



MAPPING RESILIENCE

A Blueprint for Thriving in the Face of Climate Disasters | APEN | 2019

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EXECUTIVE SUMMARY



OVERVIEW

FROM INTENSE STORMS THAT HAVE CAUSED DEADLY MUDSLIDES AND FLOODING TO RECORD-BREAKING WILDFIRES AND HEAT WAVES, THE PAST SEVERAL YEARS HAVE DEMONSTRATED THE DESTRUCTIVE IMPACTS OF CLIMATE CHANGE IN REGIONS ACROSS CALIFORNIA. IN THE MOST DEVASTATING CASES, THESE DISASTERS HAVE RESULTED IN DEADLY CONSEQUENCES FOR THOSE LIVING ON THE FRONTLINES OF CLIMATE IMPACTS. We have also seen communities forced to evacuate, displaced from their homes, or left without access to critical resources. Climate change, as a threat multiplier, exacerbates existing inequalities in health, housing, land use, transportation, and economic opportunities. This means those who are most impacted are consistently communities with the least resources to respond.

Although there is mounting evidence of the unequal effects of the climate crisis, researchers and advocates agree that there are relatively few robust, well-disseminated frameworks to account for, measure, and display the multiple and interacting factors contributing to differences in climate vulnerability across populations and places. CalEnviroScreen, one of the most widely applied screening tools in California environmental policy, is an exemplary model of an indicator set, assessment framework, and visualization tool to communicate complex information for planning and decision making to address the cumulative impacts from poverty and pollution. Complementing CalEnviroScreen with information derived from a climate vulnerability assessment framework offers enormous promise to help local and state agencies make broader climate policy decisions based on comprehensive data.

In light of these research needs, this report provides a review of existing frameworks related to community vulnerability to climate impacts and identifies strengths and gaps in the field.

KEY FINDINGS

1. CLIMATE DISASTERS HAVE UNEQUAL IMPACTS.

The past several years of disasters underline the way that the climate crisis disproportionately impacts the state's most vulnerable communities. These include (but are not limited to): transit-dependent populations such as the elderly, young children, and disabled; outdoor and informal workers; low-income communities; rural communities; indigenous people; undocumented immigrants; and incarcerated populations. For example, many agricultural workers are day laborers who cannot afford to miss work, and therefore are more likely to agree to work in dangerous conditions. During the aftermath of the Thomas Fire in 2017, amidst falling ash and extremely poor air quality, farmworkers in Oxnard continued working in the fields without protective masks, experiencing symptoms like burning eyes and nosebleeds.

2. REGIONAL CHARACTERISTICS DETERMINE CLIMATE RISK.

Climate change impacts on communities vary across the state based on biophysical setting, climate, and jurisdictional factors. For example, threats from sea level rise are specific to coastal communities, including those along the Pacific Ocean like Los Angeles and along the San Francisco Bay. There are also unique population characteristics in rural areas as compared to urban areas. For example, densely populated areas tend to have a much larger number of highly vulnerable populations, but in less-populated rural areas, a larger percentage of the population is characterized by high social vulnerability.

3. EXISTING FRAMEWORKS VARY IN SCOPE AND QUALITY.

Some frameworks are specific to distinct climate impacts, while others are more comprehensive and depict interacting social, health, and environmental factors across multiple climate impacts. We provide a brief overview and assessment of more than 40 climate vulnerability frameworks across sectors and scope. Comparison of the range of the frameworks included in this review reveals key distinctions in breadth and accessibility.

According to existing literature, there are relatively few approaches that combine multiple factors into a single framework to address the intersectional nature of climate vulnerability. Based on this analysis, four statewide frameworks stand out in regard to comprehensively integrating multiple exposures, population sensitivity, and adaptive capacity. These frameworks are selected based on breadth (those that incorporate the greatest number of indicators across exposures and vulnerability factors) as well as accessibility of data (those with high-quality visualization platforms). They are:

- Public Health Alliance of Southern California's **California Healthy Places Index** (HPI);
- California Building Resilience Against Climate Effects **Climate Change and Health Vulnerability Indicators** (CalBRACE CCHViz);
- California Energy Commission's (CEC) **Social Vulnerability to Climate Change**; and
- **Climate Change Vulnerability Screening Index** (English et al.).

Although three of these frameworks were developed by California agencies to inform planning and action around the state, they do not appear to be in broad use at this time.

Two additional frameworks stand out in depicting vulnerability to specific climate impacts, similarly selected based on statewide data availability and accessibility of data. These are:

- Four Twenty Seven's **California Heat Assessment Tool** (CHAT); and
- Climate Central's **Surging Seas Risk Zone Map**

4. FURTHER RESEARCH IS NEEDED TO ADDRESS REMAINING DATA GAPS AND CAPTURE OVERLOOKED FACTORS.

Limits in data collection imply that many relevant factors and trends underlying community vulnerability are either overlooked or reflect inaccuracies. For example, there is a wealth of data and knowledge about population sensitivity, but fewer indicators representing adaptive capacity (e.g., transportation access, public facilities, government infrastructure). Other data gaps include certain climate impacts (e.g., worsening air quality, environmental justice implications, drought vulnerability), health outcomes (e.g., infectious diseases, mental health), and socioeconomic factors (e.g., informal workers, immigration status, homelessness). Efforts to address gaps are currently being undertaken across a variety of agencies, including the Strategic Growth Council's Climate Change Research Program. Efforts to strengthen data accuracy should continue to be pursued.

5. A COMPREHENSIVE STATEWIDE INDICATOR SET, ASSESSMENT FRAMEWORK, AND PLATFORM CONNECTING SOCIAL VULNERABILITIES WITH CLIMATE IMPACTS HAS NOT YET BEEN FULLY REALIZED.

The field currently lacks shared framework(s) for understanding the unique climate risks and social vulnerabilities faced by low-income and disadvantaged communities. Moreover, there is a lack of consistency across the multitude of frameworks that aim to account for, measure, and display the multiple and interacting factors contributing to climate vulnerability. Researchers and advocates continue to recommend the development of a robust, well-disseminated climate vulnerability framework mirroring the development and application of CalEnviroScreen. Therefore, there is growing consensus around the need for an interactive mapping tool that incorporates projected climate change impacts, environmental health risks, socioeconomic data, and adaptive capacity.

KEY RECOMMENDATIONS

BASED ON THESE FINDINGS, WE OFFER KEY RECOMMENDATIONS REGARDING FUTURE NEEDS AND OPPORTUNITIES TO ADVANCE THE DEVELOPMENT AND APPLICATION OF CLIMATE VULNERABILITY FRAMEWORKS.

1. CLIMATE VULNERABILITY SHOULD BE ASSESSED AND DEPICTED BASED ON REGIONAL CHARACTERISTICS AND SPECIFIC CLIMATE THREATS.

Regional variations caution against making statewide measurements and comparisons and instead warrant a regional and climate impact-specific lens in the state's approach to understanding and addressing climate vulnerability. A regional lens also supports the application of the data since much of land use planning, as well as infrastructure development, occurs through regional or local policymaking.

2. RESEARCHERS DO NOT NEED TO DEVELOP NEW CLIMATE VULNERABILITY INDICATOR SETS.

There is a rich volume of existing frameworks to identify geographic areas and populations most impacted by climate change threats with significant redundancy of indicators used across frameworks. Moreover, there are enough underlying data, established indicators, and published methodologies that assert relevant factors contributing to vulnerability. Therefore, there is not an imminent need to create a wholly new set of indicators to conceptualize and assess climate vulnerability in California.

3. CALIFORNIA POLICYMAKERS REQUIRE A CENTRALIZED AND WELL-DISSEMINATED SET OF CLIMATE VULNERABILITY INDICATORS AND AN ACCOMPANYING VISUALIZATION PLATFORM.

Although we identify several comprehensive frameworks, there is no single set of indicators that exhaustively captures the most significant interacting factors that contribute to climate vulnerability. The density of frameworks available to inform adaptation planning is overwhelming, which results in a difficulty to discern which set of indicators or framework is most appropriate for the given application. This may create gaps in the way the abundance of available data is effectively informing policy action. Moreover, the availability of so much data is leading to paralysis of action. Accordingly, local, regional, and state policymakers developing new policies and implementing adaptation programs would benefit immensely from a streamlined compilation of the most significant indicators into a single interface. This platform would include indicators for exposure (e.g., temperature, wildfire threat, flood risk), population sensitivity (e.g., linguistic isolation, unemployment), and adaptive capacity (e.g., vehicle access). In order to support ease of use, this interface would also automatically populate relevant indicators based on the selected climate impact. The selection of indicators should be informed by a complementary policy framework that identifies priority issues, programs, policies, and funding opportunities.

4. PUBLIC OFFICIALS SHOULD GROUND-TRUTH AND COMPLEMENT VULNERABILITY MAPS WITH COMMUNITY EXPERTISE.

Vulnerability mapping is helpful to target vulnerable areas or communities, but data limitations should caution public officials against relying on any single such framework to identify and capture all factors and trends contributing to community vulnerability. Therefore, government officials should integrate the information derived from quantitative indicators and mapping with experiential knowledge and stories from community residents through ground-truthing processes. This will ensure that the public processes involving the development and application of climate vulnerability mapping are inclusive and participatory to generate well-informed decisions.

A detailed topographic map of California, showing state boundaries, major cities, and geographical features like mountains and rivers. The map is oriented vertically, with the top of the state at the top of the page.

OVERVIEW OF *MAPPING* RESILIENCE REPORT

THIS REPORT AIMS TO PROVIDE A COMPREHENSIVE REVIEW OF APPROACHES RELATED TO COMMUNITY VULNERABILITY TO CLIMATE IMPACTS. IT CONTAINS FINDINGS AND RECOMMENDATIONS REGARDING THE FOLLOWING:

1. Background on communities disproportionately impacted by climate change-related disasters in California and lessons learned from examples across the U.S.;
2. Key existing indicators, data, tools, and analytical frameworks for understanding the intersection of climate impacts, health and well-being outcomes, socioeconomic vulnerability, and adaptive capacity factors;
3. Major data limitations and knowledge gaps;
4. Lessons learned from development and use of indicators in related fields (e.g., public health, environmental justice, and land use); and
5. Anticipated uses of indicators to advance key fields and policies, as well as opportunities for working with other nonprofits, academic institutions, and public agencies to advance the development and effective use of useful indicators.

Various sectors are implementing programs to promote climate adaptation, but these efforts are often siloed and focus on protecting natural resources or built infrastructure. As programs continue to develop, there is a need to better characterize and promote the notion of community resilience as part of broader adaptation strategies toward a vision that is deeply rooted in climate justice and equity.

The field currently lacks shared and consistent framework(s) for understanding the unique climate risks and social vulnerabilities faced by low-income and disadvantaged communities. Although robust data already exists for certain regions in California, we have not seen a comprehensive statewide platform that connects social vulnerabilities with various climate impacts through a regional frame.

This report is intended for state-level decision makers (e.g., legislative committees and regulatory agency staff), climate justice advocates, climate and health researchers, funders, and other relevant partners. In addition to offering concrete suggestions for policy applications that such information could be applied to, this report also aims to raise the public visibility of the needs of vulnerable populations and places within statewide climate adaptation and resilience efforts.

A woman wearing a blue and white patterned shawl over a pink shirt and a purple patterned skirt is working in a garden. She is using a wooden tool to tend to green plants. In the background, there is a wooden fence and more greenery.

BACKGROUND: COMMUNITY IMPACTS FROM CLIMATE CHANGE

A detailed map of California, showing major cities like San Francisco, Sacramento, and Los Angeles, as well as geographical features like the Sierra Nevada mountains and the Pacific Ocean.

