

BUILDINGENERGY BOSTON

Keeping it Cool! Toolkits and Strategies for Extreme Heat and Urban Heat Island Mitigation

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Curated by Tristan Grant

Northeast Sustainable Energy Association (NESEA) | March 23, 2026

Keeping it Cool! Toolkits Strategies for extreme heat and Urban Heat Island Mitigation

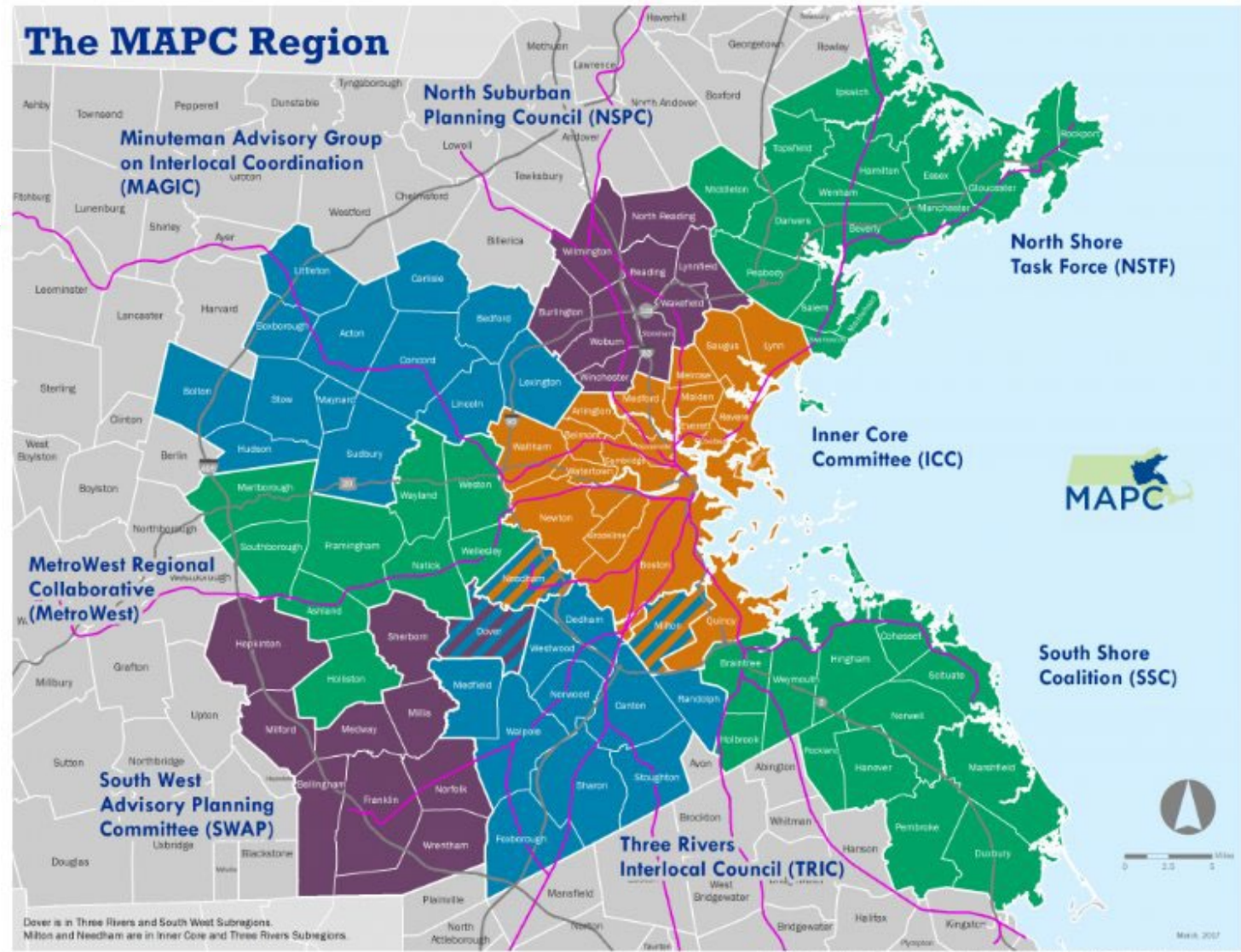
BuildingEnergy Boston 2026

March 23, 2026

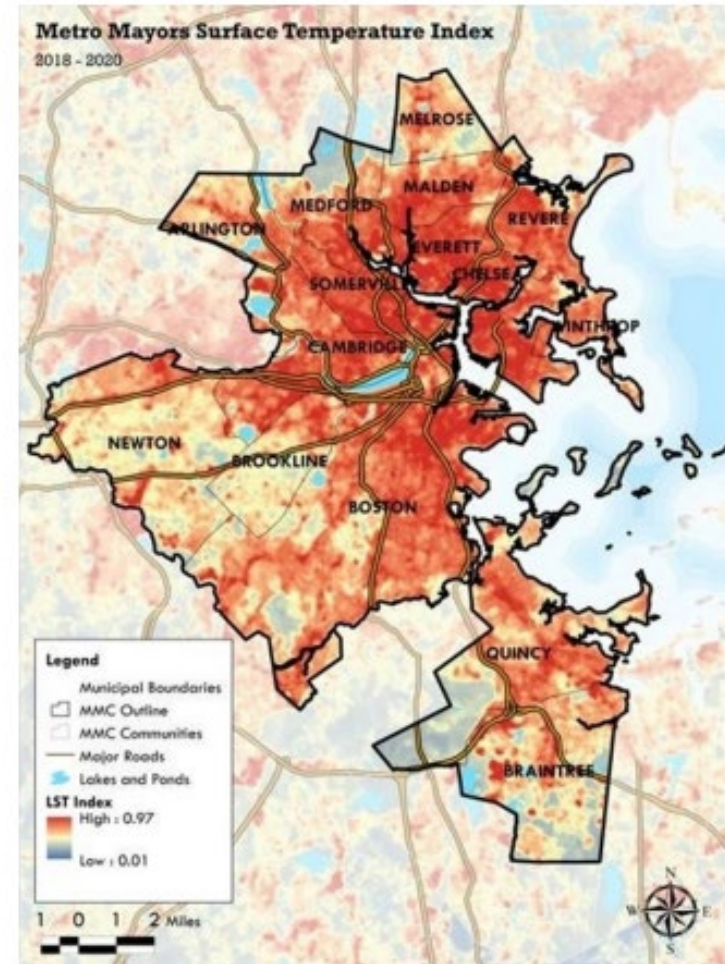
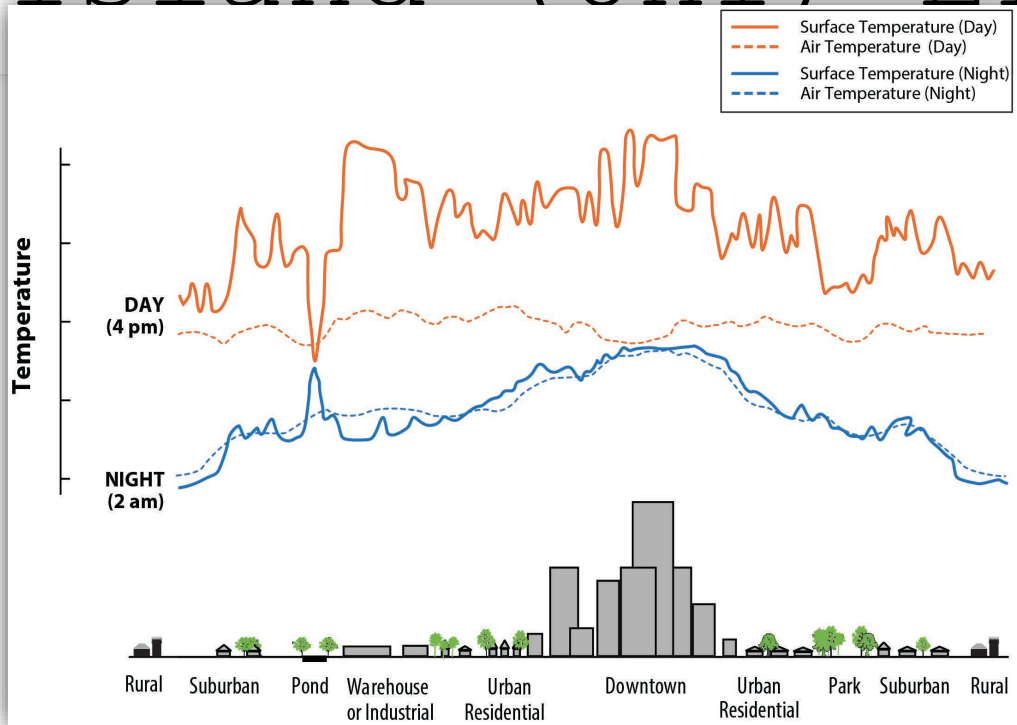
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The Metropolitan Area Planning Council (MAPC) is the regional planning agency for the 101 cities and towns of Greater Boston.

