA low income persons live in flood or hurricane evacuation zones.



INVESTING FOR EQUITY

VERMONT

GEOGRAPHIES AFFECTED

High transportation burdens are found throughout the state

Low levels of physical access, low frequencies of service, low levels of walkability, and high transportation costs exist across the state, even in urban areas.

Emissions are high in the southern portions and northwest corners of the state

High concentrations of emissions and related risks vary but are regularly found in the same areas: south of Route 4 and from Burlington to the Canadian border.

Higher temperatures are found along the western edge of the state

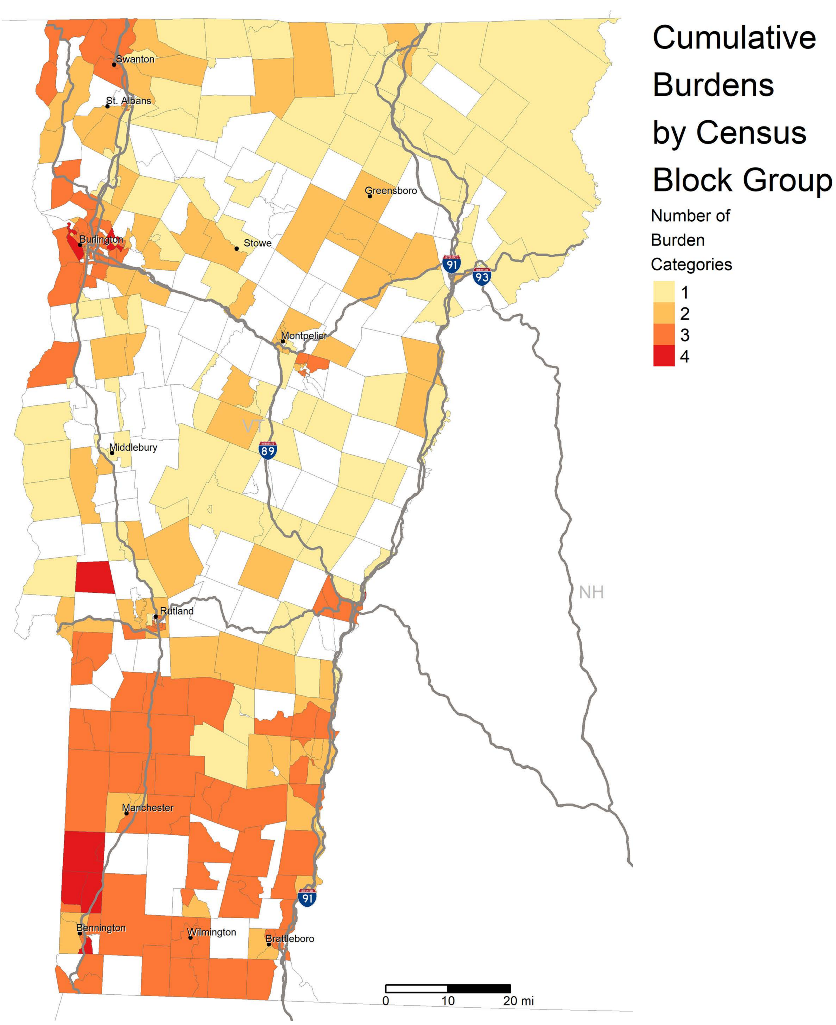
High daytime and nighttime temperatures as well as urban heat islands are highest along the shores of Lake Champlain and southeast along I-91.

Flood and fluvial erosion risks are found throughout the state

Almost 62,000 people are exposed to flood risks or fluvial erosion risks.[4]

41% of municipalities in Vermont have block groups that experience three or more categories of highest burdens

The highest burdened places are most often found in the southern part of the state and the northwest corner around Burlington and at the Canadian border.



[4] It is possible that flood risks are higher than we estimated because much of the lack of publicly available digital data from FEMA for the central and northern parts of Vermont, including areas along Lake Champlain.

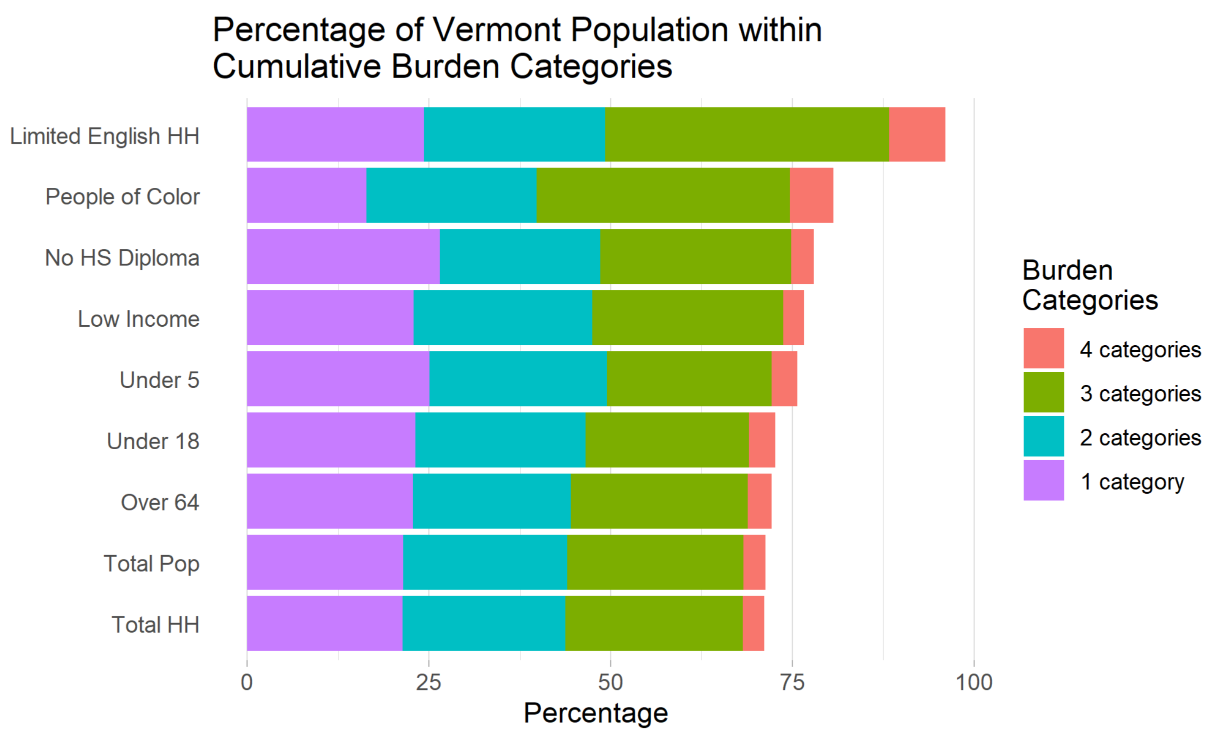
PRIORITY POPULATIONS

Over 143,000 people in Vermont live in places that experience at least one highest burden and over 169,000 live with three or more categories of highest burden.

Limited English speaking households and people of color are the most affected group

Limited English speaking households, despite low population numbers, most frequently experience the greatest number and types of burdens. Cumulatively, limited English speaking households also experience the highest levels of burden across all types of burdens. People of color and low income persons are the largest populations in terms of absolute numbers who experience individual and cumulative burdens.

Populations affected vary by type of burden. Well over half of limited English speaking households and people of color experience the highest emissions and evacuation burdens. In addition, over half of limited English speaking households and people of color experience the highest heat burdens. Limited English speaking households and those without a high school diploma tend to live in areas with the highest transportation burdens.

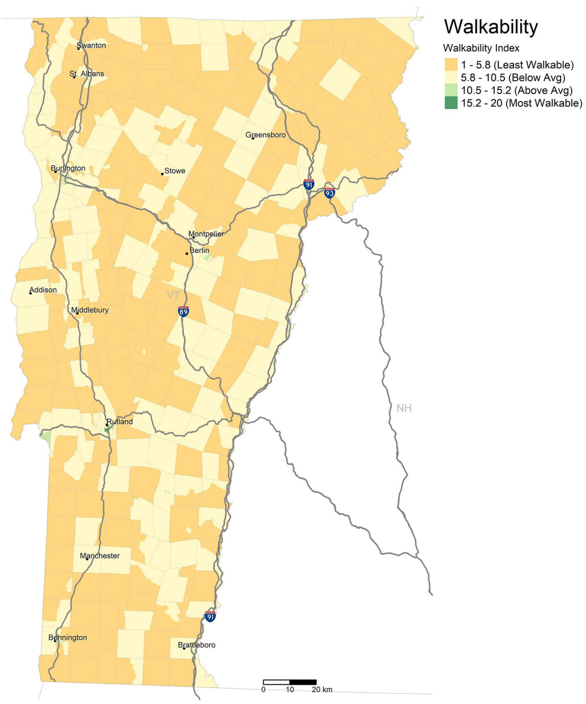


TRANSPORTATION

Vermont is served by 10 local bus agencies or transit districts, two inter-state rail lines operated by Amtrak, local and inter-state ferry services on Lake Champlain, and several private inter-city bus services. In addition, there are over 100 Park and Ride lots throughout the state, variously owned by the state, municipalities, and by public transit agencies. The analysis here only considers public transit services for which publicly available geospatial data is available, which includes the 10 regional public transit agencies and the 47 Park and Ride lots that are directly serviced by these transit agencies. We analyzed 89 fixed public transit routes across the state.

GEOGRAPHIES AFFECTED

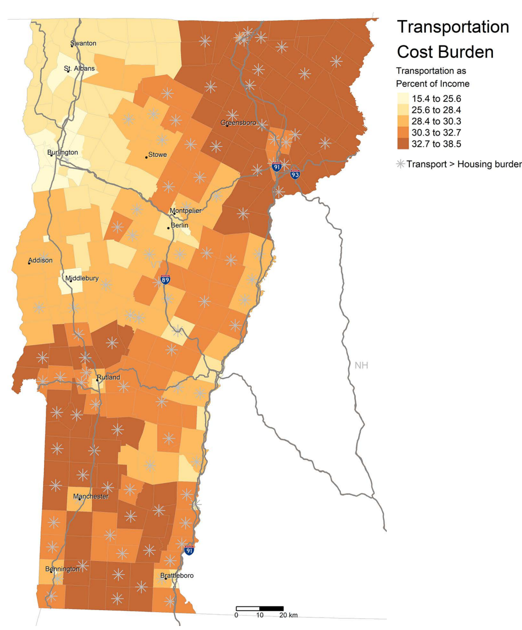
Most of Vermont's bus services are concentrated in a handful of cities. Only 38% of the state's population lives within a reasonable distance of a bus stop or Park and Ride lot. Almost 385,000 people have no physical access to any form of public transit.



The most frequent service is found in cities. However, the average time between scheduled arrivals (i.e., headways) are very long all across the state. The average headway is almost 5 hours. For all but three of the agencies analyzed, the shortest headways were greater than 45 minutes.

Walkability scores across the state are most frequently below average to least walkable. The highest walkability scores are found in Burlington, Montpelier, Fairhaven, and Rutland.

Transportation cost burdens for moderate income households are generally high across the state. The average transportation cost burden is 28% of household income for moderate income households, which is 75% higher than the US average. There are 101 census tracts where the transportation cost burdens exceeds housing cost burdens. This is 55% of all census tracts in the state. The lowest transportation cost burdens were found in the northwest corner of the state, especially in Burlington, Middlebury, and St. Albans.



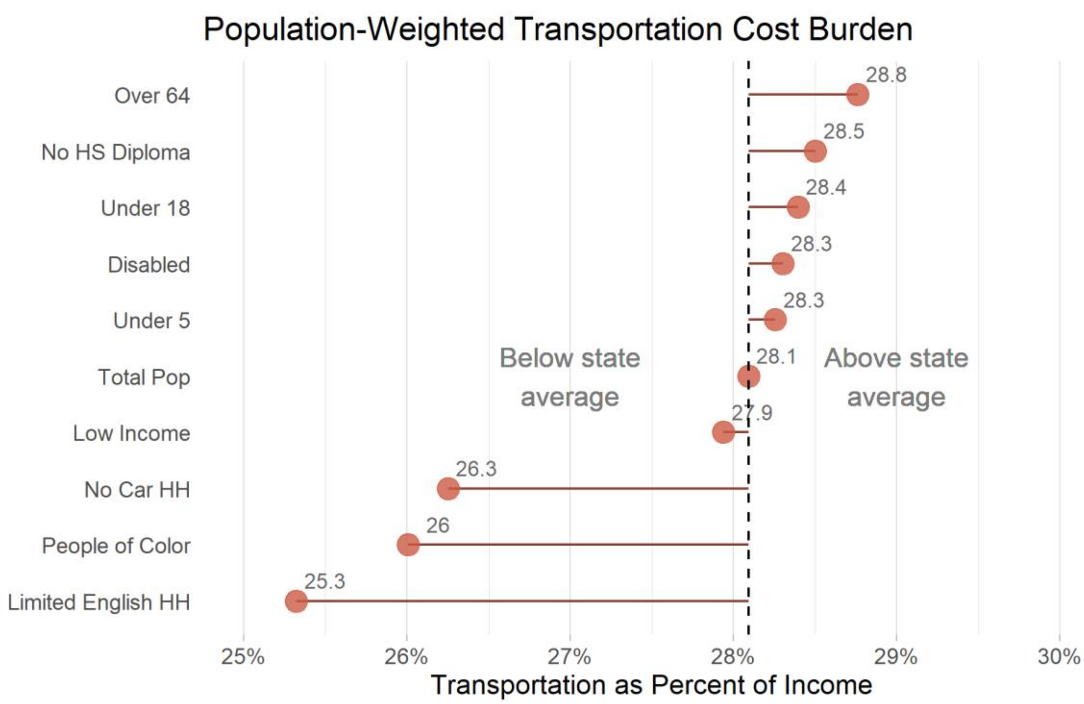
PRIORITY POPULATIONS

The population with the least access to public transit, living in the least walkable areas, and experiencing the highest transportation cost burden are those 64 years old and older. Minors (those under 18 and those under 5 years of age) experience these same burdens as well as the worst frequencies of service. Those without a high school diploma are disproportionately affected by transportation burdens. Over 13,000 people without a high school diploma live in areas in the highest transportation burden category

It should be noted that, while minors experience the least frequent service, all priority populations experience very long headways. Limited English speaking households, which experience the "best" frequency, still encounter an average 1 hour between busses.

All priority populations also live in areas with below average walkability scores.

Most priority populations live in areas with transportation cost burdens that are above the state average. It should be noted, however, that transportation cost burdens are generally high for all priority populations. Limited English speaking households have the lowest cost burden of all priority populations. And yet, it is estimated that moderate income households in this group, on average, spend about 25% of their household income on transportation. This is 56% higher than the US average of 16%.

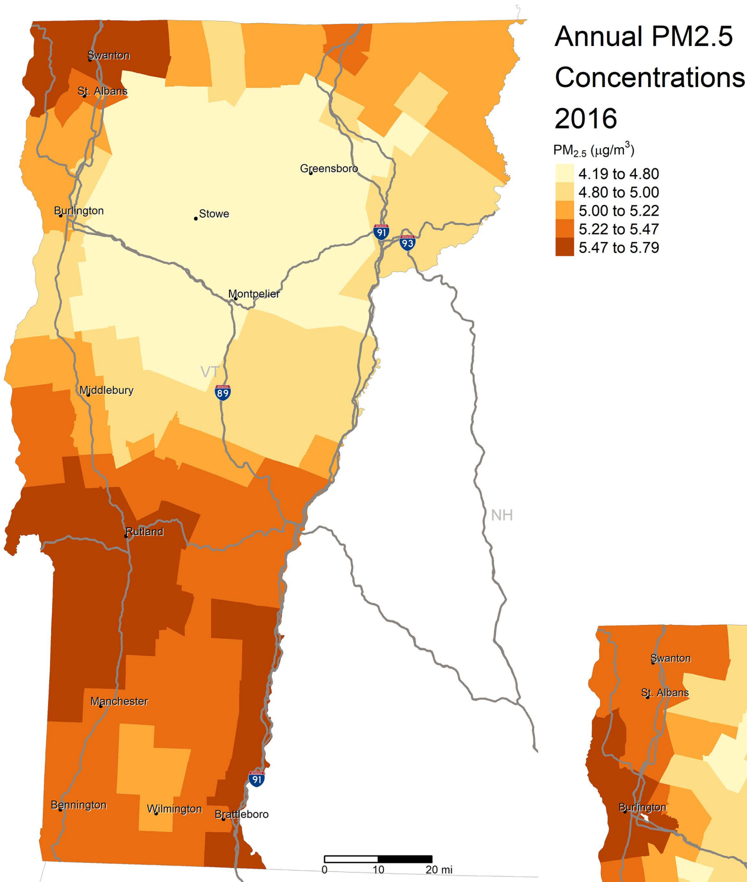


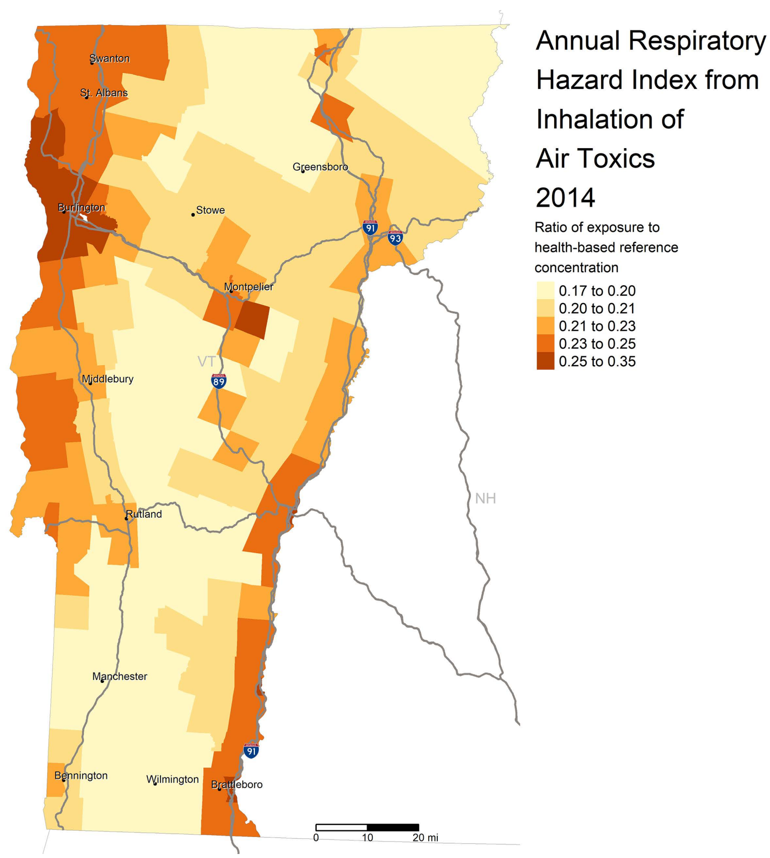
EMISSIONS

Median emissions and related risks in Vermont are below the medians for New England with the exception of CO_2. $PM_{2.5}$ emissions have declined almost 34% between 2011 and 2016. Ozone (O_3) emissions have declined 0.5% in the same time span. Median CO_2 emissions are above the median for New England.

GEOGRAPHIES AFFECTED

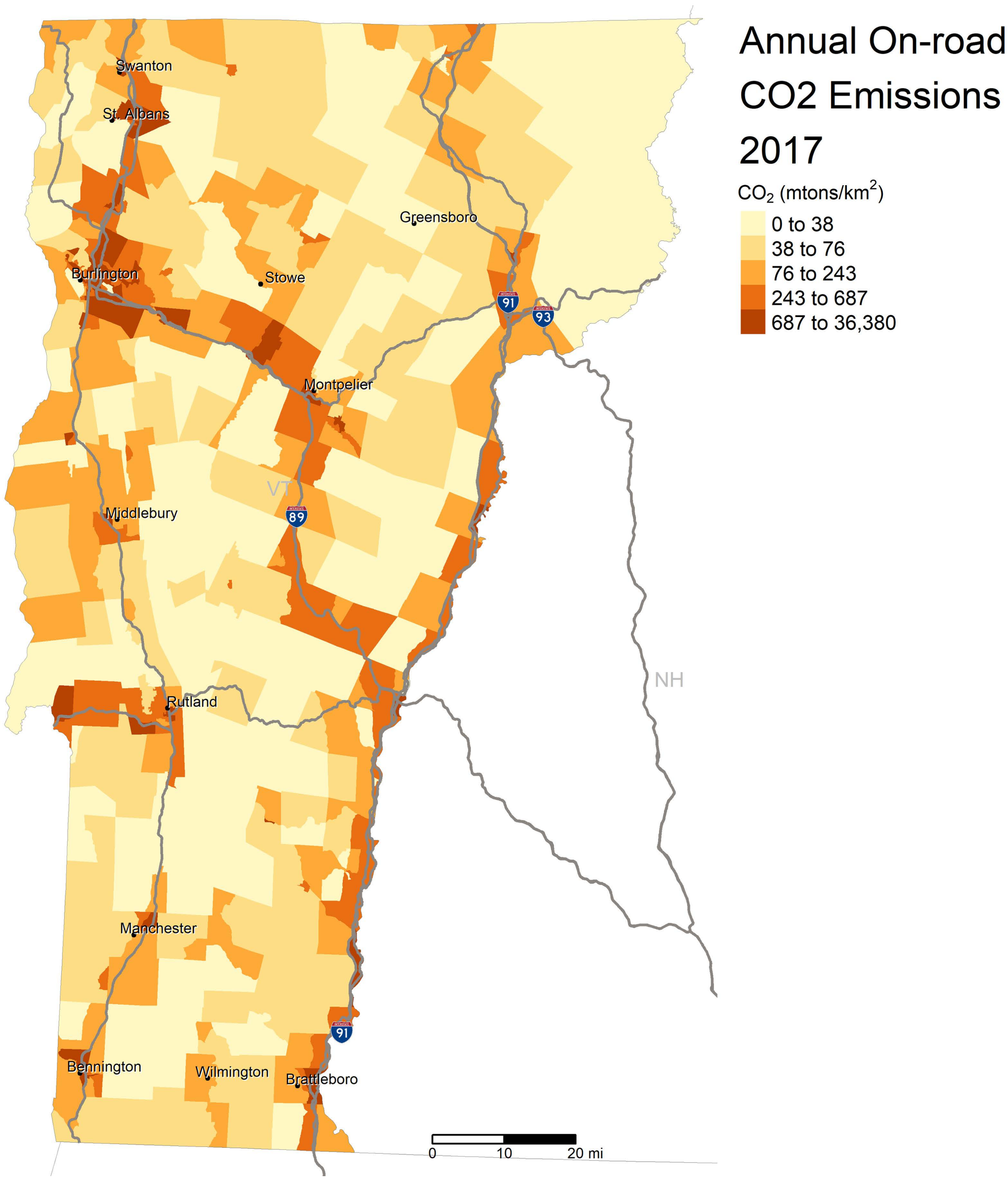
The southern half and the northwest corner of Vermont regularly demonstrate higher concentrations for all emissions and higher levels of all related risks evaluated here. The most frequent outliers are found in and around Burlington. Rutland shows up as an outlier in regards to $PM_{2.5}$.





On-road CO_2 emissions vary widely across the state. They are highest in and around Vermont's population centers with a cluster of high CO_2 emissions in and around Burlington.

