Extreme Heat in Georgia: Local Impact Research and Resolutions

May 6, 2022

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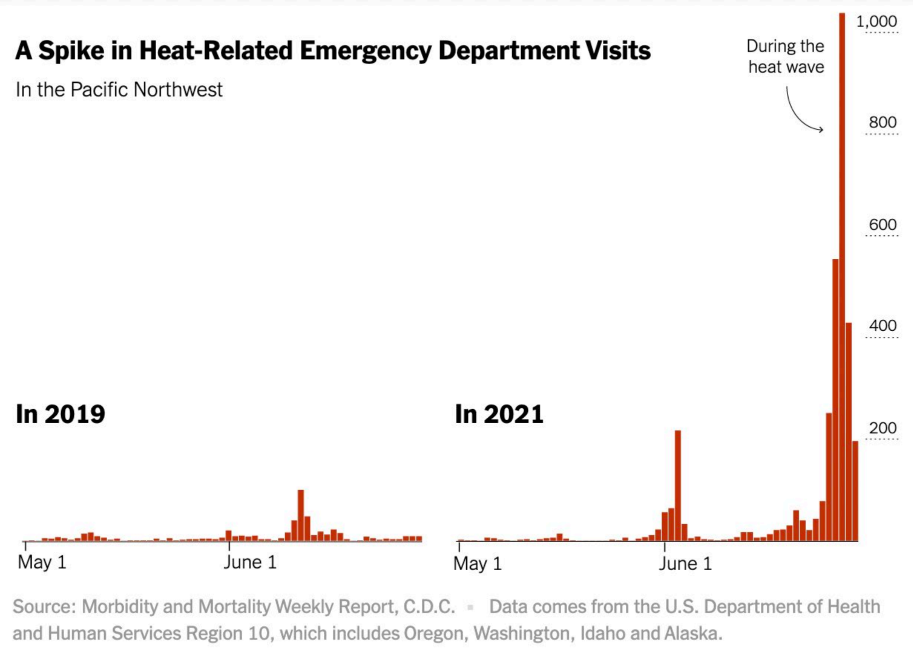
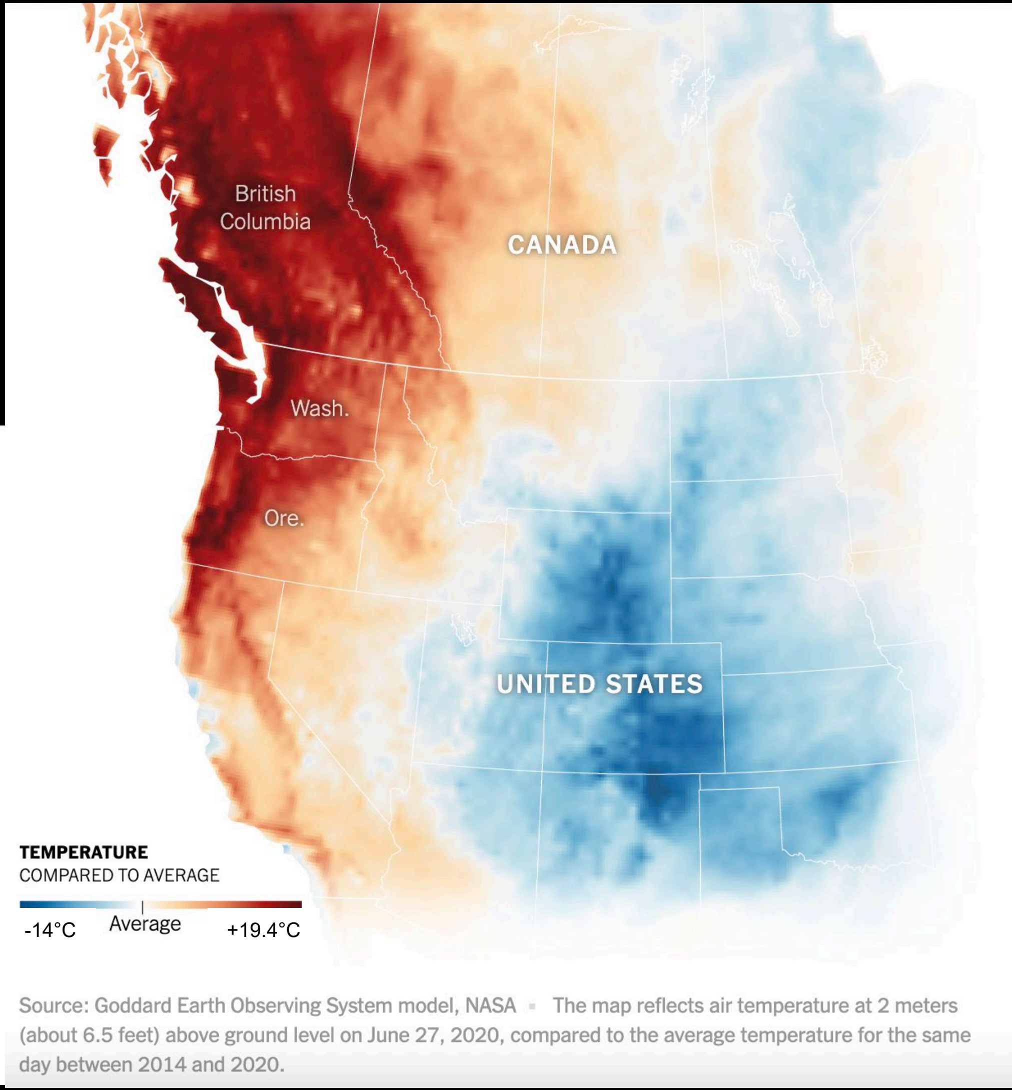
College of Design

Northwestern US Heat Wave, June 2021

2,779 heat-related emergency department visits in 6 days





Pacific Northwest at 116°F

The intense Portland heat has caused streets and sidewalks to buckle. (AccuWeather/Bill Wadell)

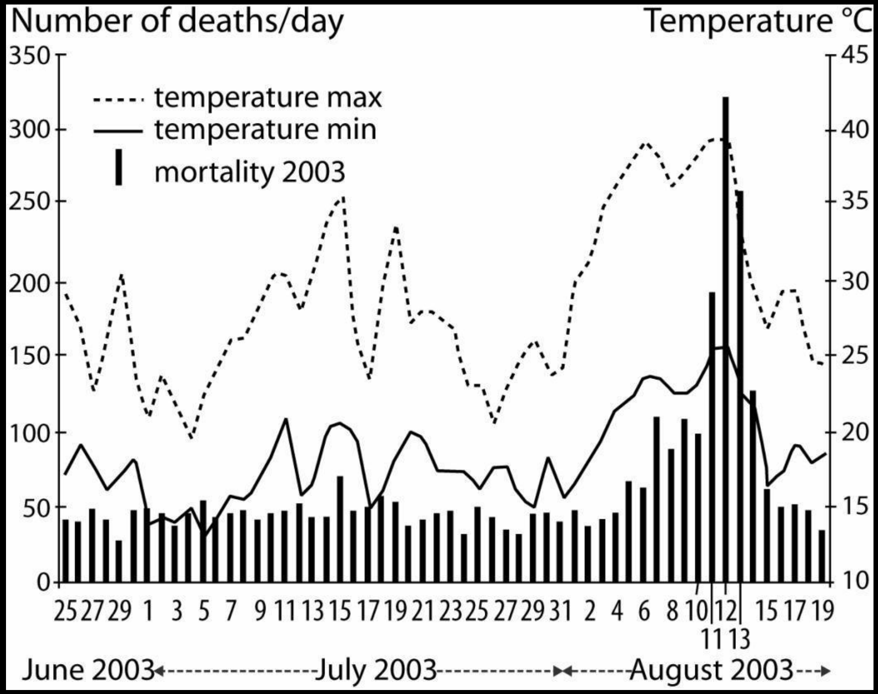
Portland Streetcar
@PDXStreetcar

In case you're wondering why we're canceling service for the day, here's what the heat is doing to our power cables.

7:07 PM · Jun 27, 2021 · Hootsuite Inc.

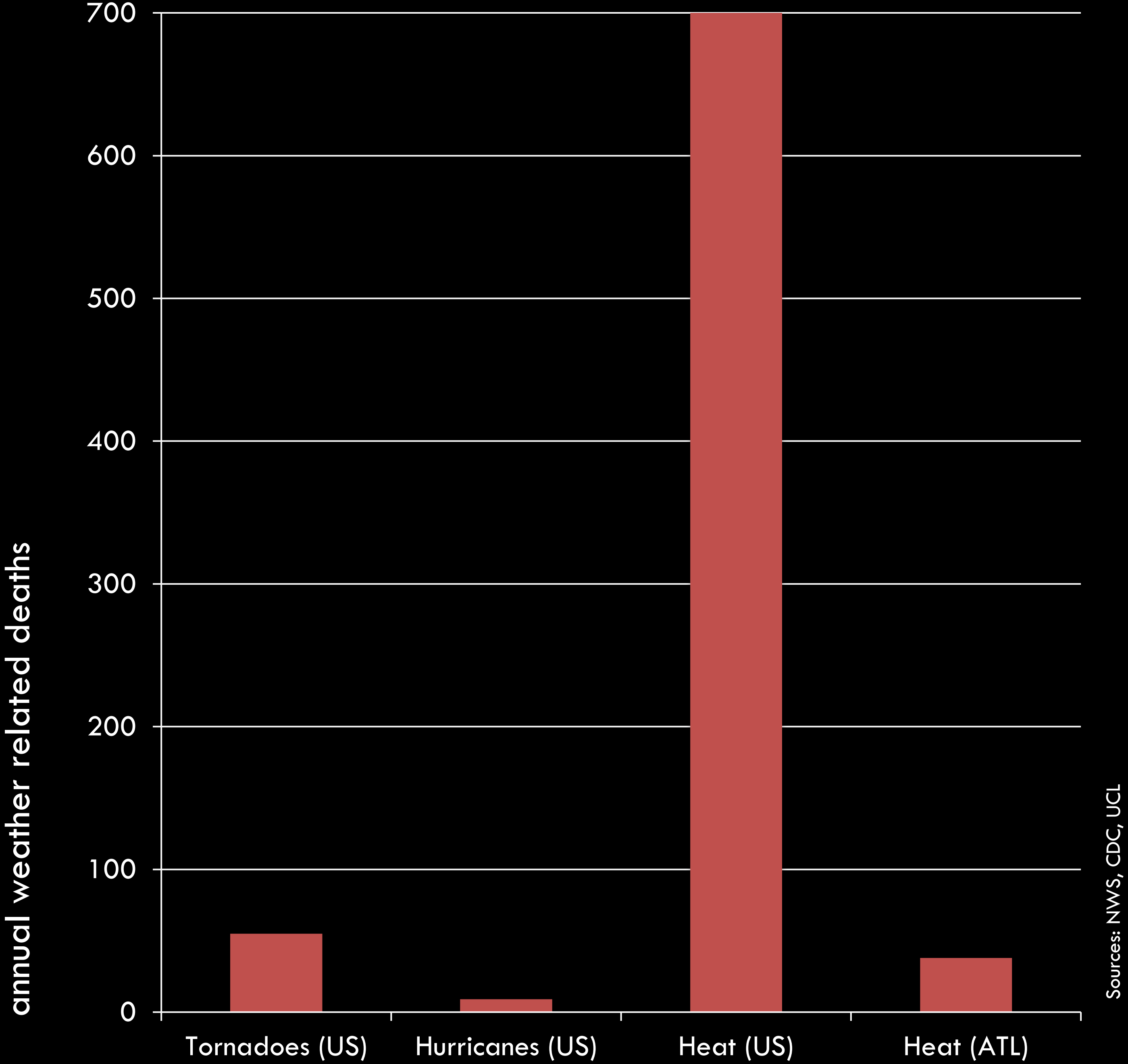
Heat & Health

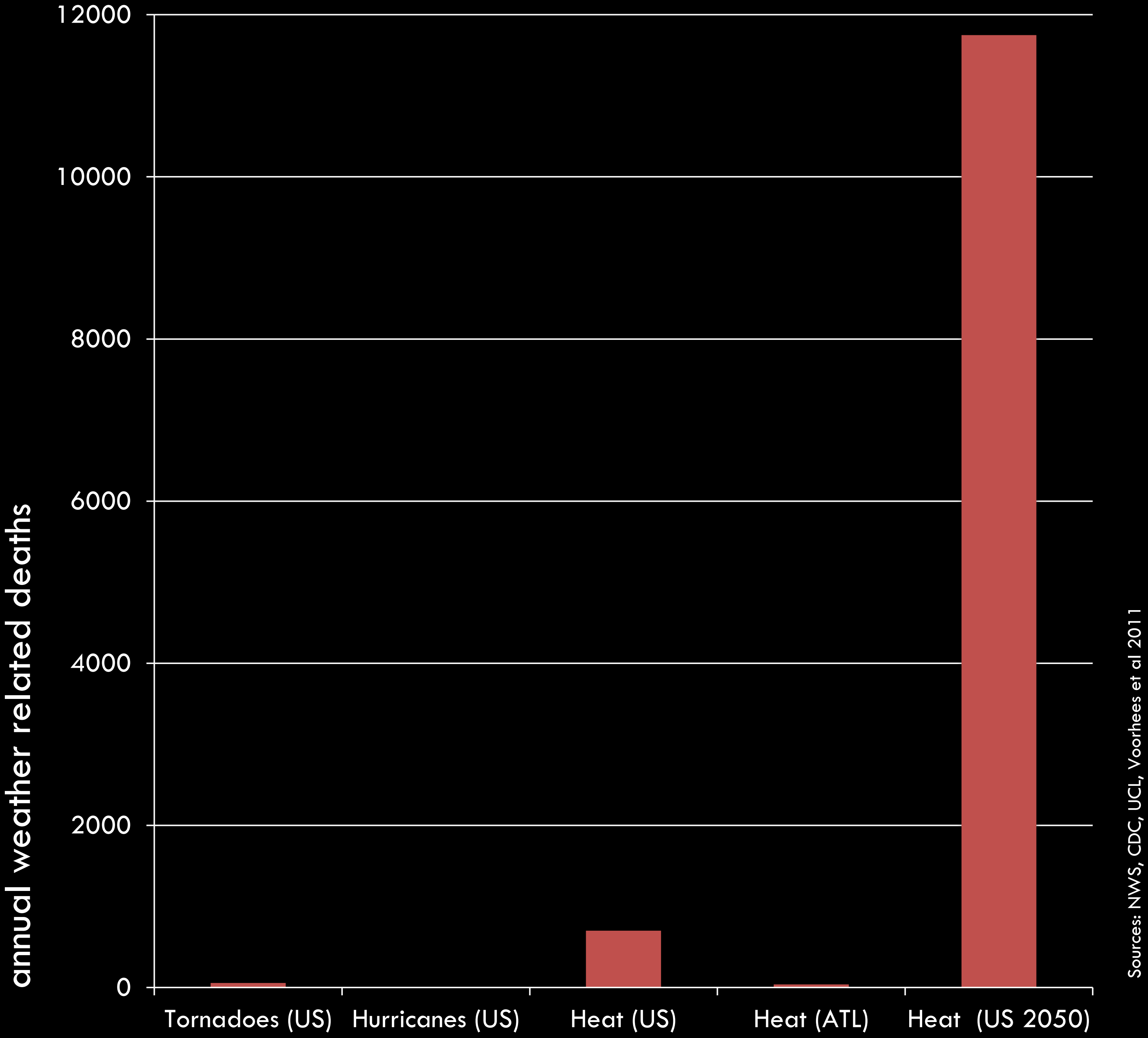
- Exposure to high temperatures can cause[1,2,3]
  - Heat stroke
  - Heat exhaustion
  - Heat syncope
  - Heat cramps
  - Death
- Annual US heat-related mortality may increase by up to 34,000[4]



Dousset et al. (2010)

[1]Bouchma et al. (2002); [2]Kovats et al. (2008); [3]Luber et al. (2008); [4]Voorhees et al. (2011)


700
600
500
400
300
200
100
0
annual weather related deaths
Tornadoes (US)
Hurricanes (US)
Heat (US)
Heat (ATL)
Sources: NWS, CDC, UCL



annual weather related deaths
12000
10000
8000
6000
4000
2000
0
Tornadoes (US)
Hurricanes (US)
Heat (US)
Heat (ATL)
Heat (US 2050)
Sources: NWS, CDC, UCL, Voorhees et al 2011

The Washington Post
Democracy Dies in Darkness

Humidity and heat extremes are on the verge of exceeding limits of human survivability, study finds

Humans cannot survive prolonged exposure to certain combinations of heat and humidity

By **Andrew Freedman** and **Jason Samenow**

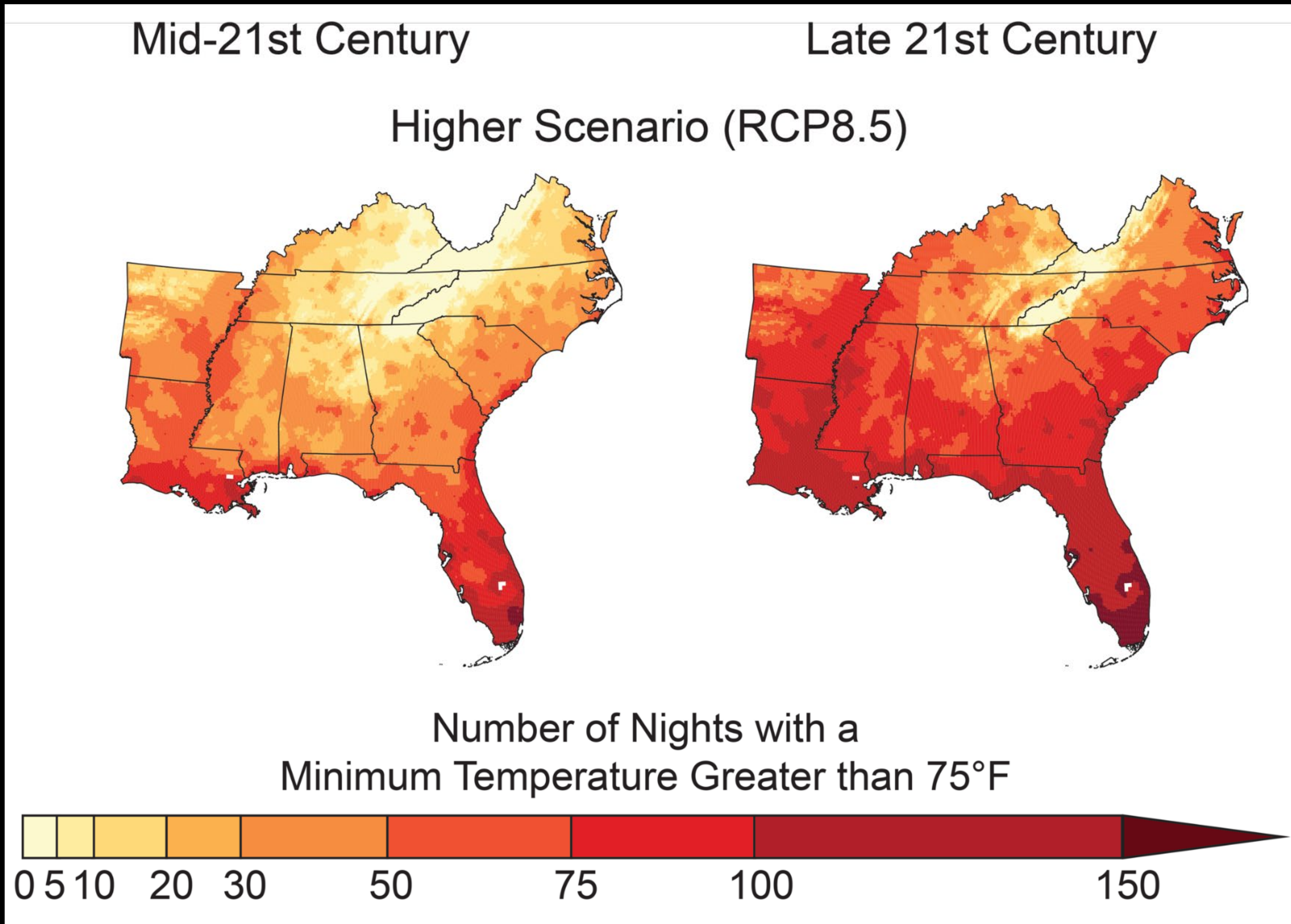
May 8, 2020 at 4:21 p.m. EDT

The New York Times

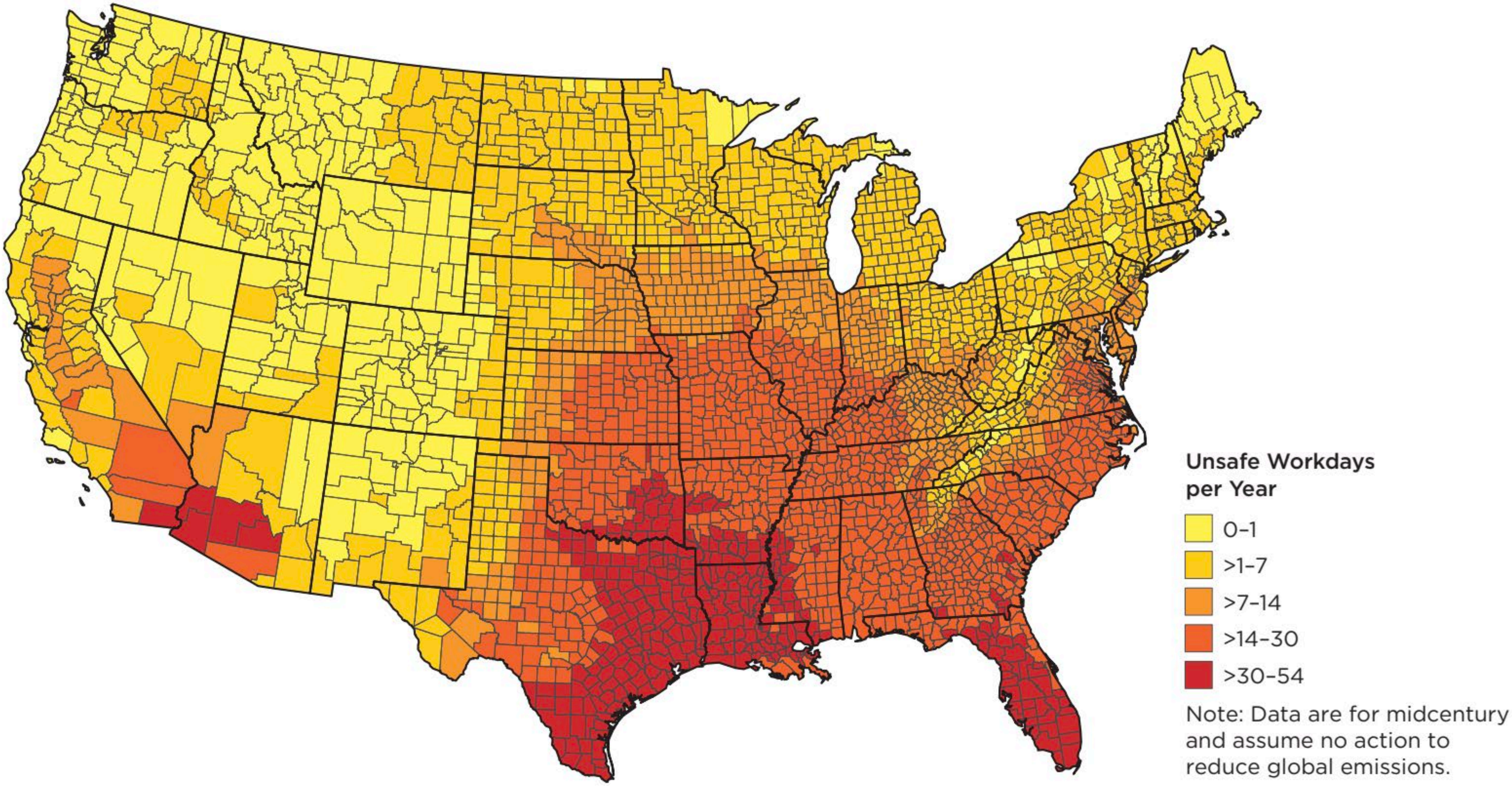
As Phoenix Heats Up, the Night Comes Alive

That will be true for many more cities as the world gets hotter.

