CAPITAL REGION
CLIMATE READINESS
COLLABORATIVE

CAPITAL REGION TRANSPORTATION SECTOR

Urban Heat Island Mitigation Plan

SACRAMENTO METROPOLITAN
AIR QUALITY
MANAGEMENT DISTRICT

Local
Government
Commission
Leaders for Livable Communities

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The urban heat island technical and modeling details presented in this report are the result of analyses conducted by Altostratus for this project.

The Technical Advisory Committee (TAC) is a collection of regional stakeholder agencies who have provided insight and guidance for this project and supported its development. The TAC met quarterly to review project milestones and provide feedback and technical advice. Their regional expertise informed their many useful comments on UHI assessment methodology and this plan's structure.

TAC MEMBERS

California Department of Public Health

California Environmental Protection Agency

City of Davis

City of Elk Grove

City of Folsom

City of Sacramento

El Dorado County

El Dorado County Air Quality Management District

El Dorado County Transportation Commission

Feather River Air Quality Management District

Local Government Commission

Placer County Air Pollution Control District

Sacramento Area Council of Governments

Sacramento County

Sacramento Metropolitan Air Quality Management District

Sacramento Metropolitan Utility District

Sacramento Regional Transit

Sacramento Tree Foundation

Yolo County

Yolo-Solano Air Quality Management District

Prepared by:

WSP USA | Sacramento, CA | wsp.com/usa

GLOSSARY

TERM	DEFINITION
Albedo	A unitless quantity describing a surface's solar energy reflectivity on a scale from zero to one. Lighter surfaces have a higher (closer to one) albedo and reflect more solar energy than darker surfaces, which have a lower (closer to zero) albedo.
Daily Minimum Temperatures	The coolest temperatures of a summer day (which generally occur in the hours around 0600 PDT). The urban heat island (UHI) modeling presented in this report compares temperature changes resulting from mitigation measures against both minimum and maximum daily temperature averages to show a range of cooling potential for each measure.
Daily Peak Temperatures	The hottest temperatures of a summer day (which generally occur in the hours around 1500 PDT). The UHI modeling presented in this report compares temperature changes resulting from mitigation measures against both minimum and maximum daily temperature averages to show a range of cooling potential for each measure.
Disadvantaged Community	As defined by the Office of Environmental Health Hazard Assessment (OEHHA) and the California Environmental Protection Agency (CalEPA), disadvantaged communities represent the top 25 percent of census tracts that are disproportionately burdened by and vulnerable to pollution. The State of California uses its CalEnviroscreen tool to designate these disadvantaged communities for Senate Bill 535 purposes.
Modeling Priority Areas	This project involved modeling mitigation measure efficacy at a 500-meter scale. Because of the intensive nature of the computational calculations needed to evaluate at this high level of granularity, complete coverage of the Capital Region was infeasible. Therefore, the project team examined regional UHI effect results (along with the proportion of underserved communities and the density of transportation projects) to identify six priority areas to model in greater detail.
Smart Growth	The use of development strategies that preserve community health, the surrounding natural environment, air and water quality, and other resources. Common strategies include reusing developed land, designing compact and walkable neighborhoods, preserving open space, supporting community involvement in design, and providing multiple transportation options.
Thermal Emittance	The ability of a material to release absorbed heat, represented by a number between 0 and 1, or 0 percent to 100 percent. An object that perfectly reflects radiant energy would be designated as 0 and an object that perfectly absorbs radiant energy would be designated as 1 (Energy Star).
Underserved/Under-resourced Community	Communities with lower resource availability that may experience lower socioeconomic status, higher housing costs, unemployment, linguistic isolation, and limited opportunities for transportation, education, financial advancement, and medical services. The term "underserved" often describes medically underserved areas (as designated by the Health Resources and Services Administration).
Urban Heat Island (UHI)	Locations in cities and suburbs with temperatures elevated beyond those in comparable rural and natural environments. Elevated temperatures persist after sunset and can migrate to surrounding areas. This plan discusses several causes.
Vulnerable Populations	Those who are particular susceptible to health impacts from high heat. For this document, and as defined by the California Department of Public Health (CDPH), vulnerable populations include people who are: • Transit (or active transportation) dependent • Without transportation access • Outdoor workers (e.g., farm laborers) • Immigrants • Elderly • Children • Pregnant • Of lower socioeconomic status • Socially or linguistically isolated • Living in institutions • Experiencing homelessness • Suffering from pre-existing health conditions or on multiple medications (Neil Maizlish 2017).

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1 INTRODUCTION

Situated in the northern Central Valley, the Capital Region is comprised of El Dorado, Placer, Sacramento, Sutter, Yolo, and Yuba counties, encompasses approximately 4,770 square miles, and is home to more than 2.5 million residents. Climate change poses threats to the natural environment, biodiversity, health, and economy of this vital region. Extreme heat and heat stress are significant climate risks for this region, and UHIs, a direct result of an area's level of urbanization, will further exacerbate these threats. In recognition of extreme heat and UHI risks, and with California SB1 Adaptation Planning Grant funding, the Sacramento Metropolitan Air Quality Management District (SMAQMD) and Local Government Commission (LGC) have developed this UHI Mitigation plan. This plan's purpose is to improve understanding of this region's UHI effects and identify opportunities to implement transportation-sector mitigation measures. Figure 1 provides a summary of this plan's primary goals and outcomes.

	PLAN GOALS		PLAN OUTCOMES
1	Understand the extent, intensity, and variability of UHI effect in the SACOG region	→	Map of urban heat during the high sensitivity period of June–September, overlaid with disadvantaged communities
2	Document the risks posed by the UHI effect on the SACOG region	→	Analysis of impacts to transportation, health, environmental, and community priorities
3	Identify optimal urban heat mitigation opportunities within the transportation sector	→	Best practices, case studies, and co-benefit analysis at the project category level
4	Prioritize urban heat mitigation opportunities within high priority regions	→	Detailed modeling of the quantitative impact of mitigation actions within priority regions
5	Provide recommendations for incorporating urban heat mitigation actions into transportation plans and focus projects	→	UHI implementation strategy for local jurisdictions

Figure 1: Summary of Plan Goals and Outcomes

1.1 What is the Urban Heat Island Effect?

The UHI effect refers to the higher temperatures that occur within and around urban areas, as compared to nearby suburban, rural, and natural areas. There are many drivers behind this effect, a primary one being that the built environment (such as concrete, asphalt, and roofs) absorbs and re-radiates more solar energy than the natural ground cover it replaced. Darker material absorbs more solar energy and re-radiates it to the surrounding environment. These surfaces have low albedo, which means they have a limited ability to reflect solar energy. Lighter surfaces have a higher albedo and reflect more solar energy. The low albedo of many artificial materials increases urban temperatures throughout the day and even after the sun has set. On a hot, sunny day, ground temperatures in urban areas can be 50 to 90°F (28-50°C) higher than the air temperature (U.S. EPA 2019).

Other primary UHI effect drivers stem from the population density of urban areas. Because so many people gather in urban cores, there is a greater concentration of equipment, vehicles, and buildings. Heat-generating mechanical processes like air conditioners, refrigerators, car engines, and generators exacerbate the effect. The concentration of structures in urban environments can also reduce airflow, making heat dissipation more difficult (Bartlett and Jain 2019). Land use and transportation planning have significant impacts on urban density and the UHI effect overall. For example, infill development is a useful solution to urban sprawl and helps protect surrounding open space—but it also increases infrastructure density and UHI effects.

Finally, because urban areas have less vegetation than natural areas, they also have less shade and evaporative cooling effects from evapotranspiration1 (U.S. EPA 2016). The aggregate impact of these drivers can be significant. Air temperatures in cities experiencing severe UHI effects can be as much as 22°F (12.2°C) warmer than neighboring rural areas (U.S. EPA 2019). Figure 2 illustrates the UHI effect and the differences found for various land cover types.

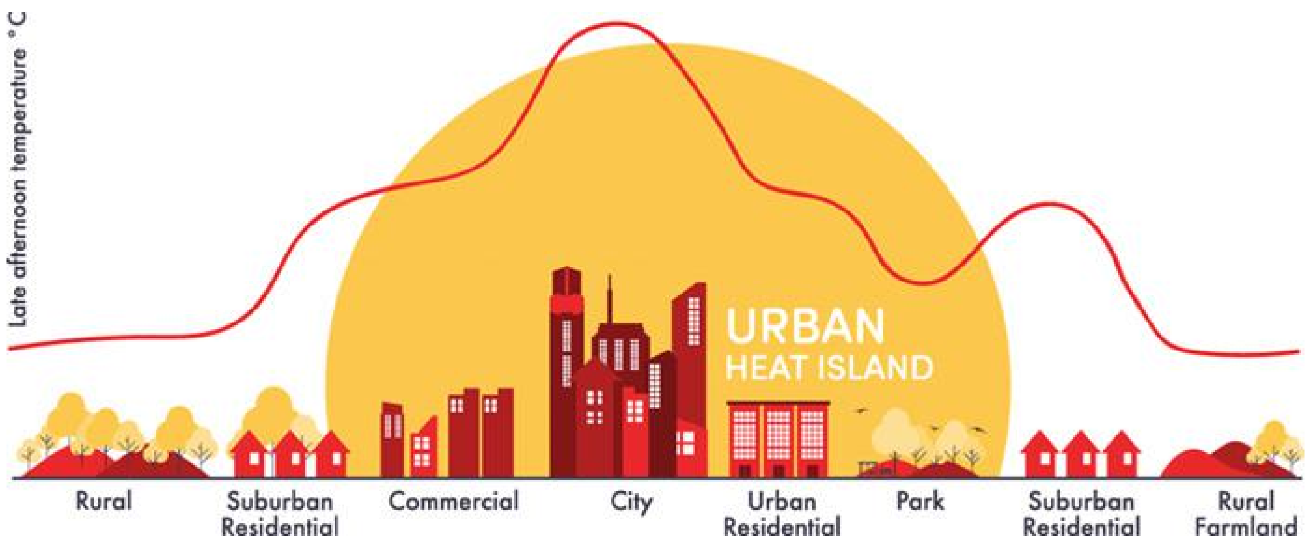

Figure 2: Visualization of the UHI Effect

Source: Kamyar Fuladlu

1.2 How does the transportation sector impact the UHI effect?

The transportation sector both contributes to and experiences the impacts of the UHI effect. In Sacramento, impermeable concrete or asphalt pavements cover about 35 percent of surface area in residential areas on average and up to 68 percent in commercial areas (Hashem Akbari 2002). Pavement is critical for transportation and community coherence, but it is also a significant UHI effect driver. The low albedo of pavement is what drives its UHI effect—it absorbs solar heat and re-emits it over time, which increases surrounding temperatures. In addition to paving and construction materials, a city's transportation system design can also increase UHI effects. For example, internal combustion engines emit waste heat, and single-occupancy vehicles consume more fuel and generate more heat per passenger than buses and subway systems, and thus contribute more to the UHI effect (Givoni 1998).

1 Evapotranspiration is the sum of evaporation from the land surface and transpiration from plants. Evaporation is when water moves from a land surface to the atmosphere in the form of water vapor. Transpiration is when water vapor is released from plants to the atmosphere. Both processes provide a cooling effect. For more information visit: https://www.usgs.gov/special-topic/water-science-school/science/evapotranspiration-and-water-cycle?qt-science_center_objects=0#qt-science_center_objects

1.3 Regional Context

There are growing concerns that California's rising temperatures combined with the UHI effect will cause extreme heat impacts (Louise Bedsworth 2018). While the UHI effect will cause challenges across the state, this plan addresses potential impacts specific to the Capital Region of California, which includes El Dorado, Placer, Sacramento, Sutter, Yolo, and Yuba counties (see Figure 3: SACOG Boundaries).[2] The Sacramento Area Council of Governments (SACOG) represents the Capital Region and its 22 cities (see Table 1: SACOG County and City Members), which are both urban and rural. The Capital Region's urban cores lie primarily on the valley floor in Yuba, Sutter, Yolo, Sacramento, and Placer counties. Its most populated cities are Sacramento and Elk Grove. The region's eastern part is more rural and lies in the Sierra Nevada and its foothills.

As the area's Metropolitan Planning Organization (MPO), SACOG leads transportation planning efforts, develops the long-range transportation plan (including the Metropolitan Transportation Plan/Sustainable Communities Strategy, or MTP/SCS), provides funding for regional projects, and conducts regional studies as necessary. This plan is written from a transportation planning perspective and focuses on incorporating UHI effect mitigation into the Capital Region's transportation network—which includes roadways, bike lanes, sidewalks, bus routes, and passenger, freight, and light rail.

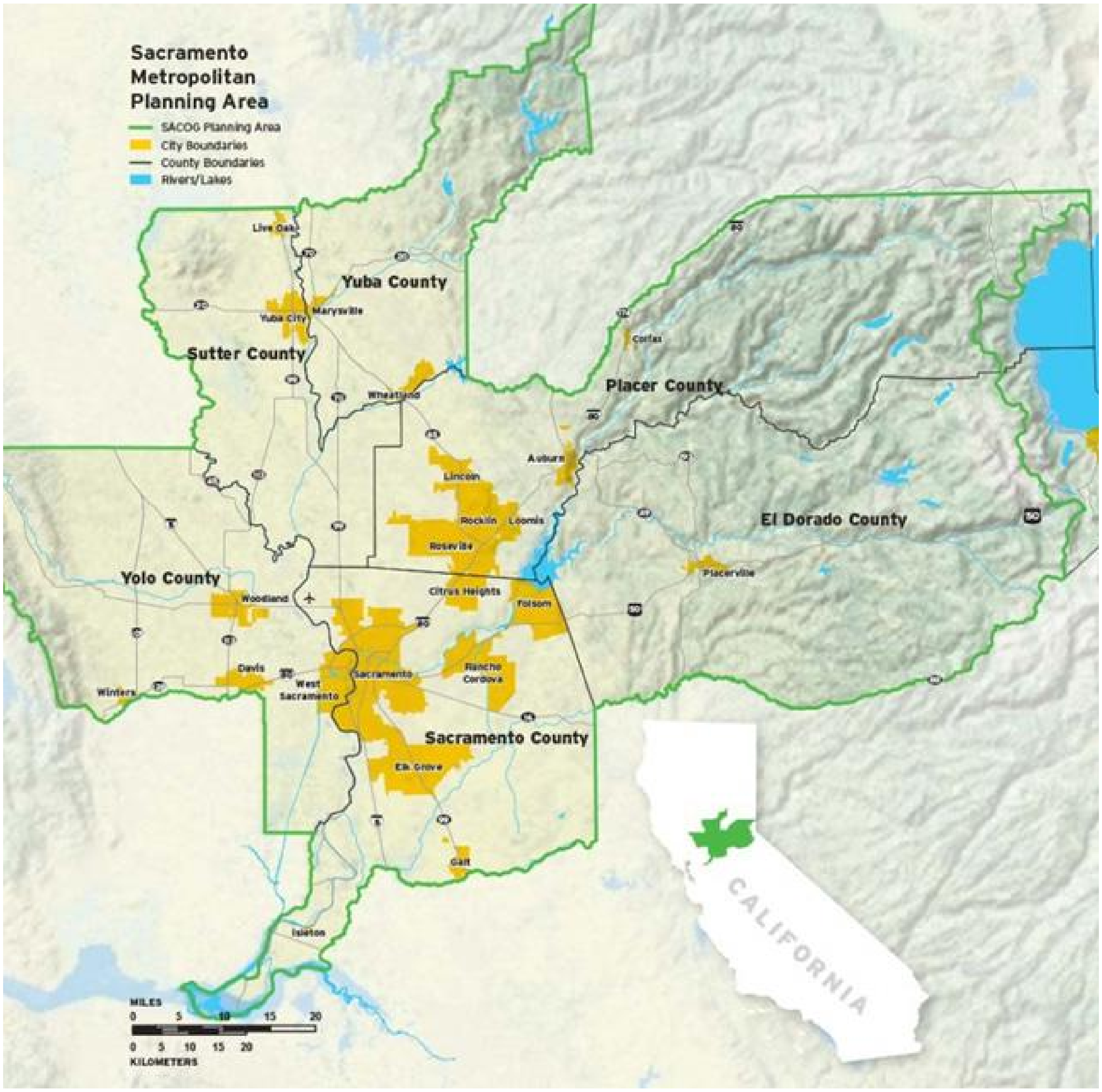

Figure 3: SACOG Boundaries

2 SACOG does not cover the Tahoe Basin portions of El Dorado or Placer County.

TABLE 1: SACOG COUNTY AND CITY MEMBERS

SACOG COUNTY	CITIES
El Dorado	Placerville
Placer	Auburn, Colfax, Lincoln, Rocklin, Roseville, Loomis
Sacramento	Sacramento, Elk Grove, Galt, Rancho Cordova, Citrus Heights, Folsom, Isleton
Sutter	Live Oak, Yuba City
Yolo	Davis, Woodland, Winters, West Sacramento
Yuba	Marysville, Wheatland

SACOG is one of many entities concerned about the impacts of the UHI effect and climate change in the Capital Region, which has a climate change collaborative called the Capital Region Climate Readiness Collaborative (CRC). CRC is a member of the Alliance of Regional Collaboratives for Climate Adaptation (ARCCA), and ARCCA represents leading collaborative networks from across California that strive to build regional climate impact resilience. The CRC focuses on climate change impacts to SACOG member counties and cities and helps drive their cross-sectoral partnerships to find solutions to the climate crisis.

A Technical Advisory Committee (TAC) made up of regional stakeholders (including CRC members such as the Sacramento Metropolitan Utility District (SMUD), the Sacramento Tree Foundation, and the Placer County Air Pollution Control District) was also instrumental in developing this plan. The TAC met quarterly to review project milestones and provide feedback and technical advice. Their regional expertise informed their many useful comments on UHI effect assessment methodology and this plan's structure.

1.3.1 CURRENT CONDITIONS

The Capital Region already experiences high temperatures and extreme heat days in summer months. To better understand how the UHI phenomenon impacts the Capital Region, and to lay a foundation for assessing various mitigation measures, this project modeled the regional UHI effect for 2013 to 2016 during the hottest time of each year—June, July, August, and the first two weeks of September from 2:00pm to 8:00pm (H. Taha, Personal communication 2019). Figure 4: UHI Impacts and Underserved Communities in the Capital Region below shows the results of this analysis and the region's disadvantaged communities, as identified by CalEnviroscreen. CalEnviroscreen represents disadvantaged communities as the top 25 percent of census tracts disproportionately burdened by pollution (OEHHA 2018).

The UHI data represent the 1400 to 2000 PDT interval average air temperature in the SACOG region from June to September, 2013 to 2016.

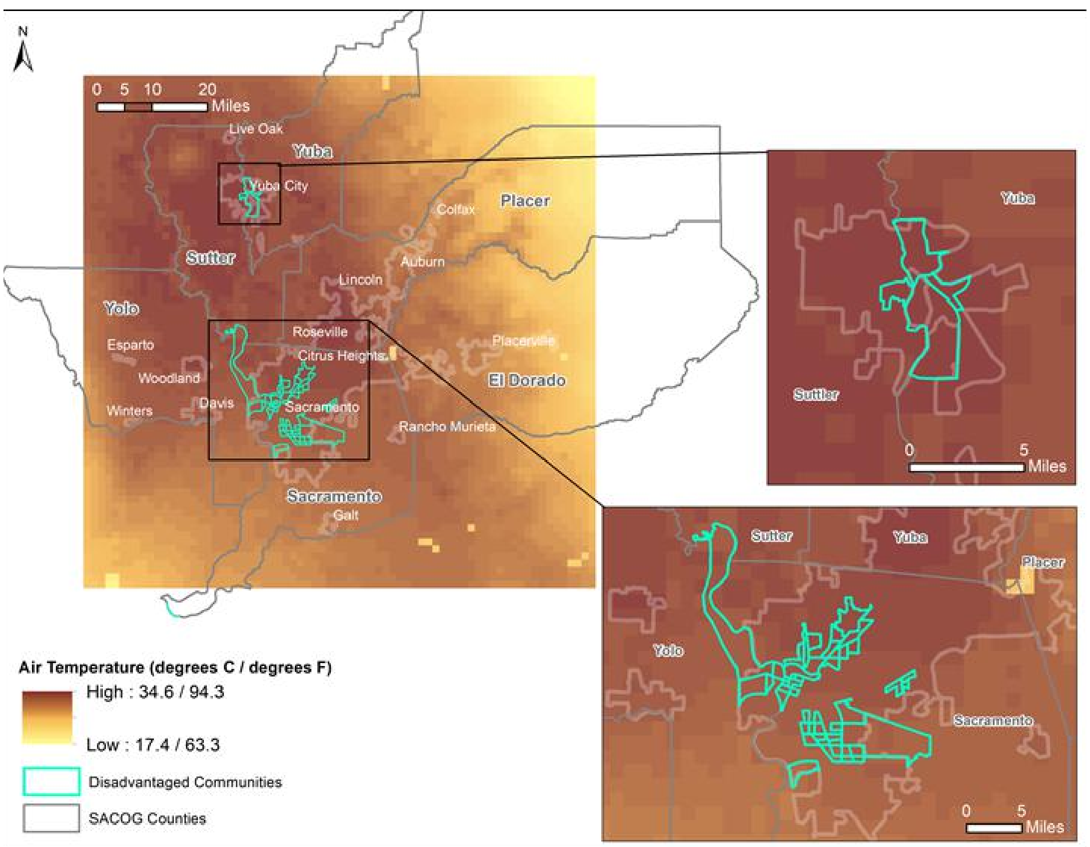

Figure 4: UHI Impacts and Underserved Communities in the Capital Region

The results indicate that hotspots are concentrated in two main core regions:[3] The first core region spans northern Sacramento County (Sacramento to Citrus Heights) to southwestern Placer County (Roseville to Lincoln), while the second spans southwestern Yuba County (Yuba City) through much of Sutter County. It is logical that these hotspots align with urban areas. However, an important result is that disadvantaged communities, particularly around Sacramento and Yuba City, experience some of the highest temperatures in the region. Prioritizing mitigation efforts in these areas will both reduce the UHI effect and directly benefit some of the region's most underserved communities.

Regulatory Context

In addition to understanding the physical impacts of the UHI effect, developing effective mitigation approaches requires understanding the applicable regulatory context. The section below summarizes applicable policies and guidance at the state and local levels. The full policy list is provided separately.

STATE POLICIES AND GUIDANCE

Existing policies, guidance, and tools related to UHIs and the assessment of future temperatures have been developed through a variety of channels, including California State Legislature policy, state agency (and their stakeholders') guidance, and research and tools developed by state agencies, research institutions, and their private partners. Table 2 summarizes the key state policies related to preparing for and adapting to future climate change, higher temperatures, and the UHI effect in the Capital Region.

TABLE 2: KEY STATE POLICIES RELATED TO CLIMATE CHANGE AND UHI

BILL OR ORDER NUMBER	YEAR	MANDATED FOR	SUMMARY
Executive Order B-30-15	2015	State agencies	Requires the consideration of climate change in all state investment decisions.
Senate Bill 379	2015	Local agencies	Requires the safety elements of General Plans to address climate change adaptation and resiliency strategies applicable to the city or county.
Assembly Bill 1482	2015	State agencies	State agencies shall prepare for climate change by collecting climate data, considering impacts in state investments, and promoting reliable transportation strategies. They will also update the Safeguarding California plan every three years.
Assembly Bill 2800	2016	State agencies	Requires consideration of climate change impacts in infrastructure planning, design, construction, investments, operations, and maintenance. Initiated the Climate-Safe Infrastructure Working Group.
Senate Bill 150	2017	State and local agencies	MPOs shall prepare Regional Transportation Plans that include, 1) a policy element describing the region's transportation needs, 2) a SCS that provides regional greenhouse gas (GHG) reduction targets, 3) the steps necessary to implement the plan, and 4) a financial element with the plan's cost. MPOs must revisit their plans every four years to monitor GHG reductions.
Senate Bill 1530	2017	State agencies	Supports the growth of urban tree canopies, especially in underserved and low-income communities.
Senate Bill 1035	2018	Local agencies	Requires the review and revision of General Plan safety elements to include climate adaptation, resiliency strategies, current flooding information, fire hazards, and climate change.

REGIONAL PLANS AND GUIDANCE

In addition to aligning with the state's climate change and UHI policies, many Capital Region jurisdictions have incorporated these elements into General Plans, Climate Action Plans, and other planning and guidance documents. Table 3: Selected Capital Region Transportation Plans and Guidancesummarizes a list of key UHI mitigation actions, goals, and policies that appear in these documents. The full collection of regional efforts is provided separately.

3 Taha 2017 defines UHI cores as "relatively larger urban areas where the UHI can develop fully and the downwind transport of heat can occur. There is one core, i.e., one main area where the UHI maximum can be defined and thus a single-core UHI index can be identified."

TABLE 3: SELECTED CAPITAL REGION TRANSPORTATION PLANS AND GUIDANCE

AGENCY	PLAN	PLAN TYPE	DATE	SELECTED ACTIONS FOCUSED ON UHI MITIGATION
City of Citrus Heights	General Plan	General Plan	2019	**Policy 60.1:** Mitigate the UHI effect and sequester carbon.
City of Citrus Heights	Greenhouse Gas Reduction Plan	Other	2011	**Measure 3-3.A:** Conduct a parking management study to monitor the implementation of revised 2006 parking standards (CHMC 106.36.080). (Co-benefit to reduce UHI).
City of Citrus Heights	Greenhouse Gas Reduction Plan	Other	2011	**Measure 7-1.A:** Enhance the city's urban forest and other green infrastructure to reduce building energy use, improve comfort, augment neighborhood aesthetics, improve stormwater quality, and maximize carbon capture and storage.
City of Davis	General Plan	General Plan	2013	**Goal #1:** The City of Davis will provide a comprehensive, integrated, connected transportation system that provides transportation mode choices. (Co-benefit to reduce UHI).
City of Elk Grove	General Plan	General Plan	2019	**Policy ER-6-1:** For severe weather conditions (including excessive heat), provide dedicated response services, including emergency services, local cooling shelters, and community notifications. **Policy ER-6-2:** Coordinate with Sacramento County Office of Emergency Services and the County Department of Public Health to communicate to vulnerable populations recommended resources, services, and impact mitigation strategies for extreme heat events. **Policy ER-6-4:** For new roadways, use cool pavements, higher-albedo impervious materials, and trees and foliage along the rights-of-way.
City of Folsom	General Plan	General Plan	2018	**NCR 1.1.8:** Planting in New Developments: Require landscaping and tree planting for streets, parking lot canopies, screening, and other amenities in all new developments (consistent with city landscaping development guidelines), to minimize the UHI effect. Planting strips must be large enough to accommodate a large tree canopy and healthy root growth.
City of Galt	General Plan	General Plan	2009	**Policy COS-7.4:** Energy Efficient Development: In addition to the energy regulations of Title 24, the city shall encourage energy efficiency in all new development. Possible energy-efficient design techniques include solar access, building siting to maximize natural heating and cooling, and landscaping to aid passive cooling and protection from winter winds.
City of Rancho Cordova	General Plan	General Plan	2018	**Action NR.4.2.6**: Establish guidelines to require tree planting to reduce the UHI effect and reduce air conditioning needs to conserve energy. **Action NR.4.3.3**: Coordinate with SMUD to offer property owners programs and resources on proper tree selection and recommendations on the best locations for reducing heat transfer effects, planting, and maintenance. **Action NR.4.3.4**: Actively participate in the Sacramento Tree Foundation Greenprint initiative.
City of Sacramento	Climate Action Plan	Climate Action Plan	2012	**Measure 6.1:** Prepare for Increases in Average Temperatures: Continue tree planting and replacement programs with an annual goal of 1,000 new trees. Explore options in the Green Development Code update process to improve parking lot shading requirements and overall tree health. Allow the installation of new trees and landscaping in existing parking lots without requiring parking space replacement when increasing building area or changes in use are not proposed. Explore options in the Green Development Code update process to require paving for new development to meet minimum Solar Reflectance Index (SRI) values. Incorporate cool pavement technology into the regular maintenance of existing streets, sidewalks, parking areas, and bike lanes.

City of Woodland	General Plan	General Plan	2017	**Policy 3.H.3:** Parking Lot Design: Require that parking lots be designed to minimize the UHI effect. Establish significant tree canopies with ample landscape areas designed to pretreat stormwater runoff (where feasible) and ensure pedestrian access.
El Dorado County	DRAFT 2040 Regional Transportation Plan	Regional Transportation Plan	2020 (Draft)	**Goal #2:** Encourage sustainable transportation options, embrace new technologies, and develop climate adaptation and resiliency strategies.
Sacramento County	General Plan	General Plan	2017	**Policy AQ-2:** promotes the use of "Cool Community" strategies to mitigate UHI effects, reduce energy use and ozone formation, and maximize air quality benefits.
Sutter County	Climate Action Plan	Climate Action Plan	2010	**R3-L2:** Heat Island Plan: Implementing this measure would include expanding the Sutter Pointe guidelines for cool roofs, cool pavements, strategically placed shade trees, and parking lot shading to the entire county. Countywide design guidelines would need amendments that all new developments and major renovations (additions of 25,000 square feet or more) are encouraged to follow strategies to reduce heat gain for 50 percent of the non-roof impervious site landscape (such as parking, roads, sidewalks, courtyards, and driveways). Strategies include: • Shading (within five years of occupancy) • Paving materials with an SRI of at least 29 • Open grid pavement system • Covered parking (with shade or cover with an SRI of at least 29)
Yolo County	General Plan	General Plan	2009	**Policy CI-3.6:** Incorporate "complete streets" concepts that require consideration of all street users. Develop roadway cross-sections for community and rural areas that address: number of travel lanes, lane width, medians, drainage control, shoulder width, parking lanes, bike lanes, fire and emergency response standards, curb and gutter design, landscaped strip, and sidewalk width. The intent is that roadway cross-sections in the county be as narrow as possible (particularly in community areas) while still meeting recommended safety standards, general plan requirements, and user needs.

Future Conditions

The UHI effect must be considered at multiple time scales as the effect will worsen with temperature rise over time. Jurisdictions should consider future conditions in addition to current modeling when developing mitigation strategies. Projections for the Sacramento Valley region include: 1) an average daily maximum temperature increase of 10°F by the end of the century, 2) that extreme heat days (where temperatures exceed 103.9°F) will become more frequent (with midtown Sacramento seeing an average of 36 additional extreme heat days each year) (Benjamin Houlton 2018). Meanwhile, the region's population is expected to keep growing—SACOG projects growth of 25 percent by 2040 in their most recent MTP (Sacramento Council of Governments 2019). The transportation and housing sectors will need to accommodate this growth, which will affect the region's land use and require new housing and new transportation projects to serve the area'scommuters.

The project team modeled the temporal change of UHI effects given temperature rise based on Relative Concentration Pathway (RCP) 4.5 and RCP 8.5, as well as future urbanization levels and changing land use (based on the USGS LUCAS model) through 2050 (USGS n.d.). The scenarios included both business-as-usual and smart growth, which assumes that 15 percent less urbanization occurs by 2050. This plan includes summary results and conclusions of this analysis in Section 3, and the associated technical report includes full details.

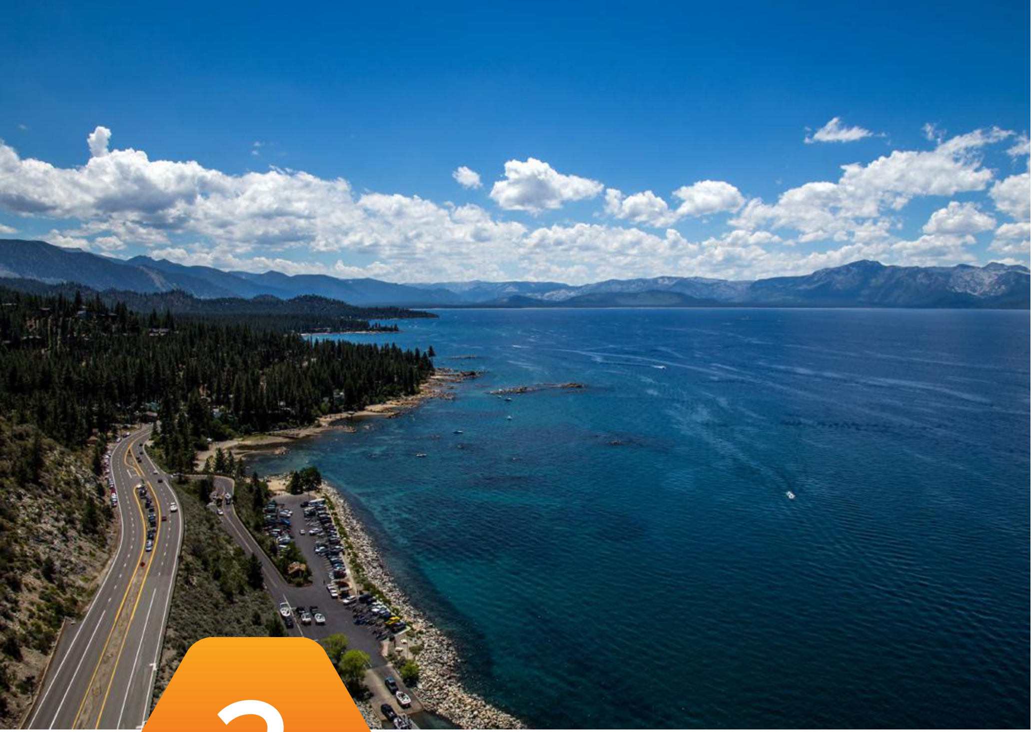

Figure 5: US 50 Pavement Buckling During 2017 Heat Wave

2 UHI IMPACTS

Hot weather, exacerbated by the UHI effect, impacts many facets of life in the Capital Region. The UHI effect impacts the transportation sector, causes serious health and public safety concerns, and hurts the environment—this section provides a summary.

2.1 Transportation Impacts

Transportation-related heat hazards that are worsened by the UHI effect fall into two general categories: 1) physical infrastructure impacts, and 2) ridership impacts. Project-level design choices must consider many variables—however, heat resilience increases safety and prolongs infrastructure lifespan, so prioritizing it is increasingly valuable in a warming climate.

2.1.1 TRANSPORTATION INFRASTRUCTURE

Many transportation infrastructure design processes rely on historical temperatures to determine final design—however, UHI effects and climate change trends will cause temperatures to increasingly exceed historical ranges. Infrastructure asset designs must be sufficiently resilient to avoid disruption, damage, or failure. This section provides an overview of how heat can impact the transportation network.