We work to create a more sustainable, equitable, collaborative, and climate-resilient



Extreme Heat: Urban Heat Island (UHI) Effect



Source: US EPA [Reducing Urban Heat Islands: Compendium of Strategies - Urban Heat Island Basics](#)

Extreme Heat: A Growing Threat to MA

Source: City of Cambridge "Heat Risk" Resilient Cambridge Report

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31	1	2
3	4	5	6	7	8	9
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1971 - 2000
(Baseline)

S	M	T	W	T	F	S
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27	28	29	30	31	1	2
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24	25	26	27	28	29	30

2015 - 2044
(2030)

S	M	T	W	T	F	S
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15	16	17	18	19	20	21
22	23	24	25	26	27	28
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3	4	5	6	7	8	9
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17	18	19	20	21	22	23
24	25	26	27	28	29	30

2055 - 2084
(2070)

- Above 90°F - Low Scenario
- Above 90°F - High Scenario
- Above 100°F - Low Scenario
- High 100°F - High Scenario

By the 2030s, average summer heat index in the City can be around 95°F, and by the 2070s, average summer heat index can be as high as 110°F.

Why are we vulnerabl



Aging infrastructure and old housing stock not built for prolonged heat



Lack of policies and standards protecting people from extreme heat



Residents are less culturally / behaviorally adapted to extreme heat



Public health threat- increase heat-related illnesses and exacerbate existing health



WEATHER

Record-high temperatures leave thousands of Mass. customers without power

Tuesday marked the peak of a recent heat wave in the Northeast, leaving nearly 14,000 customers without power.

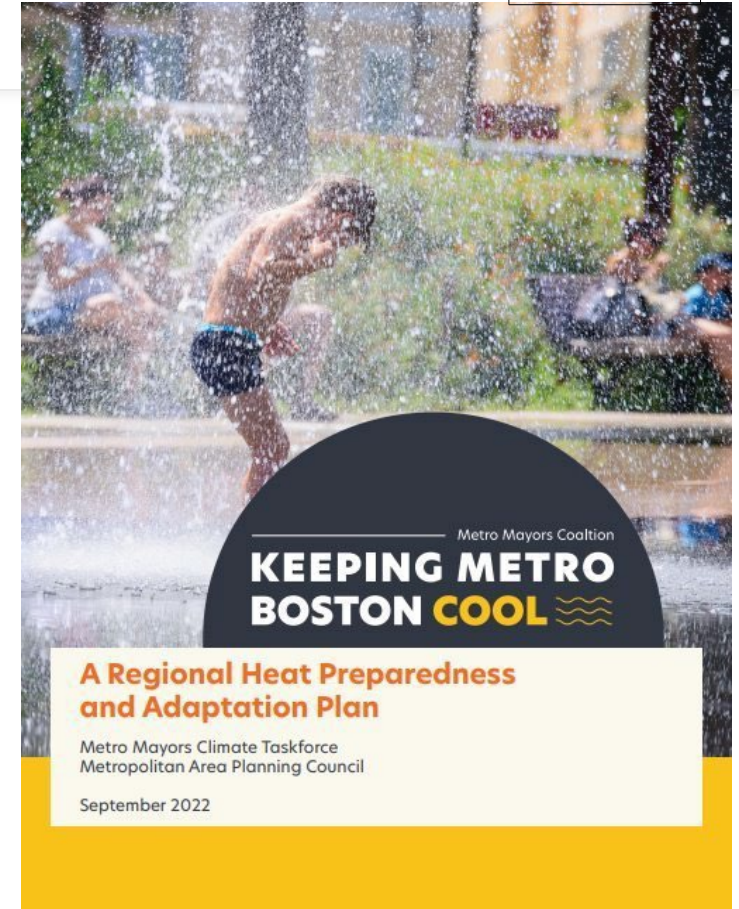
Support for Communities

Data & community centered planning

Coalition building, policy, & advocacy

Implementation & technical assistance
for solutions

Data & Community Centered Planning



Coalition Building, Policy & Advocacy

- [Resilient Land Use Toolkit](#) - examples for local zoning across a variety of climate impacts
- [Healthy Environments Advance Learning](#) – policies and procedures for addressing heat in schools
- Research and advocacy for local and state policies



FOSTERING COLLABORATIONS
A Symposium to Advance Equitable Heat Health Actions

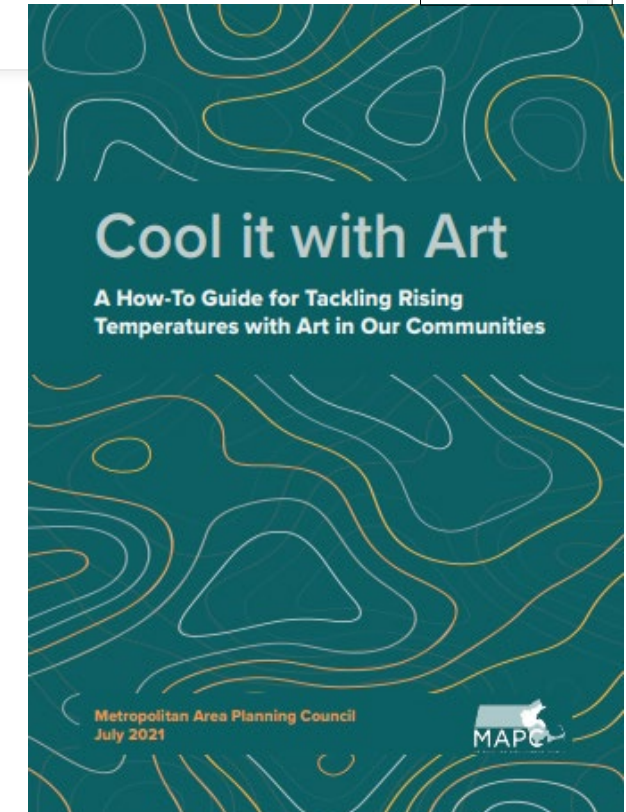
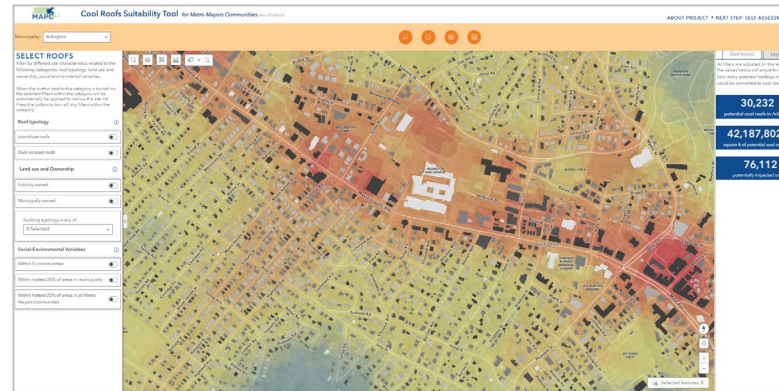
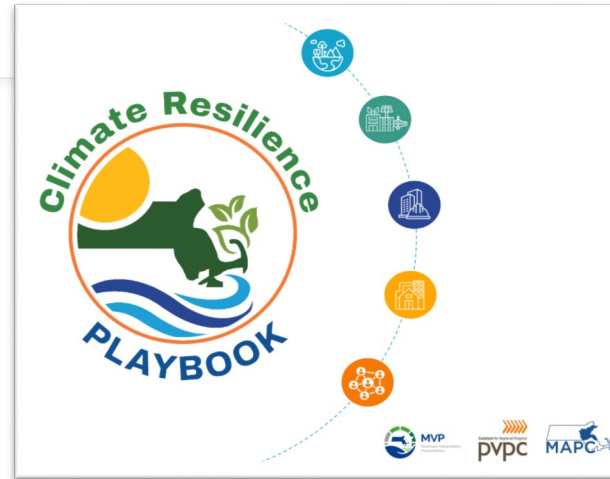


HARIRI INSTITUTE



Implementation Resources for Extreme Heat

- [Cool Roof Site Suitability Tools](#)
- [Resilience Playbook](#)
- Cool Communications and Social Media Toolkits
 - [Social Media Toolkit](#)
- [Cool it with Art](#) guidebook





The Smart Surfaces Coalition is made up of more than 50 leading national and international organizations with a shared commitment to creating **cooler**, **healthier**, and **more resilient** cities by cost-effectively reducing the impacts of extreme urban heat and flooding.