Total emissions have increased since 1990, however there has been a general downward trend since around 2005. In addition, there has been a decline in per capita emissions since 1990.



Annual on-road CO_2 emissions: Change over time

1990 CO_2 (mtons)	2017 CO_2 (mtons)	% change	Per capita 1990 CO_2 (mtons/person)	Per capita 2017 CO_2 (mtons/person)	Per capita % change
2,891,449	3,032,079	5%	5.14	4.85	-6%

PRIORITY POPULATIONS

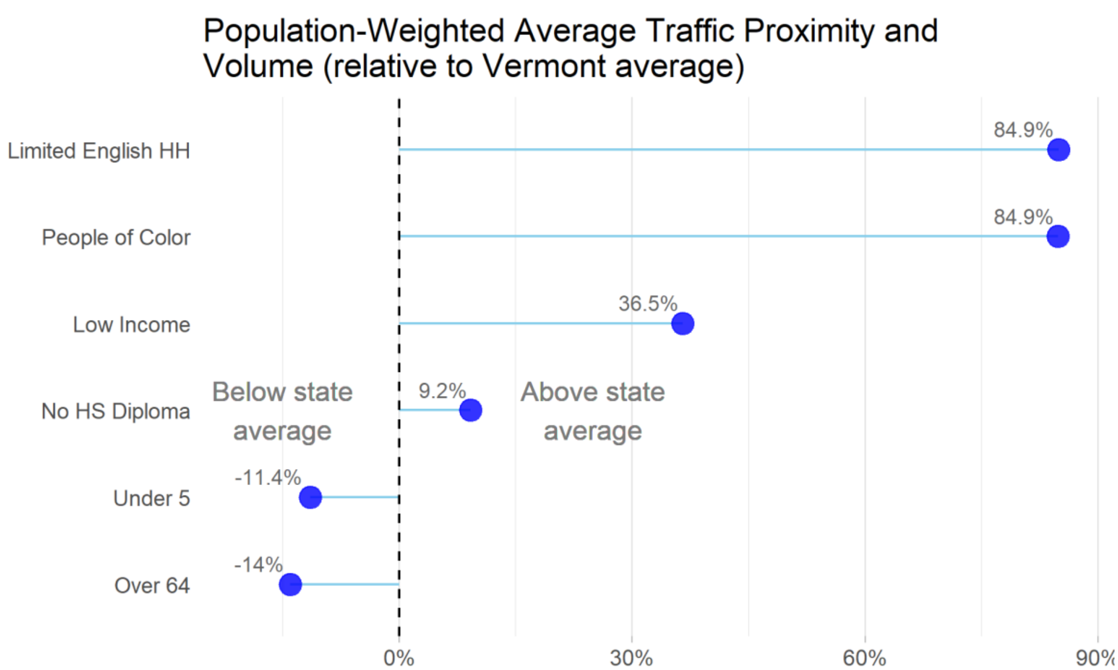
With the exception of $PM_{2.5}$,[5] limited English speaking households and people of color experience the highest exposures to all emissions and related risks evaluated here.

They are also the most exposed to the highest levels of emissions. Over 1,200 limited English speaking households and over 26,000 people of color experience the highest burdens of emissions. In absolute numbers, low income persons are the largest group affected by highest emission burdens; over 79,000 low income persons are living in areas in the highest burden emissions category.

Distribution of the highest emissions burdens

	% Emissions Category
Total Pop	42%
People of color	60%
Low income	48%
No HS diploma	46%
Over 64	42%
Under 5	41%
Under 18	41%
Total HH	43%
Limited English HH	68%

Note: Categories are defined as block groups with high proportions of priority populations and are in the top 20% of burdens for emissions. For example, 68% of limited English speaking households are present in areas in the highest burden emissions category.



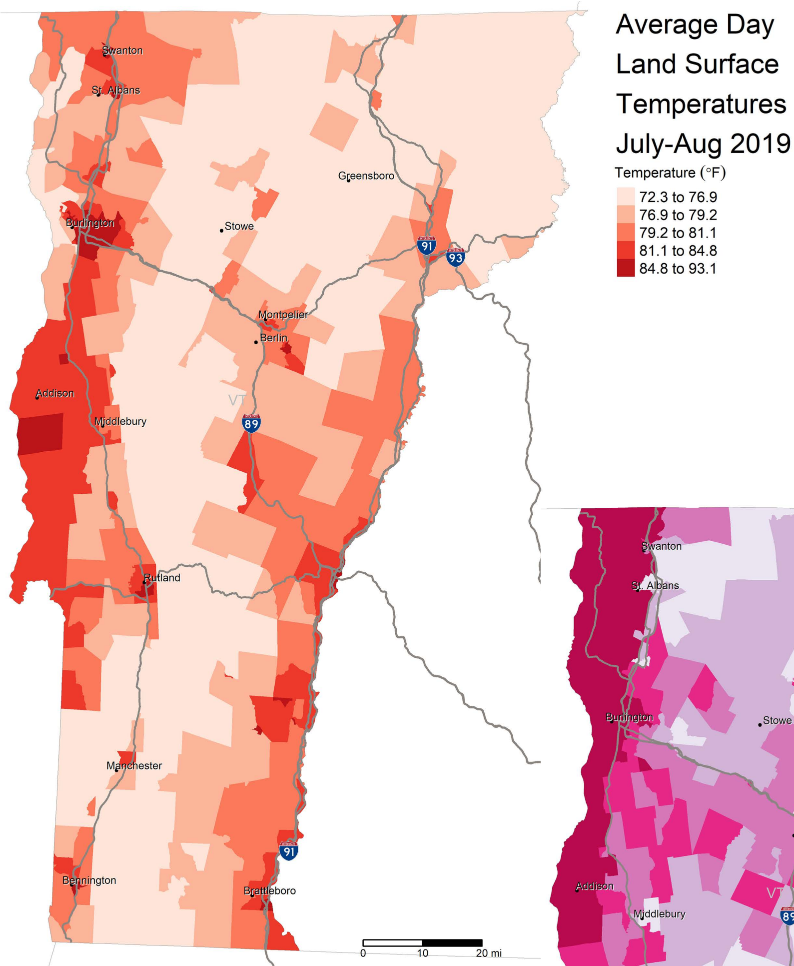
[5] For $PM_{2.5}$, the population weighted exposure for all priority populations is below the state average.

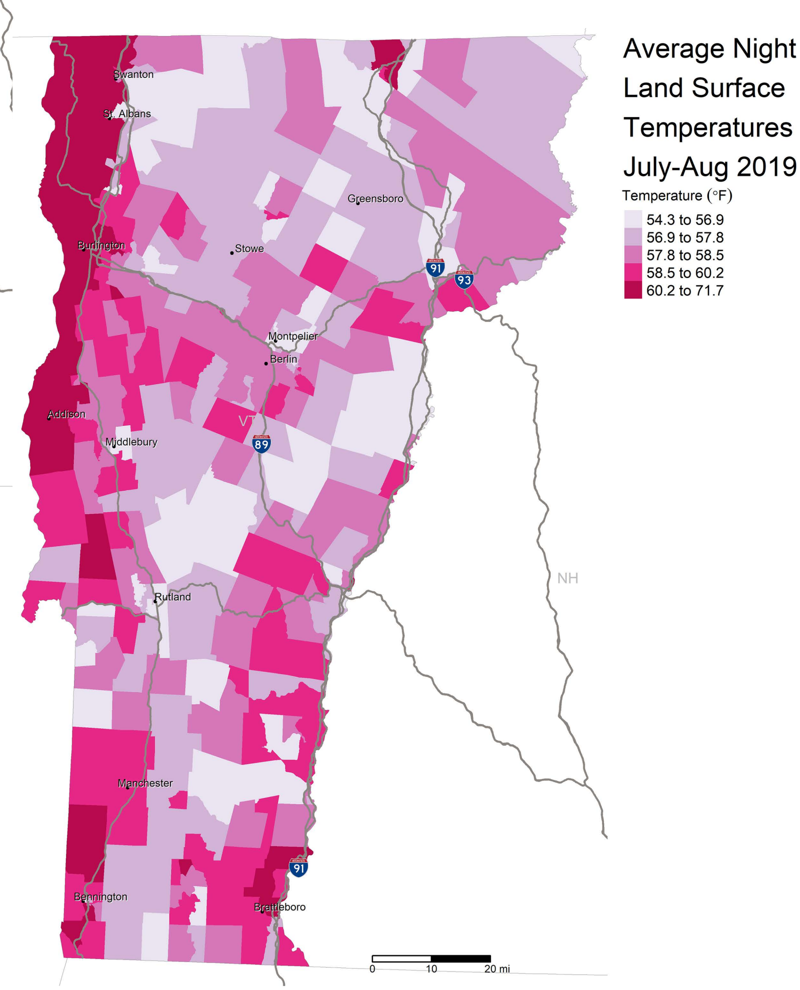
HEAT

Across the day, during the time period studied, average land surface temperatures (LST) ranged from almost 65° to 80°. The highest daytime temperature reached 93° and the highest nighttime temperature reached 72°.

GEOGRAPHIES AFFECTED

Temperatures and urban heat island vary significantly across the state and across the day. In general, population centers experience the highest daytime temperatures. This is especially the case in the western and northwestern parts of Vermont. Higher nighttime temperatures are more widespread across the state. They are highest along the shore of Lake Champlain as well as in and near Bennington and Brattleboro.





PRIORITY POPULATIONS

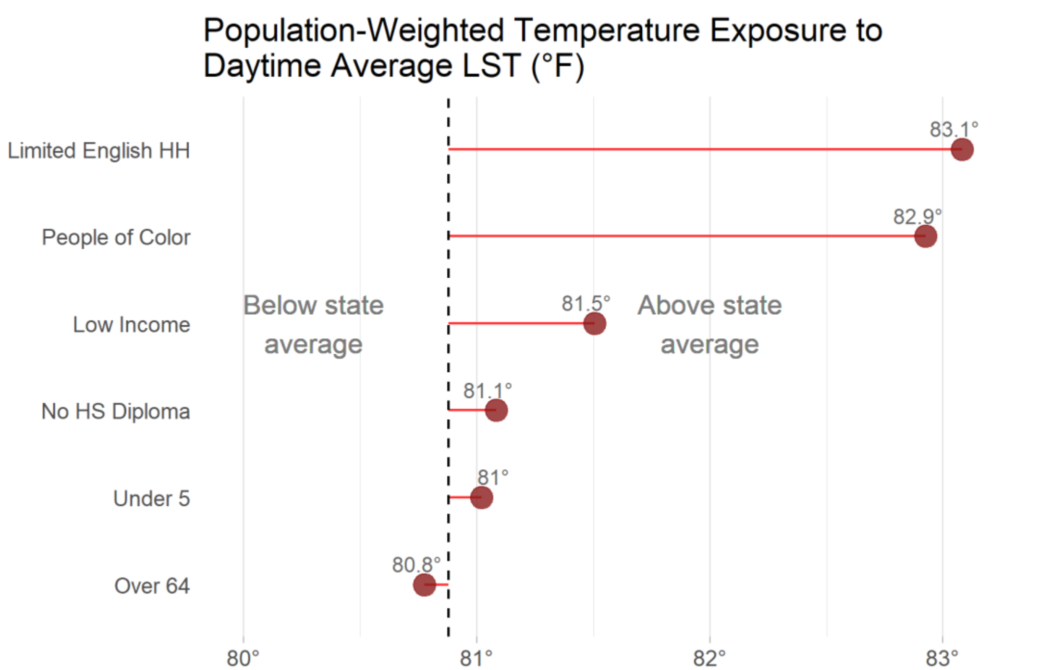
Over 133,000 people live in areas with the highest heat burden. Limited English speaking households and people of color are more likely to experience the highest daytime and nighttime temperatures. They also disproportionately experience the highest temperatures. Over 1,000 limited English speaking households and almost 21,000 people of color experience the highest daytime temperatures. This is 59% of all limited English speaking households and 47% of people of color in the state.

In addition, people of color, low income persons, and those without a high school diploma live in areas that experience the highest burdens of heat. In absolute numbers, low income persons are the most affected with over 51,000 living in areas with the highest heat burden.

Distribution of the highest heat burdens

	% Heat Category
Total Pop	27%
People of color	47%
Low income	31%
No HS diploma	28%
Under 5	27%
Under 18	26%
Over 64	24%
Total HH	27%
Limited English HH	59%

Note: Categories are defined as block groups with high proportions of priority populations and are in the top 20% of burdens for temperature. For example, 47% of people of color are present in areas in the highest burden heat category.

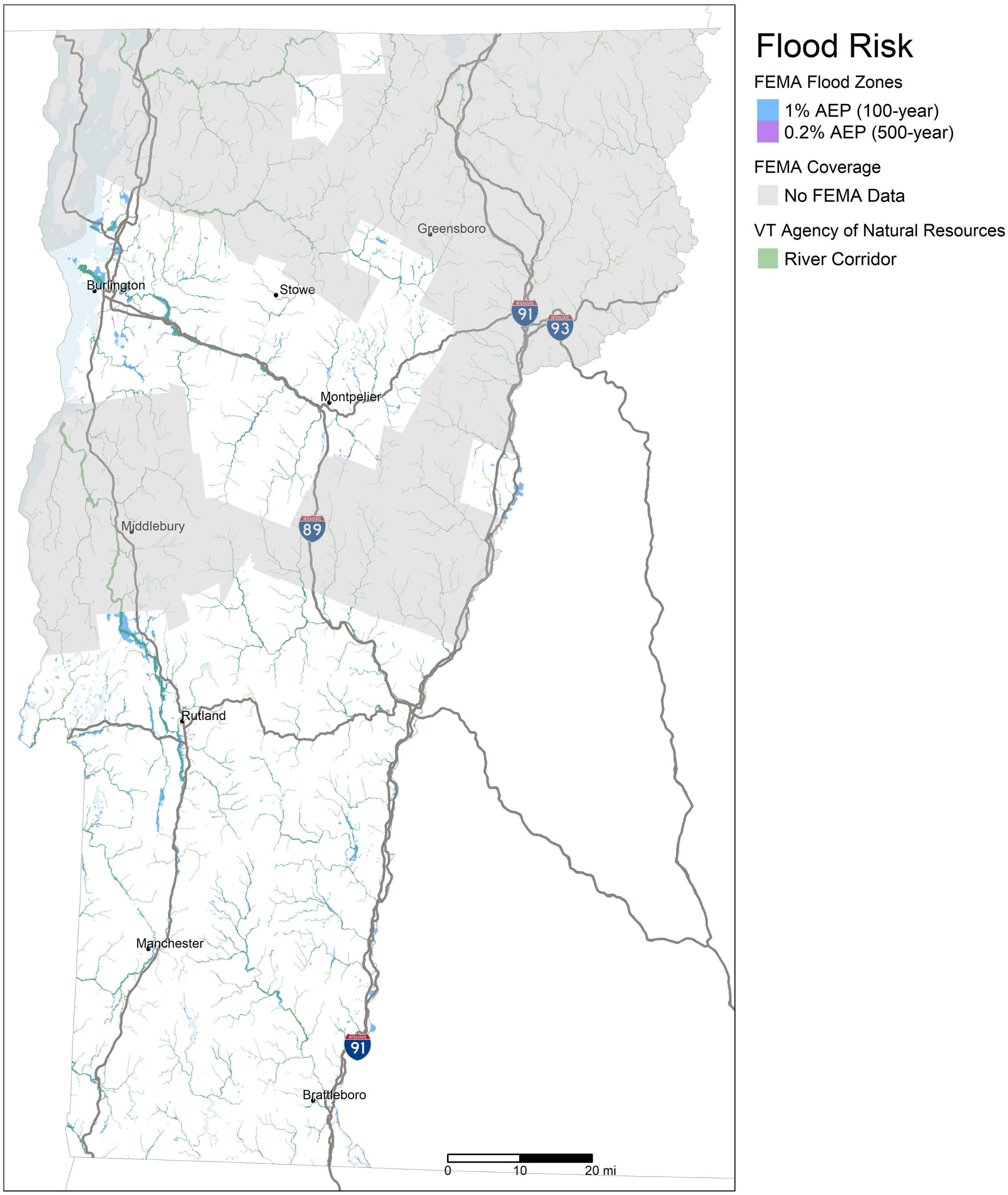


EVACUATION RISKS

In comparison to other parts of New England, relatively little of Vermont's land area is within flood zones. However, a significant proportion of the population are nevertheless exposed to the risk of flooding from overbanking of inland water bodies (e.g., ponds and rivers) as well as fluvial erosion from streams and rivers. Indeed, damage surveys in Vermont have shown that fluvial erosion, not inundation, is the most common natural hazard type in Vermont.

GEOGRAPHIES AFFECTED

Vermont is a landlocked state and therefore does not have an ocean coastline to evaluate hurricane evacuation risk. However, flood zones and fluvial erosion risks are located all throughout the state. It is important to note that FEMA has not made digital flood data for the northwest, northeast, and much of the central portions of the state publicly available. Overall, 4.4% of land area is found in either a flood zone or in a river corridor subject to fluvial erosion.



PRIORITY POPULATIONS

Over 62,000 people live in a flood zone. Low income persons and households without a car are more likely to live in a flood zone or river corridor compared to the general population or other priority populations. Over 18,000 low income persons and almost 2,000 households without a car live in a flood zone or river corridor.

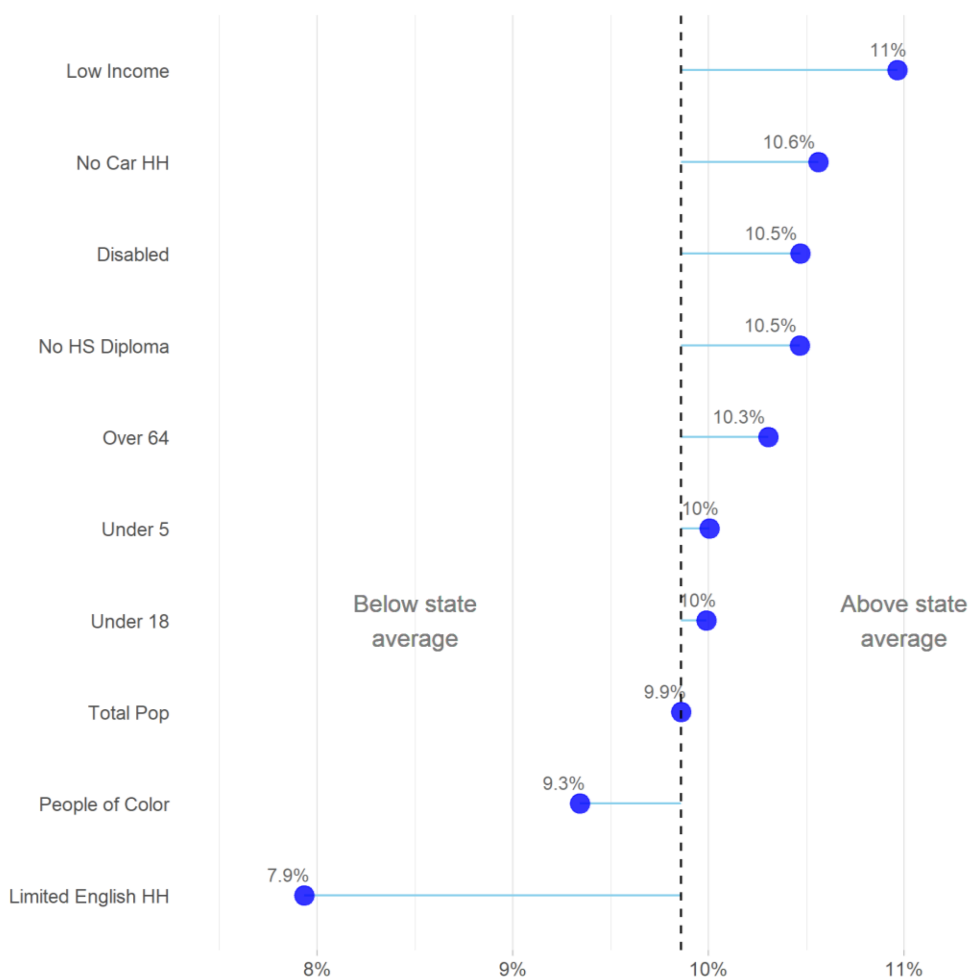
Limited English speaking households and people of color are disproportionately living in areas in the highest burden evacuation categories. Over 1,000 limited English speaking households and over 26,000 people of color live in in areas with the highest evacuation burden.

Distribution of evacuation burdens

	% Evacuation Category
Total Pop	48%
People of color	55%
Under 5	52%
Over 64	50%
Under 18	50%
Low income	49%
No HS diploma	48%
Total HH	49%
Limited English HH	56%

Note: Categories are defined as block groups with high proportions of priority populations and are in either a flood zone or river corridor. For example, 55% of people of color are present in areas in the highest burden evacuation category.

Vermont Populations Living within FEMA Flood Zones or River Corridors



INVESTING FOR EQUITY

NEW HAMPSHIRE

GEOGRAPHIES AFFECTED

High transportation burdens are found throughout the state

Very low levels of physical access, low levels of walkability, and high transportation costs exist across the state.

Emissions are highest in the southeast corner of the state

High concentrations of emissions and related risks vary but are regularly found in the same areas: in and around Nashua and Manchester along I-93 and frequently in and around Portsmouth.

Higher temperatures are most frequently found in the southeast corner of the state

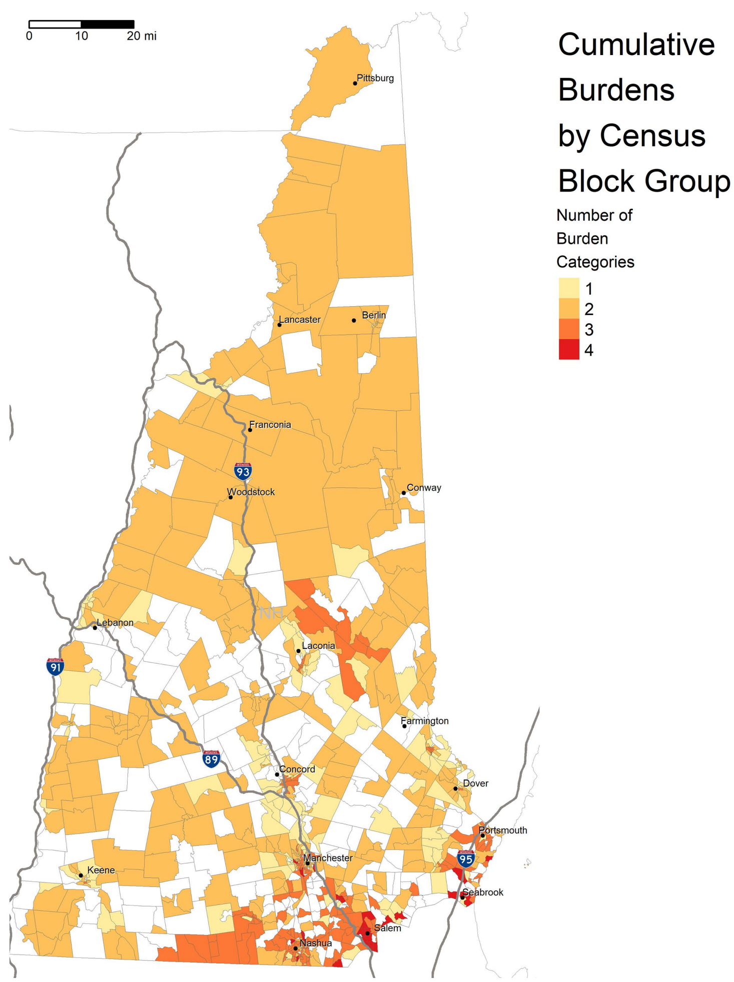
Higher daytime and nighttime temperatures as well as urban heat islands are highest in the urbanized areas in southeast New Hampshire and around Lake Winnipesaukee.