Pavements

Caltrans and the California State Transportation Agency consider minimum and maximum regional air temperatures when choosing pavement mix binders (the "glue" that holds the aggregate together when it expands and contracts with temperature changes). When temperatures exceed these ranges, thermal cracking and pavement distortion can occur (Qiang Li 2011).[4]

Electrical Equipment

Higher temperatures can cause electrical transportation equipment to overheat. Some rail systems, such as the Sacramento Regional Transit (SacRT) light rail system, use overhead catenary systems (OCS) to power rail cars. OCS lines can stretch with heat, which may sever the connection with the rail car or cause malfunction. To mitigate this impact and preserve rider safety, SacRT issues slow orders to reduce train speeds when temperatures are above 100°F (38°C) (SacRT 2018). Slow orders reduce system efficiency, inconvenience riders, and create additional costs for transit operators. When temperatures exceed design specifications, substations, signal rooms, and electrical boxes are also at increased risk of failure.

4 A flexible pavement transfers load (the vehicle's weight on the road) through aggregate material to the earth below. A rigid pavement consists of concrete slabs that distribute the load over a wide area (Mishra n.d.).

Battery Electric Buses and Electric Vehicles

Battery electric buses (BEBs) and electric vehicles (EV) are also transportation assets vulnerable to heat-related impacts. BEBs are being deployed across California due to the state's mandate to adopt electric transportation approaches to meet GHG reduction goals. Heat impacts to BEBs are not yet well-documented, but potential risks include increased energy use (causing decreased range), and cost, reliability, and long-term capacity concerns. National Renewable Energy Laboratory research indicates that the desired operating temperature that maximizes BEB range is between 59 and 95°F (15-35°C) (NREL 2011)—this means that as temperatures rise, BEB batteries become less efficient. UHI effects can impact both the in-service efficiency of the vehicle and the facilities and technology required to operate and maintain the fleet. Transit agencies are now beginning to develop resiliency plans for their operations and maintenance facilities to better prepare for transitions to BEB fleets. In areas vulnerable to UHI effects, facilities are being designed to minimize heat impacts and maximize equipment efficiency. California's Zero-Emission Vehicle (ZEV) regulation requires auto manufacturers to produce a certain number of ZEVs and plug-in hybrids each year—unfortunately, their batteries are also vulnerable to UHI effects.

Rails

Like other infrastructure types, rails are designed to operate within a specific temperature range, which varies depending on the rail type. The type selected depends on the projected temperature range that the project may experience. At rail temperatures too outside the functional range, compressive or tensile forces can cause rail buckling and warping rail (U.S. Department of Transportation Volpe Center 2018). SacRT light rail trains must slow down or stop under temperatures that stress the rail. The SacRT website states, "Like many materials, the metal on the SacRT track system is subject to contraction and expansion based on the temperature. During times of high heat, it is possible for a 1,000 foot stretch of track to expand by as much as eight inches. Extreme temperatures could inevitably cause failure at a switch, bridge or crossing. To prevent these problems, SacRT will implement speed restrictions so that the system can continue to operate safely" (SacRT 2018). Other Capital Region rail systems (both freight and passenger rail) will be similarly affected if design temperatures do not accurately reflect real-world conditions.

2.1.2 TRANSIT RIDERSHIP AND ACTIVE TRANSPORTATION IMPACTS

A recent analysis of the Fresno Area Express (FAX) bus system on hot summer days found that ridership decreased as temperatures increased, suggesting that some riders switched to alternative transportation modes, or avoided travel altogether, during periods of extreme heat.[5] There are several potential explanations for this trend. In general, increased temperatures can make every aspect of a transit trip more challenging. Transit-dependent populations are typically located in areas with less tree canopy and higher UHI effect. In these settings, walking, biking, or skating to and from transit stops can be dangerous or strenuous on hot days. Similarly, a lack of shade from trees or shelters at bus stops can make waiting for buses unpleasant and unsafe, especially if service is infrequent or late. Finally, some buses (particularly older models) and light rail cars do not have effective air conditioning. If significant numbers of riders shift from transit to single-occupancy vehicles because of heat impacts, transit revenues will decrease and GHG emissions will increase.

Similarly, heat impacts will disproportionately affect people who depend on active transportation, such as walking, biking, or skating—without alternative options such as a vehicle or nearby transit stop, they may avoid travel altogether. If forced to travel, they may suffer discomfort or health impacts.

2.2 Health Impacts

High heat has been responsible for more deaths over the last 30 years than any other type of natural disaster in California (Four Twenty Seven 2018). High heat can eventually exceed the body's thermoregulation capacity and lead to heat-related illnesses, especially if those affected cannot escape the heat. Heat-related illnesses manifest in different ways, including rhabdomyolysis (muscle breakdown), heat rash, heat syncope (fainting and dizziness), heat cramps, heat exhaustion, and heatstroke.[6] These conditions can escalate and lead to death if left untreated (OSHA n.d.). The Capital region already experiences more heat-related deaths and hospital visits than the state average, and as temperatures rise, this trend could worsen over time (Neil Maizlish 2017).

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5 Internal WSP source.

6 For more information on heat-related illness see: https://www.osha.gov/SLTC/heatstress/heatrelated_illness_firstaid.html

Other unanticipated high heat impacts are still being discovered and assessed. The California Office of Environmental Health Hazard Assessment (OEHHA) studies the human health impacts of temperature rise and found a link between heat exposure and both infant mortality (OEHHA 2015) and low birth weight (Rupa Basu 2018). Another study, completed as supporting research for California's Fourth Climate Change Assessment, found correlations between high temperatures and increased mental health emergency room visits (Rupa Basu 2018).

Another important consideration of heat-related illness is the need for the body to acclimatize to new temperatures—this is especially important for workers exposed to heat, such as those who work outdoors. Per the Occupational Safety and Health Administration's (OSHA) website, "most outdoor fatalities, 50 to 70 percent, occur in the first few days of working in warm or hot environments because the body needs to build a tolerance to the heat gradually over time" (OSHA n.d.). There is evidence that repeated heat stress can damage the kidneys, causing permanent injury and chronic kidney disease (Fabiana Nerbass 2017). There are documented cases of chronic kidney disease of unknown origin around the world, particularly in tropical and low-to-middle income countries, which are now thought to result from heat stress due to high temperatures, intense physical exertion, dehydration, and long work hours (Fabiana Nerbass 2017).

Heat health impacts can be especially severe during heatwaves, when extreme temperatures extend into multiple days or temperatures do not drop at night. Heatwaves can be fatal and hit vulnerable populations the hardest (see the *Vulnerable Populations* section below). These events can put extreme pressure on infrastructure, including power grids, transportation, and medical services. The 1995 Chicago heatwave is a poignant and gruesome example of how heat can cause a massive public health emergency and overwhelm city services. Hospitals were overwhelmed, over 700 people died within five days, and the Cook County Medical Examiner's Office became one of the city's most crowded places because the hundreds of bodies requiring storage exceeded its capacity (AdaptNY 2016). Mitigating the public health impacts caused by such events and having an emergency plan in place are critical for ensuring that the public is provided adequate services and care.

2.2.1 VULNERABLE POPULATIONS

Heat vulnerability varies geographically (local surface temperature, tree cover, and distance from the coast) and demographically (age, socioeconomic status, health, pregnancy, and occupation). According to California Department of Public Health (CDPH) research, the Capital Region's vulnerable populations include people who are:

- Transit (or active transportation) dependent
- Without transportation access
- Outdoor workers (e.g., farm laborers)
- Immigrants
- Elderly
- Children
- Pregnant
- Of lower socioeconomic status
- Socially or linguistically isolated
- Living in institutions
- Experiencing homelessness
- Suffering from pre-existing health conditions or who are on multiple medications

Socioeconomic status is a significant determinant of heat vulnerability. In the 2006 California heat wave, nearly 90 percent of the victims were in underserved communities (Four Twenty Seven 2018). The connection between economic opportunity and heat is essential to recognize because cooling measures require resources such as air conditioning, water, and transportation (Four Twenty Seven 2018). People living in poverty may avoid using air conditioning if they are worried about their electricity bill. Outdoor workers may struggle through shifts on excessively hot days to maintain their paychecks. People experiencing homelessness may not be able to find places to cool off and rest.

Socioeconomic status is also a key predictor of overall health, with those below the poverty line suffering worse health outcomes than those above (Public Health Alliance of Southern California 2018). Conditions in the built environment, such as transportation access, education, health care, and a clean environment, can also affect health. Other social determinants of health include the conditions in which communities "live, work, and play" (Let's Get Healthy California 2016). See Figure 6 for a more detailed look at the social determinants of health. Inequitable environments and the resulting negative health outcomes can put communities at a disproportionate risk of heat vulnerability.

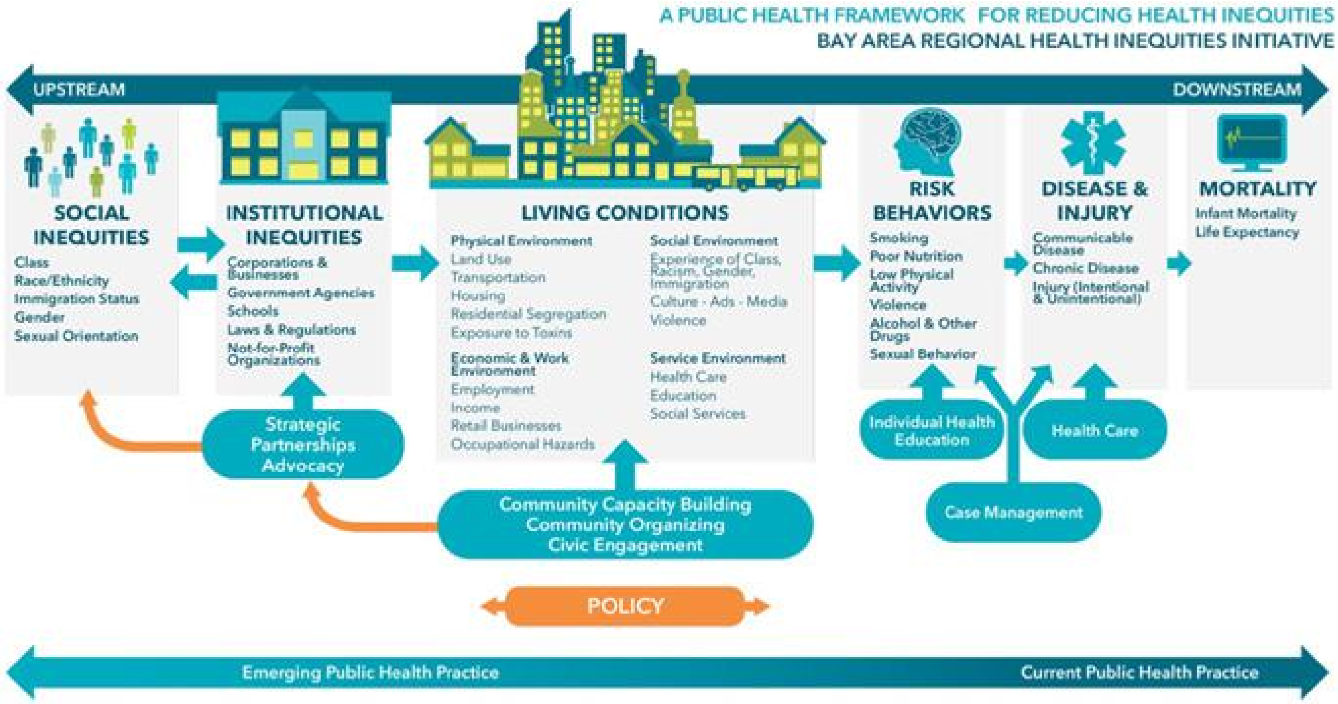


Figure 6: Social Determinants of Health

Source: https://letsgethealthy.ca.gov/sdoh/

2.3 Environmental Impacts

2.3.1 IMPAIRED AIR QUALITY AND GREENHOUSE GAS EMISSIONS

The energy production necessary to meet the region's energy demands increases GHGs and unhealthy air pollutants. In warmer months, when energy demand rises due to higher temperatures and air conditioning needs, the increased consumption leads to higher emissions and worse air quality. As the frequency and severity of high-heat events increase in the future, air conditioning-related energy demands will also increase. A 2012 Lawrence Berkeley National Laboratory study indicates that maximum per-capita peak loads could increase by an average of 18.5 percent by the end of the century (Lawrence Berkeley National Laboratory 2012). Increased air-conditioning use releases waste heat, further worsening the UHI effect, creating a feedback loop. Increased heat also accelerates ozone formation, which is a concern for the Capital Region because it has not yet attained the 2008 or 2015 National Ambient Air Quality Standards for ozone. Excessive ozone can exacerbate asthma, chronic lung disease, cardiovascular diseases, and even mortality rates—California is projected to see an additional nine days of unhealthy ozone levels by 2050 (L. Shen 2016). Reducing the UHI effect can help decrease ozone levels.

The mix of energy sources in a given region (particularly the extent to which it relies on fossil fuels) determines pollution and emission outputs, which affect regional air quality. The following utilities provie the Capital Region's electricity needs: SMUD serves most of Sacramento County and a small part of Yolo and Placer Counties, Roseville Electric serves the City of Roseville, and the Pacific Gas & Electric (PG&E) company serves the rest of the region. Table 4 shows the 2018 power mix for SMUD and PG&E.

TABLE 4: 2018 POWER MIX FOR BASE PLAN CUSTOMERS (ROUNDED)

ENERGY SOURCE	SMUD	PG&E
Renewable[7]	20%	39%
Coal	0%	0%
Large Hydroelectric	26%	13%
Natural Gas	54%	15%
Nuclear	0%	34%
Other[8]	<1%	0%

7 Biomass/waste, geothermal, eligible hydroelectric, solar, wind.

8 Includes unspecified sources.

2.3.2 IMPAIRED WATER QUALITY AND AQUATIC LIFE

High temperatures for pavement, rooftops, and other human-made materials can impair water quality and threaten aquatic life by heating stormwater runoff. Runoff is directed into storm drains and sewers, and eventually enters natural waterways, like creeks, rivers, and lakes. Runoff that has passed through urban spaces can be 25ºF warmer than the original rainfall, which raises the overall temperature of a body of water (U.S. EPA 2019). This is called *thermal pollution* and it can kill aquatic life, in part because it can worsen infectious disease and parasites and compromise species immunity (Grażyna Walkuska 2009). Higher temperatures also decrease water's dissolved oxygen saturation level, which is a limiting factor for aquatic organisms (Grażyna Walkuska 2009).

2.3.3 TERRESTRIAL IMPACTS

While not extensively studied, the UHI effect may affect terrestrial urban flora and fauna. A 2016 study found that the UHI effect can affect plant phenology (the timing of plant growth and change) (Samuel C Zipper 2016). UHI impacts on urban wildlife are not well-defined, but evolutionary biologists are increasingly studying potential negative effects and how urban wildlife adapts and evolves to them (Marc T.J. Johnson 2017).

2.4 Community Priorities

The project team recognized both the importance and challenges of incorporating authentic community perspectives on extreme heat and improvements to their neighborhoods and transportation systems. After holding a series of listening sessions with community leaders and organizations, the project team developed a community engagement plan and determined that attending existing community events, rather than hosting standalone events, would reduce barriers to community participation. A priorities survey helped to gather feedback about transportation concerns, heat vulnerabilities, climate change concerns, and priorities for neighborhood and regional improvements. The project team shared the survey both online and at 24 community events throughout the region, ensuring that nearly a third of the responses came from in-person respondents, who are likely to be more diverse representative of the overall region. Games, prizes, and other educational activities helped to encourage participation. The survey results showed that many respondents desired improvements to active transportation networks, public transit, as well as more street trees, and that the environment, air quality, and climate change were key concerns. Please see the accompanying Communities Priority Report for an in-depth summary and discussion.

3 MITIGATION MODELING METHODOLOGY

To understand the transportation sector's role in mitigating the UHI effect, this project modeled the cooling impact of a range of UHI mitigation measures and the severity of the effect itself (Section 1). The methodology provides a repeatable process for ongoing evaluation of mitigation actions for their efficacy and regional relevance. Figure 7 below summarizes this process and its outcomes.

Each mitigation was modeled across the entire study region using a screening analysis at a 2-kilometer resolution (Step 1). These results (with other pertinent considerations) were used in Step 2 to identify six priority areas for more detailed mitigation potential modeling (Step 3). The results of both levels of mitigation modeling, and an assessment of co-benefits, informed the best practices for each mitigation measure shown in Section 4.

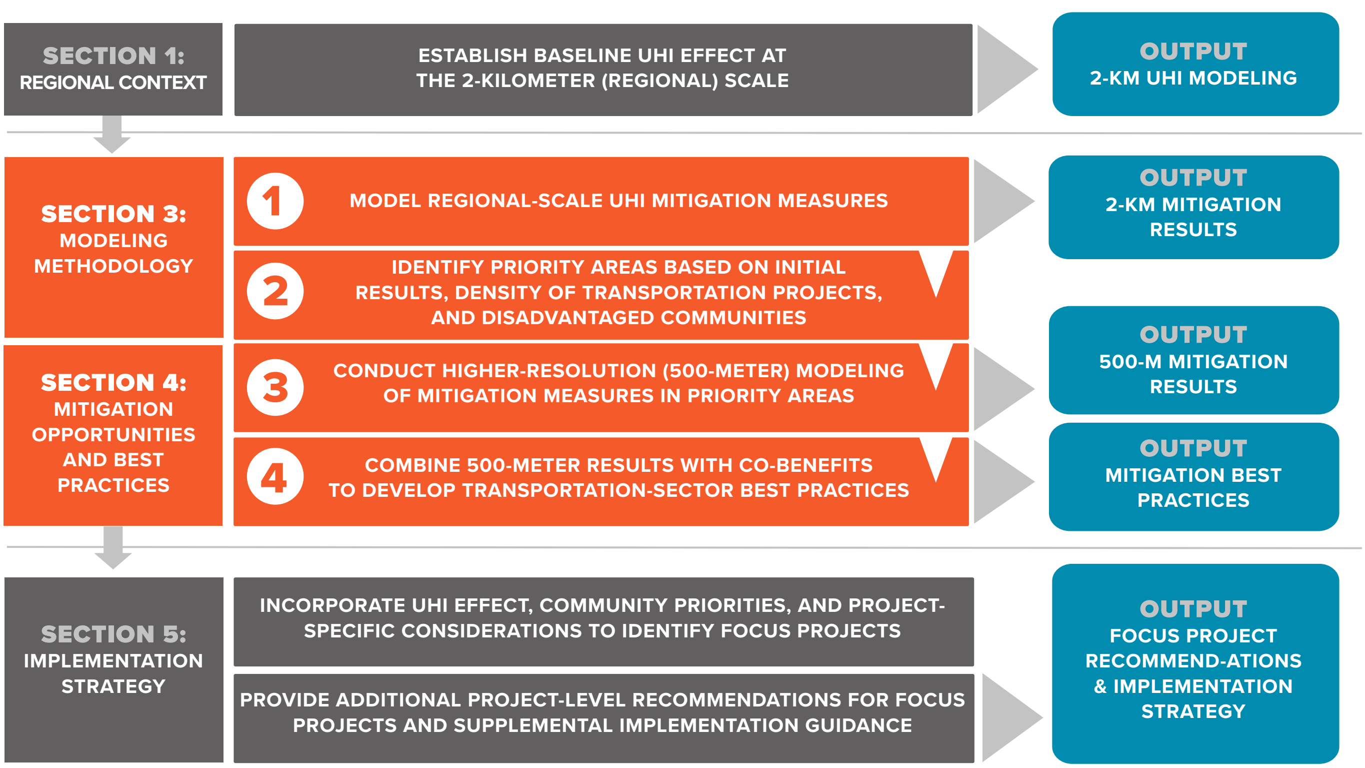


Figure 7: Mitigation Modeling Process Overview

3.1 Application of Regional (2-kilometer) Results

The project team modeled mitigation measures at the 2-kilometer level for the entire region. The modeled measures include increasing tree canopy cover by 12 and 20 percentage points, increasing roof and pavement albedo by 0.10 and 0.20, and a combined scenario with increased albedo and increased vegetation. The sections below show the results (in potential degrees of cooling) of the individual mitigation measures for each modeled area. For comparison, Figure 8 shows the results of the combined scenario. In this scenario (and in the individual-measure scenarios described in the sections below), areas with high cooling potential align with the UHI hotspots in northern Sacramento County (Sacramento to Citrus Heights), southwestern Placer County (Roseville to Lincoln), and southwestern Yuba County (Yuba City). Because these areas have the highest UHI effect under existing conditions, mitigating that effect in these areas could have an outsized impact on mitigating the UHI effect in the region overall. Additionally, these results reflect that some of the areas of highest cooling potential intersect with underserved communities—further supporting that mitigation measures can and should be prioritized in transportation projects in these areas. The specific mitigation categories below provide the individual-measure mitigation results.

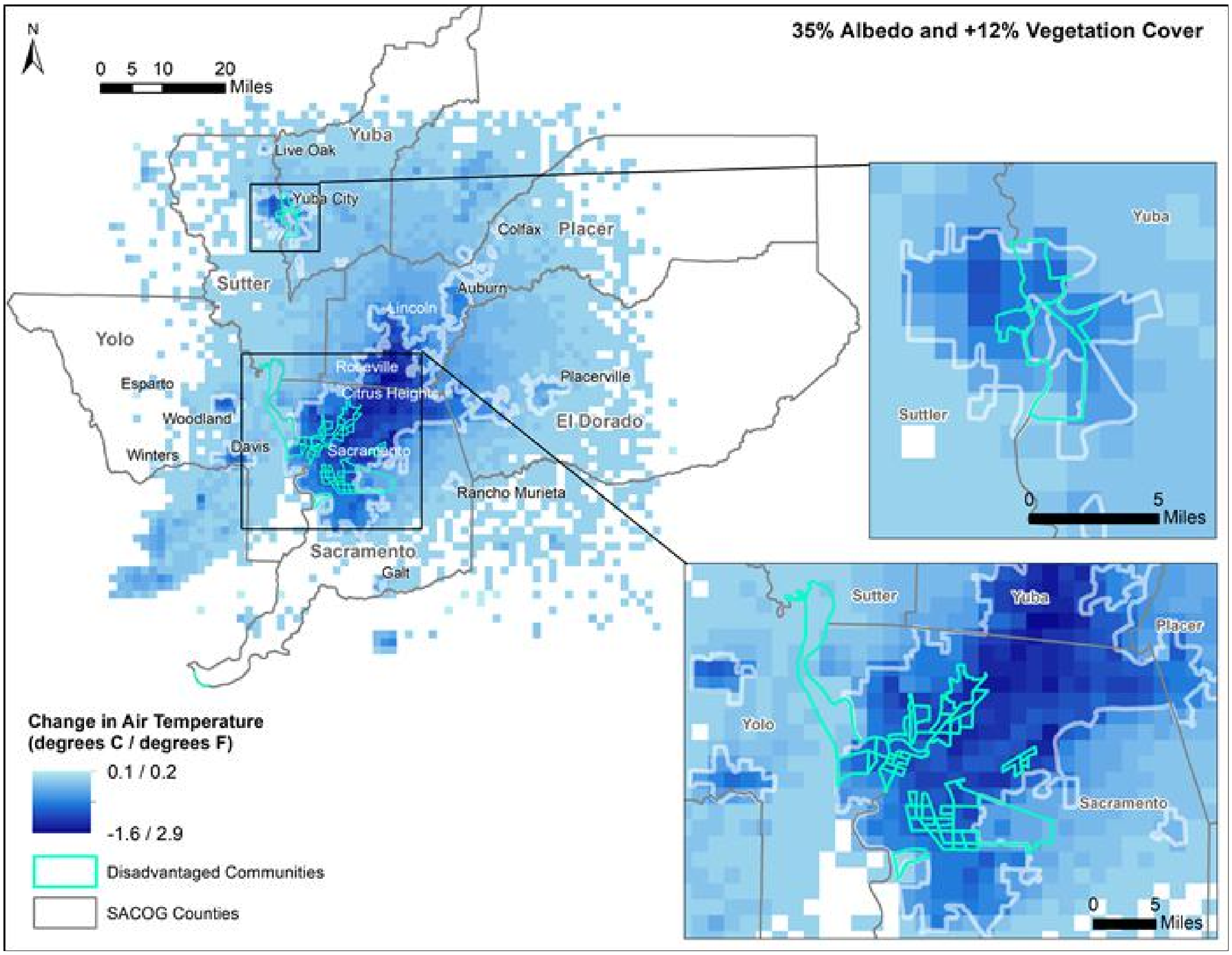


Figure 8: Increased Effectiveness of Combined UHI Mitigation Measures

This scenario represents an increase in albedo to 35 percent (from a mean of 12 percent albedo) and an increase in vegetation cover of 12 percent. The cooling-potential data represents the 1400 – 2000 PDT interval average air temperature in the SACOG region from June-September, 2013-2016.

3.2 Identification of 500-Meter Priority Areas

In addition to regional modeling at the 2-kilometer scale, this project also involved detailed modeling of mitigation measure efficacy at a 500-meter scale. Due to the intensive nature of the computational calculations needed to evaluate at this higher level of detail, complete coverage of the Capital Region was infeasible. Therefore, the project team examined regional UHI results along with the proportion of underserved communities and the transportation project density to identify six priority areas to model in greater detail.

The following table shows the priority areas identified through this process, and Figure 9 shows their geographic distribution. Modeling results can inform local projects, demonstrate mitigation measure efficacy variations across the region, and serve as proxies for similar study area locations.

TABLE 5: IDENTIFIED PRIORITY AREAS FOR 500-METER MODELING

PRIORITY AREA ID	AREA COVERED
1	Yuba City and Marysville
2	Woodland
3	Sacramento and Southeast Sacramento
4	North Sacramento, Roseville, and Granite Bay
5	El Dorado Hills and Folsom
6	Placerville

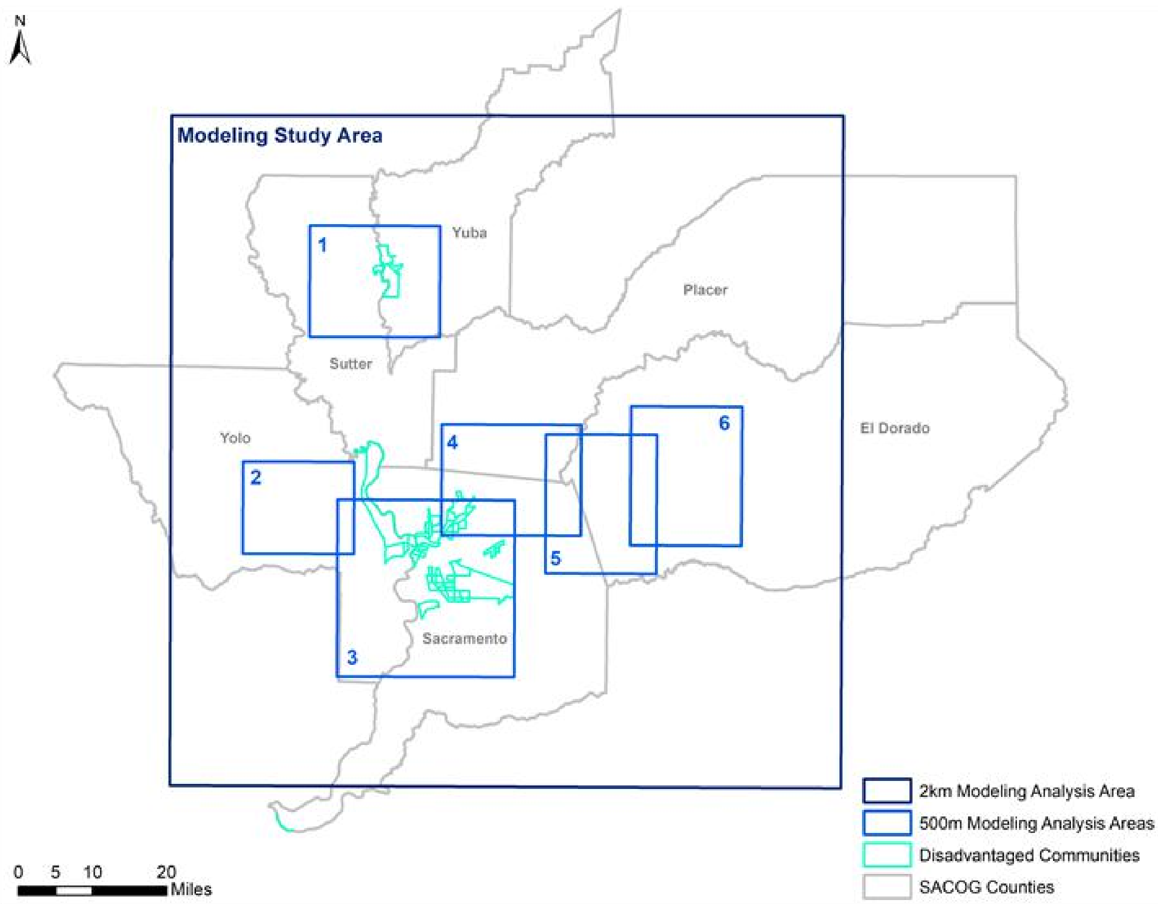


Figure 9: Geographic Distribution of Priority Areas

Section 4 discusses the modeling result details for each mitigation measure separately. However, aggregating the data across the six modeled areas reveals useful insights for the general region. As shown in Figure 10 below, there is a significant difference in the modeled measures' mitigation potential across locations. For some measures, the impact is relatively consistent across the region (e.g., electric vehicles), while for others (e.g., cool pavements), the impact varies by more than 1°F between priority areas. Despite these differences and the relative impact of each mitigation measure, they all play important roles in mitigating UHI effects and many areas will likely require a combination of measures to achieve the desired cooling levels (H. Taha, Personal communication 2019).

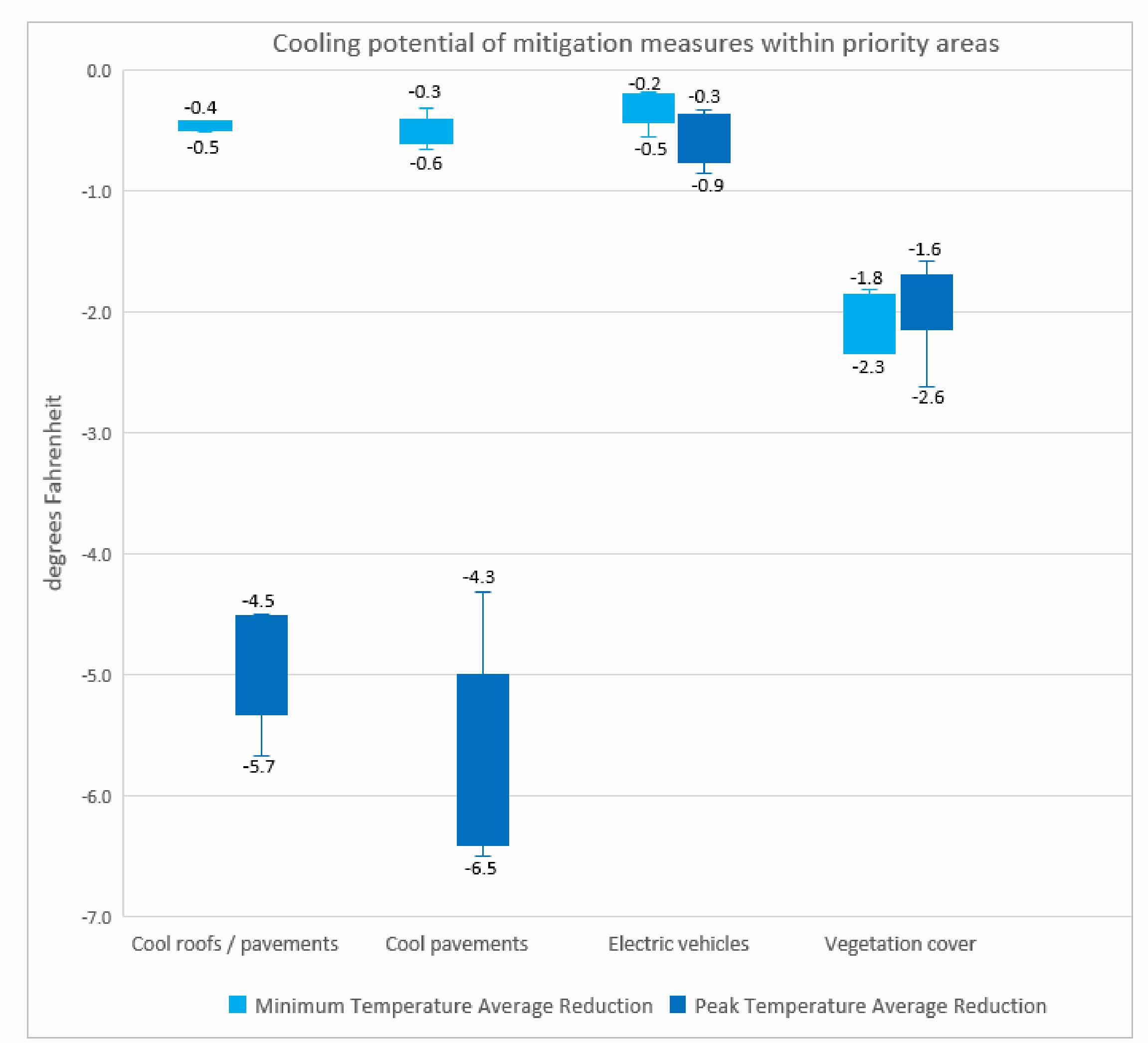
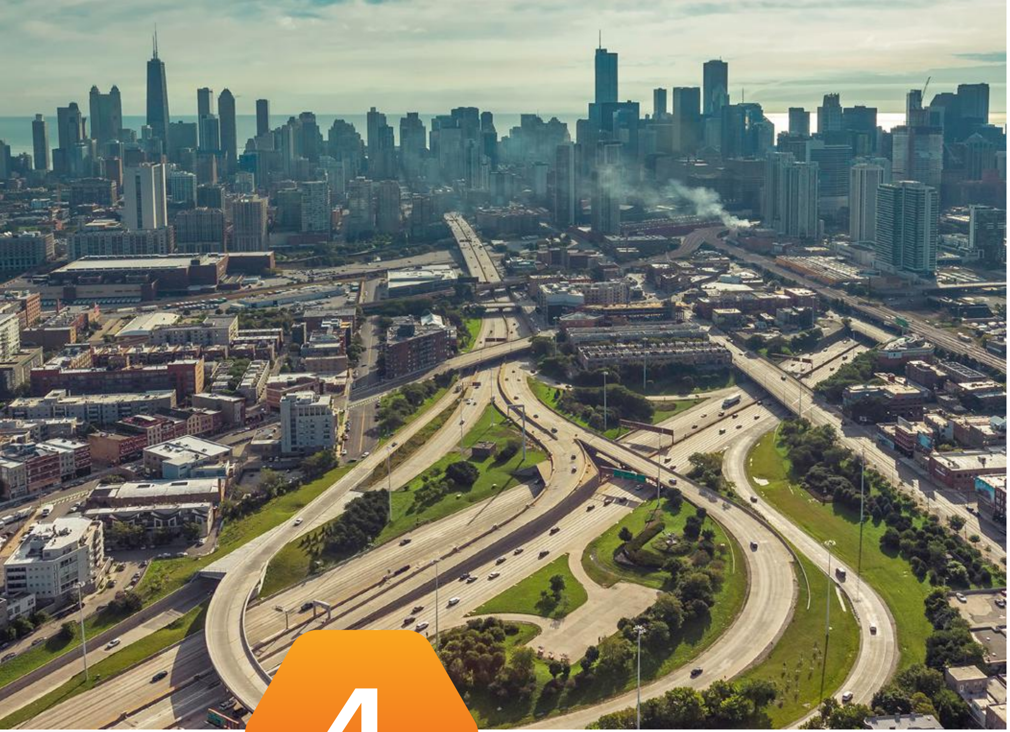


Figure 10: Summary of 500-Meter Mitigation Modeling Results Across Each of the Six Priority Areas within the SACOG Region

This chart shows the upper and lower bounds for cooling across the priority areas. Minimum temperatures refer to the coolest temperatures of a summer day (during the hours around 0600 PDT), while peak temperatures refer to the hottest temperatures of a summer day (during the hours around 1500 PDT).