CLIMATE CHANGE IMPACTS IN CALIFORNIA

In 2017, global warming increased Earth's average temperature to approximately 1°C above pre-industrial levels, with a sizable portion of the global population having already experienced warming of more than 1.5°C in at least one season. Largely a result of anthropogenic greenhouse gas (GHG) emissions, climate change has already impacted and will continue to shift physical and biological systems around the world. **In California, climate impacts include but are not limited to wildfires, drought, extreme heat, mudslides, poor air quality, sea level rise, and flooding due to severe storm events. As surface air and water surface temperatures increase, nearing 1.5°C or more above pre-industrial levels, these impacts will only intensify, resulting in major social, economic, health, and environmental consequences for communities across the state.**¹

- **Wildfires.** In California, wildfires have been growing in size each year for the last 68 years. Out of the 20 largest wildfires by area burned, half have occurred in the last 10 years.² 2018's Mendocino Complex Fire previously held the record; the twin fires burned more than 459,000 acres and destroyed more than 280 structures.² The more recent Butte County Camp Fire broke this record and became the deadliest and most destructive wildfire in California's history. A history of fire suppression and climate change have made increasingly large and destructive wildfires California's new normal.^{3,4}
- **Mudslides.** Wildfires and torrential rain, both climate impacts that are increasingly becoming threats because of climate change, can trigger or intensify mudslides.⁵

Both destabilize a region—wildfires by destroying vegetation that help to hold soil in place, and torrential rain by washing away or oversaturating soil. Southern California experienced this in January 2018, when mudslides that followed wildfires and torrential rain devastated the city of Montecito. The resulting debris flows killed 23 people and damaged or destroyed 400 homes.⁶ A 2018 study in *Nature Climate Change* projects a 25–100 percent increase in extreme dry-to-wet precipitation events in California this century, which may mean an increased risk of mudslides.⁷

- **Extreme Heat.** Extreme heat, which can cause illnesses such as heat cramps, heat exhaustion, and heat stroke, is one of the deadliest climate impacts.⁸ In recent decades, extreme heat events and nighttime heat waves have become more frequent in California.⁹ 2014 and 2015 were the two hottest years in the state’s recorded history, while July 2018 was the hottest month since record keeping began in 1895.^{15,10} As the state’s climate continues to change, extreme heat is expected to become increasingly problematic.⁸
- **Drought.** Natural climate variability has historically made drought common throughout California.¹¹ However, rising temperatures caused by climate change have decreased soil moisture and reduced winter snowpack, intensifying the effects of drought.¹² California instituted mandatory conservation measures for the first time during the 2011–2017 hydrologic drought,

which was part of the longest duration of drought in the state since 2000.^{13,14} The period between late 2011 and 2015 was also the driest since 1895.¹⁵ The potential for more frequent and dangerous droughts may increase in the near future due to climate changes like increased warming.^{16,17}

- **Sea Level Rise.** In the last century or so, sea level has increased along California’s coast, where almost a quarter of the state’s population lives.^{9,18} For example, over the past century, sea level has increased about 7 inches in San Francisco.⁹ California has already experienced the impacts of sea level rise such as beach loss, ocean acidification, coastal flooding during storms and periodic tidal flooding, and increased coastal erosion, and will continue to do so as the climate changes.^{18,19}
- **Extreme Precipitation.** Climate change is driving an increase in heavy precipitation across all storm types. Warming temperatures have resulted in an increase in the fraction of rainfall (rather than snowfall), compounding the threat of flooding due to runoff from melting snowpack. Increasingly heavy atmospheric river storms in recent years brought record rainfall to parts of the state, putting local infrastructure and property at risk. The 2017 Oroville Dam spillway overflow, which prompted the evacuation of more than 180,000 people, was in part driven by greater than average runoff during peak precipitation.^{9,20}

CLIMATE CHANGE DISPROPORTIONATELY IMPACTS THE STATE'S MOST VULNERABLE COMMUNITIES

Historic inequity in land use and zoning policies, underinvestment, and lack of meaningful engagement in planning and policy decisions have resulted in disparities in how communities respond to and recover from climate impacts, and how prepared they are to make lifestyle changes necessary for adapting to a continually changing environment.²¹

According to California’s Fourth Climate Change Assessment’s *Climate Justice Report* (Framework 19),

vulnerable populations include, but are not limited to, low-income individuals and families; people of color; women; the young; the elderly; people with disabilities; people with existing health issues, including mental health issues; people with limited English proficiency (LEP); immigrants and refugees; agricultural workers and day laborers; traditional native communities; people who are or have been incarcerated; and people without a high school education.¹⁸

The Strategic Growth Council asserts an important note that the term “vulnerable” overlooks the many assets these communities also possess, and particularly the community residents for whom these places are home. In many of these communities there are organized groups of neighborhood leaders actively engaged in local planning efforts, policy campaigns, and other efforts to make their communities healthier, safer, and more sustainable.²¹

In general, climate disasters disproportionately impact already marginalized communities, including undocumented immigrants, LEP individuals, homeless populations, low-income families, older adults, and people with disabilities. Moreover, effective disaster

preparedness and response for these communities requires additional considerations, such as culturally and linguistically appropriate communications, safe and accessible sheltering, and targeted evacuation protocols based on their diverse needs. The California Office of Emergency Services (OES) designates these groups, among others, as those with “access and functional needs” and integrates these needs across emergency management systems.²²

The following examples further underline the way specific communities are vulnerable to the adverse health and livelihood impacts associated with climate disasters and events.

WILDFIRES

TRANSIT-DEPENDENT POPULATIONS

Those requiring assistance during evacuations are more vulnerable to wildfire impacts. Transit-dependent populations, or those unable to drive due to lack of driver’s license or access to a vehicle, are among this group.²³ The elderly, young, and people with disabilities are more likely to be transit-dependent. The October 2017 Northern California wildfires exemplified the way that elderly and people with disabilities struggled to—or were unable to—evacuate. A majority of the 44 victims who died were older than 65.²⁴ Of those fires, the Tubbs Fire alone killed 22 people, many of whom were elderly and/or disabled. During this fire, the second most destructive in state history, Santa Rosa CityBus drivers who helped evacuate individuals with mobility impairments struggled when the number of wheelchair users severely outnumbered the vehicles’ wheelchair capacity.^{25,26,27} Disembarking was a lengthy process since almost all non-ambulatory passengers had to leave their wheelchairs and other mobility support devices behind.²⁸ However, not all elderly and disabled residents received the assistance they needed. In September 2018, the state moved to de-license two senior housing facilities in Santa Rosa on the grounds that employees abandoned dozens of elderly and disabled residents during a frantic evacuation during the Tubbs Fire.²⁹

PEOPLE SUSCEPTIBLE TO HEALTH IMPACTS OF AIR POLLUTION

Wildfires add fine particulate matter and other pollutants to the air, thus having far-ranging impact beyond just acreage burned. They can also release additional chemicals into the air in the case of industrial fires.¹⁸ People with respiratory issues like asthma or those already suffering disproportionate impacts from poor air quality are thus especially vulnerable. In August 2018, 17 major wildfires burned across the state and negatively impacted the quality of the air well beyond their immediate areas. According to the EPA, almost 20 percent of California was exposed to “unhealthy” air. Smoke from the Camp Fire in November 2018 resulted in widespread pollution: Communities across Northern California experienced the effects of extremely poor air quality, ranking amongst the dirtiest in the world (exceeding pollution levels of cities in India and China). In the Bay Area, air quality levels ranked amongst the region’s worst air quality on record. Health advisories resulted in widespread school closures and warnings to stay indoors.^{30,31}

OUTDOOR WORKERS

Agricultural workers and other outdoor workers face increased health risks from wildfire impacts, including

injuries and death from burns and smoke inhalation, as well as exacerbation of cardiovascular diseases and asthma.¹⁸ Farmworkers particularly suffer high death rates due to respiratory illness.³² These health vulnerabilities are compounded by socioeconomic vulnerabilities. Wildfire damage negatively affects the industries that employ agricultural, construction, and landscaping workers, as well as day laborers, thereby threatening their economic livelihoods.¹⁸ Since many agricultural workers are day laborers and cannot afford to miss work, they are more likely to agree to work in dangerous conditions. Linguistic isolation and authorities' failure to provide sufficient notice in locally spoken languages can also expose vulnerable populations like agricultural workers to heightened risks during wildfire evacuations. During the 2017 wildfires in Napa County, where 30 percent of the population identifies as Latinx, a majority of emergency messages were in English.³³

During the aftermath of the 2017 Thomas fire, amidst falling ash and extremely poor air quality, some farm owners failed to give respirators to strawberry farmworkers in Oxnard and illegally continued work without protection. Farmworkers reported burning sensations in their eyes and nose, as well as nosebleeds.³⁴ For farmworkers impacted by wildfires, displacement is also a significant concern: Many farmworkers live in crowded subsidized worker housing or poor-quality rental housing near worksites, and are vulnerable to the predatory price-gouging tactics of landlords taking advantage of wildfire-induced housing scarcity.³²

ELECTRICITY-DEPENDENT POPULATIONS

As a last resort to prevent wildfires, utilities may preemptively shut off electricity. In December 2017, San Diego Gas & Electric (SDG&E) and Southern California Edison (SCE) both chose to do this during extremely high winds. Pacific Gas and Electric Company (PG&E) did it for the first time in October 2018, resulting in power outages for tens of thousands of customers.^{35,36} Power outages under any circumstances can be life-threatening for those who rely on electrically powered medical equipment, but they also pose increased risks for already vulnerable communities specifically in the context of wildfires. For example, inability to use air conditioning as a proxy for air filtration can be dangerous for those taking shelter indoors during a wildfire. Power outages

also put those who depend on landline phones for emergency alerts at increased risk.

INCARCERATED FIREFIGHTERS

California's prison population serving time for nonviolent crimes make up nearly 40 percent of firefighters, saving the state \$100 million per year. This workforce is particularly vulnerable since they cannot unionize and are not protected by minimum wage, worker compensation, and other laws. The state only pays incarcerated firefighters \$1 an hour plus \$2 a day and does not offer death benefits. Furthermore, formerly incarcerated people are routinely denied emergency medical technician licenses, a requirement for firefighters. This means that incarcerated firefighters, despite having hands-on experience, cannot become firefighters upon release.³⁷ This represents a significant, yet often overlooked, economic injustice.³⁸

WORKERS IN THE INFORMAL ECONOMY

Climate change disproportionately impacts those working in the informal economy.³⁹ For domestic workers, gardeners, cooks, and other informal workers, who often earn minimum wage, lost wages resulting from climate disasters can have a serious impact on their ability to survive. There also tends to be significant overlap between these workers and those who are undocumented. During the 2018 mudslides in Montecito following wildfires, almost a third of the people who died were service workers from immigrant families.⁴⁰ The workers who survived, predominantly Latinx, lost wages as a result of enforced layoffs during the mudslides, with no pay for lost time. As wealthy Montecito residents recovered, many workers struggled without access to Federal Emergency Management Agency (FEMA) assistance due to their immigration status.⁴¹

EXTREME HEAT

NEIGHBORHOODS LACKING GREEN SPACE

Urban heat islands (UHIs) exacerbate the effects of extreme heat by increasing local temperatures in cities.⁴³ Green space such as parks, gardens, other vegetated areas, and tree canopy-covered areas can reduce neighborhood temperatures, and therefore enhance a community's capacity to adapt to extreme heat events. However, neighborhoods concentrated with low-income communities of color have less tree coverage in California's urban areas as compared to neighborhoods that are composed of predominantly affluent white residents.⁴⁴ Consistently, densely populated communities in North Orange County, home to more than half of the county's Latinx population and almost a third of its Asian and Pacific Islander population, have less green space and limited public transportation to parks and beaches, putting these areas at higher risk for the health impacts of extreme heat.⁴⁵

POPULATIONS LACKING ACCESS TO AIR CONDITIONING

Those without access to air conditioning are especially vulnerable to impacts of extreme heat, as air conditioning use can prevent heat-related illnesses and deaths. Cooling is also necessary for safe storage of many medicines and foods.⁴⁶ Two heat waves in the Bay Area in June and September 2017 killed at least 14 people and hospitalized hundreds more in the region. Residents living in the Bay Area are uniquely vulnerable to heat illness because they are less acclimatized to higher temperatures and are far less likely to live in homes equipped with central air conditioning.^{46,47}