Flood and hurricane evacuation risks are found throughout the state

At least 78,000 people are exposed to flood risks.[6] An additional 14,000 people are exposed to hurricane evacuation risks.

24% of municipalities in New Hampshire have block groups that experience three or more categories of highest burdens

The highest burdened places are most often found in the southeast part of the state, mostly in and around Salem, Nashua, and Manchester.



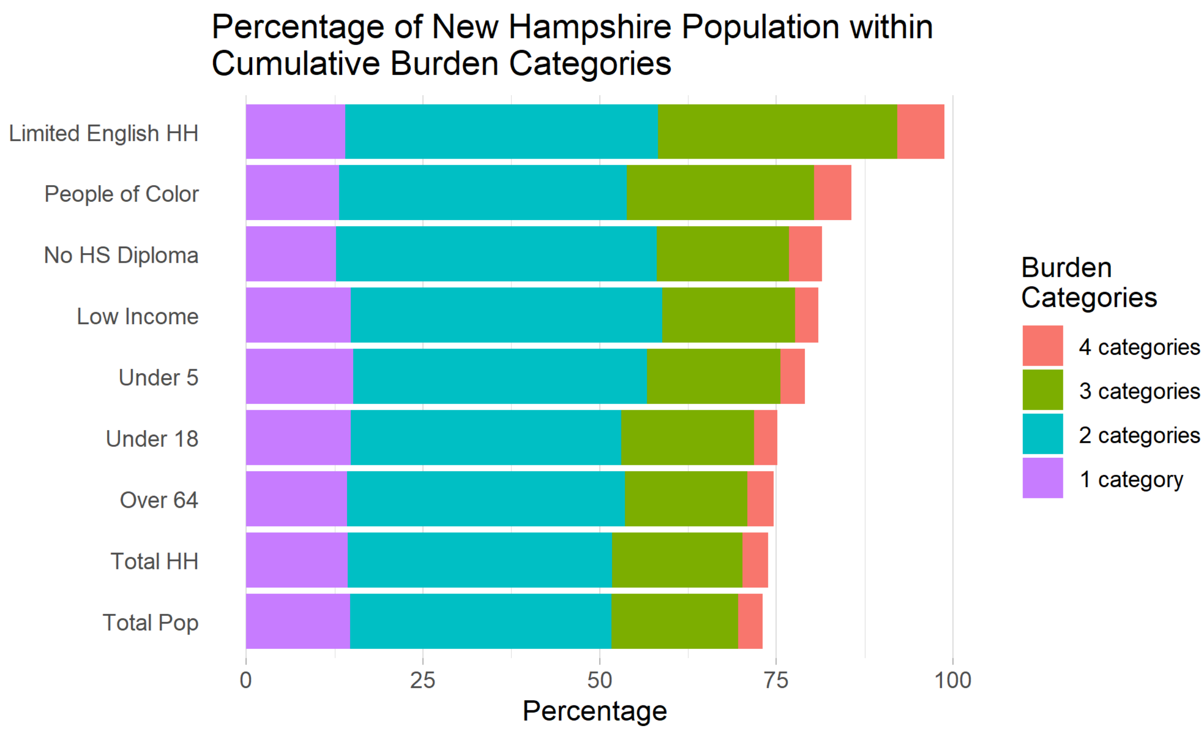
[6] It is possible that there are flooding risks in the central part of the state and south of Lake Winnipesaukee that are not captured here due to lack of publicly available digital data from FEMA.

PRIORITY POPULATIONS

Almost 197,000 people in New Hampshire live in places that experience at least one highest burden and over 287,000 live with three or more categories of highest burden.

Limited English speaking households, despite low population numbers, most frequently experience the greatest number and types of burdens. Cumulatively, limited English speaking households and people of color experience the highest levels of burden across all types of burdens. Low income persons are the largest populations in terms of absolute numbers who experience individual and cumulative burdens.

Populations affected vary by type of burden. Well over half of limited English speaking households and people of color experience the highest emissions, heat, and evacuation burdens. In addition, over half of people of color experience the highest emissions and heat burdens.



TRANSPORTATION

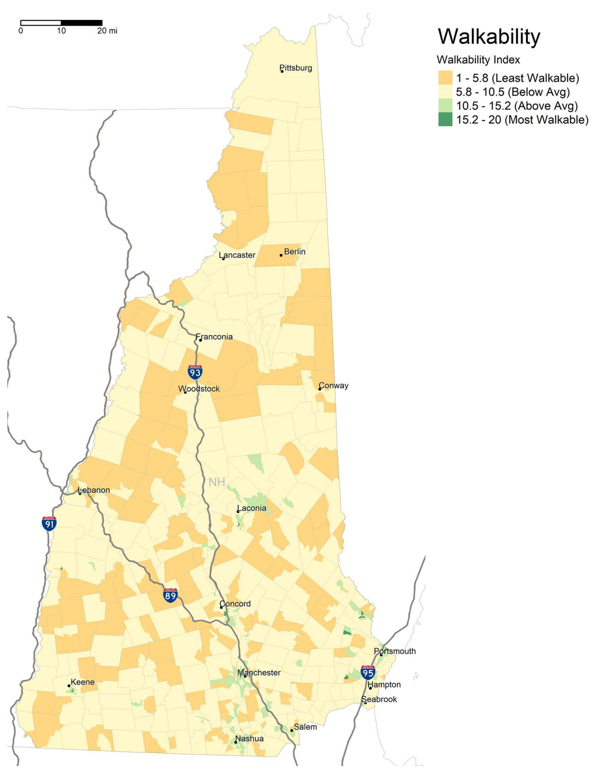
New Hampshire is served by 8 fixed-route local bus service agencies that are open to the general public and for which route maps are publicly available. The analysis here only considers public transit services for which geospatial data is publicly available. We analyzed 59 fixed public bus routes across the state.

We also evaluated non-fixed route options as a case study to understand the structure and operation of transportation services in states with large rural populations. We found that most non-fixed route/ non-public transportation options in New Hampshire are primarily organized by non-profit and/or religiously affiliated organizations. These are largely structured in one of two ways. The most common structure is transportation service as a program within in a multi-service agency. These services are highly dependent on government funding or foundation grants as well as typical non-profit fundraising efforts. The other common structure is transportation service as a mutual aid effort relying on volunteer drivers, frequently using their own vehicles. Organizations providing this kind of transportation service are generally volunteer led with, at most, one or two paid staff managing a variety of service programs. In both cases, residents often do not pay any fare, although sometimes donations are requested. In addition, transportation is often limited to the elderly for any reason or to those who need to get to medical appointments.

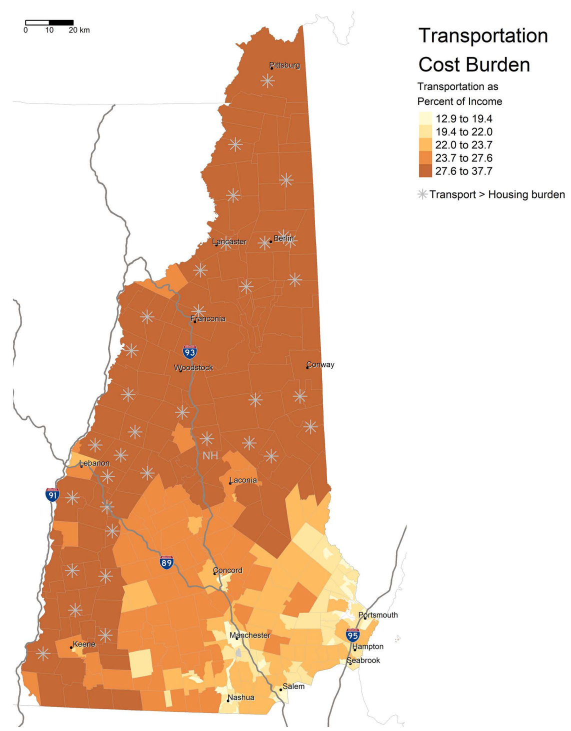
GEOGRAPHIES AFFECTED

Most of New Hampshire's bus services are either concentrated in a handful of cities or are inter-city services. Approximately 75% of the state's population does not live within a reasonable distance of a bus route. Over one million people have no physical access to any form of public transit.

Walkability scores across the state are most frequently below average to least walkable. The highest walkability scores are found in Nashua, Manchester, Concord, Laconia, Keene, and Portsmouth.



Transportation cost burdens for moderate income households are generally high across the state. The average transportation cost burden is 23% of household income for moderate income households, which is 44% higher than the US average. There are 35 census tracts where the transportation cost burdens exceeds housing cost burdens. This is 12% of all census tracts in the state. These were mostly found in the northern and western parts of New Hampshire. The lowest transportation cost burden were found in the southeast corner of the state, especially in Salem, Nashua, Manchester, Concord, and Portsmouth.



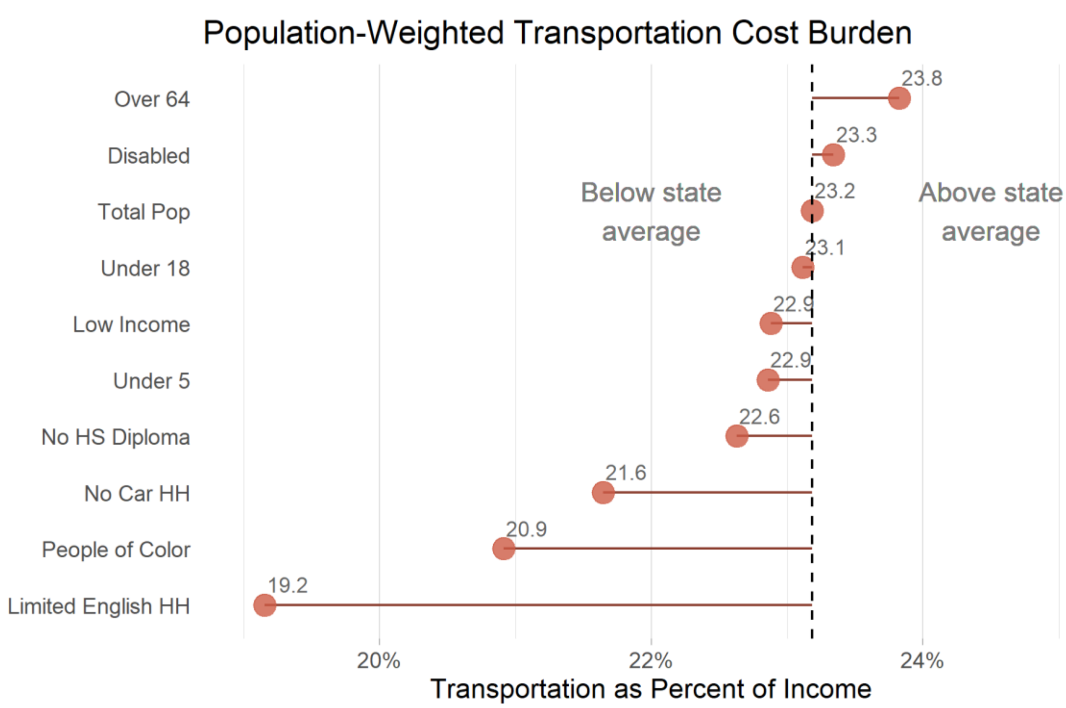
PRIORITY POPULATIONS

The population with the least access to public transit, living in the least walkable areas, and experiencing the highest transportation cost burden are those over the age of 64 as well as minors (mostly those under 18 and occasionally those under 5 years of age). They are also disproportionately affected by transportation burdens. Over 100,000 people over 64 and over 111,000 people under 18 live in areas in the highest transportation burden category.

Those living with disabilities experience transportation cost burdens that are 44% higher than the state average.

All priority populations also live in areas with below average walkability scores.

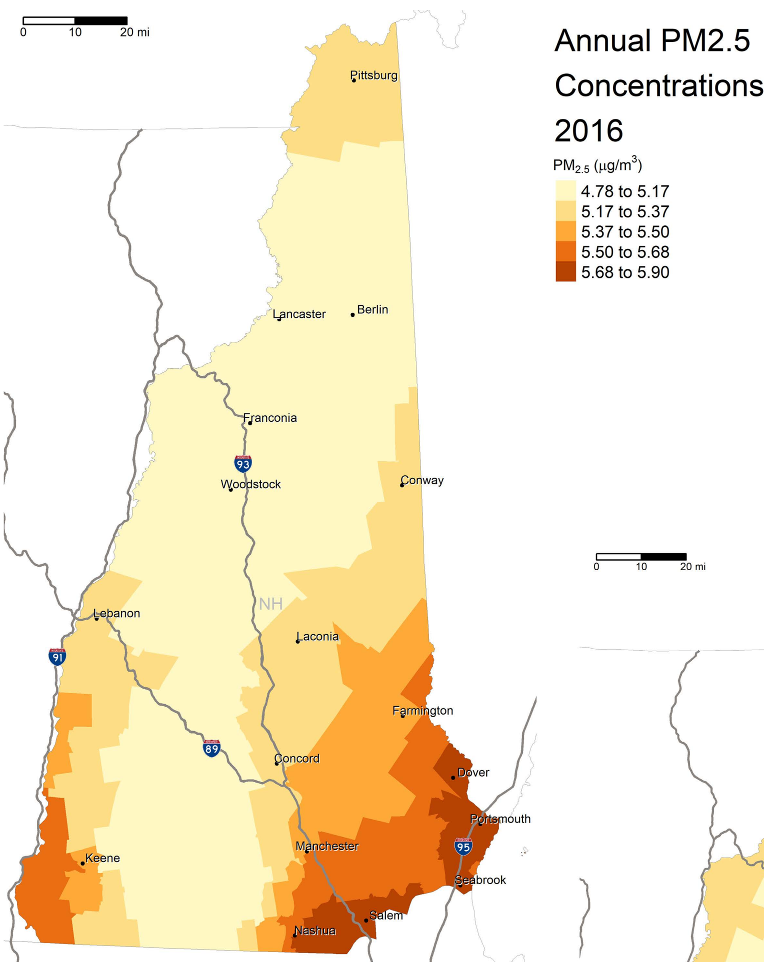
Most priority populations live in areas with transportation cost burdens that are above the state average. It should be noted, however, that transportation cost burdens are generally high for all priority populations. Limited English speaking households demonstrate the lowest cost burden of all priority populations. And yet, moderate income households in this group, on average, spend about 19% of their household income on transportation. This is higher than the US average of 16%.

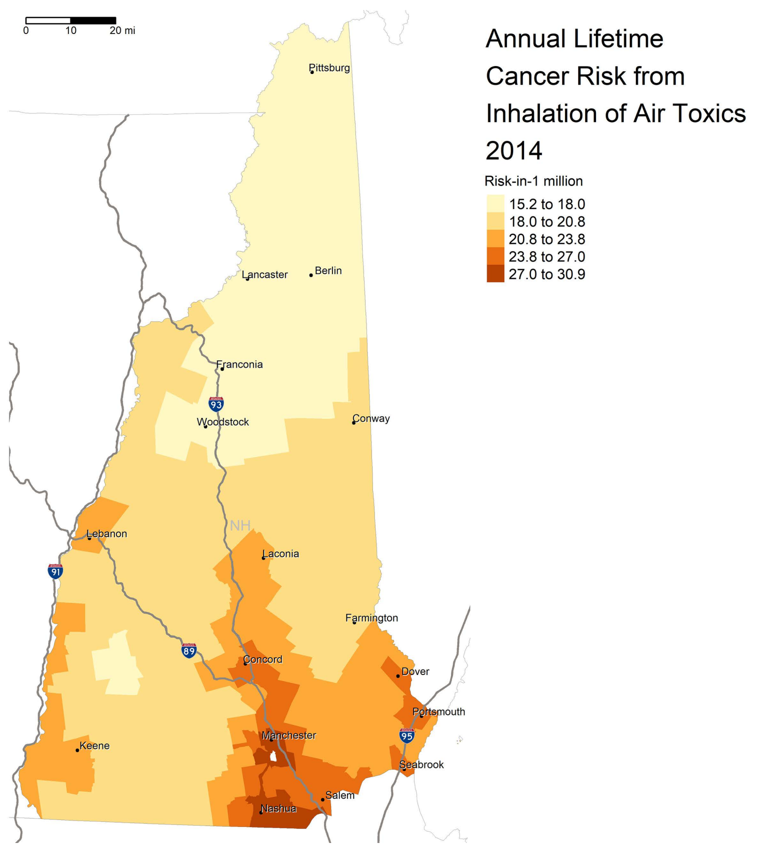


Median emissions and related risks in New Hampshire are below the medians for New England with the exception of CO_2. $PM_{2.5}$ emissions have declined almost 34% between 2011 and 2016. Ozone (O_3) emissions have declined 1.2% in the same time span. Median CO_2 emissions are above the median for New England.

GEOGRAPHIES AFFECTED

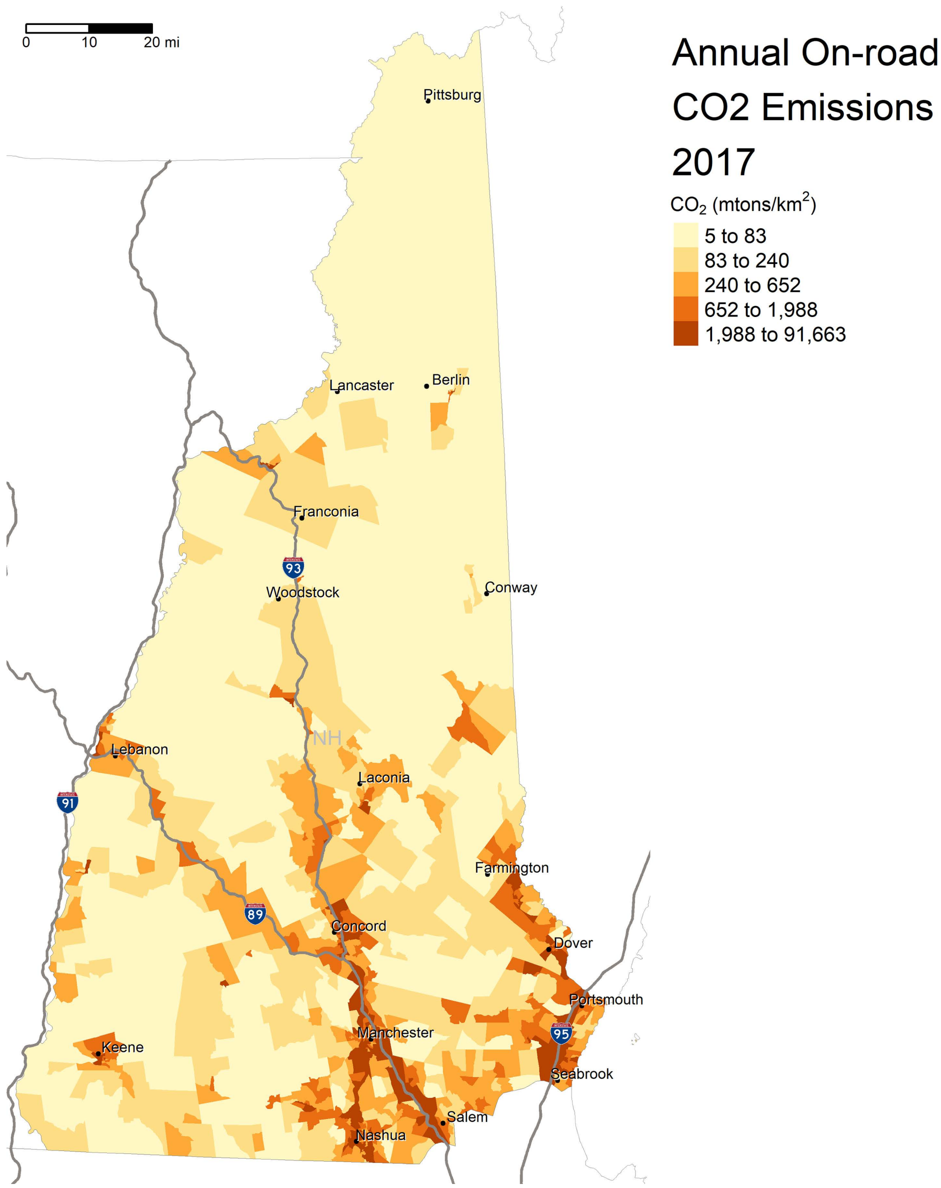
The southeast corner of New Hampshire regularly demonstrates higher concentrations for all emissions and higher levels of all related risks evaluated here. In addition, the southwestern edge of the state experiences slightly higher exposures to $PM_{2.5}$, cancer risks from air toxics, and respiratory hazards. The most frequent outliers are found in and around the I-93 corridor from Salem to Manchester. The area in and around Portsmouth also shows up as a hotspot for several types of emissions and related risks.





On-road CO_2 emissions vary widely across the state. They are highest in and around New Hampshire's population centers with a cluster of high CO_2 emissions in and around Manchester.

Total emissions have increased significantly since 1990. The high rates of emissions have roughly stabilized since 2005 but have not declined. Emissions growth also exceeds population growth.



Annual on-road CO_2 emissions: Change over time

1990 CO_2 (mtons)	2017 CO_2 (mtons)	% change	Per capita 1990 CO_2 (mtons/person)	Per capita 2017 CO_2 (mtons/person)	Per capita % change
4,904,291	6,553,188	34%	4.42	4.88	10%

PRIORITY POPULATIONS

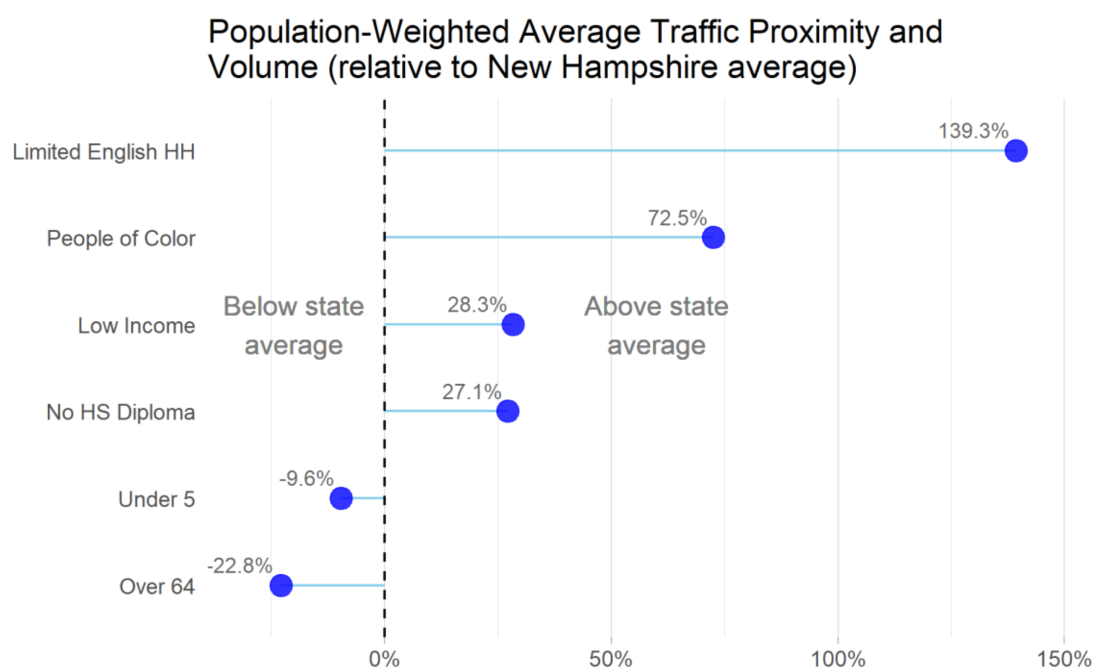
Limited English speaking households and people of color experience the highest exposures to all emissions and related risks evaluated here.

