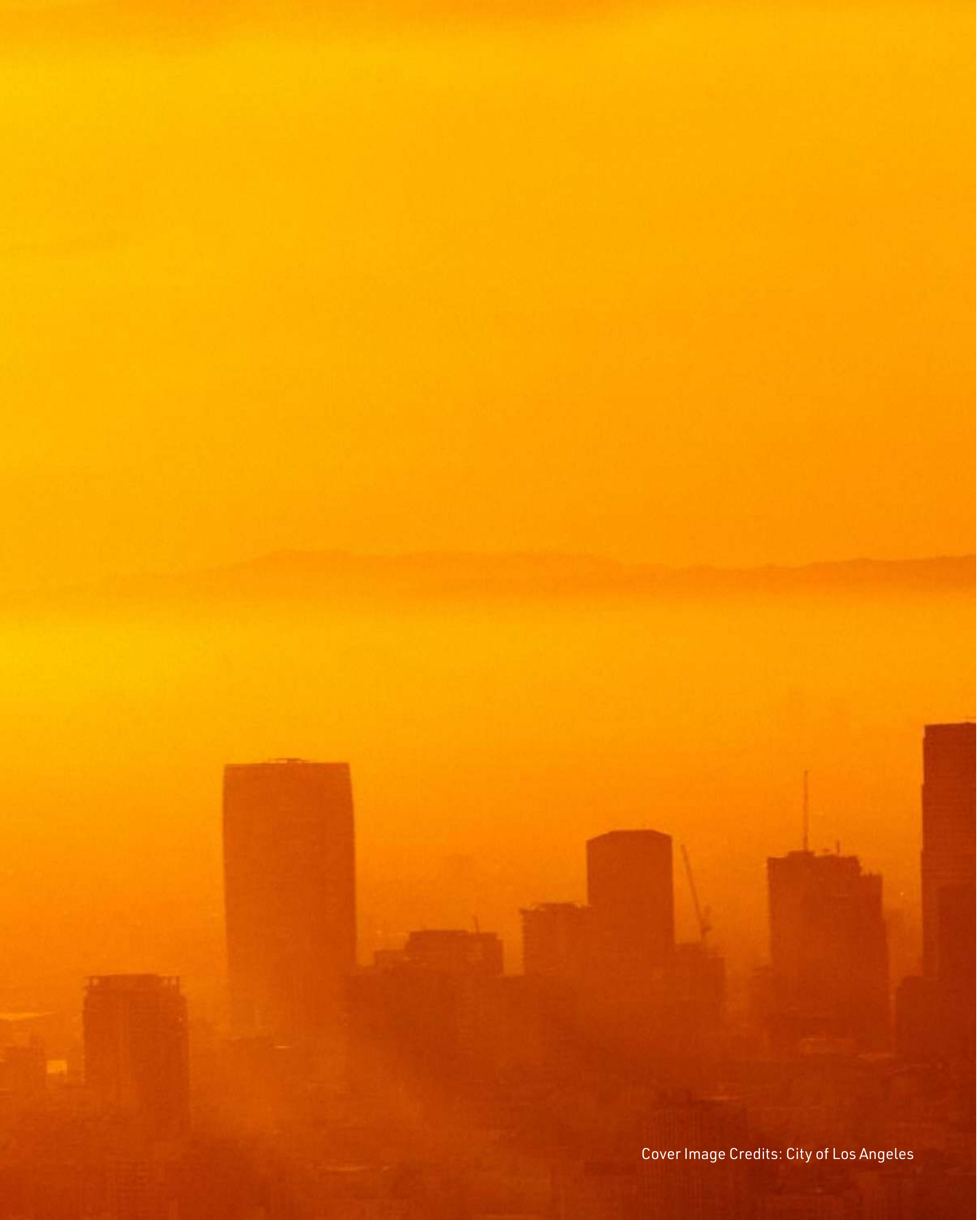
Heat Vulnerability in Los Angeles County

Resource and Methodology Assessment



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HEAT VULNERABILITY IN LOS ANGELES COUNTY

RESOURCE AND METHODOLOGY ASSESSMENT

June, 2020

Prepared by the **Center for Resilient Cities and Landscapes** at Columbia University for **Los Angeles County** with the generous support of the **Conrad N. Hilton Foundation**

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CONTENTS

LA COUNTY HEAT VULNERABILITY AND METHODOLOGY ASSESSMENT 4

I. HEAT VULNERABILITY | ASSESSMENT OF RESOURCES 5

DEFINING AND PROJECTING EXTREME HEAT 6

TRUST FOR PUBLIC LAND: CLIMATE-SMART CITIES 8

ECOSTRESS AND RELATED SENSITIVITY STUDIES 10

FOURTH CLIMATE ASSESSMENT, CALIFORNIA AND LOS ANGELES REGION 12

CAL ADAPT 16

CALIFORNIA HEAT ASSESSMENT TOOL (CHAT) 17

READY FOR TOMORROW, CLIMATE RESOLVE 19

CAL BRACE 20

CALIFORNIA HEALTHY PLACES INDEX (HPI) 23

II. GLOBAL PRACTICES IN DEFINING AND STUDYING HEAT VULNERABILITY 26

III. RECOMMENDATIONS FOR LA COUNTY METHODOLOGY 30

APPENDIX 36

LA COUNTY HEAT VULNERABILITY AND METHODOLOGY ASSESSMENT

To support research and planning that advances resilience and climate adaptation planning in Southern California, The Center for Resilient Cities and Landscapes (CRCL), the County of Los Angeles, and Resilient Cities Catalyst intend to collaborate on the Southern California Resilience Initiative. In service of this goal, the Center for Resilient Cities and Landscapes assessed existing climate studies in the region and global best practices in order to inform the methodology used by the County in their broader climate adaptation planning effort.

In support of this work, CRCL has prepared analysis and recommendations with respect to three key elements and objectives:

1. **Heat Vulnerability: Assessment of Resources**
   How do existing studies and tools define and illustrate heat vulnerability? What are their limitations in light of the County's goals to raise awareness about heat vulnerability and begin a decision making process about land use decisions?

2. **Global Practices in Defining and Studying Heat Vulnerability**
   How are other cities defining and studying heat vulnerability and how might this inform the approach that the County takes?

3. **Recommendations for LA County Methodology**
   Recognizing that the County has made strides in identifying strategic targets and actions related to climate resilience and urban heat, how can these tools and resources help to confirm, refine, or meet these targets and actions? What methodologies can be used to prioritize decision making and spatial planning related to the following targets? For the purposes of tool evaluation and initial methodologies recommended, this assessment focuses on the 2025 targets, with the expectation that targets may be refined for future time scales.

In an effort to cultivate integrated planning that addresses health, the built environment, nature-based Infrastructure, and communities, the County has established two primary strategies in the OurCounty Plan:

Strategy	Integrate climate adaptation and resilience into planning, building, infrastructure, and community development decisions		Ensure a climate-appropriate, healthy urban tree canopy that is equitably distributed
Baseline	Research is currently being conducted to understand how much of LA County's land area is covered by heat-trapping surfaces.	In 2014 there were seven heat-stress emergency department visits per 100,000 residents.	LA County had 20% urban tree canopy cover as of 2016.
Target 2025	Convert 10% of heat-trapping surfaces to cool or green surfaces	Reduce by 15% the number of heat-stress emergency department visits per 100,000 residents	Increase urban tree canopy cover by 10% of baseline
Target 2035	Convert 20% of heat-trapping surfaces to cool or green surfaces	Reduce by 45% the number of heat-stress emergency department visits per 100,000 residents	Increase urban tree canopy cover by 15% of baseline
Target 2045	Convert 30% of heat-trapping surfaces to cool or green surfaces	Reduce by75% the number of heat-stress emergency department visits per 100,000 residents	Increase urban tree canopy cover by 20% of baseline

I. HEAT VULNERABILITY: ASSESSMENT OF RESOURCES

Heat vulnerability is a function of exposure to a hazard, such as mean temperature or extreme heat events, and sensitivity, or the factors that indicate who may be less able to adapt or more susceptible to the acute impacts of any type of stress or hazard. In service of the above goals, CRCL prepared a review of the most widely recognized LA County-based climate studies and heat assessment methodologies and tools considering the following aspects: Purpose and use, understanding exposure, understanding sensitivity, key findings and application to LA County, and limitations.

The materials are a combination of indicators, planning and suitability analysis, and platforms for data to inform decision-making. Some of them include climate projection data that can inform a broad understanding of exposure in the future, but in and of themselves are not an indicator of heat vulnerability. Looking across these studies and resources, the aim is to inform potentially more refined vulnerability analyses with respect to impermeable pavement, tree canopy, and heat-related ER visits.

Trust for Public Land: Climate-Smart Cities
Decision Support Tool for a "Climate-Smart" city, which uses existing national and local data to help prioritize where to invest in green infrastructure strategies. Best used for design and policy decisions around green infrastructure at the County level.

ECOSTRESS and Related Sensitivity Studies
A NASA JPL program in which a sensor is mounted onto the ISS to measure and photograph Land Surface Temperature. Best used for imagery analysis of surface temperature exposure at the County scale or as input into a broader sensitivity analysis as was done by researchers at JPL, UCLA, and UCSB.

Fourth Climate Assessment, California and Los Angeles Region
A platform of tools and data at the State level that prepares broad climate projections and impacts as well as a regional report outlining the climate risk and vulnerabilities at the scale of the LA Region in narrative format. Best used for narrative analysis of heat and climate impacts across health, environment, economy at a regional scale.

Cal Adapt
The State's portal for the climate projections produced for the Fourth Assessment, enabling data downloading and visualizations of climate scenarios at the local level and wildfire projections for the entire state. Best used for development of climate projection scenarios to clarify global trends in exposure at the county scale.

California Heat Assessment Tool (CHAT)
An interactive mapping tool funded through the Fourth Assessment that specifically looks at variables related to Heat Health Events (HHE), any event that results in negative public health impacts, regardless of the absolute temperature. Best used for spatial analysis within the County to prioritize the interaction of one exposure indicator to one social vulnerability indicator.

Ready for Tomorrow, Climate Resolve
A narrative report that provides a snapshot of the current status of municipal-level climate preparedness planning within and near Southern California Edison's (SCE's) service territory. Best used for an overview of planning efforts that overlap or complement with the County.