RESIDENTS LIVING IN OLDER HOMES

Housing characteristics can also make certain communities more vulnerable to extreme heat. Homes that are older tend to be more poorly insulated, and certain types of housing structures may promote heat buildup.⁴⁸ An October 2018 KQED investigation of indoor heat in the Bay Area found that the indoor air temperature for many homes was consistently higher than outdoor temperatures.⁴⁸ In fact, for those without access to air conditioning, the most dangerous place to be during a heat event may actually be indoors. Housing

security, too, is an important consideration—even those who experience housing-related heat health issues may be unwilling to bring up any issues to landlords for fear of retaliation.⁴⁸

PEOPLE SUSCEPTIBLE TO HEALTH IMPACTS FROM POOR AIR QUALITY

Higher temperatures induced by climate change worsen air quality by increasing allergens and intensifying the processes that produce pollutants like ozone, PM2.5, and smog.^{49,50} In addition, increased fossil fuel consumption corresponding to increased air conditioner use will also worsen air quality. People most vulnerable to the health impacts of worsening air quality caused by rising temperatures include those with respiratory and cardiovascular diseases, children, the elderly, outdoor workers, and those who are low-income. African-Americans and Latinxs are especially vulnerable since they are already disproportionately impacted by asthma and asthma-related health problems.⁵¹ In places like Imperial County, a predominantly Latinx county whose air quality is among the worst in the country due to industrial activity and a drying Salton Sea, climate change-induced rising temperatures will likely exacerbate existing ozone and other air quality problems.^{52,53,54}

DROUGHT

COMMUNITIES RELIANT ON GROUNDWATER FOR DRINKING WATER

When surface water supply decreases during drought conditions, groundwater becomes a crucial resource.¹⁸ This can lead to increased reliance on groundwater, which can in turn lead to overdraft. During overdraft conditions, fertilizer runoff, heavy metals, and other pollutants can concentrate in the remaining groundwater, making it unsafe to drink. Overdraft can also lead to increased salinity from seawater intrusion.⁵¹ The 2011–2017 California drought exacerbated already low groundwater levels, contributing to the San Joaquin Valley suffering from the most contaminated drinking water in the country.⁵⁵ The majority of the region's residents are dependent on groundwater for drinking water, disproportionately impacting rural, poor, and Latinx communities.^{55,56}

AGRICULTURAL WORKERS

Agricultural workers are especially vulnerable to effects of drought, including job loss, poverty, and negative mental health impacts.^{18,51,57} In cities where agriculture makes up a large portion of available jobs, drought conditions worsen economic consequences of poor crop production. In California, where 400,000 farmworkers live and work, most are not employed full time.⁵⁷ In fact, according to the Economic Policy Institute, agricultural workers earned an average of \$17,500 in 2015.⁵⁸ Unable to

find consistent work from drought-related conditions, farmworkers suffer from poverty-related issues such as food insecurity, substandard housing, displacement, and homelessness.^{51,57,59} Undocumented agricultural workers, who make up 60 percent of the state's agricultural worker population, are even more vulnerable, as they are unable to access government assistance that they would otherwise qualify for.^{18,57}

INDIGENOUS COMMUNITIES

Indigenous communities dependent on natural resources for subsistence hunting, fishing, and farming, as well as cultural survival, are especially impacted by climate change. Impacts of sea level rise such as saline intrusion and drought are also contributing to fisheries collapse throughout the world, threatening food security for communities reliant on fish use, including those in California. In Northwestern California, drought has decimated the salmon stock, an important food, economic, and ceremonial resource for the Yurok, Hoopa Valley, and Karuk tribes on the Klamath and Trinity rivers.⁶⁰ For indigenous communities, connecting to cultural heritage can be an important way to cope with the traumas of colonization and structural violence.^{61,62} By endangering the subsistence hunting and fishing practices of indigenous communities, climate change impacts not only threaten nutritional and economic well-being, but also community health—both directly and indirectly by exacerbating existing inequities.⁶³

LESSONS LEARNED FROM EXTREME PRECIPITATION AND FLOODING OUTSIDE OF CALIFORNIA

Although California is not susceptible to experiencing hurricanes such as those seen in the Gulf Coast and Atlantic states, acute risks from severe storms (e.g., atmospheric rivers as well as chronic risks from sea level rise) already put regions across the state at risk for deadly flooding. As flood risk continues to worsen in California, historic storms in regions across the U.S. offer key lessons about community vulnerability.

ENVIRONMENTAL JUSTICE COMMUNITIES

Extreme precipitation and flooding uniquely threaten environmental justice communities who live in close proximity to hazardous facilities. The Rockaways, the neighborhood hit hardest by Hurricane Sandy's initial impact in 2012, is predominantly African American and Latinx, and is characterized by severe income inequality.⁶⁴ Environmental justice communities along

the city's south coast, like those in the Rockaways, faced larger barriers to recovery due to low rates of flood insurance and existing issues like a history of mold and moisture problems in public housing developments.^{65,66} Those living along the industrial waterfront also may have been exposed to floodwaters contaminated by pollutants from Superfund sites.⁶⁷ Similarly, communities vulnerable to Hurricane Harvey's impacts in Texas were those living in neighborhoods located near the city's many petrochemical plants and toxic waste sites. Mostly low-income neighborhoods and communities of color, these areas were exposed to toxic floodwaters potentially contaminated with cancer-causing compounds.⁶⁸ In addition, a flood-damaged chemical plant in Crosby, Texas, exploded, causing residents to evacuate and sending emergency workers to hospitals.^{69,70}

INCARCERATED POPULATIONS

Those who are incarcerated in prisons, jails, detentions centers, and juvenile centers are especially vulnerable to climate disasters because they are limited in their options to address the conditions of their confinement. Moreover, the ability to protect institutionalized populations largely depends on the emergency and safety protocols employed at the facilities they occupy.⁷¹ Prisons are also often located on or near environmental contamination, which can worsen during flooding and storms. Incarcerated people in Texas were hit especially hard by Hurricane Harvey in 2017, a Category 4 hurricane that is tied with Hurricane Katrina as the costliest tropical cyclone on record.⁷² Inmates across Texas reported being left in cells flooded knee-high with water contaminated by urine and feces during and after the hurricane, unable to access sufficient food, water, and medicine. They also reported the inability to flush toilets, take showers, or change clothes for several weeks.⁷³ During Hurricane Florence in September 2018, a Category 4 hurricane, South Carolina jails chose not to evacuate prisoners despite regional evacuation orders and warnings from the National Hurricane Center characterizing the projected impact as life-threatening.

UNDOCUMENTED IMMIGRANTS

Immigrant populations, who already struggle with

CASE STUDY

HURRICANE MARIA IN PUERTO RICO

Weeks after Hurricane Irma hit in 2017, Hurricane Maria, a Category 5 hurricane, hit the Caribbean. In Puerto Rico, where the death toll was nearly 3,000, the hurricane not only left a trail of destruction via direct impact, but also resulted in an 11-month, island-wide blackout. The largest in U.S. history and the second largest in the world, the blackout prevented people from using electrical medical equipment and safely storing medicines, contributing to the enormous death toll.⁷⁸ The storm and ensuing power outage also caused a mental health crisis on the island, with the number of people who attempted suicide after the hurricane hit more than tripling.⁷⁹ A combination of lasting impacts from previous natural disasters, a dubious electrical grid repair contract, and neglect by the U.S. government, as well as the consequences of American colonialism and continued imperialism, contributed to the extreme social vulnerability of the people of Puerto Rico, with the poor, disabled, and elderly representing the most impacted.^{79,80,81} Hurricane Maria also caused the largest mass migration from Puerto Rico in recorded history. Thousands fled the island to the mainland United States in the aftermath of the storm.⁸² As of August 2018, thousands of displaced Puerto Ricans who were able to leave the island continued to live in transitional housing on the mainland funded by FEMA. However, the funding has since run out, leaving many families stranded, unable to pay for housing on the mainland, and unable to return to Puerto Rico.⁸³

higher rates of poverty and less access to medical care, are disproportionately impacted by disasters. For example, after Hurricane Harvey, 64 percent of immigrants suffered unemployment and income losses compared to 39 percent of their U.S.-born neighbors.⁷⁴ Undocumented immigrants are particularly vulnerable since they are ineligible for federal disaster aid and thus lack access to economic relief. Undocumented disaster victims may be afraid to seek emergency shelters or other local assistance programs due to fears of exposing

their immigration status. In fact, Houston's population of undocumented immigrants, the third largest in the country, may have chosen not to evacuate due to the Border Patrol refusing to suspend checkpoints during the hurricane.^{75,76} In addition, many undocumented immigrants who worked in industries impacted by flooding from Hurricane Harvey sought out construction work as part of cleanup and rebuilding efforts, which introduced additional threats such as unsafe working conditions, wage theft, and insufficient training.⁷⁷

CONTEXT AND FRAMING FOR THE *MAPPING RESILIENCE* REPORT

Growing Consensus Among Researchers and Advocates on Utility of Frameworks that Illustrate Climate Vulnerability

Although there is mounting evidence of the unequal effects of the climate crisis, researchers and advocates agree that there are few robust frameworks that account for and display the multiple and interacting factors contributing to differences in vulnerability across populations and places. California's Fourth Climate Change Assessment's *Climate Justice Report* (Framework 19) asserts that "the cumulative and synergistic nature of multiple social, economic, and environmental factors can limit a person's and community's ability to prepare for, respond to, and cope with climate change. . . . [Therefore], identifying and mapping communities in relation to current and anticipated climate risks (e.g., high social vulnerability or high exposure to climate impacts) is an essential part of the scientific foundation for understanding the state's changing conditions related to climate change."¹⁸

Although identified as a critical step to protecting communities, the report's author was unable to find an interactive mapping tool that incorporates projected climate change, environmental health risks, socioeconomic data, and adaptive capacity. The Union of Concerned Scientists finds that there is lack of clarity as to whether there is adequate and consistent analysis, data, and tools to assess the social, health, and climate risks faced by low-income communities of color, particularly related to infrastructure disruptions.⁸⁴ This gap is echoed by advocates in the Climate

Justice Working Group (CJWG), who underline the need to "identify and reduce frontline communities' vulnerabilities to climate change, with a focus on physical, economic, and quality-of-life factors."⁸⁵

In light of the knowledge gaps, researchers and advocates continue to push for a shared framework to depict climate vulnerability. For example, the *Climate Gap* report recommends using geographic information system (GIS) mapping technologies to identify vulnerable neighborhoods by overlaying vulnerability models and socioeconomic, racial/ethnicity, and cultural group distributions in California.⁸⁶ Advocates in the CJWG note that these types of mapping efforts could also support state agencies to conduct cross-sector vulnerability assessments to identify and prioritize climate change-related threats to the region's frontline communities.⁸⁵ In 2017, the California Strategic Growth Council (SGC) endeavored to address this gap in its first round solicitation for its Climate Change Research Program. Within the research priorities to 1) protect vulnerable communities from climate change impacts; and 2) increase data accessibility for climate planning, SGC poses the same question: "How can communities assess, aggregate, and appropriately represent climate vulnerability when developing 'hot spot' visualizations that aggregate multiple climate-related impacts?"⁸⁷

COMMUNITY VULNERABILITY AND RESILIENCE TO CLIMATE CHANGE: KEY DEFINITIONS

The way climate vulnerability is framed varies based on the values and assumptions underlying the approach. This report is focused on understanding vulnerability from a community perspective. Therefore, terms such as community resilience and social vulnerability are central concepts in the framing of this report. Throughout this document, we rely on the following terms and definitions adapted from various sources.