They are also the most exposed to the highest levels of emissions. Almost 6,000 limited English speaking households and over 74,000 people of color experience the highest burdens of emissions. In absolute numbers, low income persons are the largest group affected by highest emission burdens; over 101,000 low income persons are living in areas in the highest burden emissions category.

Distribution of the highest emissions burdens

	% Emissions Category
Total Pop	33%
People of color	58%
No HS diploma	41%
Low income	39%
Under 5	37%
Under 18	35%
Over 64	31%
Total HH	34%
Limited English HH	76%

Note: Categories are defined as block groups with high proportions of priority populations and are in the top 20% of burdens for emissions. For example, 76% of limited English speaking households are present in areas in the highest burden emissions category.

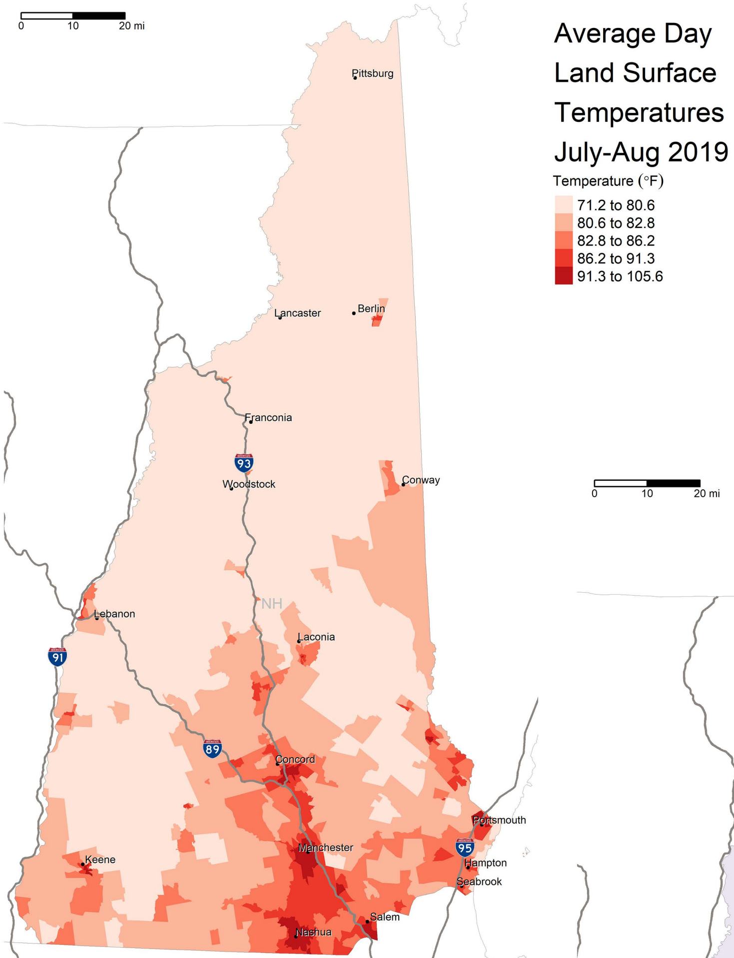


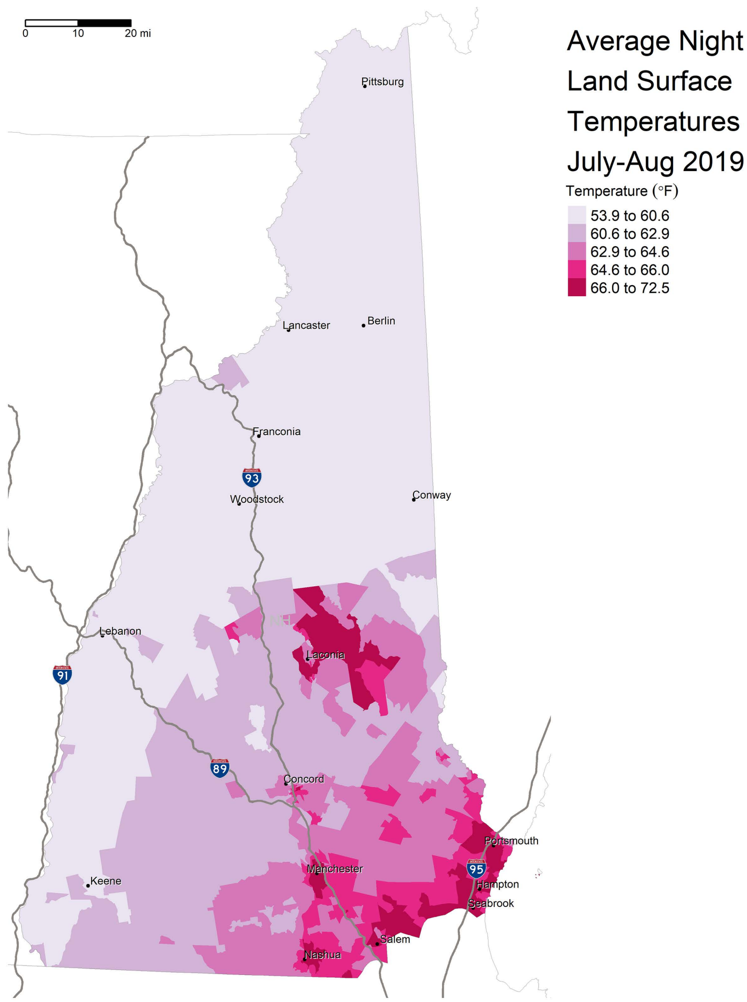
HEAT

Across the day, during the time period studied, average land surface temperatures (LST) ranged from almost 63° to 87°. The highest daytime temperature reached 106° and the highest nighttime temperature reached 73°.

GEOGRAPHIES AFFECTED

Temperatures and urban heat island vary significantly across the state. In general, population centers in the southeast corner of New Hampshire experience the highest daytime temperatures. Higher nighttime temperatures are more widespread across the state. Outliers for daytime temperatures are found in and around Nashua and Manchester. Outliers for nighttime temperatures are found in and around Manchester as well as Lake Winnipesaukee.





PRIORITY POPULATIONS

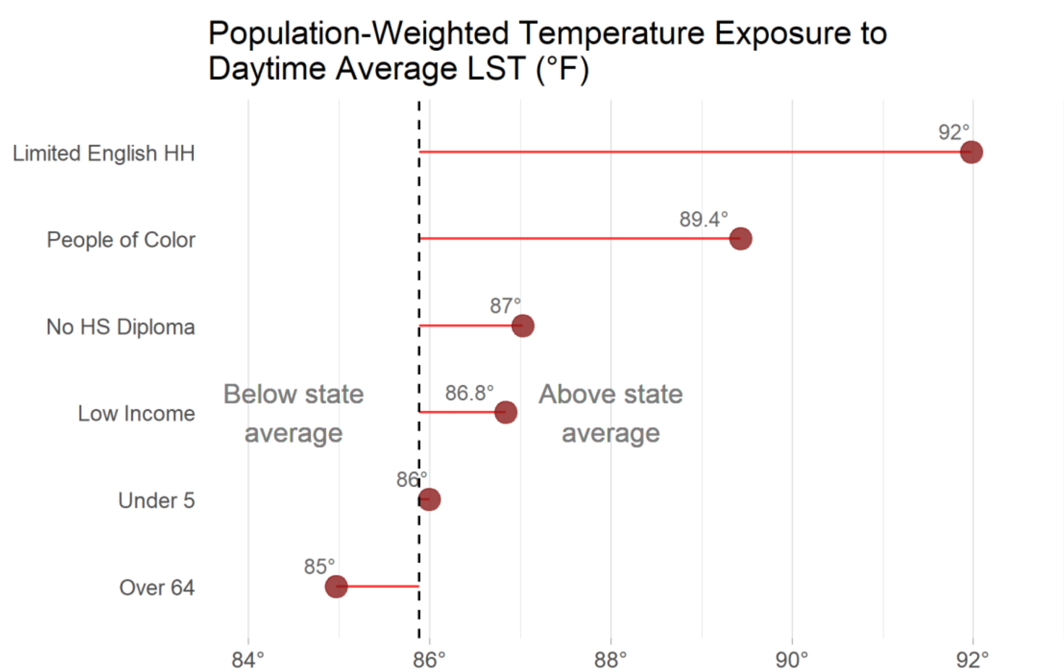
Almost 226,000 people live in areas with the highest daytime heat burden. Limited English speaking households and people of color are more likely to experience the highest daytime and nighttime temperatures compared to the general population or other priority populations. They also disproportionately experience the highest temperatures overall. Over 4,000 limited English speaking households and over 52,000 people of color experience the highest temperatures across the day relative to the state average. This is 56% of all limited English speaking households and 41% of people of color in the state.

In absolute numbers, low income persons are the most affected with over 72,000 living in areas with the highest heat burden. Over 20,000 persons without a high school diploma are similarly affected.

Distribution of the highest heat burdens

	% Heat Category
Total Pop	20%
People of color	41%
No HS diploma	30%
Low income	28%
Under 5	22%
Under 18	20%
Over 64	20%
Total HH	21%
Limited English HH	56%

Note: Categories are defined as block groups with high proportions of priority populations and are in the top 20% of burdens for temperature. For example, 47% of people of color are present in areas in the highest burden heat category.



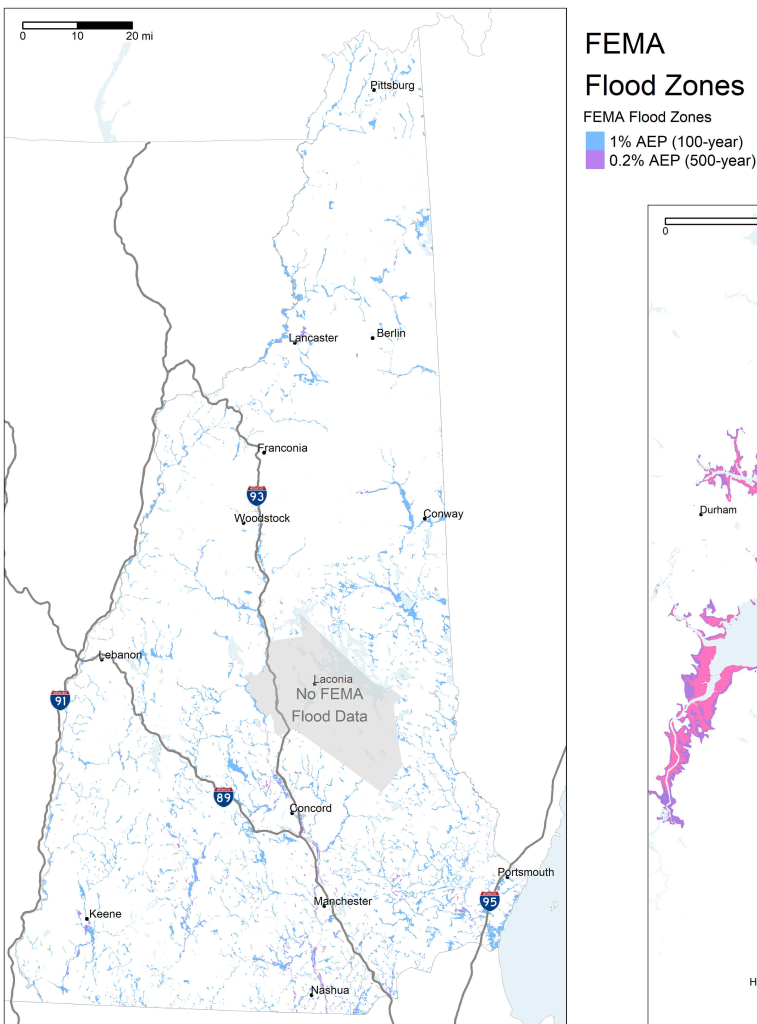
EVACUATION RISKS

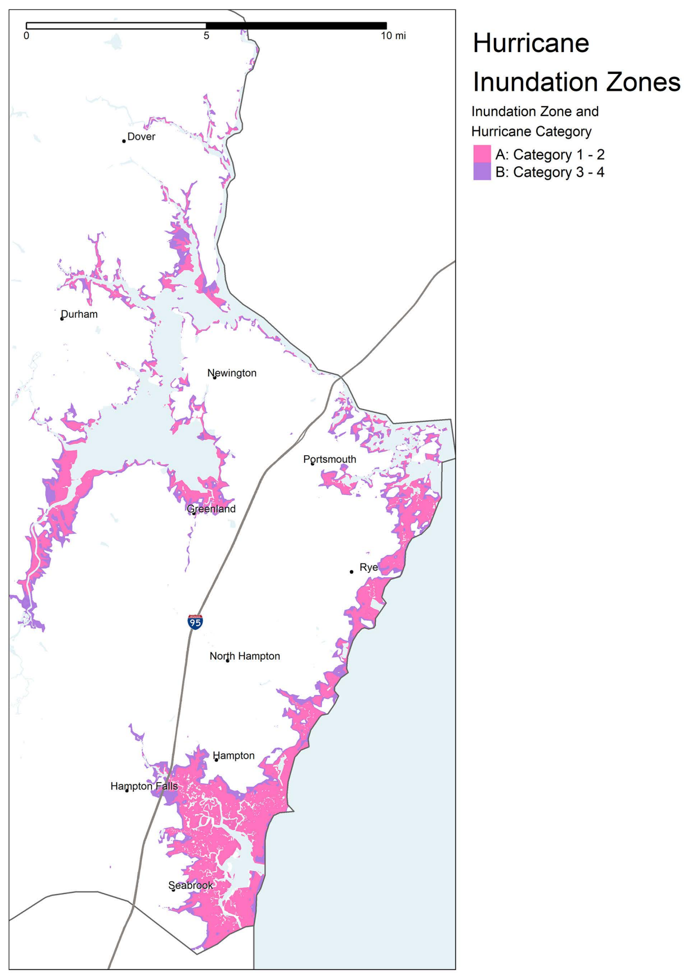
As a humid, coastal state, a significant portion of New Hampshire's land area and population are exposed to the risk of flooding from overbanking of inland water bodies (e.g., ponds and rivers) or from coastal storm surge and sea level rise. New Hampshire is also subject to hurricane risk. Since 1900, New Hampshire has been struck by hurricanes twice. The most recent hurricane to hit New Hampshire directly was Hurricane Bob in 1991, a Category 2 storm when it struck the south shore of New Hampshire. The latter caused over $2.3 million in damages in New Hampshire alone and left 20% of the state without power.[75] Hurricane Sandy in 2012 did not hit New Hampshire directly, but nevertheless resulted in flooding of New Hampshire coastal communities that resulted in over $1.6 million in damages. In general, New Hampshire is subject to a hurricane return period of approximately 30 years.[76]

GEOGRAPHIES AFFECTED

At least 5% of land area is found in a flood zone. Flood zones are located all throughout the state. It is important to note that FEMA has not made digital flood data for a portion of the central part of the state publicly available. This includes areas south of Lake Winnipesaukee.

In addition, 0.3% of land area falls within a hurricane evacuation zone. There is also significant risk of inland intrusion from hurricane related storm surge through Hampton Harbor, the Piscataqua River, and the Great Bay.





PRIORITY POPULATIONS

Over 78,000 people live in a flood zone. Households without a car and low income persons are more likely to live in flood zones compared to the general population or other priority populations. Over 2,000 households without a car and over 17,000 low income persons live in a flood zone. In terms of absolute numbers, people with disabilities are disproportionately affected; over 10,000 people living with disabilities live in a flood zone.

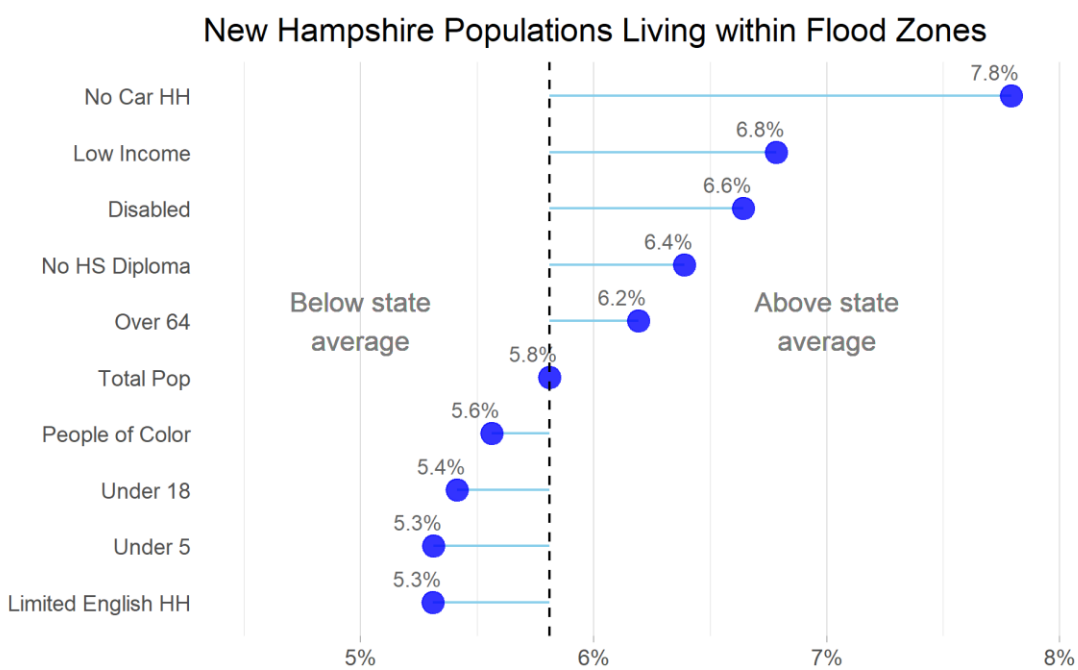
Over 14,000 people live in a hurricane evacuation zone. Those over 64 years of age and households without a car are more likely to live in a hurricane evacuation zone compared to the general population or other priority populations. Over 3,000 people over 64 and almost 400 households without a car live in a hurricane evacuation zone. In terms of absolute numbers, low income persons are disproportionately affected; over 2,000 low income persons live in hurricane evacuation zones.

All priority populations are living in areas in the highest burden evacuation category at rates higher than the state average. Limited English speaking households are disproportionately living in areas with the highest burden evacuation categories. Over 5,000 limited English speaking households live in areas in the highest burden evacuation category. In absolute numbers, low income persons are the most impacted; over 169,000 low income persons are living in areas in the highest burden evacuation categories.

Distribution of evacuation burdens

	% Evacuation Category
Total Pop	63%
People of color	66%
Under 5	66%
Over 64	65%
Low income	65%
No HS diploma	65%
Under 18	64%
Total HH	63%
Limited English HH	72%

Note: Categories are defined as block groups with high proportions of priority populations and are in either a flood or hurricane evacuation zone. For example, 55% of people of color are present in areas in the highest burden evacuation category.



INVESTING FOR EQUITY

MAINE

GEOGRAPHIES AFFECTED

High transportation burdens are found throughout the state

Very low levels of physical access, low levels of walkability, and very high transportation costs exist across the state.

Emissions are highest in the southeast corner of the state

High concentrations of emissions and related risks vary but are regularly found in the same areas: along I-95 between Kittery to Bangor.

Higher temperatures are most frequently found in the southeast corner of the state and along the coast

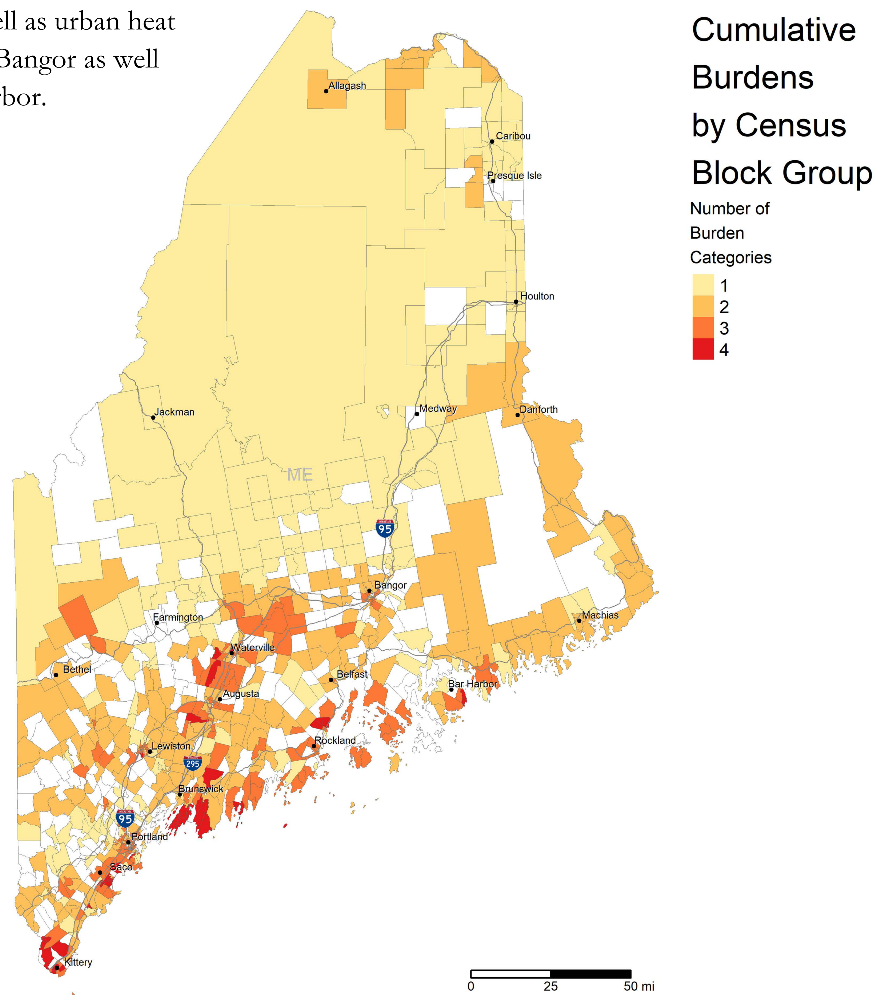
Higher temperatures across the day as well as urban heat islands occur along I-95 from Kittery to Bangor as well as along the coast as far north as Bar Harbor.

Flood and hurricane evacuation risks are found throughout the state

At least 32,000 people are exposed to flood risks.[7] An additional 59,000 people are exposed to hurricane evacuation risks.

27% of municipalities in Maine have block groups that experience three or more categories of highest burdens

The highest burdened places are most often found in the southeast part of the state, primarily in and around Portland, Lewiston, and Bangor.