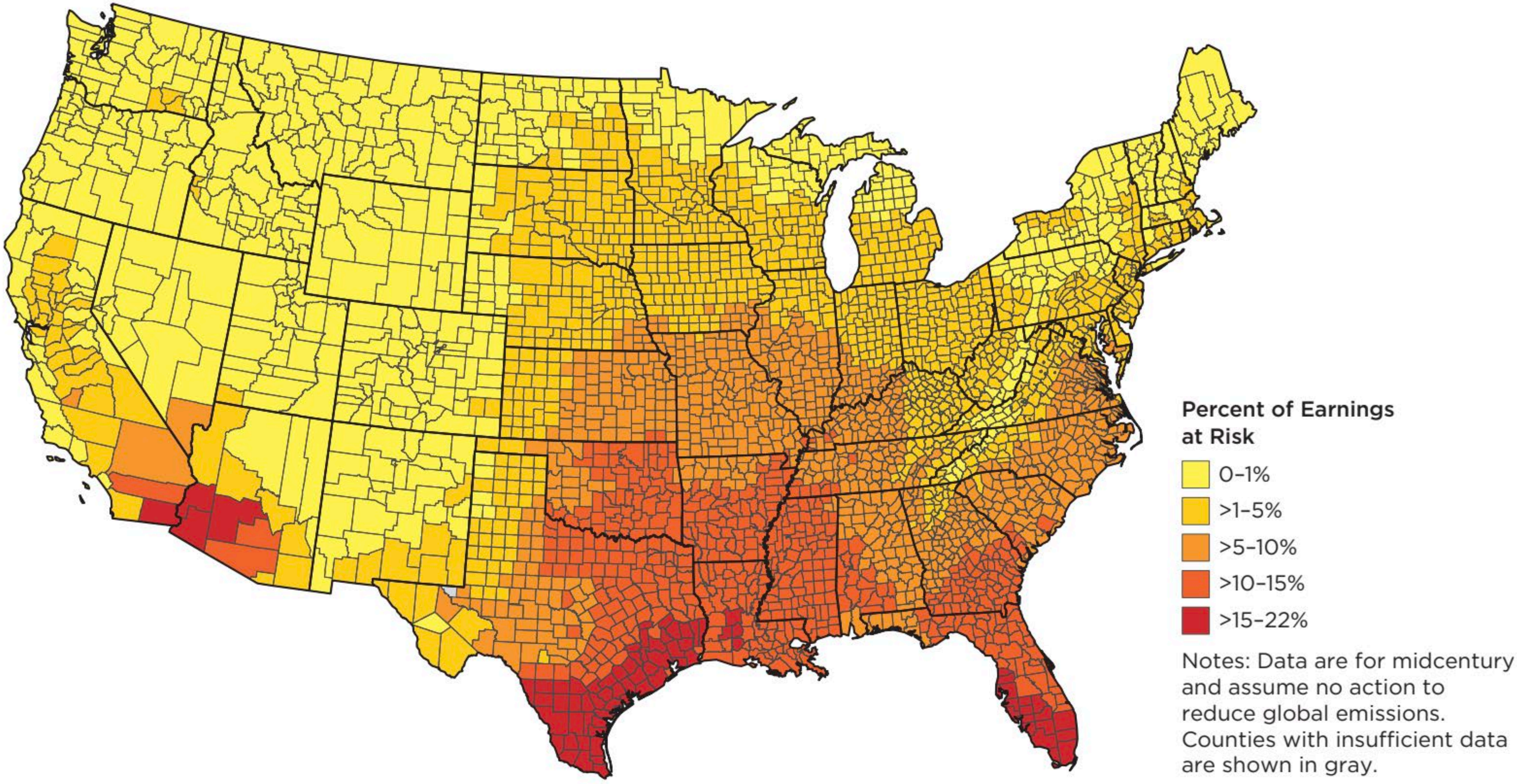
Photographs by George Etheredge | Written by Marguerite Holloway



Fourth National Climate Assessment


Unsafe Workdays per Year
0–1
>1–7
>7–14
>14–30
>30–54
Note: Data are for midcentury and assume no action to reduce global emissions.

UCSUSA, 2021



Percent of Earnings at Risk
0–1%
>1–5%
>5–10%
>10–15%
>15–22%
Notes: Data are for midcentury and assume no action to reduce global emissions. Counties with insufficient data are shown in gray.

UCSUSA, 2021

Extreme Heat Could Threaten $2.1 Billion Annually in Georgia Outdoor Worker Earnings by Midcentury

Nation, Georgia Lack Mandatory Standards to Keep Workers Safe as US Extreme Heat Days Set to Quadruple

Published Aug 15, 2021

UCSUSA, 2021

drivers of extreme heat in cities

global greenhouse effect + urban heat island effect

drivers of extreme heat in cities

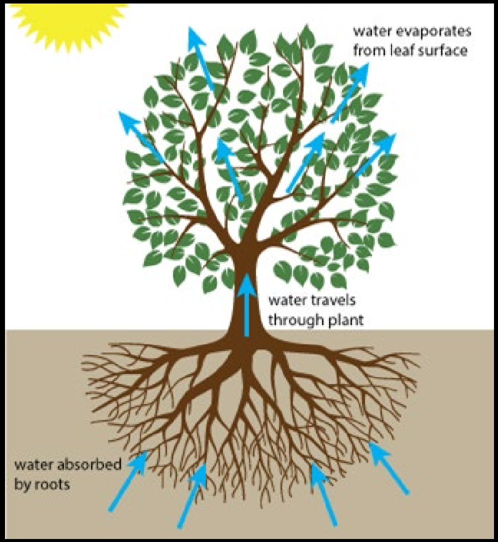
global greenhouse effect + urban heat island effect

Shading:
Surface Temperature

Goodspeed (2015)

20 - 45 °F cooler than unshaded

Evapotranspiration:
Air Temperature



woodlandtree.com

2 - 9 °F cooler than unvegetated

Bowler et al., 2012; Yuan et al., 2007


x 34.5 °C (94°F)
x 61.0 °C (142°F)
e2designlab
61.0 °C
60.0
55.0
50.0
45.0
40.0
35.0
30.0
25.0
25.0 °C

drivers of extreme heat in cities

global greenhouse effect + urban heat island effect

albedo and surface heat absorption

drivers of extreme heat in cities

global greenhouse effect + urban heat island effect

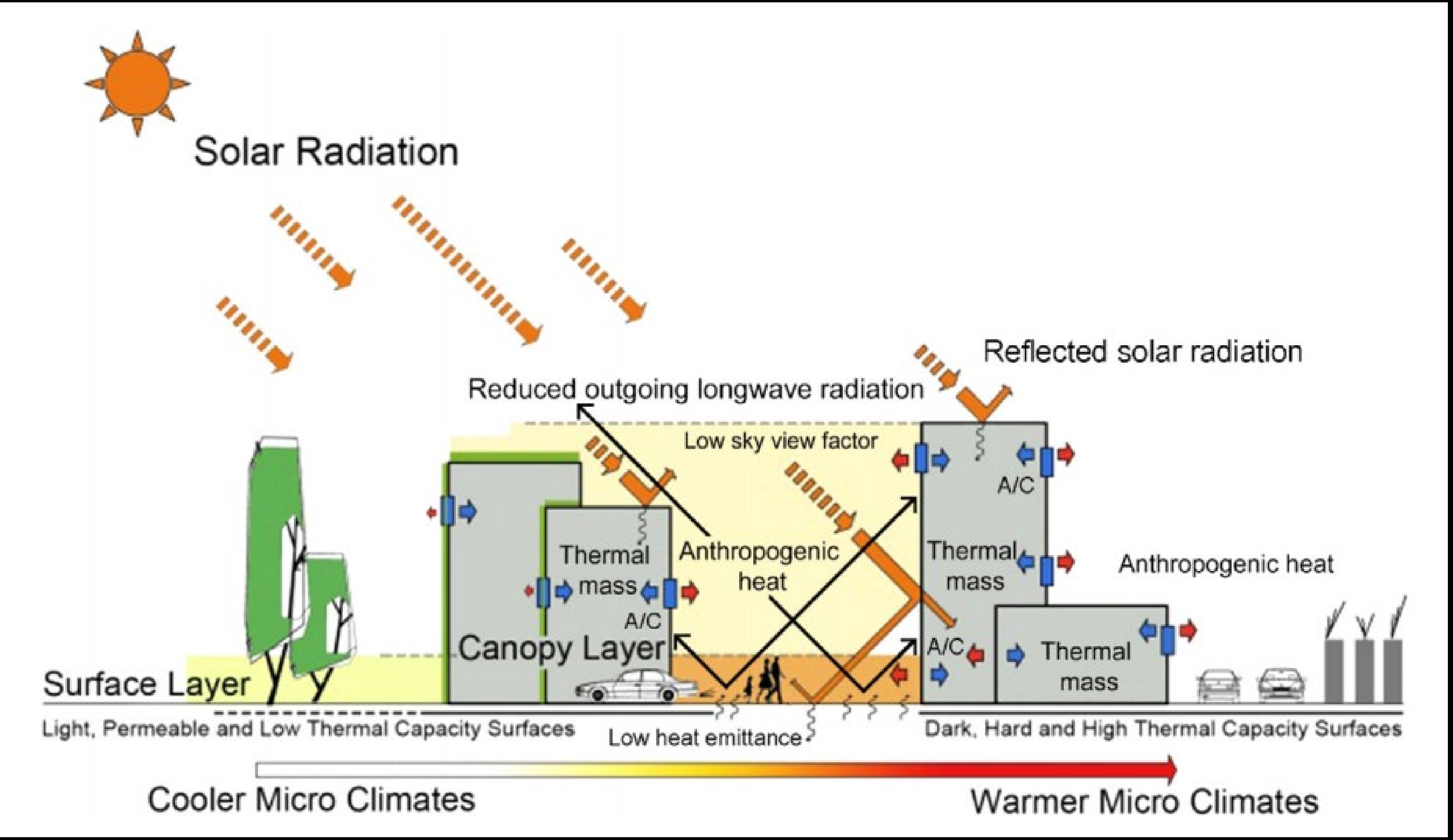
anthropogenic heat

Atlanta Journal Constitution

drivers of extreme heat in cities

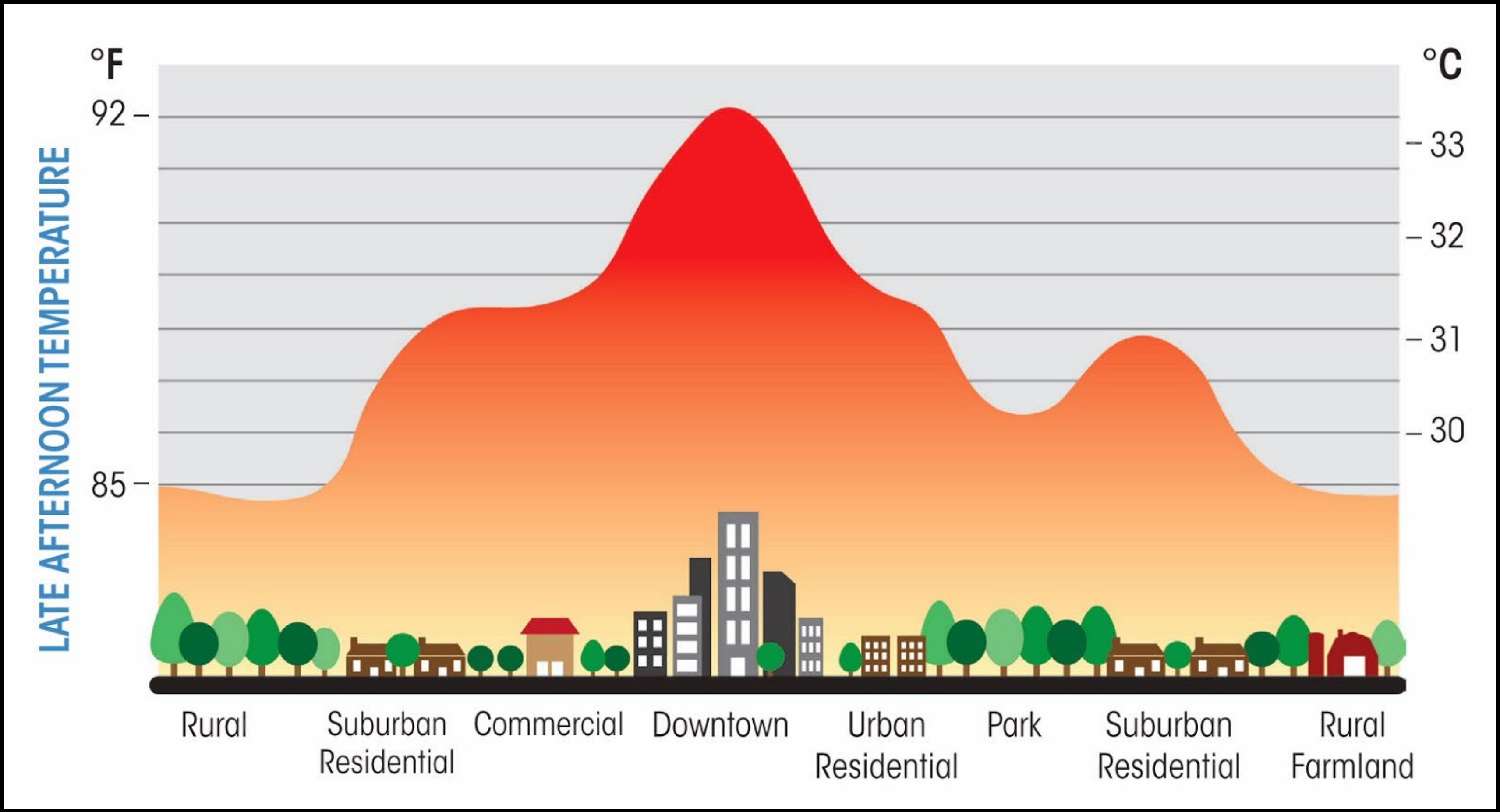
global greenhouse effect + urban heat island effect

urban canyon

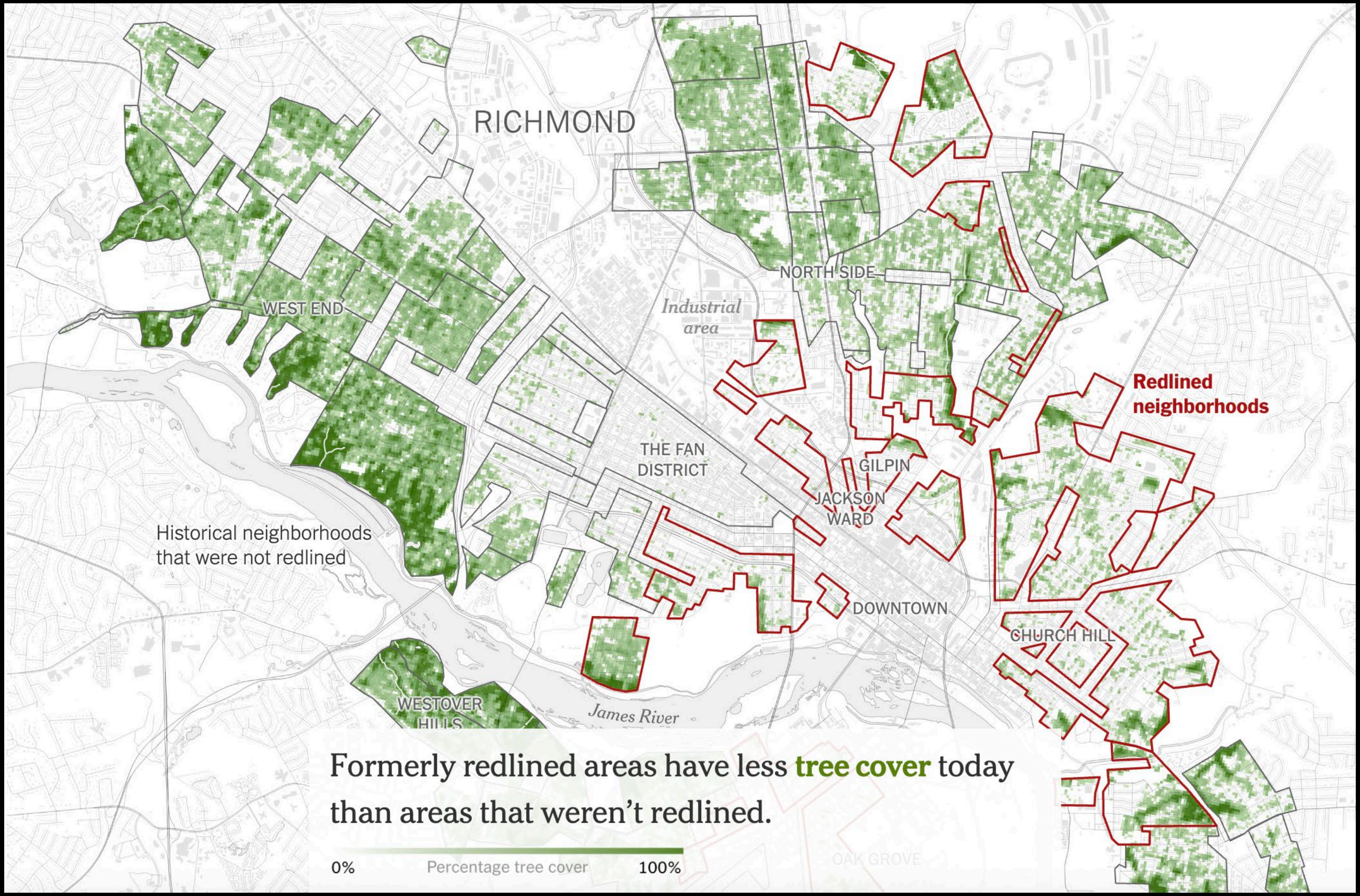


Soltani & Sharifi, 2017

The Urban Heat Island Effect

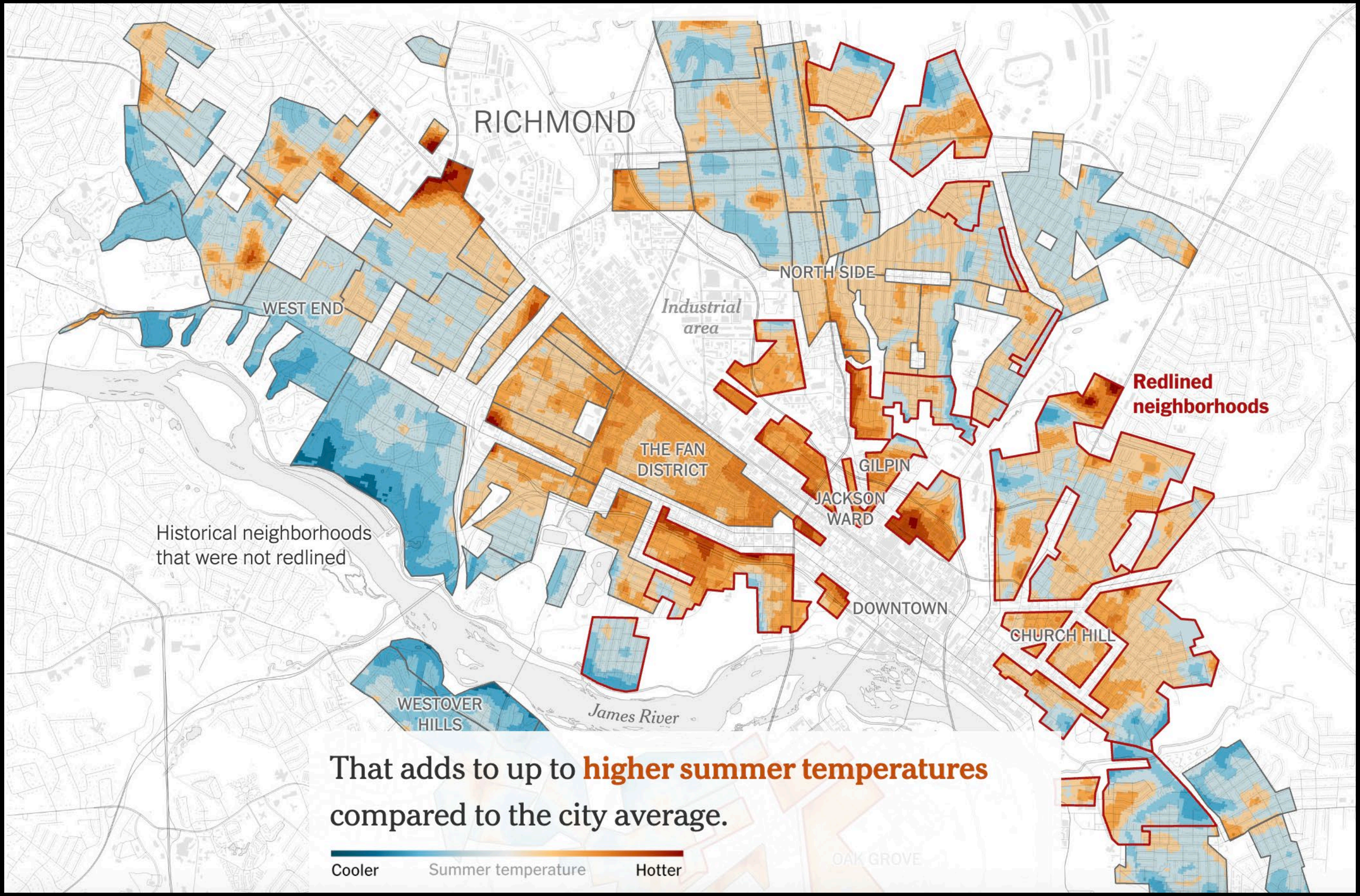


Tunza Eco Generation



Hoffman et al., 2020, New York Times

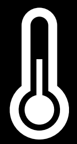
Hoffman et al., 2020, New York Times



Hoffman et al., 2020, New York Times

Defining Vulnerability

Exposure + Sensitivity ± Adaptive Capacity = Vulnerability

Common Vulnerability Indicators

Exposure + **Sensitivity** ± **Adaptive Capacity** = **Vulnerability**

Exposure	Sensitivity	Adaptive Capacity
Hot/heatwave days	Old age	AC access
Consecutive hot days	Infants, young age	Rental / homeowner
Min/Mean/Max temp.	Sex	Unhoused
Land surface temp.	Pre-existing illness	Education
Vegetation	-Diabetes	Ethnicity
Urban density	-Cardiovascular	Language
Land cover	-Renal	Foreign-born
Land use		Cognitive impairment
Population density		Cooling / community center
		Living alone
		Working outdoors

Targeting Interventions

Sensitivity / Adaptive Capacity

- Shorter-term, emergency response
- Community-based adaptations
- Cooling centers, phone trees

Exposure

- Longer-term, heat mitigation response
- Tree-planting priority
- Cool materials

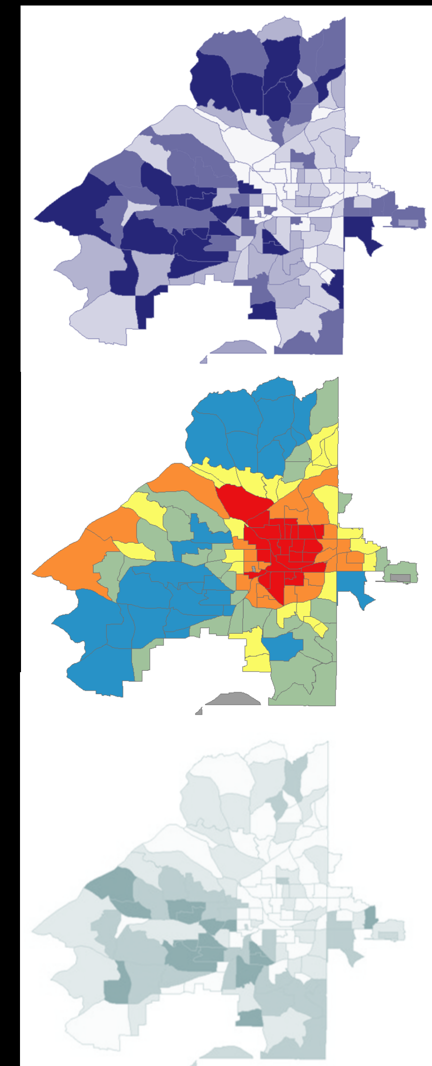
Vulnerability

- All-of-the-above response
- Highest priority, pilot projects here
- Identify local stakeholders / champions