What are Smart Surfaces?

Infrastructure strategies that cost-effectively manage urban heat and stormwater while maximizing health, climate, and equity co-benefits

Reflective/Cool Roofs



Green Roofs



Porous & Permeable Pavements



Solar Photovoltaics



Reflective/Cool Pavements



Trees



Green Stormwater Infrastructure

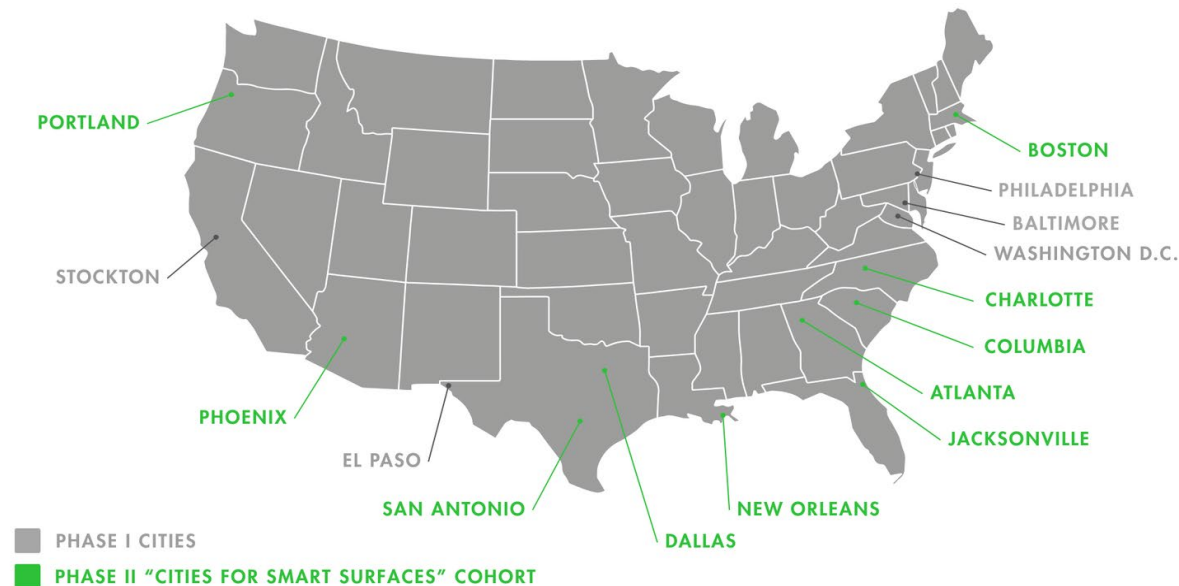


Zero & Negative-Carbon Concrete

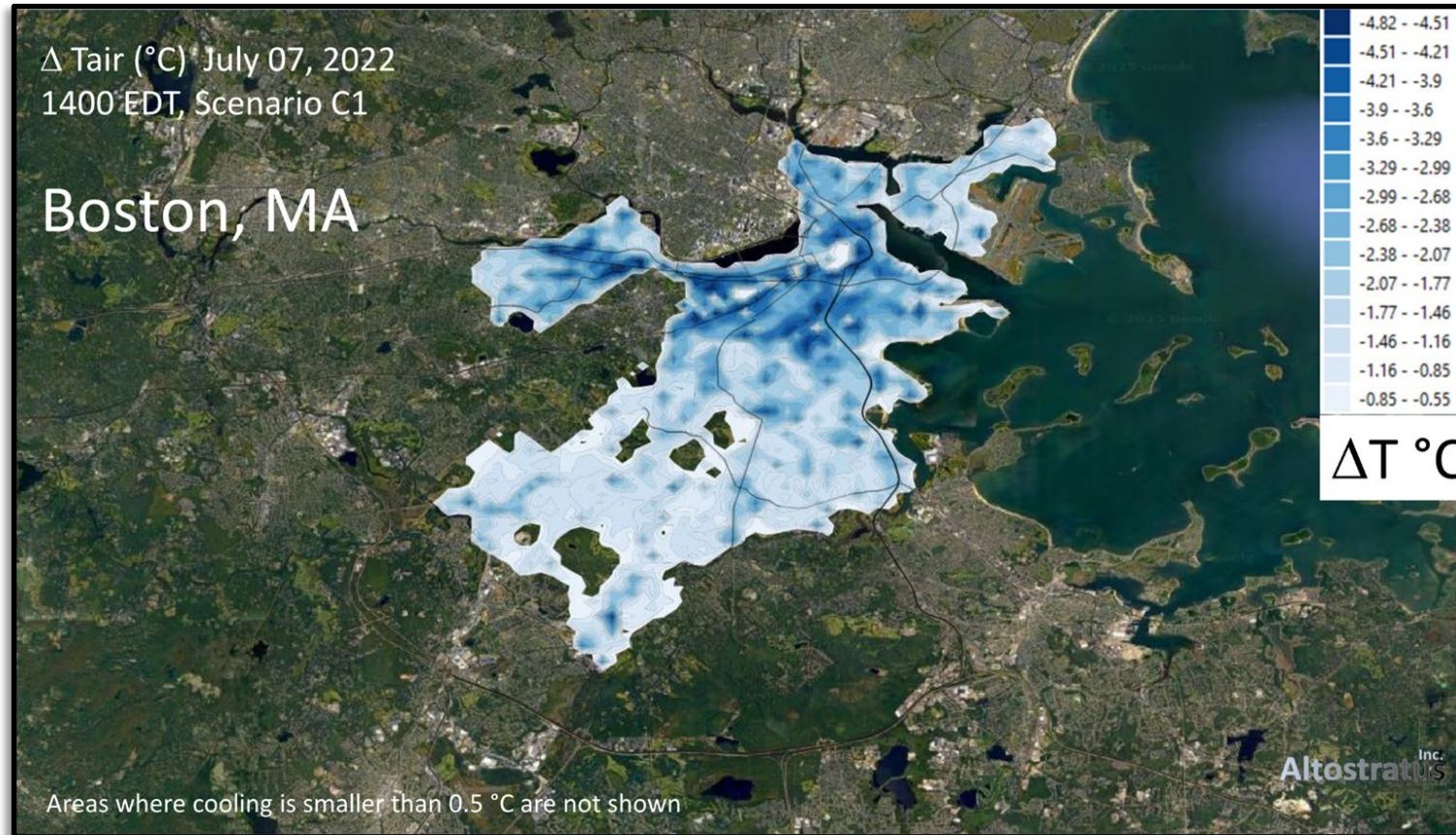


Cities for Smart Surfaces Program

SSC is partnering with 10 metro areas across the US to facilitate the adoption of Smart Surfaces at the metropolitan level and working with communities in those regions to support community-led, local Smart Surface implementation projects.