[7] At the time of this study, there was no publicly available digital data from FEMA for most of the northern half of Maine, with a handful of exceptions, as well as much of the southeast portion of the state, including large population centers. It is very likely that the risk of flooding is much greater than we were able to ascertain at this time.

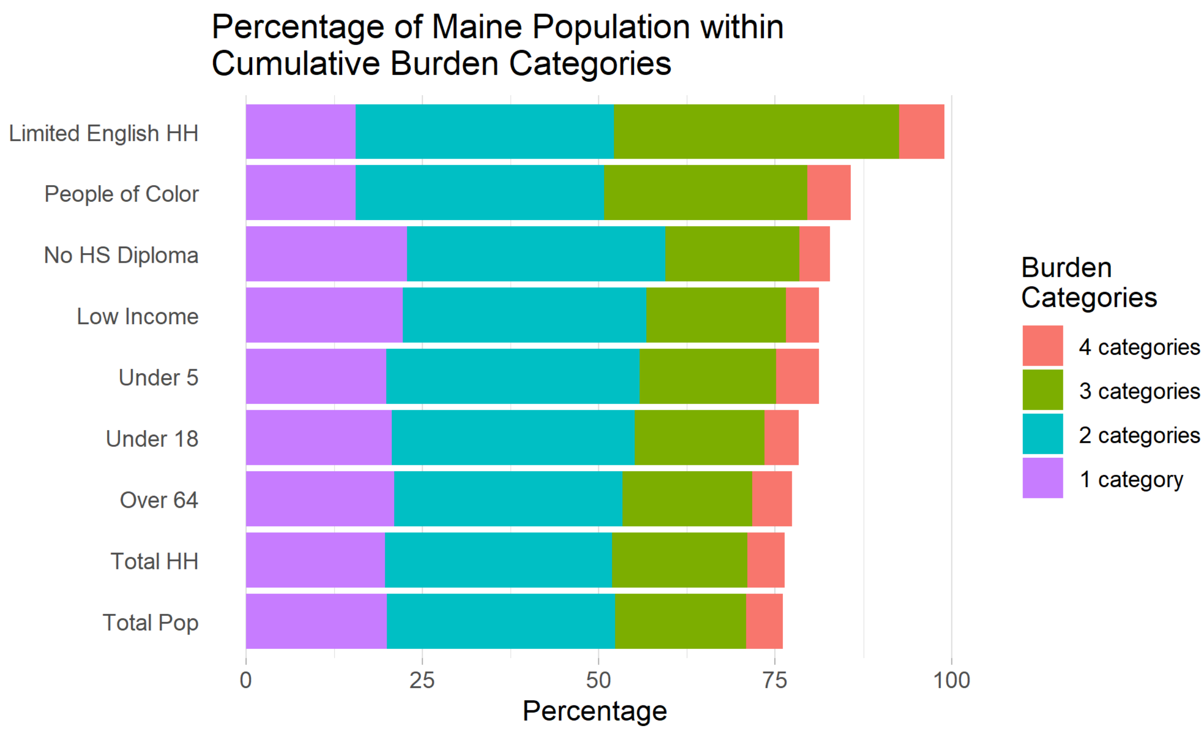
PRIORITY POPULATIONS

Almost 266,000 people in Maine live in places that experience at least one highest burden and over 316,000 live with three or more categories of highest burden.

Limited English speaking households and people of color are the most affected group

Limited English speaking households and people of color most frequently experience the greatest number and types of burdens. Cumulatively, limited English speaking households and people of color experience the highest levels of burden across all types of burdens. Low income persons are the largest populations in terms of absolute numbers who experience individual and cumulative burdens.

Populations affected vary by type of burden. Well over half of limited English speaking households and people of color experience the highest emissions and evacuation burdens.



TRANSPORTATION

Maine is served by 12 fixed-route local bus service agencies that are open to the general public and for which route maps are publicly available. The analysis here only considers public transit services for which geospatial data is publicly available. We analyzed 70 fixed public bus routes across the state.

Maine's transportation systems are operated by a mix of non-profit and public/ quasi-public agencies. Publicly operated services generally offer fixed route services to the general public. Some publicly operated systems offer services in one municipality while others cover multiple municipalities. Services operated by non-profit organizations tend to offer a wider variety of options to support specific populations, often under contract with either state agencies or local medical providers. Flex route pick up services are common and primarily provided by non-profit transportation operators. There were also several seasonal transportation options servicing tourist areas. This analysis excluded exclusively seasonal transit services but it is important to recognize that there are communities where seasonal transit service may be significant to local economy and local populations.

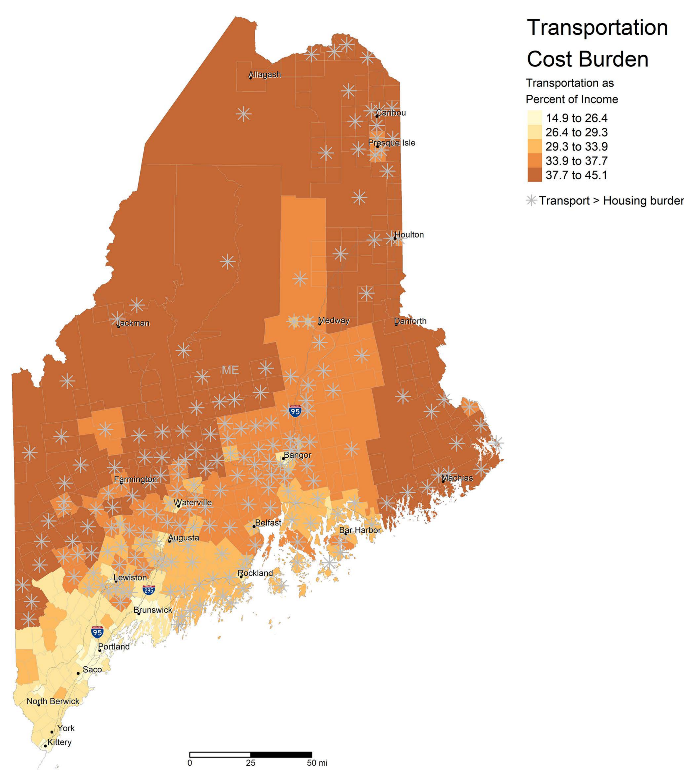
Transportation services in Maine are highly dependent on state and federal transportation department grants, which are historically inadequate and declining. Services that do not receive government funding directly are at risk for closure. There were several services that were listed in the Maine Transit Association directory that were no longer in operation when this case study was completed in April 2020. For example, Aroostook Regional Transportation System (ARTS) operated a service for Presque Isle which was funded in part by local businesses, anchor institutions, civic organization, and individuals. ARTS pulled out of operating the Presque Island Loop at the start of the COVID crisis after only operating the service for 5 months largely in anticipation of financial instability. As of this writing, Presque Island was unable to find a new operator and remains without any public transit system.

GEOGRAPHIES AFFECTED

Most of Maine's bus services are concentrated in a handful of cities, mostly in the southeast corner of the state. Approximately 73% of the state's population does not live within a reasonable distance of a bus route. Over 1,000,000 people have no physical access to any form of public transit.

Walkability scores across the state are most frequently below average to least walkable. The highest walkability scores are found in Kittery, York, Portland, and Bangor.

Transportation cost burdens for moderate income households are the highest in New England. The average transportation cost burden is 31% of household income for moderate income households, which is almost twice the US average. There are 202 census tracts where the transportation cost burdens exceeds housing cost burdens. This is 56% of all census tracts in the state. These were mostly found in the northern and western parts of Maine. The lowest transportation cost burden was found in the southeast corner of the state from Kittery to Brunswick.

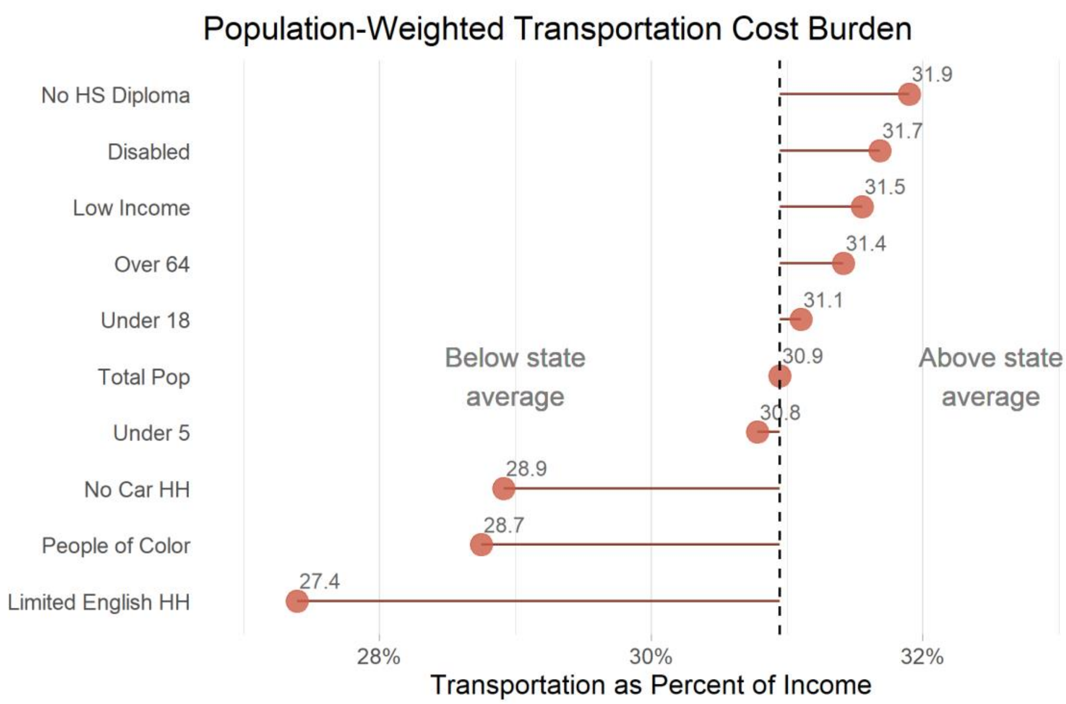


PRIORITY POPULATIONS

The population with the least access to public transit and living in the least walkable areas are those over 64 years of age as well as minors (mostly those under 18 and occasionally those under 5 years of age). Those without a high school diploma and low income persons are disproportionately affected by transportation burdens. Over 40,000 people without a high school diploma and over 199,000 low income persons live in areas in the highest transportation burden category.

All priority populations also live in areas with below average walkability scores.

The transportation cost burdens in Maine are generally high for all priority populations. Limited English speaking households demonstrate the lowest cost burden of all priority populations. And yet, moderate income households in this group, on average, spend about 27% of their household income on transportation. This is 69% higher than the US average of 16%.

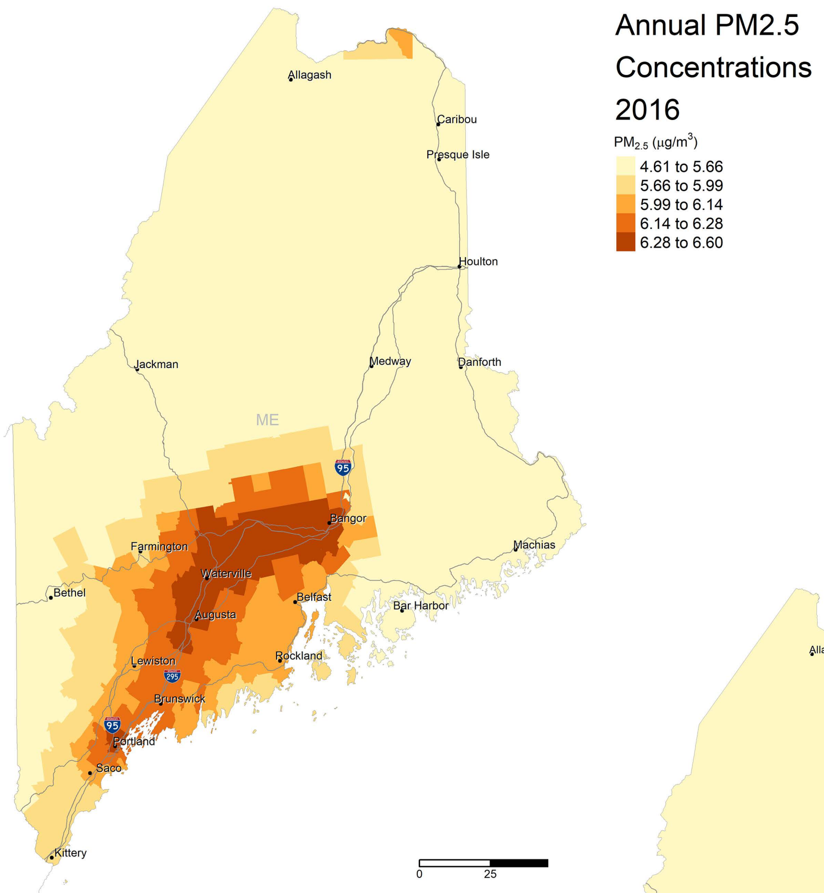


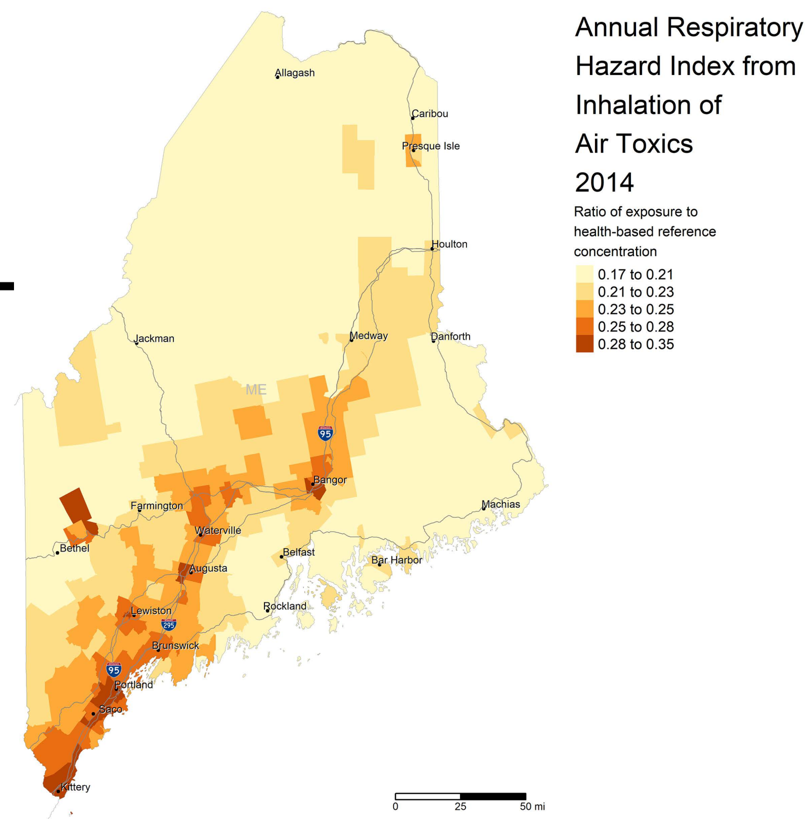
EMISSIONS

Median emissions and related risks in Maine are below the medians for New England with the exception of CO_2. $PM_{2.5}$ concentrations have declined almost 21% between 2011 and 2016. Ozone (O_3) concentrations have declined 2.3% in the same time span. Median CO_2 emissions are above the median for New England.

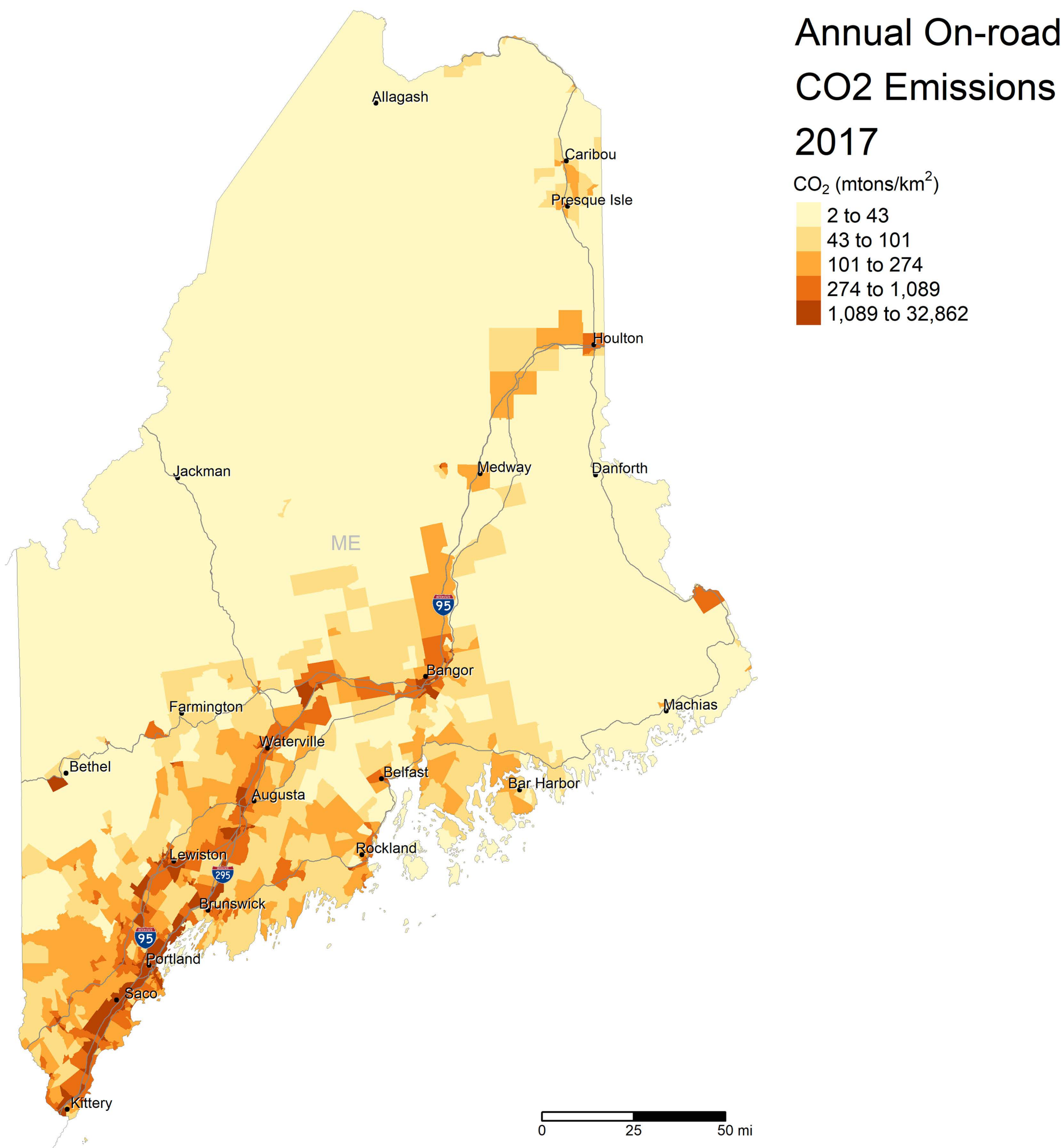
GEOGRAPHIES AFFECTED

The southeast corner of Maine and areas on or near I-95 as far north as Bangor regularly demonstrates higher concentrations for all emissions and higher levels of all related risks evaluated here. The most frequent outliers are found in and around the I-95 corridor from Kittery to Portland. Bangor also shows up as an outlier for $PM_{2.5}$.





On-road CO_2 emissions vary widely across the state. They are highest in and around population centers in the southern half of the state. Kittery shows up as an outlier.



Total emissions have increased significantly since 1990. A short period of decline between 2003 and 2006 was followed by a steep rise in emissions. Emissions growth has exceeded population growth over this period of time.

Annual on-road CO_2 emissions: Change over time

1990 CO_2 (mtons)	2017 CO_2 (mtons)	% change	Per capita 1990 CO_2 (mtons/person)	Per capita 2017 CO_2 (mtons/person)	Per capita % change
6,166,688	7,776,422	26%	5.02	5.83	16%

PRIORITY POPULATIONS

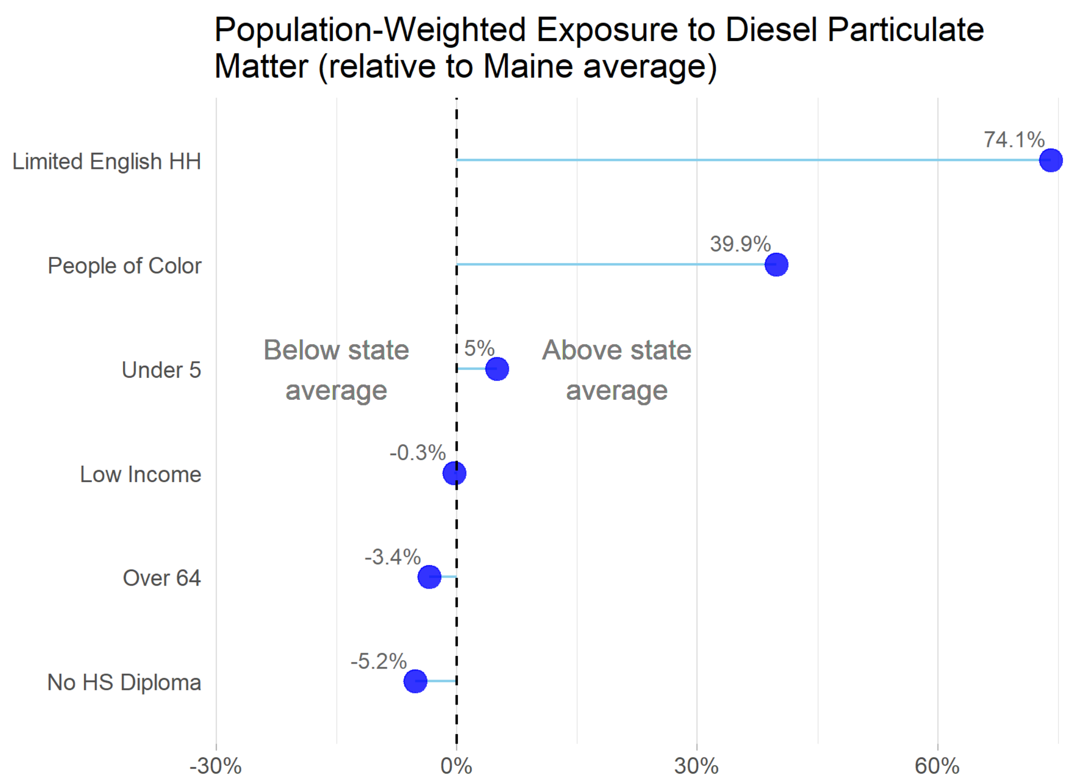
Limited English speaking households experience the highest exposures to all emissions and related risks evaluated here except ozone (O_3). People of color experience the highest levels of exposure for all emissions including O_3.[8]

Limited English speaking households and people of color are also the most exposed to the highest levels of emissions. Almost 4,000 limited English speaking households and over 50,000 people of color experience the highest burdens of emissions. In absolute numbers, low income persons are the largest group affected by highest emission burdens; over 168,000 low income persons are living in areas in the highest burden emissions category.