Sensitivity

Exposure

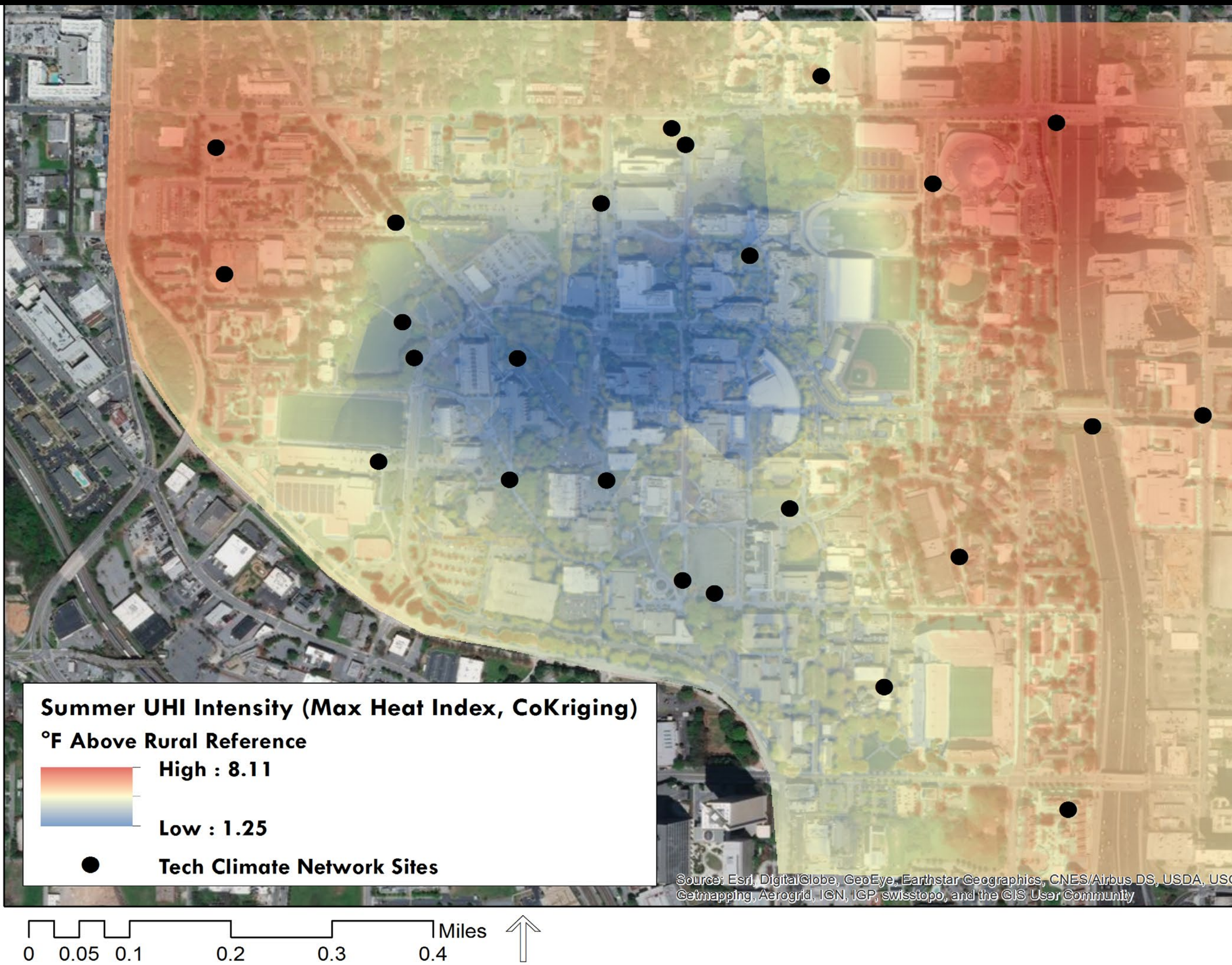
Vulnerability

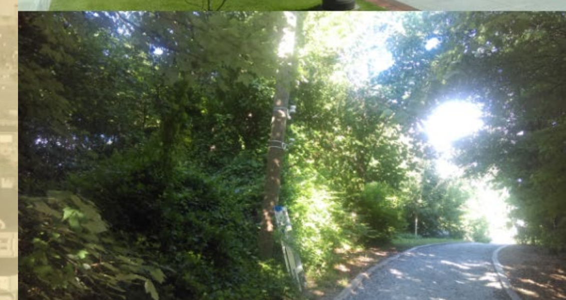


Longitudinal Heat Monitoring: the Georgia Tech Climate Network

- Goal
  - Analyze thermal environments of Georgia Tech's microclimates related to the Urban Heat Island
  - Inform planning and design decisions to enhance thermal comfort for pedestrians

- 44 total sites
  - 33 across campus microclimates
  - 12 deployed in Atlanta metro area





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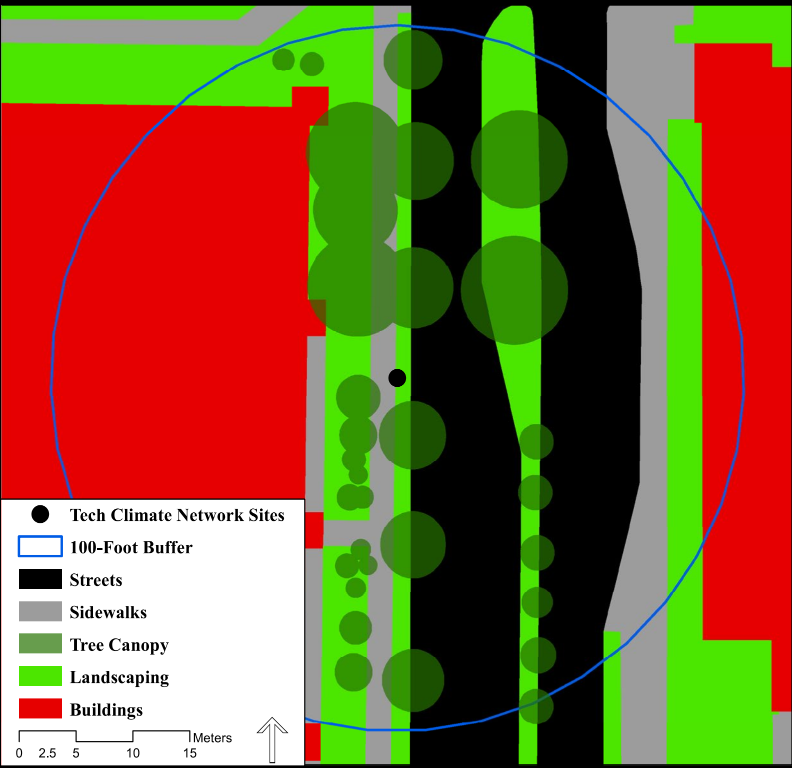
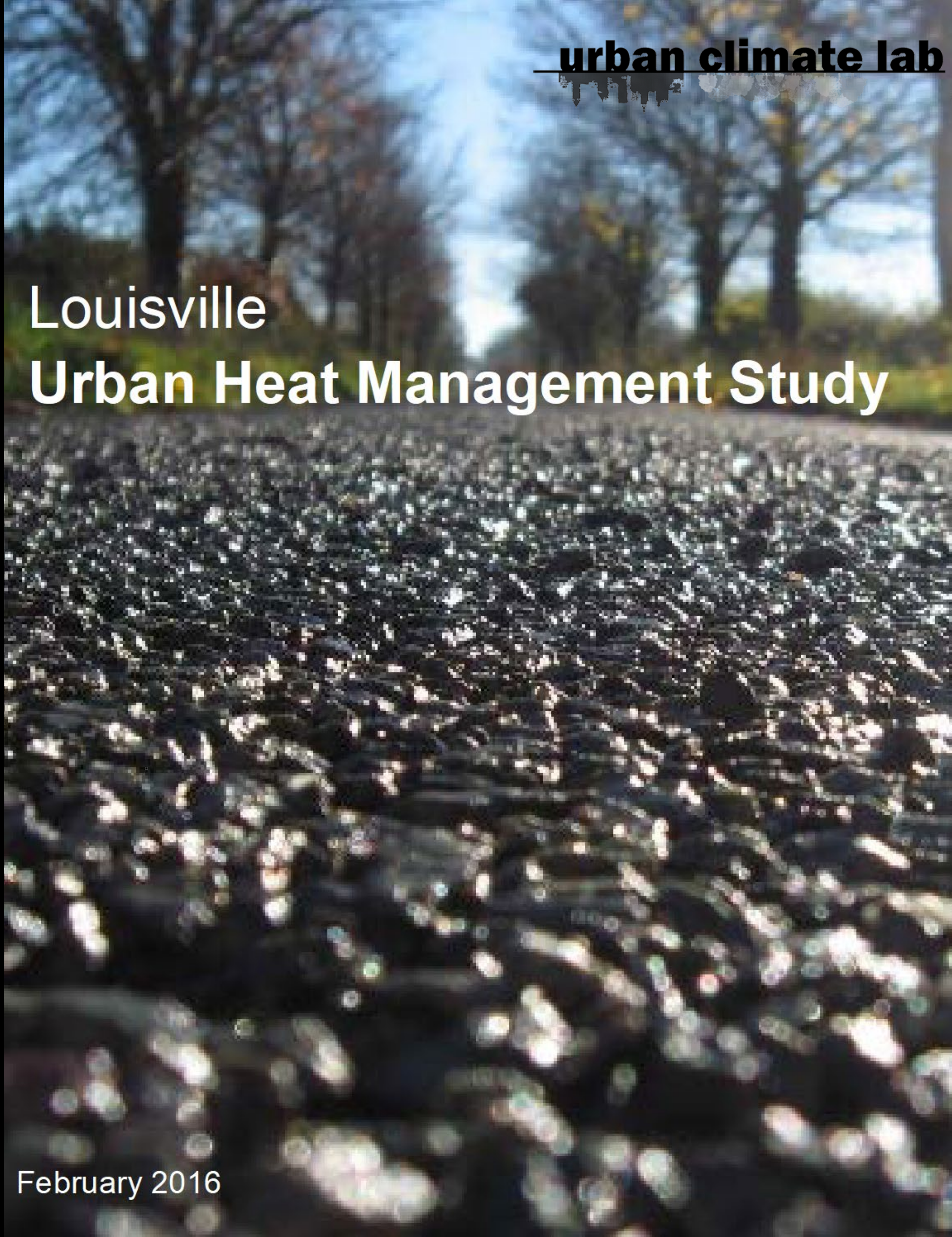
Hot Days Above 91°F (Summer 2017)



	T_{min} UHI			T_{avg} UHI		
	B	Std. Error	P-Value	B	Std. Error	P-Value
(Intercept)	2.3724	0.2948	***	2.5596	0.3802	***
Streets	-0.0036	0.0032		0.0012	0.0041	
Sidewalks	-0.0037	0.0039		-0.0014	0.0050	
Tree Canopy Area	0.0029	0.0039		-0.0075	0.0050	
Landscaping	-0.0116	0.0028	***	-0.0061	0.0036	
Direct Overhead Canopy	-0.1384	0.1199		-0.3506	0.1546	*
R-Squared	0.6689			0.6999		
	T_{max} UHI			Hot Days		
	B	Std. Error	P-Value	B	Std. Error	P-Value
(Intercept)	3.6313	0.9564	**	32.9876	7.9362	***
Streets	0.0011	0.0103		-0.0194	0.0852	
Sidewalks	-0.0029	0.0125		-0.0745	0.1040	
Tree Canopy Area	-0.0289	0.0125	*	-0.2509	0.1040	*
Landscaping	-0.0037	0.0090		-0.0726	0.0747	
Direct Overhead Canopy	-0.5328	0.3888		-3.8331	3.2265	
R-Squared	0.5633			0.5813		

Mallen et al., 2020



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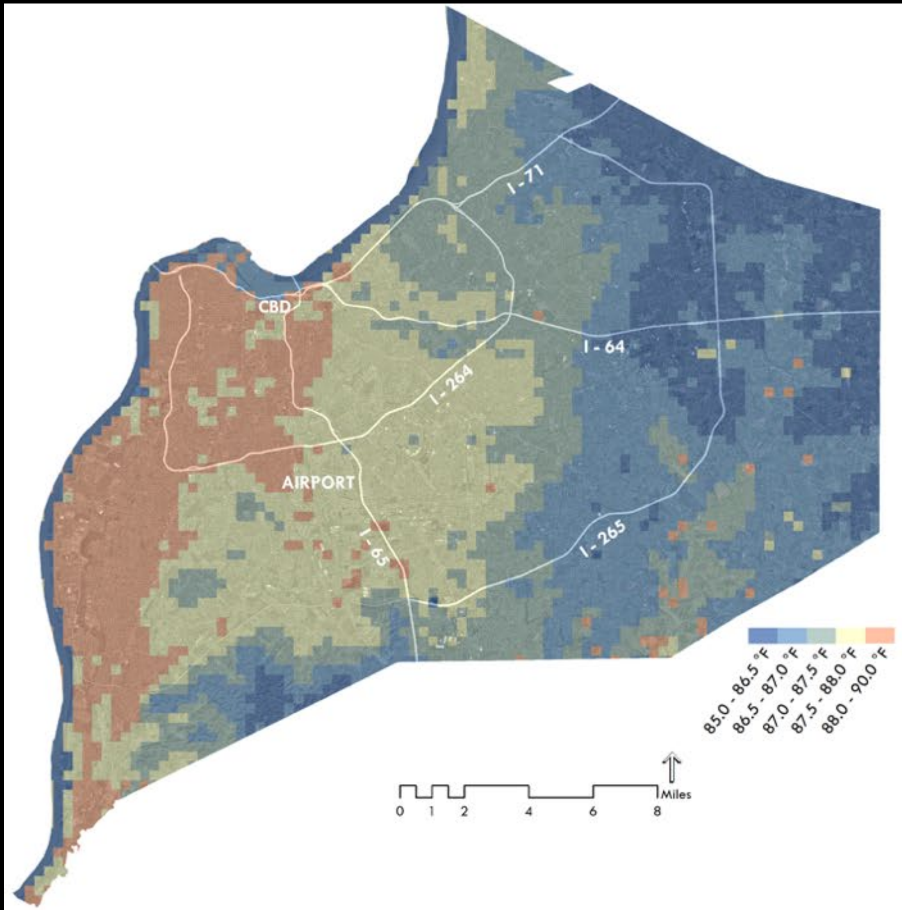
Louisville

Urban Heat Management Study

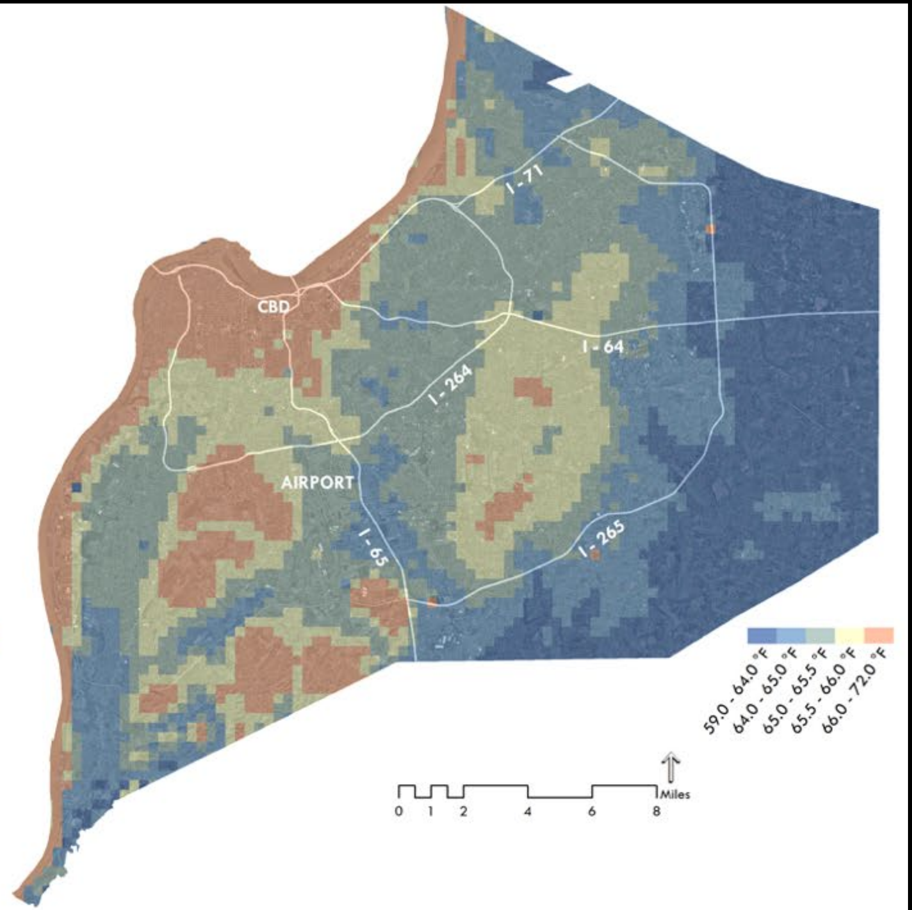
February 2016

Daily Maximum Temperature



Range: 5°F

Daily Minimum Temperature



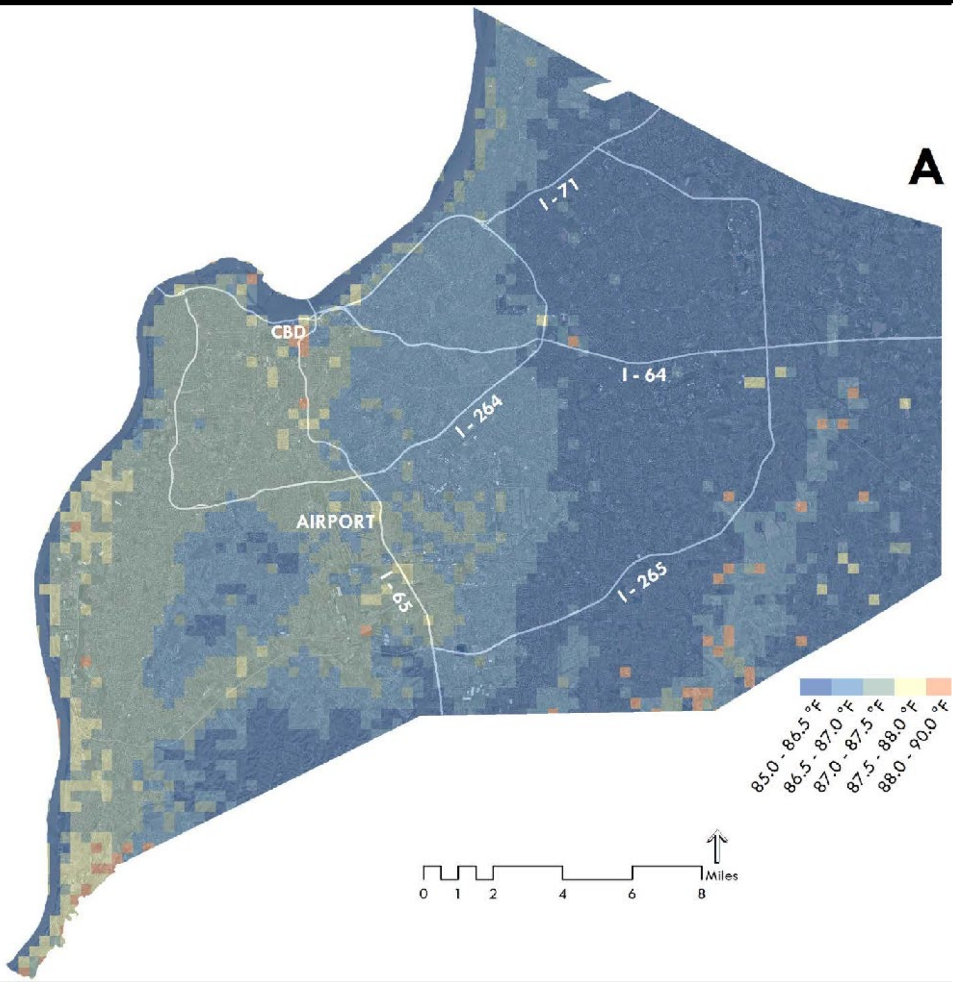
Range: 13°F

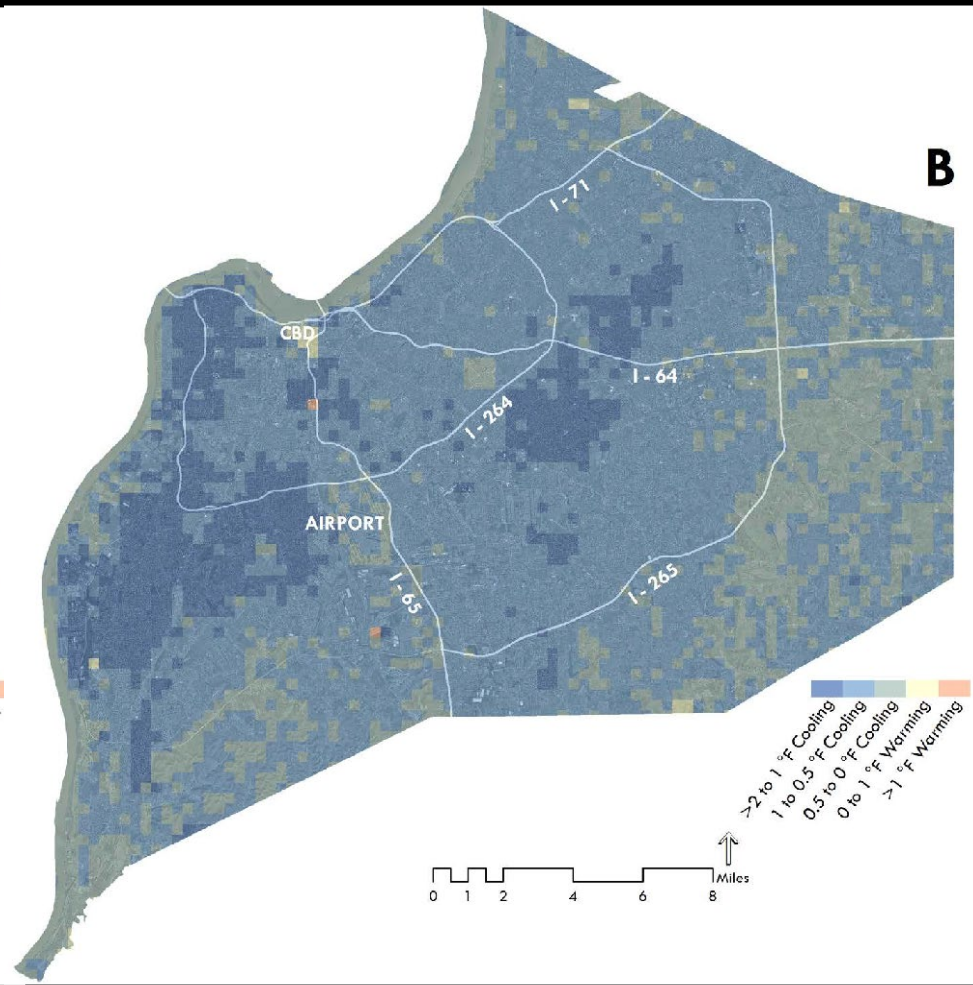
cool materials scenario

assumes all building roofs, roadways, and parking lots meet a minimum standard for reflectivity

Cool Materials Scenario

Difference from Current Conditions





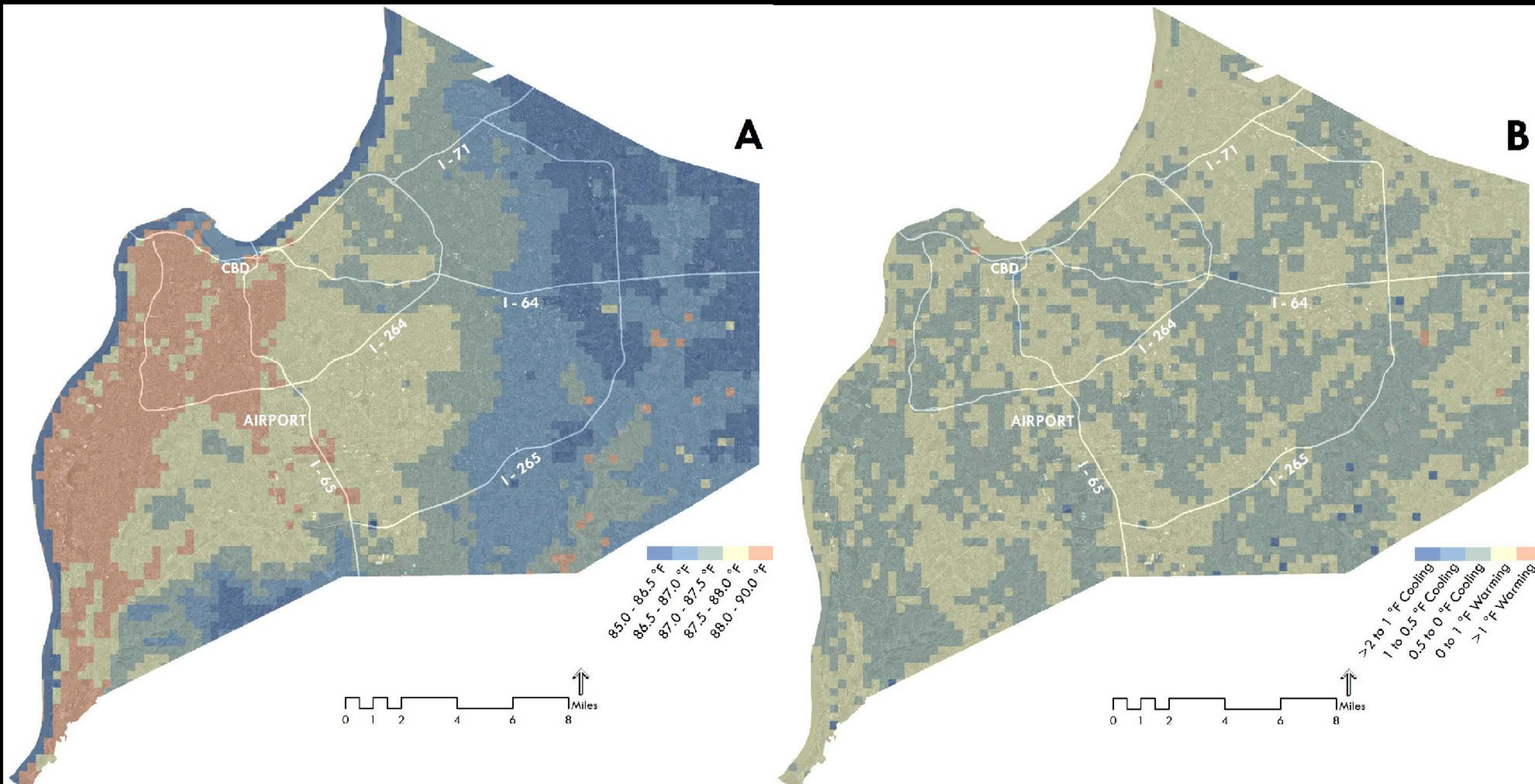
Cool materials: 2-3°F cooler on average

greening scenario

assumes 20-50% higher canopy coverage over roadways

Zoning Class	Green Cover Minimum
Single Family Residential	80%
Multifamily Residential	70%
Commercial	50%
Industrial	40%
Public/Institutional	60%
Parkland	90%
Farmland	100%
Vacant	100%