CALBRACE
An interactive data visualization and mapping tool showing California Counties based on levels of both an exposure variable and a population sensitivity variable. Best used for prioritization of risks across the State and for a framework of weighing exposure and sensitivity.

California Healthy Places Index (HPI)
An interactive mapping and data platform and policy guides developed by the Public Health Alliance of Southern California in partnership with the Virginia Commonwealth University's Center on Society and Health, that can be used to explore and change community conditions that predict life expectancy. The HPI combines 25 community characteristics into a single indexed HPI Score. HPI scores for each census tract can be compared across the state to paint an overall picture of health and well-being in each neighborhood in California.

DEFINING AND PROJECTING EXTREME HEAT

In the United States, definitions vary by region, but a heat wave is most commonly seen by NASA as a period of at least three consecutive days above 90°F (32.2°C). However, determining the threshold against which to plan for extreme heat and extreme heat events depends on a number of factors, including the scenarios developed in climate projection models, the downscaling approach, and the intentions behind planning purposes in the near- and long-term. When considering projections for planning purposes on a community-by-community level, important factors might include:

- **Specific geography and scale.** Baselines for climate projections are determined based on observed and modeled historical averages, which vary by geographic locations and therefore influence the change factor that determines the future projected model outputs. For long-term planning purposes, the County might either consider using a geographic unit assumption that represents a portion of LA County or using the Statewide projection assumptions represented in the Fourth Climate Assessment.

- **Temperature sensitivity.** Temperatures that relate to climate projection outputs are typically represented by a percentile of historical averages. For example, as represented by Cal-Adapt, the default definition of extreme heat is based on the 98th percentile of the historical average. The actual equivalent temperature then varies depending on geography: For example, the 98th percentile in Sacramento is 103.8°F, while the 98th percentile for Los Angeles is 95.2°F. Further, depending on the policy in question, that threshold may need to be refined. For example, depending on the temperature at which heat health events spike, this temperature threshold may be too high to ensure the safety and health of at-risk populations. As another example, the County may want to consider the temperature threshold at which infrastructure, like rail lines and asphalt, becomes unstable.

FOR THE BIG PICTURE

Recommendation: Fourth Climate Assessment Los Angeles Region

This report derives climate projections from a variety of sources and across a wide geography. By and large, it provides a view of the relative change in the intensity and frequency of extreme heat are also projected to increase over the LA region as compared with the rest of California, which includes Ventura County, LA County, and Orange County along with adjacent urbanized portions of San Bernardino and Riverside Counties. Key definitions and findings that can be used for bigger-picture planning purposes include:

- Across the region, average maximum temperatures are projected to increase around 4-5°F by the mid-century, and 5-8°F by the late-century.

- The hottest day of the year may be up to 10°F warmer for many locations across the LA region by the late-century under RCP8.5.

- The average hottest day of the year is expected to increase roughly 4-7°F under RCP4.5 and 7-10°F under RCP8.5 by the late 21st century

FOR COMMUNITY-BY-COMMUNITY SPECIFICITY AND PLANNING

Recommendation: Cal-Adapt

The Cal-Adapt tool can define and establish extreme heat and related projections on a community-by-community basis in LA County. Key functions and capabilities of this tool allow for:

- Analysis of varied geographic units including: 6x6km grid cell, Watershed (HUC10), Census Tracts with CalEnviroScreen 3.0 Data, and Incorporated and Census Designated Places (2015).
- Manual adjustment to the the sensitivity of temperature thresholds from the default of the 98th percentile (e.g., to 90°F) and number of days/nights of extreme heat
- Adjustment of timescale(s) and ranges of projections in the future
- Generation of specific outputs for communities for extreme heat days, heat events, and duration of heat waves

The following definitions and projections are derived direction from the Cal-Adapt tool, and are useful terms around which to organize planning regardless of scale or unit of comparison:

Extreme Heat Day: An extreme heat day or warm night is defined as a day in a year when the daily maximum/minimum temperature exceeds the 98th historical percentile of daily maximum/minimum temperatures based on observed historical data from 1961–1990 between April and October. Users have the option of setting a different value for threshold temperature or reset back to the 98th percentile value.

Heat Waves: Periods of sustained, extreme heat, although there is no universal definition of a heat wave. For purposes of this tool, a heat wave is defined as a period of 4 consecutive extreme heat days or warm nights when the daily maximum/minimum temperature is above the extreme heat threshold. Each 4 day/night period is counted, so that if extreme temperatures persist for 10 consecutive days/nights, it counts as 2 Heat Waves. Users have the option of choosing a different value for a number of consecutive days/nights. Users can also view the longest stretch of consecutive days when daily maximum temperatures are above extreme heat.

Example Community-Level Output

We used the tool to generate projections for Grid Cell (34.09375, -118.2187), which generally captures the neighborhoods of Elysian Valley, Northeast LA, and Highland Park. In this location, the 98th historical percentile is the equivalent of **98.6°F**.

Extreme heat days

Emissions Scenario	Observed Historical 1961-2005	Model Historical 1961-2005	Emissions Scenario 2070-2099
RCP 8.5	**4**	**3**	**31**
RCP 4.5	**4**	**3**	**16**

Heat Waves

Emissions Scenario	Observed Historical 1961-2005	Model Historical 1961-2005	Emissions Scenario 2070-2099
RCP 8.5	**0.2**	**0.2**	**3.9**
RCP 4.5	**0.2**	**0.2**	**1.4**

Maximun Duration

Emissions Scenario	Observed Historical 1961-2005	Model Historical 1961-2005	Emissions Scenario 2070-2099
RCP 8.5	**2.3**	**1.8**	**31**
RCP 4.5	**2.3**	**1.8**	**5.0**

CLIMATE-SMART CITIES

Owner

The Trust for Public Land

Scale

LA County

Purpose and use

Decision Support Tool for a "Climate-Smart" city, which uses existing national and local data to help prioritize where to invest in green infrastructure strategies, including where to:

- **Connect:** Trails and transit lines provide carbon-free transportation and link residents to popular destinations and each other.
- **Cool:** Shady green spaces reduce the urban "heat island" effect, protect people from heat waves, and reduce summer energy use.
- **Absorb:** Water-smart parks, playgrounds, and green alleys absorb rainfall, reduce flooding, and recharge drinking water supplies while saving energy for water management.
- **Protect:** Strategically placed shoreline parks and natural lands buffer cities from rising seas, coastal storms, and flooding.

This GIS-driven decision analysis tool has, so far, been developed for about 15 cities, including LA City and County.

Output

Decision map for prioritizing green infrastructure

Understanding exposure

One of the four "Climate-Smart" objectives is to use green infrastructure to reduce the urban heat island effect. The tool identifies urban heat island hotspots as "areas of the region with elevated land surface temperatures averaging at least 1.25 degrees above the mean daily temperature during July and August 2015." The model uses 2015 MODIS (Moderate Resolution Imaging Spectroradiometer) 1km Land Surface Temperature & Emissivity data to map urban heat island hotspots. The final "hotspot map" is a weighted overlay based on the daytime heat island hotspots (75 percent) and nighttime heat island hotspots (25 percent).

Understanding sensitivity

Climate-Smart Cities LA features a Social Vulnerability map prioritizing low-income areas in addition to four objectives listed above. The map is a weighted overlay based on the following criteria:

- People of color
- Low-income populations
- Less than high school education
- Linguistic isolation
- Population under 5
- Population over 64
- Unemployment
- Asthma
- Low birth weight

The same or similar selection of indicators is oftentimes used in heat vulnerability studies to create a heat sensitivity map, although Climate-Smart LA strategy does not specifically mention heat in the context of social vulnerability.

Key findings and applications to LA County

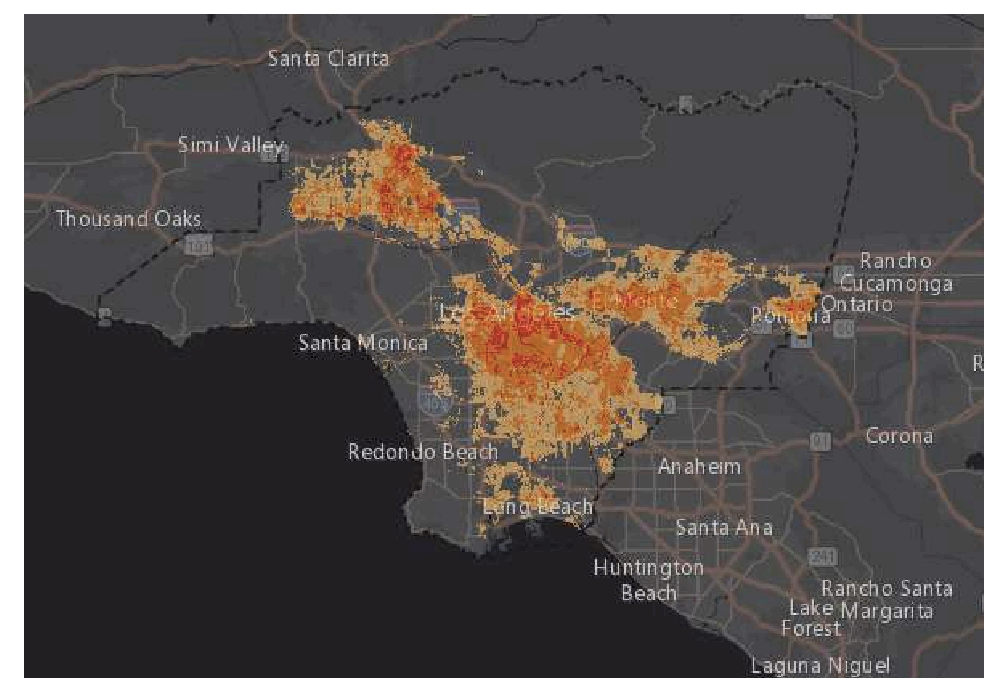
The Climate-Smart Cities planning strategies start with the question: which areas of LA County should we prioritize for **green infrastructure solutions?** The multi-step, data-driven approach also includes identifying areas vulnerable to heat (both in terms of exposure and in terms of sensitivity) since green infrastructure is considered as one of the possible solutions for urban heat island mitigation.

The final map, "putting it all together," overlays all factors including heat and social vulnerability, spanning the boundaries of the County.