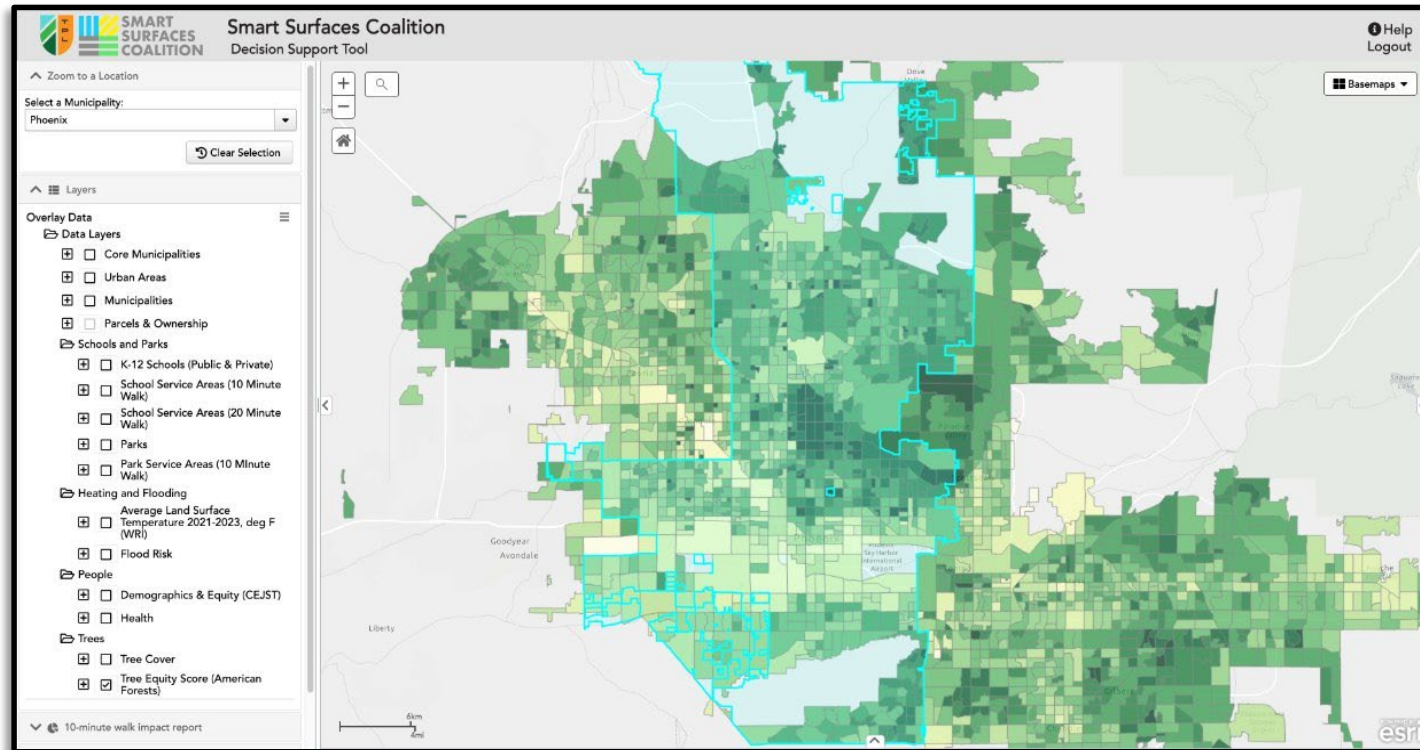


Micrometeorological Modeling



- Establishes baseline air temperatures
- Models air temperature reductions as a result of:
 - Cool roofs
 - Cool pavement
 - Urban trees
- Used for benefit-cost modeling in policy and planning tools

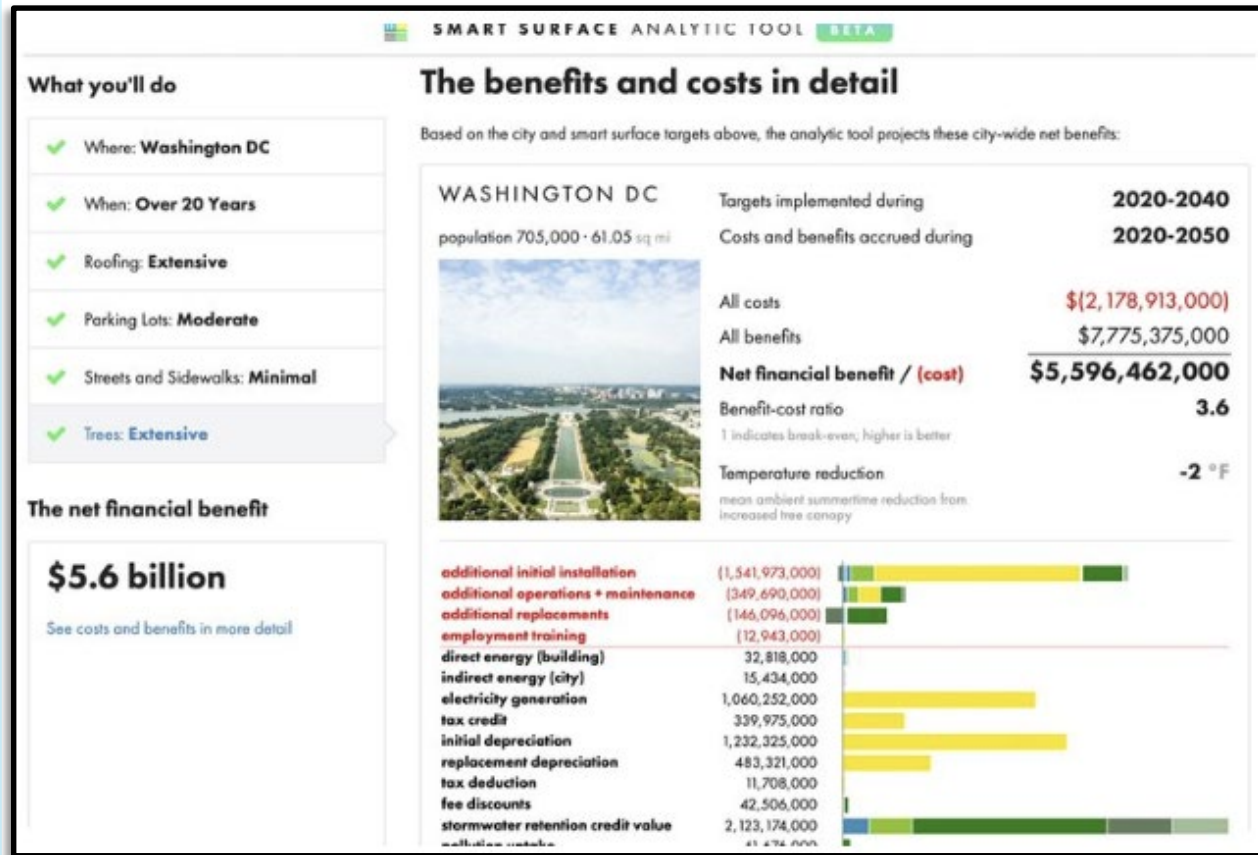
Decision Support Tool



Supports:

- Communication/education between city staff, policy makers, and public
- Development of city plans, policies, and grant applications
- Project and site prioritization

Benefit-Cost Analysis Tool



Includes:

- \$\$, °F, and CO2e impact through 2030, 2040, and 2050
- Benefits from infrastructure, energy, health, and environmental sectors

Allows municipalities to:

- Model impacts of policy changes and city- and neighborhood-scale infrastructure projects
- Communicate to public, city staff, policy makers, and City Manager/Mayor
- Generate metrics for city plans and federal and state grant applications

Smart Surfaces Policy Tracker

POLICY TRACKER

Policy is a crucial pathway for adopting [Smart Surfaces](#) at scale. Building code amendments, zoning ordinances, and citywide or regional commitments are critical in accelerating implementation at scale and driving down costs. Many U.S. cities are already adopting Smart Surfaces policy across a wide range of geographic, political, and legal environments. The Smart Surfaces Policy Tracker can help you discover model ordinance language from peer cities, compare regulatory metrics in different communities, and understand the landscape of Smart Surfaces policy in the U.S. Before replicating any of these policy actions in your jurisdiction be sure to research, with the aid of counsel, how to adapt these to suit your particular jurisdiction.

Get started below!