Greening Scenario | Difference from Current Conditions



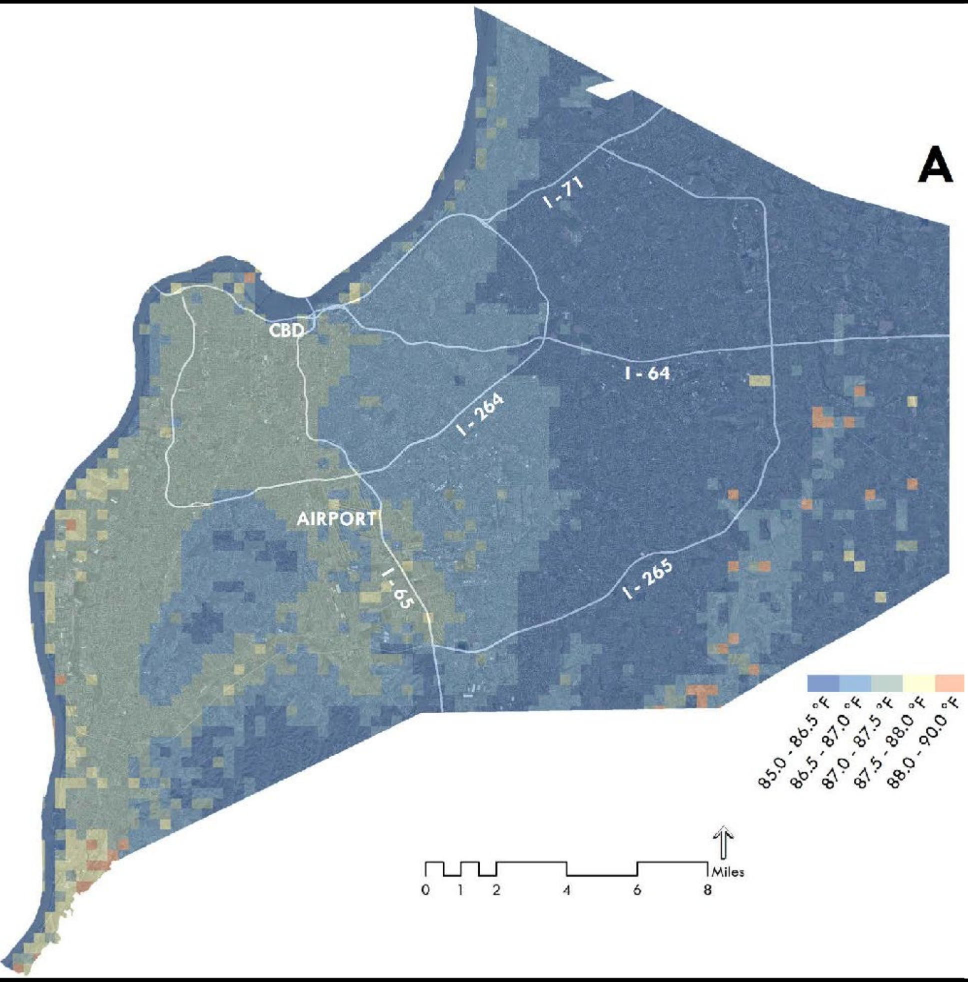
Street trees: 1-2°F cooler on average

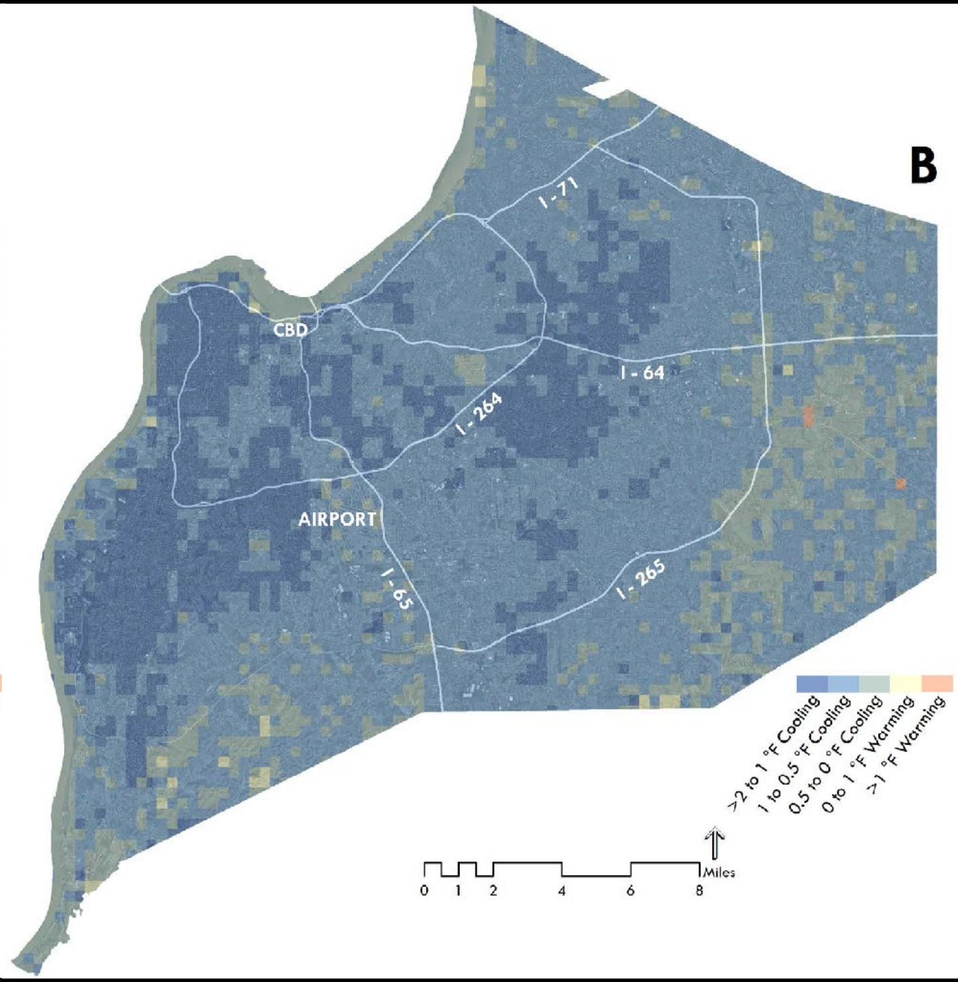
Note: Greening 1.2 times more effective than cool materials per unit area combined strategies scenario

+

Combined Scenario

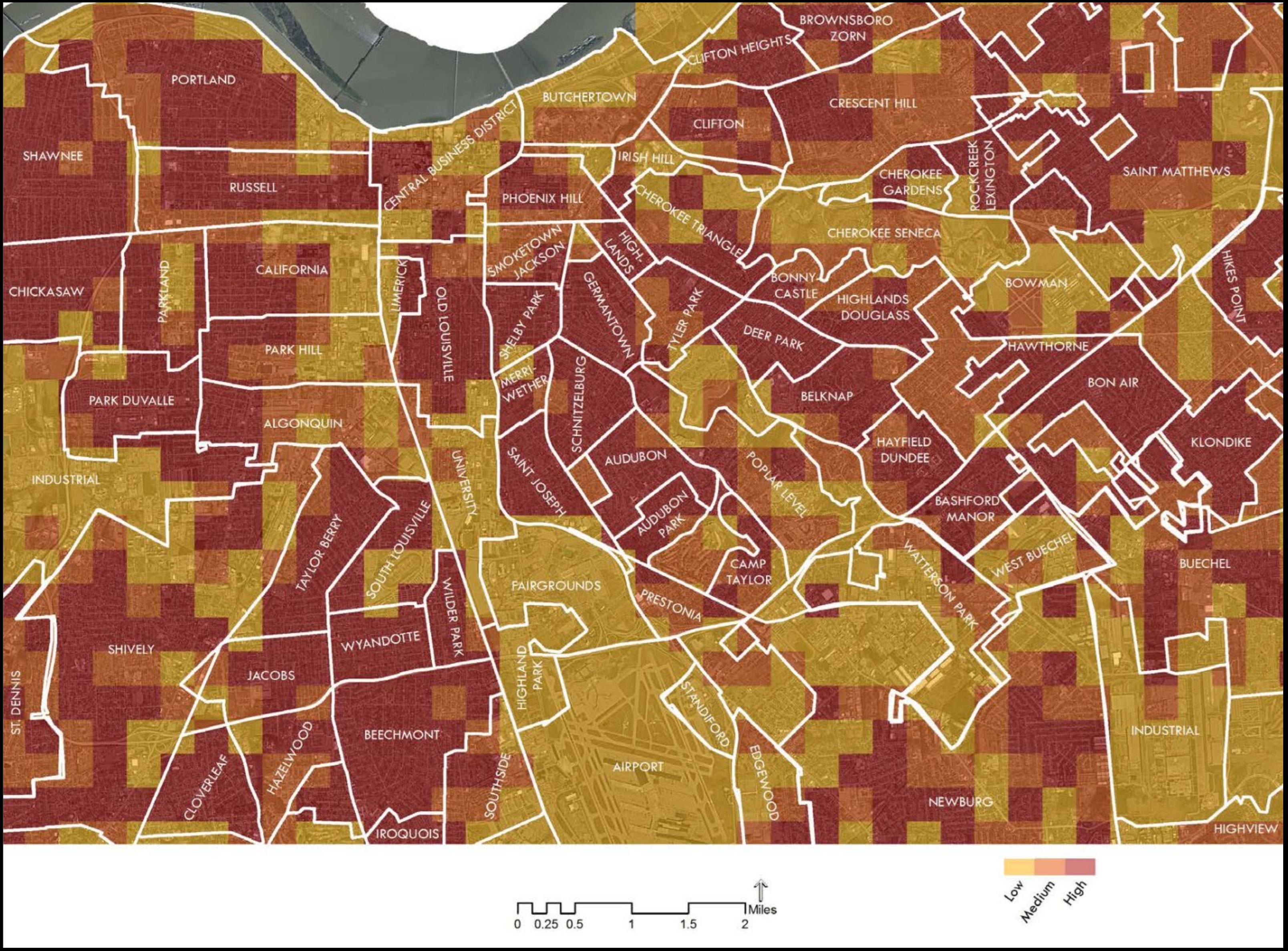
Difference from Current Conditions



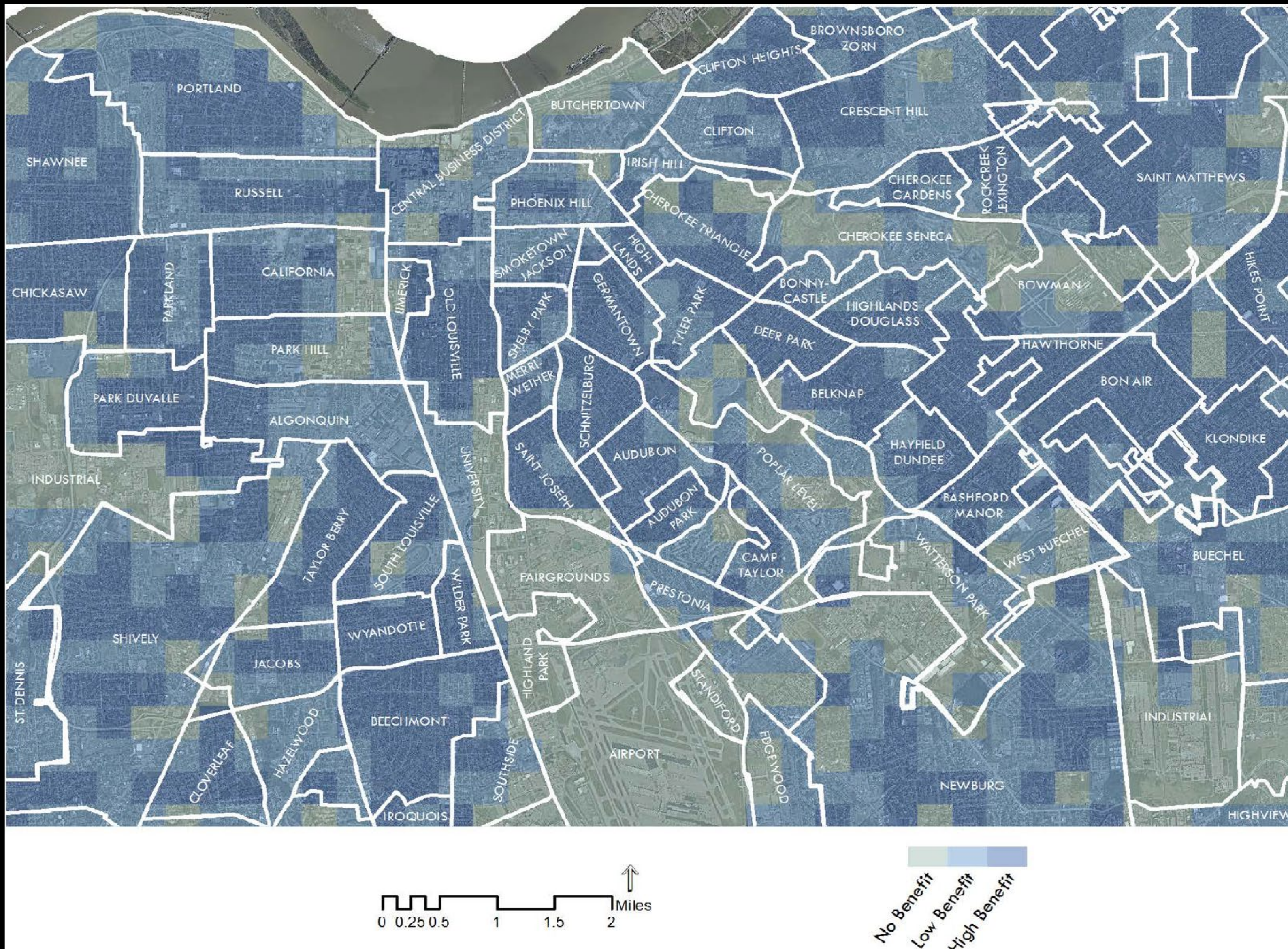


Combined: Over 3°F cooler on average

Distribution of Heat-Related Mortality



Avoided Mortality from Combined Scenario (21.4%)



Louisville Heat Management:
Green Heart Project

PRESS RELEASE

Green Heart Project Launches in Louisville

TNC partners with the University of Louisville and others on a first-of-its-kind study into the human health benefits of urban greening.

PARTNERSHIPS

Louisville: YouthBuild Tree Inventory

The YouthBuild Louisville team inventoried trees and monitored tree health for TNC's Green Heart project.

PARTNERSHIPS

Growing a Better Community

Ked Stanfield of Louisville Grows is helping to put trees in the ground in the Green Heart project study area.

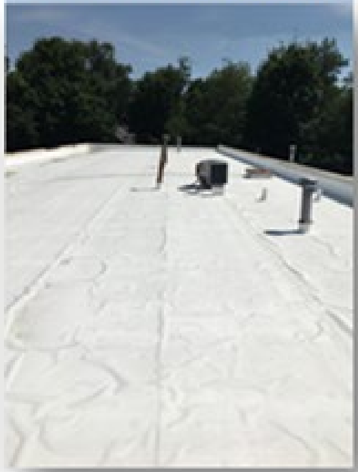
Louisville Heat Management: Cool502

#cool502

GREENING | COOLING | CONSERVING

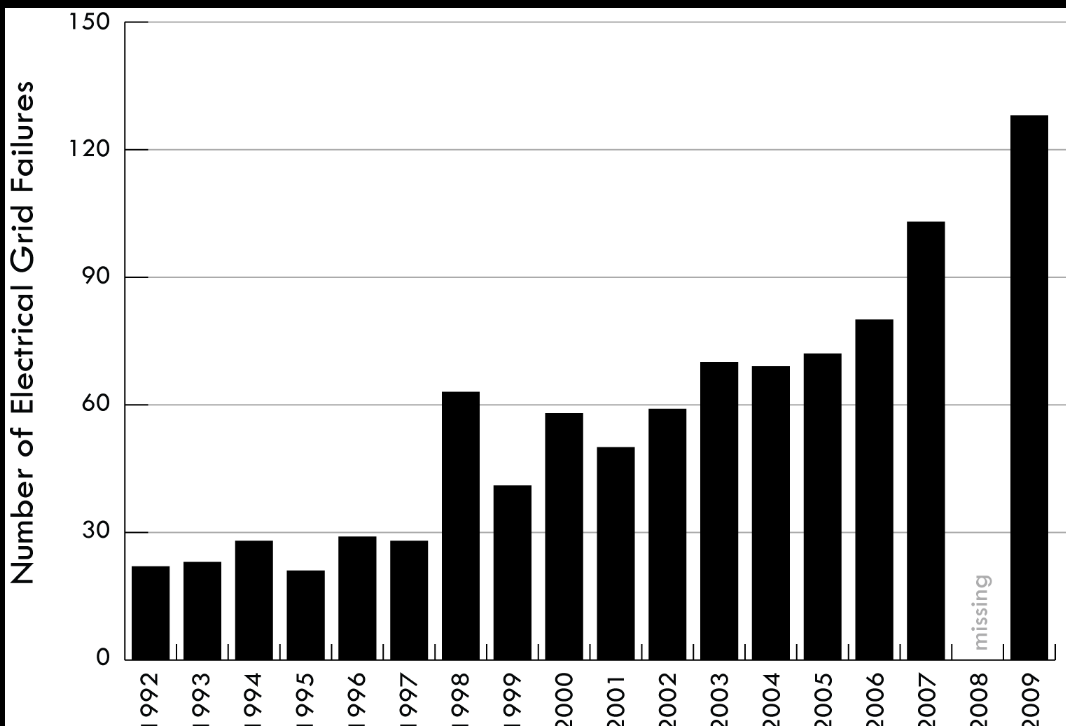
Cool Asphalt Shingles

Flat White Roof

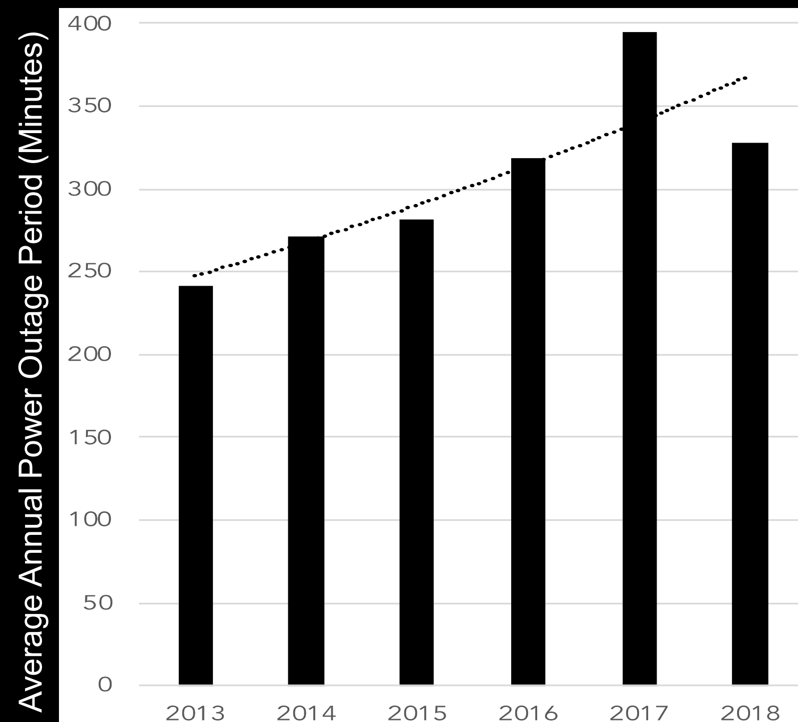


Cool Metal Roof

Rising Power Outages



NERC



Systems Average Interruption Duration Index (SAIDI)

USEIA, 2019

Blackout Causes

- Heat-related infrastructure damages
- Grid stress from high demand
- Preventative outages (wildfires)

Portland Streetcar
@PDXStreetcar

In case you're wondering why we're canceling service for the day, here's what the heat is doing to our power cables.

7:07 PM · Jun 27, 2021 · Hootsuite Inc.

The New York Times

The Greatest Killer in New Orleans Wasn't the Hurricane. It Was the Heat.

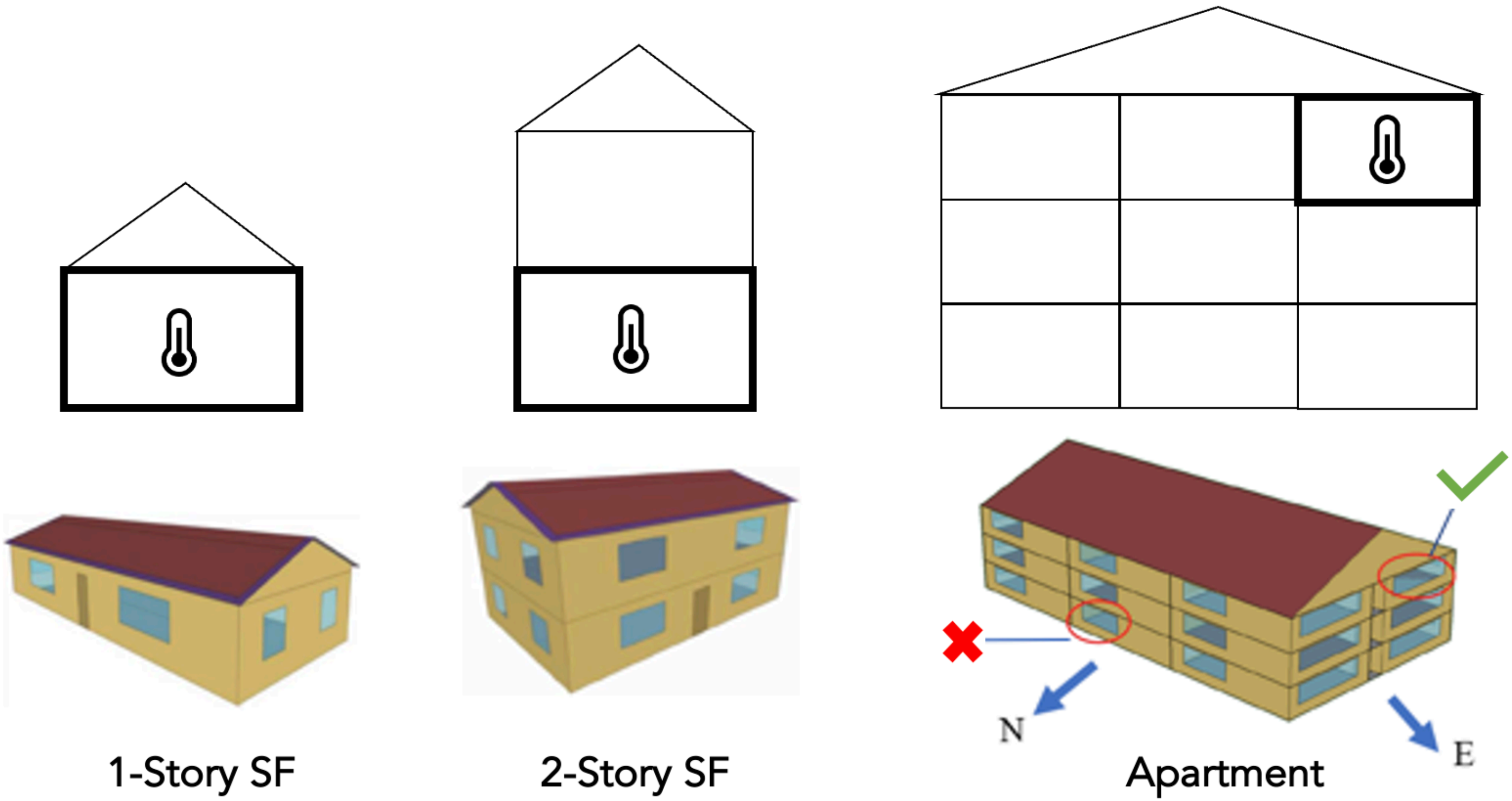
A huge power failure after Hurricane Ida left vulnerable residents in sweltering apartments for days. At least 10 deaths in the city have been tied to the heat.