Limitations

While Climate-Smart Cities considers a range of land uses in its decision tool in order to guide green infrastructure strategies, it does not look at other aspects of land use, such as housing development and areas of potential growth.

Also, the extent of the decision layers and of the final weighted overlay map do not correspond to the County's administrative boundaries, possibly omitting certain populated parts of the County.



CLIMATEN SMART CITIES LA WEIGHTED OVERLAY DECISION MAP

Using the Tool to Refine or Meet the Targets

Convert 10% of heat trapping surfaces to cool or green surfaces	Climate-Smart Los Angeles is intended to answer the question 'which areas of the county should we prioritize for green infrastructure solutions' and so it is conceptually an ideal spatial prioritization resource for meeting this target, if the county subscribes to the same four strategies: Connect, Cool, Absorb, Protect. Given that the outputs of this tool are cartographic, and the final weighted overlay map prioritizes certain areas of the city over the other for conversion into green surfaces, this tool could also be used to refine the target i.e. the area's most suitable for conversion could amount to more or less than 10 percent of the heat trapping surfaces in the County.
Reduce by 15% the number of heat stress emergency department visits per 100K residents	One of the goals of the Climate-Smart Los Angeles is to find areas where one project can provide multiple benefits to the community, prioritizing socially vulnerable neighborhoods for heat mitigation strategies.
Increase urban tree canopy cover by 10% of baseline (20% in 2016)	Climate-Smart Los Angeles focuses on increasing 'nature-based green infrastructure' solutions, which could inherently help meet this specific target. One of the Climate-Smart strategies, Cool, specifically highlights areas to convert to 'shady green spaces' but it doesn't offer more details. Similarly to the first target, this tool could be used to refine it: areas specifically designated for conversion to shady green spaces by Climate-Smart Cities could amount to either more or less than the 10 percent of the baseline.

ECOSTRESS AND RELATED SENSITIVITY STUDIES

Owner

NASA Jet Propulsion Lab / CalTech

Scale

30 meter resolution, global scale

Purpose and use

ECOSTRESS is a NASA JPL program in which a sensor is mounted onto the ISS to measure Land Surface Temperature (LST). Its primary mission is to monitor plant health (one of the core ECOSTRESS products is Evaporative Stress Index). However, surface temperature data are also useful in detecting other heat-related phenomena, such as heat waves, volcanoes and fires. Unlike previous LST products (MODIS, Landsat), ECOSTRESS data can be acquired at different times of the day which makes it particularly useful in detecting urban heat island effect.

Output

Satellite imagery

Understanding exposure

Generally, LST is considered the most fitting proxy for heat exposure and is included as an indicator in a host of heat vulnerability studies. ECOSTRESS acquires data at ~70m spatial resolution.

Understanding sensitivity

While ECOSTRESS is not an image of sensitivity, researchers at JPL, UCSB, and UCLA have however used ECOSTRESS (as a proxy of exposure) in combination with sensitivity indicators (elderly, population density, poverty, disabled, unemployment, building height, education, income, green vegetation fraction, distance to cooling centers) to explore vulnerability at the County level.

Key findings and applications to LA County

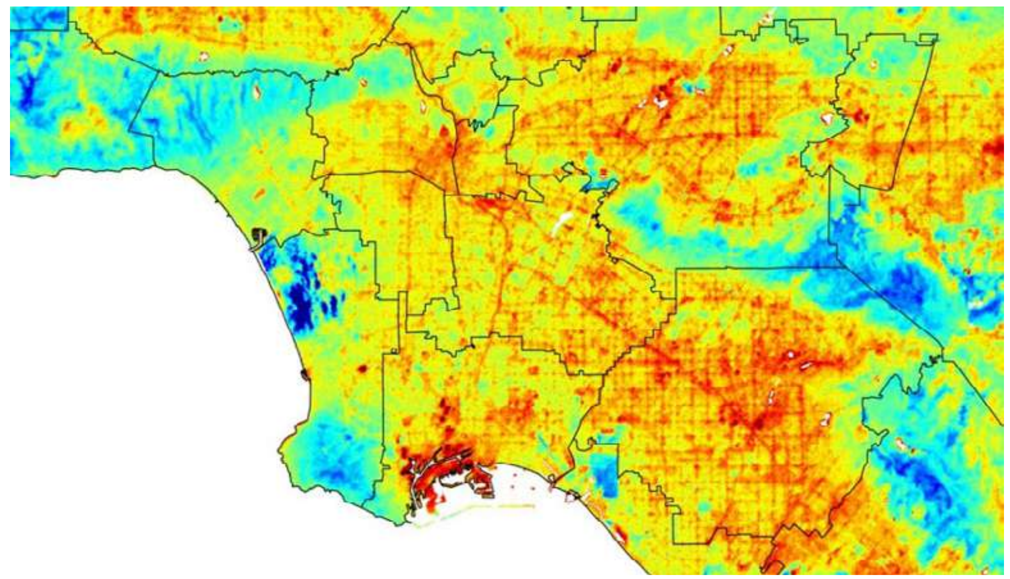
In September 2018 NASA JPL published "LA's Hot Spots" mapped by ECOSTRESS at different times of the day/night, between July 22nd and Aug 14th (first of its kind to be taken at different times of the day). The images show how and where different urban surfaces warm up and cool down throughout the day, and in particular how roof surfaces cool at a much faster rate than roads and other asphalt surfaces that have a higher heat capacity.

Findings from the JPL/UCSB/UCLA, indicate that East LA, South LA, Central LA, Southeast LA, and Pomona Valley are among the most at-risk across the County when ECOSTRESS was considered alongside sensitivity factors.

This tool could be used as an infrastructure vulnerability indicator by spatially overlaying Land Surface Temperature data from ECOSTRESS with existing infrastructure (e.g., highways, bus stations, roads) and housing typology features in the County and then selecting those in the hottest regions.

Limitations

ECOSTRESS imagery is a product that could be used in a heat vulnerability study as an exposure indicator, but in itself does not constitute a heat vulnerability study because it does not consider any factors of sensitivity.



ECOSTRESS CAPTURED SURFACE TEMPERATURE VARIATIONS IN LOS ANGELES IN THE EARLY MORNING HOURS OF JULY 22.
CREDIT: NASA/JPL-CALTECH

Using the Tool to Refine or Meet the Targets

Convert 10% of heat trapping surfaces to cool or green surfaces	ECOSTRESS can accurately measure land surface temperature and thus identify the hottest heat trapping surfaces for conversion. It could be used as a spatial prioritization tool to refine and meet the target (Climate-Smart LA uses another, lower accuracy and lower resolution land surface temperature data for prioritizing hottest areas in the County).
Reduce by 15% the number of heat stress emergency department visits per 100K residents	By identifying hottest areas of the city, this tool can enable the County to allocate resources where they're most needed and in doing so reduce the number of heat stress emergency department visits. Alone, this is not a tool correlating heat stress and health risk, but it could be used combined with other variables, such as distance to cooling centers, as is identified in the JPL, UCLA, and UCSB study.
Increase urban tree canopy cover by 10% of baseline (20% in 2016)	ECOSTRESS can be used in selecting areas in need of additional tree canopy but also in indicating existing urban tree canopy health (one of the ECOSTRESS products is an evaporative stress Index, a leading drought indicator).

FOURTH CLIMATE ASSESSMENT, STATE OF CALIFORNIA AND LOS ANGELES REGION

Owner

State of California

Scale

State, LA Region

Purpose and use

California's Climate Change Assessments contribute to the scientific foundation for understanding climate-related vulnerability at the local scale and informing resilience actions, while also directly informing State policies, plans, programs, and guidance, to promote effective and integrated action to safeguard California from climate change. California's Fourth Climate Change Assessment (Fourth Assessment) advances actionable science that serves the growing needs of state and local-level decision-makers from a variety of sectors.

The Fourth Assessment produced a regional report for the Los Angeles region, which outlines the specific risks and vulnerabilities of the region as well as recommendations for policy and design. The Los Angeles region topography and boundary encompasses Los Angeles, Ventura, and Orange Counties, and adjacent urbanized portions of San Bernardino and Riverside Counties.

Output

Platform of data and tools
Regional reports

Understanding exposure

At the State level, the Fourth Assessment considers a broad range of hazards and exposure indicators to climate in terms of temperature, extreme heat events, sea level, snowpack, heavy precipitation, drought, and wildfire.

At the regional scale, the Fourth Assessment Los Angeles Region Report considers the same exposures. The report shows spatial patterns of a number of key factors related to heat exposure:

- Mean maximum air temperature changes assuming RCP 4.5 and RCP 8.5 scenarios in three time periods : 2006-2039, 2040-2069, 2070-1200
- Average hottest day of the year in historical 1976-2005 and assuming RCP 4.5 and RCP 8.5 in 2070-2100 time periods
- Average wettest day of the year in historical 1976-2005 and in the 2070-2100 under RCP 4.5 and RCP 8.5 scenarios

Understanding sensitivity

At the regional level, the Fourth Assessment considers the impacts of climate change across social and physical dimensions. It considers impacts across the following indicators and provides thorough narrative context around each:

- Public Health
    - Extreme heat
    - Air quality
    - Wildfires
    - Infectious disease and valley fever
    - Floods/mudslides
    - Mental health
    - Emergency management

- Economic systems
    - Energy
    - Generation
    - Transmission and distribution
    - Consumer demand
    - Transportation
    - Vehicles
    - Operations of pedestrians and air craft

- Land use and community development
    - Urban tree canopy
    - Public transit during extreme heat
    - Land use in wildfire corridors
    - Coastal land use
    - Vegetation and flora
    - Agriculture
    - Water