FILTER BY POLICY TYPE(S): Any	FILTER BY STATE: Any
FILTER BY POLICY GOALS(S): Any	FILTER BY REGION: Any
FILTER BY SMART SURFACE(S): Any	FILTER BY JURISDICTION: Any
FILTER BY CLIMATE ZONE: Any	FILTER BY JURISDICTION SIZE: Any

SEARCH:
Enter keywords

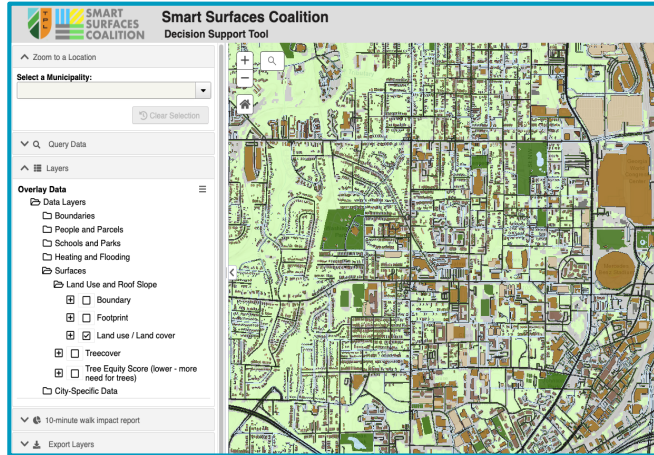
SEARCH CLEAR

Allows policymakers to:

- Search for policies by Smart Surface technology, jurisdiction size/location, climate zone, etc.
- Identify/compare policy language from peer cities
- Review 2,000+ policies to date
- Explore expert guidance about:
 - [Green stormwater infrastructure](#)
 - [Tree canopy](#)
 - [Cool roofs](#)
 - [Permeable pavement](#)
 - [Cool pavement](#)

Three New SSC Tools for Citywide Transformation

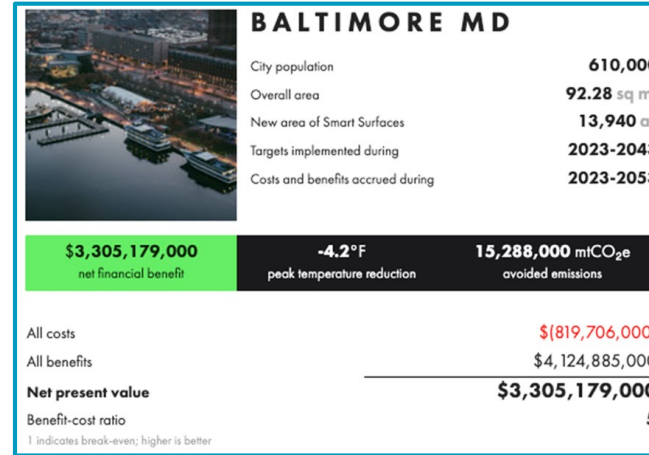
Decision Support Tool



Provides cities with highly detailed characterization of albedo, porosity, surface and ambient temperatures, along with census-tract level population health and equity data.

[Watch DST Demo](#)

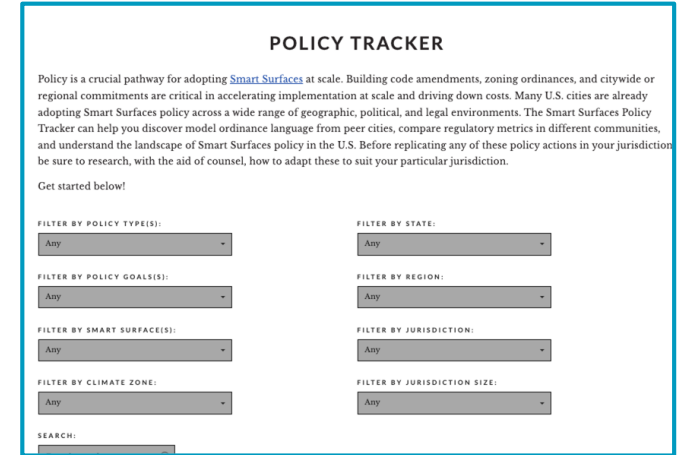
Benefit-Cost Analysis Tool



Enables cities to model the financial, health, environmental, and energy impacts of Smart Surface infrastructure interventions using at the census tract, city, and metro area levels.

[Watch BCAT Demo](#)

Smart Surfaces Policy Tracker



Enables cities to search from 2,000 Smart Surfaces policies and codes from all states to craft policies. SSC also developed model policy language to enable citywide adoption.

[Visit SSPT Site](#)

Project Implementation Platform

Design Resources

Permeable Pavement

Cumulative gross benefits of ~190-208 kg CO₂e/ft² in mitigated GHG emissions and \$88-\$92 S/ft² from reduced drought risk, attributable heat-related mortality reductions, and avoided gray infrastructure costs across different applications.

Permeable Articulating Concrete Blocks (Open Joints)
4.5-5.6" thick concrete blocks with high infiltration rates and load capacity

Initial Cost: ~\$13.50-\$18.10/ft²
Lifespan: 35+ yrs Initial Infiltration Rate: 1000-1600 in/hr
Maintenance: Vacuum clean only as needed (~\$0.75/ft²/treatment)
Uses: Most paved areas (roadways >35 mph). Interlocking paver design allows for easy removal, replacement, and underground utility repair access.

Permeable Pavers (Filled Joints)
Concrete or brick pavers in various colors and shapes with aggregate-filled joints

Initial Cost: ~\$8.00-\$29.90/ft²
Lifespan: 20-50 yrs Initial Infiltration Rate: 400-1000 in/hr
Maintenance: Clean with regenerative air or commercial vacuum sweeper 1-2x per year (~\$0.80-\$2.00/ft²/treatment due to aggregate joint fill replacement)
Uses: Most paved areas (pavers must be >3/4" thick for roadways <35 mph)

Precast Porous Concrete Panels
Modular precast porous concrete panels that arrive to project sites fully cured

Initial Cost: ~\$28.10-\$29.20/ft²
Lifespan: 20-30 yrs Initial Infiltration Rate: 250-1600 in/hr
Maintenance: Clean sweepers 2x per year
Uses: Parking lanes

Pour-in-Place Permeable Concrete
Cast on site with aggregate

Initial Cost: ~\$12-20/ft²
Lifespan: 20-30 yrs
Maintenance: Clean sweepers 2x per year
Uses: Driveways, parking lots

Permeable Resin
Mixture of small aggregate and resin

Initial Cost: ~\$29.10/ft²
Lifespan: 15-25 yrs
Maintenance: Pressure wash
Uses: Tree pits, parking areas

Note: Permeable pavement costs include surface material and cost of installed finish aggregate originating from 800-year-old layers on materials not included in the above cost estimates.

For guidance, refer to the [Georgia Stormwater Manual](#).

Bioswales

Low-sloped, vegetated channels that capture and infiltrate (or convey) stormwater while reducing runoff. To reduce maintenance and maximize biodiversity benefits, bioswales should be planted with native, herbaceous perennials, trees, and grasses.



- Initial Cost: Design dependent — ~\$6.88/ft² — ~\$71.60-\$601/ft² in benefits, including avoided gray infrastructure costs
- Benefits:**
- Bioswales provide ~2.35 kg CO₂e/ft² in avoided gray infrastructure costs
 - Bioswales can be designed to manage reducing or slowing rainfall contribution events.
 - A 400-foot long bioswale can capture 100,000 gallons of water.
 - Vegetation filters out sediment pollution before it reach sensitive water bodies.

Maintenance: ~\$0.08-\$0.26/ft²/year for weeding, litter pickup, unclogging adjacent drains

Potential Uses: Adjacent to roads/highways, parking lots, curb bumpouts

SMART SURFACES COALITION Project Design Checklist

Use the design checklist below to identify where Smart Surface strategies can be implemented in building and infrastructure projects and how they align with sustainable infrastructure rating systems. Each Smart Surface strategy lists applicable credits that may be earned through four widely used Frameworks: Envision (v3, 2019), LEED for Communities v4.1 (Existing Communities and Plan & Design Communities), LEED Building Design and Construction (BD+C v5 Green Construction and Core & Shell Construction), and the SITES Rating System (v2, 2015). Please note: Use of this checklist does not guarantee that projects will receive credits under Envision, LEED for Communities, LEED BD+C, or SITES. Credits for these frameworks are evaluated on a project-by-project basis. Refer to the original frameworks for complete credit requirements. See also USGBC's guidance on [Synergies between Smart Surfaces and LEED](#).

Smart Surfaces can be deployed broadly and serve a wide range of project goals; therefore, this checklist is not exhaustive. For example, the LEED Credit Library includes regional priority credits, exemplary performance credits, pilot credits, and project type credits not included in this checklist, but which Smart Surface strategies may also help achieve. When pursuing credits, note that individual Smart Surface strategies may not always reach minimum credit requirements on their own; combining them with other Smart Surface or sustainable building strategies can help maximize benefits and meet credit thresholds.