Climate Adaptation vs. Resilience

Although **climate adaptation** and **resilience** are often used interchangeably, they reflect distinct concepts. The California Office of Planning and Research (OPR) distinguishes the terms by framing adaptation as an action or set of actions and resilience as a desired outcome. Moreover, adaptation is preparing for the impacts of climate change, which can contribute to achieving resilience.⁸⁸

- **Adaptation** is the process of responding to the impending or inevitable consequences of the climate disruption already set in motion that, due to lag effect, cannot be avoided or reversed.
- **Resilience** is the capacity of a system (whether a community or an economy) to maintain 1) an intact core identity in the face of change; and 2) a state of dynamic balance within which change can be avoided or recovered from without a fundamental transition to a new form. Resilience can bridge mitigation and adaptation, and economy and ecology, and can help us create more social cohesion, inclusion, power, and participation and more holistic and systemic interventions.⁸⁹

[Definitions adapted from Movement Strategy Center]

Community Resilience as a Unique Concept

OPR outlines the elements of a resilient California, which include: 1) built infrastructure systems; 2) people and communities; and 3) natural systems.⁹⁰ These elements are inherently interconnected as part of a broader system, and therefore altogether essential in holistically preparing for and responding to disasters. Dominant uses of the term *resilience*, however, often

refer to infrastructure or natural systems. Community resilience, therefore, is unique in its focus on people and consideration of public health, social structures, and economic development.

Community resilience is the ability of communities to withstand, recover, and learn from past disasters, and to learn from past disasters to strengthen future response and recovery efforts. This can include physical and psychological health of the population; social and economic equity and well-being of the community; effective risk communication; integration of organizations (governmental and nongovernmental) in planning, response, and recovery; and social connectedness for resource exchange, cohesion, response, and recovery.⁹¹

- Facets of a community that can be integrated toward the goal of enhancing disaster resilience include infrastructure, governance structures, economy, natural resources and attributes, demographic character, and social interactions.
- In its original ecological context, the notion of bouncing back defined resilience, but in the disaster context, this has been expanded to include bouncing forward, not merely just bouncing back.⁹¹

[Definition adapted from Cutter et al. (2014)]

Vulnerability Is a Multidimensional Concept

Climate vulnerability describes the degree to which natural, built, and human systems are at risk of exposure to climate change impacts. Vulnerable communities experience heightened risk and increased sensitivity to climate change and have less capacity and fewer resources to cope with, adapt to, or recover from climate impacts such as sea level rise, hurricanes, floods, heat waves, air pollution, and infectious diseases.⁹²

[Definition adapted from Shonkoff et al. (2011)]

Elements contributing to vulnerability are:

- **Environmental exposure**, which refers to the magnitude, frequency, and duration of an environmental exposure or disease risk;
- **Sensitivity**, which refers to the physiological and socioeconomic factors that directly or indirectly affect the degree to which a population is impacted by climate-related changes; and

- **Adaptive capacity**, which refers to 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 consequences.

[Definition adapted from California Department of Public Health CalBRACE Project]

Social vulnerability, as an element of overall climate vulnerability, refers to the susceptibility of a population to harm from a natural hazard and examines those characteristics of the population that influence their resilience.⁹³

- Vulnerable populations may need special assistance in preparing for, responding to, and recovering from disasters.
- Social vulnerability is place-based and context-specific, and helps explain why some portions of the country or some communities experience a hazard differently, despite having the same exposure.
- Social vulnerability helps us to understand the inequalities in disaster impacts and is a multi-attribute concept that includes socioeconomic status, race and ethnicity, gender, age, housing tenure, and so forth, as well as how these factors influence a community's resilience.⁹³

[Definition adapted from The National Academies]

Vulnerability Is Not Distributed Equally Across Communities

The **Climate Gap** refers to the disproportionate and unequal implications that climate change and climate change mitigation hold for people of color and the poor.⁸⁶ These disproportionate effects are caused by physical (built and environmental), social, political, and/or economic factors, which are exacerbated by climate impacts.

Other social and economic factors related to climate vulnerability including:

- Inequities in access to and benefits of education, economic investment, social capital, health protection initiatives, and/or government services;
- Institutionalized bias or exclusion with respect to political and decision-making power;



VULNERABILITY IS A CONDITION, NOT A CONSEQUENCE.

“Conventional approaches to adaptation and mitigation view vulnerability as a characteristic or condition of groups of people and not as a circumstance or consequence of the ways social groups have been historically and systemically marginalized and excluded from opportunity. As a result, the policy and practices that have been brought to bear don’t address the underlying historical roots of vulnerability. These conventional approaches and views often reinforce the exclusion of these groups from democratic decision making. They also exclude them from having a voice in setting policy priorities or allocating resources to address the issues. Rather than being viewed as victims to be protected and saved, vulnerable communities should instead define, develop, and drive the solutions.”⁸⁹

[Excerpt from Movement Strategy Center]

- Disparities in environmental and living conditions; and
- Disparities in individual, family, and community health status. Urban, suburban, and rural communities experience climate vulnerability, but may be vulnerable in different ways, depending on the context and on the relative presence or absence of the above factors.⁸⁵

An individual or community may be vulnerable with respect to multiple factors of vulnerability at once. The cumulative effects of these factors may contribute to heightened vulnerability.⁸⁵

[Definitions adapted from The Climate Gap report and Climate Justice Working Group Recommendations]

“By 2030, we envision a resilient California where our most vulnerable communities are ready to respond to the physical, environmental, economic, and health impacts brought on by climate change, and thrive after climate events. California must proactively bring public and private investments into vulnerable communities to foster robust and thriving communities that are engaged, healthy, just, economically viable, and safe from environmental threats.”⁸⁵

— Climate Justice Working Group

COMMUNITY VULNERABILITY AND RESILIENCE TO CLIMATE CHANGE: KEY PRINCIPLES

In addition to definitions of key terms, the values underlying the development of this report are consistent with several sets of principles developed by leading thought partners and advocates in the field. This includes CJWG members, the Integrated Climate Adaptation and Resiliency Program (ICARP) Technical Advisory Committee (TAC), the Union of Concerned Scientists (UCS), and Movement Generation.

Shared elements emerging across these principles are:

- Ensure meaningful and active **engagement** with most impacted communities
- Practice both **adaptation and mitigation** simultaneously
- Promote **equity** by prioritizing and protecting the most vulnerable populations
- Encourage actions that provide **multiple benefits**
- Consider **unintended consequences** and avoid maladaptive practices that cause harm
- Maximize **transparency** and **accountability**
- Drive decision making through strong **scientific evidence** and **local knowledge**
- Create **adaptive processes** that provide flexibility and opportunity for revision
- Advance a **just transition** toward a diversified and regenerative economy

These principles reveal the types of policies and programs that truly advance resilience planning through a climate justice lens. That is, one that “requires California leaders to ensure that the people and communities who are least culpable in the warming of the planet, and most vulnerable to the impacts of climate change, do not suffer disproportionately as a result of historical injustice and disinvestments.”⁸⁵

This legacy of historic disinvestment in frontline communities also means that policies and programs must be designed not only to protect these communities from harm, but also prioritize resources that allow them to thrive. Many of these communities are already creating their own solutions using cultural knowledge and assets, but require further support to realize a vision toward a resilient California.



CLIMATE JUSTICE WORKING GROUP (CJWG) GUIDING PRINCIPLES⁸⁵

1. Actively engage frontline communities in research, planning, implementation, education, and decision making about potential climate change impacts and about the development, funding, implementation, and evaluation of adaptation and resilience policies. Create enabling conditions for frontline communities' early, continuous, and meaningful participation in the development of adaptation policy and funding decisions. Partner with local leaders and community-based organizations to enhance the effectiveness of adaptation research and innovation, education, decision making, and policy implementation. *This overarching principle applies to all of the subsequent climate justice principles and recommendations.*
2. Identify and reduce frontline communities' vulnerabilities to climate change, with a focus on physical, economic, and quality-of-life factors.
3. When planning for infrastructure investments, prioritize actions that increase the resilience of essential facilities and associated services that provide health care, food, drinking water, evacuation routes, and emergency shelter for frontline communities. Reduce community health and safety risks from potential damage to sensitive facilities such as water treatment plants, hazardous waste facilities, and power plants and transmission lines.
4. Promote adaptation policies, funding decisions, and implementation actions that increase training, employment and economic development opportunities among frontline communities. Where applicable, prioritize opportunities that advance a "just transition" from dependence on fossil fuels and further enhance community resilience to the impacts of climate change.
5. Promote and support regional and local adaptation efforts that generate multiple benefits across sectors.
6. During planning and implementation of land use and community development decisions, consider and avoid negative consequences of actions, including displacement, that could inadvertently increase frontline communities' and individuals' climate vulnerability.
7. Promote adaptation co-benefits of toxic chemical and greenhouse gas reduction policies by supporting those that also reduce frontline communities' climate vulnerability and enhance their resilience.
8. Ensure that adaptation policies, funding decisions, and implementation actions comply with relevant laws and policies that are designed to protect and advance civil rights and environmental justice.
9. Promote local, regional, and state agency transparency, accountability, and adaptive management by developing and applying easy-to-understand climate justice metrics, data and information resources, and annual reporting protocols.
10. Identify needed funding, establish needed funding mechanisms, and allocate adequate funding to support adaptation policy development, implementation, and evaluation in frontline communities.



CALIFORNIA OFFICE OF PLANNING AND RESEARCH (OPR) INTEGRATED CLIMATE ADAPTATION AND RESILIENCY PROGRAM (ICARP) PRINCIPLES⁸⁸

1. Prioritize integrated climate actions, those that both reduce greenhouse gas emissions and build resilience to climate impacts, as well as actions that provide multiple benefits.
2. Prioritize actions that promote equity, foster community resilience, and protect the most vulnerable. Explicitly include communities that are disproportionately vulnerable to climate impacts.
3. Prioritize natural and green infrastructure solutions to enhance and protect natural resources, as well as urban environments. Preserve and restore ecological systems (or engineered systems that use ecological processes) that enhance natural system functions, services, and quality and that reduce risk, including but not limited to actions that improve water and food security, habitat for fish and wildlife, coastal resources, human health, recreation, and jobs.
4. Avoid maladaptation by making decisions that do not worsen the situation or transfer the challenge from one area, sector, or social group to another. Identify and take all opportunities to prepare for climate change in all planning and investment decisions.
5. Base all planning, policy, and investment decisions on the best-available science, including local and traditional knowledge, including consideration of future climate conditions out to 2050 and 2100, and beyond.
6. Employ adaptive and flexible governance approaches by utilizing collaborative partnership across scales and between sectors to accelerate effective problem solving. Promote mitigation and adaptation actions at the regional and landscape scales.
7. Take immediate actions to reduce present and near future (within 20 years) climate change risks for all Californians; do so while also thinking in the long term and responding to continual changes in climate, ecology, and economics using adaptive management that incorporates regular monitoring.



UNION OF CONCERNED SCIENTISTS (UCS) CLIMATE RESILIENCE PRINCIPLES⁹⁴

1. Consider projected climate conditions.
2. Use systems thinking.
3. Match the scope of planning to the magnitude of projected change.
4. Aim for robust decisions and policies.
5. Create opportunities to revise and change course.
6. Decide with, not for.
7. Minimize harm and maximize options.
8. Equip and empower local experts.
9. Maximize transparency, accountability, and follow-through.
10. Weed out maladaptation, both existing and proposed.
11. Consider the costs of inaction.
12. Work to protect what people cherish.
13. Reflect a long-term vision.
14. Appreciate limits to adaptation and push mitigation.

MOVEMENT GENERATION JUST TRANSITION PRINCIPLES⁸⁹

The Principles of a Just Transition to Resilient Communities

Form follows function: Scale and process

PRINCIPLES OF A JUST TRANSITION TO RESILIENT COMMUNITIES



Facing the Climate Gap highlights a multitude of detailed case studies that embody the practice of these principles in local contexts across California. Together these projects, campaigns, and programs exemplify the possibility for meaningful impact and deep engagement with adherence to principles consistent with climate justice.⁴⁴



REVIEW OF EXISTING CLIMATE VULNERABILITY FRAMEWORKS



A VARIETY OF FRAMEWORKS EXIST TO ASSESS THE CUMULATIVE FACTORS THAT CONTRIBUTE TO A COMMUNITY'S VULNERABILITY TO CLIMATE CHANGE. Some are specific to distinct climate change impacts, while others are more comprehensive and depict interacting social, health, and environmental factors across multiple climate impacts. Assessment of the multitude of frameworks offers general insights regarding California's climate vulnerability and data availability. Based on distinctions in quality, rigor, and accessibility, we then highlight the strongest frameworks based on criteria described below. This informs recommendations for the path forward in the field of climate vulnerability frameworks.