By Nicholas Bogel-Burroughs and Katy Reckdahl

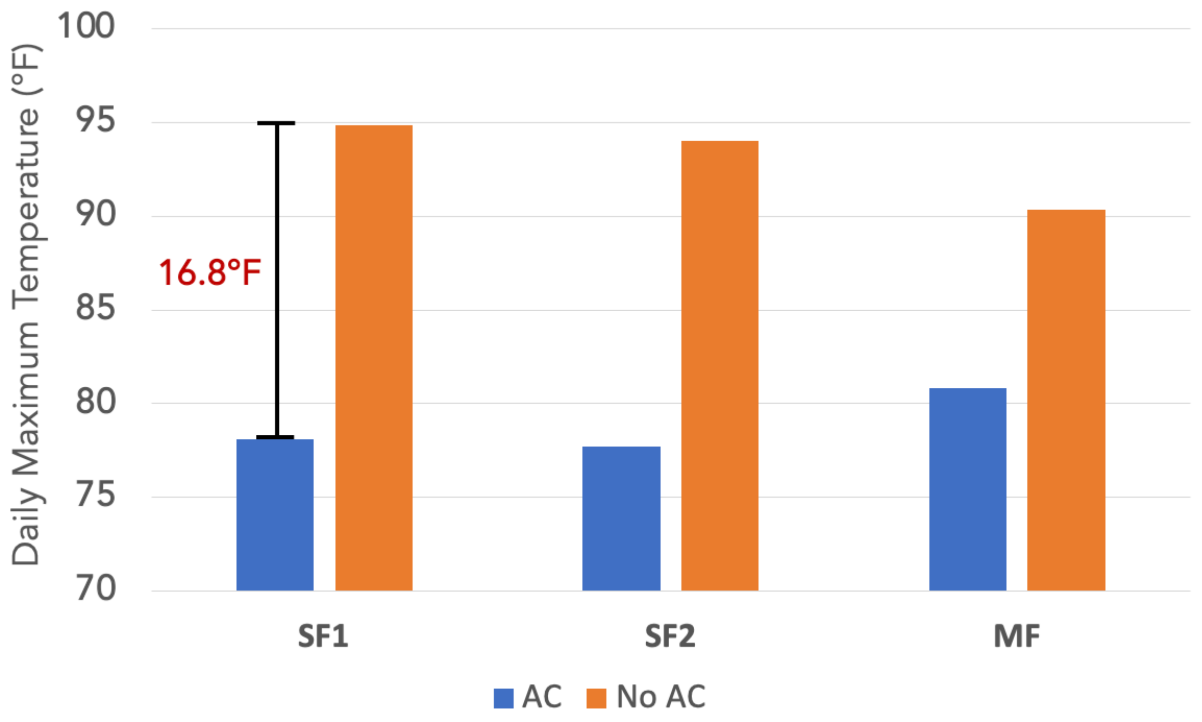
Sept. 15, 2021

National Guard members distributed ice outside a community center in New Orleans on Sept. 1. The city was without power for days after Hurricane Ida made landfall. Johnny Milano for The New York Times

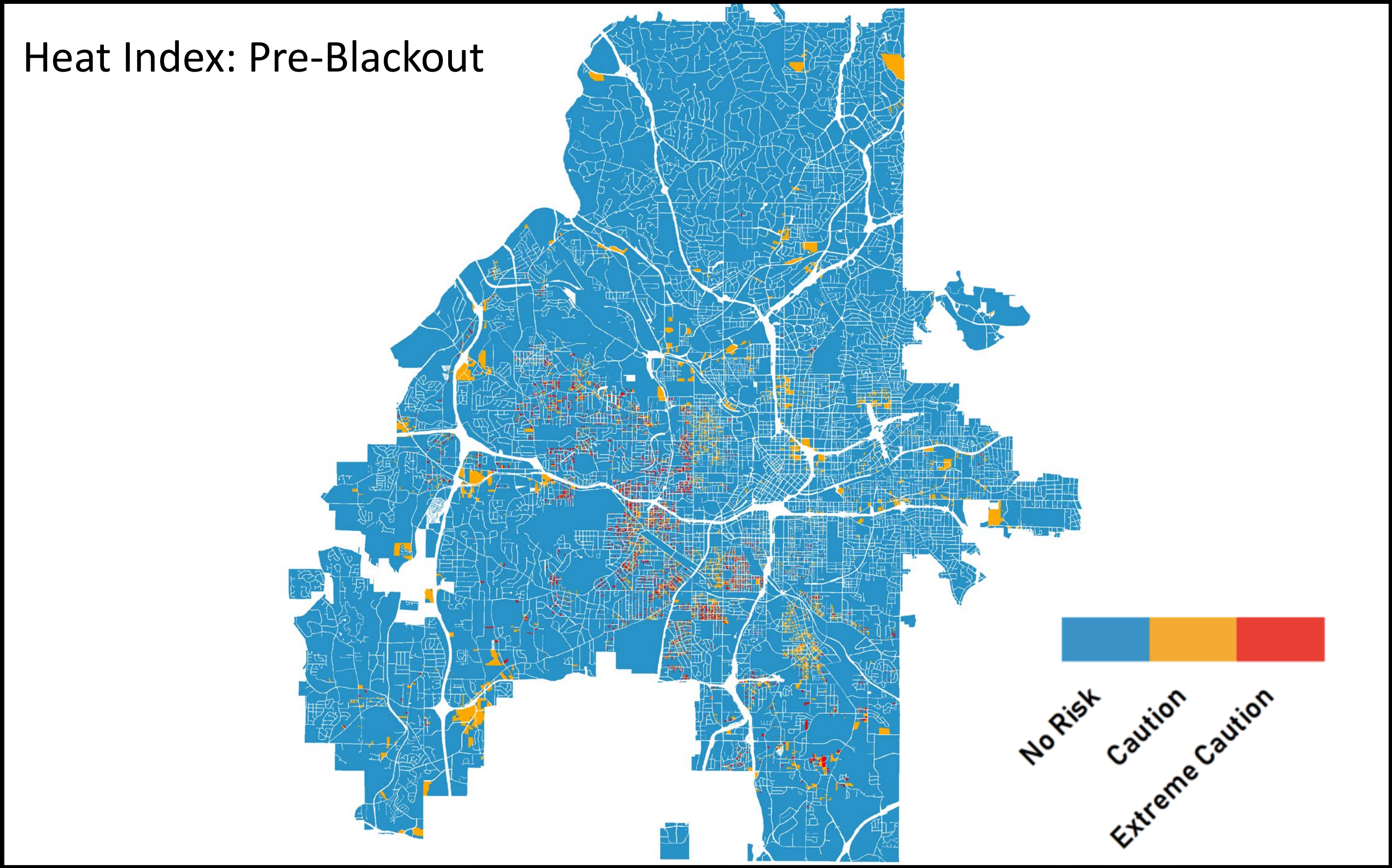
Residential Structure Prototypes



Blackout Impacts: Atlanta

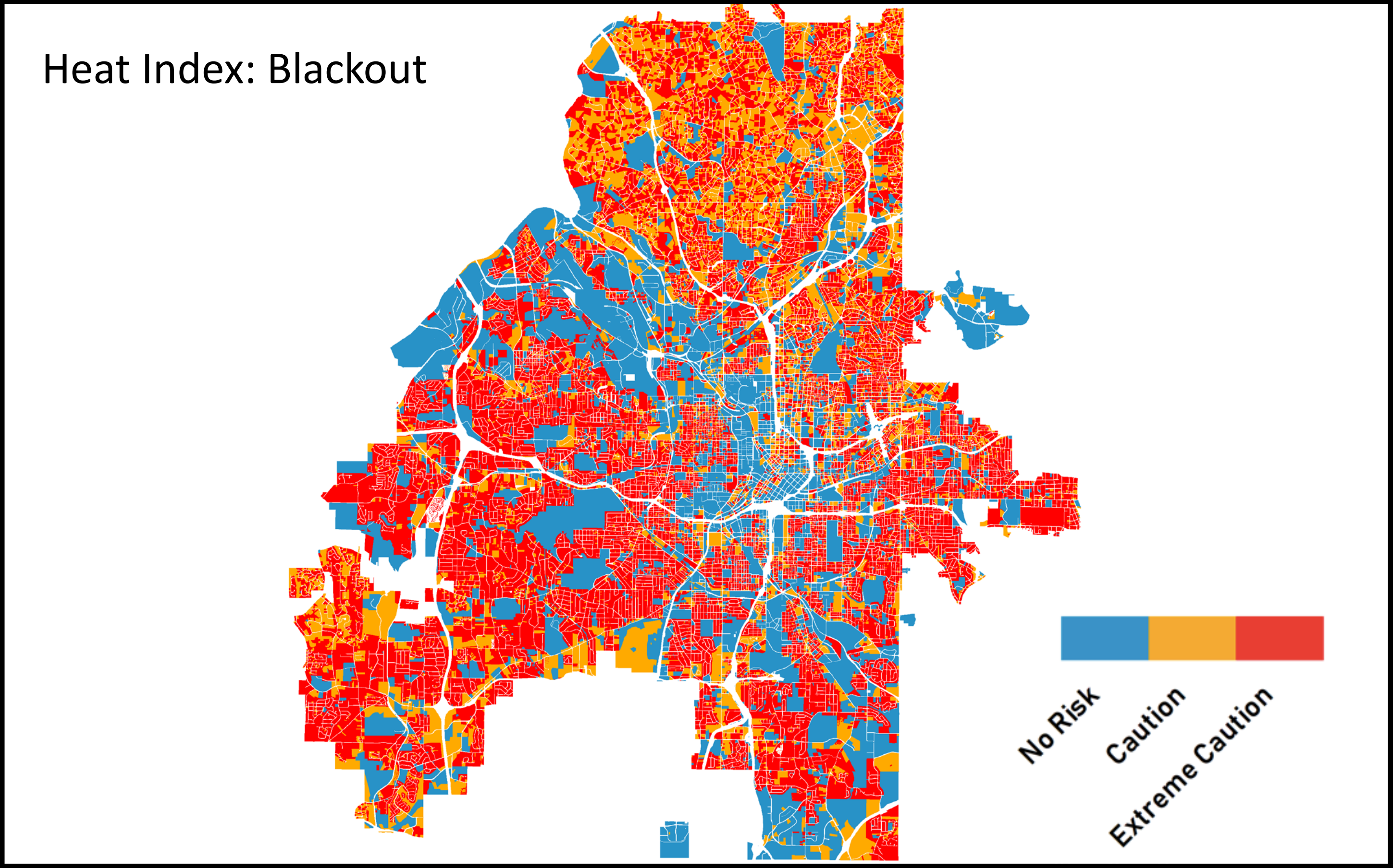


Atlanta Interior Heat Risk



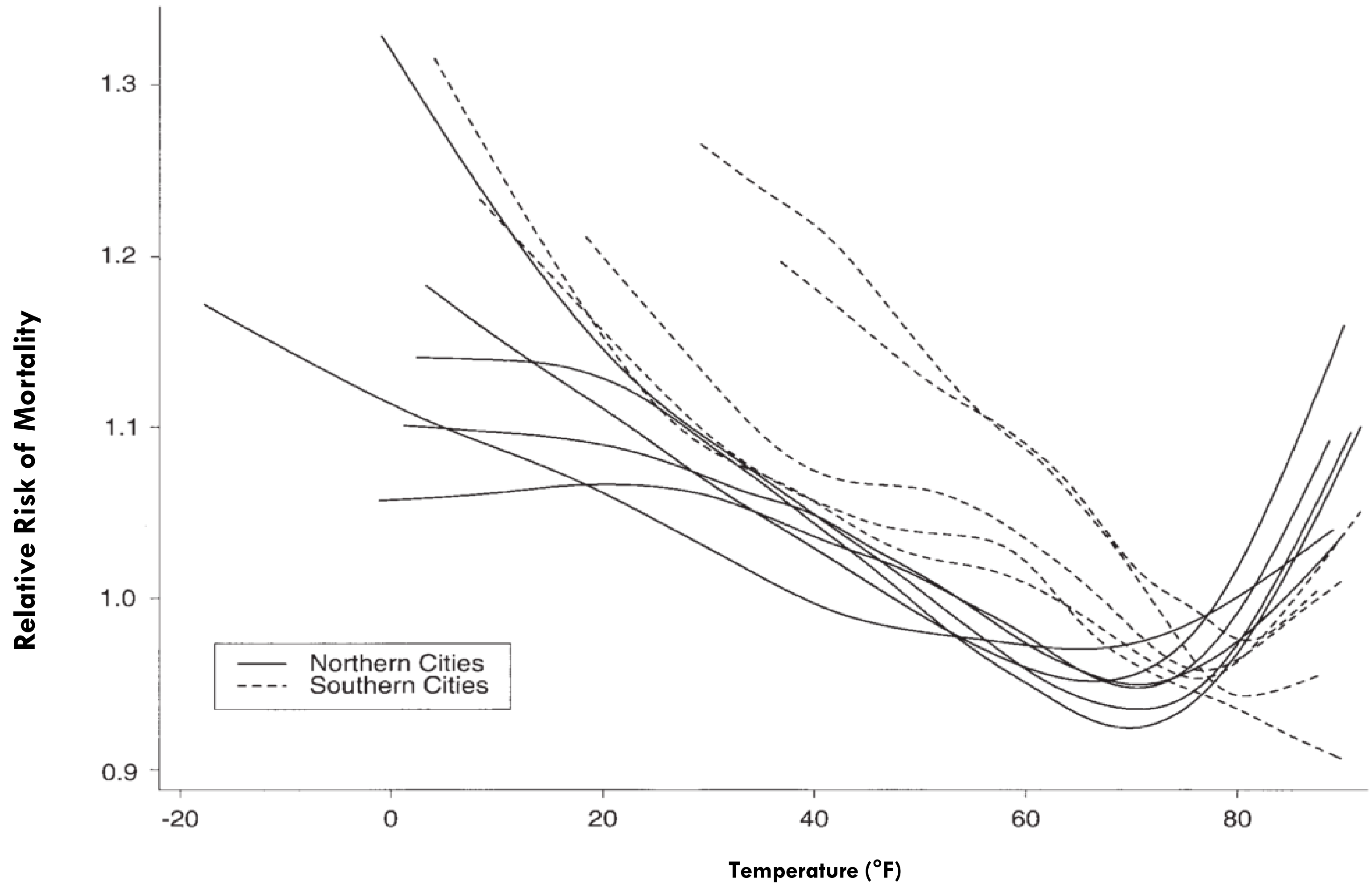
Stone et al. (2021b)

Atlanta Interior Heat Risk



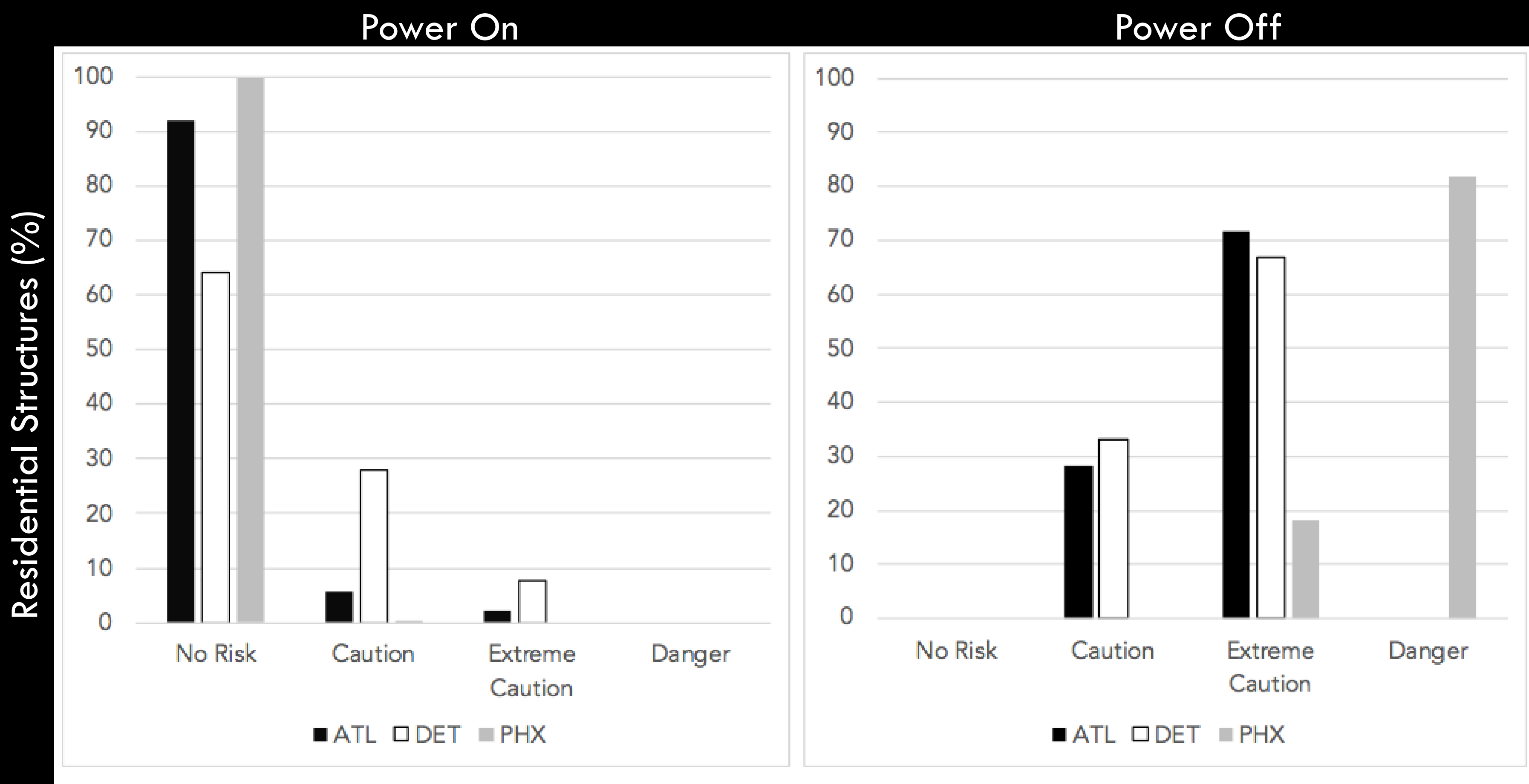
Stone et al. (2021b)

Physiological Acclimatization

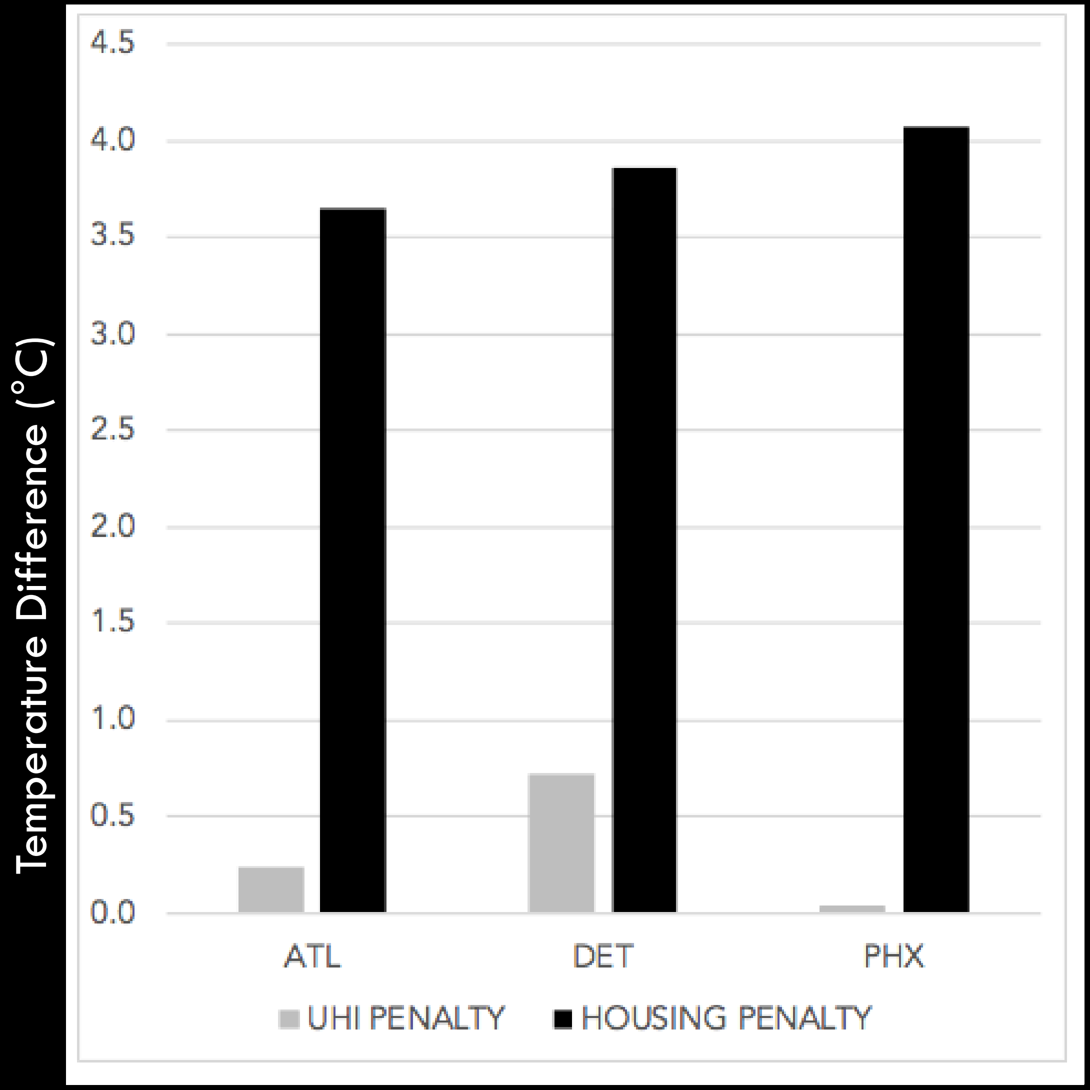


I. Temperature-mortality relative risk functions for 11 US cities, 1973–1994. Northern cities: Boston, Massachusetts; Chicago, Illinois; New York; Philadelphia, Pennsylvania; Baltimore, Maryland; and Washington, DC. Southern cities: Charlotte, North Carolina; Atlanta, Jacksonville, Florida; Tampa, Florida; and Miami, Florida. °C = 5/9 × (°F − 32).