4 TRANSPORTATION-SECTOR MITIGATION OPPORTUNITIES AND BEST PRACTICES

This section provides best practices for all transportation projects to consider and for using the 500-meter resolution modeling results to gain insight into areas with the high-potential. Best practices are organized into four categories of model-based mitigation options: vegetation cover, cool pavement, cool and green roofs, and electric vehicles. Co-benefits of each mitigation measure (such as impacts on public health and economic wellbeing) are noted where applicable. There are also general recommendations for implementing each mitigation measure for:

- Transportation infrastructure, including:
  - Roadways
  - Electric vehicle facilities
  - Vision Zero/Complete Streets projects
- Transit services and infrastructure
- Active transportation corridors

As the regional results presented earlier demonstrate, no one mitigation measure can address the UHI effect alone. Instead, it is best to consider all options when evaluating UHI mitigation at a regional scale. This section concludes with a discussion of land use planning and smart growth considerations pertinent to UHI mitigation. This overview provides a useful context for the Implementation Strategy section, which includes greater detail on implementation mechanisms for the best practices identified.

4.1 Vegetation Cover

One of the easiest ways for metropolitan regions to mitigate the UHI effect is by increasing vegetation cover. As described in Section 1.3, many municipalities in the Capital Region have incorporated this approach into general plans, climate action plans, and other planning documents to help mitigate UHI effects. While there are many benefits associated with tree planting, the main benefit is their shade, which helps prevent the low-albedo surfaces prevalent in urban areas from absorbing and releasing solar heat. Additionally, transpiration and evaporation (collectively called evapotranspiration) both have a slight cooling effect. Evaporation is when water moves from a land surface to the atmosphere in the form of water vapor. Transpiration is when plants release water vapor back to the atmosphere.

The cooling potential of evapotranspiration is often overstated—plants tend to close stomata to reduce water loss during hot periods (Bartlett and Jain 2019). Although other local variables, such as humidity, have an impact, most plants begin to close their stomata at 96.8°F (36°C), which reduces evapotranspiration's UHI effect mitigation effectiveness (Hofstra and Hesketh 1969).

The increase of surface roughness (variation of height among urban landscape elements) and the reduction of atmospheric pollutant concentrations (which can trap heat) are two important cooling mechanisms of cooling of urban forestry. Height variability improves atmospheric convection, which allows surface heat to move into the upper atmosphere more efficiently (Gunawardena, Wells and Kershaw 2017). Even small-scale (as small as 0.2-0.3 square kilometers) urban forestry projects provide effective cooling (Vidrih and Medved 2013). This is particularly applicable for transportation-sector projects which often have minimal room for vegetation.

Water-related elements in urban environments can also have significant cooling effects. A 2012 study found that cooling of up to 1.8°F (1°C) can occur at 98 feet (30 meters) from a river. At greater distances, streets that open to the river can receive effective cooling from the river breeze combined with vegetation (Hathway and Sharples 2012).

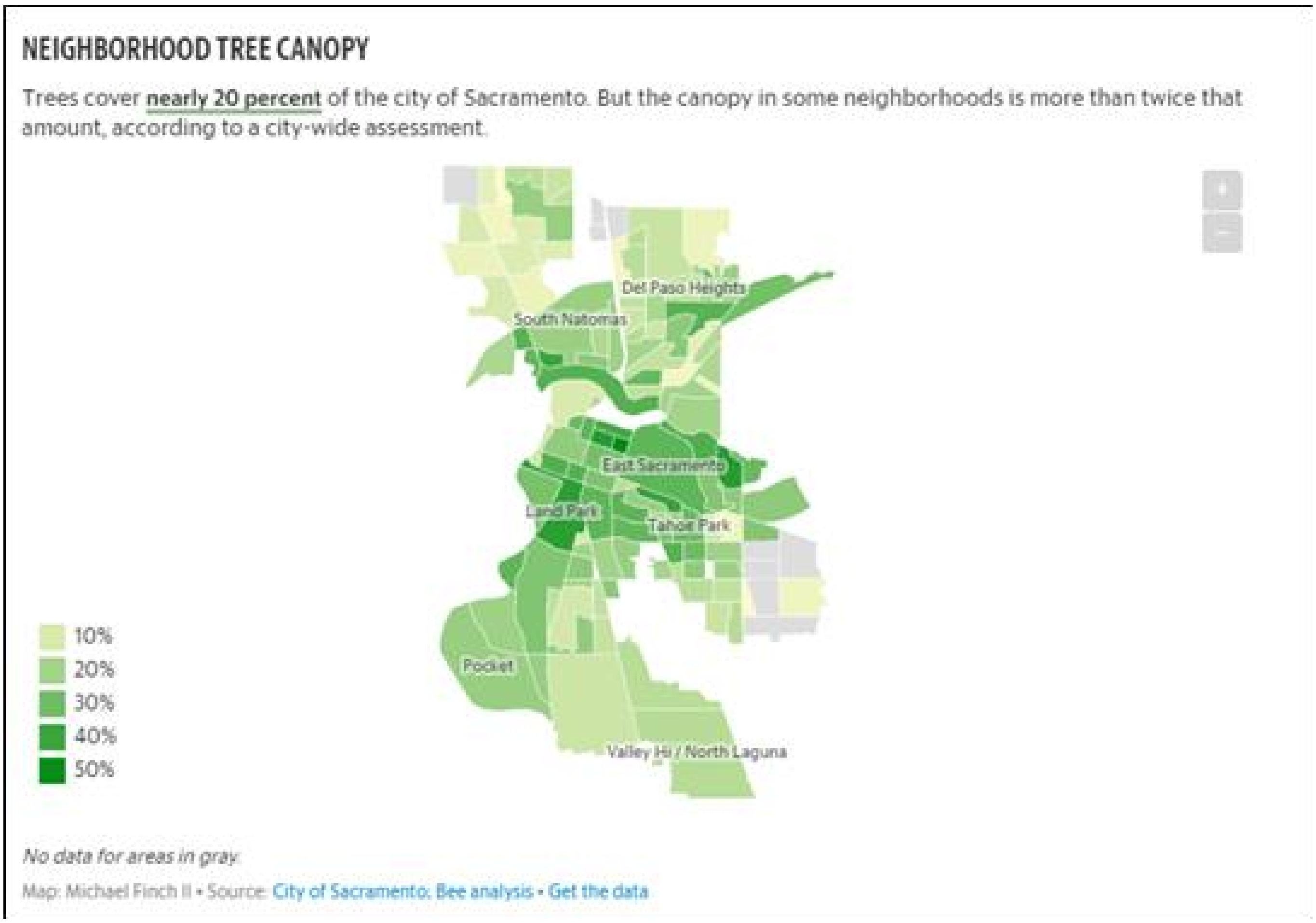


Figure 11: Existing City of Sacramento Tree Canopy

Source: https://www.sacbee.com/news/local/sacramento-tipping-point/article235884122.html

Communities of differing income levels often experience differing degrees of tree canopy benefits. The City of Sacramento's 2018 Urban Tree Canopy Assessment, for example, found a 30-percent discrepancy between the tree cover in affluent and less-affluent neighborhoods (City of Sacramento 2018). Sacramento is addressing this discrepancy by setting canopy goals based on the land use in each neighborhood. However, except for new streets and complete streets projects (which can have higher street tree requirements), these goals are not generally tied to transportation. There are also several green infrastructure approaches that can be incorporated into a wider range of transportation projects. Table 6 summarizes a set of green infrastructure approaches that have both UHI mitigation potential and significant co-benefits.

TABLE 6: OVERVIEW OF TRANSPORTATION-SECTOR VEGETATION COVER STRATEGIES

APPROACH	DEFINITION	SAMPLE PROJECT
Bioretention and bioswales	Bioswales are a type of stormwater retention that uses an open-channel shape and vegetation to slow runoff and filter pollutants, reducing strain on stormwater infrastructure and improving water quality. Often integrated into streetscapes or used to convey stormwater away from critical infrastructure, bioswales can also reduce the need for gray stormwater systems by capturing and storing some of the stormwater. Bioswales can also increase habitat for urban wildlife and improve air quality. Another befit is that they are often aesthetically pleasing and can increase property values.	 Source: https://www.soils.org/discover-soils/soils-in-the-city/green-infrastructure/important-terms/rain-gardens-bioswales
Rain gardens	Rain gardens are small gardens designed to survive precipitation extremes and help retain or reduce stormwater runoff through infiltration or storage. The gardens are often small and placed strategically in areas where stormwater overwhelms drainage capacity. Rain gardens reduce nutrient pollution, reduce temperatures, provide wildlife habitat, and improve aesthetics. They can be installed in many different areas and do not require much space.	 Source: https://blog.savesfbay.org/wp-content/uploads/2016/01/Newcomb-and-Phelps-Rain-Garden-Wet.jpg
Green streets, alleys and parking lots	Green streets, alleys, and parking lots can combine all of the above strategies into a coherent package. By combining strategies, green streets can provide multiple benefits, including cooling, runoff and pollutant reduction, and air quality improvement. Local governments primarily install green streets in public right-of-ways, but green alleys and parking lots can be installed on both public and private land. For all three, minimizing pavement is an essential element.	 Source: https://www.straughanenvironmental.com/green-streets-improve-stormwater-mitigation/
Pedestrian- and bicycle-only roadways	Roadways designed exclusively for pedestrian and bicycle use have a greater potential for tree canopy and general vegetation cover because many of the requirements for cars (parking, sight distance, and wider lane widths) do not apply. This approach directly mitigates the UHI effect, and offers the co-benefits of incentivizing emission-free transportation modes such as public health benefits and reduced GHGs.	 Source: https://fitt.co/los-angeles/articles/where-to-ride-the-best-bike-paths-los-angeles

Source: https://www.georgetownclimate.org/adaptation/toolkits/green-infrastructure-toolkit/green-infrastructure-strategies-and-techniques.html#ref-10

4.1.1 CO-BENEFITS

In addition to the high UHI-effect mitigation potential of green infrastructure measures, they also offer a wide range of co-benefits. These co-benefits, and other considerations pertaining to green infrastructure, should be incorporated into the decision-making process regarding the best measures to include in specific transportation projects.

TABLE 7: CO-BENEFITS OF INCREASED VEGETATION COVER

CO-BENEFITS OF VEGETATION COVER	
Carbon sequestration	Natural landscape elements sequester carbon, reducing atmospheric GHG concentrations and the resulting warming impacts.
Improved air quality	Urban forests and other vegetated spaces improve local air quality by filtering airborne contaminants and shading parked cars. One analysis predicted that evaporative emissions of volatile organic compounds (an ozone precursor) from parked light-duty vehicles throughout Sacramento County could be reduced by 2 percent per day if parking lot tree canopies increased from 8 percent to 50 percent (U.S. EPA 2008).
Stormwater benefits	Urban vegetation provides important stormwater benefits by reducing runoff, increasing groundwater recharge, and filtering water as it permeates. A City of Sacramento analysis found that, between air quality and stormwater benefits, the city's trees provide $2.5 million in environmental benefits each year (City of Sacramento 2018).
Increased soil stability	The vegetation roots help bind soil layers together, preventing them from blowing or washing away.
Public health benefits	Decades of studies have identified a connection between urban green space and human health. Vegetated areas are attractive locations for outdoor exercise, but recent research also reveals higher birth rates and faster surgery recovery in densely vegetated areas, which strengthens the case that exposure to greenery is therapeutic. In recent years, "forest bathing" has gained attention worldwide for its correlation with indicators of improved mental health, such as reduced cortisol levels and improved immune system function. Some of this benefit is attributed to exposure to phytoncides—antimicrobial compounds emitted from vegetation for protection (Hanson and Frank 2016). Planting fruit-bearing trees can offer even more public health support by providing the community with nutritious produce.
Improved aesthetics and social cohesion	Urban forestry creates a more aesthetically pleasing urban environment, which may improve opportunities for outdoor recreation and social gatherings and support community cohesion and social networks. Social cohesion can be critical to community health during heatwaves, because people will be more likely to help each other. As neighborhoods become more attractive, however, the risk of gentrification and displacement of existing residents also increases. While a project-level design decision is unlikely to have a specific effect on this phenomenon, plans recommending increases in vegetation-related aesthetics should consider including anti-displacement measures.
Ecological benefits	Vegetation cover, particularly native plant species, also offers a wide range of environmental benefits. The vegetation can serve as a habitat for animal species that are vulnerable in an urban environment, helping to increase biodiversity and ecosystem resilience by increasing the available ecological niches.
OTHER CONSIDERATIONS	
Tree root hazards	While trees offer many public health benefits, they can also present risks. Tree fall can damage power infrastructure, particularly during storms. Tree roots growing under roads, sidewalks, and driveways can damage infrastructure over time. Many design strategies facilitate the coexistence of healthy trees and functional infrastructure. The City of Portland offers an accessible summary of these design approaches in this article (Black n.d.).
Maintaining healthy vegetation	Urban forests require maintenance, particularly in the near-term after installation. Unhealthy, poorly maintained trees become a fall risk and a danger to property and people. However, studies indicate that the benefits offered by urban vegetation outweigh the costs—one survey found that benefit-cost ratios for street and park trees range from 1.5:1 to 1.9:1 (McPherson 2003). Costs can be managed through careful tree selection and proactive urban planning that prevents tree-infrastructure conflicts.

4.1.2 HIGH-OPPORTUNITY AREAS

General Conclusions from 2-Kilometer Results

The figure below shows that a moderate (12 percent) increase in vegetation cover will most effectively reduce air temperatures in the Roseville, Citrus Heights, and North Highlands area north of Sacramento. Throughout this area, there is a consistent potential for vegetation increase to reduce temperatures by at least 0.7°F (0.4°C). This area also includes the highest proportion of underserved communities. As discussed earlier in this section, the co-benefits of increased vegetation cover are often the highest for underserved communities and should be considered alongside UHI mitigation potential when weighing the costs and benefits of green infrastructure projects in the transportation sector.

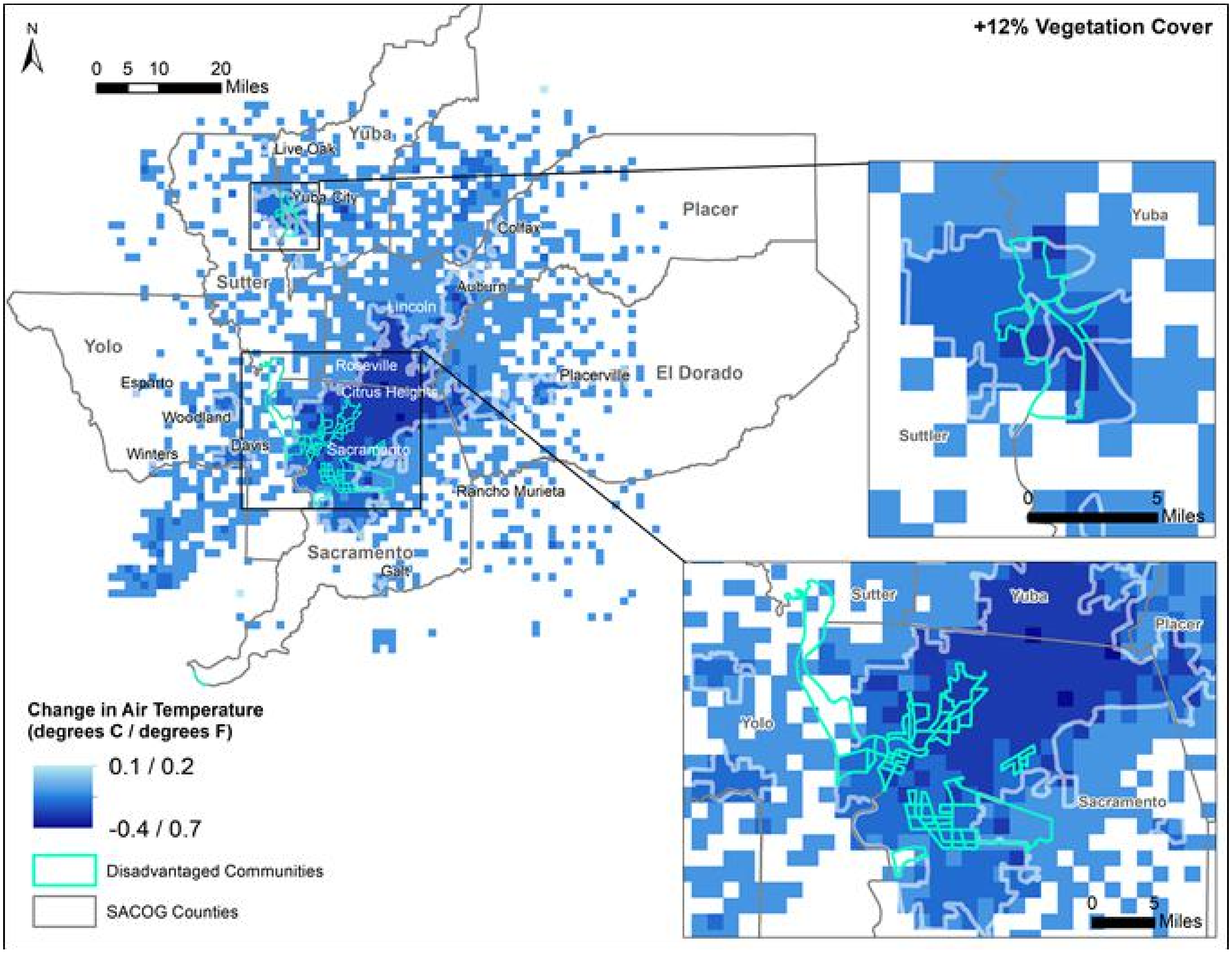


Figure 12: Impacts of Vegetation Cover on Air Temperature

This scenario represents an increase in vegetation cover of 12 percent. The cooling potential data represents the 1400 –2000 PDT interval average air temperature in the SACOG region from June-September, 2013–2016.

Specific Conclusions from 500-Meter Results

The modeled vegetation cover mitigation scenario showed an increase of over 500 trees per 0.25 square kilometer. As indicated in the table and figure below, this canopy cover increase would provide effective cooling if implemented in each of the six focus areas. However, the Yuba City/Marysville area would experience the greatest benefit—up to 2.6°F (1.5 °C) of cooling during peak temperature conditions (i.e., the hottest part of the day). Therefore, UHI mitigation measures incorporating vegetation cover should be prioritized for this and similar regions. Areas that would experience the greatest cooling from increasing vegetation cover (Yuba City and Sacramento/Southeast Sacramento) are also the areas with the highest concentration of underserved communities (as shown in the map above). Given the documented correlation between lack of tree canopy and lower socioeconomic status, green infrastructure projects such as increased tree canopy should be prioritized in these and similar areas.

TABLE 8: EFFECTIVENESS OF INCREASED VEGETATION AT MITIGATING SUMMER UHI

	CHANGE IN SUMMER TEMPERATURES	
	DAILY PEAK TEMPERATURE (°F/°C)	DAILY MINIMUM TEMPERATURE (°F/°C)
Priority Area 1 (Yuba City/Marysville)	-2.6/ -1.5	-2.3/ -1.3
Priority Area 2 (Woodland)	-1.7/ -1.0	-1.8/ -1.0
Priority Area 3 (Sacramento/Southeast Sacramento)	-2.0/ -1.1	-2.3/ -1.3
Priority Area 4 (Sacramento/Roseville/Granite Bay)	-1.8/ -1.0	-2.0/ -1.1
Priority Area 5 (El Dorado Hills/Folsom)	-1.6/ -0.9	-1.9/ -1.0
Priority Area 6 (Placerville)	-1.9/ -1.1	-2.3/ -1.3

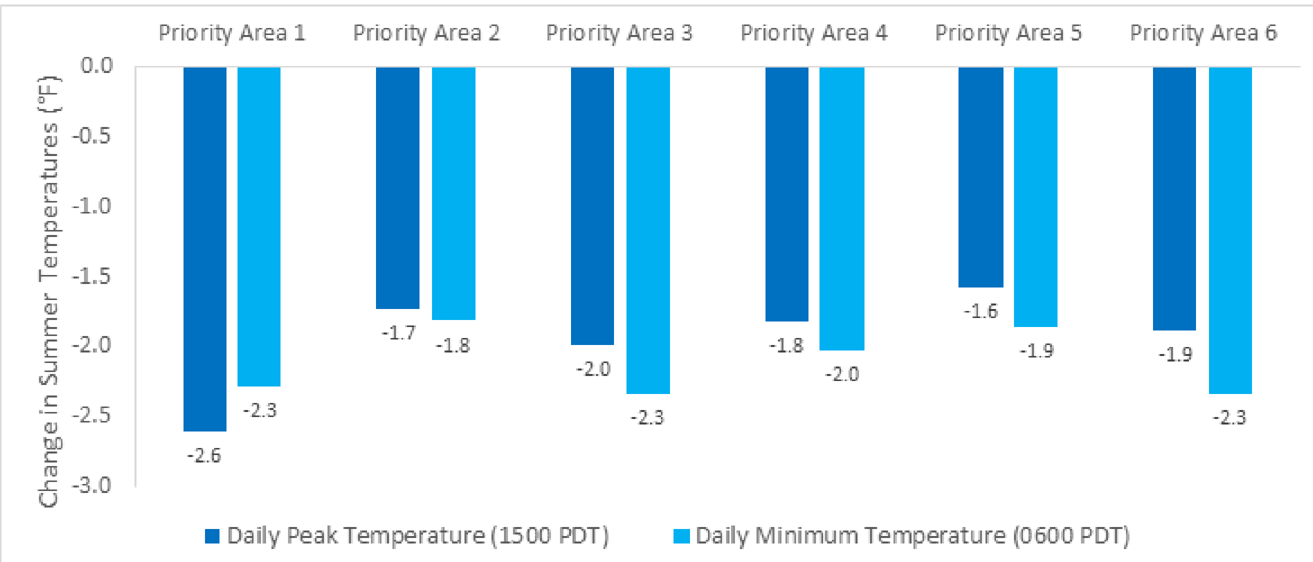


Figure 13: Effectiveness of Increased Vegetation at Mitigating Summer UHI

The data represents average changes in surface and air temperatures. Since canopy cover has effects on temperatures both above and below the canopy, a fairer comparison between the effects of cool surfaces and canopy cover is to use both air and surface temperatures for tree scenarios (and averaging them) rather than separating air and surface temperatures (H. Taha, Personal communication 2019).

CASE STUDY

YOLO BYPASS

The Yolo Bypass is considered one of the nation's leading examples of leveraging green infrastructure to protect transportation systems while also achieving significant co-benefits. This bypass, shown in purple on the aerial map above, is located between Davis and Sacramento close to I-80 and other transportation corridors. Although the specific UHI mitigation capacity of this system has not been quantified, the 2012 study cited above found that cooling up to 1.8°F (1°C) can occur at a distance of 30 meters. At greater distances, streets that are open to the river can experience effective cooling from the river breeze combined with vegetation (Hathway and Sharples 2012). Due to its proximity to the San Francisco Bay system and the lack of structures impeding airflow, the Yolo Bypass is often a conduit for a cool southerly breeze during hot summer evenings (California Department of Fish and Game 2008). In addition, during non-flood conditions, much of the land in the bypass is used for agriculture—which takes advantage of the nutrient-rich sediment deposited by previous floods. In the winter, the bypass fills with water and provides habitat for birds and aquatic life. This system channels floodwaters away from Sacramento's development and transportation infrastructure, increasing the region's resilience despite its location at the junction of the American and Sacramento Rivers. This green space also provides recreational and aesthetic value to adjacent communities and is a popular location for hunting and other outdoor activities (Ugartemendia 2017).

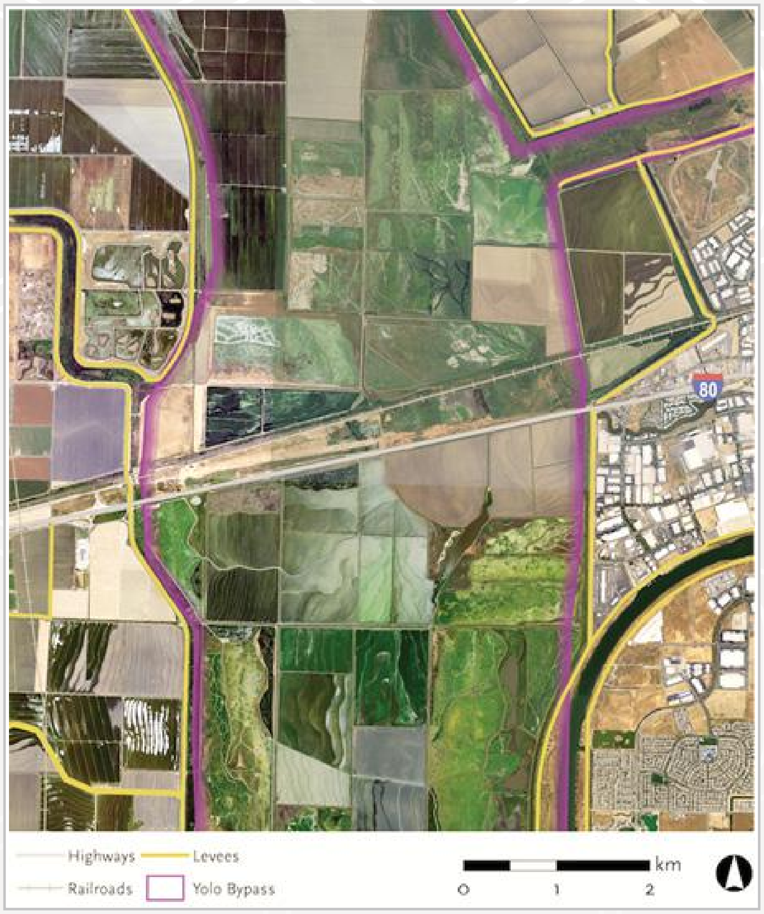


Figure 14: Aerial view of Yolo Bypass.

Source:(Ugartemendia 2017) California Department of Water Resources, Central Valley Flood Protection Board, CA Department of Fish and Wildlife, US Fish and Wildlife Service, Natural Resources Conservation Service, Dixon and Yolo Resource Conservation Districts, Sacramento Area Flood Control Agency, Yolo County, City of West Sacramento, City of Davis.

In addition to confirming the cooling potential of green spaces, this project demonstrates some of the challenges associated with implementing such projects. For example, the same breeze that cools the immediate area also pushes heat generated in Sacramento's urban core to adjacent areas. Additionally, the bypass is often a bottleneck in the region's traffic patterns. Many jurisdictions are taking steps to mitigate these challenges—for example, improving functionality by implementing the UHI mitigation measures included in this report, or, in the case of the traffic bottlenecks, exploring bypass design changes (such as managed lanes and separated bicycle and pedestrian circulation). When implementing UHI effect mitigation measures, preparedness for, and adaptability to, these types of secondary challenges help ensure a beneficial long-term solution.

4.1.3 TRANSPORTATION-SECTOR BEST PRACTICES

Best Practices for Transportation Infrastructure

BEST PRACTICE #1: BIOSWALES ALONG ROADWAYS

Bioswales reduce strain on stormwater infrastructure and improve water quality. They are often integrated into streetscapes to convey stormwater away from critical infrastructure and reduce the need for gray stormwater systems by capturing and storing some of the stormwater. Bioswales can mitigate temperature increase through mechanisms associated with both blue and green infrastructure which are either vegetated or water-filled (depending on weather conditions). In addition to UHI effect mitigation, these features also offer the wide range of public health and resiliency co-benefits associated with green infrastructure.

BEST PRACTICE #2: GREEN STREETS, ALLEYS, AND PARKING LOTS

By implementing green infrastructure practices in multiple components of the transportation system infrastructure, local jurisdictions can maximize green infrastructure co-benefits while minimizing paved surface area. Increasing vegetation cover in this way also has significant equity impacts because it helps close the gap in vegetation density between communities of varying income levels.

BEST PRACTICE #3: SHADE TREES ALONG ALL TYPES OF ROADWAYS

For some project types, it may not be feasible to implement a comprehensive green streets approach. However, shade trees should still be incorporated to the extent possible. Vidrih and Medved 2013 found that even very small areas of urban forest can make a measurable impact on local temperature—so project designers should include trees whenever possible, even when the available surface area is limited.

Best Practices for Transit Services and Infrastructure

BEST PRACTICE #1: GREEN INFRASTRUCTURE AT TRANSIT STATIONS

Adding shade trees, or other forms of green infrastructure, such as bioswales or rain gardens, at transit stations mitigates their UHI effects and, in the case of trees, provides direct shade and better comfort for waiting passengers. This strategy also offers local co-benefits, such as air pollution filtration, and helps avoid potential risks from albedo increases. More reflective surfaces can also reduce visibility for drivers and raise temperatures for pedestrians. The Cool Pavements section below further describes these hazards. By serving transit users, this recommendation brings the benefits of green infrastructure to a population that is more likely to be under-resourced and more vulnerable to UHI impacts.

BEST PRACTICE #2: GREEN TRANSIT CORRIDORS

Transit corridors usually include large areas of impermeable, paved surfaces. Supplementing functionally necessary surfaces such as roadways with adjacent vegetation can reduce UHI effects within transit corridors while also providing the co-benefits of reduced stormwater runoff, improved local air quality, and enhanced aesthetic qualities. In addition to directly improving public health, these enhancements may make transit use more desirable and reduce car trips, and the negative public health outcomes that result.

Best Practices for Active TransporTation Corridors

BEST PRACTICE #1: SIDEWALK AND BIKE-LANE SHADING

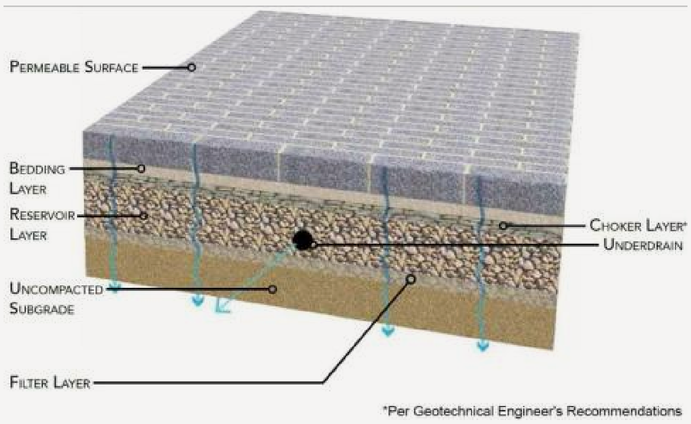
Sidewalks and bike lanes allow for safe pedestrian and bike travel, but they also contribute to local UHI effects due to their impermeable, dark surfaces. Adding shade trees next to heavily traveled sidewalks and bike lanes provides the most cost-effective way to increase traveler comfort, reduce air pollution, avoid stormwater runoff, and enhance aesthetic character. Shading active transportation corridors is particularly important on hot days, as is ensuring that active transportation remains a feasible, comfortable, zero-emissions transportation mode in the future. As described earlier in the plan, populations without access to a private vehicle are among those most vulnerable to the UHI effect, and the most likely to rely on walking and biking for mobility. This best practice, therefore, has an enhanced impact on equity.

4.2 Cool Pavement

Along with urban forestry, cool roofs, electric vehicles, and solar photovoltaic (PV), cool pavements provide an opportunity to incorporate urban heat mitigation efforts into transportation projects throughout the Capital Region. Pavement choices have a significant impact on the UHI effect because pavement can comprise a third of the urban land cover. Because conventional dark pavements absorb 80-95 percent of incoming sunlight, they can absorb significant amounts of heat, sometimes peaking at surface temperatures of 48-67°C (120-150°F) (Akbari H 1999), (U.S. Environmental Protection Agency 2012). This heat is then released at night, warming neighborhoods and negatively impacting public health. Conversely, cool pavements can help mitigate some urban heat impacts.

Cool pavements refers to materials that absorb less heat and maintain lower surface temperatures than conventional products. While there is no formal definition for cool pavements, practitioners focus on two main categories: reflective (or high albedo) pavements and permeable or evaporative pavements (U.S. Environmental Protection Agency 2012) (European Commission n.d.) (County of San Diego 2019).

TABLE 9: OVERVIEW OF COOL PAVEMENT STRATEGIES

APPROACH	DEFINITION	SAMPLE PROJECT
Reflective pavements	Reflective or cool-colored pavements absorb less sunlight, and therefore hold less heat than conventional pavement. They are created by using a reflective or clear binder, or a cool-colored surface coating, and can be used to coat both new and existing pavement.	 Source: Washington Post, 2017
Permeable pavements	Permeable pavements are porous and allow air, water, and water vapor into voids, which allows evaporative cooling. Permeable pavements can be non-vegetated (i.e., porous or rubberized asphalt, pervious concrete, and brick or block pavers) or vegetated (i.e., grass or concrete grid pavers) and are most applicable to low-traffic areas such as road shoulders, alleys, parking lots, and parking lanes. However, new research from a 2018 study by the National Center for Sustainable Transportation and Metrans Transportation Center suggests that certain permeable pavement designs may be suitable for heavy-duty vehicular strain (National Center for Sustainable Transportation 2018).	 Source: County of San Diego Green Infrastructure Guidelines, 2019

There are several cool pavement technologies, each of which varies in cost, materials, and application. Each technology is suited to different transportation contexts. The optimal technology depends on a wide range of project variables, including local climate, underlying soils, project size, expected traffic, and the desired pavement life (U.S. Environmental Protection Agency 2012). Table 10: Cool Pavement Technologies below includes descriptions, costs, and target uses for different pavements.