Smart Surfaces Strategy | **Eligible credit or points in framework**

Best Practices to Guide Construction Procedures

Follow a performance-based procurement policy

The performance targets set in a performance-based procurement policy can meet the energy efficiency, stormwater management, and solar reflectivity credits identified in this project checklist for building and infrastructure projects.

Buildings

Install a cool roof on buildings.
Cool roof defined as:

- Low-slope roofs
 - A minimum 3-year aged solar reflectance (SR) of 0.75, thermal emittance (TE) of 0.75
- Steep-slope roofs
 - Asphalt shingles: 3-year aged SR of 0.25 or higher; TE of 0.75
 - Tile 3-year aged SR of 0.40 or higher; TE of 0.75
 - Metal or other materials: 3-year aged SR of 0.50 or higher; TE of 0.75

See the Cool Roof Rating Council's Cool Roof Product Directory to identify available products above this threshold.

Cool roof products are available at the same (or lower) cost as equivalent, conventional dark roof products, and rarely come in lighter colors that reflect more solar radiation, reducing building energy consumption and urban heat island.

RA2.0 Innovate or Exceed Credit Requirements (1-10 pts possible)

IN Innovation (1-6 pts possible) | LEED for Communities

IN Innovation (1-6 pts possible) | LEED for Communities

C1.0 Innovation or Exemplary Performance (Option 2 - 3 pts) | SITES

RA2.1 Reduce Operational Energy Consumption (6-26 pts possible)

CR2.0 Reduce Greenhouse Gas Emissions (8-26 pts possible) | Envision

Plan and Design EN Energy Efficiency (1-4 pts possible) | LEED for Communities

IN Innovation (1-6 pts possible) | LEED for Communities

SS-9 Heat Island Reduction (2 pts possible)

EA1 Operational Carbon Projection and Decarbonization Plan (Required)

EA2 Reduce Peak Thermal Loads (Option 4 - 3 pts possible)

New Construction EA3 Enhanced Energy Efficiency (10 pts possible)

Core and Shell EA3 Enhanced Energy Efficiency (7 pts possible) | LEED BD+C

CA.9 Reduce Urban Heat Island Effects (4 pts)

C1.0 Innovation or Exemplary Performance (Option 1 - 3 pts) | SITES

Benefit-Cost Analysis Calculator + Report

STEP 1: Project Location and Project Details

Select the major city nearest to your project location. This tool is based on modeling conducted for 10 specific cities as part of Phase II of the Cities for Smart Surfaces. If your city is not listed, please select the most similar city to yours (based on proximity, climate zone, population, etc). If you're interested in modeling for your city, contact us at [info@smart-surfaces.org](#).

Project Location
City:

Project Finances
Analysis Timeline*:
Social Cost of Carbon: USD per Metric Ton of CO₂e
Discount Rate (real):

*This calculator assumes that a project will be implemented in a single calendar year, eg year 0. The analysis timeline refers to the period over which costs are realized.

STEP 2: Provide Existing Site Characteristics

Based on the following categories, specify areas in square feet (ft²). Costs and benefits cannot be calculated for the "Undefined Surface Type" land category.

Total Project Area (ft²):

For each land category, provide either the area (ft²) or the distribution percentage. The other cells will auto-calculate. Make sure inputs are complete before clicking "Calculate".

Land Category	Area (ft ²)	Percentage
Road	<input type="text" value="30,000"/>	<input type="text" value="30%"/>
Parking Lot	<input type="text" value="10,000"/>	<input type="text" value="10%"/>
Other Pavement*	<input type="text" value="5,000"/>	<input type="text" value="5%"/>
Steep Slope Roof	<input type="text" value="10,000"/>	<input type="text" value="10%"/>
Low Slope Roof	<input type="text" value="30,000"/>	<input type="text" value="30%"/>
Grass/Lawn	<input type="text" value="15,000"/>	<input type="text" value="15%"/>
Undefined Surface Type	<input type="text" value="0"/>	<input type="text" value="0%"/>
Total	100,000	100%

*Other pavement includes sidewalks, driveways, alleys, or any other hardscape comprised of concrete or asphalt that has not been classified into roads or parking.

STEP 3: Provide Project Details

Note: Each square foot of a given surface type can only be allocated to ONE measure type (i.e. Cool Roofs and Solar PV cannot be placed on the same square foot of roof area).

SMART SURFACES COALITION SMART SURFACES IN ATLANTA

Green, permeable, and reflective surfaces mitigate extreme heat and manage stormwater, improving health outcomes and saving money. This project advances Atlanta's goals of making the urban heat island effect and stormwater flooding, improving air and water quality, increasing tree canopy, saving energy and costs, more cost-effective ways to spend dollars, and delivering a more equitable and resilient built environment for all residents.

PROJECT DETAILS

Analysis Timeline	35	35	35
Total Costs	(\$475,000)	Cool Pavement	0.000
Total Benefits	\$1,200,000	Cool Roof	0.000
Total Present Value	\$1,488,000	Permeable Pavers	0.000
Benefit-Cost Ratio	4.51	Solar PV	0.000
		Urban Trees	0.000

BIORETENTION

Bioretention systems such as rain gardens or bioswales improve urban drainage by collecting and filtering stormwater runoff, reduce city All Costs: (\$388,000) S/ft²
costs for gray infrastructure, improve health outcomes, recharge All Benefits: \$1,488,000 S/ft²
groundwater, promote biodiversity, and add aesthetic value. In Net Present Value: \$1,200,000 S/ft²
addition, the application to these systems cools the surrounding Benefit-Cost Ratio: 4.74
environment through evapotranspiration.

COOL PAVEMENT

Cool (or "high albedo") pavements use reflective materials and coatings to bounce All Costs: All Costs: S/ft²
sunlight and heat away from cities, reducing surface temperatures. They also S/ft²
provide the underlying pavement, according to used life. Cool pavements can be Net Present Value: Net Present Value: S/ft²
used for roads and parking lots. Benefit-Cost Ratio: Benefit-Cost Ratio: S/ft²

COOL ROOF

Cool roofs are light colored and engineered to reflect sunlight, reducing the All Costs: All Costs: S/ft²
heating of both the building and outdoor air. Traditional dark colored roofs absorb S/ft²
more solar energy, radiating heat into the building and the surrounding air, which Net Present Value: Net Present Value: S/ft²
increases energy costs while decreasing comfort. Benefit-Cost Ratio: Benefit-Cost Ratio: S/ft²

➤ Cost and benefit data

➤ Performance specifications

➤ Case studies

➤ Design recommendations

- Quantified costs and benefits of Smart Surface strategies across infrastructure, energy, health, and environmental sectors
- Pre-formatted project report

Smart Surfaces Peer Learning Network

- Connects staff across cities and agencies to share strategies for urban climate resilience
- Regular Zoom meetings highlight city-led case studies and implementation lessons
- Access to SSC's Policy Help Desk for policy guidance and technical support
- Engagement with researchers on performance measurements and best practices



[Smart Surfaces Peer Learning Network Webpage](#)

Urban Heat Island Mitigation Toolkit

Design strategies, policy implementation approaches, and product recommendations for jointly considering UHI mitigation strategies with **other climate hazards and priorities.**

Covers:

Wildfire
Cold-Climate Considerations
Embodied Carbon

Intended for:

Policymakers
City planners
AEC community
Product specifiers

UHI and Wildfire Mitigation Strategies



The Issue

- **Replacing natural landscapes with buildings** and impermeable surfaces raises urban temperatures.
- **Wildfires** are becoming more frequent and intense due to **rising temperatures and prolonged drought** conditions.
- Cities exposed to both extreme heat and wildfire risk face **conflicting demands**: many wildfire-resilient strategies can worsen the UHI effect.
- **The need**: Recommendations for how to implement strategies that **reduce the hazards of wildfire** while **avoiding exacerbation of UHI**.