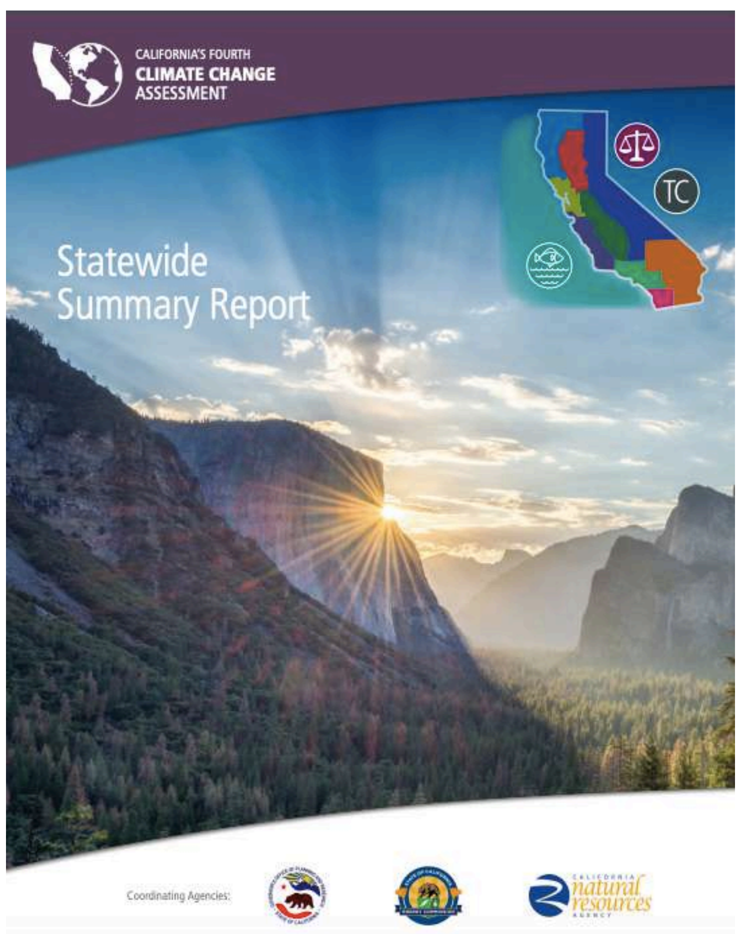
Key findings and applications to LA County

The report is effective in terms of global climate trends, and can be used for understanding broad spatial patterns of global climate projections. It also demonstrates the broad interactions of precipitation, drought, cloud cover, air quality, and humidity as related climate impacts. With respect to sensitivity, it provides a robust and useful narrative that frames climate impacts across sensitive groups and infrastructure. This study takes a comprehensive look at infrastructure and climate impacts, however they are not spatially represented.

Limitations

The report, while a thorough narrative that could be useful in raising awareness about heat impacts and in identifying vulnerable populations more broadly, is not particularly useful in exploring compounding impacts or spatial characteristics of risk. For example, while the report considers accessibility to air conditioning in the LA-Long Beach area as a critical indicator of heat vulnerability, it does not explore the spatial characteristics of these aspects. Similarly, while it broadly offers energy impacts (increases in demand), it does not explore the spatial relationship between buildings or their ages and efficiency. In another example, spatial characteristics are presented from the LA County Climate Change vulnerability by Census Tract, using vulnerability screening scores of the Environmental Justice Screening Method. However, this is not in any way layered with the other compounding impacts or conditions that might guide land use decisions.

Another limitation is that the study does not allow for any level of specificity *within* the County.



CALIFORNIA'S FOURTH CLIMATE ASSESSMENT STATEWIDE SUMMARY REPORT

Using the Tool to Refine or Meet the Targets

Convert 10% of heat trapping surfaces to cool or green surfaces	Confirms that low income communities and communities of color are disproportionately impacted due to lack of trees and higher instances of impervious surfaces, which are four spatial characteristics to help prioritize. These are all represented in other tools, except for communities of color. Offers that street-level vegetation reduces temperatures by an average of 0.15°C and direct shade reduces temperature by 7°C, and that cool pavement infrastructure increased radiant temperature and thermal discomfort in unshaded areas, but increased comfort in shaded areas. This suggests that the combination of both vegetation and cool pavement is most impactful: look for opportunities where the two can be combined.
Reduce by 15 % the number of heat stress emergency department visits per 100K residents	Confirms that reduced access to air conditioning and disparity in heat-related mortality between blacks and whites may be explained by the prevalence of central AC in homes, and that sensitive populations like the very young, elderly, and poor are more vulnerable. Further, that low income households may be less likely to have air conditioners and less willing to use it to save electricity. Confirmed that low-income populations are already more likely to suffer from respiratory illnesses that increase vulnerability to poor air quality. During the 2006 heat wave, there were increases in hospital visits for kidney-related diseases, diabetes, and cardiovascular diseases and mortality increased by 9 percent for every 10°F in LA County. This suggests that you might focus on these populations first in interventions (e.g., install cool roofs and tree canopy at these homes first, offer cooled transit vehicles where there are dense populations of these groups).
Increase urban tree canopy cover by 10% of baseline (20% in 2016)	Suggests that low-income communities and communities of color often experience a great heat island effect due to lack of trees and vegetation, which suggests where you might prioritize planting first. Suggests that while trees reflect cultural desires, in a region that was not originally forested, maintenance and cover would have to improve dramatically to have an impact on the region. In order to achieve the target, the report suggests that resources for watering, labor, and maintenance assistance is needed and that tree planting efforts are only as successful as the cultivation and maintenance efforts.

CAL-ADAPT

Owner	UC Berkeley's Geospatial Innovation Facility (GIF)
Scale	6km resolution, Statewide
Purpose and use	Cal-Adapt is the State's portal for the climate projections produced for the Fourth Assessment, enabling data downloading and visualizations of climate scenarios at the local level and wildfire projections for the entire state. The data used within the Cal-Adapt visualization tools have been gathered from California's scientific community, and represent peer-reviewed, high quality science. The Cal-Adapt tools show projections for two possible climate futures, one in which emissions peak around 2040 and then decline (RCP 4.5) and another in which emissions continue to rise throughout the 21st century (RCP 8.5).
Output	Data platform and visualization tool
Understanding exposure	Frequency and duration of Extreme Heat events is among the observed and projected climate variables for California. The data, derived from 32 coarse-resolution (~100 km) global climate models from the CMIP5 archive, were bias corrected and downscaled using the Localized Constructed Analogues (LOCA) statistical method and are available at a resolution of 1/16° (about 6 km, or 3.7 miles) for the whole state.
Understanding sensitivity	N/A
Key findings and applications to LA County	Most climate models project a significant rise in the number of days exceeding what is now considered extremely hot for LA County. This can be helpful in framing the design criteria for future land uses, materials, green infrastructure, and emergency services.
Limitations	General guidance and limitations in using climate projections are well documented: https://cal-adapt.org/resources/using-climate-projections/. While this provides a robust set of projections, they are in and of themselves not a vulnerability analysis.

Using the Tool to Refine or Meet the Targets

As the datasets in Cal Adapt's collections relay global climate projections, the tool is not applicable to the direct refinement or achievement of the targets for tree canopy coverage, previous pavements, or health events. These projections, while critical for planning purposes that define the future of extreme heat in California for long-term and community-based planning, will in and of themselves not establish a baseline against which to measure the success of interventions that address canopy, pavements, or health interventions.

CALIFORNIA HEAT ASSESSMENT TOOL (CHAT)

Owner	2018 California Energy Commission, State of California
Scale	Census tracts, statewide
Purpose and use	The Fourth Assessment supported the development and expansion of new and existing resources to directly support climate action, including California Heat Assessment Tool (CHAT). Cal-Heat is a new tool funded to inform local public health officials' initiatives to protect the public during climate-exacerbated extreme heat events. Four Twenty Seven, in partnership with Argos Analytics, Habitat Seven, and the Public Health Institute (PHI) developed this tool for local and state health practitioners to better understand dimensions of heat vulnerability driven by climate changes and where action can be taken to mitigate the public health impacts of extreme heat in the future. The tool specifically looks at variables related to Heat Health Events (HHE), any event that results in negative public health impacts, regardless of the absolute temperature.
Output	Interactive map
Understanding exposure	Exposure is defined as Heat Health Events (HHEs) and is characterized and spatialized according to projected changes in HHEs, for 8 time periods between 2011 and 2099, including: • Annual number of health events • Average event duration • Average maximum temperature • Average minimum temperature • Average maximum relative humidity • Average minimum relative humidity
Understanding sensitivity	The tool considers a range of "vulnerability indicators" that show the conditions that exacerbate heat impacts. Vulnerability is defined as a function of HHE's and vulnerability. Each indicator can be turned on and off one at a time, and include: • Percent no high school diploma • Percent outdoor workers • Percent poverty • Percent no vehicle access • Percent linguistic isolation • Rate of asthma • Percent low birth weight • Rate of cardiovascular disease • PM 2.5 Concentration • Ozone exceedance • Percent impervious surfaces • Change in development (2050) • Percent no tree canopy • Urban Heat Island (Delta)

Key findings and applications to LA County

The tool ranks counties in order of priority for the County for specific indicators, which can be a helpful prioritization resource. The tool also prepares a heat health action index that is a statistically weighted result of the vulnerability indicators as well as prepares and prioritizes "Urban Heat Island Delta." The tool provides projections for annual numbers of "high heat events" as well as average event duration, both critical inputs in determining the resources needed to serve at-risk populations with healthcare.