TABLE 10: COOL PAVEMENT TECHNOLOGIES[9]

PAVEMENT TYPE	COOL PAVEMENT APPLICATION	CONSTRUCTION OR MAINTENANCE	SOLAR REFLECTANCE	ESTIMATED SERVICE LIFE (YEARS)	APPROXIMATE INSTALLED COST ($ / SQUARE FOOT)*	DESCRIPTION AND TARGET USE
Conventional asphalt	Asphalt with high albedo aggregate	New construction	5-20%	7-20	$0.10 – $1.50	Description: Asphalt binder mixed with high albedo aggregate. Solar reflectance can increase as conventional asphalt ages. Target use: Relevant for all road applications. May be most effective in large, exposed areas such as parking lots.
Conventional concrete	Portland cement	New construction	40-70%	15-35	$0.30 - $4.50	Description: Portland cement mixed with water and aggregate. Solar reflectance varies based on color of concrete mixture (e.g., gray or white) and can decrease over time. Target use: Relevant for all road applications. May be most effect in large, exposed areas such as parking lots.
Other reflective pavements	Resin-based (clear binder)	New construction and maintenance	30-50%	Variable	$3.00	Description: Clear-colored tree resins in place of cement to bind the aggregate. Solar reflectance can decrease over time. Target use: Low traffic volume areas (i.e., sidewalks, trails, parking lots).
	Colored asphalt and concrete (i.e., pigments and seals)	New construction and maintenance	10-80%	5-10	$0.10	Description: Colored pigments or seals that may be more reflective than the conventional equivalent. Solar reflectance is dependent on material used. Target use: Effective in large, exposed areas such as parking lots.
Non-vegetated permeable pavement	Porous asphalt	New construction	5-20%	7-10	$2.00 - $2.50	Description: Spaces in the asphalt to allow water to drain through the surface. Solar reflectance is similar to conventional asphalt. Target use: Potential use for roads and highways. Common in low traffic volume areas (i.e., alleys or parking lots/lanes).
	Pervious concrete	New construction	35-40%	15-20	$5.00 - $6.25	Description: Voids in the concrete to allow water to drain through the surface. Solar reflectance is dependent on material type. Target use: Potential use for roads and highways. Common in low traffic volume areas (i.e., alleys or parking lots/lanes).
	Paving blocks	New construction	10-80%	> 20	$5.00 - $10.00	Description: Clay or concrete brick or block pavers filled with rocks, gravel, or soil. Solar reflectance dependent on material type. Target use: Low traffic volume areas (i.e., alleys or parking lots/ lanes).

9 Table adapted from Tables 2 and 3 in the Cool Pavements chapter of EPA's Reducing UHIs: Compendium of Strategies as well as Table 5 of the Chula Vista Cool Pavements study.

PAVEMENT TYPE	COOL PAVEMENT APPLICATION	CONSTRUCTION OR MAINTENANCE	SOLAR REFLECTANCE	ESTIMATED SERVICE LIFE (YEARS)	APPROXIMATE INSTALLED COST ($ / SQUARE FOOT)*	DESCRIPTION AND TARGET USE
Vegetated permeable pavement	Grass, concrete or gravel lattice pavers	New construction	25-60%	> 10	$1.50 - $5.75	Description: Plastic metal or concrete lattices to support vegetation growth between pavers. Target use: Low traffic volume areas (i.e., alleys or parking lots and lanes).
Surface applications	Chip seals with high albedo aggregate	Maintenance	20%	2-8	$0.10 - $0.15	Description: Aggregate used to resurface road and highway surfaces. Solar reflectance can decrease over time. Target use: Paving low traffic volume, large, exposed areas such as parking lots.
	Microsurfacing with high albedo materials	Maintenance	>35%	7-10	$0.35 - $0.65	Description: Thin sealing layer used for road maintenance. Target use: Extending pavement life of low- to medium-volume roads, airport runways, and parking areas.
	Ultra-thin whitetopping	Maintenance	40-70%	10-15	$1.50 - $6.50	Description: Layer of concrete applied over existing or new asphalt to add strength. Solar reflectance is similar to conventional concrete and can decrease over time. Target use: Resurfacing road segments, intersections, and parking lots.

**Costs presented here do not account for savings accrued by some technologies for their co-benefits (e.g., reduced need for stormwater infrastructure when permeable surfaces are installed).*

Recent research has revealed both benefits and potentially negative consequences to cool pavements. While modeling results show that cool pavements can mitigate urban heat, there are uncertainties about their application, durability, life cycle benefits, and human health effects. Table 11: Co-Benefits and Other Considerations of Cool Pavements, adapted from research by the U.S. Environmental Protection Agency and the Lawrence Berkeley Laboratory, provides a summary (Berkeley Lab Heat Island Group 2017).

4.2.1 CO-BENEFITS

TABLE 11: CO-BENEFITS AND OTHER CONSIDERATIONS OF COOL PAVEMENTS

CO-BENEFITS OF COOL PAVEMENTS	
Improved air quality, human comfort, and health	Cool pavements can reduce UHI effects (particularly in the evening), reduce heat-related illnesses, slow smog formation, and make conditions more comfortable for pedestrians, cyclists, and those working or playing outdoors.
Improved water quality	By lowering surface temperatures, cool pavements reduce the temperature of stormwater runoff, thereby lessening local watershed damage.
Reduced energy usage, emissions, and street lighting cost	Lowering outside air temperature reduces the need for cooling nearby buildings and lowers energy costs. Reflective pavement may also reduce the need for street lights in some areas by reflecting light more effectively, also lowering energy costs.
Increased driver safety	High albedo pavements increase street light and vehicle headlight reflectivity, improving driver visibility.
Reduced maintenance and repair costs	By reducing pavement surface temperature, cool pavements can reduce the risk of premature asphalt failure and temperature-related stresses that can crack concrete. Some cool pavement coatings applied to existing pavements can reduce maintenance costs by extending the pavement lifespan.

CASE STUDY

LOS ANGELES COOL PAVEMENTS

Since 2017, Los Angeles has coated roadways and pavement with two layers of a high albedo reflective surface made by CoolSeal across 15 residential blocks in the city, as shown in Figure 14 (Barboza 2019). This project's goal is to have 1,500 of the most heat-stricken blocks covered in the next ten years (about 2 percent of LA's total city blocks). CoolSeal's manufacturer, GuardTop, suggests that the technology can cool surface temperatures by 10°F. The coating costs $40,000 per mile and lasts roughly seven years (Renee 2018). While GuardTop had mainly applied CoolSeal to parking lots and playgrounds before this project, results from this first-time application and an additional re-application on public streets have verified that CoolSeal provides a 10°F cooling (U.S. EPA 2018) on average, and up to 23°F in the Canoga Park neighborhood (Hickman 2018).

The shaded areas in this map show the footprints of each of LA's 15 City Council Districts. The dots show the locations of the pilot CoolSeal projects (one in each council district).

Figure 15: Los Angeles Cool Pavements Overview

OTHER CONSIDERATIONS OF COOL PAVEMENTS

Life cycle energy and carbon impacts	Cool pavements are more energy and carbon-intensive to manufacture than conventional pavements. Also, the energy and carbon savings from reduced building energy use are less pronounced than those from cool roofs (Levinson, Gilbert and Pomerantz 2017).
Human comfort during the daytime	There are concerns that reflective pavements may cause people (especially pedestrians) to feel warmer during the daytime than conventional pavement (Bloch 2019). The sample sizes of these studies are small and do not account for nighttime cooling—but if implemented at a broad scale, cool pavements will likely provide an overall regional cooling benefit.
Product costs	Manufacturers have developed and marketed cool pavement products, but the market is relatively nascent, and cool pavements are generally priced higher than conventional pavements. Porous pavements, in particular, can be more costly than traditional pavements due to installation costs and annual maintenance to ensure consistent permeability (Hoverter 2012). However, as the market matures, costs will likely decrease. As mentioned earlier, some cool pavement coatings applied to existing pavements can reduce maintenance costs by extending the pavement lifespan, thus offsetting their installation cost.

Cool pavements are becoming more prevalent in municipal standards and best management practice (BMP) design guidelines (e.g., Caltrans AB296 and the County of San Diego BMP design guidelines), but their use has been selective in California and across the country and world (Committee 2011), (County of San Diego 2019). Jurisdictions tend to use permeable pavements more commonly than reflective pavements because the technology and applications are more accessible. Despite this, reflective pavements have been recently tested in some cities worldwide including Los Angeles, Tokyo, and Melbourne (C40 Cities 2016), (Associates 2019). The following case study describes efforts in Los Angeles.

4.2.2 HIGH-OPPORTUNITY AREAS

General Conclusions from 2-Kilometer Results

The figure below shows that an increase in albedo will be effective at reducing air temperatures in the urbanized area around Sacramento and Yuba City. Throughout the core Sacramento region, there is a consistent potential for increased albedo to reduce temperatures by nearly 1ºF (0.4 – 0.5ºC). With more pavement in dense urban areas like Sacramento, there are more opportunities to increase albedo and mitigate urban heat. Areas with new growth (e.g., Yuba City, Marysville, and areas in Placer County at the time of this report) could capitalize on the opportunity to incorporate cool pavements into their initial designs and development plans immediately. The highest heat mitigation potential overlaps with many areas that have underserved communities, so they should be prioritized when implementing mitigation measures.

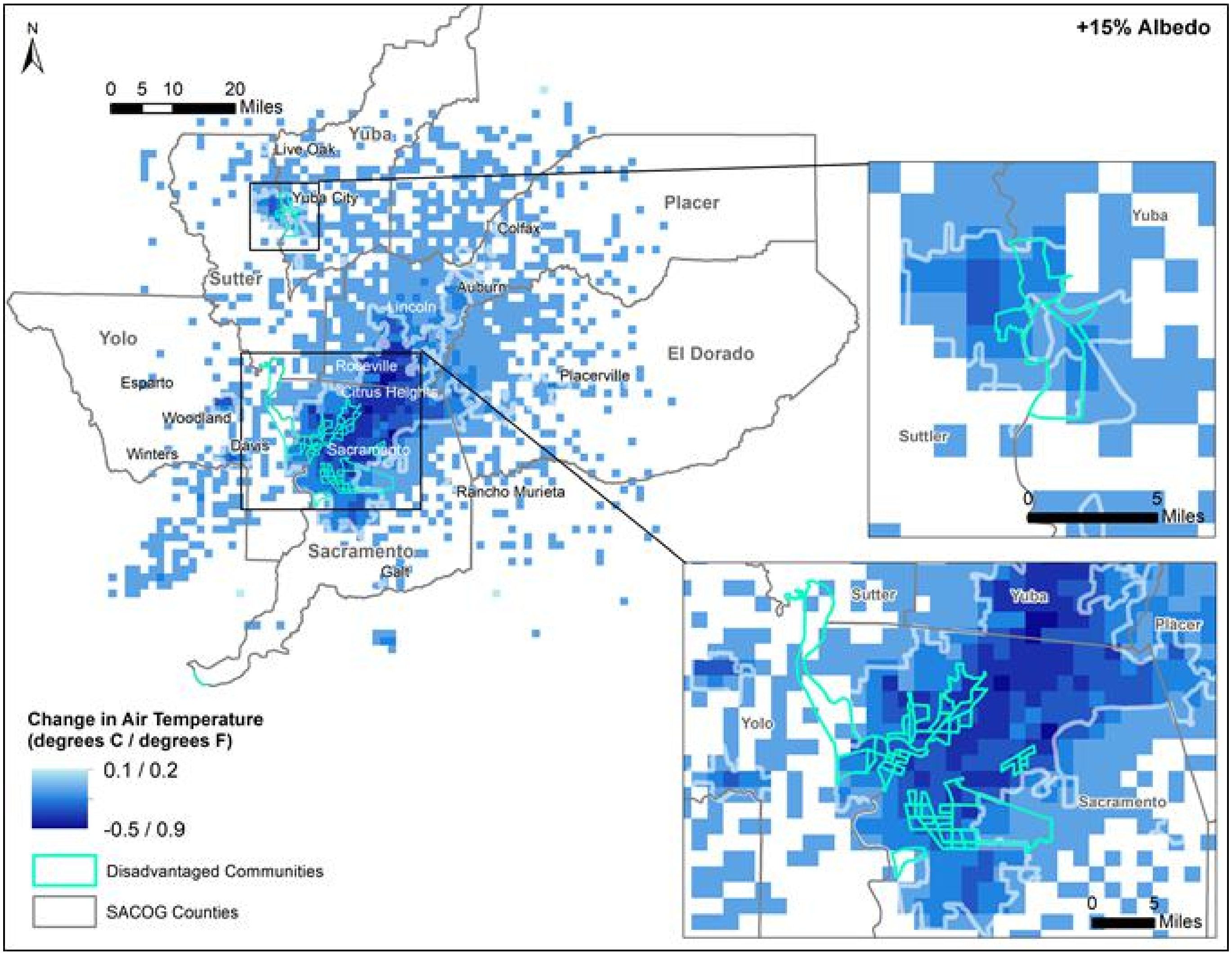


Figure 16: Impacts of Increased Albedo

This scenario represents an increase of 15 percent albedo. The cooling-potential data represents the 1400 – 2000 PDT interval average air temperature in the SACOG region from June-September 2013-2016.

Specific Conclusions from 500-Meter Results

The 500-meter modeling results in the table and figure below suggest that high albedo measures, particularly cool pavements, consistently have the most heat reduction potential from peak temperatures across all domains. These results are intuitive because where there are high concentrations of low-albedo pavements, there are opportunities for cool pavement applications to mitigate heat. Despite this potential, there are still questions about the durability, life cycle benefits, and human health effects of cool pavement technologies—these issues should also be considered when evaluating cool pavement applications.

TABLE 12: EFFECTIVENESS OF COOL PAVEMENTS AT MITIGATING SUMMER UHI

	CHANGE IN SUMMER TEMPERATURES[10]	
	DAILY PEAK TEMPERATURE (°F/°C)	DAILY MINIMUM TEMPERATURE (°F/°C)
Priority Area 1 (Yuba City/Marysville)	-4.3/ -2.4	-0.3/ -0.2
Priority Area 2 (Woodland)	-5.2/ -2.9	-0.5/ -0.3
Priority Area 3 (Sacramento/Southeast Sacramento)	-5.2/ -2.9	-0.4/ -0.2
Priority Area 4 (Sacramento/Roseville/Granite Bay)	-6.5/ -3.6	-0.7/ -0.4
Priority Area 5 (El Dorado Hills/Folsom)	-6.4/ -3.5	-0.5/ -0.3
Priority Area 6 (Placerville)	-5.8/ -3.2	-0.6/ -0.3

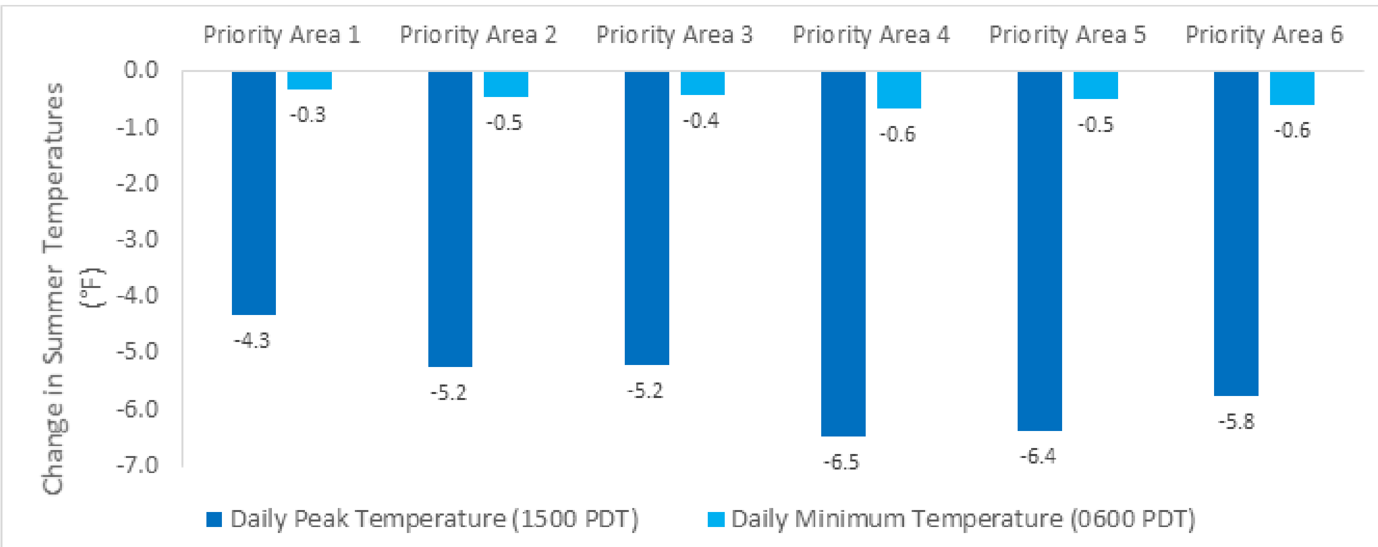


Figure 17: Effectiveness of Cool Pavements at Mitigating Summer UHI

4.2.3 TRANSPORTATION-SECTOR BEST PRACTICES

Best Practices for Transportation Infrastructure

BEST PRACTICE #1: MAINTENANCE SURFACE APPLICATIONS FOR LOW TRAFFIC VOLUME AREAS

Surface treatments such as reflective surfaces, microsurfacing, and chip-sealing with high albedo materials or whitetopping would increase albedo and help maintain low-volume traffic areas such as parking lanes, parking lots, alleys, sidewalks, bike lanes, plazas, playgrounds, and some intersections. As in Los Angeles, these treatments provide an excellent opportunity to test the effectiveness of high albedo surfaces in maintaining the transportation infrastructure and mitigate UHI effects in the Capital Region. As the technologies improve and costs decrease, these surface applications may become more applicable to high-volume traffic areas as well.

BEST PRACTICE #2: NON-VEGETATED PERMEABLE PAVEMENT FOR NEW CONSTRUCTION OF LOW VOLUME TRAFFIC AREAS

Porous asphalt or pervious concrete can be used when constructing parking lanes, parking lots, and alleys as well as in pedestrian areas such as playgrounds, sidewalks, and plazas. These permeable pavements, especially those with high albedo materials, reduce the quantity and temperature of stormwater runoff and improve water quality by filtering dust, dirt, and pollutants, thereby lessening damage to the Capital Region's watersheds. Additional co-benefits include reduced localized flooding, alleviated pressure on stormwater infrastructure, and replenished groundwater.

10 Change in air temperature. See modeling technical report for additional methodology detail.

Best Practices for Transit Services and Infrastructure

BEST PRACTICE #1: HIGH ALBEDO OR PERMEABLE PAVEMENTS FOR TRANSIT STATIONS, CENTERS, AND CORRIDORS

Transit infrastructure, such as parking lots and exterior waiting areas, provides ample opportunities to apply cool pavements. Generally, landscaping improvements and building overhangs (or shelter structures) are the most common strategies for minimizing heat impacts at transit stations and stops. However, high albedo or permeable pavements are becoming more viable options for both circulation elements and the transit structure. For example, transit center vertical infrastructure (such as buildings) may provide opportunities for high albedo building materials and cool walls (the Cool and Green Roofs section includes further detail on cooling potential of high albedo walls), while permeable pavements can be used for parking lots and pedestrian areas.

Best Practices for Active TransporTation Corridors

BEST PRACTICE #1: HIGH ALBEDO AND NON-VEGETATED PERMEABLE PAVEMENT BICYCLE PATHS

Permeable pavement bicycle paths provide urban heat mitigation and other co-benefits for jurisdictions with existing or planned bicycle paths. Permeable pavements allow air and water to pass through, reducing stormwater runoff, and can reduce UHI effects by increasing evaporation and reducing heat storage. Another cost-effective solution is omitting smaller aggregates from asphalt and concrete to increase porosity. Given the limited rainfall in the SACOG area during the hottest times of year (and thus fewer opportunities for evapotranspiration to occur), high albedo pavements may be as, or more, effective than the region's permeable pavements. Regardless of the measure, these approaches support active transportation and increase its potential for public health and equity co-benefits.

BEST PRACTICE #2: HIGH ALBEDO OR PERMEABLE PAVEMENTS FOR PEDESTRIAN CORRIDORS

Both high albedo and permeable pavements are highly applicable for pedestrian corridors such as sidewalks, trails, or areas around transit centers. Factors such as foot traffic volume, material costs, and co-benefits for specific locations should be considered when implementing this best practice. For example, both non-vegetated and vegetated permeable pavement materials are often costlier than conventional pavements but are practical in areas where reduced stormwater runoff and improved water quality are necessary. Despite the potential higher upfront cost, some cool pavement coatings applied to existing pavements can reduce long-term maintenance costs by extending the pavement's lifespan.

4.3 Cool and Green Roofs

Cool and green roofs are two popular strategies for mitigating the UHI effect. Generally, cool roofs offer lower costs and lower co-benefits. Green roofs (depending on their design) have higher upfront costs with greater co-benefits. Green roof design is flexible and can incorporate plants adapted to hotter, drier climates, (such as Sacramento), that have higher leaf succulence and lower water requirements. Green roofs generally offer all the benefits of cool roofs (such as reduced albedo) plus additional cooling and aesthetic benefits. Because of the limited applicability of roof-based approaches to the transportation sector, these approaches are discussed together.

Cool Roofs

Cool roofs incorporate materials with high solar reflectance and thermal emittance[11]—two factors that contribute to roof temperature and, in turn, UHI effects (U.S. EPA 2014). Given the limited roof area associated with most transportation projects, this mitigation measure has far greater impact in building-related sectors. However, because of the significant mitigation potential of this measure, consider the approaches below for transportation-related facility roofs whenever possible. A 2019 study from the Department of Energy's Lawrence Berkeley National Laboratory examined the effectiveness of cool roofs in mitigating the UHI effect in California. The study found that, for California's urban areas, widespread implementation of cool roofs by 2050 could offset 51-100 percent of the increased heat exposure anticipated due to climate change (Vahmani, Jones and Patricola 2019). In addition to this high mitigation potential, high-visibility buildings, such as transit stops, transit stations, and transit maintenance facilities are ideally suited to serve as cool-roof demonstration projects. Cool roofs reduce interior temperatures, which reduces energy demand and increases occupant comfort, even in locations with no air-conditioning (such as patios or garages). There are several cool-roof technologies, each suited to different building contexts. When a building is constructed, inherently cool surface coverings such as certain tiles or shingles may be used. When applied retroactively to existing roofs, these approaches use white or reflective, cool-colored coatings. The best technology depends on a wide range of project variables; however, all roofing materials with an ENERGY STAR label must meet minimum solar reflectance and reliability criteria. The *Implementation Strategy* provides additional detail on different types of cool-roof technologies.

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11 A material's ability to release absorbed heat.

SOLAR PHOTOVOLTAIC (PV) SYSTEMS AND COOL ROOFS:

Where feasible, installing a solar PV system alongside cool-roof technology can result in greater cooling and cost benefits (Magallanes 2011). Solar system efficiency can increase when installed on a cool roof because the increased reflectiveness of the roof increases the energy absorbed by the solar panel (as opposed to the roof). Both technologies can reduce the energy and cost demands of building cooling: for cool roofs, by reducing absorbed heat, and for solar PV systems, by generating energy when cooling is needed. Finally, solar energy reduces the need for fossil fuel energy to help avoid the effects of climate change and its associated increases in temperature.

This study evaluated the potential impacts of solar PV measures on near-surface temperatures (temperatures near the ground). Several parameters, including surface albedo, solar panel conversion efficiency, and panel cover were considered when evaluating the standalone effects of ground- and roof-based solar PV. Since there are exponential combinations of these parameters (including their evolution over time, potential future climates, and various urban surface properties), a scenario results sample for the Folsom area is provided here—the technical report provides additional details and results. The following table shows the PV implementation scenarios:

TABLE 13: SCENARIOS OF SOLAR PV IMPLEMENTATION

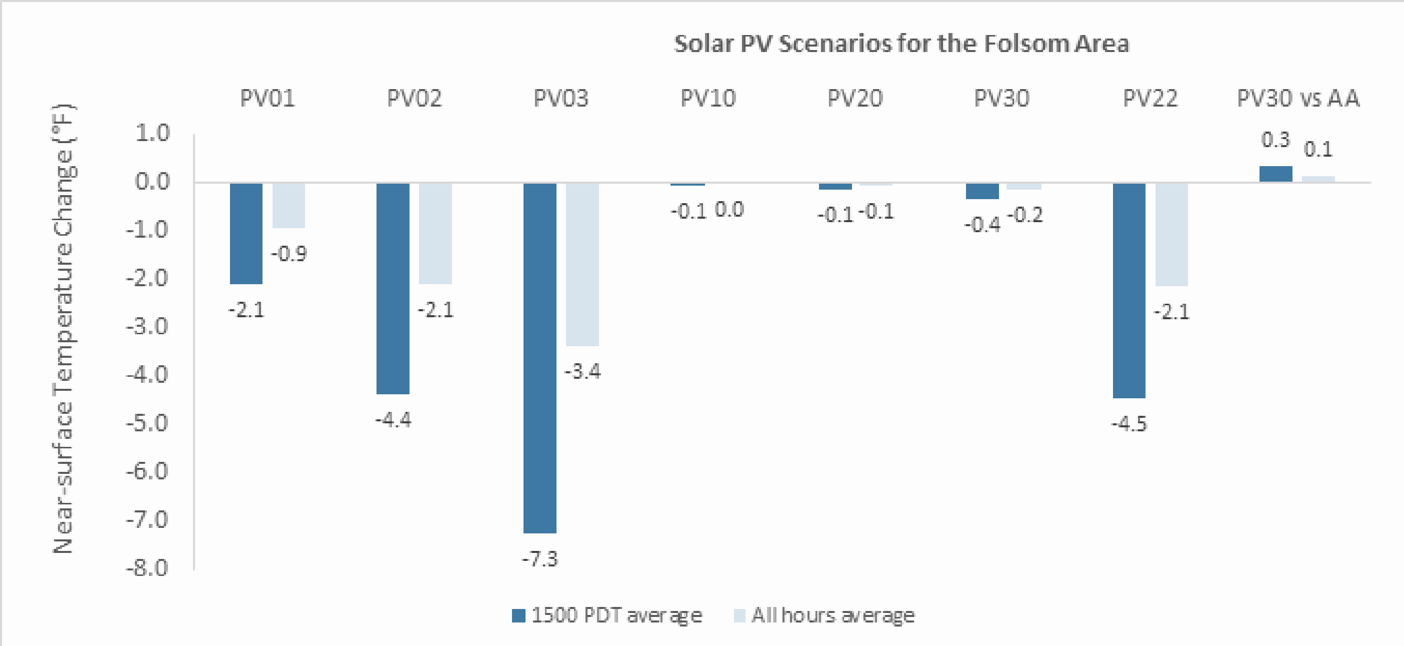
SCENARIO	SURFACE ALBEDO	SOLAR PANEL CONVERSION EFFICIENCY	SOLAR PANEL COVER
PAVED SURFACES (E.G., PARKING LOTS)			
PV01	~10-12%	15%	60%
PV02	~10-12%	30%	60%
PV03	30%	30%	80%
Roof surfaces			
PV10	~17-20%	15%	40%
PV20	~17-20%	30%	40%
PV30	50%	30%	60%
COMBINATION OF ROOFS AND PAVED SURFACES			
PV22	Paved surfaces: ~10-12% Roof surfaces: ~17-20%	Paved surfaces: 30% Roof surfaces: 30%	Paved surfaces: 60% Roof surfaces: 40%
PV30 vs AA	Future scenario demonstrating the potential negative effects of solar PV if implemented widely in the future when cool roofs and cool pavements have been implemented at a large scale.		

Results from the analysis (see Table 13: Scenarios of Solar PV Implementation) indicate that ground-based PV panels (e.g., those installed over parking lots) affect near-the-ground urban canopy temperatures more than roof-level PV panels. This is because 1) the roof modification effects occur at higher elevations above street level so they have smaller impacts on temperature near the ground, and 2) the albedo of roofs and the effective albedo of the solar panels are roughly similar. This example evaluates only near-ground-level temperature impacts; however, near the top of the canopy layer and above roof level, both roof-based and ground-based solar PV have significant and similar effects on air temperature.

Case PV02's larger cooling effect (relative to case PV01's) is due to increased PV conversion efficiency (15 to 30 percent) and represents the range of possible cooling effects offered by current technology and typical urban areas albedo ranges.

The near-surface temperature reductions resulting from roof-based solar PV (cases PV10 and PV20) are small, for the reasons listed above. Nevertheless, these numbers show that solar PV installation benefits (in terms of electricity) at roof level can be attained without incurring negative atmospheric effects (such as increasing air temperature at street level). In a scenario where both roof and ground-based solar PV are implemented (for example, case PV22), the cooling is only slightly larger than in case PV02.

In cases PV03 and PV30, the background albedos of roofs and pavements are also increased by installing solar PV—consequently, the resulting significant cooling effects are attributable mostly to the increases in background albedo. Case PV30 vs AA demonstrates the potential negative effects of solar PV if implemented widely in the future, when cool roofs and cool pavements may also be implemented at a large scale. In this case, the solar PV installation could increase near-surface temperature by an average of 0.14°F (0.08°C) for the all-hours average temperature and 0.32°F (0.18°C) at the time of the peak temperatures (1500 PDT). This occurs only if cool roofs and pavements are installed at a large scale, but this scenario's temperatures are still cooler than a no-mitigation base scenario. Solar PV also has many co-benefits that are unaccounted for in these scenarios that justify its implementation with cool roofs and pavements measures.



Note that scenarios PV03 and PV30 include significant increases in background albedo in addition to changes due to solar PV.

Green Roofs

Green roofs (also known as vegetated roofs or living roofs) generally consist of a waterproofing membrane, growing medium (soil), and vegetation (plants) overlying a traditional roof. This roof type is another popular UHI mitigation approach. The specific design of a green roof can vary based on project size and need, but there are two general categories—extensive and intensive. Extensive roofs are comprised of a thin soil layer and resilient plants, such as succulents, that require little maintenance. Intensive roofs feature thicker soil layers and a greater variety of plants and design features. Most green roofs on commercial and public buildings are extensive unless the space is publicly accessible and intended for recreation (U.S. General Services Administration 2011). In many ways, green roofs combine the benefits of urban forestry and cool roofs. Like cool roofs, a green roof reduces a building's energy demand (and the related impacts). Like urban forestry projects, green roofs reduce heat by shading the structure on which they are located, which prevents them from absorbing heat, and by increasing evapotranspiration. Although the transportation sector involves far less roof area than the buildings sector, the highly visible nature of many transportation-related buildings (such as bus stops) makes them ideal candidates for green roof pilot projects.

4.3.1 CO-BENEFITS

TABLE 14: CO-BENEFITS OF COOL AND GREEN ROOFS

CO-BENEFITS OF COOL AND GREEN ROOFS (COOLCALIFORNIA.ORG N.D.)	
Reduced energy demand	By reducing the heat stored in the building's materials, green and cool roofs reduce internal building temperatures, and thus the need for air conditioning. This reduces the building's energy demand and utility bills.
Increased comfort and safety in uncooled areas	Lowering a building's temperature is particularly important for uncooled areas, such as garages, warehouses, or patios. Reducing temperatures in these areas can increase occupant comfort and mitigate heat-related health and productivity impacts.
Increased roof durability	Both green roofs and cool roofs increase the service life of the underlying roof because its materials are more insulated and protected from exposure.
Reduced energy demand and grid stability	Less energy demand reduces the emissions associated with power generation, which improves air quality and lowers GHGs. Reducing energy demand for cooling, which is often highest during hot summer afternoons and evenings, also reduces electrical grid strain and the likelihood of power outages and the resulting public health and economic impacts.
Improved stormwater management	Green roofs can reduce roof stormwater runoff by up to 65 percent and the risk of drainage system overload during peak discharge periods.
Biodiversity and habitat	Green roofs increase a city's vegetated footprint and offer a refuge for plant and animal species in an otherwise inhospitable landscape.
OTHER CONSIDERATIONS	
Additional costs of cool roofs	While costs vary widely between cool-roof technologies, their installation may cost between $0 and $0.20 per square foot. The investment's payback period is approximately zero and six years, which is reduced if financial incentives (from a utility or other organization) are available (Globalcoolcities.org n.d.). The payback period will likely be larger in areas with hot summers, such as the Capital Region, where cooling savings are realized more rapidly.
Additional costs of green roofs	Depending on the complexity of the green roof system installed, upfront and maintenance costs can be significantly higher than a conventional roof. The US General Services Administration, which maintains over 2 million square feet of green roofs, found that the calculated payback period for the additional investment of a green roof is 6.2 years—but cost savings will likely increase as environmental regulations become more stringent (U.S. General Services Administration n.d.).
Winter heating penalty	The ability of a cool roof to resist holding heat persists during cold weather, when heat-holding may be desirable for building occupants. However, studies have found that this "winter heating penalty" is small compared to the summer cooling benefits—particularly in regions where winters are relatively mild (such as the Capital Region). The impact is small because, in winter, the sun is lower, the days are shorter, and cloudy skies reduce the amount of sunlight that roofs can absorb (Levinson and Akbari 2010).

4.3.2 HIGH-OPPORTUNITY AREAS

General Conclusions from 2-Kilometer Results

This project's modeling examines the impact of various types of mitigation measures, rather than the specific mechanisms through which those changes are achieved. The 2-kilometer modeling does not distinguish between an increase in albedo from cool roofs and cool pavements, nor does it distinguish between an increase in vegetation cover from green infrastructure and green roofs. Rather, these measures are combined at the 2-kilometer level to highlight cool spots across the region that can be further examined through localized 500-meter modeling. To avoid redundancy, the cool pavements and green infrastructure sections include regional recommendations for these two mitigation measures.