Distribution of the highest emissions burdens

	% Emissions Category
Total Population	42%
People of color	57%
Under 5	45%
Low income	43%
Under 18	42%
No HS diploma	42%
Over 64	41%
Total HH	43%
Limited English HH	70%

Note: Categories are defined as block groups with high proportions of priority populations and are in the top 20% of burdens for emissions. For example, 70% of limited English speaking households are present in areas in the highest burden emissions category.



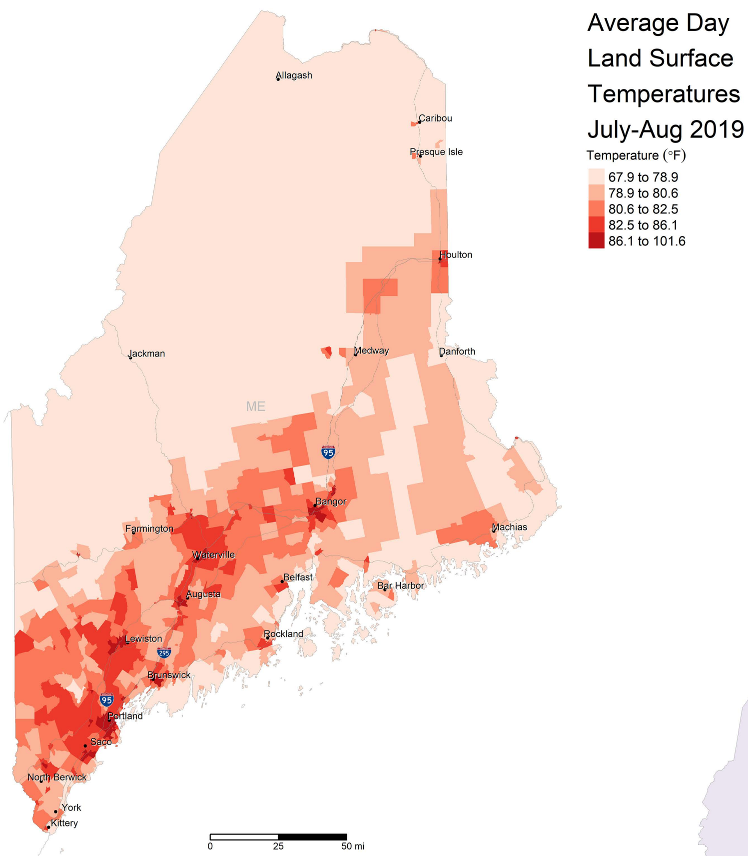
[8] Those over 64 experience the highest exposure to O_3. However, it is important to note that their exposure is only 0.5% above the state average.

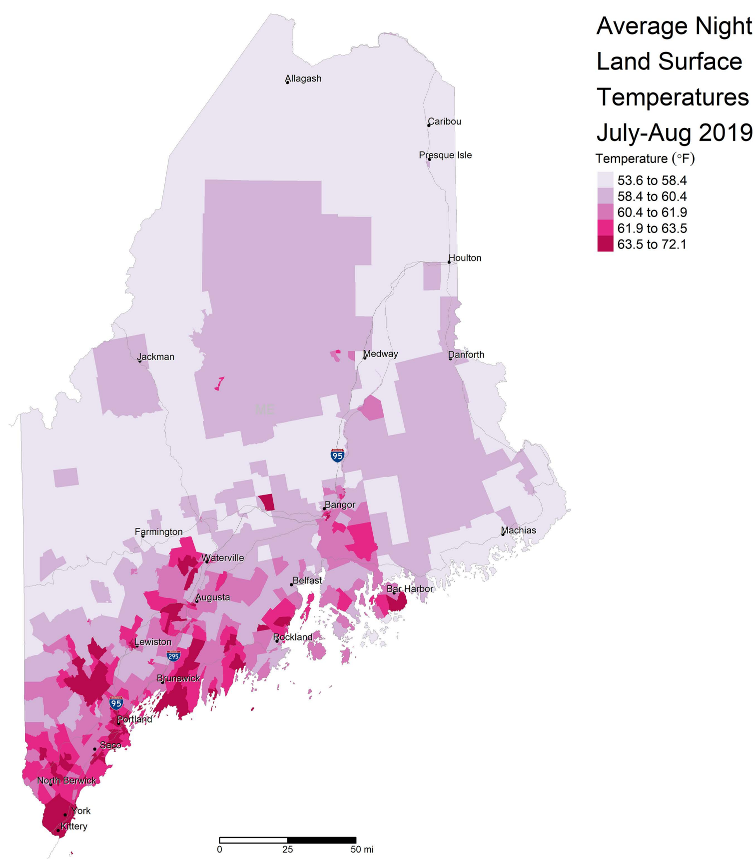
HEAT

Across the day, during the time period studied, average land surface temperatures (LST) ranged from almost 61° to 83°. The highest daytime temperature reached 102° and the highest nighttime temperature reached 72°.

GEOGRAPHIES AFFECTED

Temperatures and urban heat island effects vary significantly across the state. In general, areas in and around I-95 as far north as Houlton experience the highest daytime temperatures. Higher nighttime temperatures are more widespread across the state and include much of the southern coastline. Outliers for daytime temperatures are found in Portland and Lewiston. Outliers for nighttime temperatures are found in and around Lewiston as well as Kittery and South Portland.





PRIORITY POPULATIONS

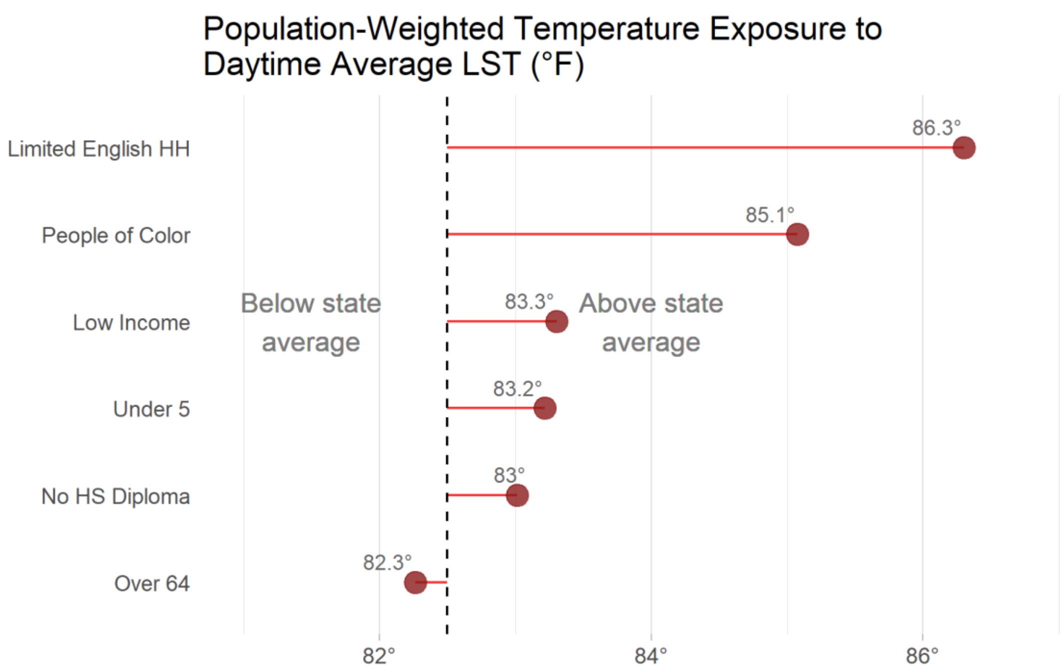
Almost 269,000 people live in areas with the highest daytime heat burden. Limited English speaking households and people of color are more likely to experience the highest daytime and nighttime temperatures compared to the general population or other priority populations. They also disproportionately experience the highest temperatures overall. Over 3,000 limited English speaking households and over 39,000 people of color experience the highest heat burdens.

In absolute numbers, low income persons are the most affected with almost 111,000 living in areas with the highest heat burden.

Distribution of the highest heat burdens

	% Heat Category
Total Population	26%
People of color	44%
Under 5	28%
Low income	28%
No HS diploma	27%
Under 18	25%
Over 64	25%
Total HH	27%
Limited English HH	56%

Note: Categories are defined as block groups with high proportions of priority populations and are in the top 20% of burdens for temperature. For example, 44% of people of color are present in areas in the highest burden heat category.



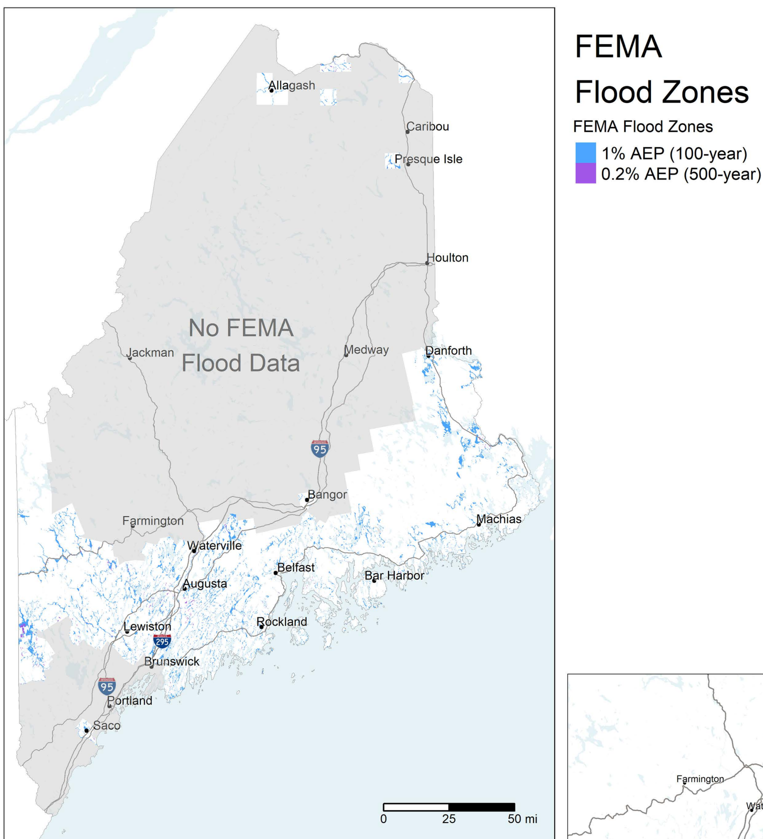
EVACUATION RISKS

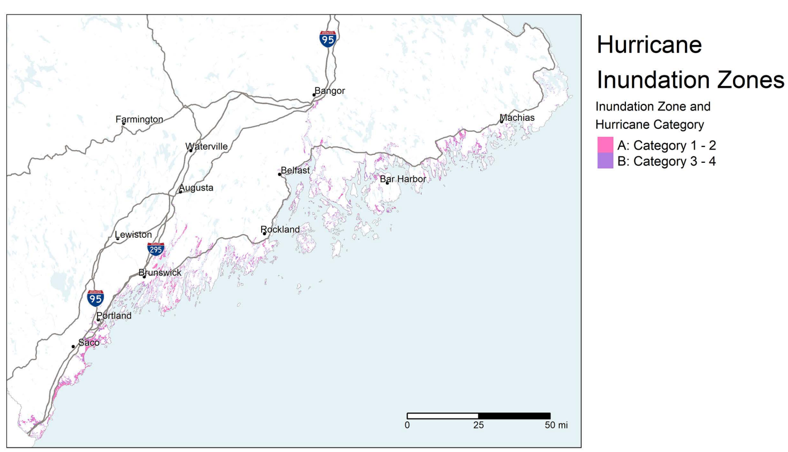
As a humid, coastal state, a significant portion of Maine's land area and population are exposed to the risk of flooding from overbanking of inland water bodies (e.g., ponds and rivers) or from coastal storm surge and sea level rise. Maine is subject to hurricane risk. Since 1900, Maine has been struck by hurricanes four times. The most recent hurricane to hit Maine directly was Hurricane Bob in 1991, a Category 2 storm that affected six counties in the southern and central part of the state.[77] The storm resulted in 3 deaths, power outages, and over $5 million in damages as well as a presidential disaster declaration.[78] Hurricane Sandy in 2012 had been downgraded to a tropical storm by the time it hit Maine, but nevertheless left 90,000 people across the state without power due to high winds.[79] In general, Maine is subject to a hurricane return period of between 29 and 59 years, depending on the area.[80]

GEOGRAPHIES AFFECTED

At least 1.8% of land area is found in a flood zone. It is important to note that FEMA has not made digital flood data publicly available for most of the state. This includes much of the most populated parts of the Maine. Our results on flood risk should be considered as extremely conservative estimates.

Separately, 0.8% of land area falls within a hurricane evacuation zone. This encompasses most of Maine's coastline but also includes areas considerably inland from the coast. For example, areas of storm surge are estimated to affect areas as far inland as Bangor, which is 50 miles from the coast.





PRIORITY POPULATIONS

At least 33,000 people live in a flood zone. Households without a car, those over 64, low income persons, and the disabled are more likely to live in flood zones compared to the general population or other priority populations. Almost 41,000 households without a car, over 7,000 persons over 64, almost 11,000 low income persons, and over 5,000 people living with disabilities, at minimum, live in a flood zone.

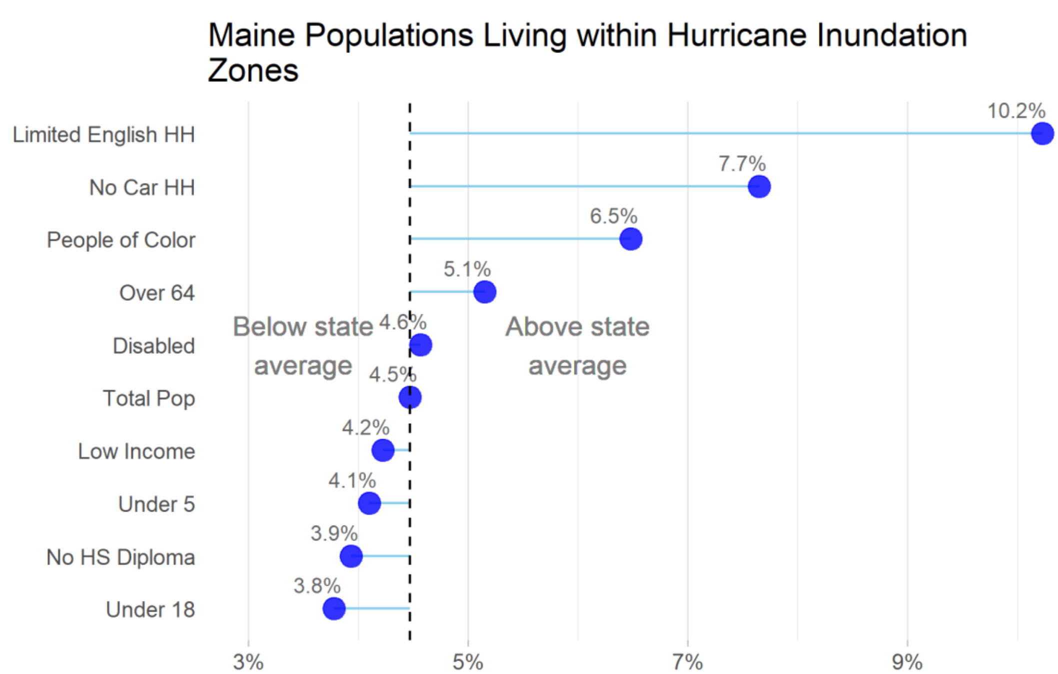
Over 59,000 people live in a hurricane evacuation zone. Limited English speaking households, households without a car, and people of color are more likely to live in a hurricane evacuation zone compared to the general population or other priority populations. Almost 600 limited English speaking households, over 3,000 households without a car, and almost 6,000 people of color live in a hurricane evacuation zone. In terms of absolute numbers, low income persons are disproportionately affected; almost 17,000 low income persons live in hurricane evacuation zones.

All priority populations are living in areas in the highest burden evacuation category at rates higher than the state average. Limited English speaking households and people of color are disproportionately living in areas with the highest burden evacuation categories. Over 3,000 limited English speaking households and almost 48,000 people of color live in areas in the highest burden evacuation category. In absolute numbers, low income persons are the most impacted; over 188,000 low income persons are living in areas in the highest burden evacuation categories.

Distribution of evacuation burdens

	% Evacuation Category
Total Population	46%
People of color	54%
Under 5	49%
Low income	48%
Over 64	48%
No HS diploma	47%
Under 18	47%
Total HH	47%
Limited English HH	63%

Note: Categories are defined as block groups with high proportions of priority populations and are in either a flood or hurricane evacuation zone. For example, 49% of those under 5 are present in areas in the highest burden evacuation category.



NOTES

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Appendix A

Methods

APPENDIX A - METHODS

Greater details in the method and design, including sources of data, can be found in any of the technical reports.

POPULATIONS OF CONCERN

Table 1 shows the demographic characteristics used by the US EPA in its EJSCREEN tool and state governments for identifying environmental justice communities or communities of concern.

Table 1. Populations of concern identified by federal and state policy

Criteria	US EPA	CT	MA	ME	NH	RI	VT
Low income	✓	✓	✓	✓		✓	✓
Minority	✓		✓			✓	
Less than high school education	✓						
Linguistic isolation	✓		✓				
Children under age 5	✓						
Adults over age 64	✓	✓		✓		✓	

In these analyses, we used only public data that was available for the entire region in order to make the analysis and its conclusions comparable, transparent, and reproducible. Geographic analyses were done at the Census Block Group level wherever possible to provide the highest level of spatial resolution at which detailed demographic and environmental data are available. Demographic data was derived from the American Community Survey five-year estimates for 2014 – 2018, the most current demographic data available at the time the analysis was performed in late 2020.

RESEARCH QUESTIONS AND DESIGN

Identify the geographic and demographic characteristics of communities that are underserved by transportation options or overburdened by transportation costs

Access to transit: To identify the populations with access to transit, 400 meter, 800 meter, and 4800 meter buffers were generated around all bus, rapid transit, and commuter rail stops and Park and Ride lots, respectively. The transit buffer was intersected with the developed portions of Census Block Groups. Developed portions of Census Block Groups were identified based upon the National Land Cover Database (NLCD), using a process of areal apportionment. The population with access to transit was calculated as the product of the areal proportion of the intersecting buffer and developed Block Group polygons:

Population with transit access = Proportion of developed Block Group Intersection x Population of developed Block Group

For example, if 10% of the developed area of a Census Block Group intersected/overlapped with the 400m buffer around transit stops, it was assumed that 10% of the population has access to those transit stops. Assuming a population of 100 people in the developed portion of the Block Group, this would mean 100 x .10 = 10 people would have access to transit via those stops. This transit access analysis was done in R.

Frequency of Transit Service: Headways analyzed here are based on static schedules provided by the transit agency through the General Transit Feed System (GTFS). GTFS is a common format for public transportation schedules and associated geographic information. Public transit agencies increasingly publish their transit data electronically via GTFS "feeds" primarily to allow software developers to create applications which can tap into these feeds and provide users with detailed or timely transit schedules or route planning.[9] GTFS is also increasingly used by transportation researchers because it provides an efficient way to acquire detailed scheduling and routing information for transit networks. While GTFS feeds can provide real-time data on vehicle movements and locations, most data are provided as static schedules, and vehicle frequencies and headways are inferred from the schedules. Scheduled headways likely differ from actual vehicle frequency due to traffic, dispatch management, accidents or breakdowns, and other issues.[10]

GTFS data for this analysis was acquired either directly from transit agencies or from public distributors of GTFS data such as Trillium or Open Mobility. GTFS data was processed using the tidytransit package in R.[11] Schedules for all routes running Monday through Friday, 6am to 9pm, were extracted. Headways for each transit stop on these routes were then calculated based on route schedules, and these headways were also averaged for each route. To calculate headways experienced by different population groups, transit stop points with calculated headways were intersected with the developed portions of Census Block Groups and that were within 400m, 800m, and 4800m of stops for buses, rapid transit, and commuter rail, respectively. Headways for these intersecting stops were then aggregated to provide mean headways for their intersecting Block Groups. Populations within those intersecting Block Groups were assumed to be subject to those mean headways.

Walkability: The National Walkability Index is a nationwide geographic data resource produced by the U.S. Environmental Protection Agency that ranks Census Block Groups according to their relative walkability.[12] Walkability was modeled based on characteristics of the built environment that influence the likelihood of walking being used as a mode of travel. These characteristics of Block Groups include:

- mix of employment types (greater mix = more walkable)
- amount or density of occupied housing (higher density = more walkable)
- street intersection density (higher density = more walkable)
- proportion of workers who carpool (more carpooling = more walkable)

The Walkability Index was downloaded as a shapefile from the US EPA's Smart Location Mapping website at https://www.epa.gov/smartgrowth/smart-location-mapping#walkability. Population-weighted averages for the walkability index were computed for Block Groups and Tracts to compare population groups. To compare walkability

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[9] Google Transit APIs. "GTFS Static Overview." https://developers.google.com/transit/gtfs

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index values with disabled populations and households without a car, Block Group walkability index values were aggregated to the overlying Census Tract as simple averages.

Transportation cost burden: The Location Affordability Index (LAI) is a nationwide geographic data resource developed by the U.S. Department of Housing and Urban Development (HUD) in collaboration with the U.S. Department of Transportation under the federal Partnership for Sustainable Communities.[13] The LAI was developed as a way of integrating both housing and transportation costs into estimates of the affordability of specific neighborhoods and cities. The LAI provides estimated total expenses from transportation, whether transit or motor vehicle, as well as transportation cost as a percentage of household income, for eight different household types — which vary by household income, size, and number of commuters — at the Census Tract level. For this analysis Location Affordability Index Model Version 3 (LAIM Version 3 or LAIM3), released in March 2019, was used. LAIM Version 3 estimates housing and transportation costs for eight different household profiles, to focus on the impact of the built environment on these costs by holding demographic characteristics constant. These household profiles are described in the table below. The LAI can be interpreted as the percentage of the specified household profile's income that would be needed to cover housing, transportation, or combined costs if that household type were to live in the specified Census Tract. So, for example, a household profile (such as single-parent family) with a housing LAI of 40% would be expected to pay 40% of their income for housing if they lived in the specified location.

Household Profile	Income	Household Size	Commuters
Median-Income Family	MHHI[1]	4	2
Very Low-Income Individual	National poverty line	1	1
Working Individual	50% of MHHI	1	1
Single Professional	135% of MHHI	1	1
Retired Couple	80% of MHHI	2	0
Single-Parent Family	50% of MHHI	3	1
Moderate-Income Family	80% of MHHI	3	1
Dual-Professional Family	150% of MHHI	4	2

[1]MHHI = Median household income for a given area (CBSA or County)

Because the LAI does not provide a simple or average cost estimate for each Census Tract, transportation costs as a percentage of income for moderate-income households (households with one commuter making 80% or less of area median household income) was used as a proxy to represent transportation cost burden for all areas.[14] LAI data were also downscaled to the Block Group level for the purpose of demographic analyses and comparisons.