Recommendations for UHI Mitigation in Fire-Prone Areas

Cooling Strategy	Area Fire Risk Level (Max.)	Wildfire Considerations	Sample Policy Approaches
Mapping and planning	Citywide	Distinguish levels of risk across the city and implement solutions accordingly.	<ul style="list-style-type: none"> Zoning and overlays Heat and hazard mapping
High-albedo surfaces (pavements and roofs)	High	Light and reflective surfaces reduce the amount of heat absorbed and are suitable strategies for areas with high fire risk: no added fire fuel.	<ul style="list-style-type: none"> Zoning and overlays Jurisdictional ordinances Municipal programs
Urban forests and landscaping	High	Publish standards and guidelines that specify species selection, spacing, pruning, and fuel-load management to avoid increasing fire risk. Institute fire-resistant vegetation and fuel-reduction techniques , such as prescribed burns and removal of fire fuels.	<ul style="list-style-type: none"> Climate Plans and Urban Heat Island Mitigation Plans Wildfire-resilient landscape guidelines Municipal ordinances Landscaping initiatives
	Low	Institute continuous vegetation area to contribute to citywide cooling.	
Site design and landscaping	High	Create 30-100 ft defensible space (depending on hazard level) from building and institute distinct strategies based on proximity to building. Trees with min. 10' spacing from structure and each other. Populate with cool pavements, shade structures, low-fuel plants.	<ul style="list-style-type: none"> Zoning codes Building codes Wildfire-resilient landscape guidelines
	Medium	Trees with min. 10' spacing. Ground cover permitted but may not form means of transmitting fire to structure.	
Building envelope design	High	Adhere to Wildland Urban Interface (WUI) Code or equivalent.	<ul style="list-style-type: none"> Building and Green Codes Zoning Codes Weatherization Programs
	High	High-albedo building materials including walls and facades reduce heat without vegetation-related fire risk. Use non-vegetative shade structures near buildings.	
	Medium	Fire risk for green roofs and green walls depends on plant/species selection, maintenance, and irrigation	

Strategy Deep Dive: Evaluation of WUI Code Provisions

WUI Code Parameter	Notes on UHI Tradeoffs
Ignition-resistant and noncombustible exterior materials (Sections 503.2, 504.5)	<ul style="list-style-type: none"> Light-colored, non-combustible materials reduce heat absorption and do not add fire risk. If not lightly colored, darker materials can increase heat. To avoid, specify high-albedo cladding.
Class A roof coverings (highest fire resistance) (Section 504.2)	<ul style="list-style-type: none"> Cool roofs often meet Class A requirements, but may not always meet wildfire performance standards if they are combustible or prone to ember intrusion. Some fire-rated shingles have low reflectance. Specify cool-roof-rated Class A assemblies.
Tempered, multilayered glazing (Section 504.8)	<ul style="list-style-type: none"> Better insulation can reduce cooling loads. Pair with noncombustible shading devices if glazing is anticipated to increase solar heat gain.
Noncombustible decks and projections (Section 504.7)	<ul style="list-style-type: none"> Light-colored ignition-resistant decking can reduce heat. Metal or concrete decking can be specified with high reflectance.
Protected eaves, soffits, fascia (Section 504.3)	<ul style="list-style-type: none"> Insulated assemblies can reduce heat gain. Conflict: Cross-ventilation strategies improve thermal comfort and can relieve heat in drier climates but can also allow smoke or embers to enter.
Fire-resistant landscaping (Sections 603, 604)	<ul style="list-style-type: none"> Low-fuel plants can provide cooling, but limited canopy (widely-spaced) can reduce shade. Ground cover permitted in defensible space and can reduce UHI. Trees are permitted in defensible space but must be spaced 10' apart and away from structure. Characteristics of fire-resistive vegetation provided in Appendix F.
Defensible space (0-30 ft) and structure separation/spacing (Sections 503.4, 603, 604)	<ul style="list-style-type: none"> More hardscape can worsen UHI. Removing vegetation reduces natural cooling. Populate with cool pavements, shade structures, low-fuel plants.

UHI Mitigation Strategies in Cold Climates



The Issue

- The UHI effect is not limited to cities located in warm climates: **UHI has been observed in almost all urban areas, including in colder climates.**
- Colder climate cities can still overheat especially during the summer months.
- Many cities located in cool and cold climates are **already planning or and implementing UHI mitigation strategies.**
- **The need:** Recommendations for how to implement strategies to **mitigate UHI in the summer** while remaining mindful of these strategies' winter-time implications.



Overview of Recommendations

Cooling Strategy	Cold Climate Considerations	Sample Policy Approaches
Green Infrastructure	Covers a broad range of infrastructure and landscaping strategies employed to capture water, mitigate flood risk, and reduce UHI offer storm inundation mitigation benefits as well as summer cooling benefits.	<ul style="list-style-type: none"> • Impervious Coverage Limits • Street Design Standards • Zoning Standards and Guidelines
Trees and greening	Native species can tolerate a city's unique climatic conditions. Deciduous trees can offer significant passive energy benefits by providing shade in the summer and allowing for solar gain in the winter.	<ul style="list-style-type: none"> • Climate Plans and Urban Heat Island Mitigation Plans • Municipal Ordinances • Heat Island Reduction Codes • Tree Canopy Minimums
Pavements	Pervious and reflective pavements reduce heat absorbed by sun-facing surfaces. Cool infrastructure must also be able to withstand winter conditions.	<ul style="list-style-type: none"> • Permeable Paving Code • Reflective Surface Ordinance
Cool and green roofs	“Winter heating penalty” represents the risk that cool roofs can increase the need for heating and associated energy cost and demand in the winter. However, generally, cool roofs offer net annual energy savings in cold climates; winter heating penalties are often limited. Green roofs also provide added insulation in wintertime.	<ul style="list-style-type: none"> • Zoning Codes • Building and Green Codes • Economic Incentives
Building envelope design	Passive design strategies like reflectivity, insulation, air tightness are useful in cold climates to control indoor environments from outdoor extreme weather events (cold and heat).	<ul style="list-style-type: none"> • Building and Green Codes • Weatherization Programs • Economic Incentives

Strategy Deep Dive: Wintertime Penalties

Existing research on impacts of high-albedo roofs:

Wintertime heating penalties sometimes occur in colder-climate cities, but the **magnitude is often modest**, particularly when roofs are **well-insulated**. Penalties are usually **small compared to summer cooling savings**.

- **Annual net energy impact** is often small or still favorable to cool roofs, even in colder climates.
- Summer **cooling savings are substantial** for high-albedo roofs.
- **Snow cover moderates heating penalties**, already making the roof light-colored.
- Study in Greater Toronto Area showed potential **annual energy cost savings of more than \$11 million for ratepayers**.

Existing research on impacts of green roofs:

- In cold climates, green roofs provide **additional insulation**.
- Green roofs reduce summer heat gains and **do not incur the same winter penalty profile** as highly reflective roofs: by contrast, their surface properties **change seasonally** and they **add thermal mass**.
- Most building-energy studies find **modest but generally positive annual energy impacts** in colder climates.
- Benefits for **top-floor comfort**.