Curriero et al. (2002)



Stone et al., 2021

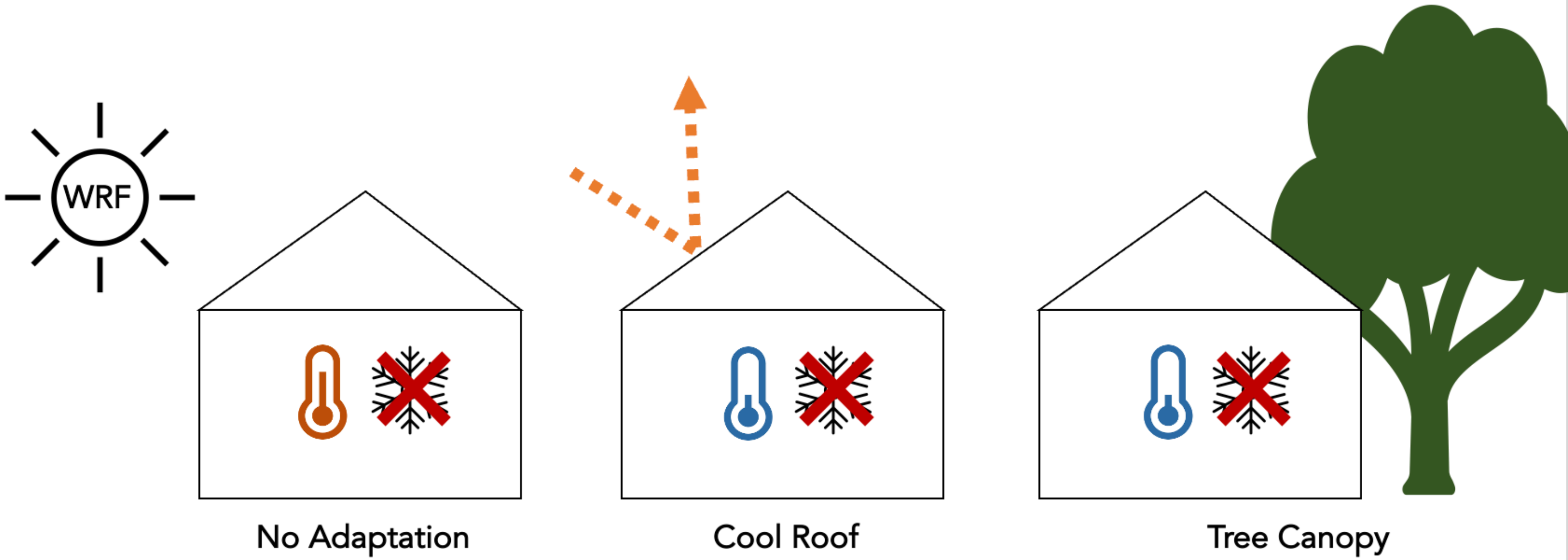


UHI Penalty:
Difference in interior temperatures between warmest and coolest areas of city within housing type

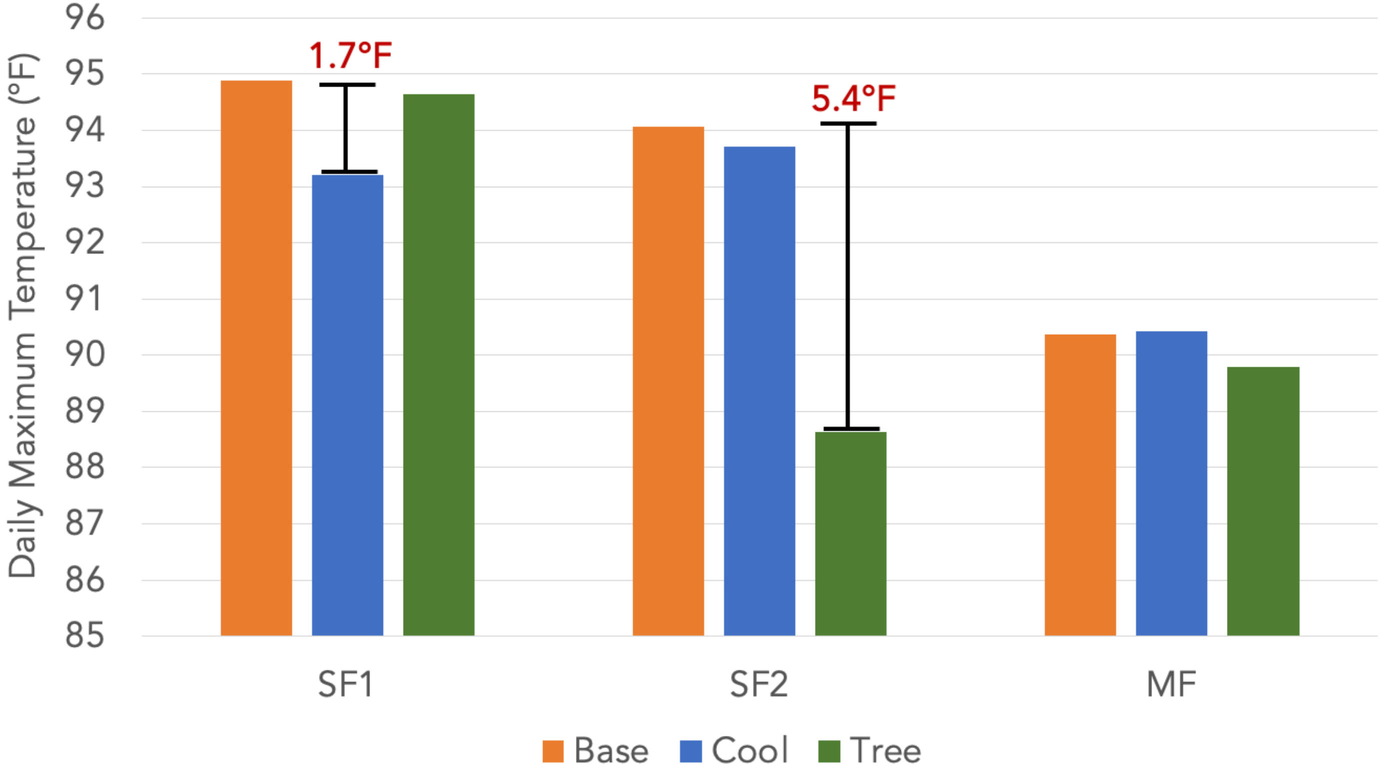
Housing Penalty:
Difference in interior temperatures between warmest and coolest building type for each city

Stone et al., 2021

How effective are cool roofing and tree canopy in reducing building-interior heat exposures?

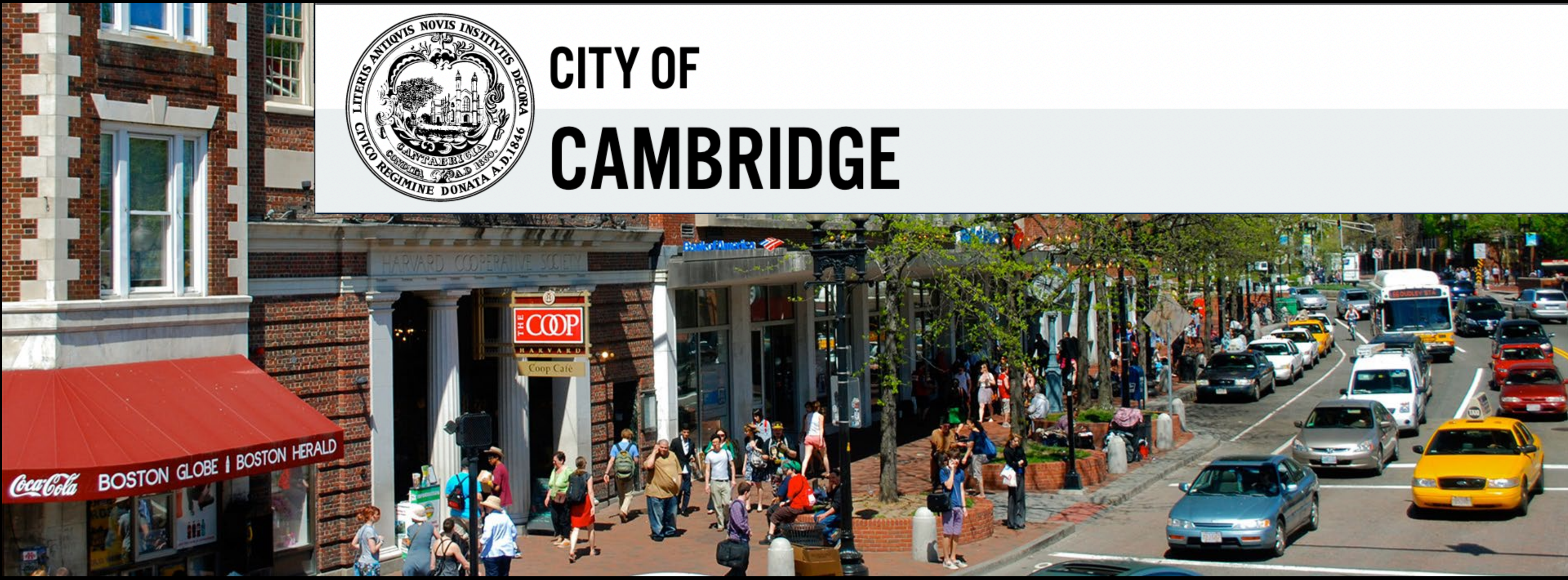


Heat Management Strategies: Atlanta



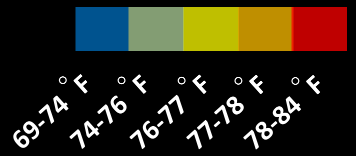
Personal Adaptations

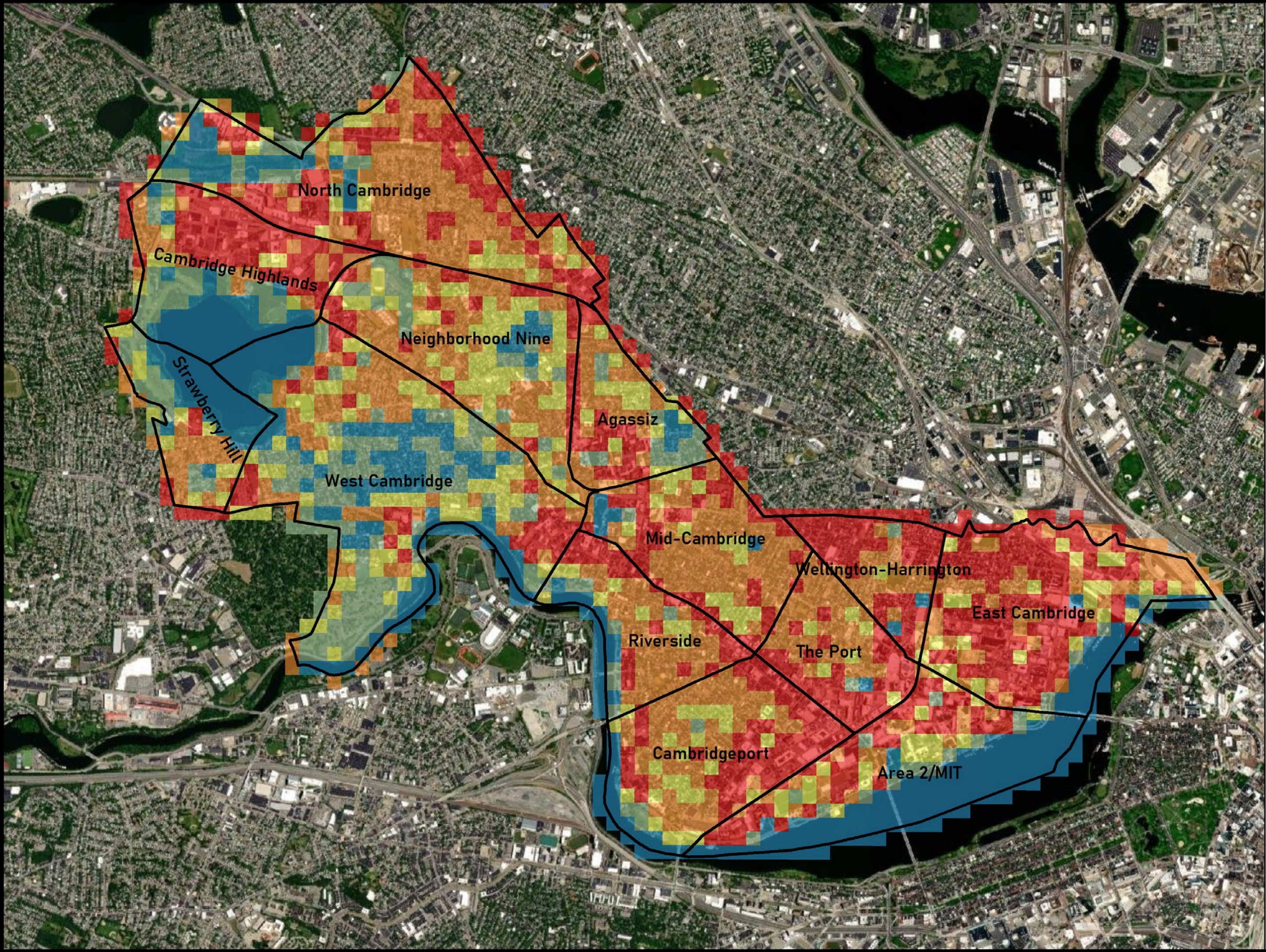
Community-Driven Climate Adaptation Planning

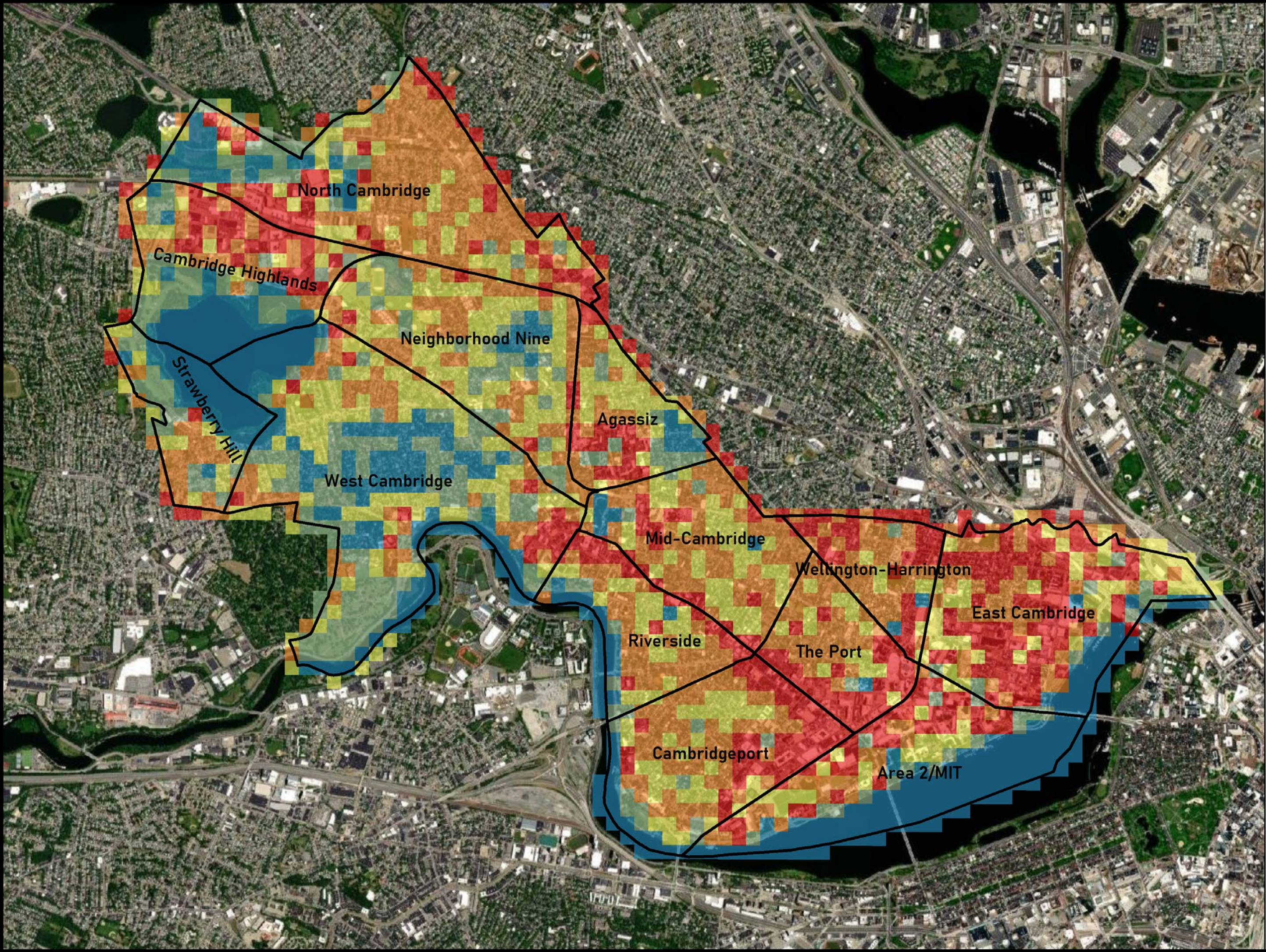


Cambridgema.gov

BASE SCENARIO
SUMMER (AvgT)





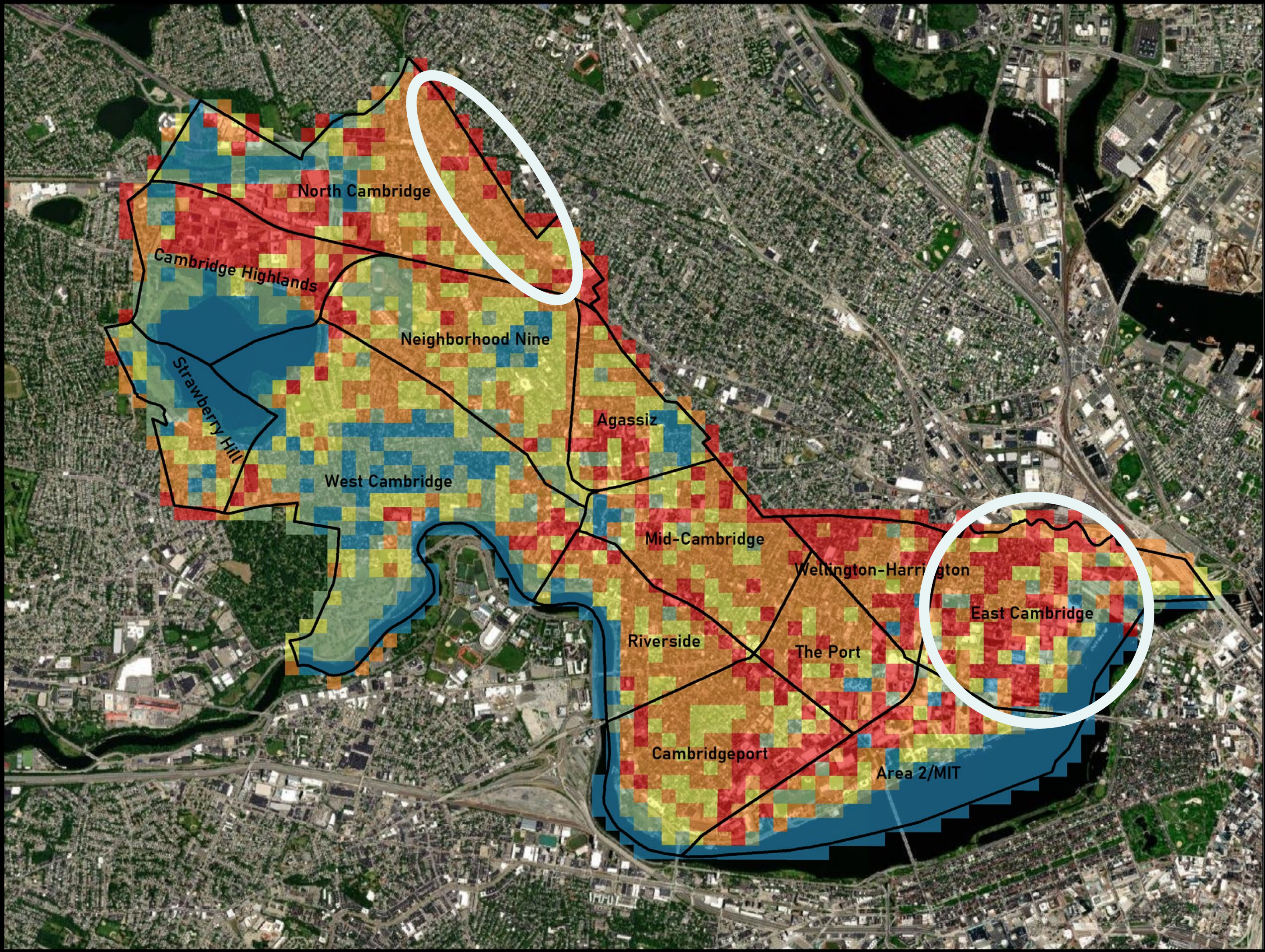


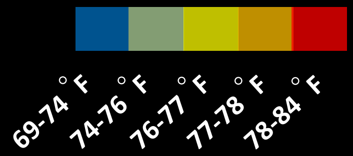
ALBEDO SCENARIO
SUMMER (AvgT)

69-74 °F
74-76 °F
76-77 °F
77-78 °F
78-84 °F

Street trees are also effective in reducing temperatures along large roadways and in neighborhood cores lacking significant tree cover.

ST TREE SCENARIO SUMMER (AvgT)

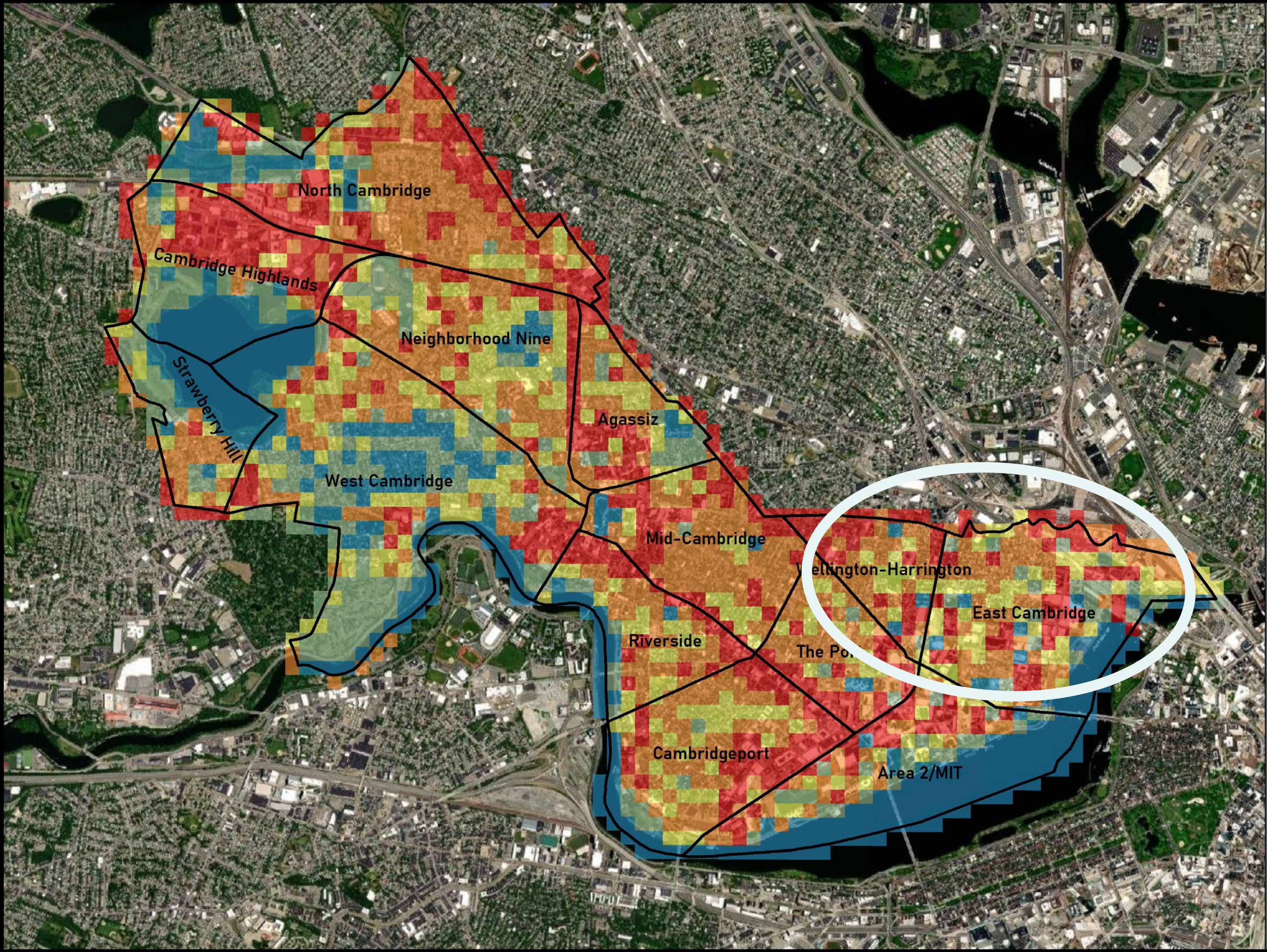




Increasing neighborhood tree cover to a minimum of 30%, along streets and all areas outside of roofing and water, has the greatest effect in neighborhoods with low canopy.