Specific Conclusions from 500-Meter Results

The impacts of cool and green roofs alone at a 500-meter level were not modeled as part of this project. Individually, these impacts are small at a local level and are combined for the purposes of presentation in this report. However, even small measures can have an important impact on mitigating UHI effects, particularly when combined with other measures. To demonstrate the multiplicative effect of combining mitigation measures, the 500-meter results of the cool-roof impacts are presented in conjunction with those of cool pavements. The combined impacts are most pronounced in El Dorado Hills/Folsom, where implementing both cool roofs and cool pavements could result in a temperature reduction of 5.7°F (3.2°C) during peak temperature conditions. The nearby area that includes Sacramento, Roseville, and Granite Bay also has a high modeled efficacy of 5.2°F (2.9°C) for this mitigation measure combination. These areas have low air temperatures relative to the more urban portions of the study area—this may make UHI mitigation less of a priority in them than in other areas. However, as discussed above, green and cool roofs offer a number of co-benefits in addition to reducing the UHI effect and should be considered even in less-impacted regions. It is also important to consider that the effect of these combined mitigation measures is high in the modeled 500-meter areas throughout the region. As a result, the combination of cool pavements and cool roofs is an effective UHI mitigation measure in a wide range of local contexts and should be considered for all transportation-sector roofs.

TABLE 15: EFFECTIVENESS OF COOL ROOFS AND PAVEMENTS AT MITIGATING SUMMER UHI

	CHANGE IN SUMMER TEMPERATURES[12]	
	DAILY PEAK TEMPERATURE (°F/°C)	DAILY MINIMUM TEMPERATURE (°F/°C)
Priority Area 1 (Yuba City/Marysville)	-4.9/ -2.7	-0.4/ -0.2
Priority Area 2 (Woodland)	-4.5/ -2.5	-0.5/ -0.3
Priority Area 3 (Sacramento/Southeast Sacramento)	-4.9/ -2.7	-0.5/ -0.3
Priority Area 4 (Sacramento/Roseville/Granite Bay)	-5.2/ -2.9	-0.5/ -0.3
Priority Area 5 (El Dorado Hills/Folsom)	-5.7/ -3.2	-0.5/ -0.3
Priority Area 6 (Placerville)	-4.5/ -2.5	-0.4/ -0.2

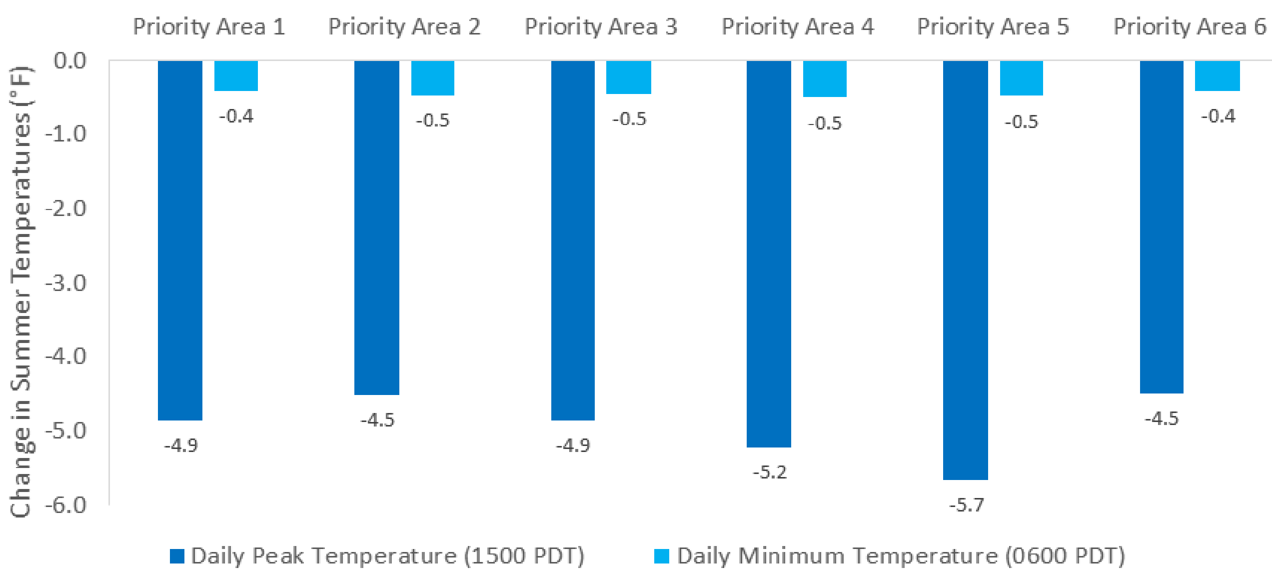


Figure 18: Effectiveness of Cool Roofs and Pavements at Mitigating Summer UHI

12 Change in air temperature. See modeling technical report for additional detail on methodology.

A NOTE ON THE IMPACT OF COOL WALLS

Similar to cool and green roofs, cool walls (walls made with high albedo materials) have limited applicability in the transportation sector, but may be appropriate for building infrastructure for transit and other forms of transportation. This study quantified the impacts of an increase in wall albedo from 15 to 40 percent across various summer time periods and intervals. The results in Figure 19: Impacts of Cool Walls Across the SACOG Region During the Summer suggest that cool walls impact daytime temperatures the most, with a maximum cooling average of 1.91°F (1.06°C) across the region.

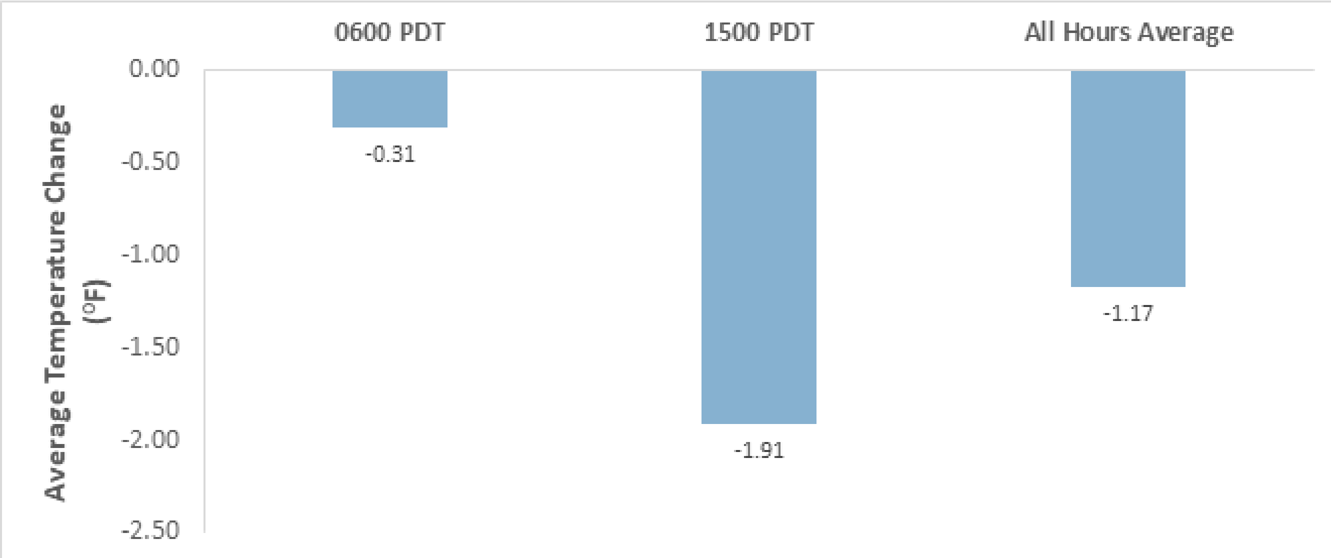


Figure 19: Impacts of Cool Walls Across the SACOG Region During the Summer

CASE STUDY

Figure 20: One of More Than 300 Pollinator-Friendly Green Roofs on Transit Stations in Utrecht, Netherlands

TRANSIT STOPS GREEN ROOFS

Cities in California and around the world are installing green roofs on transit stops. In San Francisco, a 2008 demonstration project installed native, low-maintenance plants on top of the city's bus shelters. A similar project was implemented in Philadelphia a few years later. More recently, the city of Utrecht in the Netherlands has scaled up the concept, adding 316 "bee-friendly" green roofs to its transit stops to provide both shade for passengers and habitat for endangered bee species (Staugaitis 2019).

4.3.3 TRANSPORTATION-SECTOR BEST PRACTICES

Best Practices for Transportation Infrastructure

BEST PRACTICE #1: SOLAR PV SHADING FOR PARKING LOTS

As described above, solar PV systems are complementary with cool roofs in many ways. When installed on shelters above a parking lot, they can provide shade for vehicles parked below while generating fossil-fuel-free energy. The reduced temperatures in shaded areas increase comfort while avoiding the reduced fuel economies that cars experience when running air conditioning (a penalty of up to 25 percent on hot days) (Energy Sage n.d.). The energy generated from these systems can reduce the need for fossil fuel energy and further reduce climate change heat impacts.

Best Practices for Transit Services and Infrastructure

BEST PRACTICE #1: GREEN AND COOL ROOFS AT TRANSIT STATIONS

Green and cool roofs are recommended for uncooled areas, such as bus stops. Incorporating these techniques at transit stations reduces heat-related health and productivity impacts while mitigating the broader UHI effect. Although the benefits of this small-scale implementation are fewer than for other types of buildings, green and cool roofs can improve the aesthetics of the area, increase public awareness of this design strategy, and (in the case of green roofs) offer a refuge for wildlife. The addition of low-cost educational signage could easily enhance the awareness-building capacity of green roofs at transit stations. There is greater potential to educate the public on the benefits of vegetation cover with this method than with green infrastructure.

Best Practices for Active TransporTation Corridors

BEST PRACTICE #1: COOL AND GREEN ROOFS FOR GREENWAY TRAILS

Designated bike and pedestrian greenway trails often have restrooms, rest areas, or shade structures in otherwise vegetated surroundings. Because these facilities are typically not surrounded by gray infrastructure, the shade they provide may not have a significant impact on pavement temperatures. However, they do offer cooling to facility users and help incentivize no-emission transportation.

4.4 Electric Vehicles

Traditional internal combustion engine vehicles lose 58 to 62 percent of their gasoline's energy as waste heat, which is released into the surrounding environment (Department of Energy n.d.). This waste heat contributes to the UHI effect, which is further amplified by low-albedo highway and roadway surfaces. In contrast, zero-emission vehicles (ZEVs), including both electric vehicles (EVs) and hydrogen vehicles, are far more efficient, with very little energy lost as waste heat (Department of Energy n.d.). Replacing fossil fuel vehicles with EVs can mitigate the UHI effect. A study in Beijing, China, showed that EVs emit only 19.8 percent of the total heat that conventional vehicles emit per mile, and that converting all cars to EV could lower summer urban temperatures by 1.7 °F (0.9 °C) (Li 2015). More locally, sample results from one modeled scenario show that if central Sacramento had 30 percent vehicle electrification, roadway surfaces could cool by up to 4.3°F (2.4 °C) and surrounding air temperatures by up to 3°F (1.7 °C) at 5:00 pm (H. Taha 2019). This is a significant cooling benefit (especially for pavement maintenance), which could be amplified by deploying other heat mitigation measures.

Current and projected increases in average temperatures will impact EV range and long-term battery health—extreme heat causes long-term degradation that will reduce overall battery lifespan (Reddy 2011). As the Capital Region and California strive for higher vehicle electrification levels, it is important to consider electric vehicle heat vulnerabilities and resiliency improvement strategies. Designing public charging stations with passive cooling elements can help protect batteries as they charge and help reduce overall UHI effects.

Electric vehicle charging station solutions could include shade canopies, solar photovoltaic (PV) canopies, higher-albedo pavements, permeable pavements, trees, and other vegetation. Conventional pavements can be 50 (27.7 °C)to 90ºF (50 °C) warmer than surrounding air temperatures by absorbing 80 to 95 percent of incoming solar energy, and the heat would then be radiated back to the electric vehicles (Lawrence Berkeley National Laboratory n.d.). By contrast, permeable and cool pavements would absorb and reflect less heat. Shaded parking can reduce the internal temperature of a parked car during hot days, saving battery power for cooling the interior. An appropriately sized solar PV canopy can provide some (or all) of the electricity needed for electric vehicle charging. If designed well, greenery and urban vegetation can provide electric vehicle travelers both cooling and a desirable place to rest and rejuvenate while waiting for their vehicles to recharge.

CASE STUDY

Figure 21: Conceptual Design of the Sortimo Innovationspark Zusmarshausen

Source: Yardi

THE SORTIMO INNOVATIONSPARK ZUSMARSHAUSEN

The largest electric vehicle fast-charging station in the world aims to make electric vehicle charging a pleasant and productive experience. The design evokes the experience of being in a park, with green spaces, walking paths, and green roofs shading the chargers, all of which provide passive cooling for vehicles, people, and the surrounding environment. The station will also feature meeting rooms, office spaces, restaurants, and shopping. There will be 144 chargers, including fast chargers, that can handle up to 4,000 cars daily (Yardi n.d.). The electricity will be primarily sourced from on-site solar with battery storage, while waste heat from the transformer, battery, and electric vehicle service equipment will be used to heat the building via heat pumps (Transsolar n.d.). Overall, the station is projected to help reduce 60,000 tons of GHGs each year. The station is located near Augsburg on the A8 highway that links automotive powerhouses Mercedes Benz in Stuttgart and BMW in Munich. Construction is underway and will be completed in mid-2020 (SWP n.d.)

4.4.1 CO-BENEFITS

TABLE 16: CO-BENEFITS OF ELECTRIC VEHICLES

CO-BENEFITS OF ELECTRIC VEHICLES	
Reduced GHGs	In regions with a relatively low carbon-intensive electricity supply like Sacramento (compared to other US regions with more fossil fuel-based electricity generation), transitioning to EVs could reduce GHGs.
Reduced criteria air pollutant emissions	Transitioning to EVs can result in reduced local-level air pollutant emissions if a majority of the electricity supply is from renewable sources.
Fuel savings	The high efficiency of EV components can reduce fuel costs dramatically. Depending on the driving style, today's EVs can exceed the equivalent of 100 miles per gallon (Department of Energy n.d.). In the US, it costs an average of half as much to drive an EV as a conventional gasoline fueled vehicle (Department of Energy n.d.).

CASE STUDY

Figure 22: EVgo's Charging Station in Baker, California

Source: EVgo

COMBINING, SOLAR, FAST-CHARGING, AND BATTERY STORAGE

Charging company EVgo is deploying innovative new stations that deploy second-life batteries repurposed from retired BMW test vehicles to store electricity generated on-site by solar PV canopies (EVgo n.d.). The combination of solar, storage, and fast charging ensures that vehicles will be charged with renewable energy and energy grid demand will be reduced. According to staff at UC San Diego (which hosted the demonstration site), users appreciate the solar shade canopies. The design has since been introduced elsewhere, including Baker, California.

Similarly, many of Tesla's newest supercharger stations incorporate battery storage and solar panels over every stall.

This charging station has a 20kW Solar System in Combination With Fast Chargers (50-350kW) and a 60kW / 88 kWh storage system.

4.4.2 HIGH-OPPORTUNITY AREAS

Specific Conclusions from 500-Meter Results

The 500-meter modeling results in the table and figure below suggest that a 25-percent increase in electric vehicle adoption (as per SMAQMD's ZEV readiness plan), has moderate heat reduction potential for daily minimum and peak temperatures across all domains. The highest potential reduction in daily peak temperature is 0.9°F (0.5°C) for the Sacramento, Roseville, and Granite Bay area.

TABLE 17: EFFECTIVENESS OF ELECTRIC VEHICLES AT MITIGATING SUMMER UHI

	CHANGE IN SUMMER TEMPERATURES	
	DAILY PEAK TEMPERATURE (°F/°C)	DAILY MINIMUM TEMPERATURE (°F/°C)
Priority Area 1 (Yuba City/Marysville)	-0.4/ -0.2	-0.2/ -0.1
Priority Area 2 (Woodland)	-0.4/ -0.2	-0.3/ -0.2
Priority Area 3 (Sacramento/Southeast Sacramento)	-0.7/ -0.4	-0.4/ -0.2
Priority Area 4 (Sacramento/Roseville/Granite Bay)	-0.9/ -0.5	-0.6/ -0.3
Priority Area 5 (El Dorado Hills/Folsom)	-0.5/ -0.3	-0.3/ -0.2
Priority Area 6 (Placerville)	-0.3/ -0.2	-0.2/ -0.1

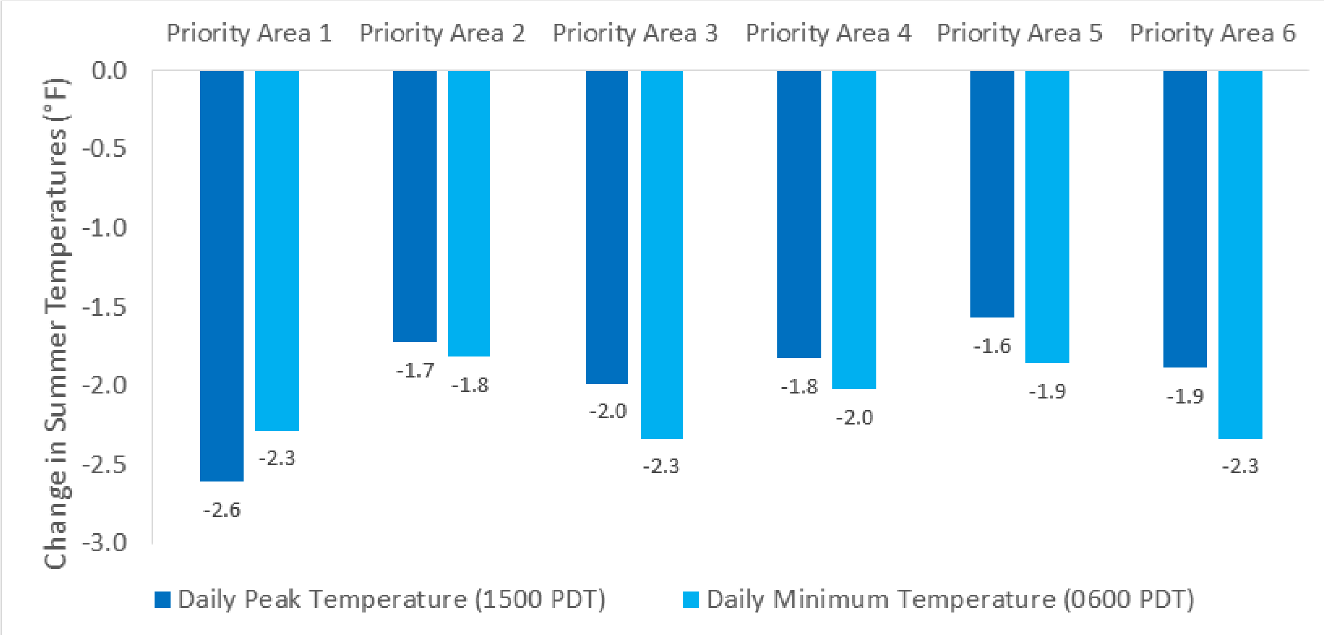


Figure 23: Effectiveness of Electric Vehicles at Mitigating Summer UHI

This data represents an average of the changes in surface and air temperatures. Since tailpipe heat emissions are closer to the ground, a fairer comparison between the effects of cool surfaces and electric vehicles is to use both air and surface temperatures for electric vehicles (i.e., averaging them) rather than separating them (H. Taha, Personal communication 2019).

4.5 Smart Growth

Typical urban area characteristics can influence UHI effect formation. Lack of trees and vegetative cover, a high percentage of impervious surface area, less-reflective materials used for buildings and paved surfaces, and dense, compact design that prevents heat loss, can all contribute to and exacerbate the UHI effect. As such, the built environment plays a significant role in the UHI effect, and smart growth development strategies provide an opportunity to mitigate it (U.S. Environmental Protection Agency n.d.).

Smart growth strategies help protect the natural environment and make communities more attractive, livable, and economically vibrant. These strategies focus on how and where to accommodate both new development and redevelopment, and how to improve transportation system efficiency (United States Environmental Protection Agency 2011). The Local Government Commission developed the Ahwahnee Principles for Resource-Efficient Communities in 1991, which served as the basis for new urbanism efforts and helped guide smart growth efforts into the future. The principles are designed to help decision-makers at the community-level minimize sprawl and increase efficient development.

Ahwahnee Principles for Resource-Efficient Community

"Existing patterns of urban and suburban development seriously impair our quality of life. The symptoms are: more congestion and air pollution resulting from our increased dependence on automobiles, the loss of precious open space, the need for costly improvements to roads and public services, the inequitable distribution of economic resources, and the loss of a sense of community. By drawing upon the best from the past and the present, we can plan communities that will more successfully serve the needs of those who live and work within them. Such planning should adhere to certain fundamental principles" (Peter Calthorpe n.d.)

COMMUNITY PRINCIPLES:

1. All planning should be in the form of complete and integrated communities containing housing, shops, work places, schools, parks and civic facilities essential to the daily life of the residents.
2. Community size should be designed so that housing, jobs, daily needs and other activities are within easy walking distance of each other.
3. As many activities as possible should be located within easy walking distance of transit stops.
4. A community should contain a diversity of housing types to enable citizens from a wide range of economic levels and age groups to live within its boundaries.
5. Businesses within the community should provide a range of job types for the community's residents.
6. The location and character of the community should be consistent with a larger transit network.
7. The community should have a center focus that combines commercial, civic, cultural and recreational uses.
8. The community should contain an ample supply of specialized open space in the form of squares, greens and parks whose frequent use is encouraged through placement and design.
9. Public spaces should be designed to encourage the attention and presence of people at all hours of the day and night.
10. Each community or cluster of communities should have a well defined edge, such as agricultural greenbelts or wildlife corridors, permanently protected from development.
11. Streets, pedestrian paths and bike paths should contribute to a system of fully connected and interesting routes to all destinations. Their design should encourage pedestrian and bicycle use by being small and spatially defined by buildings, trees and lighting; and by discouraging high-speed traffic.
12. Wherever possible, the natural terrain, drainage, and vegetation of the community should be preserved with superior examples contained within parks or greenbelts.
13. The community design should help conserve resources and minimize waste.
14. Communities should provide for the efficient use of water through the use of natural drainage, drought tolerant landscaping and recycling.
15. The street orientation, the placement of buildings and the use of shading should contribute to the energy efficiency of the community.

More recently, the Smart Growth Network, a partnership of government, business, and civic organizations, has developed ten basic smart growth principles (United States Environmental Protection Agency 2011). They are:

- Mix land uses, such as residential, commercial, and recreational
- Take advantage of compact building design
- Create a range of housing opportunities and choices
- Create walkable neighborhoods
- Foster distinctive, attractive communities with a strong sense of place
- Preserve open space, farmland, natural beauty, and critical environmental areas
- Strengthen and direct development toward existing communities
- Provide a variety of transportation choices
- Make development decisions predictable, fair, and cost-effective
- Encourage community and stakeholder collaboration in development decisions.

UHI mitigation strategies can incorporate these smart growth principles—increased tree cover not only helps create more attractive, naturally beautiful communities but also assists in reducing urban heat impacts in developed areas. Likewise, smart growth initiatives can incorporate UHI mitigation strategies, such as incorporating cool roofs into building designs in smart growth areas. These principles are designed to be flexible and adaptable and have been successfully applied in locations throughout the US.

Smart growth strategies have multiple community benefits—for example, focusing development in the urbanized core close to existing transportation networks and key community resources (such as shopping or jobs) can help reduce vehicle dependency, promote active transportation modes, and encourage sustainable infrastructure. Focused development in existing communities can also help avoid the need to build new roads and infrastructure, which can help to reduce a community's percentage of impermeable surfaces. A side effect of this focused development, typically when coupled with other growth policies, is the preservation of rural greenspace. Together, these efforts can help minimize the UHI effect. However, sprawl alone does not increase UHI effects, which a recent study in Sacramento-sized Brisbane, Australia shows (Deilami and Kamruzzaman 2017). The study suggests that sustainable strategies and increased tree canopies in developments outside the urban core may also help to alleviate UHI effects.

TABLE 18: POTENTIAL SMART GROWTH APPROACHES (U.S. ENVIRONMENTAL PROTECTION AGENCY N.D.)

SMART GROWTH SOLUTION	SOLUTION DESCRIPTION
Reducing off-street parking and using porous paving materials	• Because surface parking lots replace natural vegetation with pavements that transfer heat to the surrounding air, providing on-street parking and planning compact, pedestrian-oriented development will promote active transportation choices and help minimize the size and number of parking lots.
Planting, preserving, and maintaining trees and vegetation	• Trees and vegetation cool surrounding areas by providing shade and increasing evapotranspiration—a natural process that draws heat from the air to convert water in the leaf structure to water vapor. • Rooftop gardens and green roofs can also mitigate UHI effects while increasing the energy efficiency and attractiveness of commercial and residential buildings. • More parks and shared green spaces can help reduce UHI effects in more compact and denser areas.
Promoting infill and higher-density development	• Development within existing communities can preserve open space and help offset UHI effects. A 2001 report found that for every acre of brownfield redevelopment, 4.5 acres of open space are preserved. Additional research found that compact development can contribute less heat energy to the surrounding air than existing developments that have low-density dispersed growth patterns (Stone and Rodgers 2001).
Increasing public education and outreach	• UHI effect mitigation strategies should reflect local variations in the built environment, as well as local preferences and attitudes. • Policies should be tailored based on stakeholder input to meet these needs and be effectively communicated to the public. • Committees formed to address urban heat mitigation should include representatives from citizen groups, local governments, non-governmental organizations, universities, and others concerned about their community's growth. • A lead organization should be appointed to distribute information to the community, solicit feedback, and incorporate issues and concerns into action plans. • Working together, communities can address UHI effects while enhancing the quality and character of their neighborhoods.

4.5.1 CO-BENEFITS

In addition to the UHI mitigation potential of smart growth strategies, these strategies also offer a range of co-benefits. These co-benefits, and other considerations pertaining to smart growth, should be incorporated into the decision-making process and strategies for transportation projects.

TABLE 19: CO-BENEFITS AND OTHER CONSIDERATIONS OF SMART GROWTH

	CO-BENEFITS OF SMART GROWTH
Increase in the aesthetic value of communities	Trees and vegetation contribute to the beauty, distinctiveness, and material value of communities by incorporating the natural environment into the built environment.
Reduced energy demand in buildings	Trees provide shade, interior cooling, and reduced air conditioning energy demand when planted near homes and buildings,
Reduced air pollution	Trees and vegetation planted along medians and sidewalks can decrease evaporative emissions from cars and filter out air pollution.
Reduced GHGs	Compact development could reduce vehicle miles traveled (VMT) by 20 to 40 percent compared with dispersed development, resulting in reduced automobiles GHG emissions.
Enhanced public health	Compact, connected development patterns increase overall activity levels. Increased physical activity (30 minutes per day of moderate exercise) can reduce obesity and improve health.

4.5.2 HIGH-OPPORTUNITY AREAS

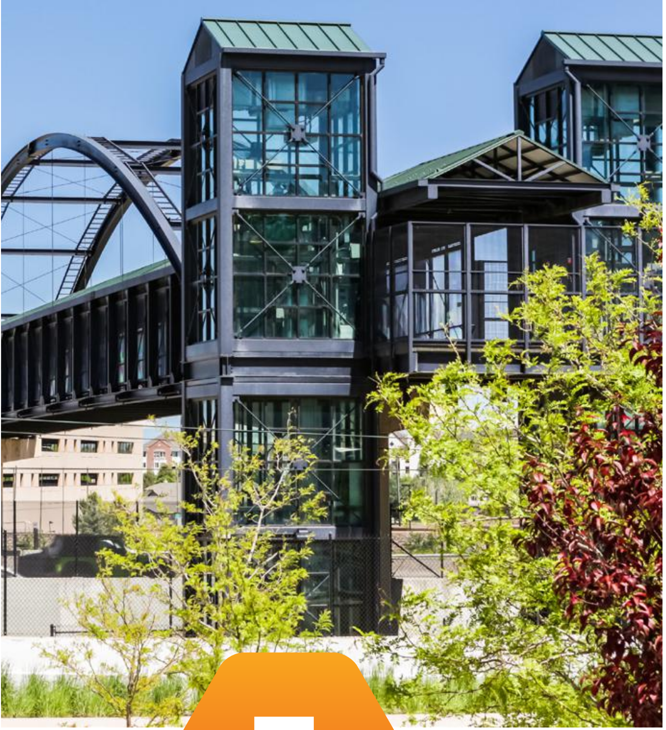
Specific Conclusions from 500-Meter Results

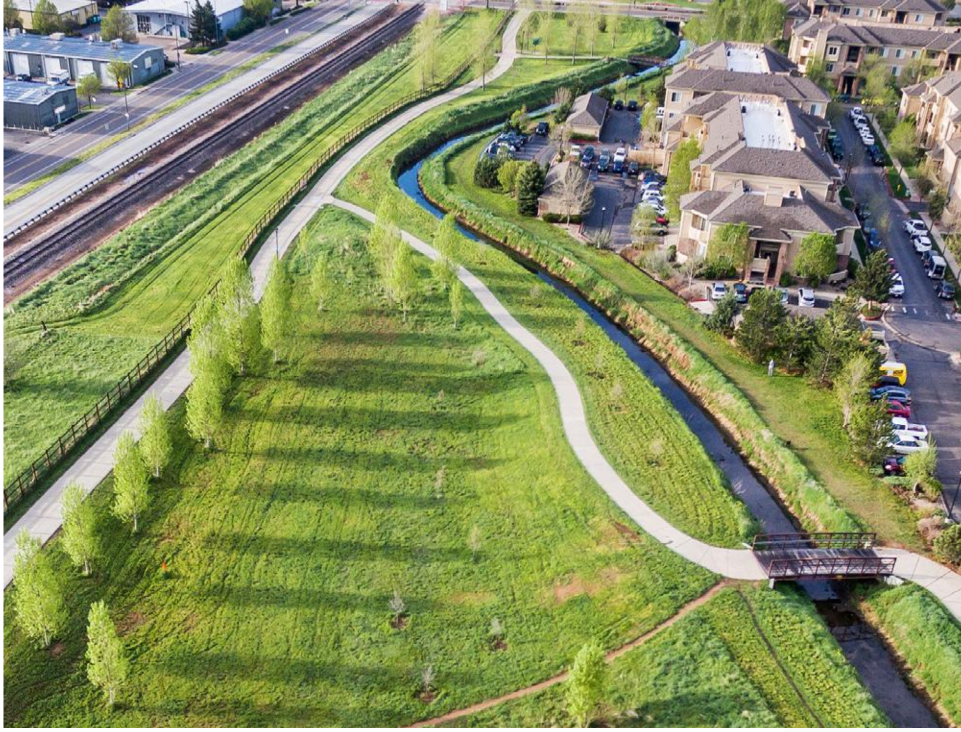
This study evaluated a smart growth scenario in which 15 percent less urbanization occurs by 2050 relative to a business-as-usual scenario in which growth primarily occurs at the edge of existing urban areas. While there are several ways smart growth impacts can be quantified (including averaging over an entire region or priority area), this study focused on evaluating impacts at locations where urbanization was prevented (see detailed technical report for additional detail). These results significantly decreased warming relative to a regional average and within urbanized priority areas.

The table below summarizes time-specific warming trend avoidance both regionwide and in areas with less urbanization to summarize how time-of-day and geographic scale can impact results. The results suggest that smart growth measures have a larger impact at night as opposed to day—which parallels the concept that urbanization affects night temperatures more than day temperatures.

TABLE 20: IMPACTS OF REGIONAL SMART GROWTH MEASURES IMPLEMENTED BY 2050 ACROSS VARIOUS TIMES OF DAY

TIME OF DAY (PDT)	SMART GROWTH IMPACTS
0600	The average avoided warming is about 3.6°F (2°C) in areas where urbanization was prevented or minimized. If averaged over each priority area, the effects of smart growth are an avoided warming of between 0.09°F (0.05°C) and 0.27°F (0.15°C) regionwide.
1300	Avoided warming ranges from an average of 0.09°F (0.05°C) in Davis to up to an average of 0.7°F (0.4°C) in Auburn. If averaged over each priority area, the effects of smart growth are an avoided warming of between 0.09°F (0.05°C) and 0.18°F (0.1°C) regionwide.
1500	Avoided warming ranges from an average of 0.35°F (0.20°C) in Davis to up to an average of 1.1°F (0.6°C) in Auburn and Yuba City. If averaged over each priority area, the impacts of smart growth are an avoided warming of between 0.14°F (0.08°C) and 0.27°F (0.15°C) regionwide.
All hours	Except for Auburn and El Dorado Hills, there is less variation across the priority areas and similar avoided warming of between 2.2°F (1.2°C) and 2.9°F (1.6°C).





5 IMPLEMENTATION STRATEGY

The results of the regional heat Island modeling effort and best practices analysis suggest that each mitigation measure has a role to play to effectively achieve regional cooling. These results can be used to inform heat abatement strategies for a wide range of transportation projects in the Capital Region as well as other projects related to the built environment and land use planning. However, moving from ideas to implementation can be challenging, and the best path forward is not always clear. This section highlights a set of implementation mechanisms that can be used by local jurisdictions and guidance on overcoming barriers to implementation and tailoring solutions to the Capital Region.

Specifically, the Implementation Strategy is broken up into the following subsections:

- **UHI Strategy Implementation Mechanisms –** An overview of the different types of implementation mechanisms local jurisdictions have at their disposal, including incentives, programs, and mandates.
- **Overcoming Implementation Challenges –** Common challenges that local jurisdictions may face when implementing UHI mitigation strategies and guidance for overcoming those barriers.
- **Solution-Tailored Implementation –** Tailored solutions for the Capital Region, which can be adapted by local jurisdictions for their own use.
- **Pilot Project Implementation Strategies –** An overview of representative transportation projects in the Capital Region and opportunities for incorporating the UHI mitigation measures covered in Section 4 – Transportation-Sector Mitigation Opportunities and Best Practices.

It is important to note that while this document provides examples of UHI mitigation measures and relevant case studies, it is intended as guidance for consideration by local jurisdictions rather than prescribing a specific approach. The unique economic, political, and regulatory contexts of each jurisdiction should ultimately inform the implementation of UHI mitigation measures, dictating which measures are locally applicable and impactful in achieving other related goals to address climate change and community priorities. Applicability may also vary based on the availability of funding sources and the success of certain measures. Lastly, the Implementation Strategy is primarily focused on opportunities in the transportation sector and as such, the project team recognizes that the set of strategies and mechanisms covered in this section does not represent an exhaustive list of all possible strategies.

5.1 UHI STRATEGY IMPLEMENTATION MECHANISMS

A variety of mechanisms are available to local jurisdictions to assist in the implementation of measures to mitigate urban heat impacts. Some provide financial outlets for specific projects, while others are linked to policies and programs. On their own, each potential mechanism can help encourage projects to consider alternative strategies; when combined, they can become powerful tools that drive change at a larger scale for a broad array of projects. This section provides an overview of the mechanisms available (see Table 21 for a summary of these mechanisms).