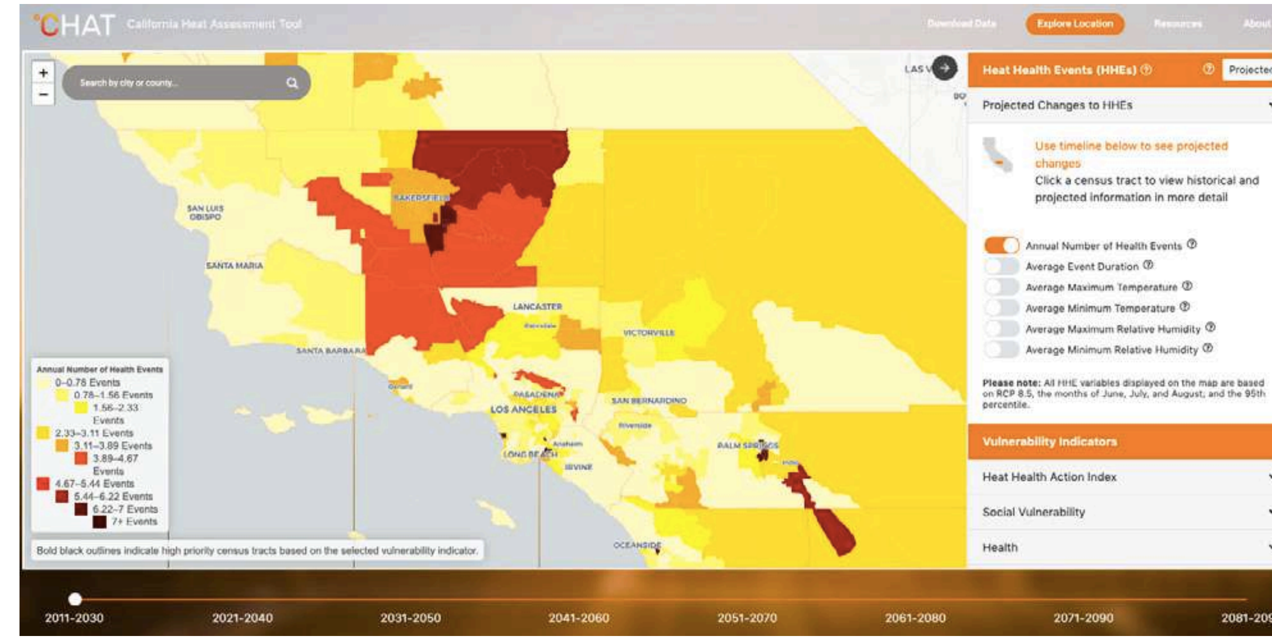
Limitations

The tool does not show the interactions of exposure factors, such as humidity and heat. Further, the tool does not allow for an overlay of different factors in the tool to see where certain combinations of vulnerability indicators overlap or compound – a user can only see one vulnerability indicator at a time which limits its capacity as a decision-making tool.

While the tool presents a number of indicators that could guide land use decision making (e.g, changes in development, impervious surfaces) they cannot be overlaid with multiple risks or multiple social characteristics or weighted. The tool also does not map land uses, such as existing housing or infrastructure.

Using the Tool to Refine or Meet the Targets

Convert 10% of heat trapping surfaces to cool or green surfaces	Displays data related to "percent impervious surfaces" as well as other environmental conditions, including PM2.5 concentration, ozone, change in development, and percent no tree canopy. Combined health and social vulnerability indicators, the spatial "Heat Health Action Index" shows areas of highest priority for the County when all factors combine. The County might specifically look to prioritize the areas with high rate of change in development to achieve a forward looking mitigation strategy for surfaces and material regulations.
Reduce by 15% the number of heat stress emergency department visits per 100K residents	The tool provides a spatial and quantitative projection of health events which can be used to prioritize areas where outreach and education of the community are needed first. It may also be an input into coordination with local health care providers so that they might better prepare for beds and equipment needed in anticipation of more frequent and longer HHEs. To refine this target, the County might want to analyze emergency room and local care provider capacities to assess the overage or stresses on the healthcare system. Then, use the assumptions in this tool around the number of health events and event duration to determine the target so that healthcare provision and outreach is matched to the anticipated need.
Increase urban tree canopy cover by 10% of baseline (20% in 2016)	Assuming the recommendation made by the Fourth Assessment, cooling surfaces work best when combined with vegetation and shading and also notes that tree canopy might exacerbate particulate exposure; one might use this tool to layer PM2.5, ozone, impervious surfaces, and no tree canopy. Areas where there is low PM2.5 and low ozone, but high impervious surfaces and no tree canopy may be suggested as areas to prioritize. Further, combining with the heat health index areas, gives a spatial view of where trees might be most impactful and not exacerbating existing air quality exposures.



CHAT INTERACTIVE MAP INTERFACE

READY FOR TOMORROW

Owner	Climate Resolve
Scale	Region
Purpose and use	The research presented in this report gives a snapshot of the current status of municipal-level climate preparedness planning within and near Southern California Edison's (SCE's) service territory. This report frames and defines several types of local climate preparedness plans and gives examples of best practices. The report is complemented by a searchable Matrix on Climate Resolve's website that details the status of climate preparedness planning by more than 200 municipalities. This research also identifies third-party funding sources to support municipal climate planning.
Output	Policy summary report and recommendations
Understanding exposure	N/A
Understanding sensitivity	N/A
Key findings and applications to LA County	All of the policy recommendations made in this report are applicable to the County and should be aptly considered and applied to all of the County's climate-related planning and coordination with the State and municipalities. The recommendations, while not specific measurable inputs needed to refine or meet the targets explored in this assessment, are necessary overarching actions over the climate strategies identified in the OurCounty Plan.

Limitations Does not provide a “vulnerability assessment” related to heat specifically. It is a set of policy recommendations for climate adaptation planning more broadly.

READY FOR TOMORROW
POLICY SUMMARY REPORT

CALBRACE

Owner Climate Change and Health Equity Program–CalBRACE Project, part of the California Department of Public Health.

Scale LA County

Purpose and use The CalBRACE Project developed climate change and health indicators, narratives, and data to provide local health departments and partners tools to better understand the people and places in their jurisdictions that are more susceptible to adverse health impacts associated with climate change, specifically extreme heat, wildfires, sea level rise, drought, and poor air quality. The assessment data can be used to screen and prioritize where to focus deeper analysis and plan for public health actions to increase resilience.

Output Interactive data visualization platform

Understanding Vulnerability Vulnerability assessments are a key tool to begin to prepare and plan for resilience to climate change and health impacts. A climate change and health vulnerability assessment helps to identify where a person’s or neighborhood’s susceptibilities to injury or disease exist due to their distance and sensitivity to climate-related environmental exposures or hazards. Adaptive capacity can offset the potential for injury and disease from exposure and sensitivity to hazards associated with climate change. Understanding more about neighborhoods and populations with multiple or complex social vulnerabilities can improve prioritization of efforts, inclusive planning, communication, and evaluation of adaptation and interventions developed to protect communities from the effects of climate change. The suite of domains and indicators developed by the CalBRACE Project is focused on assessing current and future climate change exposures (such as wildfires, extreme heat, air pollution, sea level rise, and drought), the people and places most susceptible to health risks from climate exposures, and the capacity to adapt to a changing climate.

Understanding exposure Environmental exposure refers to the magnitude, frequency, and duration of an environmental exposure or disease risk. The platform considers the following:

- Extreme heat days
- Air quality (PM2.5)
- Air quality (Ozone)
- Drought
- Wildfires
- Sea level rise

Understanding sensitivity Sensitivity refers to the physiological and socio-economic factors which directly or indirectly affect the degree to which a population is impacted by climate-related changes. The platform considers the following:

- Children less than 5 years
- Elderly older than 65 years
- Poverty
- Education
- Race and ethnicity
- Outdoor workers
- Vehicle ownership
- Linguistic isolation
- Physical and mental disability
- Health insurance
- Violent crime rate

CALBrace also considers Adaptive Capacity defined as the broad range of responses and adjustments to the impacts of climate change, including the capacity to moderate potential damages, take advantage of opportunities, and cope with the consequences.

- Households with air conditions
- Tree canopy coverage
- Impervious surfaces
- Public transit access

Key findings and applications to LA County

The plot and visualizations illustrate the intersection of hazard (from the aspect of climate change) and sensitivity (from circumstances of the population or place that tend to increase susceptibility to the hazards of climate change). Counties are assigned to the bottom (least), middle, or top (most) third for both exposure and sensitivity. The most vulnerable counties appear in the top and right-most portions of the figure. Points are sized according to the population living in that county. Hover-over-points show county name, population, and indicator values.

Some examples of important combinations to consider are:

- Heat + elderly / outdoor workers / health insurance / air conditioning / tree canopy / impervious surfaces
- Ozone + children
- PM2.5 + children
- Wildfire + elderly / disability

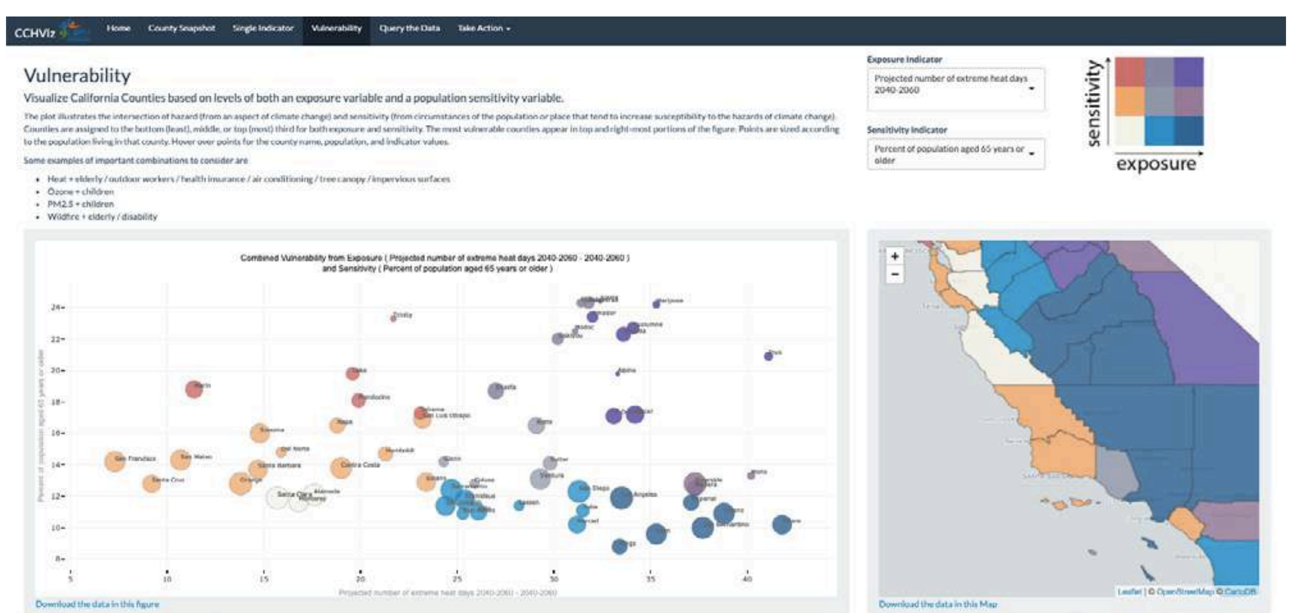
Limitations

Spatial data only exists as an aggregate for the County, so on it's own, the tool wouldn't help illustrate spatial characteristics of vulnerability within the County. This would be an ideal tool for State- level policy decisions.