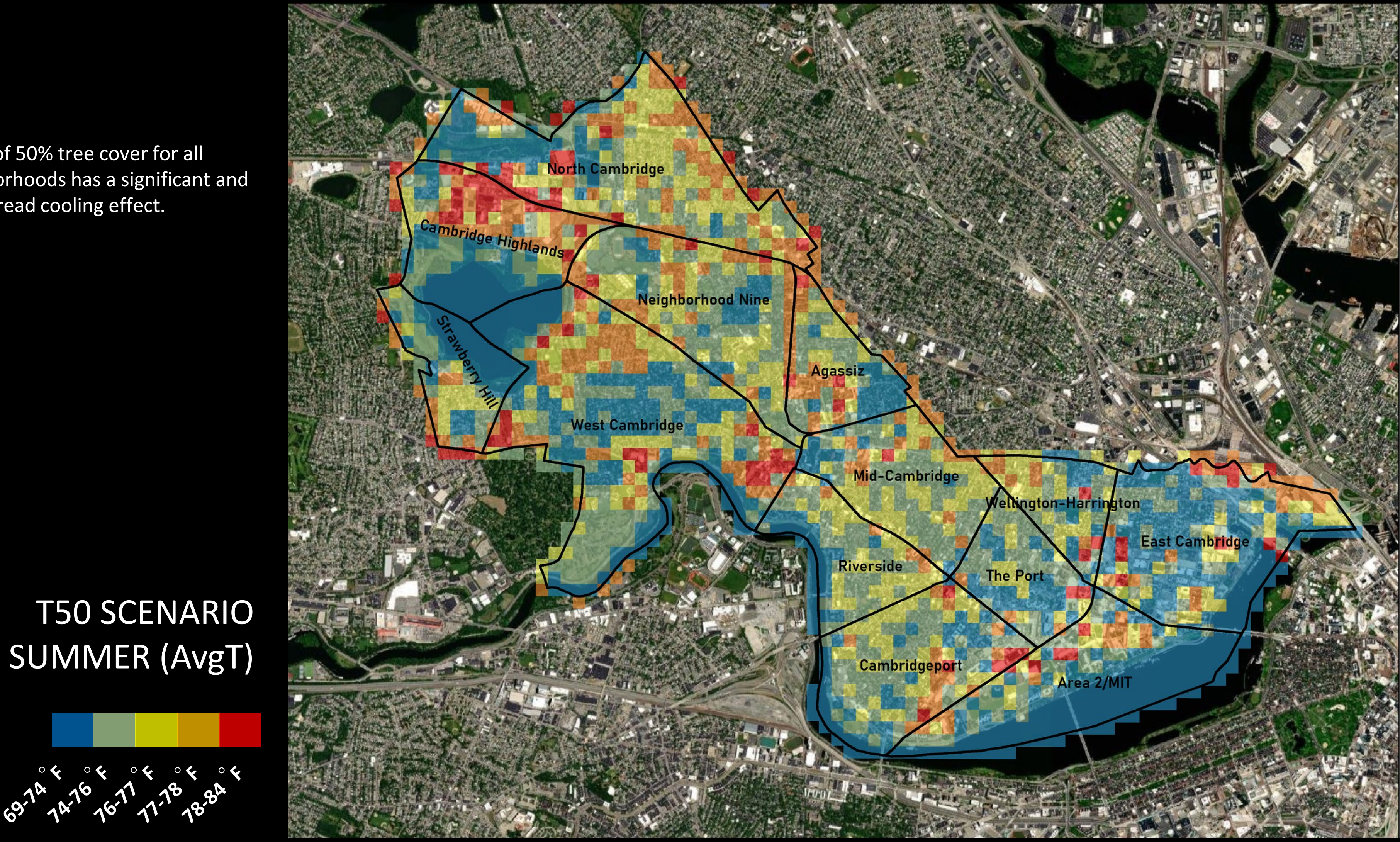
T30 SCENARIO SUMMER (AvgT)

69-74 °F | 74-76 °F | 76-77 °F | 77-78 °F | 78-84 °F



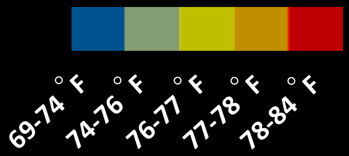
A goal of 50% tree cover for all neighborhoods has a significant and widespread cooling effect.

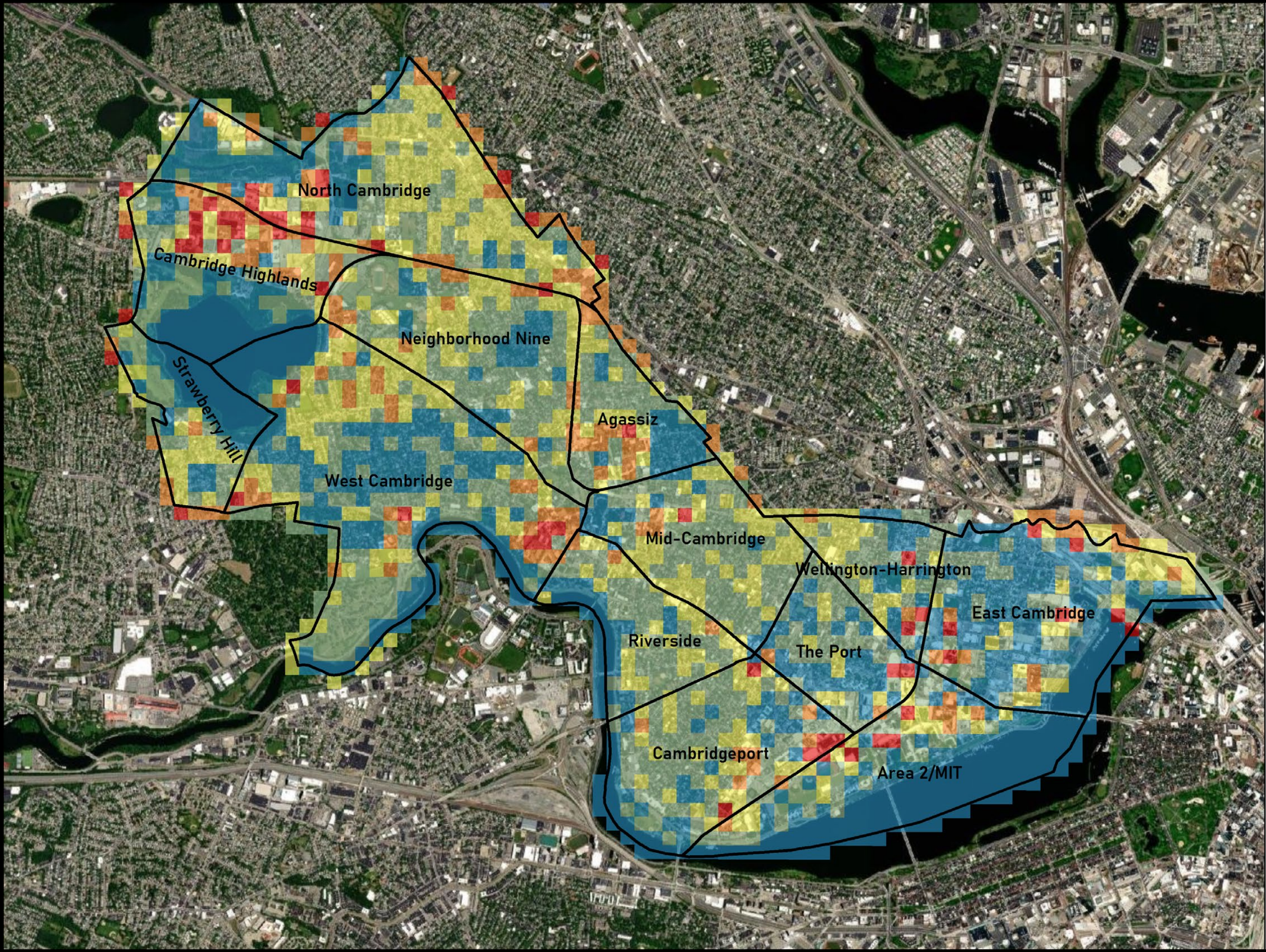
T50 SCENARIO SUMMER (AvgT)



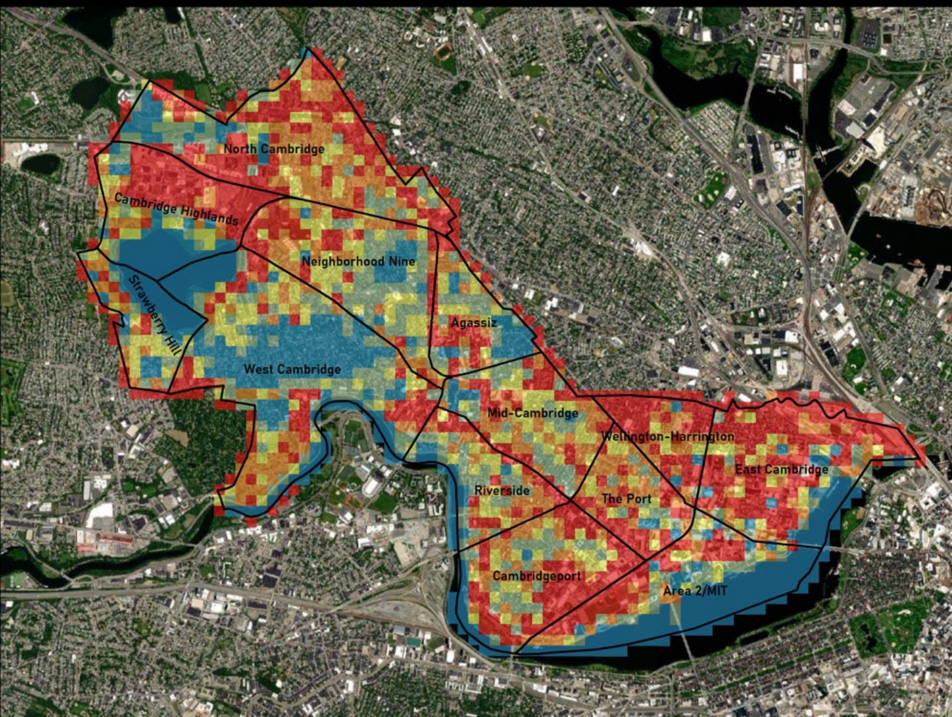
The all combined scenario, combining the effects of 50% neighborhood tree cover and cool materials, reduces neighborhood average temperatures by between 0.5 and 4 °F.

COMBINED SCENARIO SUMMER (AvgT)

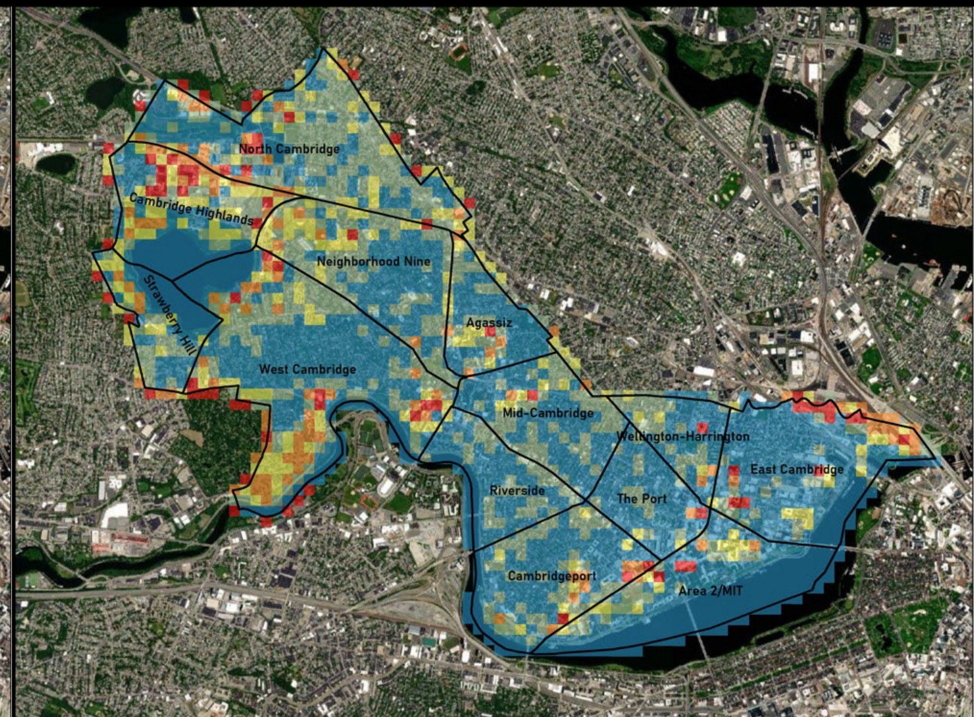




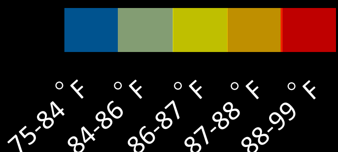
Urban climate models enable scenario assessment of specific heat management strategies



BASE SCENARIO



COMBINED SCENARIO



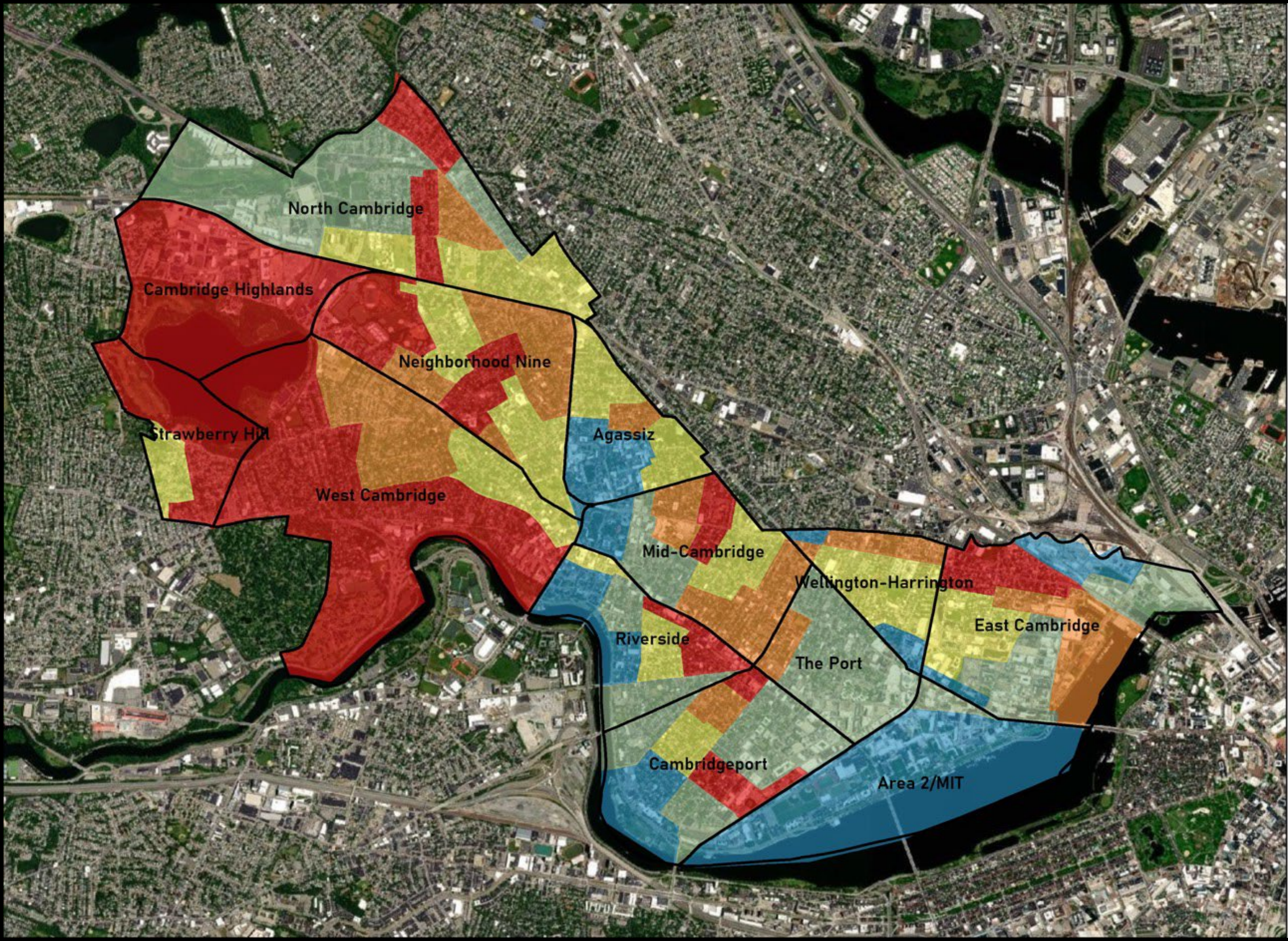
Urban climate models enable scenario assessment of specific heat management strategies

Neighborhood	Small Street Trees	Large Street Trees	Cool Roofing (Albedo, 000s sq ft)	Cool Paving (Albedo, 000s, sq ft)
Agassiz	490	90	2,509	2,670
Area 2/MIT	1,259	231	3,102	4,763
Cambridge Highlands	631	116	2,446	5,623
Cambridgeport	877	161	4,028	4,226
East Cambridge	2,732	502	5,761	9,208
Mid-Cambridge	790	145	3,878	4,169
Neighborhood Nine	1,317	242	4,949	6,996
North Cambridge	2,213	407	5,741	9,116
Riverside	1,074	197	3,505	3,915
Strawberry Hill	487	89	1,069	2,049
The Port	1,149	211	4,060	4,432
Wellington-Harrington	574	105	2,206	3,045
West Cambridge	1,051	193	4,616	7,001
Total	**14,646**	**2,690**	**47,871**	**67,214**

Subsequent Analyses

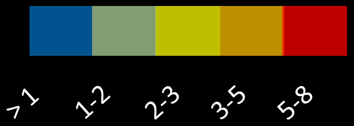
- Stormwater management
- Air quality
- Energy savings
- Carbon sequestration
- Property values
- Health impact assessments
- Economic modeling
- Housing policy
- Community development

Public Health Impact



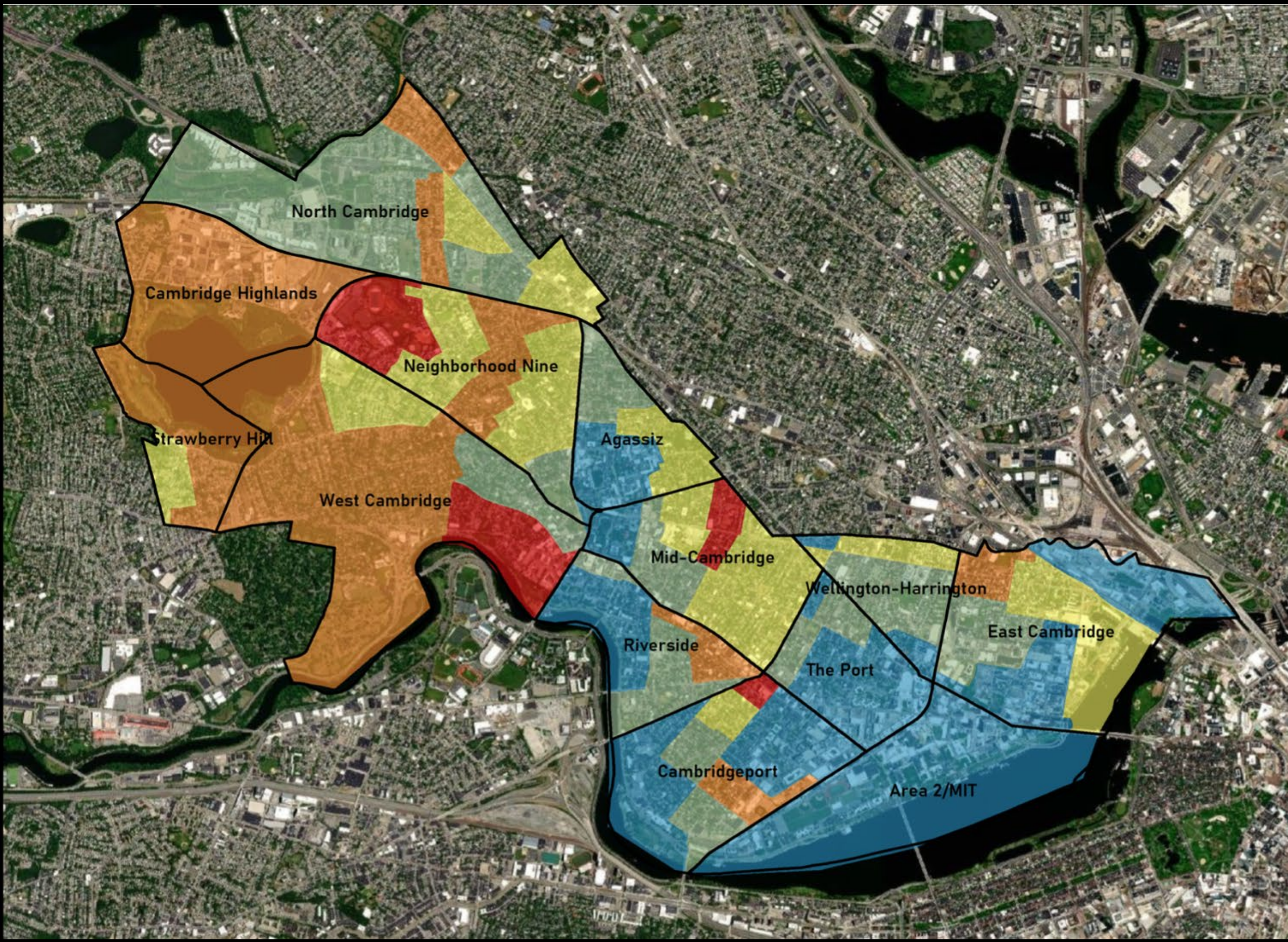
BASE SCENARIO

Heat-Related Mortality
by Block Group (per 100,000)



Public Health Impact

The Combined Scenario reduces citywide heat mortality by 30%, with neighborhood level reductions as high as 46%.