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[14] A similar approach in the use of LAI was adopted by Efficiency Vermont. 2016. Mapping Total Energy Burden in Vermont: Geographic Patterns in Vermonters' Thermal, Electric, and Transportation Energy Use. https://www.efficiencyvermont.com/news-blog/whitepapers/mapping-total-energy-burden-vermont

Identify the geographic and demographic characteristics of communities that are overburdened by transportation-related emissions and related externalities

Six of these seven indicators (excluding CO_2) were derived from the U.S. EPA's EJSCREEN. EJSCREEN is an online environmental justice mapping and screening tool that provides a "nationally consistent dataset and approach for combining environmental and demographic indicators." EJSCREEN provides data on 11 environmental indicators, ranging across air, land, and water. The six indicators analyzed here were chosen based on their relationship to transportation sources, especially motor vehicles. Data for each indicator is available by Census Block Group across the U.S. The 2015 (earliest available) and 2019 (latest available) data sets were downloaded from https://www.epa.gov/ejscreen/download- ejscreen-data as CSV files and processed in R. All data was analyzed or aggregated geographically by Census Tract and Block Group.

$PM_{2.5}$: The analysis of $PM_{2.5}$ presented here is based on data from the EPA's EJSCREEN.[15] EJSCREEN data provides $PM_{2.5}$ annual concentrations at the Census Block Group level for the years 2011 to 2016 (as of December 2019). Population-weighted averages for $PM_{2.5}$ were computed for Block Groups and Tracts to compare population groups.

Ozone (O_3): The analysis of ozone (O_3) presented here is based on data from the EPA's EJSCREEN.[16] EJSCREEN data provides ozone (O_3) May–September (summer/ ozone season) average of daily-maximum 8-hour-average ozone concentrations, in parts per billion (ppb), at the Census Block Group level for the years 2011 to 2016 (as of December 2019).[17] Population-weighted averages for ozone were computed for Block Groups and Tracts to compare population groups.

Carbon dioxide (CO_2): The analysis of carbon dioxide (CO_2) presented here is based on data from the Database of Road Transportation Emissions (DARTE), a product of the NASA Carbon Monitoring System (CMS). DARTE provides CO_2 emissions from on-road transportation annually for 1980-2017 as a continuous surface at a spatial resolution of 1 km and also aggregated at the Census Block Group level.[18] For the purposes of this analysis, DARTE Block Group data for the years 1990 to 2017 was downloaded as a geodatabase and processed in R. CO_2 concentrations were mapped and summarized by Census Block Group, municipality, and state.

Diesel particulate matter: The analysis of Diesel Particulate Matter (DPM) presented here is based on data from the EPA's EJSCREEN.[19] EJSCREEN data provides annual DPM concentrations, in micrograms per cubic meter of air ($\mu g/m^3$), at the Census Block Group level for 2014, the latest year of data available from the National Air Toxics

[15] U.S. Environmental Protection Agency (EPA), 2019. EJSCREEN Technical Documentation. For more information see www.epa.gov/ejscreen

[16] U.S. Environmental Protection Agency (EPA), 2019. EJSCREEN Technical Documentation. For more information see www.epa.gov/ejscreen

[17] Note that the EJSCREEN values do not directly indicate nonattainment of the NAAQS standard because the EJSCREEN data is based on estimates from a combination of modeling and monitoring for a single year, while nonattainment is determined for a large area (often a county) based on three years of monitoring data. For example, five counties in Massachusetts have been designated as "nonattainment" status for NAAQS ozone standards as of March 2020. For a list of nonattainment counties see EPA 8-Hour Ozone Designated Area State/Area/County Report. https://www3.epa.gov/airquality/greenbook/jbcs.html#MA

[18] Gately, C., L.R. Hutyra, and I.S. Wing. 2019. DARTE Annual On-road CO2 Emissions on a 1-km Grid, Conterminous USA, V2, 1980-2017. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1735

[19] U.S. Environmental Protection Agency (EPA), 2019. EJSCREEN Technical Documentation. For more information see www.epa.gov/ejscreen

Assessment. Population-weighted averages for DPM were computed for Block Groups and Tracts to compare population groups.

Air Toxics Cancer Risk: The analysis of air toxics cancer risk presented here is based on data from the EPA's EJSCREEN.[20] EJSCREEN data provides lifetime cancer risk from inhalation of air toxics, as risk-in-1 million, at the Census Block Group level for 2014, the latest year of data available from the National Air Toxics Assessment. Population-weighted averages for cancer risk were computed for Block Groups and Tracts to compare population groups.

Respiratory hazard index: The analysis of respiratory hazard presented here is based on data from the EPA's EJSCREEN.[27] EJSCREEN data provides respiratory hazard, as a ratio of exposure concentration to a health-based reference concentration (RfC), at the Census Block Group level for 2014, the latest year of data available from the National Air Toxics Assessment. Population-weighted averages for the hazard index were computed for Block Groups and Tracts to compare population groups.

Traffic proximity and volume: EPA's EJSCREEN provides an indicator of traffic exposure measured as residential proximity to roads weighted by traffic volume. More specifically, EJSCREEN's Traffic Proximity and Volume indicator is a count of vehicles (average annual daily traffic) at major roads within 500 meters of residential areas (i.e., Census Blocks) divided by distance in kilometers (km).[21] For example, a residential area at 100 meters distance from a single highway with 33,000 AADT (average annual daily traffic) would result in a score of 33,000/100=330, which is approximately the median person's block group traffic proximity indicator value in New England. The Traffic Proximity and Volume indicator values are aggregated at the Census Block Group level. Population-weighted averages for traffic proximity and volume scores were computed for Block Groups and Tracts to compare population groups.

Identify the geographic and demographic characteristics of communities that are at increased risk for heat island effects, which exacerbates transportation related air pollution

LAND SURFACE TEMPERATURE (LST): Land Surface Temperatures (LST) were derived from NASA's Moderate-resolution Imaging Spectroradiometer (MODIS) satellite sensor.[22] Unlike ambient air temperature measured by thermometers in ground-based weather stations, LST is a measure of the radiant energy (i.e., emissivity) of the ground or surface. When a surface, such as concrete or water, is heated by the absorption of sunlight, that surface will re-radiate that thermal energy in the form of invisible (but sensible) thermal radiant energy. LST values tend to be slightly higher than ambient air temperatures but are highly correlated with air temperatures. Abundant research has shown that satellite-derived LST is an acceptable proxy for air temperature.[23] Moreover, while weather stations are

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[20] U.S. Environmental Protection Agency (EPA), 2019. EJSCREEN Technical Documentation. For more information see www.epa.gov/ejscreen

[21] Measures of traffic proximity in EJSCREEN are based on average annual daily traffic (AADT) estimates in the Highway Performance Monitoring System (HPMS) dataset in the Department of Transportation (DOT) National Transportation Atlas Database (NTAD).

[22] NASA MODIS Land Surface Temperature and Emissivity (MOD11). https://modis.gsfc.nasa.gov/data/dataprod/mod11.php

[23] Itai Kloog, Francesco Nordio, Brent A. Coull, and Joel Schwartz. 2014. "Predicting spatiotemporal mean air temperature using MODIS satellite surface temperature measurements across the Northeastern USA." *Remote Sensing of Environment* 150:132-139. https://doi.org/10.1016/j.rse.2014.04.024; Thanh Noi Phan and Martin Kappas. 2018. "Application of MODIS land surface temperature data: a systematic literature review and analysis." *Journal of Applied Remote Sensing* 12(4): 041501. https://doi.org/10.1117/1.JRS.12.041501.

sparsely and unevenly distributed, satellite- derived LST has the advantage of providing an unbroken and continuous snapshot of temperature at high resolution across a region at any given moment.

The MODIS data used here covers average day and night LST for an 8-day period from July 28 to August 4, 2019 for New England. That week constituted the conclusion of a historically warm month for the region. Daytime LST values represent data collected over the region during the time period of 11:48am to 2pm. Nighttime LST values represent data collected during the time period of 12am to 3:06am. Day-Night average LST values are the simple average of day and night LST values for each pixel. LST data was validated against ground weather station data for the same time period using NOAA's Integrated Surface Data ('ISD') from the NOAA National Centers for Environmental Information (https://www.ncdc.noaa.gov/isd/data- access) using the Commmon Access tool (https://www.ncei.noaa.gov/access/search/data-search/global-hourly). This yielded 77 weather stations across New England with air temperature data available for the same period as the MODIS LST data. Spearman's Rho correlations between LST values and weather station readings were all statistically significant with strong positive correlations ranging from 0.73 for day LST to 0.84 for day-night average LST.

Urban Heat Island (UHI) effect: UHI effect is measured as the difference in temperature between rural and urban areas. For this analysis, the UHI for New England was calculated as the difference between LST values across New England for each time period and the average LST for rural regions for the same time periods. It is represented by the following formula:

UHI effect = LST - Mean Rural LST

For example, to calculate the UHI effects for daytime temperatures, daytime LST pixels falling within the rural regions of New England were all averaged to provide a mean rural LST benchmark value. This mean rural LST value was then subtracted from the daytime LST values of each pixel across the region. The resulting value for each pixel indicates the magnitude or size of the difference, and the sign (+/-) indicates whether it is warmer or cooler than the mean rural LST. Rural regions of New England were identified according to the U.S. Census Bureau's urban-rural classification.[24]

MODIS LST data originates at 1km spatial resolution and was aggregated to average temperatures at each Census Block Group separately for day-night averages, daytime, nighttime, and urban heat island effects. Population-weighted average temperatures by Census Block Group were computed for each demographic group to perform comparisons of heat and UHI exposure.

Identify the geographic and demographic characteristics of communities that are likely to experience evacuation risks and other transportation-related vulnerabilities flowing from flooding, extreme weather, and other climate stressors

FEMA flood zone risk: The analysis of flood exposure presented here is based on the Federal Emergency Management Agency's (FEMA) National Flood Hazard Layer (NFHL). The NFHL is a digital geospatial database that contains current effective flood hazard mapping data from FEMA's National Flood Insurance Program (NFIP). NFHL data is available for download at https://msc.fema.gov/portal/advanceSearch. This geodatabase identifies areas subject to various levels of flood risk as determined by FEMA, consistent with Flood Insurance Rate Maps

[24] Urban areas are defined by the U.S. Census as Census Blocks meeting specific population density thresholds, as well as land use. See U.S. Census Bureau. Urban and Rural. https://www.census.gov/programs-surveys/geography/guidance/geo- areas/urban-rural.html

(FIRMs), based upon hydrodynamic models as well as historic flooding.[25] FEMA's FIRMs are a national standard used by all federal agencies for the purposes of requiring and rating the purchase of flood insurance and regulating new development.

In order to identify populations at risk from floods with a 1% or 0.2% annual exceedance probability, NFHL polygons pertaining to the 1% flood risk (zones A, AE, AH, AO, and VE) and the 0.2% flood risk (zone X), and excluding water or areas of "minimal flood hazard," were extracted and intersected with the developed portions of Census Block Groups. Developed portions of Census Block Groups were identified based upon the National Land Cover Database (NLCD), using a process of areal apportionment. The population at risk from flooding was calculated as the product of the areal proportion of the intersecting flood and developed Block Group polygons:

Population at risk = Proportion of developed Block Group Intersection x Population of developed Block Group

For example, if 10% of the developed area of a Census Block Group intersected/overlapped with a flood polygon, it was assumed that 10% of the population is exposed to that flood risk. Assuming a population of 100 people in the developed portion of the Block Group, this would mean 100 x .10 = 10 people would be subject to flood risk. FEMA flood risk modeling was done in R.

Vermont River Corridors: River corridors are areas that encompass both the channel and adjacent land of rivers and streams. The adjacent land in a river corridor is the minimal area needed to contain the meander of a river in its least erosive form. These corridors were delineated to identify areas "with the expectation that new and existing structures outside the corridor may be protected from lateral channel migration using bank stabilization practices without creating new or additional hazards. Within a river corridor, existing infrastructure and improved property may be at a heightened risk from erosion and be more likely to require river management to protect over time."[4] Indeed, state officials have found that most flood-related damage in Vermont occurs outside of FEMA's Special Flood Hazard Areas and inside of river corridors, primarily as a result of fluvial erosion.

For the purposes of this analysis, a statewide geospatial data layer of river corridors was downloaded from the Vermont Open Geodata Portal (https://geodata.vermont.gov/datasets/VTANR::river-corridors-august-2019), last updated in August 2019.

In order to identify populations at risk within river corridors, river corridor polygons were intersected with the developed portions of Census Block Groups. Developed portions of Census Block Groups were identified based upon the National Land Cover Database (NLCD), using a process of areal apportionment. The population at risk within river corridors was calculated as the product of the areal proportion of the intersecting river corridor and developed Block Group polygons:

Population at risk = Proportion of developed Block Group Intersection x Population of developed Block Group

For example, if 10% of the developed area of a Census Block Group intersected/overlapped with a river corridor polygon, it was assumed that 10% of the population is exposed to that river corridor risk. Assuming a population of 100 people in the developed portion of the Block Group, this would mean 100 x .10 = 10 people would be subject to river corridor risk. River corridor risk modeling was done in R.

Hurricane evacuation or storm surge risk: The National Oceanic and Atmospheric Administration (NOAA), specifically the National Weather Service's (NWS) National Hurricane Center (NHC), utilizes the hydrodynamic Sea,

[25] FEMA National Flood Hazard Layer (NFHL). https://www.fema.gov/national-flood-hazard-layer-nfhl.

Lake, and Overland Surges from Hurricanes (SLOSH) model to simulate storm surge from tropical cyclones, including hurricanes. SLOSH models of coastal storm surge are based on tens of thousands of climatology-based hypothetical tropical cyclone simulations.[26] The composite results of these simulations are used to assess and visualize storm surge risk under varying conditions. Maps and estimates of risk are provided to federal, state, and local partners to assist in a range of planning processes, risk assessment studies, and operational decision-making.[27] SLOSH models and maps are the basis of state-level hurricane evacuation zone designations. However, only three of the six New England states (Connecticut, Massachusetts, and Rhode Island) have developed hurricane evacuation zone maps. Maine and New Hampshire, which are subject to hurricane risk, have not developed, or do not publicly offer, hurricane evacuation zone maps. In order to model hurricane evacuation risk in those states, SLOSH inundation zones were used instead. The use of storm surge inundation risk, rather than hurricane evacuation zones, likely underestimates the population that would be subject to evacuation in the event of an approaching hurricane.

In order to identify populations at risk from hurricane evacuation in Maine and New Hampshire, SLOSH surge hazard maps were downloaded from the National Hurricane Center in the form of GeoTIFF raster files. Specifically, scenarios for Category 2 and Category 4 hurricanes at high tide were used. The raster files were clipped to the land areas of Maine and New Hampshire and converted to a vector polygon layer and merged. Hurricane storm surge polygons were intersected with the developed portions of Census Block Groups. Developed portions of Census Block Groups were identified based upon the National Land Cover Database (NLCD), using a process of areal apportionment. The population at risk from hurricane storm surge risk was calculated as the product of the areal proportion of the intersecting storm surge polygons and developed Block Group polygons:

Population at risk = Proportion of developed Block Group Intersection x Population of developed Block Group

For example, if 10% of the developed area of a Census Block Group intersected/overlapped with a hurricane storm surge polygon, it was assumed that 10% of the population is exposed to that flood risk. Assuming a population of 100 people in the developed portion of the Block Group, this would mean 100 x .10 = 10 people would be subject to hurricane storm surge risk. Processing of SLOSH GeoTIFF files and polygon intersection were performed in ArcGIS 10.7.

Connecticut, Massachusetts, and Rhode Island provide maps and geospatial layers identifying evacuation zones in their respective states in the event of a hurricane. These hurricane evacuation zone maps were developed in cooperation between state emergency management agencies and the U.S. Army Corps of Engineers. Hurricane storm surge risk was based on the SLOSH model. Hurricane evacuation zones generally encompass an area larger than the specific areas subject to inundation.

Connecticut Hurricane Evacuation Zones: https://data.ct.gov/Public-Safety/Hurricane- Evacuation-Zones-2014-/kdsj-af66

Massachusetts Hurricane Evacuation Zones: https://www.nae.usace.army.mil/Missions/Projects-Topics/Massachusetts-Hurricane-Studies/

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[26] NOAA National Hurricane Center and Central Pacific Hurricane Center. "National Storm Surge Hazard Maps - Version 2." https://www.nhc.noaa.gov/nationalsurge/.

[27] The National Hurricane Center provides static and interactive maps of storm surge flooding vulnerability across the country based on SLOSH modeling. See NOAA National Hurricane Center and Central Pacific Hurricane Center. National Storm Surge Hazard Maps - Version 2. https://www.nhc.noaa.gov/nationalsurge/

Rhode Island Hurricane Evacuation Zones: http://www.riema.ri.gov/resources/citizens/prepare/evacuation.php

In order to identify populations at risk from hurricane evacuation, hurricane evacuation zone polygons were intersected with the developed portions of Census Block Groups. Developed portions of Census Block Groups were identified based upon the National Land Cover Database (NLCD), using a process of areal apportionment. The population at risk from hurricane evacuation risk was calculated as the product of the areal proportion of the intersecting evacuation zone and developed Block Group polygons:

Population at risk = Proportion of developed Block Group Intersection x Population of developed Block Group

For example, if 10% of the developed area of a Census Block Group intersected/overlapped with a hurricane evacuation zone, it was assumed that 10% of the population is exposed to that evacuation risk. Assuming a population of 100 people in the developed portion of the Block Group, this would mean 100 x .10 = 10 people would be subject to hurricane evacuation risk.

Appendix B

Overburdened Municipalities

CONNECTICUT

Populations Experiencing 3 or 4 Categories of Burdens by City/Town Sorted by 3+ Burdens [1]

	3 Burdens		4 Burdens		3+ Burdens	
	Population	%	Population	%	Population	%
Bridgeport	94,656	65%	2,874	2%	97,530	67%
New Haven	58,079	44%	13,183	10%	71,262	55%
Stamford	39,675	31%	9,975	8%	49,650	38%
Hartford	33,663	27%	2,304	2%	35,967	29%
Stratford	24,994	48%	3,969	8%	28,963	55%
Norwalk	20,607	23%	0	0%	20,607	23%
Greenwich	15,455	25%	4,361	7%	19,816	32%
Waterbury	14,583	13%	4,369	4%	18,952	17%
East Hartford	15,343	30%	1,964	4%	17,307	34%
Trumbull	17,239	48%	0	0%	17,239	48%
Newington	13,154	43%	3,995	13%	17,149	57%
New Britain	15,054	21%	1,500	2%	16,554	23%
Darien	10,261	47%	5,614	26%	15,875	73%
West Hartford	14,655	23%	0	0%	14,655	23%
Milford	11,107	21%	3,031	6%	14,138	26%
Meriden	10,150	17%	2,118	4%	12,268	20%
Windsor	11,939	41%	0	0%	11,939	41%
Fairfield	11,856	19%	0	0%	11,856	19%
Danbury	10,645	13%	1,027	1%	11,672	14%
Wethersfield	8,895	34%	0	0%	8,895	34%
East Haven	6,632	23%	1,548	5%	8,180	28%
New London	6,603	24%	0	0%	6,603	24%
Westport	4,849	17%	1,264	5%	6,113	22%
West Haven	4,856	9%	1,128	2%	5,984	11%
New Canaan	5,718	28%	0	0%	5,718	28%
Groton	4,351	11%	1,070	3%	5,421	14%
Enfield	5,055	11%	0	0%	5,055	11%
Berlin	4,780	23%	0	0%	4,780	23%
Weston	4,777	46%	0	0%	4,777	46%
Branford	3,850	14%	0	0%	3,850	14%
Wilton	3,620	20%	0	0%	3,620	20%
Naugatuck	3,491	11%	0	0%	3,491	11%
Southington	3,313	8%	0	0%	3,313	8%
Bristol	2,786	5%	0	0%	2,786	5%
Plainville	2,648	15%	0	0%	2,648	15%
Madison	2,045	11%	0	0%	2,045	11%
Hamden	2,032	3%	0	0%	2,032	3%
Wallingford	1,965	4%	0	0%	1,965	4%
Guilford	1,831	8%	0	0%	1,831	8%
North Haven	1,755	7%	0	0%	1,755	7%
Woodbridge	1,475	17%	0	0%	1,475	17%

Populations Experiencing 3 or 4 Categories of Burdens by City/Town Sorted by 3+ Burdens [1]

	3 Burdens		4 Burdens		3+ Burdens	
	Population	%	Population	%	Population	%
Shelton	1,453	4%	0	0%	1,453	4%
North Branford	1,340	9%	0	0%	1,340	9%
Redding	1,265	14%	0	0%	1,265	14%
Montville	1,235	6%	0	0%	1,235	6%
Rocky Hill	1,111	6%	0	0%	1,111	6%
Orange	1,100	8%	0	0%	1,100	8%
Manchester	1,031	2%	0	0%	1,031	2%
Old Saybrook	0	0%	995	10%	995	10%
New Milford	848	3%	0	0%	848	3%
Derby	527	4%	0	0%	527	4%
Ridgefield	4	0.02%	0	0%	4	0.02%

[1] Categories are defined as block groups with high proportions of priority populations and are in the highest concentration or category of burden for any burden.