Strategy Deep Dive: Pavement Performance Ratings

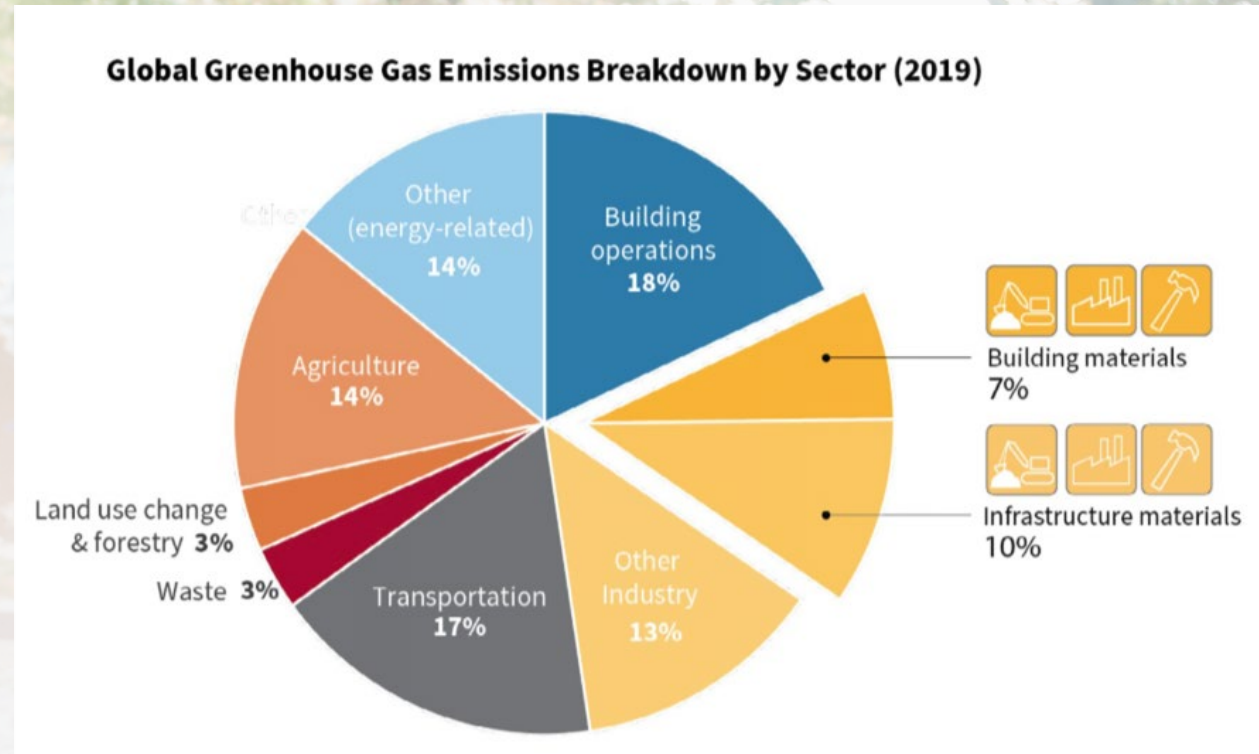
Product Type	UHI Performance	Cold Weather Performance
Reflective asphalt sealcoats	<ul style="list-style-type: none"> Reflective coatings can reduce surface temperatures by up to 12°F. Cooling effect can improve performance of asphalt mixtures in the field. 	<ul style="list-style-type: none"> Standard sealcoats reduce heat absorption and hinder snowmelt during winter. Thermochromic coatings offer an option: change color based on ambient temperature.
Concrete additives	<ul style="list-style-type: none"> Some additives (vermiculite, perlite, crushed glass) reduce thermal conductivity and daily temperature swings. Reduces heat retention but not as reflective as coatings or light-colored pavements. 	<ul style="list-style-type: none"> Durable in cold climates. Can handle freeze-thaw cycles and plowing. Additive improve resilience, longevity, and thermal stability. Phase-change materials (PCMs) can stabilize surface temperatures through the year.
Unit concrete or brick pavers (non-permeable)	<ul style="list-style-type: none"> Non-permeable surfaces store heat. Modest reflectivity gains. Light-colored options slightly reduce surface temperatures compared to conventional asphalt. 	<ul style="list-style-type: none"> Durable in cold climates. Can handle freeze-thaw cycles and plowing.
Permeable interlocking concrete pavers	<ul style="list-style-type: none"> Combined reflectivity and permeability. Light-colored PCIPs can increase reflectivity. Infiltration reduces surface heat. 	<ul style="list-style-type: none"> When over an open-grade base, good resistance to frost heave and cracking. Joint openings allow ice expansion and melt.
Grass pavers	<ul style="list-style-type: none"> Absorb less heat than conventional paving like asphalt and concrete. Evapotranspiration cools surfaces. Must be maintained and irrigated. 	<ul style="list-style-type: none"> Can tolerate freeze-thaw cycles with proper drainage. De-icing salts should be limited to protect vegetation.
Gravel-filled plastic grid pavers	<ul style="list-style-type: none"> Gravel surfaces store less heat than asphalt. Lacks reflectivity. Open-grid structure reduces heat retention. 	<ul style="list-style-type: none"> Plowable and skid-resistant. Fewer freeze-thaw issues with well-drained base. Compatible with de-icing salts.

Low Embodied Carbon UHI Mitigation Strategies



The Issue

- The **materials** that make up cities, buildings, and infrastructure are **principal culprits in contributing to UHI and to global emissions**. Many prevalent materials in cityscapes **absorb and trap heat while also constituting some of the highest embodied carbon materials**.
- Choosing high embodied carbon materials can **accelerate and contribute to the problem of climate change**, which exacerbates UHI.
- **The need:** Recommendations for strategies that **reduce UHI while minimizing the carbon and environmental impacts of material choices** that do so.










Source: Carbon Leadership Forum, based on data from World Resources Institute (WRI) and International Energy Agency (IEA)

Overview of Solutions Explored

UHI Reduction Strategy	Embodied Carbon Considerations	Sample Policy Approaches
<p>Urban forests, parks, green corridors, and other greening measures</p>	<ul style="list-style-type: none"> • No embodied carbon impact of vegetation; often net carbon sink. • For parks, hardscapes and structures may add embodied carbon but can be designed with low-carbon and reused materials. 	<ul style="list-style-type: none"> • Climate Plans and Urban Heat Island Mitigation Plans • Municipal ordinances • Requirements for low-carbon materials in city-funded parks • Incentives for private-sector greening
<p>High-emittance pavements</p>	<ul style="list-style-type: none"> • Conventional concrete and asphalt are carbon-heavy. • However, low-carbon and high-emittance alternatives exist. • High-albedo coatings add material impacts and do not eliminate the carbon footprint of the underlying pavement but can extend lifespan and reduce maintenance and replacement needs. 	<ul style="list-style-type: none"> • Pavement reflectance and GWP criteria in zoning/public works specifications • Pilot programs for cool and low-GWP pavements
<p>Cool roofs and facades</p>	<ul style="list-style-type: none"> • Polymer-based reflective coatings, membranes, and insulation can be carbon-intensive. • Frequent recoating or short service life replicates embodied carbon impacts. • Favoring low-carbon (durable membranes, mineral based coatings, etc.) materials and coatings where feasible can reduce embodied impacts. 	<ul style="list-style-type: none"> • Building and zoning codes • Municipal ordinances • Minimum reflectance/emissivity and maximum project GWP standards
<p>Green roofs and walls</p>	<ul style="list-style-type: none"> • Structural reinforcement, plastic drainage layers, and growing media can add embodied carbon. • Use lightweight, bio-based growing media and recycled plastic or mineral drainage layers and prioritize extensive, low-structure systems on existing buildings to avoid major structural upgrades. 	<ul style="list-style-type: none"> • Building and zoning codes • Design guidelines for low-GWP green roofs

Strategy Deep Dive: Roofing Products

Product Type with “Cool” Alternatives	Average Upfront GWP (kgCO ₂ e/m ²)	Embodied Carbon Considerations
	Asphalt shingles	3-6 <ul style="list-style-type: none"> • High embodied carbon from petroleum-based asphalt binders; not readily recyclable as roofing • End-of-life carbon contributions are significant • Shorter lifespan (15-30 years) requires more frequent replacements compared to metal, tile, slate • Lightweight compared to other products (less mass per square meter), meaning less material is used overall
	Metal shingles	Steel: 8-15 Aluminum: 20-40 <ul style="list-style-type: none"> • High upfront emissions associated with steel and aluminum production, but often contains recycled content • Longer lifespan (40-70 years) and high recyclability lowers lifetime embodied carbon
	Concrete tile	12-25 <ul style="list-style-type: none"> • 50+ year lifespan minimizes replacements • High upfront carbon emissions of cement/concrete production
	Clay tile	8-20 <ul style="list-style-type: none"> • 50+ year lifespan minimizes replacements • Lower upfront carbon emissions compared to concrete and other metals
	Vegetated roofs	20-60 <ul style="list-style-type: none"> • Several layers accumulate impacts: waterproofing + root barrier; drainage layer; filter fabric; growing media; structural reinforcement • Benefits include longer lifespan of membrane and carbon sequestration from greenery (reported separately) • Use lightweight, bio-based growing media and recycled plastic or mineral drainage layers and prioritize extensive, low-structure systems on existing buildings to avoid major structural upgrades.
	Coatings, single-ply membrane	3-12 depending on product <ul style="list-style-type: none"> • Boosts adhesion, durability, and corrosion resistance, extending service life of the roof • Medium lifespan for single-ply membranes (20-30+ years) • May not alone offset roof embodied carbon but extends service life • Emissions associated with manufacturing, production, and transportation of coatings relatively small
	Wood	1-6 <ul style="list-style-type: none"> • Smaller upfront carbon emissions compared to asphalt, steel, aluminum, assuming responsible



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