CLIMATE VULNERABILITY IN CALIFORNIA

The national indices reviewed in this report offer insight into how California compares to other states and regions across the country in terms of climate vulnerability and resilience. For example, according to the Climate Resilience Screening Index (CRSI) (Framework 1) developed by the Environmental Protection Agency, EPA Region 9 (which includes California) is impacted by multiple exposures, including extreme heat and rising temperatures, drought, and insect outbreaks, which have cumulatively contributed to increased wildfires in recent years. Overall, the region's CRSI score is above the national average. The region scores below the national average specifically in governance for climate impacts, highlighting a potential opportunity

for improvement. California counties vary significantly in terms of resilience; some represent the highest scores in the region, while others are at the lower end of the spectrum. Although the majority of risks arising from exposure are climate impacts, proximity to toxic release sites and Superfund sites are prevalent industrial hazards in the western region. Indicators of particular importance in contributing to the overall CRSI score in this region include vacant structures, housing characteristics, and socioeconomic demographics.⁹⁵

Based on the Baseline Resilience Indicators for Communities (BRIC) (Framework 2) metric developed by University of South Carolina researchers, most of California ranks moderately low in terms of disaster resilience. Notably, California counties ranked lowest across the country for social resilience and community capital. In fact, Imperial County, Calif., has the lowest overall BRIC score in the nation. In the context of this metric, significant contributors to the higher BRIC scores include health insurance coverage, food security, employment, and homeownership. The primary drivers for the lower scores based on this metric include low educational attainment, limited English proficiency, lack of access to a vehicle, fewer physicians, high levels of food insecurity, a high number of recent immigrants, lower levels of voter participation, and water stress.⁹¹

The Social Vulnerability Index (SoVI®) (Framework 3) also developed by University of South Carolina researchers indicates that California counties rank medium to medium high in regard to social vulnerability factors as compared to the rest of the nation. Imperial County ranks high for social vulnerability within California, which is consistent with the BRIC results. According to the Social Vulnerability Index (SVI) (Framework 4) results, highest vulnerability is concentrated in the San Joaquin Valley as well as in Imperial and Riverside counties.⁹⁶

REGIONAL VARIABILITY WITHIN CALIFORNIA

The frameworks reviewed in this report also offer insight about the regional variability of indicator scores across the state. In fact, the findings of this report evidence the regional nature of climate impacts. This is substantiated by California's Fourth Climate Change Assessment led by the California Natural Resources Agency, which includes regionally specific assessments of climate-related risks and adaptation strategies for nine regions:

North Coast, Sacramento Valley, Sierra Nevada, San Francisco Bay Area, San Joaquin Valley, Central Coast, Los Angeles, San Diego, and Inland South (Figure 1).¹⁸



Figure 1 California's nine climate regions
(California's Fourth Climate Change Assessment).

“The impact of climate change in California varies across the state due to diversity in biophysical setting, climate, and jurisdictional characteristics. The California Adaptation Planning Guide organized the state into climate impact regions based on county boundaries in combination with projected climate impacts, existing environmental settings, socioeconomic factors, and regional designations and organizations.”^{19,97}

One example of regional variation is offered by Cooley et al. (Framework 17), who recommend using caution when comparing urban and rural areas. Densely populated areas tend to have a much larger number of highly vulnerable populations, but in less-populated rural areas, a larger percentage of the population is characterized by high social vulnerability. This evidence warrants a regional lens in the state's approach to depicting vulnerability.⁹⁸ To explore this concept further, the following sections summarize regional trends of various climate impacts as identified by key frameworks.

Extreme Heat

Overall, many regions of California, both urban and rural, are vulnerable to the impacts of extreme heat. Depending on the index or metric used, different parts of California are vulnerable to heat impacts. For example, according to Cooley et al. (Framework 17), regions in California at risk include the San Joaquin Valley, particularly Fresno and Tulare counties, as well as Los Angeles, San Diego, and San Bernardino counties. According to this report, these areas are characterized by both high exposure of future extreme heat days and high social vulnerability based on a composite measure of 19 indicators (e.g., tree canopy cover, elderly living alone, outdoor occupations).⁹⁸ Knowlton et al.'s findings (Framework 32) reveal that the 2006 heat wave in California resulted in excess heat-related hospitalizations among residents in the Central Coast (including the San Francisco Bay Area), which suggests the unique vulnerability of residents living in this region due to less acclimatization, fewer resources for adaptive capacity, or lack of awareness about health risks and coping strategies.⁹⁹ Consistently, Reid et al. (Framework 31) find that, based on national estimates, most of the highest scoring cumulative heat vulnerability index values were found in the Bay Area (San Francisco and Alameda Counties) as well as in Los Angeles County.¹⁰⁰

Coastal Flooding

According to Cooley et al. (Framework 17), the risks from coastal flooding based on earlier sea level rise projections were particularly severe in the Bay Area, namely Alameda, Contra Costa, San Mateo, and Monterey counties.⁹⁸ More recent research incorporating updated sea level rise projections from the Union of Concerned Scientists (UCS) (Framework 27) reinforce these findings and project disruptive flood risks in the Bay Area as well as Novato, Union City, and East Palo Alto in 2100. Based on this study, disruptive flooding also threatens communities living on the Central Coast, particularly Ventura County, as well as Orange County in the Los Angeles region.¹⁰¹

Amongst these impacted areas, Cooley et al. find that composite social vulnerability was higher in the Bay Area and in Ventura County, but lower in the Los Angeles region. This is largely due to regional

distinctions in economic geography: Los Angeles is characterized by the most valuable properties located along low-lying areas adjacent to the ocean, while the Bay Area's most valuable properties are higher up in the hills. The UCS analysis highlights that the LA region is likely to experience disruptive flooding in 2100, with impacts on infrastructure and neighborhoods in Long Beach, Seal Beach, Huntington Beach, and Newport Beach (**Figure 2**). Of those coastal communities at high risk of being impacted by sea level rise in Los Angeles, the most socially vulnerable groups are those that lack access to transportation and have a high concentration of elderly populations.¹⁰²

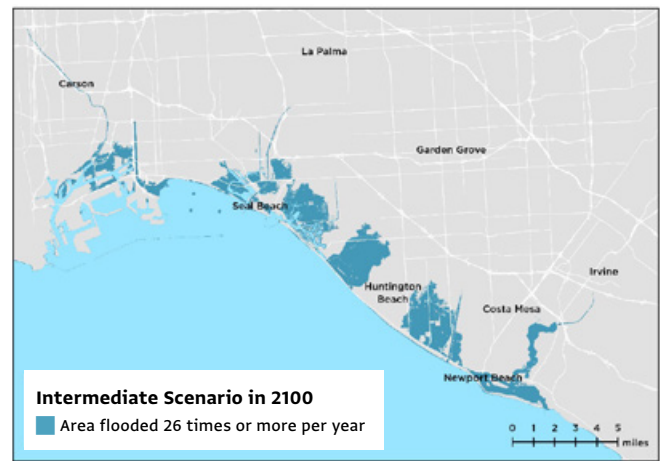


Figure 2 Chronic Inundation in the Greater Los Angeles Region in 2100 in the Intermediate SLR Scenario.

In addition, Martinich et al. (Framework 26) find that the most socially vulnerable areas at risk of sea level rise are agricultural communities east of the Bay Area.¹⁰³ This is substantiated by the Surging Seas Risk Zone Map (Framework 25), which indicates high social vulnerability among much of the populations in Stockton and Sacramento. Accompanying maps offer a closer visual representation of the effects of sea level rise on the levee system in the Sacramento-San Joaquin River Delta (**Figure 3**). This stress threatens not just Sacramento and Stockton, but also much of California's fresh water supply.¹⁰⁴

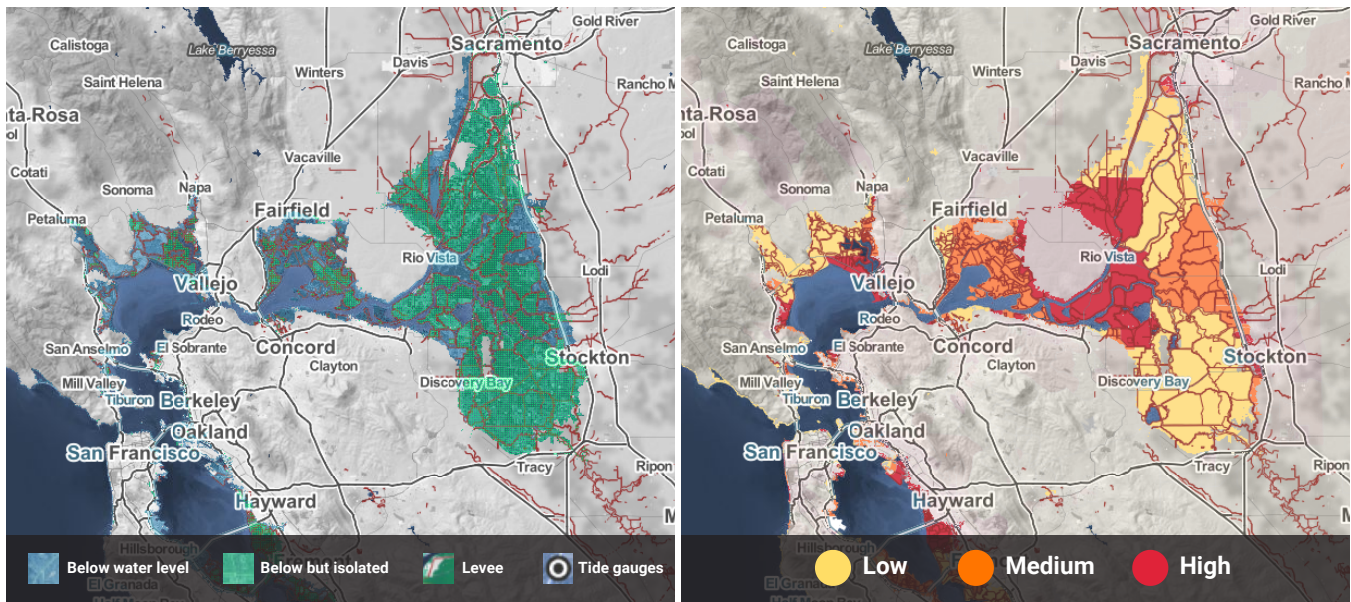


Figure 3 Left: Surging Seas Risk Zone Map for Stockton and Sacramento at water level of 5 feet; Right: Social Vulnerability Index (SVI) map of Stockton and Sacramento at water level of 5 feet.

Wildfires

According to the California Department of Forestry and Fire Protection (CAL FIRE) Fire Hazard Severity Zones and Wildland-Urban Interface maps (Framework 33), communities across the state are threatened by wildfires.^{105, 106} According to these maps, large percentages of rural communities in Northern California counties, such as those living in Tuolumne, Trinity, Nevada, Plumas, Shasta, and Siskiyou, are at risk of extreme fire dangers.^{107,119} According to future projections of wildfire risk, Cooley et al. (Framework 17) also identify high-risk populations located in Southern California, including Los Angeles, Orange, San Bernardino, and San Diego counties.⁹⁸

Air Quality

Particulate matter concentrations are expected to significantly increase in California due to climate change. According to Cooley et al. (Framework 17), vulnerable communities in areas exceeding state standards for PM_{2.5} levels in 2050 are expected to be concentrated in Southern California (i.e., Los Angeles, Orange, and Imperial counties) and along the San Francisco Bay (i.e., Santa Clara, San Francisco, and Alameda counties).⁹⁸

DATA AVAILABILITY

The overwhelming majority of frameworks in this review use publicly available data and clearly identify specific data sources and indicator development methodologies. The mapping tools and sets of indicators consistently articulate the sources of data from which the indicators are developed. Some discuss assumptions and limitations associated with

the data utilized. Many mapping frameworks are accompanied by in-depth technical reports that outline the methodology underlying the conceptualization and development of the tool—the California Healthy Places Index (Framework 13) and Surging Seas Risk Zone Map (Framework 25), for instance. Similarly, all of the research studies determining specific factors of

significance for community vulnerability to various climate impacts present data sources and explain underlying rationale in their methodology sections. By contrast, the qualitative policy reports in this review

do not offer information about data availability, but review the literature and offer evidence to substantiate the role of a multitude of social, environmental, and economic factors in climate vulnerability.