TABLE 21: SUMMARY OF UHI STRATEGY IMPLEMENTATION MECHANISMS

MECHANISM TYPE	SPECIFIC IMPLEMENTATION MECHANISM
Incentives	• Floor-Area Ratio Bonuses • Tax Credits and Rebates • Green Building Incentives
Programs	• Grant Programs • Local Partnerships • Community Programs and Public Education • Contractor Education • Procurement Programs
Mandates	• Zoning and Municipal Code • Building Code • Policies and Planning Guidelines • Design and Landscape Guidelines

Note that while many of the case studies and examples focus on green roofs, green roofs are more expensive to install and maintain than cool roofs and may have limited applicability in hotter parts of the Capital Region as they will increase water demand, especially as the summer Is also California's driest period. Nonetheless, the strategies and programs by which cities encourage green roof development can also be adopted easily for cool roofs, and thus they are included here.

5.1.1 INCENTIVES

Local agencies can offer a range of incentives to developers to encourage the adoption of UHI mitigation measures. These incentives can be planning-based (e.g., floor-area ratio bonuses) or financial-based (e.g., tax credits and rebates), and can be targeted to specific building types, individuals, or neighborhoods. For example, targeted rebates, tax credits, or preferential permitting can incentivize developers to include heat-reducing elements in large residential development projects for both buildings and surrounding transportation infrastructure, such as new paths, roadways or parking.

However, most public transportation infrastructure projects are not initiated by private developers and, as such, financial incentives alone may not be sufficient. Projects led by public agencies are poised to benefit more from grant programs and incentives provided by outside entities, such as by state agencies, SACOG, SMUD or PG&E. Green building and sustainable infrastructure frameworks like LEED and Envision can also provide incentives to develop more sustainable designs, which may incorporate UHI mitigation strategies.

FLOOR-AREA RATIO BONUSES

A floor-area ratio bonus allows developers to increase the amount of buildable space of a development beyond what zoning permits, in exchange for providing certain amenities (e.g., creation or preservation of affordable housing or public space) or including provisions that support environmental objectives. Providing floor-area ratio bonuses can incentivize inclusion of UHI mitigation measures and several U.S. cities have included such incentives in their zoning codes. Portland provides floor-area ratio bonuses in exchange for the inclusion of a green roof (City of Portland, Oregon n.d.), and Chicago does the same for green roofs that cover more than 50 percent of a building's roof in the city's downtown mixed-use district. While green roofs may not be the most suitable choice in the Sacramento region, these types of programs could easily be translated to other strategies like cool roofs, tree planting/urban forestry/landscape elements, and cool pavements.

CASE STUDY

PHILADELPHIA GREEN ROOF TAX CREDIT

The City of Philadelphia has implemented a green roof tax credit against the Business Income and Receipts Tax (BIRT); up to 50% of all costs incurred as part of green roof construction can be claimed, not to exceed $100,000. The City doubled the maximum from 25% to increase the incentive and encourage uptake. To qualify, the green roof must cover 60% of the roof area and only one tax credit can be received per building (Philadelphia Water 2016).

Figure 23: Green Roof System in Philadelphia, PA.

Source: https://www.philadelphiagreenroofs.com/projects/tajdeed-residences-philadelphia/attachment/img_7027/

TAX CREDITS AND REBATES

Many communities in the U.S. offer tax credits and rebates for installing UHI mitigation measures. While most tax credit and rebate programs are geared toward residential buildings, Washington D.C.'s RiverSmart Rooftops Green Roof Rebate program provides rebates on water bills for voluntary green roof installation for residential, commercial, and institutional buildings (Washington DC Department of Energy & Environment n.d.). Countless other programs have been adopted across the country; other relevant tax credit and rebate programs include (but are not limited to):

- Portland's Treebates program in Oregon
- Louisville and Jefferson County's Green Infrastructure: Incentives and Savings through the Metropolitan Sewer District in Kentucky
- Toronto's Eco-Roof Incentive Program
- Montgomery County's RainScapes Rewards Rebates program in Maryland

GREEN BUILDING INCENTIVES

Green building standards such as Leadership in Energy and Environmental Design (LEED) have been integrated into many local government building codes. These standards guide the inclusion of building design elements that have the potential to mitigate the UHI effect, including green roofs, cool roofs, and cool pavements. The program itself provides an incentive as buildings can achieve different levels of LEED certification depending upon the number of sustainability features incorporated into their design. As LEED applies to both public and private development, buildings and facilities that support transportation systems are ideal candidates for LEED certification and application of UHI mitigation measures.

The Envision framework developed by the Institute of Sustainable Infrastructure provides a similar incentive to go "above and beyond" in sustainable infrastructure development. As Envision is applicable to all types of infrastructure, the framework is directly applicable to transportation.

5.1.2 PROGRAMS

Local and regional agencies can implement a variety of programs to facilitate UHI mitigation, from cost-effective public education campaigns to robust programs to drive implementation. Agencies can lead by example by piloting demonstration projects that illustrate the benefits of UHI mitigation measures and how they can be implemented. Demonstration projects can be a mechanism to measure and document benefits of specific heat-reduction strategies, which can test the effectiveness of new products and methods to demonstrate proof-of-concept and ultimately help improve heat-mitigation technologies.

Programs can also focus on specific heat-mitigation strategies, such as cool roof or urban forestry programs. Coordinating and partnering with other entities, such as utilities and nonprofits, can make these types of programs more effective by leveraging multiple resources and reaching a broader audience. While processes for developing programs may vary, agencies should aim to establish programs with the following core components:

- Critical foundations to support the programs such as specific requirements and goals,
- Funding for implementation,
- A management structure like a board or committee, and
- A monitoring plan for progress.

Local grant programs can successfully serve as financial incentives. In New York City, the Green Infrastructure Grant program provides funding for private property owners for the design and construction of green roofs, rain gardens, and porous pavement (NYC Department of Environmental Protection n.d.).

Large transportation infrastructure projects led by transit agencies, state agencies, and local governments should consider climate change risks and impacts at every step in the planning process – from design to construction. Agencies can have considerable influence over the final project by developing and implementing a green procurement program that requires heat-reducing measures. Green procurement programs expand beyond traditional evaluation factors to include the consideration of environmental impacts. For transportation projects, specifications can include the use of specific products for building finishes (e.g. cool roof materials) and construction materials (e.g. higher-albedo pavements or permeable pavements), as well as fleet-related specifications (e.g. use of EVs for transit or construction fleets).

The sections below discuss some of these program implementation mechanisms in more detail, along with multiple examples of relevant programs from both inside and outside the Capital Region.

GRANT PROGRAMS

Grant programs implemented by California state agencies have proven effective in funding UHI assessments and responses. For example, the California Natural Resources Agency's Urban Greening Grants Program recently provided $19 million in funding for 11 infrastructure projects throughout the state, including numerous street tree planting projects (California Natural Resources Agency n.d.). This program is administered through California Climate Investments, funded by proceeds from the State's Cap-and-Trade program deposited to the Greenhouse Gas Reduction Fund

In addition, the Caltrans Adaptation Planning Grants ($6 to 7 million annually) supported regional efforts to prepare the transportation system for the impacts of climate change and extreme weather. These funds were used to fund projects such as this Capital Region UHI Mitigation Plan and others planning projects that evaluate climate risks and adaptation opportunities in the transportation sector.

CASE STUDY

TORONTO ECO-ROOF INCENTIVE PROGRAM

In 2009, the City of Toronto created the Eco-Roof Incentive Program, which encourages building owners to install eco-roofs by providing grants for structural assessments and green or cool roof installations. The Eco-Roof Incentive Program is now a key part of the City of Toronto's Climate Action Plan, which is complemented by Toronto's Green Roof Bylaw that requires new buildings over 2,000 square meters (21,527 square feet) to include a green roof. The Bylaw also includes an option for developers to pay $200/ m2 as cash-in-lieu instead of constructing the required green roof. These funds are then directed to the Eco-Roof Incentive Program, so overall it is a self-sustaining program (C40 Cities 2018).

Figure 24: Eco-Roof in Toronto, Canada

Source: https://urbantoronto.ca/news/2015/12/toronto-incentivizing-eco-roof-conversions

One final example is the CalFire Urban and Community Forestry Grants Program, which is funded through California Climate Investments. This grant program provides local governments and nonprofits with funds to initiate tree planting projects in their community. These projects are required to demonstrate additional co-benefits, including economic, environmental, and social benefits, to community members.

In total, 450,000 square meters (4.8 million square feet) of eco-roofs have been installed since 2009, which is the equivalent of 420 permits granted, 350 for cool roofs and 70 green roofs. This generates 1,000 megawatt hours (MWhs) of energy savings and offsets an average of 220 metric tons of GHG emissions annually (C40 Cities 2018).

LOCAL PARTNERSHIPS

Partnerships can extend the reach of heat mitigation efforts to benefit more communities by leveraging resources and talents across multiple organizations. One example of an effective local partnership in the Sacramento area is the Free Shade Tree Program developed in coordination between SMUD and the Sacramento Tree Foundation. This program has been in place for thirty years and has planted more than 500,000 shade trees across the Capital Region (SMUD 2020) to provide air quality and urban cooling benefits. SMUD's currently dormant Cool Roof Program may be another mechanism to encourage cool roofs adoption with local coordination.

Elk Grove developed a Tree Preservation and Protection fund, which collects payments made to mitigate loss of trees removed during a project. These funds can only be used to plant more trees or maintain existing trees. The Elk Grove code notes that "fund monies may be directed by the City Council to nonprofit organizations for the implementation of programs consistent with the purposes of the tree preservation fund. [Ord. 6-2011 §4, eff. 3-25-2011]" (City of Elk Grove 2019). The City of Elk Grove already works closely with the Sacramento Tree Foundation (City of Elk Grove n.d.) and could consider directing Tree Preservation and Protection funds to a collaborative program with the Tree Foundation, focused on urban heat reduction and expanding the tree canopy across the city. This type of partnership could direct funding to organizations with existing programs to gain efficiencies and accelerate the pace of tree planting.

COMMUNITY PROGRAMS AND PUBLIC EDUCATION

Public education programs can increase public understanding of heat mitigation measures and their co-benefits to increase public and political will to invest in these solutions. The outreach and engagement activities conducted as part of this project demonstrate how community engagement activities can be structured to educate public members on the impacts of UHI while also soliciting their input on heat-related challenges and local priorities from a more informed standpoint. Working with the public in this way can stimulate broader change by encouraging people to think about individual actions that can be taken to prepare for/mitigate UHI in their own lives and by gathering important input to inform larger projects. Input gathered can be used to guide decision-making around the types of UHI mitigation strategies needed and where and when to implement them. For example, the public's feedback from the community surveying completed for this Plan helped the project team select high priority areas for modeling (see Section 3.2) and identify pilot project locations across the region (see Section 5.4).

In addition, UHI mitigation strategies can double as public education tools to showcase technologies or solutions to encourage deeper engagement and catalyze action. For example, the Yolo County Water Efficient Landscaping Ordinance requires that all model homes with water-efficient landscaping include signage with information about low water use, landscape design, and "low water use approaches to landscaping such as using native plants, graywater systems, and rainwater catchment systems" (Yolo County 2014). The ordinance further requires that literature about water-efficient landscape design be provided to anyone touring the model home. This provides one example of how mitigation strategies themselves can be showcased to the public. While this example focuses on local water reduction efforts, a similar education program could be implemented for cool or green roofs, or landscapes focused on reducing heat pollution.

Outside of the Capital Region, the City of Los Angeles recently announced a cool streets program, which will include ten pilot projects that install cool pavements and make city streets more comfortable to pedestrians (Powell 2019). For the first pilot, the city will install four new bus benches with shade canopies, 14 new shade trees along a two-block stretch of road, and 35,000 square feet of cool pavement (Powell 2019). While all pilot locations have not been selected yet, the city plans to focus on the most heat vulnerable and transit-dependent communities first (Flores 2019). As a symbol to the public of what is to come, the city installed temporary umbrellas at bus stops in South LA (Flores 2019).

CASE STUDY

PORTLAND GREEN ROOF VIEWING

The City of Portland compiled the addresses of green roofs around the city so that the public can tour the different roofs and learn about each facility, including its green roof specifications. The city aims to encourage community members to adopt green roofs by providing opportunities for the public to learn how to install and maintain green roofs. This program was followed by the Portland Ecoroof Incentive, which provides property owners and developers with $5 per square foot to construct ecoroofs. This incentive program has helped implement over 130 projects that created more than 8 acres of green roofs. Portland additionally adopted a Green Roof Requirement in its central city plan for 100% of the roof for buildings over 20,000 square feet (Greenroofs.com n.d.).

Figure 25: Tour of Portland Green Roof

Source: https://www.portlandoregon.gov/bes/article/386023

CONTRACTOR EDUCATION

The novelty of certain UHI mitigation technologies and techniques may serve as a barrier for widespread adoption among contractors. Providing contractors with training opportunities can accelerate the implementation of these strategies, which can include educating contractors about funding sources to ensure they have what they need to procure new equipment, as needed. Assisting or funding contractors to become accredited in green building rating systems like LEED, WELL, and Building Performance Institute Approved Standards is another way to build contractor qualifications.

Workforce development programs are another way to build a trained workforce experienced in implementing UHI mitigation measures. For example, GRID Alternatives has a workforce development program that offers training and hands-on solar installation experience to the public, with a focus on individuals that are underrepresented in the industry.

PROCUREMENT PROGRAMS

Sustainable and green procurement programs are also available to local jurisdictions to ensure their projects apply the best available, most environmentally responsible technologies and materials. The California Sustainability Alliance developed a Local Government Green Procurement Guide for local governments to help agencies adopt a sustainable and environmentally conscious procurement and purchasing plan. The eight key steps to developing this plan are as follows (California Sustainability Alliance n.d.):

1. Form a green purchasing team,
2. Conduct a baseline inventory,
3. Establish environmental criteria,
4. Develop green bid specifications,
5. Take advantage of partnership opportunities,
6. Establish a green procurement policy,
7. Educate staff and residents, and
8. Regularly review policies for updating.

The guidebook provides a variety of tools for local governments to achieve these steps, including draft language for modifying existing procurement documents, samples of detailed green bid specifications, and case studies of California cities and agencies that have initiated similar green procurement programs (California Sustainability Alliance n.d.).

5.1.3 MANDATES

Mandates can require a variety of heat mitigation and adaptation measures to be implemented through revisions or additions to zoning, municipal, or building codes, as well as the adoption of new or revised policies, planning guidelines, and design guidelines. Zoning and municipal codes are tools that ensure established policies, such as those in General Plans, are implemented effectively and at the pace and scale necessary to achieve local goals. While some jurisdictions may be more inclined to encourage voluntary compliance through incentives, mandates are likely needed to achieve lasting change and build community resilience in a more inclusive manner. The following section summarizes some of the types of mandates that local jurisdictions can adopt to ensure UHI mitigation measures are implemented within their boundaries.

ZONING AND MUNICIPAL CODE

Zoning and municipal codes can take many forms and can be used to influence local development. Codified examples include requirements for stormwater management, urban tree canopy, permeable and/or high albedo paving, and compliance with LEED or other sustainability framework standards. Additionally, specific zoning ordinances, which are more expansive than specific codes, can be developed to focus on a certain UHI mitigation measure and can be specific to certain development types. The most common UHI mitigation ordinances are related to urban tree canopy, EVs, cool/green roofs, and rooftop solar.

The revised Green Buildings Ordinance provides more flexible compliance options than the original Initiative 300. New or re-roofed buildings greater than 25,000 square feet are required to install a cool roof, in addition to undertaking one of the following options: install green space, on-site solar or other renewable generation; purchase solar or renewable energy credits; reduce onsite energy use; pay into the Green Building Fund; provide proof of green building certifications;, or some combination thereof (City of Denver n.d.).

Many local jurisdictions in the Capital Region have already incorporated considerations of the UHI effect and heat pollution into their zoning and municipal codes. Others have begun to incorporate language into code related to

CASE STUDY

LEED COOL PAVEMENT CREDITS

The LEED v4.1 Building Design and Construction (BD+C) rating system from January 2019 applies to buildings that are newly constructed or going through a major renovation. This version of the rating system includes a heat island reduction credit with two options: 1) use a combination of roof and "nonroof" (i.e. providing shade and vegetation) measures, and 2) place a minimum of 75% of parking spaces under cover, which must be a reflective roof, vegetated roof, or renewable energy generation system. The high-reflectance requirement involves using roofing materials that meet certain solar reflectance targets, which are measured by how long the roof retains its reflectivity, and thermal emittance targets, which are measured by a material's ability to re-release heat into the air. These two factors are combined to create an overall Solar Reflectance Index (SRI). The LEED requirement is to use roofing materials that have an SRI equal or greater than the values provided in Table 22 (Cool Roof Rating Council 2019).

The City of Dallas implemented comprehensive green building standards to require all new residential and commercial construction to meet the minimum requirements of the Dallas Green Construction Code or be certifiable by LEED. The use of certifiable – not certified – is notable as it allows projects to use LEED standards without bearing the cost of LEED certification. Therefore, developers are encouraged to meet LEED solar reflectance requirements, seen as a cost-effective strategy which can pay itself back, rather than an additional expense. This is especially relevant as 30% to 40% of the developed land in Dallas is made up of paved surfaces. The 'Sustainable Skylines Initiative' highlights the strategies needed in order to achieve the relevant LEED credits (Houston Advanced Research Center 2009).

TABLE 22: MINIMUM LEED SOLAR REFLECTANCE INDEX VALUE BY ROOF SLOPE

	SLOPE	INITIAL SRI	3–YEAR AGED SRI
Low-sloped roof	< 2:12	82	64
Steep-sloped roof	> 2:12	39	32

cooling measures such as sustaining and maintaining an urban tree canopy. While it is not an exhaustive list, Table 3 summarizes some of the existing zoning and municipal codes in the Capital Region relevant to heat mitigation that can serve as an example for other jurisdictions and as a starting point for future improvements.

The City of Davis landscape design zoning code is primarily focused on reducing water demand. By revising the code to include shade potential as an additional criterion in the selection of trees, the City can take a more holistic approach that considers both drought and heat risks (see Table 3 for more information). The code could point to the existing Tree Guide for Davis to guide shade tree selection or provide another list of fast-growing shade trees appropriate for the city. This additional criterion could be added under 40.42.090.A.

The City of Sacramento tree removal code (12.56.040) could be revised to be a tree replacement code, requiring that in addition to avoiding damaging and replacing existing city trees, new trees shall be planted for each tree removed by a public project. Alternatively, a new code could be adopted which requires that public projects must plant shade trees as part of the project design and construction. The Environmental Resources section of the City of Sacramento General Plan explicitly states that the city “shall continue to promote planting shade trees with substantial canopies, and require, where feasible, site design that uses trees to shade rooftops, parking facilities, streets, and other facilities to minimize heat island effects” (City of Sacramento 2015). By expanding existing code to not only avoid replacing and damaging trees, but plant new trees over the course of public projects, the City of Sacramento could build upon the goals set in its General Plan related to UHI mitigation.

The Yuba County code provided below is focused on residential units and therefore has limited applicability to transportation projects. However, revising the code or providing an additional code to streamline rooftop solar for commercial buildings and public facilities could extend the reach of this code to mitigate the UHI effect through rooftop solar.

Capital Region jurisdictions are encouraged to review the relevant, existing codes listed in Table 3 below to identify mandates that that may be replicated or adapted. While a “one size fits all” approach is not possible for all jurisdictions across the Capital Region, these examples can provide a helpful starting point to build upon, as noted in the examples above.

CASE STUDY

DENVER GREEN BUILDINGS ORDINANCE

In November 2017, residents in the City of Denver voted on a first of its kind citizen initiative on green roofs. The initiative passed thanks to a grassroots campaign, despite heavy opposition from the real estate and construction industry (Kaufman 2018). The ordinance, Initiative 300, took effect in January 2018, and required that new buildings 25,000 square feet or larger include a green roof or solar panels (Kaufman 2018). Unfortunately, the initiative did not generate green roof development initially. In addition to new roofs, the ordinance applied to roof replacements and building additions, and many existing buildings were not built for the weight of a green roof (Kaufman 2018). In response, the City Council revised the ordinance in October 2018 to require cool roofs instead (City of Denver n.d.).

Figure 26: Community College of Denver Green Roof

Source: https://greenroofsco.com/item/community-college-of-denver/

TABLE 23: SELECTED CAPITAL REGION MUNICIPAL AND ZONING CODES

AGENCY	CODE	YEAR	MANDATES THAT APPLY TO UHI MITIGATION
City of Auburn	Municipal Code	n.d.	**153.06 Parking Lot Requirements:** 1. All automobile parking lots constructed, (excepting for single-family use, excluding mobile homes) which are to be used for customer, resident, client or employee automobile parking, shall be designed and developed in accordance with the following landscape design standards. 1. *Perimeter landscaping* 1. A landscaped strip at least 4 feet wide shall be installed and maintained adjacent to any building or fence or to any property line separating the parking area from residential, commercial, industrial or office building zoned or used properties and adjacent parking lots. Decorative native rock retaining walls or masonry retaining walls shall need only a 2- foot wide planter area. 2. The strip shall be landscaped using live ornamental trees, shrubs, and ground cover in accordance with the following minimum specifications. As a guide to the number of trees and shrubs and subject to practical variation in placement, trees (minimum 15 gallon size) shall be planted approximately 20 feet center to center and shrubs (minimum 5 gallon size) shall be spaced appropriately between trees. Ground cover shall be planted in all areas not occupied by trees or shrubs. Plants shall be rooted cuttings from flats and placed so as to have uniform covering within 12 months after planting. 2. *Landscaped strips.* A landscaped strip at least 4 feet wide shall be constructed adjacent to the street frontage on parking lots, except that portion of the frontage within 2 feet of driveways or alleys. 1. The planting in the landscaped area shall be the same as set forth in division (B)(1) above. 2. Screening shall be provided by one of the following methods or combinations thereof: 1. A decorative masonry wall between 24 inches and 30 inches in height shall be placed approximately in the center of the planting area parallel to the street. 2. A screening hedge may be planted using shrubs which shall not exceed 3 feet in height and shall consist of compact evergreen plants having a minimum height of 18 inches within 18 months after the initial installation. 3. An earth berm with a height of 3 feet to 4 feet may be substituted provided the landscaped strip is widened appropriately to provide ease of maintenance and slopes not to exceed 2 feet horizontally to 1 foot vertically. 3. Plants used in these planter areas shall not be located within 10 feet of a street or alley intersection or within 10 feet of the driveway. The last 10 feet can be decorative rock or bark, or equal, or low ground cover. 3. *Interior planting areas.* 1. To break the expanse of paving, planting areas shall be installed on the interior of all parking lots providing more than 10 spaces. One 3-foot wide landscape break shall be provided every 8 stalls, or, as an alternate, the grouping of landscaped break areas may be permitted, except that in no case shall there be more than 16 stalls without a landscape break. 2. Not less than 3% of the gross area of the parking lots shall be devoted to the interior planting areas. Landscaping provided in conjunction with the development of a building shall not be considered as part of the 3%. 3. The planting areas shall be distributed as evenly as possible throughout the parking area. All unused space resulting from the design of the parking spaces shall be used for planting purposes. 4. A minimum of 1 tree (minimum 15-gallon size) shall be in each planter area which shall contain 20 square feet. Shrubs and ground cover shall be used in all planter areas.

AGENCY	CODE	YEAR	MANDATES THAT APPLY TO UHI MITIGATION
City of Auburn	Municipal Code	n.d.	**153.06 Parking Lot Requirements, Cont'd:** 4. General requirements. 1. At least 50% of the plants and shrubs shall be living evergreen vines, shrubs, ground cover or a combination thereof. The remaining 50% would be deciduous varieties of shrubs and trees. Trees shall be living, a minimum of 50% of which shall be evergreen type. The following minimum sizes shall be: trees, 15-gallon; and shrubs, 5-gallon. 2. Planting areas shall be separated from vehicular areas and street rights-of-way by a concrete curb at least 6 inches high. 3. All landscaped areas shall be irrigated by means of a permanent automatic or manual watering system. 4. All planting areas shall have an average width of 3 feet or more. 5. If mature existing trees are involved with the parking layout, consideration will be given as to credit for parking stalls if the trees are retained.
City of Davis	Zoning Code	2019	**40.42.090 Landscape design plan:** (A) Any plant may be selected for the landscape, providing the estimated total water use in the landscape area does not exceed the maximum applied water allowance. To encourage the efficient use of water, the following is highly recommended: i. Protection and preservation of native species and natural vegetation; ii. Selection of water-conserving plant and turf species; iii. Selection of plants based on disease and pest resistance; iv. Selection of trees based on the city's master tree list; and v. Selection of plants from city, local, and regional landscape program plant lists. ... (C) Plants shall be selected and planted appropriately based upon their adaptability to the climatic, geologic, and topographical conditions of the project site. To encourage the efficient use of water, the following is highly recommended: i. Use the Sunset Western Climate Zone System which takes into account temperature, humidity, elevation, terrain, latitude, and varying degrees of continental and marine influence on local climate; ii. Recognize the horticultural attributes of plants (i.e., mature plant size, invasive surface roots) to minimize damage to property or infrastructure (e.g., buildings, sidewalks, power lines); and iii. Consider the solar orientation for plant placement to maximize summer shade and winter solar gain.
City of Elk Grove	Municipal Code	2019	**19.12.220 Tree preservation fund:** A tree preservation fund is established for the City of Elk Grove for the purposes of furthering tree maintenance and tree replacement. The monies received in lieu of replacement of removed trees shall be forwarded to the City Treasurer for deposit in the tree preservation fund. Except as provided in this section, under no circumstances shall the funds collected by the City Treasurer for the tree preservation fund be directed to any other fund to be used for any other purposes other than for tree planting (including but not limited to tree support such as installation of driplines and drainage) and preservation programs (including the creation of new woodland areas, underplantings as part of a tree planting program, and other planting activities that support the purposes of this chapter), public education programs regarding trees, and other activities in support of the administration of this chapter. Tree preservation fund monies may be directed by the City Council to nonprofit organizations for the implementation of programs consistent with the purposes of the tree preservation fund. [Ord. 6-2011 §4, eff. 3-25-2011].

AGENCY	CODE	YEAR	MANDATES THAT APPLY TO UHI MITIGATION
City of Elk Grove	Zoning Code	2019	23.54.040 Landscape development standards: A. General Location for Landscape Improvements… 1. Setbacks… 2. Unused Areas. All areas of a multifamily or nonresidential project site not intended for a specific use (including areas planned for future phases of a phased development), shall be landscaped with existing natural vegetation, wild flowers, native grasses or similar. 3. Parking Areas. Within parking lots, landscaping shall be used for shade and climate control, to enhance project design, and to screen the visual impact of vehicles and large expanses of pavement consistent with the provisions of this chapter.
City of Elk Grove	Zoning Code	2019	23.54.040 Landscape development standards: a. Planting Layout and Plant Diversity. Plant selection shall vary in type and planting pattern. Informal planting patterns are preferred over uniform and entirely symmetrical planting patterns. Use of flowering trees and colorful planting are encouraged in conjunction with evergreen species. Groupings of shrubs shall contain multiple plant types, interspersed with varying heights and blooming seasons for year-round interest. b. Water-Efficient Landscape. Consistent with the purposes of Section 65591 of the California Government Code (Water Conservation in Landscaping Act), all new multifamily and nonresidential development shall comply with EGMC Chapter 14.10, Water Efficient Landscape Requirements. c. Street and Parking Lot Trees. A minimum of thirty (30%) percent of the street trees and parking lot trees, respectively, shall be an evergreen species. d. Trees planted within ten (10' 0") feet of a street, sidewalk, paved trail, or walkway shall be a deep-rooted species or shall be separated from hardscapes by a root barrier to prevent physical damage to public improvements.
City of Sacramento	Municipal Code	2019	12.56.040 Removal of city trees – Public projects: A. Whenever feasible, the city shall modify the design of public projects to avoid the removal or damage to city trees. B. If the city proposes to remove city trees that have a DSH of four inches or more as part of a public project that otherwise requires city council approval, the city project manager shall provide written justification to the director of the need to remove city trees for the public project. The director shall review the written justification and if the director agrees with the written justification the director shall make a recommendation to the city council to approve the request to remove the city trees. The request for approval from city council may take place at any stage of the public project but the city shall obtain council approval prior to removing the city trees. City trees proposed to be removed as part of a public project that either does not require city council approval or has a DSH less than four inches shall be removed as provided in Section 12.56.030(C). C. The director shall provide written notice of the proposal to remove city trees as part of a public project by posting a notice of the time, date, and location of the city council meeting during which the city council is to decide whether or not to remove city trees in a conspicuous place on or in proximity to the trees at least fifteen (15) days prior to the city council meeting. (Ord. 2016-0026 § 4)
City of Sacramento	Municipal Code	2019	15.08.190 Expedited building permit process for electric vehicle charging stations: 1. The building official shall adopt a checklist of all requirements for an application for an expedited building permit for electric vehicle charging stations. The checklist shall substantially conform to the checklist and standard plans contained in the most current version of the "Plug-In Electric Vehicle Infrastructure Permitting Checklist" of the "Zero-Emission Vehicles in California: Community Readiness Guidebook" published by the Governor's Office of Planning and Research. 2. If the building official determines that the application for an expedited building permit is complete and meets the requirements of the checklist, the building official shall issue the expedited building permit.

AGENCY	CODE	YEAR	MANDATES THAT APPLY TO UHI MITIGATION
City of Sacramento	Municipal Code	2019	**15.08.190 Expedited building permit process for electric vehicle charging stations, cont'd:** 3. If the application for an expedited building permit is incomplete, the building official shall provide a written correction notice of the deficiencies and the additional information required to be eligible for expedited building permit issuance. 4. The checklist, application form, and any other documents required by the building official shall be published on the city's website. 5. An application for an expedited building permit for electric vehicle charging stations may be filed by email. 6. If the chief building official finds, based on substantial evidence, that an electric vehicle charging station could have a specific adverse impact upon the public health or safety, the city may require the applicant to apply for a conditional use permit pursuant to Title 17. (Ord. 2016-0037 § 2)
Sacramento County	Municipal Code	2019	**19.12.060 Tree Permit:** No person shall trench, grade or fill within the dripline of any tree or destroy, kill or remove any tree as defined, in the designated urban area of the unincorporated area of Sacramento County, on any property, public or private, without a tree permit, or unless authorized as a condition of a discretionary project approval by the Board of Supervisors, County Planning Commission, Zoning Board of Appeals, the Zoning Administrator or the Subdivision Review Committee. (SCC 1400 § 23, 2008; SCC 480 § 1, 1981.)
Yuba County	Municipal Code	2018	**10.10 Expedited and streamlined permitting for small residential rooftop solar energy systems:** **Purpose:** The purpose of the Chapter is to adopt an expedited, streamlined solar permitting process that complies with the Solar Rights Act and AB 2188 (Chapter 521, Statutes 2014; Amending Civil Code Section 714; and Government Code Section 65850.5) to achieve timely and cost-effective installations of small residential rooftop solar energy systems. The Ordinance encourages the use of solar systems by removing unreasonable barriers, minimizing costs to property owners and the County and expanding the ability of property owners to install solar energy systems. The Ordinance allows the County to achieve these goals while protecting the public health and safety.

CASE STUDY

CASE STUDY: LOS ANGELES COOL ROOF ORDINANCE

The City of Los Angeles implemented a Green Building Code for residential buildings in 2014. This code requires that roofing materials used in residential buildings meet certain cooling criteria (LADWP 2015). The Los Angeles Department of Water and Power (LADWP) provides rebates for qualifying roofing purchases (LADWP 2015). See Table 24 for the requirements of the ordinance for residential buildings. These same targets are in line with the roof albedo improvements modeled in this project and could be applied for residential and commercial buildings and transportation facilities in the Capital Region.

TABLE 24: LOS ANGELES COOL ROOF ORDINANCE REQUIREMENTS

ROOF PITCH	MINIMUM (3-YR) SOLAR REFLECTANCE	MINIMUM THERMAL EMITTANCE	SOLAR REFLECTANCE INDEX (SRI)
Low-sloped roof (<2:12)	0.63	0.75	75
Steep-sloped roof (>2:12)	0.20	0.75	16

Source: (LADWP 2015)

CASE STUDY

SEATTLE TREE PROTECTION CODE

The Seattle Tree Protection Code limits the number, size and type of trees that may be removed from a property. This code limits the removal of trees over 6 inches in diameter, unless the tree is designated as a high-risk hazard. This code is important in maintaining the level of urban forestry. The Seattle Tree Protection Code is as follows (Chapter 25.11 – Tree Protection (Seattle Municipal Code)):

A. Implement the goals and policies of Seattle's Comprehensive Plan especially those in the Environment Element dealing with protection of the urban forest;

B. To preserve and enhance the City's physical and aesthetic character by preventing untimely and indiscriminate removal or destruction of trees;

C. To protect trees on undeveloped sites that are not undergoing development by not allowing tree removal except in hazardous situations, to prevent premature loss of trees so their retention may be considered during the development review and approval process;

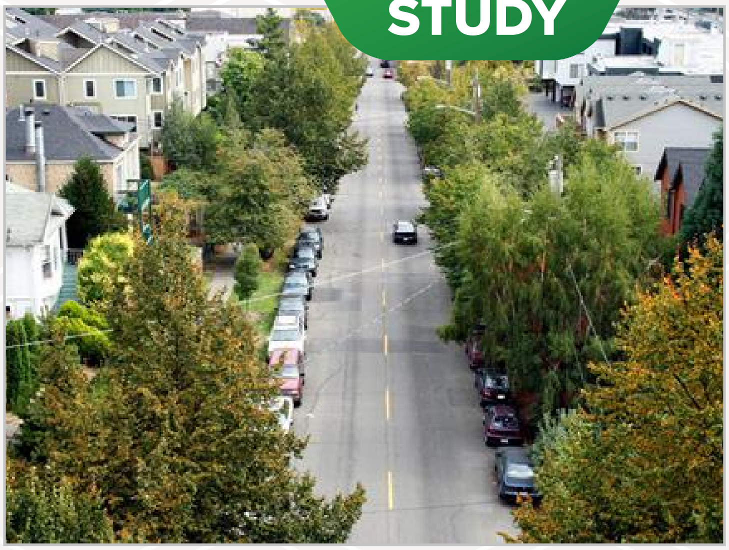


Figure 27: Seattle Street Under Tree Protection Code

Source: https://seattle.curbed.com/2018/4/30/17305014/tree-protection-ordinance-revision-seattle

D. To reward tree protection efforts by granting flexibility for certain development standards, and to promote site planning and horticultural practices that are consistent with the reasonable use of property;

E. To especially protect exceptional trees that because of their unique historical, ecological, or aesthetic value constitute an important community resource; to require flexibility in design to protect exceptional trees;

F. To provide the option of modifying development standards to protect trees over two (2) feet in diameter in the same manner that modification of development standards is required for exceptional trees;

G. To encourage retention of trees over six (6) inches in diameter through the design review and other processes for larger projects, through education concerning the value of retaining trees, and by not permitting their removal on undeveloped land prior to development permit review.