The tool allows for comparison of a single exposure indicator against a single sensitivity indicator, and cannot see the interactions of multiple hazards with multiple sensitivity indicators to see the spatial characteristics combine. For example:

LA County's vulnerability is defined by High Exposure, Low Sensitivity
Exposure: 33.5 Projected number of extreme heat days 2040-2060 - 2040-2060
Sensitivity: 11.9 Percent of population aged 65 years or older

The overlay of all sensitivity and exposure indicators be helpful in terms of decision making for land use.



CALBRACE CLIMATE CHANGE & HEALTH VULNERABILITY INDICATORS FOR CALIFORNIA INTERACTIVE DATA PLATFORM INTERFACE

Using the Tool to Refine or Meet the Targets

Convert 10% of heat trapping surfaces to cool or green surfaces	Confirms impervious surface cover is 58 percent county-wide, which could be a proxy baseline for meeting the surface retrofit target.
Reduce by 15% the number of heat stress emergency department visits per 100K residents	The tool provides race- and population weighted data for access to health insurance, which can be downloaded or reviewed with a bivariate indicator, but is otherwise redundant and less spatially specific than the California Healthy Places Index.
Increase urban tree canopy cover by 10% of baseline (20% in 2016)	The tool states that the percent ground cover without tree canopy coverage is 94.49 percent, a significant discrepancy with the baseline coverage of 20 percent that is established in the OurCounty Plan. The source of data in CalBrace is the Multi-Resolution Land Characteristics Consortium, National Land Cover Database (NLCD) 2011 , while the estimate that sourced in the OurCounty plan is Los Angeles Regional Imagery Acquisition Consortium. The County might consider investigating this discrepancy as a step in defining tree canopy and refining the target.

THE CALIFORNIA HEALTHY PLACES INDEX

Owner

Public Health Alliance of Southern California (with Virginia Commonwealth University's Center on Society and Health)

Scale

State

Purpose and use

The health of Californians is shaped dramatically by "non-health" policies and community characteristics, such as housing, education, economic, and social factors. The purpose of the HPI is to prioritize public and private investments, resources and programs.

The HPI combines 25 community characteristics into a single indexed HPI score. HPI scores for each census tract can be compared across the state to paint an overall picture of health and well-being in each neighborhood in California, with light and dark green areas indicating places with healthier community conditions compared to places symbolized in light and dark blue. The tool also allows multiple census tracts to be pooled together into a single score, allowing the comparison of zip codes, project areas, and other geographies.

In addition to the overall score, the index also contains eight sub-scores for each of the Policy Action Areas (Economic; Education; Housing; Health Care Access; Neighborhood; Clean Environment; Transportation; and Social factors). The index was created using statistical modeling techniques that evaluated the relationship between these Policy Action Areas and life expectancy at birth. The statistics were designed to maximize the ability of the Healthy Places Index to identify healthy communities and quantify the factors that shape health.

The tool includes detailed policy guides to support specific policy interventions that improve community conditions and health.

Output

Interactive map and data platform at the census tract level across California

Understanding exposure

While HPI does not include Land Surface Temperature (the most common proxy for heat exposure), it includes Extreme Heat Days and Impervious Surfaces as additional layers for mapping.

Understanding sensitivity

Common heat vulnerability indicators--Employed, Above Poverty, Bachelor's Ed or Higher, Automobile Access, Tree Canopy, Ozone, PM 2.5 and Insured--are all built into the HPI score.

The platform allows users to see how existing conditions for health intersect with areas of climate risk (such as wildfire risk) and strategies for resilience (tree canopy).

Additionally, the HPI Policy Guide includes strategies specifically designed to improve health while also building climate resilience. Climate challenges addressed specifically by the Policy Guide are: Extreme Heat Days, Impervious Surfaces, Outdoor Workers, Public Transit Access and Sea Level Rise.

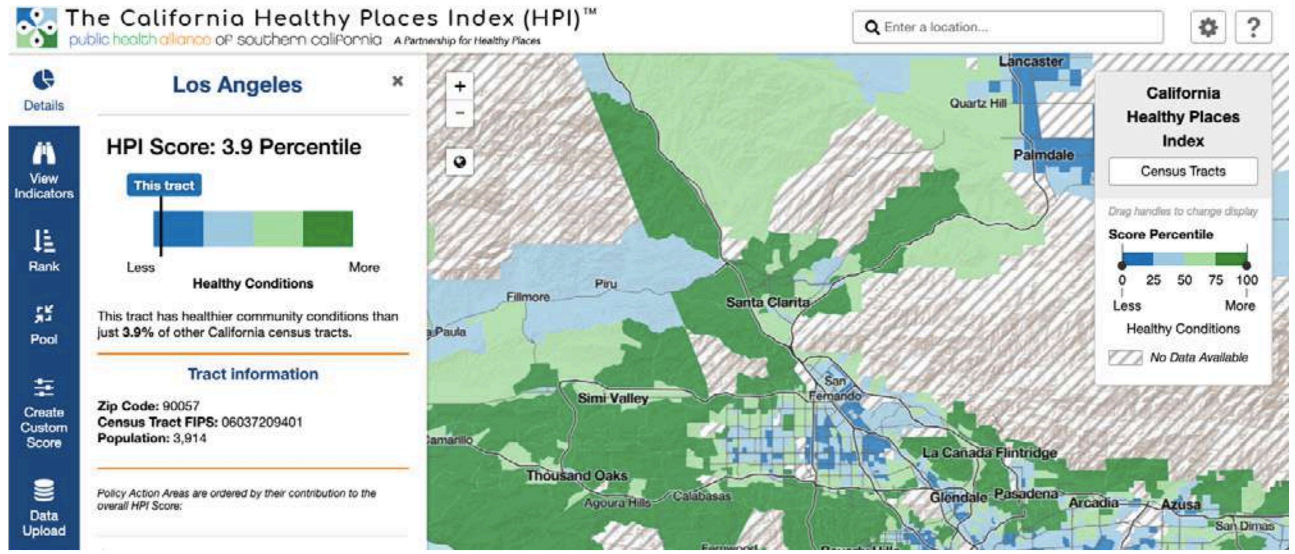
Key findings and applications to LA County

The policy guides offer a menu of practical solutions and concrete actions the County can use to improve community conditions and health.

Limitations

There are many neighborhood characteristics that are critical to health that were not included in HPI because, according to the Alliance, they did not meet the criteria for inclusion. As an example, we know social cohesion, community power, inclusion/exclusion are fundamental to good health, but at this time there are not adequate data to measure these characteristics at the neighborhood level.

The tool also does not specifically include mapping of future timescales of climate projections.



THE CALIFORNIA HEALTHY PLACES INDEX INTERACTIVE MAP PLATFORM

Using the Tool to Refine or Meet the Targets

Convert 10% of heat trapping surfaces to cool or green surfaces	The tool offers percent impervious surface coverage as a decision-support layer by census tract, and can therefore be used to map the total area of impervious surfaces.
Reduce by 15% the number of heat stress emergency department visits per 100K residents	The health vulnerabilities identified in this tool are an adequate, if not robust, view of the sensitivities facing at-risk groups to heat. It also includes policy guidelines for addressing health impacts.
Increase urban tree canopy cover by 10% of baseline (20% in 2016)	Provides population-weighted percentiles coverage of urban tree canopy per census block. This is a proxy by which the County can establish where investment in urban canopy might be prioritized in combination with other sensitivity factors identified and mapped in HPI and Climate Smart Cities. The tool lists multiple policy opportunities to address the health Impacts of urban tree canopy: • Assess current tree canopy conditions and create a vision for the future, while proactively addressing inequities by neighborhood. • Develop tools and programs to plant trees and other vegetation. • Create tools and set standards to preserve and maintain existing trees and forests.

II. GLOBAL PRACTICES IN DEFINING AND STUDYING HEAT VULNERABILITY

In order to guide the County in decision-making and framing of a future heat vulnerability study, we looked at how other public agencies are applying holistic risk assessment methodologies and tools to consider planning, design, and service delivery decisions. We filtered cities based on methodologies that represent composite views of hazard exposure and sensitivity, provide a geographic range in scale (e.g., City and State level), and clear set of decisions that the public agency intends to make using the vulnerability assessment given their authority. It should be noted that there is an extensive body of academic research related to heat vulnerability, leveraging a range of methodologies, for dozens of cities and regions worldwide. For the purposes of this assessment, we kept our review limited to governmental resources, most of which have been developed in partnership with academic institutions.

DECISION POINT OR QUESTIONS	STUDY / TOOL

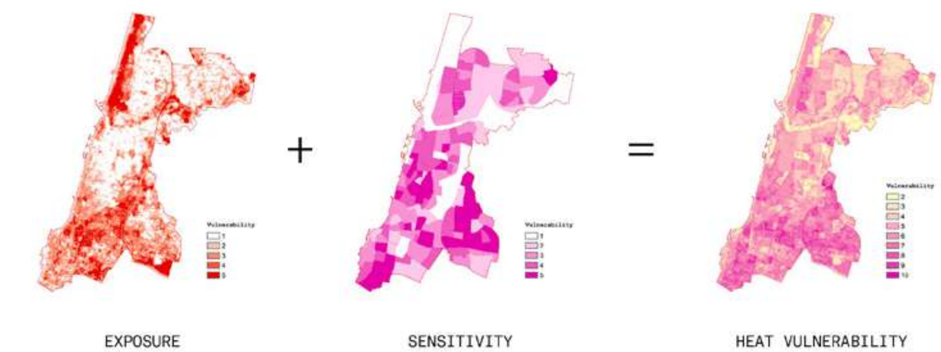
Tel Aviv-Yafo

Where to address heat in the public realm

Tel Aviv-Yafo Resilience Accelerator Urban Heat Vulnerability Study (CRCL, 2019)
In 2019, the City of Tel-Aviv Yafo (TLV-Y) conducted a heat vulnerability analysis that looked across similar indices developed for other cities, and synthesized some of the key factors associated with heat vulnerability in Tel Aviv. By using remotely sensed data from the thermal sensor of the Landsat 8 satellite and Tel Aviv-Yafo census data, we and TLV-Y identified the neighborhoods most at risk. This process, a "multi-criteria decision analysis," is intended to help prioritize where a number of factors combine and where, geographically speaking, planning efforts might be directed.