ASSESSMENT OF FRAMEWORKS

Comparison of the range of the frameworks included in this review reveal key distinctions in approach. Some focused on depicting projections and information related to a single climate impact exposure—Coastal Resilience California (Framework 28) and the Urban Heat Island Index (Framework 29)—while others included more than 30 separate indicators across various domains that could be compiled into a single index—Climate Resilience Screening Index (Framework 1) and the California Healthy Places Index (Framework 13). Therefore, some frameworks are more comprehensive in their incorporation of exposures and vulnerability indicators, while others compile specific indicators relevant to an individual climate impact.

STRONG COMPREHENSIVE FRAMEWORKS FOR MEASURING MULTIPLE CLIMATE IMPACTS

English et al. (Framework 21) note that there are relatively few frameworks that combine multiple climate change threats into a single measure that addresses the comprehensive nature of climate vulnerability.¹⁰² This review substantiates this claim: We identify just four comprehensive frameworks that reflect integration of multiple exposures, population sensitivity, and adaptive capacity for California. These are the:

1. Public Health Alliance of Southern California's **Healthy Places Index** (HPI) (Framework 13)
2. **California Building Resilience Against Climate Effects Climate Change and Health Vulnerability Indicators** (CalBRACE CCHVIZ) (Framework 14),
3. California Energy Commission's (CEC) **Social Vulnerability to Climate Change** (Framework 17), and
4. **Climate Change Vulnerability Screening Index** (English et al.) (Framework 21)

These frameworks are selected based on breadth (those that incorporate the greatest number of indicators across exposures and vulnerability factors) as well as accessibility of data (those with high-quality visualization platforms). Although three of these frameworks were developed by California agencies to inform planning and action around the state, they do not appear to be in broad use at this time.

California Healthy Places Index & CalBRACE CCHVIZ

The 25 indicators and 45 decision support data layers that compose HPI directly incorporate all 18 of CCHVIZ into its mapping platform.¹⁰⁸ Due to this redundancy in indicators, we consider the CCHVIZ as part of the broader HPI framework. Of the frameworks specific to California, HPI includes the most comprehensive and extensive range of socioeconomic factors, health outcomes, community characteristics, and environmental exposures that contribute to vulnerability. The evidence base for each of the CCHVIZ is well documented in an accompanying narrative from CalBRACE. It is important to note that climate vulnerability is not the primary or exclusive purpose of HPI; it is intended to reflect community conditions that predict life expectancy and paint an overall picture of health and well-being in California. The CCHVIZ as a stand-alone indicator set, however, are explicitly relevant to climate vulnerability.

The HPI interface is one of the most accessible and user-friendly mapping frameworks with a variety of intuitive features. For example, it allows users to select multiple relevant indicators based on desired application and then generates and displays a custom percentile ranking of “healthy conditions” based on the user’s selection. This composite score can be aggregated at geographic scales as granular as the census tract

level or as expansive as the metropolitan planning organization (MPO) level. Therefore, HPI can be used in a wide variety of decision making and policy applications both according to substantive content and geographic scope. In addition, the HPI offers a policy guide, which connects each individual indicator to a sample of concrete policy actions that can address the status of the conditions described by that indicator.

Social Vulnerability to Climate Change in California

This study from the California Energy Commission (CEC) & Pacific Institute (Framework 17) is unique in its primary objective “to identify geographic areas within the state with heightened risk to projected climate impacts, as a guide to policymakers and affected communities on where to focus climate adaptation efforts.”⁹⁸ The study highlights the cumulative nature of risk from climate change by defining it as a function of exposure to projected climate impacts and preexisting social vulnerability. The various maps outlined in the study identify both where social vulnerability to climate change is greatest and where this vulnerability intersects with the most severe projected climate change impacts. The study also offers an extensive and informative regional analysis based on counties where exposure and social vulnerability overlap.

The main limitation with this analysis is the lack of an interactive mapping platform with features to further explore data trends. Maps displaying the climate vulnerability index as well as the 19 individual indicators that compose the index are available online, but the significant lag in display reduces user ease and accessibility. Overlay of climate projection data for the four exposures included in the study are only available as static maps in the report. Furthermore, this study has not been updated since its original release in 2012. Future support to translate this analysis into a user-friendly, multifeature mapping platform with updated climate projections and social vulnerability data would address these gaps.

Climate Change Vulnerability Screening Tool

English et al.’s (Framework 21) approach to measuring climate vulnerability is comprehensive in identifying populations at high risk from climate change and overlaying community-specific cumulative impacts data. Moreover, this framework incorporates an environmental justice lens by representing the interaction between climate risk and social and health disparities alongside pollution exposure and hazard proximity. The climate data elements are less extensive than the aforementioned frameworks. The risk scores developed in this study, which average cumulative impacts and climate change vulnerability, are available at the census tract level for Los Angeles and Fresno. The maps are not available in an interactive mapping platform, but the study concludes with a recommendation to include the data in a dynamic online tool to allow stakeholders to engage with the data based on user needs.

STRONG FRAMEWORKS FOR MEASURING INDIVIDUAL CLIMATE IMPACTS

Two additional frameworks stand out in depicting vulnerability to specific climate impacts, selected based on California-specific statewide data availability and accessibility of visualization platform. These are:

1. **California Heat Assessment Tool (CHAT)**
2. Climate Central **Surging Seas Risk Zone Map**

California Heat Assessment Tool (CHAT)

The California Heat Assessment Tool (CHAT) (Framework 30), developed by consulting firm Four Twenty Seven, offers an integrated approach to measure and display overall heat vulnerability based on projected changes to extreme heat events alongside relevant social, environmental, and health factors. This is represented by the Heat Health Action Index, a composite score of the vulnerability factors, which is overlaid with historical and projected heat data.¹⁰⁹ The interface includes many of the relevant sensitivity and adaptive capacity indicators for heat as identified in Table 2 below.

Surging Seas Risk Zone Map

The Surging Seas Risk Zone Map (Framework 25) developed by Climate Central shows areas vulnerable to near-term flooding from different combinations of sea level rise, storm surge, tides, and tsunamis, or to permanent submersion by long-term sea level rise. In addition to visualizing sea level rise and flooding

projections by various emissions scenarios, users can configure maps according to water level and overlay social vulnerability, population density, racial composition, and property value against flood maps.¹⁰⁴ Key landmarks such as hospitals, schools, houses of worship, and power plants are also represented. This tool is user-friendly and incorporates language that is accessible to non-technical audiences.

OPPORTUNITY FOR SET OF INDICATORS TO UNDERSTAND AND ASSESS COMMUNITY VULNERABILITY TO CLIMATE IMPACTS

Researchers Do Not Need to Develop New Climate Vulnerability Indicator Sets

Based on this review, there are many existing frameworks that compile indicators in order to identify places and populations most impacted by climate change threats. Table 1 underlines the redundancy of various frameworks, as many compile similar sets of indicators. However, there are discrepancies in the way the indicators are displayed. Many of the frameworks specific to California feature an interactive platform—Surging Seas Risk Zone Map (Framework 25), UCS Rising Seas (Framework 27), CHAT (Framework 30), HPI (Framework 13), CEC Energy Equity Indicators (Framework 18), for example—which offers openings for translating data into formats useful for decision making as well as public accessibility. However, several of these user-friendly frameworks fall into silos based on climate impact or sector. This makes it difficult to look comprehensively at climate risks for populations or geographic areas within California.

California Policymakers Require a Centralized and Well-Disseminated Set of Climate Vulnerability Indicators and an Accompanying Visualization Platform

Accordingly, local, regional, and state policymakers implementing adaptation programs and developing new policies could benefit from a streamlined compilation of the strongest existing mapping frameworks into a single interface. With appropriate validation and visibility, this interface could serve as an integral indicator set and visualization platform to understand and address climate vulnerability and identify where to focus particular programs. Ideally, this platform would allow users to toggle between different exposures and overlay individual exposure categories with relevant sensitivity and capacity factors. Although some vulnerability indicators overlap across several exposures, many are specifically associated with certain climate change impacts (e.g., air conditioning access and extreme heat). In order to facilitate ease in usability, the platform would automatically populate relevant vulnerability indicators for each selected exposure.

Many Indicators Apply Generally Across Multiple Impacts

Based on 1) this review of frameworks, indicator sets, and reports; and 2) data availability, Table 1 highlights particular indicators that warrant inclusion in such an indicator set and visualization platform to broadly and comprehensively assess community vulnerability across climate change impacts in California. The listed exposures are selected based on availability of existing data as well as climate projection data to represent future changes. The listed sensitivity and adaptive capacity indicators reflect those that are most frequently included across the frameworks in this review (**Table 1**), most frequently applied across multiple exposures (**Table 2**), emerged as strong drivers of vulnerability (based on statistical analysis conducted in reviewed studies), and for which rigorous data is available.

These include (but are not limited to):

- **Exposure:** temperature, wildfire threat, flood risk, drought, air quality
- **Sensitivity**
 - **Demographics:** race/ethnicity, linguistic isolation, poverty, elderly, children, disability, foreign born (percentage by census tract)
 - **Socioeconomic:** unemployment, educational attainment (high school), income inequality (Gini coefficient by city or county), health insurance coverage, food insecurity, voter participation (percentage by census tract)
 - **Housing:** tenure (percentage renters), affordability (percentage housing burdened)
- **Adaptive Capacity:** vehicle access, transit access, medical facilities, emergency services/responders

Table 1 substantiates the wealth of data and knowledge about population sensitivity. By contrast, there are fewer indicators representing adaptive capacity. This may reflect opportunities for further research.

Other Indicators Are Specific to Distinct Climate Impacts

The sensitivity and adaptive capacity indicators listed above apply across exposures. Therefore, **Table 2** further categorizes factors by relevance to specific exposures based on the evidence provided in this review. Additional sensitivity and adaptive capacity indicators have well-established links to specific projected climate impacts and therefore represent important indicators.

These include (but are not limited to):

- **Temperature**
 - **Sensitivity:** urban heat island, elderly living alone, asthma, cardiovascular disease, diabetes, obesity, outdoor workers, energy costs
 - **Adaptive Capacity:** impervious surfaces, tree canopy/green space, air conditioning
- **Wildfire Threat**
 - **Sensitivity:** elderly living alone, obesity, outdoor workers, industrial/hazardous sites, energy costs
- **Flood Risk**
 - **Sensitivity:** asthma, industrial/hazardous sites
 - **Adaptive Capacity:** impervious surfaces, flood insurance
- **Drought**
 - **Sensitivity:** farmworkers, diabetes
- **Air Quality**
 - **Sensitivity:** industrial/hazardous sites, outdoor workers, asthma, cardiovascular disease, obesity, diabetes
 - **Adaptive Capacity:** tree canopy/green space

REVIEW OF FRAMEWORKS: NATIONAL LEVEL

The following section reviews and summarizes a number of existing tools and frameworks used in the United States. In addition to providing an overview of each of the frameworks, we offer analysis around process and application, and examine strengths and limitations. It is important to note that this review is not exhaustive of the rich volume of research and analytical frameworks to characterize climate vulnerability. This report samples a multitude of approaches across sectors and scope that integrate and represent climate vulnerabilities from a community perspective. Given the scope of this report and its specific application for California, most frameworks reviewed here either include the western region or focus analysis within the state.