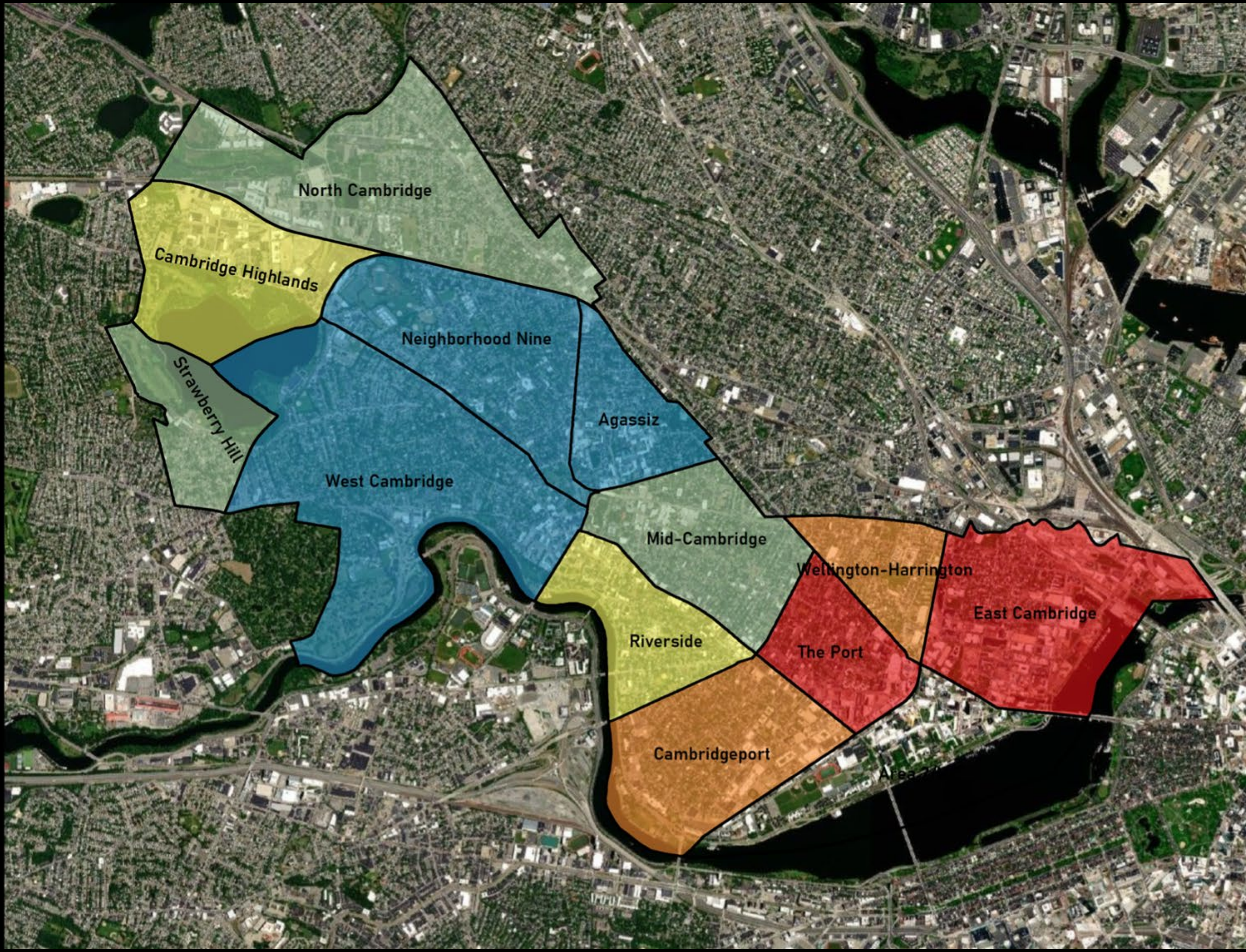


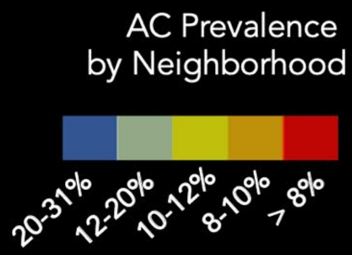
COMBINED SCENARIO

Heat-Related Mortality by Block Group (per 100,000)

<1 1-2 2-3 3-5 5-8

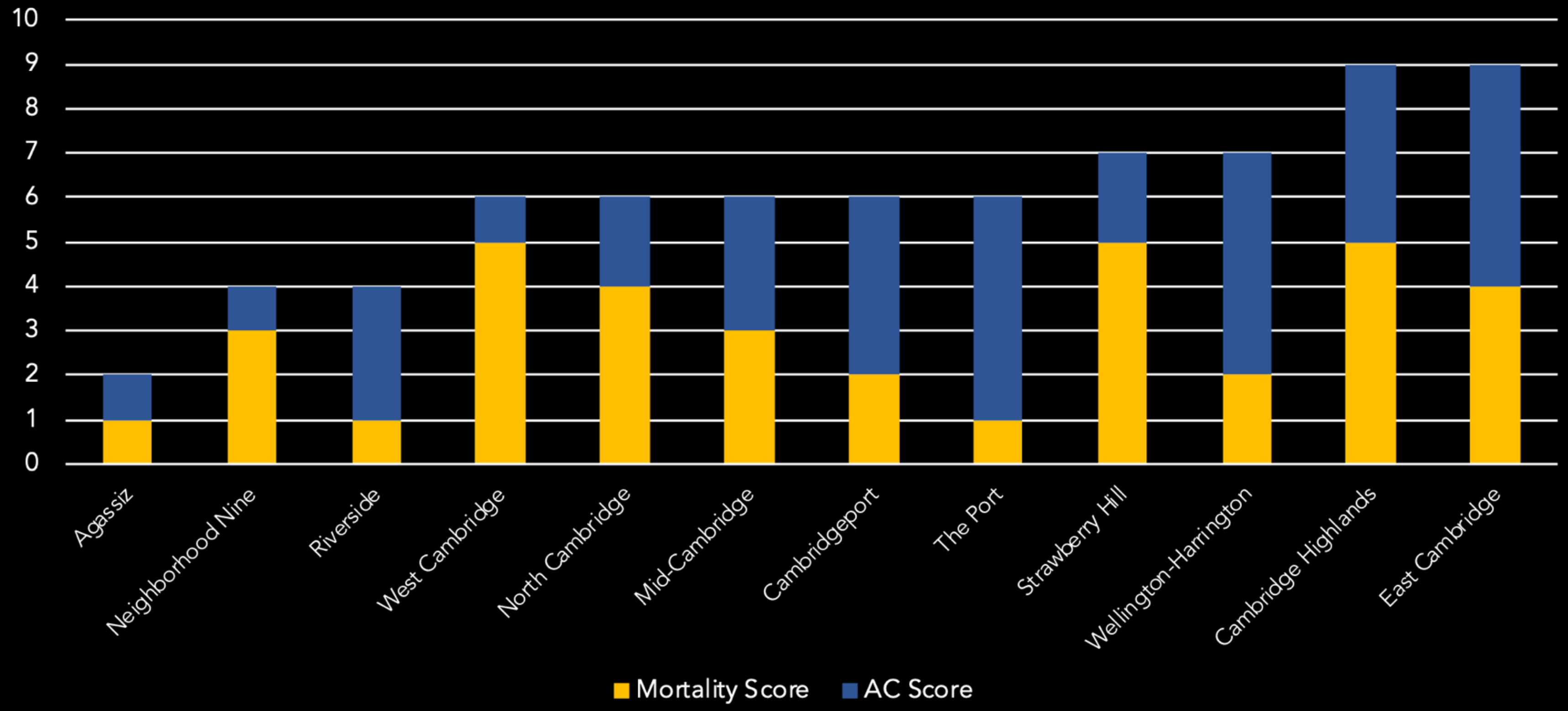
Access to Air Conditioning



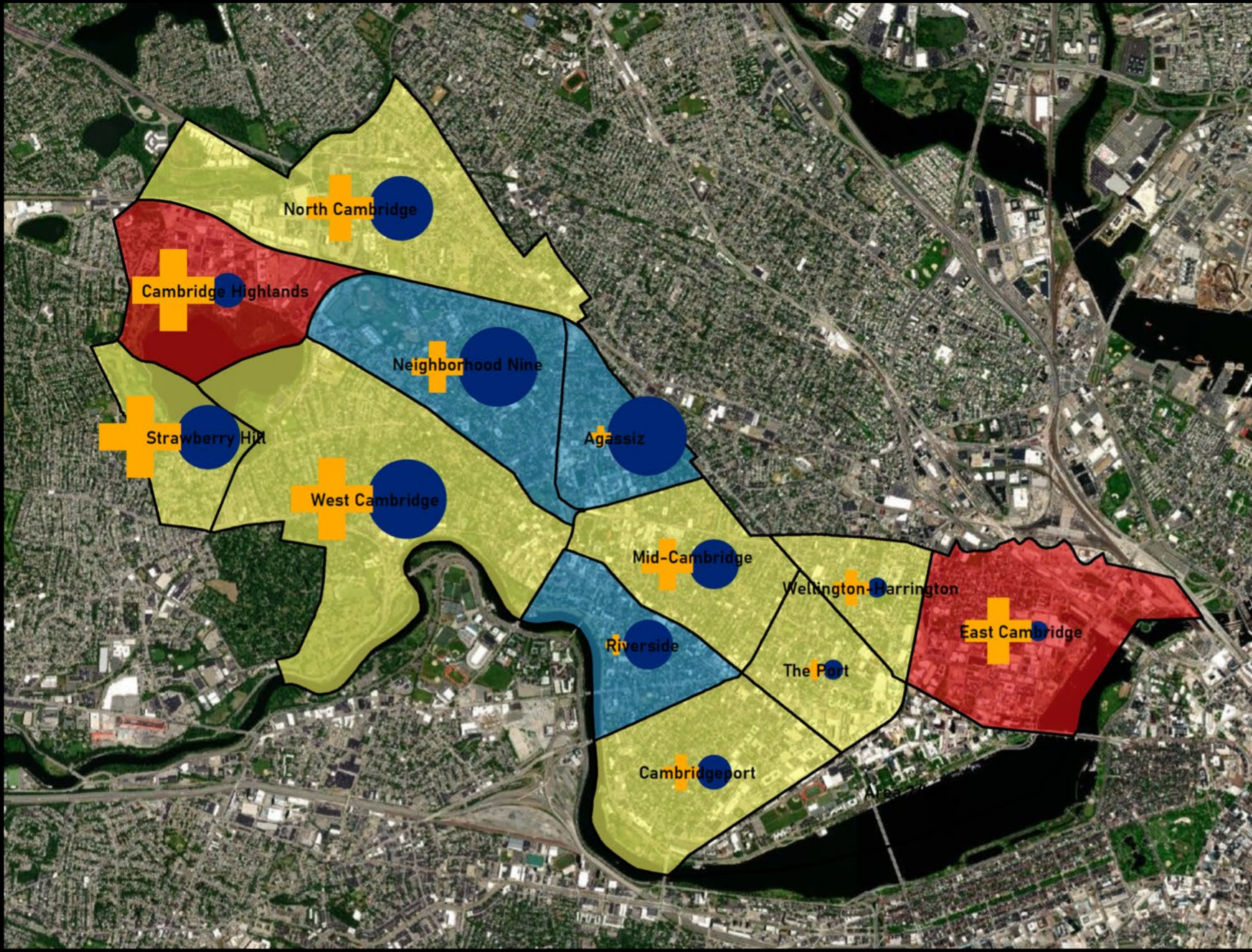


Overall Heat Risk Assessment

The mortality and AC scores are based on quintile rankings of neighborhood heat mortality rate (per 100,000 population) and central AC prevalence (% of all parcels). Higher scores indicate higher levels of exposure and sensitivity combined with lower levels of adaptive capacity for heat stress.



Access to Air Conditioning



AC Rank

Mortality Rank

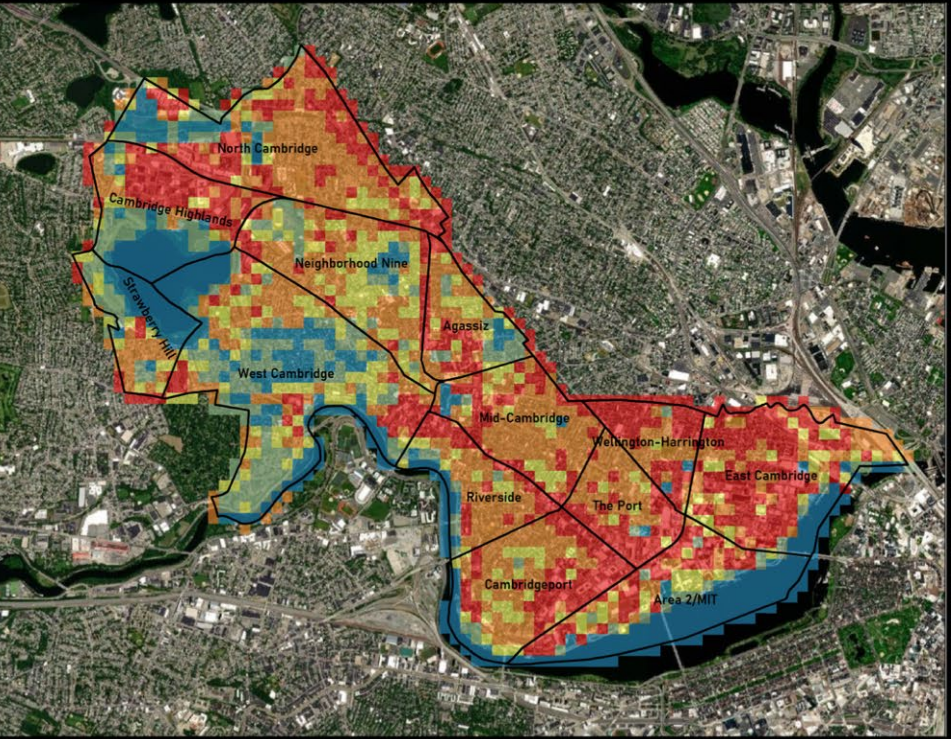
Total Heat Risk

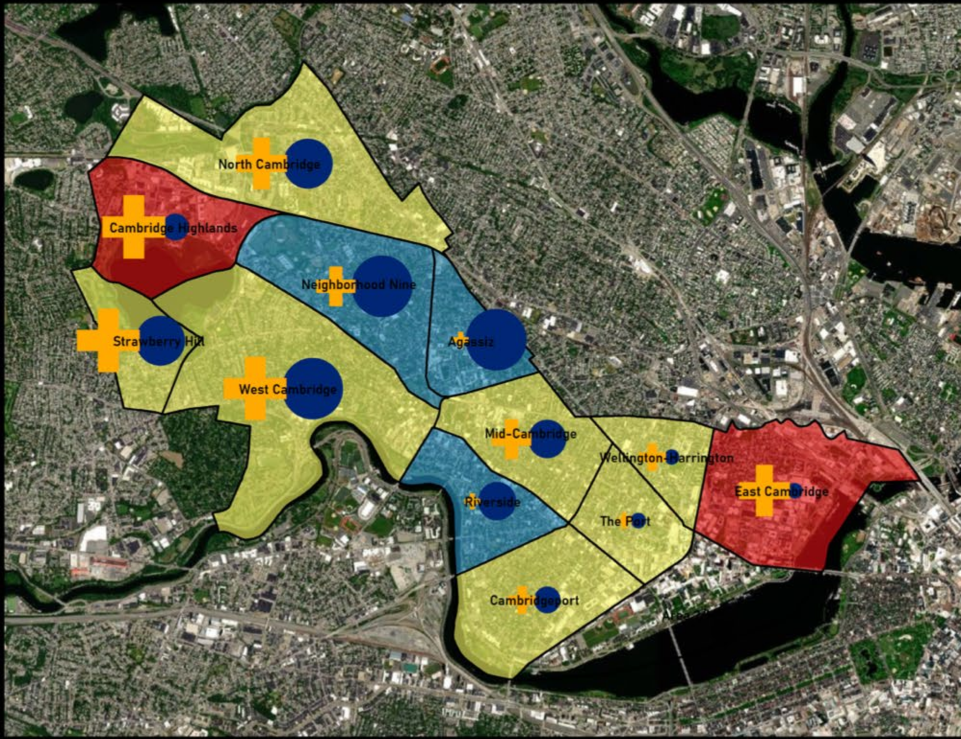
Low

Medium

High

Overall Heat Risk Assessment





Overall heat risk does not fully align with heat exposure. Despite relatively high levels of average temperature, The Port neighborhood is scored as having moderate risk, while the coolest neighborhood overall, West Cambridge, also is found to exhibit a moderate level of heat risk when accounting for population sensitivity.

Policy innovation: green area ratios

A1 - Landscaped Area <24” Soil Depth

A2 - Landscaped Area >24” Soil Depth

A3 - Rain Garden

B1 - Groundcovers <2’ Height

B2 - Plants >2’ Height

B3 - Small Tree

B5 - Medium Tree

B6 - Large Tree

B7 - Large Existing Tree

C1 - Green Roof 2-4” Growth Medium

C2 - Green Roof >4” Growth Medium

D - Green Wall

E - Water Feature

F1 - PermeablePaving 6-24” Subgrade

F2 - Permeable Paving >24” Subgrade

G - Structural Soil Systems

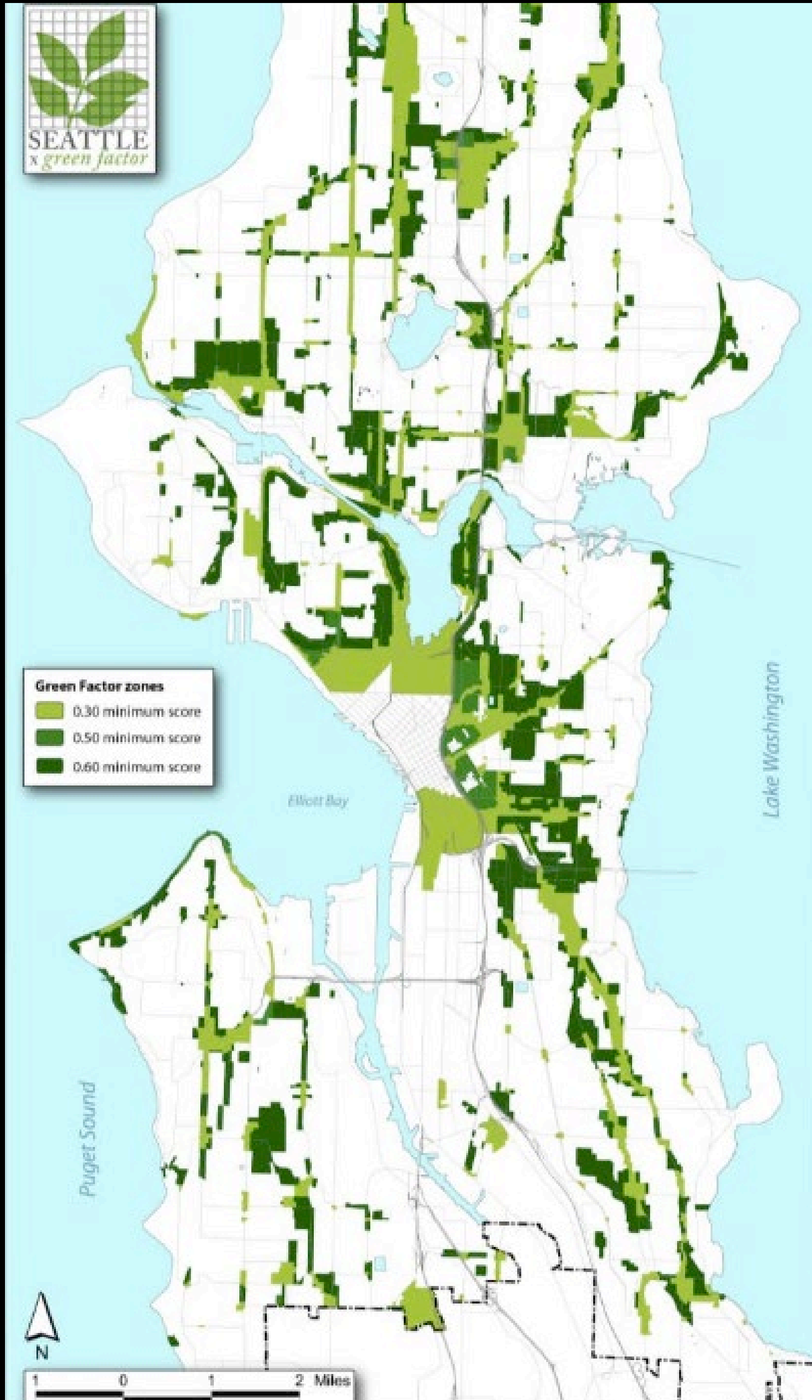
H1 - Drought Tolerant/Natives

H2 - Rainwater Cistern

H3 - Public Visibility

H4 - Food Cultivation

Berger Partnership PS, 2008

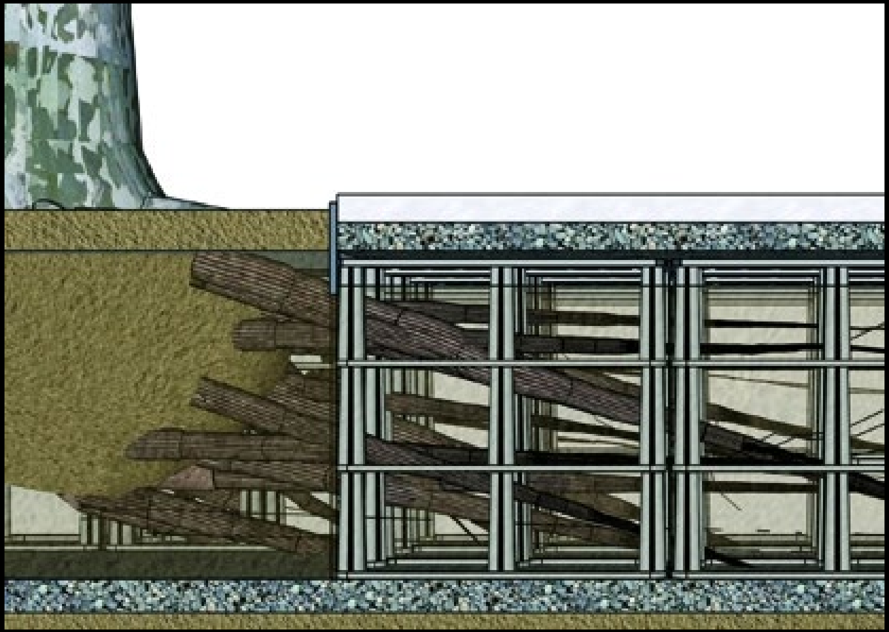


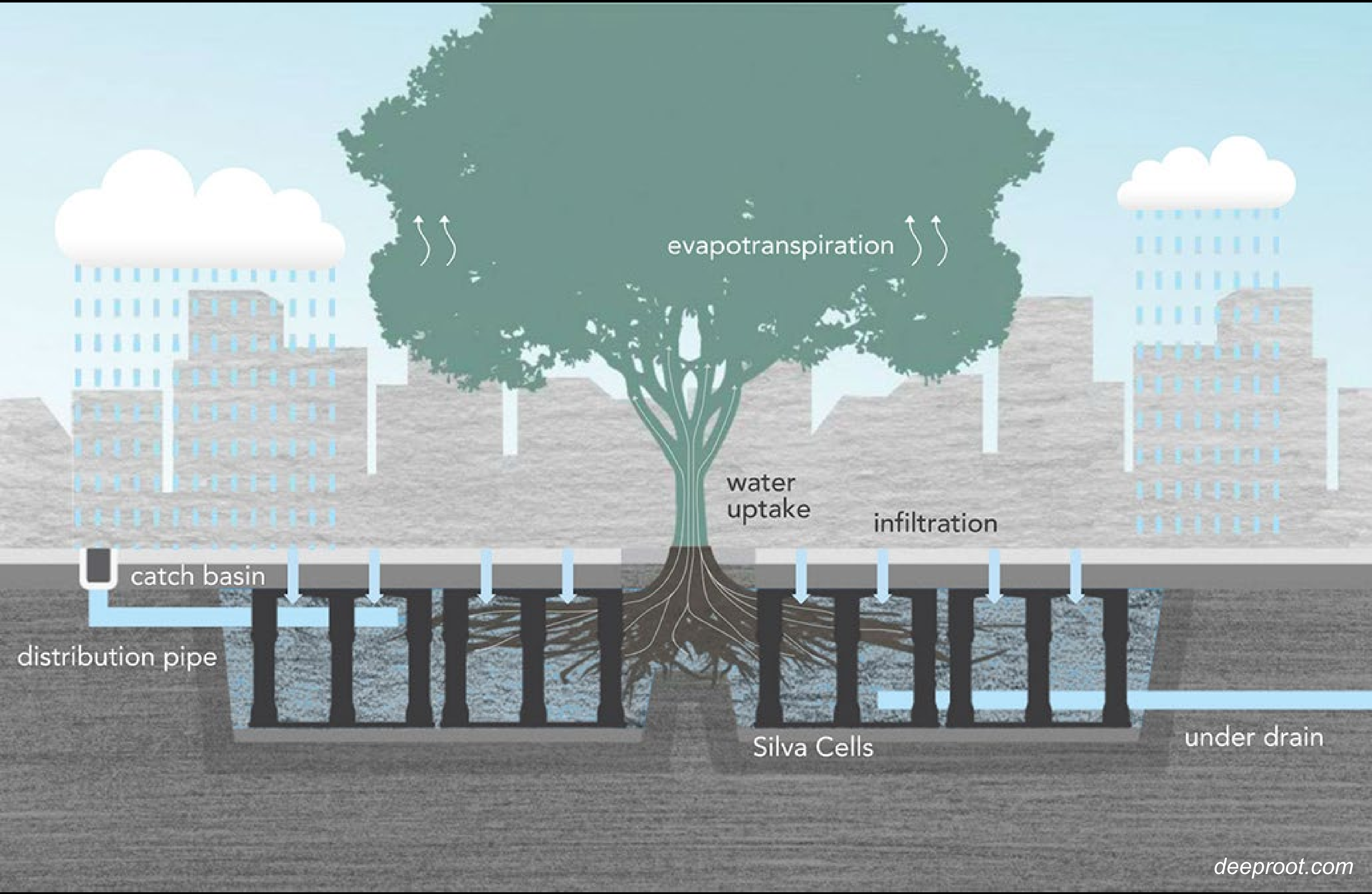
Minimum Green Factor Score by Zone

Zone	Minimum score
Commercial & Neighborhood Commercial	0.30 (2006)
Industrial Commercial (in Urban Villages)	0.30 (2010)
Midrise and Highrise Residential	0.50 (2009)
Lowrise Multifamily Residential	0.60 (2010)
South Downtown	0.30 (2011)
South Lake Union	0.30 (2013)

City of Seattle (2014)

Urban tree innovations: Silva cells




evapotranspiration
water uptake
infiltration
catch basin
distribution pipe
Silva Cells
under drain
deeproot.com

HISTORIC 4TH WARD PARK USES SUSPENDED PAVEMENT

36 New and Plaza Path Trees receive soil from Silva Cells

deeproot.com

Recommendations for Policy

1. Prepare now

Municipalities should prepare now for concurrent heatwave and power outage events. Use both **passive** (cool roof and tree canopy) and **active** (personal adaptation) strategies

2. Housing matters

Identify high-risk populations by housing type for most effective interventions

3. No "one-size-fits-all" solutions

Heat mitigation strategies must be tailored to the local climate, as effectiveness may vary

4. Look beyond "hotspots"

Implement strategies in warm **and** cool areas of a city, not just the "hotspots"

Thank you

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urbanclimate.gatech.edu


RESILIENCE
COFFEE HOUR
Friday, June 3rd
8:30 AM – 9:30 AM
bit.ly/CERN-Coffee_June
The Disproportionate
Impacts of Climate Change
on People In Poverty
Alicia Johnson
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RESILIENCE COFFEE HOUR

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