Landsat data is represented in 30x30 meter grid cells (or pixels), while census data is aggregated in statistical areas of various sizes and shapes. To overcome this difference, we re-sampled the entire area of the city and census data into this grid. This allowed us to layer multiple variables of different sizes into the same grid units. For each data set, we classified median composite values of these grids on a scale of 1–5 (e.g, the top 20th percentile is assigned a score of 5), showing relative conditions across the city. Landsat 8 scans the same location on Earth every 16 days, generating a total of 47 usable scans that include the city; imagery is utilized throughout the months of June, July, and August between 2014 and 2018. In this composite map of land surface temperature (LST), the deeper the red, the hotter the surface relative to the rest of the city. Next we investigated the areas of the city that are most "built up" using the Normalized Difference Built- Up Index (or NDBI), also derived from Landsat. This index allows for the detection of built-up surfaces as well as conditions such as bare soil and dry grasses. These areas of the city can exacerbate heat exposure.

With a goal of prioritizing vulnerable neighborhoods, we studied demographic indicators that suggest sensitivity to heat. These factors indicate who may be less able to adapt or more vulnerable to the acute impacts of any type of stress or hazard. While there are many factors that contribute to sensitivity, this composite map shows where the elderly living alone, very young, low income, single-parent households, unemployed, large households of seven or more, and low education overlap. The deeper the pink, the greater the assumed sensitivity. As a last step, we compiled all of the exposure and sensitivity maps. By stacking them we can begin to prioritize areas of the City facing the most acute impacts from heat stress. Together, these maps suggest that areas in the south of Tel Aviv-Yafo are where exposure to heat may be disproportionately impacting certain communities.



HEAT VULNERABILITY IS A FUNCTION OF EXPOSURE AND SENSITIVITY

How to expand tree canopy cover and shade

Shade Maps for Climatically-Aware Urban Design in Tel Aviv-Yafo (Aleksandrowicz, O., et al. 2018)

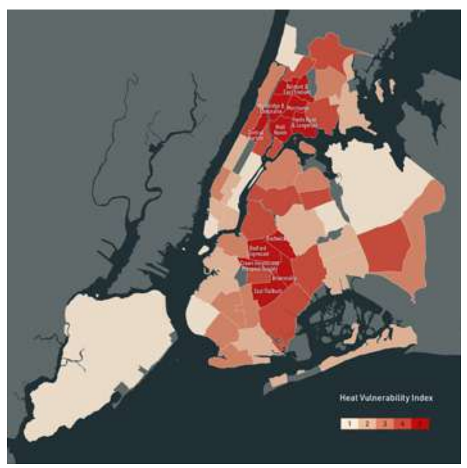
In 2018, the Tel Aviv-Yafo municipality commissioned a study to develop a new methodology for evaluation of microclimate conditions, focused on the provision of outdoor shade as a central component of urban design. Based on urban scale 2.5F GIS mapping of buildings, ground surfaces, and tree canopies researchers at the Technion - Israel Institute of Technology and PLANET employed high resolution calculation of solar exposure of streets and open spaces (public and private) covering the entire city. "The calculation produced a comprehensive 'shade map' for Tel Aviv-Yafo, showing the cumulative daily exposure to solar radiation at ground level during summer. Analysis of the shade maps enabled to relate building and tree morphologies to outdoor shading on both district and street levels, unfolding a "hierarchy of shade" across the city. For prioritizing the intervention of local planning authorities in improving poor shade conditions or conserving effectively-shaded locations, we then employed space syntax analysis techniques. The spatial analysis produced a classification of streets and urban hot spots according to their potential pedestrian attraction. By juxtaposing the climatic and spatial analyses, we were able to provide the Municipality with recommendations for targeted intensification of shade in locations where the discrepancy between pedestrian movement and lack of shade was the most pronounced. At the same time, we were also able to identify exemplary, well-shaded central streets and open spaces, thus enabling the municipality planners to initiate a "shade conservation" program for the entire city."

New York City

Where to deliver community programming and physical adaptation first

Heat Vulnerability Index (NYC DOHMH, Col umbia University)
The HVI is adapted from a study by researchers at the NYC Department of Health and Mental Hygiene and Columbia University who analyzed mortality data from 2000 to 2011. The analysis identified factors that were associated with an increased risk of deaths during a heat wave. The map shows NYC Community Districts ranked from least to most vulnerable. Each Community District HVI is the average of all census tracts in the Community District.

Using the City's Heat Vulnerability Index (HVI), the study determined geographic areas of focus, assessed the potential to cluster the implementation of roofs, identified and prioritized potential program participants, developed outreach and communication strategies to secure the participation of target building owners, and developed tools to assist owners in understanding the benefits of the program for their own buildings. As a result, the study identified a priority list of 2.7 million square feet of potential private and public buildings to conduct strategic outreach to owners in the heat-vulnerable areas of the Bronx, Central Brooklyn, and Northern Manhattan.



LEFT: HEAT VULNERABILITY INDEX (HVI) FOR NEW YORK CITY COMMUNITY DISTRICTS

RIGHT: COOL NEIGHBORHOODS NYC REPORT

NYC Cool Neighborhoods Plan (NYC MORR)
The development of the HVI informed the mayoral charge in the City's OneNYC plan to mitigate heat citywide, with a targeted response for the most at risk neighborhoods. As a result, the NYC Mayor's Office of Recovery and Resiliency (ORR) developed Cool Neighborhoods NYC: a $106 million program designed to help keep New Yorkers safe during hot weather, mitigate UHI effect drivers and protect against the worst impacts of rising temperatures from climate change.

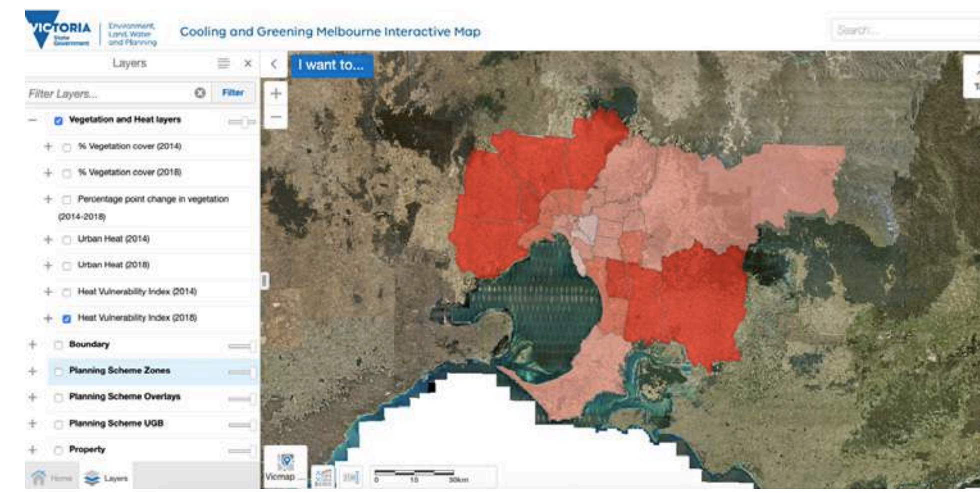
The first set of strategies outlined in this report highlights the role that the physical environment plays in driving local temperatures and describes the City's investments to increase shade, greenery, and canopy cover and increase high albedo surfaces in public and private sites to help lower surface and indoor temperatures in NYC neighborhoods with high vulnerability to heat-related illnesses and mortality. The second set of strategies outlined in this report underscores the critical role that our most trusted messengers can play in helping us adapt to climate change. The final strategy outlined in this report describes key efforts to better understand the scope of the challenge via data collection and monitoring.

Victoria, Australia

Where to prioritize greening based on heat vulnerability index

The Cooling and Greening Melbourne Interactive Map
This tool covers the city's metropolitan areas and brings together three main datasets: vegetation cover, urban heat, and the heat vulnerability index. Data was captured in 2014 and 2018. The interactive map offers a visual capture of data at local government, suburb, Australian Bureau of Statistics (ABS) Statistical Area Level 1 (SA1), and Mesh Block levels. You can access the map at
http://mapshare.maps.vic.gov.au/coolinggreening/.

The HVI rating is determined by three components: heat exposure, sensitivity to heat (due to land cover, population density, and age), and adaptive capacity (e.g. socioeconomic advantage or disadvantage). This data was integrated by summing the scores from the three vulnerability components, dividing the statistical areas into quintiles, and attributing the statistical areas with a Heat Vulnerability Rating scaled from 1 to 5 (1 = low vulnerability, 5 = high vulnerability). Equal weighting (one third each) is given to heat exposure, sensitivity to heat, and adaptive capability.



COOLING AND GREENING MELBOURNE INTERACTIVE MAP

III. RECOMMENDATIONS FOR LA COUNTY METHODOLOGY

The review of literature shows that there is extensive existing analysis at both City, County and State scales. However, the review of resources suggest that there is a gap in understanding how multiple factors of exposure and sensitivity combine to create the greatest areas of vulnerabilities with the exception of Climate Smart Cities and the CHAT tool. Given the specific targets identified in the OurCounty Sustainability Plan, these tools can be used as inputs into vulnerability studies that will help refine and meet these targets. Focusing on the 2025 targets first, we expect that future targets would be refined based on these suggested methodologies. Framed as step by step scenarios, these methodologies are based in large part on the tools shared by the County.

Target: Convert 10% of heat-trapping surfaces to cool or green surfaces

Spatial Prioritization and Target Refinement

1. First, confirm baseline percentage coverage of impervious surfaces and map the baseline coverage of impervious surfaces in the County using one of the following methods and/or sources:
    - Absolute coverage of impervious surfaces using LA County Public Works HRU Impervious Area Shapefile;
    - Using impervious surface coverage by census tract in California HPI;
    - Calculation of Normalized Difference Built-Up Index derived from LANDSAT-8 Data;
    - Downloaded from California CHAT tool (NB: This percent coverage, not absolute).
2. Use Climate Smart Cities tool, specifically the final "Weighted Overlay Map," to guide spatial prioritization of areas for conversion to green surfaces. The areas already compiled in the tool show where social, environmental, and infrastructural vulnerabilities combine and therefore illustrate opportune places for multiple benefits might be.
3. Overlay Climate-Smart Cities "Weighted Overlay Map" with impervious surface map and extract areas where the two overlap.
4. Calculate surface area of the extracted impervious surfaces. This area divided by the baseline of total impervious surfaces will offer a refined the target where it is needed most (this could amount to more or less than 10 percent of the existing heat-trapping surfaces).