QUANTITATIVE FRAMEWORKS

Framework 1. Climate Resilience Screening Index (CRSI)⁹⁵

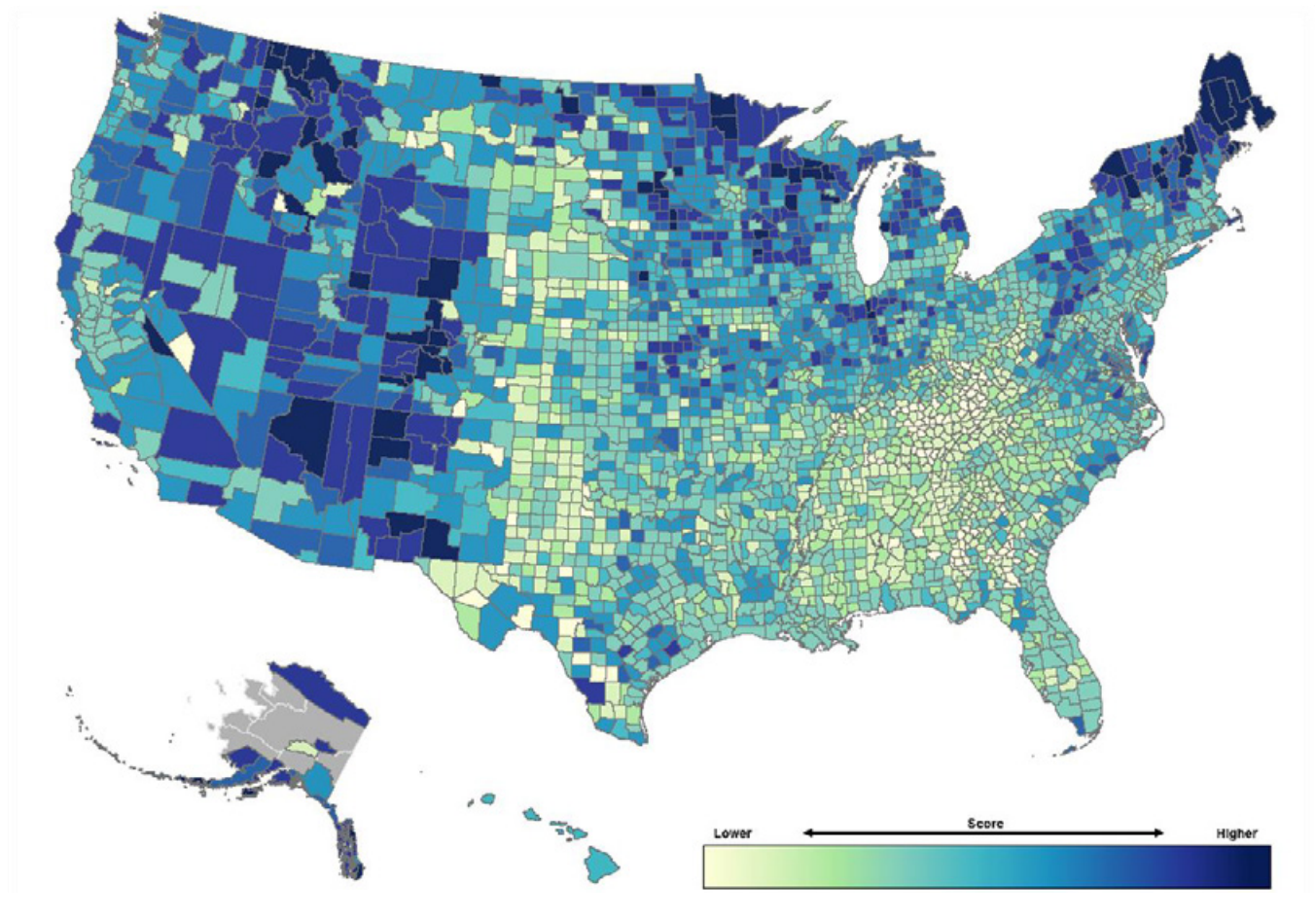


Figure 4 Map showing distribution of final Climate Resilience Screening Index (CRSI) scores across the U.S. (2000-2015). Darker colors indicate higher resilience scores; lower colors indicate lower resilience scores.

Released by the Environmental Protection Agency in October 2017, CRSI is a conceptual framework that characterizes resilience to acute climate events in light of community characteristics (**Figure 4**). It integrates metrics from a variety of county-level data sources and includes five overarching domains: 1) risk; 2) governance; 3) society; 4) built environment; and 5) natural environment, each of which contains multiple indicators (described below). The intended audience is EPA regional staff, who can use it to help communities identify potential target areas for resilience-enhancing efforts.

Development of the tool included a peer review process involving academics and EPA regional administrators, but the tool's documentation does not mention inclusion of a community engagement process. This framework is strong in its extensive literature review of existing tools. Indicators selected can be measured using publicly available and extractable data sources. Indicators within each of the domains are varied and wide-reaching: Risk includes exposure-related indicators like measures of extreme heat and drought; Governance includes community preparedness indicators like measures of structural hazard mitigation and biodiversity conservation; Society includes demographic indicators like non-English-speaking populations, as well as economic diversity and social cohesion indicators; Built Environment includes housing characteristics and physical infrastructure indicators; and Natural Environment includes indicators related to the condition of ecological resources, including forests.

Framework 2. Baseline Resilience Indicators for Communities (BRIC)⁹¹

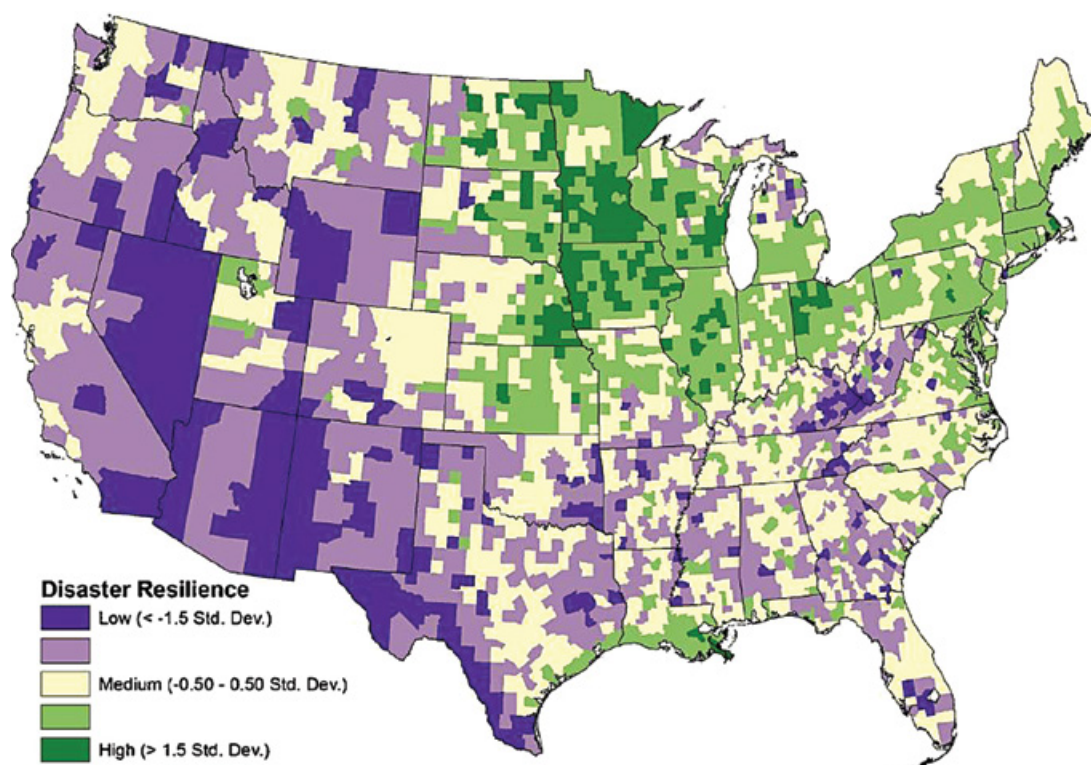


Figure 5 Map representing Disaster Resilience Index for Contiguous U.S., 2010 (Baseline Resilience Indicators for Communities).

Developed by University of South Carolina researchers, BRIC measures overall preexisting resilience in U.S. counties using six indicator sets: social resilience, economic resilience, community capital, institutional resilience, housing/infrastructural resilience, and environmental resilience. The most recent version is the 2015 BRIC, with a 2010 version also available (**Figure 5**). In constructing the BRIC, the researchers identify the data set, data provider, and year of each indicator corresponding to the resilience concept included in the overall BRIC metric. The authors note that while some of the indicators describe conditions that can be affected through policy or other action (e.g., educational and income inequality), other demographic characteristics are not intended to be altered (e.g., disabled persons or elderly).

Framework 3. Social Vulnerability Index (SoVI®)¹¹⁰

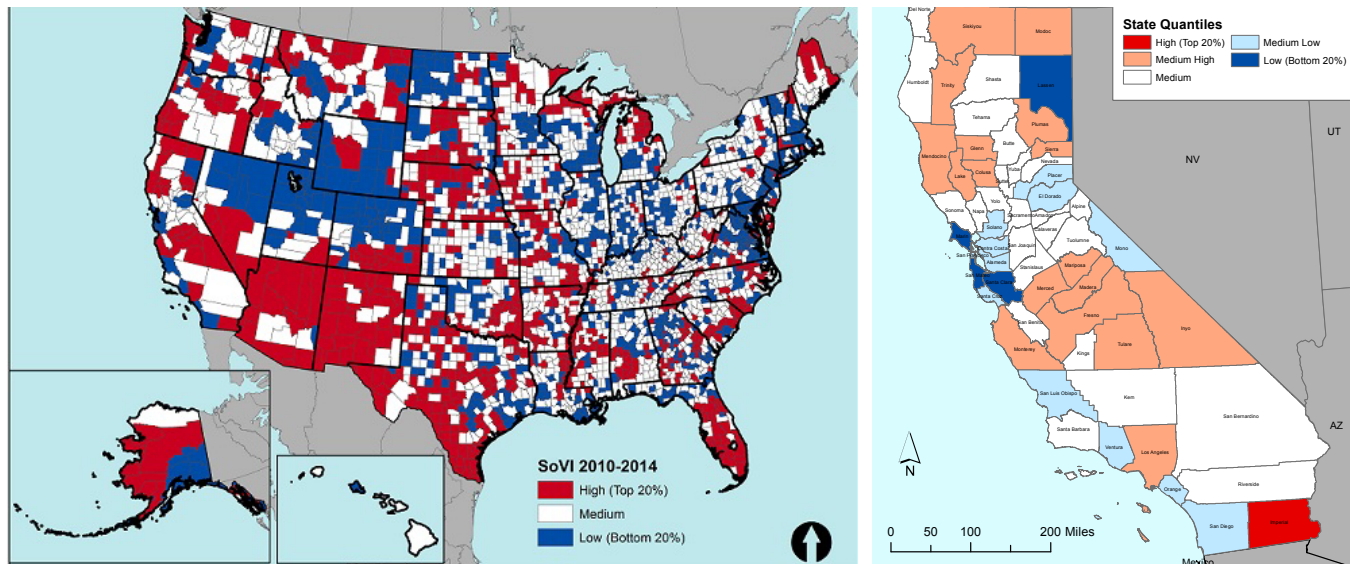


Figure 6 Overall Social Vulnerability Index (SVI) scores. *Left:* National map showing Social Vulnerability Index (SoVI®) 2010-14; *Right:* Map showing California's SoVI® 2010-2014 by county (comparison within the state).

Developed by the Hazards & Vulnerability Research Institute at the University of South Carolina in 2003, SoVI® is a social vulnerability metric that uses data primarily from the U.S. Census Bureau's American Community Survey (ACS) estimates. County-level scores by state for SoVI® 2010-2014 are available for download (**Figure 6**). The tool illustrates the variability in capacity for preparedness, response, and recovery at county and sub-county levels. SoVI® 2010-14 is the most recent version and includes additional factors capturing the role of family structure, language barriers, vehicle availability, medical disabilities, and healthcare access in disaster preparedness and response. It synthesizes 29 socioeconomic variables into a single composite value.

In SoVI® 2010-14, significant components contributing to differences in vulnerability include wealth, race (black, Hispanic, Native American), social status, percentage elderly residents, residents without health insurance, special needs individuals, service industry employment, and gender. SoVI® has been used by emergency planners as part of their state hazard mitigation planning, and has been incorporated into a number of climate vulnerability tools—e.g., UCS When Rising Seas Hit Home (Framework 27) and the Surging Seas Risk Zone Map (Framework 25).