BUILDING CODE

In addition to zoning and municipal codes, building codes can support urban heat mitigation. In California, CalGreen and the Building Energy Efficiency Standards dictate the state's building codes related to energy efficiency and sustainable building practices, which all California public projects must comply with (California Buildings Standards Commission 2019) (California Energy Commission 2019). There are many relevant codes that are geared towards mitigating the UHI effect through cool roofs, green roofs, EV use, and other strategies as discussed in Section 4 of this report. The most applicable nonresidential building codes are provided in Table 25 below.

The California 2019 Building Energy Efficiency Standards, like most energy codes today, provide two paths to compliance: a prescriptive or performance approach. A prescriptive approach requires that each component of the building is built to a specific energy efficiency standard, whereas the more flexible performance approach requires that the building as a whole can demonstrate energy performance at or below a standard design building certain requirements (Ekotrope n.d.). A couple of the Energy Efficiency Standards in Table 25 below refer to measures that are prescriptive in nature.

Codes related to cool roofs appear most frequently in California's nonresidential building code, as compared to other UHI mitigation strategies. However, a cool roof requirement as far reaching as the one implemented in Los Angeles County has yet to be included in the state's building code or in any local code in the Capital Region. The LA County Green Building Standards Code requires the installation of cool roofs for "any newly constructed nonresidential building greater than or equal to 25,000 square feet," with some exceptions and additional specifications (County of Los Angeles 2018). The California 2019 Building Energy Efficiency Standards require cool roofs for "low-sloped roof alterations if the alteration is greater than 2,000 ft^2 or greater than 50 percent of the roof area," but to date cool roofs are not mandatory for new nonresidential or high-rise buildings (California Energy Commission 2019).

TABLE 25: CALIFORNIA BUILDING CODE FOR NONRESIDENTIAL BUILDINGS

CODE DOCUMENT	YEAR	MANDATES THAT APPLY TO UHI MITIGATION
CalGreen	2019	**A5.106.11.2 Cool roof for reduction of heat island effect:** Use roofing materials having a minimum aged solar reflectance and thermal emittance complying with Sections A5.106.11.2.1 and A5.106.11.2.2 or a minimum aged SRI complying with Section A5.106.11.2.3 and as shown in Table A5.106.11.2.2 for Tier 1 or Table A5.106.11.2.3 for Tier 2. **Exceptions:** 1. Roof constructions that have a thermal mass over the roof membrane, including areas of vegetated (green) roofs, weighing at least 25 pounds per square foot. 2. Roof area covered by building integrated solar photovoltaic and building integrated solar thermal panels. **A5.106.11.2.1 Solar reflectance:** Roofing materials shall have a minimum aged solar reflectance equal to or greater than the values specified in Table A5.106.11.2.2 for Tier 1 and Table A5.106.11.2.3 for Tier 2. If Cool Roof Rating Council (CRRC) testing for aged reflectance is not available for any roofing products, the aged value shall be determined using the CRRC certified initial value using the equation $r_{aged} = [0.2 + ß [r_{initial} – 0.2]$, where $r_{initial}$ = the initial solar reflectance and soiling resistance, ß, listed by product type in Table A5.106.11.2.1. Solar reflectance may also be certified by other supervisory entities approved by the Energy Commission pursuant to Title 24, Part 1, *California Administrative Code*. **A5.106.11.2.2 Thermal emittance:** Roofing materials shall have a CRRC initial or aged thermal emittance as determined in accordance with ASTM E 408 or C 1371 equal to or greater than those specified in Table A5.106.11.2.2 for Tier 1 and Table A5.106.11.2.3 for Tier 2. Thermal emittance may also be certified by other supervisory entities approved by the Energy Commission pursuant to Title 24, Part 1, *California Administrative Code.* **A5.106.11.2.3 Solar reflectance index alternative.** SRI equal to or greater than the values specified in Table A5.106.11.2.2 for Tier 1 and Table A5.106.11.2.3 for Tier 2 may be used as an alternative to compliance with the aged solar reflectance values and thermal emittance… *(continued on pages 162 and 163 of the CalGreen guidebook).* **A5.601.2.4 Voluntary measures for Tier 1.** In addition to the provisions of Sections A5.601.2.1 and A5.601.2.3 above, compliance with the following voluntary measures from Appendix A5 is required for Tier 1: … Comply with thermal emittance, solar reflectance, or SRI values for cool roofs in Section A5.106.11.2 and Table A5.106.11.2.1
CalGreen	2019	**A5.106.3 Low impact development (LID).** All newly constructed projects shall mitigate (infiltrate, filter or treat) storm water runoff from the 85th percentile 24-hour runoff event (for volume-based BMP's) or the runoff produced by a rain event equal to two times the 85th percentile hourly intensity (for flow-based BMP's) through the application of LID strategies. Employ at least two of the following methods or other best management practices to allow rainwater to soak into the ground, evaporate into the air or collect in storage receptacles for irrigation or other beneficial uses. LID strategies include, but are not limited to: 1. Bioretention (rain gardens) filtration planters; 2. Precipitation capture (cisterns and rain barrels); 3. Green roof meeting the structural requirements of the building code; 4. Roof leader or impervious area disconnection; 5. Permeable and porous paving; 6. Vegetative swales and filter strips; tree preservation; 7. Tree preservation and tree plantings; 8. Landscaping soil quality; 9. Stream buffer; and 10. Volume retention suitable for previously developed sites.

AGENCY	CODE	YEAR
CalGreen	2019	**5.106.5.3 Electric vehicle (EV) charging. [N]** Construction shall comply with Section 5.106.5.3.1 or Section 5.106.5.3.2 to facilitate future installation of electric vehicle supply equipment (EVSE). When EVSE(s) is/are installed, it shall be in accordance with the *California Building Code*, the *California Electrical Code* and as follows: **5.106.5.3.1 Single charging space requirements. [N]** When only a single charging space is required per Table 5.106.5.3.3, a raceway is required to be installed at the time of construction and shall be installed in accordance with the *California Electrical Code*. Construction plans and specifications shall include, but are not limited to, the following: 1. The type and location of the EVSE. 2. A listed raceway capable of accommodating a 208/240-volt dedicated branch circuit. 3. The raceway shall not be less than trade size 1". 4. The raceway shall originate at a service panel or a subpanel serving the area, and shall terminate in close proximity to the proposed location of the charging equipment and into a listed suitable cabinet, box, enclosure or equivalent. 5. The service panel or subpanel shall have sufficient capacity to accommodate a minimum 40-amprere dedicated branch circuit for the future installation of the EVSE. **5.106.5.3.2 Multiple charging space requirements. [N]** When multiple charging spaces are required per Table 5.106.5.3.3 raceway(s) is/are required to be installed at the time of construction and shall be installed in accordance with the *California Electrical Code*. Construction plans and specifications shall include, but are not limited to, the following: 1. The type and location of the EVSE. 2. The raceway(s) shall originate at a service panel or a subpanel(s) serving the area, and shall terminate in close proximity to the proposed location of the charging equipment and into listed suitable cabinet(s), box(es), enclosure(s) or equivalent. Plan design shall be based upon 40-amprere minimum branch circuits. 3. Electrical calculations shall substantiate the design of the electrical system, to include the rating of equipment and any on-site distribution transformers and have sufficient capacity to simultaneously charge all required EVs at its full rated amperage. 4. The service panel or subpanel(s) shall have sufficient capacity to accommodate the required number of dedicated branch circuit(s) for the future installation of the EVSE. *(continued on pages 26 to 28 of the CalGreen guidebook).*
Building Energy Efficiency Standards	2019	**3.2.3.2 Prescriptive Requirements** **D. Roofing Products: Solar Reflectance (SR) and Thermal Emittance (TE) §10-113, §110.8(i)** In general, light-colored, high-reflectance surfaces reflect solar energy (visible light, invisible infrared and ultraviolet radiation) and stay cooler than darker surfaces that absorb the sun's energy and become heated. The Energy Standards prescribe cool roof radiative properties for low-sloped and steep-sloped roofs. Low-sloped roofs receive more solar radiation than steep-sloped roofs in the summer when the sun is higher in the sky. Roofing products must be tested and labeled by the Cool Roof Rating Council (CRRC), and liquid-applied products must meet minimum standards for performance and durability per §110.8(i)4. When installing cool roofs, the solar reflectance and thermal emittance of the roofing product must be tested and certified according to CRRC procedures. The solar reflectance and thermal emittance properties are rated and listed by the Cool Roof Rating Council at www.coolroofs.org. When a CRRC rating is not obtained for the roofing products, the Energy Standards default values for solar reflectance and thermal emittance must be used. *(continues on pages 3-8 to 3-11 of the 2019 Building Energy Efficiency Standards)*
Building Energy Efficiency Standards	2019	**3.2.4.2 Prescriptive Measures** **A. Thermal Emittance and Solar Reflectance §140.3(a)1A, TABLES 140.3-B,C,D** The prescriptive requirements call for roofing products to meet the solar reflectance and thermal emittance in both low-sloped and steep-sloped roof applications for nonresidential buildings. A qualifying roofing product under the prescriptive approach for a nonresidential building must have an aged solar reflectance and thermal emittance greater than or equal to that the values indicated in Table 3-2 below. Table 3-3 is for high-rise residential buildings and hotel/motel guest rooms, and Table 3-4 is for relocatable public school buildings where the manufacturer certifies use in all climate zones. *(continues on pages 3-11 to 3-12 of the 2019 Building Energy Efficiency Standards)*

DESIGN GUIDELINES

Design guidelines are a straightforward way to influence transportation projects and ensure that heat reduction measures are incorporated. Just like building codes, design criteria dictate the way in which infrastructure projects are designed and built. Heat reduction-focused design criteria for transportation projects could include permeable or cool pavement requirements for a certain percentage of paved area, EV charging station installation requirements, and landscape design requirements such as requiring a certain number of trees be planted along a stretch of roadway or sidewalk. Some agencies in the U.S. and in Europe have begun to develop comprehensive guidelines and scoring processes for landscape-based strategies. One comprehensive example is Washington, DC's Green Area Ratio Guidelines, which is a "zoning regulation that integrates landscape elements into parcel site design to promote sustainable and aesthetically pleasing development."

Landscape design guidelines can provide requirements for specific trees and vegetation to plant and where. The subsection below highlights some recommended shade trees that can be used along roads in the Capital Region. This information can be incorporated into local jurisdiction landscape design guidelines, as appropriate.

RECOMMENDATIONS FOR THE CAPITAL REGION URBAN TREE CANOPY AND TRANSPORTATION PROJECTS

The Capital Region is known for its extensive tree canopy and the region already has strong support for maintaining and growing tree canopy through nonprofits like the Woodland Tree Foundation, Sacramento Tree Foundation, and Tree Davis. These nonprofits provide many resources about the tree species most suitable for the Capital Region's climate and for shading. For example, the Sacramento Tree Foundation's "Shady Eighty" list provides selected shade trees suitable for the region based on characteristics like size, water needs, and growth rate. Landscape guidelines in the Capital Region can leverage these resources to develop requirements regarding the types of trees that should be planted alongside roadways, transit stops, parking lots, and active transportation corridors.

The Capital Region Heat Pollution Reduction Technical Project Report includes information regarding the best options for tree cover based upon their ability to negatively affect air quality through emissions of isoprene and/or monoterpenes (see Section 5.6.2 of the Technical Project Report for more information) (H. Taha 2020). Table 26 below combines these two lists to identify the trees reported to have a "moderate to fast" or "fast" growth rate and "good" or "excellent" air quality ratings in terms of emissions. The fast-growing shade trees were singled out as rising temperatures and heat pollution are urgent matters, and trees can take years to reach maturity and fully contribute to shading. In addition, the trees listed in Table 26 are useful as street trees and can grow in a limited planting strip. These are important considerations for the Capital Region as it continues to grow its urban canopy. Overall, these trees are some of the best to plant alongside transportation projects in the Capital Region to both provide shade quickly and maintain good air quality. In the table below, each tree's scientific name is linked to more information including minimum planting distances, water needs, and other important considerations.

TABLE 26: FAST GROWING SHADE AND STREET TREES THAT MAINTAIN AIR QUALITY

TREE COMMON NAME	TREE SCIENTIFIC NAME	AIR QUALITY RATING	GROWTH RATE
Afghan pine	Pinus eldarcia	Excellent	Moderate to Fast
Australian willow	Geijera parviflora	Excellent	Fast
Bronze loquat	Eriobotrya deflexa	Excellent	Fast
Cork oak	Quercus suber	Excellent	Moderate to Fast
Deodar cedar	Cedrus deodara	Good	Fast
Eastern redbud	Cercis canadensis	Excellent	Moderate to Fast
European Hackberry	Celtis australis	Excellent	Moderate to Fast
Evergreen Pear	Pyrus kawakamii	Excellent	Moderate
Frontier elm	Ulmus parvifolia 'Frontier'	Excellent	Moderate to fast
Littleleaf linden	Tilia cordata	Good	Moderate to fast
Pacific Sunset shantung maple	Acer truncatum 'Pacific Sunset'	Good	Fast

TREE COMMON NAME	TREE SCIENTIFIC NAME	AIR QUALITY RATING	GROWTH RATE
Pink Dawn Chitalpa	Chitalpa tashkentensis 'Pink Dawn'	Excellent	Fast
Red maple	Acer rubrum	Good	Moderate to fast
Shantung maple	Acer truncatum	Excellent	Moderate to fast
Tulip tree	Liriodendron tulipifera	Good	Fast

Source: (H. Taha 2020), Sacramento Tree Foundation

POLICIES AND PLANNING GUIDELINES

As introduced in Section 1.3.1, it is also worthwhile for agencies to examine their long-range policy documents for opportunities to include policy language to further goals and objectives for UHI mitigation. Table 3 provides a summary of relevant local planning goals, policies, measures that have been adopted in Capital Region General Plans, Climate Action Plans, Greenhouse Gas Reduction Plans, and other planning documents.

5.2 OVERCOMING IMPLEMENTATION CHALLENGES

Tackling UHI impacts can be a complex undertaking, with numerous real and perceived barriers or challenges to implementation. Common themes include:

- **Agency capacity and resources,** including costs and staff capacity, are often cited as the most common barriers to implementing new measures. Perceived costs within agencies for tree maintenance, for example, may hinder the planting of trees en masse along corridors. The durability of new pavement technologies may be questioned, along with the uncertainty of costs associated with replacement and maintenance when compared to more traditional materials. Beyond direct costs, limited agency staff and personnel may also be a concern, particularly when there is a need to develop and manage a new program or enforce compliance.
    - Solution: Internally focused educational campaign and materials can help to build the capacity of agency staff. If equipped with a stronger understanding of the co-benefits of mitigation measures, alignment with State priorities, available funding sources, or proper mitigation applications, agencies will be more inclined to develop programs, mandates, or requirements for urban heat mitigation strategies. At the staff level, internal strategies may include pre-defined and pre-approved tree species lists for different types of projects that focus on low water and low maintenance trees; development of cost databases for different treatments or products that can serve as baselines and guide decision making related to costs; development of maintenance processes, activities, and other informational guidance that can help inform the selection of different materials and better understand staffing resources needed; and funding strategies and sources available.
- **Existing guidance and policies** may differ between agencies, as well as between local agencies and a regional entity. Inconsistencies between plans and policies may create confusion in how best to implement measures or which mitigation measures to advance. Coordination between all agencies is paramount to the success of making both localized and regional reductions in urban heat. This is demonstrated in the local-project scale (500m) UHI mitigation analysis, which found that local cooling effects were essentially doubled when a local community and their upwind neighbors implemented UHI mitigation measures (H. Taha 2020).
    - Solution: Forging partnerships between the project-sponsoring agency and adjacent agencies can help to achieve alignment and create a supportive policy environment. Additionally, utilizing templates or regionally developed guidelines that each individual jurisdiction can follow will further strengthen the consistency amongst plans, policies, and project component resources. Local jurisdictions can engage in the Capital Region Climate Readiness Collaborative (CRC), a multi-sector collaborative encompassing the 6-county region, to connect and collaborate with other jurisdictions, nonprofits, academic institutions, and private sector partners.
- **Communication and understanding of challenges** within the agency, with elected officials, and with the public can create significant barriers to implementing programs and garnering public support. Education and awareness can help to alleviate these concerns, ensuring that residents and decision makers are cognizant of the issues at hand. For example, Sacramento summers are naturally hot, which will be exacerbated as temperatures continue to rise due to climate change. However, these changes may not be readily apparent for residents due to their historic experience with and resilience to higher temperatures. This in turn reduces the sensitivity and awareness of the UHI effect, the changing conditions, and the implications for the region now and moving forward. Additionally, informing local contractors about green or cool roofs and cool pavements, including their availability and how they can be constructed in a cost-effective manner, can encourage their use.
    - Solution: Robust communication protocols and educational awareness campaigns aimed at the general public, elected officials, and contractors and builders. Public-facing information can focus on the real threats that urban heat presents to public health, as well as easy and cost-effective strategies that homeowners and

renters can implement. Existing cultural brokers should be engaged to authentically and effectively engage community members and cultivate advocates. For the business community, guidance and trainings on how to incorporate UHI mitigation strategies into a range of projects, market trends, and investment opportunities, as well as information on costs, materials, and equipment, can build a prepared workforce and bring the business community on as champions.

5.3 SOLUTION TAILORED IMPLEMENTATION

5.3.1 IMPLEMENTATION STRATEGIES FOR THE CAPITAL REGION

COOL ROOFS & GREEN ROOFS

Cool roofs and green roofs are common UHI mitigation applications for development projects, although their applicability within transportation projects can be somewhat limited. Implementing these strategies at transit facilities, for example, can serve as demonstration projects for successful applications and show commitment to mitigating UHI in the community. Overall, regardless of the building type, widespread adoption and implementation of cool or green roofs can provide cooling benefits in areas where heat is especially detrimental, such as along active transportation corridors. The Capital Region's dry, hot summers can make green roofs more challenging; however, the use of heat- and drought-tolerant plants may be successful in certain applications. Extensive green roofs tend to require less maintenance and can be more widely applied due to less structural support requirements of the building. Costs for extensive roofs are also less than intensive roofs, as a result of less complexity and fewer maintenance requirements. There are a wide range of cool roof products, from simple paints or coatings, to membranes, to roof tiles or lighter colored shingles. Overall, cool roofs have much lower costs for both installation and maintenance than green roofs and, as such, have a wider ranging applicability for roofs of varying slopes, designs, and styles. Within the transportation sector, available opportunities for cool roof applications may include transit shelters, transit stations, and maintenance facilities, as well as less indirect project elements such as restroom or rest area facilities along greenways.

TABLE 27: COOL ROOF AND GREEN ROOF STRATEGIES

<table>
<tr><th>SOLUTION</th><th>SUPPORTING CONDITIONS</th><th>POTENTIAL TRANSPORTATION-SECTOR PROJECT APPLICATION</th><th>RECOMMENDED IMPLEMENTATION STRATEGY</th></tr>
<tr><td>Cool Roofs</td><td>• Any roof slope (flat, low, steep)
• Lower structural / weight-bearing capabilities
• Cost sensitivities</td><td>• Transit shelters
• Transit stations
• Transportation maintenance facilities
• Freeway rest areas</td><td rowspan="2">• Expedited permitting process, tax credits, or other incentives for projects with cool roofs components.
• Regional grant programs available to public agency-led projects
• Green procurement program for agency-led building projects
• Education efforts to building community
• Codes, ordinances and policies, such as landscape design guidelines or cool roof ordinances</td></tr>
<tr><td>Green Roofs</td><td>• Flat or low-slope (30 degrees or less) roof line
• Extensive
• Lower structure / weight-bearing capabilities
• Reduced need for stormwater management considerations
• Intensive
• Increased structural building support
• Ability to provide irrigation and fertilization</td><td>• Transit shelters
• Transit stations
• Parking garages
• Rest areas along active transportation corridors, as demonstration projects
• Freeway rest areas</td></tr>
</table>

INCENTIVES

- **Planning Based**
  - Adopt expedited permitting processes for projects that incorporate certain UHI mitigation strategies, such as developments or other projects that:
    - Incorporate a transit shelter or transit station utilizing cool roofs;
    - Propose cool pavement materials on new or reconstructed roadways;
    - Include street trees or other landscaping treatments that minimize UHI;
    - Propose zero-emission vehicle parking or infrastructure in new parking areas
- **Financial Based**
  - Partner with regional agencies, such as SMUD, SMAQMD, or SACOG, to highlight, create and expand existing financial incentives to increase participation, including:
    - Grant programs aimed at government-led projects, to help fund transportation infrastructure projects that include UHI reduction measures
    - Grant programs and local agency incentive programs aimed at contractors and builders to help offset costs and encourage use of UHI reduction measures
    - Include heat Island reduction as part of the scoring criteria for existing grants and funding, such as SACOG's various funding program
  - Adopt a tax credit or other incentive program to encourage the adoption of cool and green roofs
  - Revitalize previous programs and strengthen existing programs, including:
    - SMUD's Cool Roof Program
    - SMAQMD's Targeted Green Infrastructure Fund program

PROGRAMS

- **Agency Focused**
  - Adopt a green procurement policy that:
    - Provides a mechanism for green or cool roofs (or other UHI reduction measures)
    - Includes performance characteristics and performance measures to track results
    - Provides general specifications for various applications
    - Further supports implementation of the CalGreen building code requirements related to cool or green roofs
  - Demonstration projects at highly visible/trafficked buildings/areas, such as libraries, transit passenger facilities, rest areas along active transportation corridors, shade structures at public parks, and other similar sites.
- **Community Focused**
  - Establish community education campaigns that raise awareness about urban heat within the transportation network and benefits of cool roofs and green roofs and include:
    - Information related to how transportation more broadly impacts communities (including public health, safety, and heat pollution) and how both agencies and residents can act to reduce the negative impacts
    - Fact sheets, specification information, and other tools or resources that provide clear direction and information on cool and green roofs to project applicants and the building industry

MANDATES

Mandates have the additional benefit of helping to grow the local market, spurring contractors and builders to increase their awareness of and product supplies of cool roof materials, thus potentially leading to more widespread community-level change.

- **Code Based**
  - Update various code elements or guidelines that:
    - Require UHI reduction measures as part of a project;
    - Are explicit in the building types that are applicable;
    - Set performance or quality standards that must be used during project or proposal review.

EXAMPLE TEMPLATE LANGUAGE FOR DESIGN GUIDELINES

New commercial buildings shall develop cool roofs, rooftop terraces, gardens, green roofs and/or landscaped rooftop areas to be effective urban heat management tools.

EXAMPLE TEMPLATE LANGUAGE FOR ZONING CODE/ORDINANCE

A minimum of 50% of roof coverage for all new city (or agency) owned buildings shall be cool roofs [or green roofs].*

**Note this is a recommendation, and each jurisdiction will need to set their own goal based on community attributes, goals, and values.*

X% of all commercial roof areas shall exceed the requirements within the 2019 California Building Code (CalGreen).

- **Policy Based**
  - Develop green building programs and associated policies that require certain institutional or commercial buildings to have cool roofs. These strategies can be phased in based on square footage and allow for flexible compliance between cool roofs, green roofs, and rooftop solar PV to help alleviate cost concerns.

EXAMPLE TEMPLATE LANGUAGE FOR COOL OR GREEN ROOF POLICY

A minimum of X% of roof coverage for all new city (or agency) owned building shall be generated from cool roofs with a minimum aged solar reflectance of XX.

Municipal facilities over X square feet shall meet at least LEED Silver standards, including the use of green or cool roofs.

New commercial, institutional, and multifamily residential development shall include additional planted areas, including green roofs, green infrastructure, or green walls.

New transit shelters along vulnerable corridors shall consider use of cool or green roofs, PV solar shading, or reflective materials to contribute to UHI reduction.

Amend design guidelines and other documents to promote low-impact development strategies such as cool roofs and cool paving surfaces.

COOL PAVEMENTS

Cool pavements have the most direct applicability within transportation projects, and can be applied to roadway projects, active transportation projects, transit infrastructure, and parking facilities. Cool pavements can generally be categorized as either permeable/porous or high albedo/light-colored and offer a wide variety of options with different costs, applications, and maintenance considerations. The matrix below identifies a sampling of available cool pavement solutions and their corresponding implementation strategies based on project type. There are a number of factors that impact the choice of solution, including vehicle weights, traffic volumes, project area size, cost sensitivities, maintenance requirements, regulatory agency policies/requirements (i.e. Caltrans requirements for highway projects), and stormwater considerations.

TABLE 28: COOL PAVEMENT SOLUTIONS

	RECOMMENDED STRATEGY IMPLEMENTATION				
SOLUTION	NEW ROADWAY	MAINTEN-ANCE	ACTIVE MODES	TRANSIT	PARKING
Permeable & Porous Pavements:					
Pervious concrete	■				■
Porous asphalt	■				■
Permeable pavers			■	■	■
Vegetated pavers				■	■
High albedo/Light-Colored Pavements:					
Concrete	■			■	■
Asphalt or concrete with light aggregate	■			■	■
Rubberized asphalt			■	■	■
Resin-based pavements			■	■	■
Surface Treatments:					
Chip seals		■			
Sand seals		■			
Rubberized slurry seals		■			
Painting/colored seals		■	■	■	■
Whitetopping		■	■	■	■
Grinding/microsurfacing		■			

INCENTIVES

- **Financial Based**
  - Establish state-level tax credits or similar programs applicable to government projects and require development of specific criteria for evaluation and qualification (i.e. tied to statewide or local goals / policies).
  - Create regional agency-led grant programs to encourage and offset costs of cool pavement construction. Agencies like SACOG, for example, could develop a grant program that encourages the use of cool or permeable pavements in publicly funded or government-led infrastructure projects at a smaller scale, such as new local road and street construction, repaving and maintenance, transit centers and stations, complete street or corridor projects, or bicycle and pedestrian facilities.
  - Create state agency-led grant programs (i.e. Caltrans) aimed at implementing cool pavements for large highway infrastructure projects.

PROGRAMS

- **Agency Focused**
  - ▶ Develop and implement agency procurement programs/policies for government facilities as a means to incorporate mechanisms for cool and permeable pavement project components as well.
  - ▶ Establish criteria and performance characteristics for procurement or bid specifications to ensure implementation for transportation facilities (or other agency-led projects) and infrastructure projects. Costs may be higher at the bid stage, but long-term savings are generally received.
    - » Example: The City of Dallas (Texas) has a specific Green Cement Purchasing Policy that aides in ensuring reflective pavement is used in municipal projects.
    - » Example: Purchasing policy template language and process guidance is available through California's Institute for Local Government.
- **Community Focused**
  - ▶ Create and establish community education campaigns that raise awareness about urban heat within the transportation network and benefits of cool pavements. As with all education and outreach, costs are not static and depend on level of effort and material production requirements.
  - ▶ Provide demonstration projects for cool pavements at transportation facilities and within infrastructure projects; for example, reflective pavements could be implemented alongside other heat mitigation measures within a complete streets project to illustrate the positive impacts and how the reduced temperatures can encourage use of alternative modes.
  - ▶ Expand outreach outside of the transportation community, with resources available to school districts, developers, the building industry, and homeowners, as cool pavements can be incorporated into a wide range of projects such as playgrounds, parking lots, or residential landscaping/driveways. For larger development projects, cool pavement applications like permeable pavers can serve as a way to meet stormwater requirements.

MANDATES

- **Code Based**
  - ▶ Update various code elements or guidelines related to cool pavements within infrastructure or development projects. This may include:
    - » Requiring certain measures within a project, such as through project Conditions of Approval;
    - » Encouraging code requirements for both new roadways and maintenance activities to ensure that roadways are designed and built at the outset to support heat-resilient paving materials – especially critical in new developments where tree canopy has yet to mature.
  - ▶ Create strategies for specific project types that set performance or quality standards that must be used during proposal review. CalGreen mandates low impact development, which is inclusive of the use of cool pavements or permeable pavements; local agencies can seek to exceed these with more stringent requirements within local zoning or building codes.

EXAMPLE TEMPLATE LANGUAGE FOR ZONING CODE/ORDINANCE

At least X% of new parking lots over one-acre in size shall utilize cool pavements, including porous pavers or reflective paving surfaces with minimum aged albedo of XX.

- **Policy Based**
  - ▶ Develop green building programs requiring certain transportation infrastructure projects to implement cool pavement components, focusing on complete corridor projects or specific facility projects.
  - ▶ Develop robust stormwater management plans that include urban heat island reduction requirements through decreasing impermeable surfaces and increasing green or cool surfaces.

EXAMPLE TEMPLATE LANGUAGE FOR COOL PAVEMENT POLICY

Future outdoor surfaces, such as parking lots, new roads and roadway improvements, sidewalks, and bike lanes, shall require the use of high albedo material (with minimum aged albedo of XX) to reduce the UHI effect and save energy.

Amend design guidelines and other documents to promote low-impact development strategies such as cool roofs and cool paving surfaces.

Disperse parking into smaller fields instead of large paved areas and consider higher albedo or permeable paving materials.

VEGETATION COVER

INCENTIVES

- **Financial Based**
  - ▶ Develop incentive programs related to urban forestry, which could include:
    - » Tax-deductible programs to fund tree planting programs that can be applied to publicly led transportation projects or to increase street trees along existing roadways. Donations could be focused on non-profits or corporate sponsors, for example.
    - » Creation of a designated tree district or tree fund that is funded by fees charged as part of development projects.
  - ▶ Regional or state-led grant programs that provide funding assistance to infrastructure projects that incorporate urban forestry.

PROGRAMS

- **Community Focused**
  - ▶ Establish education programs, such as:
    - » Programs to educate local contractors on how to preserve trees during infrastructure project construction.
    - » Awareness campaigns for private developers to underscore the importance of urban canopy and its role within reducing urban heat.
    - » Resource tool kit designed fort developers, contractors, and homeowners that provides guidance on the best types of trees for development plans and projects. The toolkit should provide useful information about the most desirable attributes in street trees for reducing urban heat – canopy size, growth rate, and water requirements, for example, can all impact a tree's cooling effects.
  - ▶ Develop partnerships between local or regional agencies and community groups to work on street tree planting; in addition to planting trees, these programs educate residents about urban heat and proper tree maintenance.
    - » The Sacramento Tree Foundation publishes a list of recommended trees that are suitable for the Capital Region and can help to provide shade and carbon sequestration; in addition, they offer tree-planting and tree-care workshops, as well as regular planting and volunteer events. In general, outreach campaigns and programs can help engage residents on the importance of tree canopy and empower them to make tangible Improvements in their community
- **Agency Focused**
  - ▶ Develop targeted programs (as part of ordinance, code or other policy efforts) that help guide urban forestry within communities. These programs may:
    - » Focus on increasing canopy in underserved communities
    - » Require tree planting or other landscape-based measures as part of major roadway or utility projects
  - ▶ Establish an agency-focused resource database to help staff select tree species based on maintenance costs (some trees may have higher maintenance costs than others), structural integrity(i.e., can withstand high winds or storms with lower likelihood of falling branches), and the most appropriate planting locations (i.e., will not disrupt sidewalks or cause safety concerns).

MANDATES

- **Code Based**
  - ▶ Codify language related to urban forestry to ensure implementation of trees or other landscaping measures in projects. This may include landscaping ordinances or language specific to tree planting within certain code sections. Code or ordinance language should include tree protection requirements as well as replacement specifications if tree removal is unavoidable during project development.
    - » Example: The City of Sacramento has both the Parking Lot Tree Shading Design and Maintenance Guidelines and a tree ordinance that could serve as models for other agencies in the region.

EXAMPLE TEMPLATE LANGUAGE FOR TREE / LANDSCAPE CODE OR ORDINANCE

X% of the capital budget must be set aside for tree planting or landscaping along the public right-of-way space (including sidewalks along key corridors) or roadways.

X% canopy coverage within X years should be achieved for all new parking lots. A minimum of X% of trees required for parking lots are to be large shade-producing trees with low water requirements.

A minimum of X% of trees in non-parking lot public right-of-way are to be shade-providing, low water trees.

- **Policy Based**
  - ▶ Develop targeted urban forestry plans that provide policy level goals and strategies to increase tree canopy coverage. Agencies should give consideration to and guidance on:
    - » The types of trees that are most successful in the area, and match tree species or general tree types with different transportation infrastructure applications;
    - » Implications for network safety, transportation operations, and maintenance costs in relation to tree growth and maintenance requirements; this may include:
  - ▶ Issues such as invasive roots that may prematurely require replacement of sidewalks or roadways, or pose safety issues to bicycles or pedestrians;
  - ▶ Height requirements, to avoid impacting overhead wires impede the flow of travel for larger trucks or transit vehicles, or impact sight distance for bicyclists or motorists
    - » Baseline tree canopy levels to allow for the establishment of goals or metrics, and to guide the level of effort needed for true improvement of canopy coverage.
  - ▶ Establish goals at the community level, as well as for targeted areas like communities of concern, to ensure equitable investment and attention to urban heat impacts.
    - » Example: The City of Sacramento has been working towards the adoption of an Urban Forestry Master Plan, which could serve as an example of how to construct a plan within the Capital Region.

EXAMPLE TEMPLATE LANGUAGE FOR URBAN FORESTRY PLAN GOALS AND POLICIES

Increase the city's tree canopy from [baseline %] to X%, starting with the neighborhoods with the lowest tree canopy.

Increase the number of street trees in communities of concern or areas with vulnerable populations by X%.

ZERO-EMISSIONS VEHICLES

INCENTIVES

- **Financial Based**
  - ▶ Leverage and support existing tax credit, grant, and rebate programs at the regional agency level that increase the share of EVs in the market while reducing the financial burden for residents and organizations.
    - » Existing programs dedicated to low-income residents are incredibly important to minimize the disproportionate burden of urban heat and poor air quality for under-served communities. Launching soon in the Capital Region, the Clean Cars 4 All program will offer incentives to low-income residents to purchase or lease zero-emissions or hybrid vehicles. Overall, financial incentive programs can be very effective for increasing the share of EVs in the market.