MASSACHUSETTS

Populations Experiencing 3 or 4 Categories of Burdens by City/Town Sorted by 3+ Burdens [1]

	3 Burdens		4 Burdens		3+ Burdens	
	Population	%	Population	%	Population	%
Boston	239,987	35%	39,925	6%	279,912	41%
Cambridge	53,110	46%	0	0%	53,110	46%
Springfield	42,401	27%	7,112	5%	49,513	32%
Malden	44,666	73%	4,024	7%	48,690	80%
Lynn	27,740	30%	10,472	11%	38,212	41%
Quincy	32,397	34%	5,463	6%	37,860	40%
Medford	23,006	40%	9,614	17%	32,620	56%
Revere	28,442	53%	2,614	5%	31,056	58%
Lowell	30,578	27%	0	0%	30,578	27%
Chicopee	20,321	37%	5,321	10%	25,642	46%
Somerville	15,762	20%	8,798	11%	24,560	31%
Chelsea	24,353	61%	0	0%	24,353	61%
Fall River	20,518	23%	1,217	1%	21,735	24%
Everett	21,548	47%	0	0%	21,548	47%
Brookline	11,230	19%	7,908	13%	19,138	32%
Framingham	15,940	22%	2,079	3%	18,019	25%
Attleboro	15,341	34%	1,360	3%	16,701	37%
New Bedford	16,674	18%	0	0%	16,674	18%
Peabody	12,478	24%	3,939	7%	16,417	31%
Falmouth	14,960	48%	0	0%	14,960	48%
Lawrence	13,647	17%	0	0%	13,647	17%
North Attleborough	13,351	46%	0	0%	13,351	46%
Newton	10,778	12%	1,997	2%	12,775	14%
Westfield	12,079	29%	0	0%	12,079	29%
Ludlow	10,668	50%	0	0%	10,668	50%
Wilbraham	10,417	71%	0	0%	10,417	71%
Saugus	7,663	27%	2,362	8%	10,025	36%
Sturbridge	9,537	100%	0	0%	9,537	100%
Natick	6,598	18%	1,793	5%	8,391	23%
Waltham	7,001	11%	934	1%	7,935	13%
Longmeadow	2,402	15%	5,393	34%	7,795	49%
Franklin Town	7,349	22%	0	0%	7,349	22%
Arlington	7,009	16%	0	0%	7,009	16%
Somerset	3,296	18%	3,676	20%	6,972	38%
Plymouth	6,486	11%	0	0%	6,486	11%
Palmer Town	6,464	53%	0	0%	6,464	53%
Fairhaven	5,865	37%	597	4%	6,462	40%
Mansfield	6,281	26%	0	0%	6,281	26%
Dennis	6,057	43%	0	0%	6,057	43%
Webster	3,674	22%	2,285	13%	5,959	35%
East Longmeadow	5,945	37%	0	0%	5,945	37%

Populations Experiencing 3 or 4 Categories of Burdens by City/Town Sorted by 3+ Burdens [1]

	3 Burdens		4 Burdens		3+ Burdens	
	Population	%	Population	%	Population	%
Southwick	5,930	61%	0	0%	5,930	61%
Barnstable Town	5,791	13%	0	0%	5,791	13%
Grafton	5,336	29%	0	0%	5,336	29%
Sutton	5,180	55%	0	0%	5,180	55%
Upton	5,077	65%	0	0%	5,077	65%
Mashpee	5,077	36%	0	0%	5,077	36%
Brewster	4,967	50%	0	0%	4,967	50%
Norwood	4,960	17%	0	0%	4,960	17%
Swansea	3,706	23%	1,203	7%	4,909	30%
Eastham	4,893	100%	0	0%	4,893	100%
Worcester	4,826	3%	0	0%	4,826	3%
Southbridge Town	4,797	28%	0	0%	4,797	28%
Watertown Town	4,644	13%	0	0%	4,644	13%
Reading	4,414	18%	0	0%	4,414	18%
Seekonk	2,786	18%	1,593	10%	4,379	29%
Bourne	4,343	22%	0	0%	4,343	22%
Spencer	4,265	36%	0	0%	4,265	36%
Milford	4,263	15%	0	0%	4,263	15%
Mendon	4,209	69%	0	0%	4,209	69%
Leicester	4,122	37%	0	0%	4,122	37%
Agawam Town	4,080	14%	0	0%	4,080	14%
Medfield	4,057	32%	0	0%	4,057	32%
Beverly	4,009	10%	0	0%	4,009	10%
Millbury	3,916	29%	0	0%	3,916	29%
Harwich	3,708	31%	0	0%	3,708	31%
Wellfleet	3,481	100%	0	0%	3,481	100%
Yarmouth	3,459	15%	0	0%	3,459	15%
Acushnet	1,957	19%	1,475	14%	3,432	33%
West Springfield Town	3,417	12%	0	0%	3,417	12%
Dedham	2,398	9%	865	3%	3,263	13%
Gloucester	3,248	11%	0	0%	3,248	11%
Brockton	2,555	3%	659	1%	3,214	3%
Norton	3,189	16%	0	0%	3,189	16%
Northbridge	3,050	18%	0	0%	3,050	18%
Melrose	3,034	11%	0	0%	3,034	11%
Winthrop Town	2,977	16%	0	0%	2,977	16%
Salem	2,961	7%	0	0%	2,961	7%
Douglas	2,783	32%	0	0%	2,783	32%
Orleans	2,777	48%	0	0%	2,777	48%
Dudley	2,362	20%	0	0%	2,362	20%
Swampscott	2,169	15%	0	0%	2,169	15%
Oxford	2,148	15%	0	0%	2,148	15%

Populations Experiencing 3 or 4 Categories of Burdens by City/Town Sorted by 3+ Burdens [1]

	3 Burdens		4 Burdens		3+ Burdens	
	Population	%	Population	%	Population	%
Marlborough	2,142	5%	0	0%	2,142	5%
Wellesley	1,985	7%	0	0%	1,985	7%
Dracut	1,950	6%	0	0%	1,950	6%
Millville	1,938	60%	0	0%	1,938	60%
Holliston	1,915	13%	0	0%	1,915	13%
Sharon	1,872	10%	0	0%	1,872	10%
Needham	1,836	6%	0	0%	1,836	6%
Milton	1,826	7%	0	0%	1,826	7%
Wareham	1,768	8%	0	0%	1,768	8%
North Andover	1,573	5%	0	0%	1,573	5%
Oak Bluffs	1,524	33%	0	0%	1,524	33%
Dover	1,507	25%	0	0%	1,507	25%
Hampden	1,491	29%	0	0%	1,491	29%
Bellingham	1,458	9%	0	0%	1,458	9%
Auburn	1,426	9%	0	0%	1,426	9%
Uxbridge	1,301	9%	0	0%	1,301	9%
Braintree Town	1,218	3%	0	0%	1,218	3%
Monson	1,201	14%	0	0%	1,201	14%
Westport	1,164	7%	0	0%	1,164	7%
Holland	1,147	45%	0	0%	1,147	45%
Woburn	1,143	3%	0	0%	1,143	3%
Danvers	1,109	4%	0	0%	1,109	4%
Holyoke	1,077	3%	0	0%	1,077	3%
Chatham	1,017	17%	0	0%	1,017	17%
Foxborough	827	5%	0	0%	827	5%
Truro	794	63%	0	0%	794	63%
Nahant	490	14%	0	0%	490	14%
Millis	3	0.03%	0	0%	3	0.03%
Hopedale	3	0.05%	0	0%	3	0.05%
Medway	1	0.01%	0	0%	1	0.01%
Wayland	1	0.01%	0	0%	1	0.01%

[1] Categories are defined as block groups with high proportions of priority populations and are in the highest concentration or category of burden for any burden.

RHODE ISLAND

Populations Experiencing 3 or 4 Categories of Burdens by City/Town Sorted by 3+ Burdens [1]

	3 Burdens		4 Burdens		3+ Burdens	
	Population	%	Population	%	Population	%
Providence	40,884	23%	658	0%	41,542	23%
North Kingstown	15,400	59%	0	0%	15,400	59%
Pawtucket	13,513	19%	0	0%	13,513	19%
South Kingstown	10,360	34%	0	0%	10,360	34%
Westerly	7,921	35%	0	0%	7,921	35%
Narragansett	6,948	45%	0	0%	6,948	45%
Barrington	2,718	17%	2,833	18%	5,551	34%
Central Falls	5,054	26%	0	0%	5,054	26%
East Providence	4,847	10%	0	0%	4,847	10%
Warwick	3,897	5%	548	1%	4,445	5%
Cranston	3,455	4%	0	0%	3,455	4%
Hopkinton	2,785	34%	0	0%	2,785	34%
Jamestown	2,713	49%	0	0%	2,713	49%
East Greenwich	2,085	16%	0	0%	2,085	16%
Warren	831	8%	878	8%	1,709	16%
Charlestown	1,451	19%	0	0%	1,451	19%
North Providence	1,385	4%	0	0%	1,385	4%
Tiverton	1,304	8%	0	0%	1,304	8%
Exeter	1,010	15%	0	0%	1,010	15%
Woonsocket	857	2%	0	0%	857	2%
New Shoreham	8	1%	0	0%	8	1%
West Greenwich	2	0.03%	0	0%	2	0.03%
Richmond	2	0.03%	0	0%	2	0.03%

[1] Categories are defined as block groups with high proportions of priority populations and are in the highest concentration or category of burden for any burden.

VERMONT

Populations Experiencing 3 or 4 Categories of Burdens by City/Town Sorted by 3+ Burdens [1]

	3 Burdens		4 Burdens		3+ Burdens	
	Population	%	Population	%	Population	%
Burlington city	21,427	50%	4,961	12%	26,388	62%
South Burlington city	14,576	77%	42	0.22%	14,618	77%
Essex town	3,240	15%	6,519	31%	9,760	46%
Colchester town	8,919	51%	19	0.11%	8,938	51%
Rutland city	8,374	54%	0	0%	8,374	54%
Bennington town	5,885	39%	1,454	10%	7,339	48%
Brattleboro town	6,258	54%	0	0%	6,258	54%
Hartford town	5,224	54%	602	6%	5,826	60%
Winooski city	5,566	77%	0	0%	5,566	77%
Swanton town	5,505	84%	0	0%	5,505	84%
Shelburne town	5,150	67%	0	0%	5,150	67%
Williston town	4,720	50%	12	0.13%	4,732	50%
Shaftsbury town	1,386	40%	2,085	60%	3,471	100%
Barre city	3,420	39%	0	0%	3,420	39%
Poultney town	3,327	100%	0	0%	3,327	100%
Barre town	2,752	36%	0	0%	2,752	36%
Arlington town	0	0%	2,558	100%	2,559	100%
Pownal town	2,337	68%	0	0%	2,338	68%
St. Albans city	2,325	34%	0	0%	2,325	34%
Springfield town	2,151	24%	0	0%	2,151	24%
Westminster town	2,127	70%	0	0%	2,127	70%
Wallingford town	2,093	100%	0	0%	2,093	100%
Weathersfield town	1,936	70%	0	0%	1,936	70%
Dorset town	1,913	100%	0	0%	1,913	100%
Manchester town	1,850	43%	0	0%	1,850	43%
Newfane town	1,802	100%	0	0%	1,802	100%
Whitingham town	1,622	100%	0	0%	1,622	100%
Highgate town	1,616	44%	0	0%	1,616	44%
Londonderry town	1,598	100%	0	0%	1,598	100%
Wilmington town	1,516	100%	0	0%	1,516	100%
Ferrisburgh town	1,457	53%	0	0%	1,457	53%
Danby town	1,300	100%	0	0%	1,300	100%
Pawlet town	1,283	100%	0	0%	1,283	100%
Mount Holly town	1,167	100%	0	0%	1,167	100%
West Rutland town	1,095	46%	0	0%	1,095	46%
South Hero town	1,028	62%	0	0%	1,028	62%
Townshend town	1,015	100%	0	0%	1,015	100%
Alburgh town	1,013	59%	0	0%	1,013	59%
Dummerston town	946	49%	0	0%	946	49%
Guilford town	937	47%	0	0%	937	47%

Populations Experiencing 3 or 4 Categories of Burdens by City/Town Sorted by 3+ Burdens [1]

	3 Burdens		4 Burdens		3+ Burdens	
	Population	%	Population	%	Population	%
Putney town	888	34%	0	0%	888	34%
Rockingham town	875	17%	0	0%	875	17%
Readsboro town	683	100%	0	0%	683	100%
Halifax town	643	100%	0	0%	643	100%
Tinmouth town	637	100%	0	0%	637	100%
Grafton town	634	95%	0	0%	634	95%
Winhall town	602	100%	0	0%	602	100%
Cavendish town	595	44%	0	0%	595	44%
Hubbardton town	0	0%	567	100%	567	100%
Rupert town	560	78%	0	0%	560	78%
Isle La Motte town	441	100%	0	0%	441	100%
Jamaica town	434	51%	0	0%	434	51%
Windham town	401	100%	0	0%	401	100%
Sandgate town	369	100%	0	0%	369	100%
Wardsboro town	336	47%	0	0%	336	47%
Peru town	324	100%	0	0%	324	100%
Mount Tabor town	240	100%	0	0%	240	100%
Baltimore town	213	78%	0	0%	213	78%
Dover town	185	15%	0	0%	185	15%
Woodford town	164	57%	0	0%	164	57%
Landgrove town	87	78%	0	0%	87	78%
Searsburg town	74	72%	0	0%	74	72%
Rutland town	12	0.30%	0	0%	12	0.30%
St. Albans town	12	0.18%	0	0%	12	0.18%
Glastenbury town	3	100%	0	0%	3	100%
Vernon town	3	0.11%	0	0%	3	0.11%
Chester town	2	0.06%	0	0%	2	0.06%
Marlboro town	2	0.14%	0	0%	2	0.14%
Ludlow town	1	0.06%	0	0%	1	0.06%
Wells town	1	0.11%	0	0%	1	0.11%
East Montpelier town	1	0.04%	0	0%	1	0.04%
Grand Isle town	1	0.05%	0	0%	1	0.05%
Brookline town	1	0.16%	0	0%	1	0.16%
Fair Haven town	1	0.04%	0	0%	1	0.04%

[1] Categories are defined as block groups with high proportions of priority populations and are in the highest concentration or category of burden for any burden.

NEW HAMPSHIRE

Populations Experiencing 3 or 4 Categories of Burdens by City/Town Sorted by 3+ Burdens [1]

	3 Burdens		4 Burdens		3+ Burdens	
	Population	%	Population	%	Population	%
Nashua city	51,704	58%	6,528	7%	58,232	66%
Manchester city	31,940	29%	5,769	5%	37,709	34%
Salem town	7,257	25%	18,293	63%	25,550	88%
Windham town	13,590	94%	14	0.10%	13,604	94%
Milford town	13,385	86%	0	0%	13,385	86%
Hudson town	11,948	47%	12	0.05%	11,960	47%
Londonderry town	11,329	44%	1	0.00%	11,330	44%
Derry town	6,059	18%	5,173	15%	11,232	34%
Portsmouth city	10,830	50%	0	0%	10,830	50%
Concord city	6,809	16%	0	0%	6,809	16%
Merrimack town	6,600	26%	0	0%	6,600	26%
Pelham town	4,928	36%	845	6%	5,773	42%
Laconia city	5,618	34%	0	0%	5,618	34%
Hampton town	3,649	24%	1,786	12%	5,436	35%
Rochester city	5,377	18%	0	0%	5,377	18%
Brookline town	5,292	100%	0	0%	5,292	100%
New Ipswich town	5,283	100%	0	0%	5,283	100%
Seabrook town	798	9%	4,264	48%	5,061	57%
Bedford town	4,948	22%	4	0.02%	4,952	22%
Exeter town	3,976	27%	0	0%	3,976	27%
Wolfeboro town	2,955	47%	0	0%	2,955	47%
Hollis town	2,424	31%	0	0%	2,424	31%
North Hampton town	2,078	47%	0	0%	2,078	47%
Moultonborough town	2,073	51%	0	0%	2,073	51%
Greenville town	2,046	100%	0	0%	2,046	100%
Stratham town	2,042	28%	0	0%	2,042	28%
Rye town	878	16%	1,130	21%	2,008	37%
Greenland town	1,715	43%	0	0%	1,715	43%
Litchfield town	1,670	20%	0	0%	1,671	20%
Mason town	1,541	100%	0	0%	1,541	100%
Rindge town	1,498	25%	0	0%	1,498	25%
Plaistow town	0	0%	1,485	19%	1,485	19%
Meredith town	1,413	22%	0	0%	1,413	22%
Dover city	1,408	4%	0	0%	1,408	4%
Atkinson town	1	0.02%	1,362	20%	1,363	20%
Keene city	1,233	5%	0	0%	1,233	5%
Alton town	1,169	22%	0	0%	1,169	22%
Hampstead town	1,093	13%	0	0%	1,093	13%
Kingston town	1,083	17%	0	0%	1,083	17%

Populations Experiencing 3 or 4 Categories of Burdens by City/Town Sorted by 3+ Burdens [1]

	3 Burdens		4 Burdens		3+ Burdens	
	Population	%	Population	%	Population	%
Tuftonboro town	223	10%	0	0%	223	10%
Hampton Falls town	3	0.13%	32	1%	35	2%
Pembroke town	19	0.27%	0	0%	19	0.27%
Amherst town	12	0.11%	0	0%	12	0.11%
Gilford town	5	0.07%	0	0%	5	0.07%
Center Harbor town	5	0.49%	0	0%	5	0.49%
Newington town	2	0.28%	0	0%	2	0.28%
Lyndeborough town	2	0.11%	0	0%	2	0.11%
Goffstown town	0	0.00%	2	0.01%	2	0.01%
Hooksett town	2	0.01%	0	0%	2	0.01%
Temple town	2	0.12%	0	0%	2	0.12%
Auburn town	1	0.03%	0	0%	1	0.03%
Sharon town	1	0.29%	0	0%	1	0.29%
Gilmanton town	1	0.03%	0	0%	1	0.03%
Wilton town	1	0.02%	0	0%	1	0.02%
Belmont town	1	0.01%	0	0%	1	0.01%
Sandwich town	1	0.04%	0	0%	1	0.04%

[1] Categories are defined as block groups with high proportions of priority populations and are in the highest concentration or category of burden for any burden.

MAINE

Populations Experiencing 3 or 4 Categories of Burdens by City/Town Sorted by 3+ Burdens [1]

	3 Burdens		4 Burdens		3+ Burdens	
	Population	%	Population	%	Population	%
Portland city	26,753	40%	531	1%	27,284	41%
Biddeford city	9,692	45%	8,028	37%	17,720	83%
Saco city	5,421	28%	8,859	46%	14,280	74%
South Portland city	10,394	41%	2,731	11%	13,125	51%
Lewiston city	12,995	36%	2	0.01%	12,998	36%
Scarborough town	9,223	46%	3,132	16%	12,355	62%
Bangor city	12,350	38%	0	0%	12,350	38%
Auburn city	10,485	45%	1,077	5%	11,562	50%
Waterville city	8,373	51%	2,339	14%	10,712	65%
Augusta city	8,952	48%	0	0%	8,952	48%
Kittery town	2,817	29%	5,050	52%	7,868	81%
South Berwick town	2,637	36%	4,713	64%	7,350	99%
Old Orchard Beach town	2,037	23%	4,196	48%	6,233	71%
Falmouth town	6,099	51%	0	0%	6,099	51%
Westbrook city	5,514	30%	0	0%	5,514	30%
Rockland city	5,504	77%	0	0%	5,504	77%
Brewer city	5,379	59%	0	0%	5,379	59%
Eliot town	0	0%	5,187	80%	5,187	80%
Camden town	2,137	44%	2,696	56%	4,832	100%
Winslow town	4,776	63%	0	0%	4,776	63%
York town	2,211	17%	2,474	19%	4,684	36%
Cape Elizabeth town	4,621	50%	18	0.20%	4,639	50%
Brunswick town	4,617	22%	0	0%	4,618	22%
Sidney town	2,694	62%	1,627	38%	4,322	100%
Vassalboro town	4,321	100%	0	0%	4,321	100%
Harpswell town	0	0%	3,715	76%	3,715	76%
Skowhegan town	3,389	41%	0	0%	3,389	41%
Clinton town	3,353	100%	0	0%	3,353	100%
Oakland town	1,816	29%	1,340	21%	3,156	50%
Warren town	2,801	59%	0	0%	2,801	59%
Bristol town	2,734	100%	0	0%	2,734	100%
St. George town	2,587	100%	0	0%	2,587	100%
Unity town	2,284	100%	0	0%	2,284	100%
Fairfield town	2,218	34%	0	0%	2,218	34%
West Bath town	1,270	58%	906	42%	2,176	100%
Phippsburg town	0	0%	2,130	100%	2,130	100%
Mexico town	1,418	54%	686	26%	2,104	80%
Deer Isle town	2,025	100%	0	0%	2,025	100%

Populations Experiencing 3 or 4 Categories of Burdens by City/Town Sorted by 3+ Burdens [1]

	3 Burdens		4 Burdens		3+ Burdens	
	Population	%	Population	%	Population	%
Belgrade town	2,006	64%	2	0.07%	2,008	64%
Boothbay Harbor town	420	21%	1,588	79%	2,008	100%
Naples town	1,987	50%	0	0%	1,987	50%
Alfred town	1,958	63%	0	0%	1,958	63%
Dresden town	1,890	100%	0	0%	1,890	100%
Boothbay town	1,280	41%	582	19%	1,862	60%
Winthrop town	1,847	31%	0	0%	1,847	31%
Bar Harbor town	838	15%	1,007	19%	1,846	34%
Woolwich town	0	0%	1,740	56%	1,741	56%
Poland town	1,676	30%	0	0%	1,676	30%
Gouldsboro town	1,643	100%	0	0%	1,643	100%
Farmingdale town	1,634	56%	0	0%	1,634	56%
West Gardiner town	0	0%	1,540	46%	1,541	46%
Thomaston town	1,518	55%	0	0%	1,518	55%
Orono town	1,444	13%	0	0%	1,444	13%
Winterport town	1,425	37%	0	0%	1,425	37%
Wells town	1,383	14%	0	0%	1,383	14%
Windham town	1,330	7%	0	0%	1,330	7%
Gardiner city	1,308	23%	0	0%	1,308	23%
Topsham town	1,284	15%	0	0%	1,284	15%
Lyman town	1,185	27%	0	0%	1,185	27%
Kennebunk town	4	0.04%	1,179	10%	1,184	10%
Litchfield town	1,116	31%	0	0%	1,116	31%
Lincolnville town	1,087	58%	0	0%	1,087	58%
Stonington town	1,074	100%	0	0%	1,074	100%
Burnham town	1,062	100%	0	0%	1,062	100%
Vinalhaven town	1,061	98%	0	0%	1,061	98%
Manchester town	1,050	41%	0	0%	1,050	41%
Troy town	1,023	100%	0	0%	1,023	100%
Yarmouth town	1,011	12%	0	0%	1,011	12%
Belfast city	977	15%	0	0%	977	15%
Union town	932	34%	0	0%	932	34%
Hallowell city	930	37%	0	0%	930	37%
South Bristol town	913	100%	0	0%	914	100%
Brooksville town	895	100%	0	0%	895	100%
Nobleboro town	891	54%	0	0%	891	54%
Detroit town	869	100%	0	0%	869	100%
Owls Head town	866	56%	0	0%	866	56%
Mount Desert town	784	46%	1	0.08%	785	46%
Islesboro town	734	100%	0	0%	734	100%

Populations Experiencing 3 or 4 Categories of Burdens by City/Town Sorted by 3+ Burdens [1]

	3 Burdens		4 Burdens		3+ Burdens	
	Population	%	Population	%	Population	%
Pittsfield town	728	18%	0	0%	728	18%
Brooklin town	713	100%	0	0%	713	100%
Otisfield town	676	31%	0	0%	676	31%
Paris town	600	12%	0	0%	600	12%
Southport town	587	100%	0	0%	587	100%
Oxford town	535	13%	0	0%	535	13%
Friendship town	514	52%	0	0%	514	52%
Ogunquit town	430	38%	0	0%	430	38%
Roxbury town	273	100%	0	0%	273	100%
Byron town	101	100%	0	0%	101	100%
Berwick town	0	0%	38	0.50%	38	0%
Monhegan plantation	0	0%	0	0%	38	100%
Matinicus Isle plantation	14	15%	0	0%	14	15%
Rumford town	0	0%	13	0.23%	14	0%
Benton town	11	0.27%	0	0%	11	0%
Arundel town	0	0.06%	9	0.20%	9	0%
Muscle Ridge Islands UT	8	1%	0	0%	8	100%
Veazie town	6	0.03%	0	0%	6	0%
Cumberland town	5	0.20%	0	0%	5	0%
Thorndike town	5	0.08%	0	0%	5	1%
Bath city	2	0.01%	2	0.02%	4	0%
South Thomaston town	3	0.12%	0	0%	3	0%
Rockport town	3	0.09%	0	0%	3	0%
Sanford city	3	0.07%	0	0%	3	0%
Randolph town	2	0.05%	0	0%	2	0%
Chelsea town	2	0.08%	0	0%	2	0%
Mechanic Falls	2	0.12%	0	0%	2	0%
Casco town	2	0.04%	0	0%	2	0%
Canaan town	2	0.20%	0	0%	2	0%
Cushing town	2	0.06%	0	0%	2	0%
Norway town	2	0.07%	0	0%	2	0%
Freedom town	2	0.04%	0	0%	2	0%
Pittston town	2	0.01%	0	0%	2	0%
Dixfield town	1	0.27%	0	0%	1	0%
Jefferson town	1	0.06%	0	0%	1	0%
Hampden town	1	1%	0	0%	1	0%

[1] Categories are defined as block groups with high proportions of priority populations and are in the highest concentration or category of burden for any burden.