Public Realm

1. Determine criteria for feasible and scalable intervention, for example:
    - Feasibility of combining urban canopy with cool surfaces;
    - Engagement capacity of neighborhood or existing programs to leverage;
    - Infrastructure life-span and incorporation of cool surfaces into scheduled capital improvement;
    - Typologies of public spaces that are repeated throughout the County (e.g., school yards, sidewalks, public courtyard).
2. Establish a high priority site to test and design prototype intervention.

Private Realm

1. Map new development areas projected by 2050 using CHAT tool data.
2. Estimate the average number of substantial retrofits per year in LA County and estimate the average roof surface area of these retrofits using building footprint as a proxy.
3. Establish the future potential area for cool roof conversions.
4. Consider piloting a cool surface and/or roof ordinance that could guide new development and regulate substantial retrofits.

Target: Reduce by 15% the number of heat-stress emergency department visits per 100,000 residents

1. Map California Healthy Places Index bottom 25th percentile.
2. Extract from CHAT tool annual number of "Heat Health Events" and "Average Event Duration" for 2021 - 2040 time scale.
3. Extract land uses that contribute to disproportionate exposure to underlying conditions that drive heat-related illness, such as hazardous waste sites, heavy industrial sites, major highways, and bus depots. Also consider mapping senior care facilities, primary schools, outdoor work sites like construction areas or agriculture sites, and athletic facilities to capture additional sites where at-risk populations congregate.
4. Overlay HPI, CHAT, and land use extractions to show where heat health events combine spatially with at-risk populations.
5. Use this as a preliminary spatial assessment to define where at-risk populations are most concentrated. Consider prioritizing these areas for urban interventions and programs, such as:
    - Cooling centers;
    - Education and awareness building strategies (e.g., indoor air quality education);
    - Implementation of social projects that build community capacity (e.g., NYC Be a Buddy Program);
    - Prototype of new delivery networks for pharmaceuticals, supplies, and groceries for at-risk people during high heat events;
    - Subsidized or free cool roofs for at-risk households;
    - Energy utility subsidies for at-risk households who need access to air conditioning;
6. Determine land use actions (e.g., zoning, housing policies) needed to address proximity of at-risk groups to hazardous exposures.

Target: Increase urban tree canopy cover by 10% of baseline (LA County had 20% urban tree canopy cover as of 2016)

Spatial Prioritization and Target Refinement

1. Refine the established baseline tree coverage with the ongoing total tree canopy inventory.
2. Use Climate Smart Cities tool, specifically the final "Weighted Overlay Map," as a proxy of greatest need in order to guide spatial prioritization of areas for tree canopy. The areas already compiled in the tool show where social, environmental, and infrastructural vulnerabilities combine and therefore illustrate opportune places for multiple benefits might be.

3. Extract "Tree Canopy Percentile" (current as of 2011) from California Healthy Places Index (HPI), and map the lowest 25th percentile census tracts as a proxy of where tree canopy is lowest per capita (data is population-weighted).
4. Overlay Climate-Smart Cities "Weighted Overlay Map" with "Tree Canopy Percentile" map and extract and measure this area. This area divided by the already established tree coverage estimate, will offer a refined target for addressing canopy where it is most needed (this could amount to more or less than 10 percent of the existing tree canopy).
5. Map the "Tree Conservation Area" map in coordination with County Parks and Recreations and local municipal departments, to demonstrate where trees are prioritized for conservation and also in high vulnerability areas.
6. Map high wildfire risk areas and use the ongoing tree survey to document where there are fire in/tolerant tress and where planting of new trees may increase risk, especially in vulnerable communities.
7. Determine criteria for feasible and scalable intervention, for example:
    - Feasibility of combining urban canopy with cool surfaces;
    - Engagement capacity of neighborhood or existing programs to leverage;
    - Opportunity to align between capital investment policies that deconflict tree planting in the public realm with utility and accessibility regulations.

Considerations for Implementation and Monitoring

1. Establish a catalogue of drought and wildfire appropriate, native, and climate appropriate trees, as well as procure nursery development.
2. Use Ecostress to monitor and maintain plant health, in addition to ongoing tree survey.

PLAN AND RESOURCE ALIGNMENT

Overall, the County has at its disposal a wide range and well researched set of resources from which to draw upon and there is little need to develop wholly new vulnerability studies when it comes to understanding urban heat exposure and sensitivity of communities. Recognizing that there are some actions and strategies that are not captured by the above methodologies recommended to clarify and refine specific targets, the following is a guide to which resources might be most suited to inform planning related to all of the strategies and actions identified for urban heat mitigation in the OurCounty Plan.

Meet	Specifically useful in the methodology recommended
Refine	Data that can be used for validation or finer grained analysis (e.g., LST at a higher resolution, comparative view of redundant data already displayed in another recommended source)
Confirm	Supports or validates overall direction of the strategy

Image Credits: Doc Searls, *Downtown Los Angeles*. 2013

	Target: Convert 10% of heat-trapping surfaces to cool or green surfaces	**Target:** Reduce by 15% the number of heat-stress emergency department visits per 100,000 residents	**Target:** Increase urban tree canopy cover by 10% of base-line	**Action 29:** Develop a comprehensive heat island mitigation strategy and implementation plan that addresses cool pavements and roofs, pavement reduction, and urban greening.	**Action 28A:** Conduct a Countywide climate vulnerability assessment that addresses social vulnerability and use it to guide priorities for investments in public health preparedness, emergency preparedness and response planning, and community resiliency.	**Action 28B:** Conduct a Countywide climate vulnerability assessment that addresses physical infrastructure vulnerability and use it to guide priorities for investments in building upgrades, infrastructure improvements, and zoning and code changes.	**Action 30:** Build shade structures at major transit stops, such as those identified in Metro's Active Transportation Strategic Plan, prioritizing communities with high heat vulnerability.	**Action 43:** Create and implement a community-informed Urban Forest Management Plan that incorporates equitable urban forest practices, identifies County funding sources, and prioritizes: Tree- and park-poor communities; Climate and watershed-appropriate and drought/pest-resistant vegetation; Appropriate watering, maintenance, and disposal practices; Shading, and; Biodiversity.	**Action 44:** Implement locally tailored, youth-based tree and vegetation planting and maintenance projects in collaboration with community-based organizations to reduce the impacts of heat island in low canopy areas.	**Action 45:** Strengthen tree protections of native tree species, such as through development of an ordinance, based on findings from the Urban Forest Management Plan (UFMP).
CLIMATE SMART CITIES	**Meet**		**Meet**	●	●	●	●	●	●	●
ECOSTRESS AND RELATED SENSITIVE STUDIES	**Refine**	**Refine**	**Refine**		●					
FOURTH CLIMATE ASSESSMENT, LA REGION	**Confirm**	**Confirm**	**Confirm**		●			●		
CALIFORNIA HEAT ASSESSMENT TOOL (CHAT)		**Refine, Meet**			●	●	●			
READY FOR TOMORROW	**Confirm**				●	●				
CALBRACE		**Refine**			●					
CALIFORNIA HEALTHY PLACES INDEX (HPI)	**Meet**	**Refine, Meet**	**Meet**		●		●	●	●	●

APPENDIX: ADDITIONAL RESOURCES

The following is a summary of practices that a selection of places are testing and applying land use regulations to climate resilience planning.

Climate Resiliency Design Guidelines, New York City

New York City released new Climate Resiliency Design Guidelines that apply to all City capital projects, aside from coastal protection projects. The guidelines direct planners, engineers, architects, and others involved in project delivery on how to use regionally-specific future climate projections in the design of City facilities. For example, with respect to increasing temperature and heat wave projections designers are asked to ensure the physical components of the project itself are less vulnerable to increasing heat (e.g., by considering alternate materials and additional backup power), but also so help reduce the urban heat island effect (e.g., by integrating cooling features like green roofs). The guidelines suggest different benefit-cost analysis methods to ensure cost-effective investments, and contain information about approaches to address uncertainty (e.g., by building in flexibility to implement future adaptations).

Coastal Resilience Overlay, Norfolk

The City of Norfolk, Virginia adopted a new zoning ordinance in 2018 to enhance flood resilience and direct new more intense development to higher ground. The ordinance establishes a Coastal Resilience Overlay (CRO) zone, where new development and redevelopment will have to comply with new flood resilience requirements, and an Upland Resilience Overlay (URO), designed to encourage new development in areas of the city with lower risk of flooding.

Green Area Ratio, Washington DC

The District of Columbia (Washington D.C.) Green Area Ratio (GAR) is an environmental sustainability zoning regulation which sets requirements for landscape elements and site design to help reduce storm water runoff, improve air quality, and mitigate urban heat. The GAR sets minimum lot coverage standards for landscape and site design features to promote greater livability, ecological function, and climate adaptation in the urban environment. The GAR requirements provide a firm retention target and allow local governments to weigh the elements they prefer in order to influence behavior, while providing some measure of flexibility for property owners.

Microclimate Zoning Overlay, Tel Aviv-Yafo (Preliminary approach, in planning stages)

As a result of the Resilience Accelerator, the Municipality is considering standards for new housing and mixed-use development that take into account shading and sun exposure, vegetation and canopy, air flow and ventilation, waste heat, energy efficiency, and passive cooling. Preliminarily, this can be achieved through:

- Site specific study of microclimate conditions at the site and in relation to nearby public space (shading and sun study, thermal comfort, ventilation and airflow)
- Scenario modeling for future development programs and environmental modeling of potential climate impacts and benefits
- Convening of local designers, advocates, planners, and developers with city agencies to test new development requirements, expedited permitting, and review procedures for private development and urban renewal projects Development and testing of standards and process for investment in the public realm should consider the existing permitting and review processes to ensure feasibility, while also leveraging upcoming procurement and urban renewal projects as opportunities to innovate.

Standard development could consider resilience from multiple aspects, including:

- Cycles of existing and planned capital improvements based on infrastructure lifecycles
- Best in class climate and microclimate analysis
- Best in class materials and technologies of infrastructure
- Coordination of capital investments among agencies for operational efficiency, long-term maintenance, and funding optimization