- Develop regional agency-led grant funding and rebate programs that can be utilized by developers and local agencies to encourage inclusion of EV equipment like charging facilities in projects.
  - Participate in existing grant funding and tax rebate programs to meet California mandates for zero emission vehicles, including transit buses and agency fleet vehicles.
    - California has two rebate programs available to the public and to local agencies; the Clean Vehicle Rebate Project provide rebates to residents, while the Public Fleet Pilot Project provides rebates to local agencies with SB 535 Disadvantaged Communities.
  - Establish local agency-led grant programs for developers and homeowners.
    - Example: El Dorado County Air Quality Management District offers additional grants to help with EV purchases and charging infrastructure installations; similar programs can be found at SMUD and Roseville Electric.

- **Planning Based**
  - Revise code language, create new incentive programs, and introduce new ordinances to encourage more ZEV use. Specific to incentives, options available may include:
    - Reduction in the amount of traditional parking spaces required, provided EV charging stations are incorporated into developments or parking lots.
    - Density bonuses when EV charging is proposed.
    - Streamlining permitting processes and requirements to entice ZEV infrastructure development.

PROGRAMS

- **Agency Focused**
  - Develop local government procurement programs that include ZEV-related requirements to assist agencies in meeting California's zero emission mandate. This includes two practices common across the U.S.:
    - Requiring some or all of new fleet vehicles purchases be zero-emissions, and
    - Establishing specific charging infrastructure standards (i.e., Level 2, DC, etc., as well as the number of chargers) for projects.
  - Develop EV car-sharing programs, such as Gig Car Share and Our Community CarShare in the Capital Region or BlueLA (the latter two are both focused on communities of concern), to promote EV use, raise public awareness of their benefits, and expand economic opportunity and mobility for residents.
  - Establish a process and program to ensure a cohesive network of charging stations, and adopt policies to support equitable access to equipment. Efforts should support California's SB 454 (Electric Vehicle Charging Stations Open Access Act), which prohibits membership requirements for vehicle charging.
- **Community Focused**
  - Develop public awareness and education campaigns that are targeted towards residents as well as the business community. Programs should:
    - Provide an understanding of how ZEVs can help reduce the UHI effect as well as improve air quality;
    - Educate business owners on the benefits of having charging infrastructure adjacent to a business;
    - Educate developers on the costs, benefits, and requirements associated with EV charging.
  - Hold events, such as Ride and Drive events, led by agencies or utility companies to engage and educate the community on technology and available resources for ZEVs.
  - Develop community-supporting proclamations within local governments that solidify dedication to EV cars, infrastructure, and community safety.
  - Strengthen wayfinding and signage programs to further educate and bolster use of EVs. Local agencies should ensure that their signage programs:
    - Comply with current California regulation,
    - Include adequate signage to direct drivers to facilities,
    - Develop a cohesive and/or branded design that is easy to recognize.

MANDATES

- **Code Based**
  - ▶ Amend or adopt new codes or ordinances to support:
    - » Permitted charging locations by land use type;
    - » Wiring specifications and requirements;
    - » Curbside charging options and management.
  - ▶ Specify land uses supportive of EV charging infrastructure to aid in expanding and encouraging EV infrastructure networks. Clear language related to land use type, such as multifamily or commercial, should be included.
  - ▶ Develop EV-ready wiring codes and ordinances to ensure EV charging installations are cost-efficient ; by including the proper wiring and infrastructure at the onset, developers (or agencies) can save money, as the cost to retrofit a site is higher than that of a new installation within a new project.
  - ▶ Update local agency codes to require EV-ready or EV-installed spaces at parking lots, commercial buildings, garages, multifamily units, and other requirements.
  - ▶ Design programs that can support compliance with new building code requirements for residential solar through developing solar-shaded parking lots with EV charging.
  - ▶ Develop innovative methods for curbside charging, as well as methods to manage or protect EV parking spaces. This may include:
    - » Clear codes or ordinances that include discussions related to EV charging as part of streetlights or power poles,
    - » Permitting charger installation for residential use on sidewalks,
    - » Developing a fine/fee schedule for EV parking enforcement,
    - » Creating specifications for EV parking spots that prohibit most non-EV vehicles.

EXAMPLE TEMPLATE LANGUAGE FOR EV CODE / ORDINANCE

Where parking is provided, X% of parking spaces shall be provided with EV charging infrastructure.

Require all new development with 50 or more parking spaces to designate a minimum X% of parking spaces as ZEV only.

Require all new development with 50 or more parking spaces to pre-wire for EV charging stations and provide a minimum of X% charging spaces.

Levels 1, 2, and 3 EV charging stations are allowed in all zoning designations.

Multiple-family residential land uses shall have X percent of required parking as Level 1 stations for resident parking, and X [number of spaces] Level 2 stations for guest parking. At least one handicapped accessible parking space shall have access to an EV charging station.

- **Policy Based**
  - ▶ Expand, where needed, policies within adopted Climate Action Plans (or similar documents) through amendments to include additional language that supports ZEVs. Some expansions may include:
    - » Specific goals and policies related to increasing access to programs within communities of concern or
    - » Setting more specific targets for the percent of vehicles that should be ZEV by a certain date. These policies guide implementation, which is achieved through the zoning code, building code, or other ordinances at the local agency; as such, each jurisdiction should set specific targets based on their planning goals, climate change targets, EV policy and goals, and other plans.
    - » Updated or revise policy documents as needed prior to the development of specific code implementation strategies to ensure consistency.
    - » Other public agencies like transit operators/districts can develop their own policy documents that detail goals for moving towards zero-emission fleets and meeting GHG reduction mandates.

EXAMPLE TEMPLATE LANGUAGE FOR EV GOALS AND POLICIES

Promote clean air vehicles (CAV), and expand the network of electric car charging stations and carsharing parking spaces.

Allow car-sharing companies to designate spaces in public parking areas and multifamily housing projects.

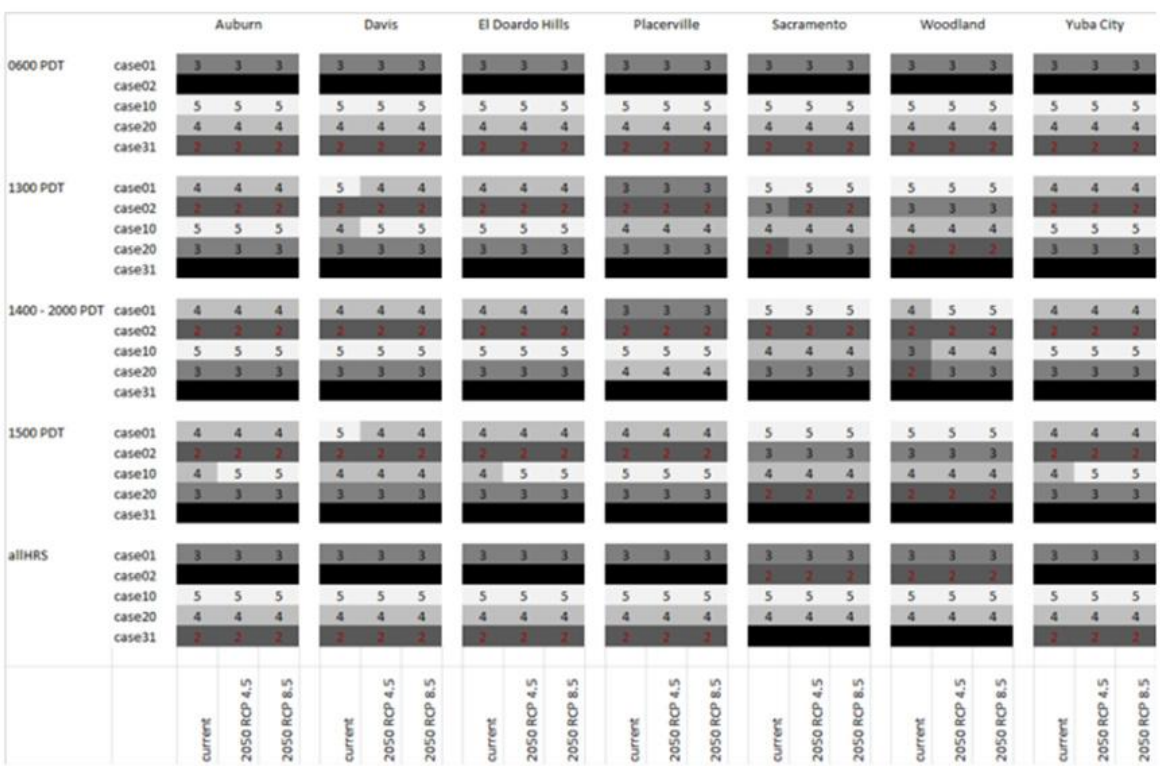
Prioritize EV car sharing programs and adequate infrastructure in communities of concern.

5.3.2 IMPLEMENTATION TIMING

The timing of implementing UHI mitigation measures is another important consideration. Some strategies, such as installing cool roofs and pavements, will provide an immediate cooling benefit. Others, such as installing green roofs and planting trees, will take longer to provide their full benefits as vegetation grows. Vehicle conversion from traditional to EVs will also take some time, as residents gradually take advantage of incentive programs and technology advancements to make the switch. Albedo-increasing strategies like cool roofs and pavements may also decrease in effectiveness over time without proper maintenance. For cool pavements, roadways with higher traffic volumes may see increased wear and thus reduced albedo over time. For roads with lightening treatments, tire markings and vehicle fluids can darken pavements and increased maintenance will be required to achieve the greatest benefits. These timing considerations further support the need to apply a mix of strategies in the Capital Region, as some strategies will be effective before others and for different durations.

Another timing consideration is the effectiveness of UHI mitigation depending upon time of day. The mitigation modeling completed for this plan indicated that albedo improvements (e.g., cool roofs and cool pavements) are the top choice for reducing daytime urban air temperature, and vegetation canopy cover can cool the air both during the day and at night (H. Taha 2020). Cooling effectiveness does not only vary between day and night, but over just a few hours. Altostratus found that the effectiveness of mitigation measures was different at 6am, 1pm, 2 to 8pm, and 3pm across the Capital Region for current and future conditions (H. Taha 2020). Figure 2 below, adapted from Figure EX-18 in (H. Taha 2020) shows the results of this analysis. Cooling scenarios are ranked from 1 (most effective, darkest color) to 5 (least effective, lightest color) for modeled areas In the Capital Region at different times of day.

Figure 28: Summary of Urban-Heat Mitigation Potential: Ranking of Measures Case01 Through Case31 by Cooling Effectiveness (Darker to Lighter = Largest to Smallest Cooling) in Future Climate (2050)



Note that case02 should be excluded in some analysis as it represents an extreme increase in tree canopy. Also note that this is impacts on air temperature, not urban heat island index. Case 01 = 12 percentage point (pp) increase in canopy cover; Case 02 = 20 pp increase in canopy cover; Case10 = 0.15 increase in albedo; Case 20 = 0.25 increase in albedo; Case 31 = a combined 0.35 increase in albedo and 12 pp increase in canopy cover. On the bottom, “current” refers to the present day, while 2050 RCP 4.5 represents an optimistic climate change scenario with less global warming, and 2050 RCP 8.5 a more extreme climate change scenario with more warming. The analysis shows that for many locations, the combination scenario of increased albedo and tree canopy is the most effective cooling mechanism, especially during the hottest times of the day, thus illustrating the importance of deploying multiple strategies simultaneously. Furthermore, the results also show that these are no-regret strategies: they can deliver cooling benefits today and will continue to do so in 2050.

5.3.3 PERFORMANCE INDICATORS

After implementation, it is important to revisit measures to monitor performance. Performance monitoring can take the form of setting indicators. For example, an agency could set an indicator that states: “By 2050, the new Granite Bay cool roof zoning code shall offset the UHI index by 50%.” Developing these performance indicators is up to the discretion of each implementing agency. These goals can be specific, like the example provided above, or more general, for example: “By 2050, the majority of new buildings in Granite Bay will have cool roofs.”

Setting performance indicators can be a helpful way to guide implementation and define the goals of the proposed mitigation measure. They provide a benchmark to check the progress and effectiveness of strategies. Critically, at regular time intervals in the project lifetime, the agency should review indicators to assess progress and inform future decision making. For example, if by 2050 Granite Bay identified that only 5% of new buildings had installed cool roofs, then the code may not be as effective as anticipated. They may take actions to change the code, provide additional services and education to contractors, provide incentives to companies/homeowners, or take an alternative action.

Finally, setting and monitoring performance indicators is a helpful tool to demonstrate project success to stakeholders, and can help to support and influence the efforts of neighboring stakeholders. Indicators are also helpful for gaining higher levels of achievement in sustainability frameworks such as LEED, Envision, the Living Building Challenge, and others. For example, in version three of the Envision Sustainable Infrastructure Framework, there are credits that require or benefit from project monitoring, review of project effectiveness, and using key performance indicators to measure effectiveness (see LD 1.1, CR 2.5 specifically) (Institute for Sustainable Infrastructure 2018).

5.4 PILOT PROJECT IMPLEMENTATION STRATEGIES

Early in the UHI assessment process, the project team reviewed Capital Region projects that are underway or in initial planning phases to identify opportunities to incorporate UHI mitigation measures. These projects were collected from SACOG’s Metropolitan Transportation Plan (MTP) and were chosen based upon the following criteria:

- Cost,
- Project type,
- Geographic distribution,
- Disadvantaged and vulnerable community representation,
- Areas of importance as identified by the TAC,
- Areas of importance as identified by the community through surveys and comments, and
- Areas of high average temperatures.

By applying these criteria, the project team chose 23 priority projects that represent a range of project types (e.g., active transit, complete streets), costs, geographies, and community input. These projects provide examples of opportunities to demonstrate how to incorporate UHI mitigation measures into already funded and approved transportation infrastructure projects. Out of these 23 projects, a diverse selection of nine pilot projects were highlighted below to provide examples of how UHI mitigation strategies could be incorporated into project planning. The project team chose mitigation strategies based on project type and the modeling results presented earlier in this report as well as in H. Taha 2020. Each of these projects is within one of the six community-level (500m) modeling domains and provides a representative area in which to implement the modeled mitigation actions.

Across each regional domain, modeling results suggested that the combination of high-albedo pavements and roofs and increased vegetation cover had the greatest cooling impacts, making them prevalent and almost foundational UHI reduction measures for the transportation projects outlined in the following subsections. For example, most Complete Streets projects below include recommendations for cool pavements and increased vegetation cover because they provide a combination of improvements to bike lanes, walkways and intersections where cooling would be beneficial to pedestrians and cyclists. Conversely, project types such as the high-capacity transit service from Cosumnes River College (CRC) to Elk Grove, a bus corridor, require the application of mitigation measures tailored to project-specific aspects such as bus stops. In this case, a combination of vegetation cover and cool roofs would be the most applicable. This point also highlights the importance of combining UHI mitigation measures where possible. As suggested in the H. Taha 2020 Technical Project Report, combining measures provides significantly larger cooling benefits than implementing those measures alone. Figure 26 depicts the locations of the nine selected projects and Table 27 summarizes the projects and the recommended combination of mitigation measures for each.

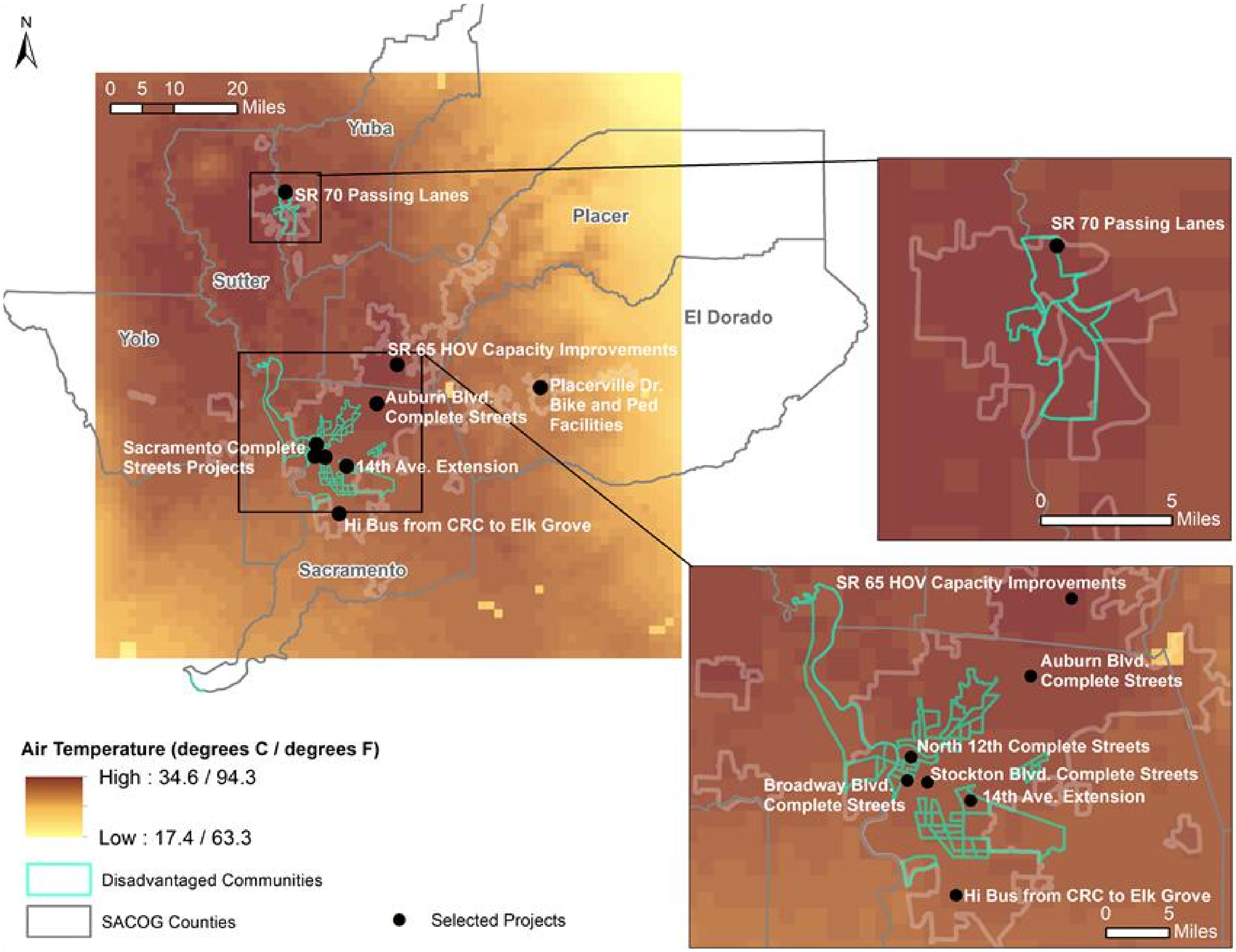


Figure 29: Location of Selected Projects for Mitigation Measure Recommendations

TABLE 29: FAST GROWING SHADE AND STREET TREES THAT MAINTAIN AIR QUALITY

PROJECTS	RECOMMENDED MITIGATIONS: VEGETATION COVER	COOL PAVEMENTS	COOL & GREEN ROOFS	SMART GROWTH	ELECTRIC VEHICLES	MODELLED COOLING POTENTIAL OF COMBINED MEASURES (°F)[13]
North 12th Complete Street Project Phase 2	■	■				2.7 – 7.2
Broadway Complete Street Project	■	■			■	3.1 – 7.9
14th Avenue Extension Phase 1	■	■				2.7 – 7.2
Stockton Blvd Complete Street	■		■			2.3 – 2.4
Auburn Blvd Complete Streets – Phase 4 & 5	■	■				2.7 – 8.3
SR 70 Passing Lanes	■	■				2.6 – 6.6
Placerville Drive Bicycle and Pedestrian Facilities	■			■		1.9 – 2.3
SR 65 Capacity & Operational Improvements (HOV)	■	■		■		2.7 – 7.2
Hi Bus from CRC to Elk Grove	■		■			2.3 – 2.4

13 This column shows a range of the sum of individual average cooling potentials for the chosen mitigations measured against minimum (0600 PDT) and peak temperatures (1500 PDT) within the modeling domain associated with each project. Per H. Taha 2020, combining mitigation measures provides significantly larger cooling benefits than a standalone measure, but the total cooling from the combined mitigation is smaller than the sum of the individual (i.e., standalone) components. While H. Taha 2020 provides a case study on the combination of mitigation measures for select areas within the Sacramento region, the combinations of mitigation measures for projects in this table were not modeled. Thus, we endeavor to give a range for the cooling potential that may result from these mitigation strategies.

5.4.1 NORTH 12TH COMPLETE STREET PROJECT PHASE 2

Cost = $5,524,224

The North 12th Complete Street Project (T15165000) will transform the North 12th Street Corridor from Richards Boulevard to H Street into a Complete Street with the installation of a two-way Class IV separated bikeway along the west side of North 12th Street. The project will also include new sidewalks, landscaping, aesthetic improvements, street and pedestrian lighting, and traffic signal improvements.

The implementation of a Class IV separated bikeway connection on North 12th Street will improve accessibility and safety in the 12th Street corridor. The project would incorporate the River District's vision of transforming the existing light industrial and commercial area into an urban community with diverse uses. The bikeway will close the gap in the region's bicycle network, allowing cyclists to ride In both directions along a high traffic corridor. The complete streets project will also provide a safer facility for pedestrians in conjunction with the existing sidewalk (see Figure 30).

MITIGATION MEASURES

Vegetation Cover: Reducing the UHI here is particularly important, as this is a light industrial area with a high percentage of paved surfaces and few trees, but is also widely traversed by people experiencing homelessness. This project plant additional trees, selected and sited to provide shade canopy, along the road and bike lanes. The new bikeway can lead to a shift to more active transportation and connectivity, linking downtown Sacramento to the neighborhoods of North Sacramento and Del Paso Blvd. This can help to reduce the UHI effect by providing an alternative to heat-intensive transport methods.

Cool Pavements: The implementation of cool pavements could also be feasible for this project. While cool pavements may cost more upfront, they provide longevity and environmental benefits that should be considered as decision criteria. There is a wide range of seals, coatings, and other cool pavement options with differing costs that are well suited to sidewalks and bike lanes, improving comfort for active transportation users as well as visibility for traffic safety. Cool pavements can be deployed as a pilot project, or through the use of a mandate, such asi in Novato, California, where they require the use of a high albedo material for future outdoor surfaces such as car parks and sidewalks.

Figure 30: North 12th Proposed Two-Way Class IV Bikeway

Source: City of Sacramento

5.4.2 BROADWAY COMPLETE STREET PROJECT

Cost = $10,000,000

Just south of downtown Sacramento, this project proposes to conduct transformative multimodal improvements on Broadway, including new buffered bicycle lanes, lane road reduction, new marked pedestrian crossing, and refuge islands.

MITIGATION MEASURES

Vegetation Cover: One goal of this project is to increase pedestrian activity and accessibility. Urban forestry can be used to improve the walking experience, as long stretches of Broadway currently lack shade tree canopy. Tree shading for sidewalks and bike lanes can help improve comfort while enhancing street aesthetics and improving air quality.

Cool Pavements: Pavements are a crucial part of this project's goal of creating a more walkable environment. High-albedo coatings and paving materials can be used for sidewalks without the concerns of maintenance and wear-and-tear that accompany roadway applications. . Permeable pavements can also be a feasible option for sidewalks, as it would provide cooling and reduce puddles, as well as support stormwater management and groundwater retention.

Electric Vehicles: Expanding uptake of EVs could occur through the installation of more EV charging stations in the Broadway area and preferential parking policy for ZEVs (e.g., reserved spaces, or free or discounted parking). Curbside charging could be an attractive amenity for EVs along Broadway, where there are fewer large parking lots.

Figure 31: Broadway Complete Streets Rendering

Source: City of Sacramento

5.4.3 14TH AVENUE EXTENSION PHASE 1

Cost = $9.5 million

A vision for 14th Avenue in the City of Sacramento is to extend and widen the street from Power Inn Road ending east of 82nd Street. The new road will consist of a two-lane roadway with class II bicycle lanes, landscape planter, and sidewalks on the south side of the roadway. The project will also include new water and drainage facilities, new streetlights, new traffic signals at 14th Avenue /Florin Perkins Rd, and modifications to existing traffic signals.

MITIGATION MEASURES

Cool Pavements: The reconstruction of 14th Avenue can be significantly improved by using high-albedo or permeable paving materials for the road, bicycle lanes and sidewalks. Both options will help to reduce the heat island effect. Permeable or porous substances (such as interlocking concrete pavers or grass/gravel pavers) contain voids for air and water to pass through, which improves drainage for stormwater mitigation as well as cooling through evaporation.

Implementing these strategies not only mitigates the UHI effect but also potentially saves money that would otherwise be spent on installation of stormwater infrastructure. Such actions would also provide advantages such as roadway safety with less standing waters, fewer potholes, and longer durability with less pavement maintenance and replacement. Permeable paving materials can be used for sidewalks, while bike lanes and roadways may be better suited for higher-albedo cooling materials.

Vegetation Cover: With the inclusion of bicycle infrastructure, increasing the urban canopy along the corridor will further aid in minimizing negative urban heat impacts. Shading will reduce ambient air temperature for cyclists and pedestrians, an effect that can increase the use of active transportation. As discussed before, an increase in active transportation can decrease vehicles on the roadway, even further decreasing UHI within the project area.

5.4.4 STOCKTON BLVD COMPLETE STREET

A complete street plan of Stockton Boulevard and the intersection with T Street poses particular safety and traffic management challenges to Sacramento. As the crossing receives new development, the need to find a long-term solution is more important than ever.

Figure 32: Stockton Blvd.

Source: City of Sacramento

MITIGATION MEASURES

Vegetation Cover: The Stockton Blvd corridor is a priority roadway for the City of Sacramento, with the potential for significant economic development as well as the need to increase safety through their Vision Zero program. Given the emphasis on the corridor, vegetation cover through street trees, parking lot shading, and general development landscaping has benefits well beyond minimizing urban heat impacts. The roadway currently has minimal street trees, and coupled with extensive empty or underutilized paved land, present extreme heat conditions for bicyclists, pedestrians, and transit riders. As part of the complete streets project, significant investment can be made in a street planting program, but should be done in a manner that does not further exacerbate safety at critical intersections and roadway segments.

The natural cooling properties of trees and plants can provide an overall strategy to address UHI, and can offer a range of not only environmental but also social and economic benefits. A more aesthetic streetscape could potentially improve walkability, leading to health benefits for residents from increased physical activity. It could also bring higher footfall for business and potentially more sales. Critically, this neighborhood experiences lower urban tree canopy than its wealthier neighbors to the north and east. Higher tree canopy – as well as cooler temperatures – is associated with improved educational performance, an important criteria for the Stockton Corridor, which is surrounded by many schools. The many nearby school campuses also provide a natural area for tree planting, with the potential for student education and engagement around tree canopy and urban heat..

Local governments can implement urban forestry by prioritizing trees over street improvements through tree protection efforts during construction and by encouraging green building standards such as LEED.

Cool and Green Roofs: SacRT Route 51 operates along Stockton Blvd, and currently generates the highest ridership amongst all system routes. However, transit passenger amenities are lacking along the corridor. The agency is considering implementation of a new Bus Rapid Transit route or similar high capacity/frequency service, which presents an optimal opportunity to incorporate transit facilities with cool or green roof structures, in addition to trees. With the potential for a new transit center at the terminus of the route on Stockton Blvd, green or cool roofs could be used to highlight this strategy as an awareness campaign while also reducing urban heat at the waiting area. Similarly, transit shelters along the route could be constructed with cool roofs, as well as other strategies like street trees, cool pavements, or landscaping features.

Moreover, one strategy to integrate multiple concepts on Stockton Blvd is to develop mobility hubs, which are strategically located hubs that provide a range of transportation options for residents. These may include bikeshare, scooter share, electric car share, and transit service, as well as EV charging stations that serve the neighborhood. Mobility hubs typically include areas for passengers to wait and are therefore prime opportunities for urban forestry programs, shaded and landscaped seating areas, or transit structures/stations (depending on the magnitude of the services provided). Access is also important for bicycles and pedestrians, further increasing the need for street trees and other landscape features.

5.4.5 AUBURN BLVD COMPLETE STREETS - PHASE 4 & 5

Cost = $48,000,000

Residents in the community within this project area have expressed the need for more trees and protected bike lanes along Greenback and Auburn Boulevard. As Auburn Boulevard was identified as the street with the second highest number of pedestrian collisions in Citrus Heights, this led to the development of the Citrus Heights Pedestrian Master Plan. The plan's vision is to increase the number of pedestrians in Citrus Heights and make the city more walkable. The Plan also includes design recommendations for streets, sidewalks and shared-use paths.

As walking represents the least expensive mode of transport and has a positive impact on people's health and wellbeing, pedestrian infrastructure is required to be built and maintained with high-quality standards. On the other hand, increasing the area of roads, bike lanes and pavements can increase the UHI effect, and therefore, new infrastructure has to be designed carefully. While the Citrus Heights Pedestrian Master Plan is as a good start, it is recommended to adopt UHI implementation strategies such as urban forestry and cool pavements.

5.4.6 SR 70 PASSING LANES (CALTRANS, YUBA COUNTY)

Cost = $32,000,000

This project will implement better passing lanes along State Route (SR) 70 to reduce vehicle accidents as well as improve overall safety. The project will increase the number of lanes on this vital route, including new continuous passing lanes in both directions from Marysville to the Butte County line. While this project's main goal is to increase safety, there is opportunity to provide UHI mitigation.

MITIGATION MEASURES

Vegetation Cover: Incorporating urban forestry into the design of new passing lanes can help provide cooling and cost savings from avoided stormwater management infrastructure, as well as improved biodiversity. Caution should be taken, as vegetation cover would need to be coordinated with Caltrans to insure there are no conflicts with other efforts, such as those to reduce wildfire risk.

Cool Pavements: For highway projects, the most appropriate high albedo pavement choices include asphalt with light aggregates or conventional concrete with or without light aggregates, as they are capable of withstanding high traffic volumes, including heavy-duty vehicles. Their associated maintenance costs are also relatively low, and can be patched or replaced with the same materials as the initial construction. The use of lighter pavements can reduce long-term maintenance costs and reduce heat-related roadway damage, as Yuba and Sutter County are modeled to have a high heat island index today and increased heat in the future.

5.4.7 PLACERVILLE DRIVE BICYCLE AND PEDESTRIAN FACILITIES

Cost = $11,868,444

The City of Placerville has a plan to construct bicycle facilities and sidewalks on the west side of Green Valley Road from Placerville Drive to Mallard Lane and to construct new sidewalks to encourage safe pedestrian travel.

MITIGATION STRATEGIES

Smart Growth: Because the project is funded by federal Congestion Mitigation and Air Quality (CMAQ) funds, this program needs to make a significant improvement in air quality. These improvements are also likely to provide co-benefits of increased cooling for the city. This program set out smart growth objectives of improving cycling and pedestrian space, which can help reduce heat by encouraging active transportation over car use, which generates waste heat.

Vegetation Cover: Further mitigation can be implemented to reduce the UHI effect through the incorporation of urban forestry in cycle lanes and pedestrian cross walks. Implementing these strategies has the potential for many benefits, including reduced temperatures, pedestrian comfort, and improved aesthetics and community wellbeing.

Cool Pavements: For the bicycle facilities and sidewalks along the corridor, the City could utilize cool pavements to further reduce UHI. Longevity, materials costs, maintenance costs, and safety are all considerations – materials such as colored bike lanes, resin-based pavement, porous asphalt, rubberized asphalt, or permeable pavers along sidewalks are all potential strategies to incorporate into the project.

5.4.8 SR 65 CAPACITY & OPERATIONAL IMPROVEMENTS (HOV)

Cost = $6,500,000

This project makes capacity and operational improvements to SR 65, from Galleria Boulevard to Lincoln Boulevard, over two phases. Phase 1 of the project runs from Galleria Boulevard to Pleasant Grove Boulevard and involves constructing auxiliary lanes on northbound and southbound SR 65, including widening the Galleria Boulevard southbound off-ramp. The City of Roseville, where this project is located, has been identified as a higher heat area through this study's modeling efforts. Given this, implementation of multiple strategies would be greatly beneficial to the project in minimizing UHI.

This route is a widely travelled freeway that experiences constant flows of traffic, with severe traffic congestion from morning to night. This project is an investment from the state authorities to provide a better, safer, and more sustainable transport network, which will help support growth in smaller towns near SR 65.

MITIGATION MEASURES

Vegetation Cover: While likely not applicable along the entire project corridor, urban forestry can be utilized as a mitigation measure in areas where there are no safety or maintenance concerns. These mechanisms provide cooling for higher temperatures expected with future trends and higher amount of vehicle traffic. In addition to tree planting, bioswales, green infrastructure, and stormwater infrastructure should be considered, which can not only provide cooling benefits, but also help with meeting stormwater requirements associated with large roadway projects.

Cool Pavements: Adopting high albedo materials can help to reduce the amount of solar heat absorbed into pavements and roads. Materials must be able to withstand high traffic volumes, such as asphalt or concrete applications that have been mixed with light aggregates. This can significantly help reduce temperatures and thus the overall UHI effect in Roseville and the surrounding area. High albedo pavements will also be more resilient to extended periods of extreme heat expected with climate change, providing lifecycle savings in terms of reduced repair and maintenance costs.

5.4.9 HI BUS FROM CONSUMNES RIVER COLLEGE TO ELK GROVE

Cost = $37,813,159

This project is to develop an enhanced 8.5-mile bus corridor along Bruceville Road to Big Horn Boulevard to Kammerer Road to Highway 99 between Cosumnes River College and Elk Grove. A principal aim for this project is to improve connectivity between Cosumnes River College and Elk Grove through smart growth. By providing a better, more efficient bus service, the anticipated benefits are expected to be more people using transit instead of cars, which have a greater impact on urban heat.

MITIGATION MEASURES

Vegetation Cover: This project can increase the amount of urban forestry and other vegetation. Trees can be strategically planted at bus stops to help shade waiting passengers, as well as at stretches of the road devoid of tree canopy.

Cool and Green Roofs: Cool roofs can be utilized as part of the passenger amenities, such as bus shelters or transit station buildings. As trees take longer to mature, cool roofs and green roofs can provide a more immediate positive effect for passengers. Assuming the development of park-and-ride lots, solar shading could be installed over parking spaces to reduce heat absorption and reflection from paved surfaces while generating renewable energy.

Cool Pavements: Cool pavements can be incorporated in the areas surrounding major passenger infrastructure, as well as bus-only lanes (assuming they are implemented). Permeable pavers or light-colored paving could be installed at passenger waiting areas, while colored coatings or light concrete could be applied in transit circulation areas. Additionally, porous asphalt, pervious concrete, or vegetated pavers, for example, could be installed in parking areas like park-and-ride lots.

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