Framework 4. Social Vulnerability Index (SVI)⁹⁶

The SVI, developed in 2011 by the Centers for Disease Control and Prevention's Agency for Toxic Substances and Disease Registry (ATSDR), uses U.S. Census Bureau data to determine the social vulnerability of every census tract in the country. The SVI ranks each tract on 15 social factors and groups them into four related themes: socioeconomic status, household composition, race/ethnicity/language, and housing/transportation. Each tract receives a separate ranking for each of the four themes, as well as an overall ranking. Available for download is documentation of the methodology underlying the SVI, a comprehensive data dictionary of variables used as well as publicly accessible state and county shapefiles ranked nationally and within each state (**Figure 7**).

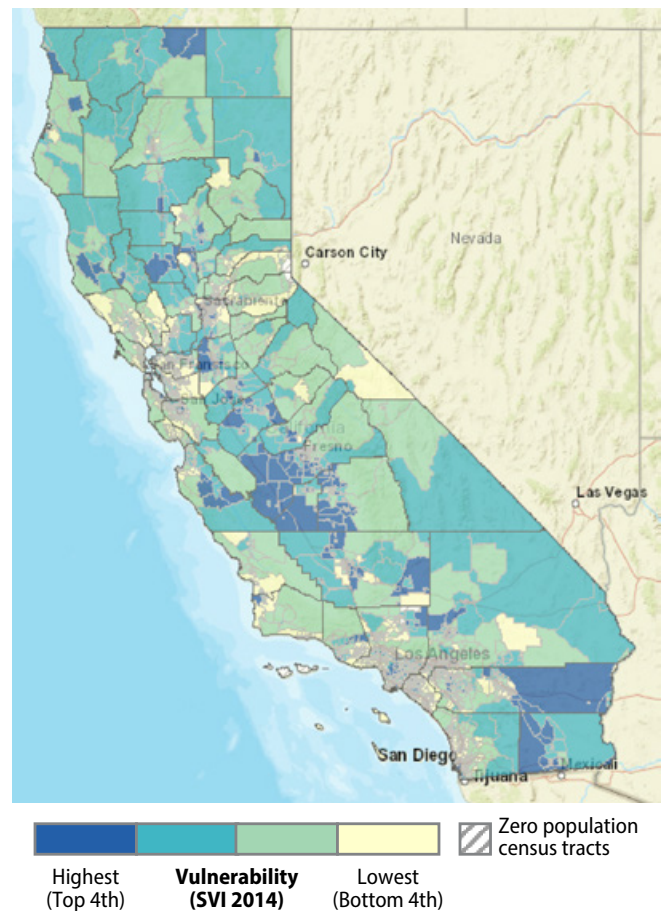


Figure 7 Overall Social Vulnerability Index (SVI) scores for California.

QUALITATIVE REPORTS

Several reports discuss various factors that should be considered in comprehensively understanding the vulnerability of low-income communities of color to climate disasters. These reports are especially useful in offering case studies and examples of the ways these factors have contributed to inequality in disaster response and recovery. The narratives are also helpful in offering a nuanced perspective on the way quantitative vulnerability indicators play out in the lived experiences of communities during extreme weather events. They are limited, however, in their assessment of data availability. Therefore, it is unclear from these reports alone whether there is data available for the factors mentioned and at what level to capture these contributing factors.

Framework 5. Social Cohesion: The Secret Weapon in the Fight for Equitable Climate Resilience¹¹¹

The Center for American Progress developed a report in 2015 underlining the importance of incorporating social cohesion into climate resilience planning. The report outlines several considerations regarding the vulnerability of low-income communities to climate change. Housing-related factors include quality of housing and infrastructure; economic-related factors include energy burden and lost wages; and health-related factors include the urban heat island effect as well as access to air conditioning.

Framework 6. A Disaster in the Making: Addressing the Vulnerability of Low-Income Communities to Extreme Weather¹¹²

This report, developed in 2013 by the Center for American Progress, outlines the unique vulnerability of low-income communities to climate disasters and identifies ways in which the federal government can strengthen its ability to address their needs at various stages of disaster response. It identifies the ways in which the strength and quality of housing, environmental factors, and economic stability programs like the Disaster Supplemental Nutrition Assistance Program (D-SNAP) and the Disaster Unemployment Assistance program all affect the ways in which people are impacted by climate disasters.

Framework 7. Equity in Building Resilience in Adaptation Planning¹¹³

A 2015 National Association for the Advancement of Colored People (NAACP) report compiled an extensive list of indicators and measures of vulnerability and resilience, underlining the argument that effective and equitable resilience planning must be designed to address preexisting vulnerabilities in communities. The report highlights preexisting vulnerabilities and assets before a climate event, encompassing domains such as demographics, housing security, mobility, health status, environmental hazards, emergency services, social services, and community knowledge, among others. This report offers no indication of data availability and accessibility in regard to the indicators identified, but comprehensively lists factors to consider.

Framework 8. Climate Change, Health, and Equity: A Guide for Local Health Departments⁵¹

This 2018 report, developed by the American Public Health Association in partnership with the Public Health Institute and Center for Climate Change & Health, offers local health departments guidance on how to address the health inequities exacerbated by climate crisis. Using a public health and equity perspective, the report highlights several components of climate vulnerability, exploring factors related to a community's exposure to climate threats, its sensitivity to climate impacts, and its capacity to adapt and respond to climate threats.

Framework 9. Proposed Recommendations for Promoting Community Resilience in Environmental Justice Industrial Waterfront Areas¹¹⁴

This 2015 report, prepared by the Community Resiliency in Environmental Justice Industrial Waterfront Communities Work Group for the U.S. Environmental Protection Agency's National Environmental Justice Advisory Council (NEJAC), discusses opportunities to build resilience among environmental justice communities in industrial waterfronts. The report does not outline data sources and indicators, but highlights specific issues that often go unconsidered in current adaptation planning. Factors contributing to the unique vulnerability of environmental justice communities highlighted in the case studies include proximity to industrial areas and hazardous waste sites, and toxic spills.

Framework 10. Mapping the Vulnerability of Human Health to Extreme Heat in the United States¹¹⁵

The EPA released the final version of this report on the development of mapping tools that capture health vulnerability to extreme heat in August 2018. The report discusses several existing methodologies in order to examine the challenges of developing these tools in the face of disagreement on appropriate approaches. With an intended readership of state and local health departments, community planners, emergency preparedness professionals, and other stakeholders, the report was created following individual interviews with experts including scientists from government and academia. The report includes a section called "Vulnerability Indicators" that discusses vulnerability and adaptive capacity indicators, as well as development of indicator indices and issues of geographic scale. Drawing from existing indices like the SoVI® 2010–2014, this discussion identifies specific relevant vulnerability and adaptive capacity indicators.

REVIEW OF FRAMEWORKS: CALIFORNIA-SPECIFIC

QUANTITATIVE FRAMEWORKS

Framework 11. California Communities Environmental Health Screening Tool (CalEnviroScreen)¹¹⁶

First developed in 2013 by the Office of Environmental Health Hazard Assessment (OEHHA), CalEnviroScreen (CES) is a statewide screening methodology and mapping tool that uses state and federal environmental, health, and socioeconomic data to rank census tracts in terms of exposure and vulnerability to pollution. CalEPA uses the tool to identify disadvantaged communities (DACs), those that are disproportionately burdened by multiple sources of pollution, for the purposes of state policy such as prioritizing protections, permitting, enforcement, and funding. Census tracts whose overall CES score lies within the top 25 percent and census tracts scoring in the top 5 percent for Pollution Burden are considered DACs.

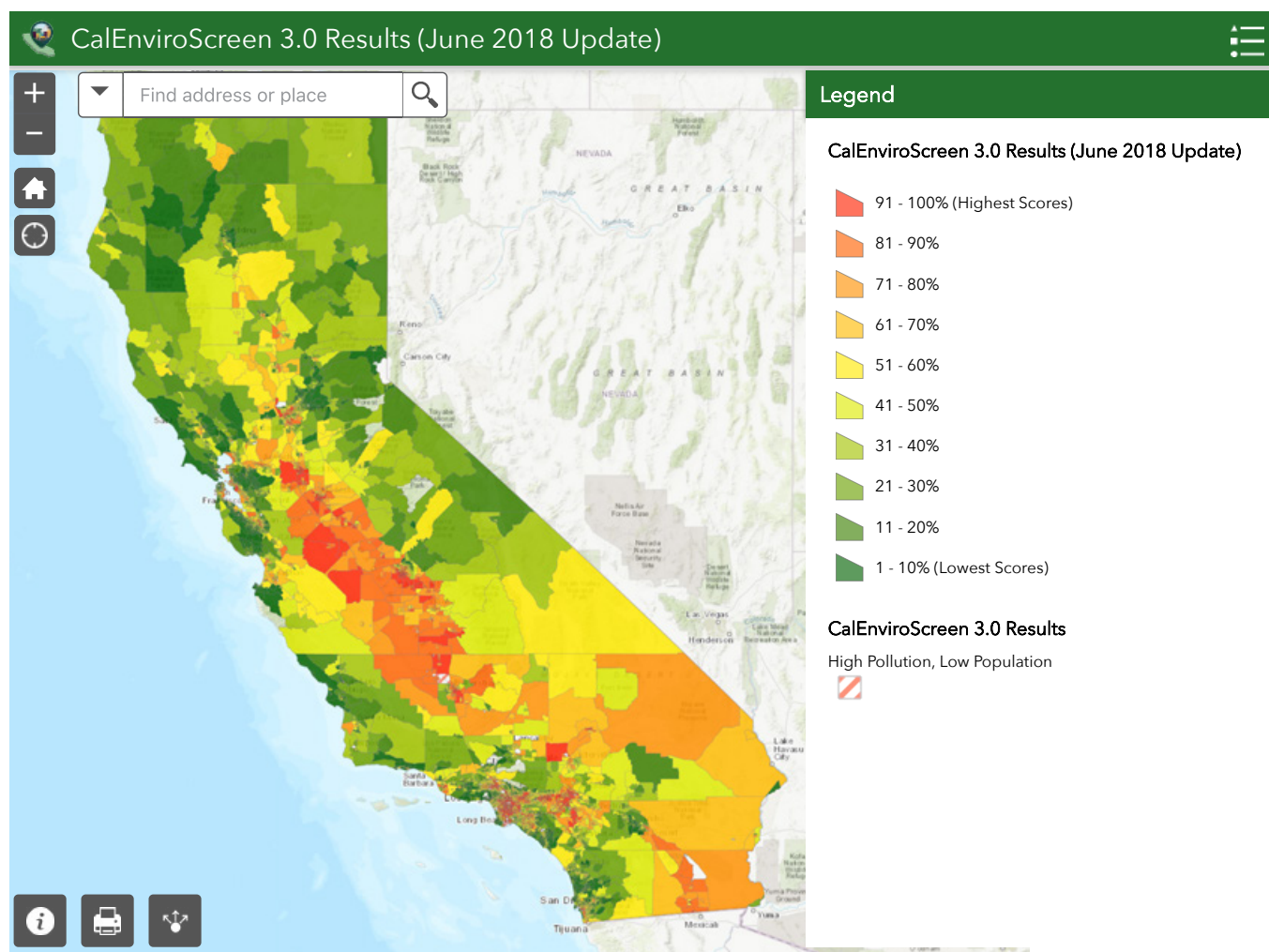


Figure 8 Overall CalEnviroScreen 3.0 (CES 3.0) scores for California.

The tool has undergone several iterations, with CES 3.0 as the most current version (last updated in June 2018). The development of each version has involved opportunities for the public to provide feedback. CES 3.0 includes 20 indicators, with exposure and environmental effects indicators making up the pollution burden domain, and sensitive population and socioeconomic factor indicators making up the population characteristic domain. It should be noted that CES is not designed to depict climate vulnerability and therefore does not include indicators related to climate impacts or adaptive capacity. It does, however, incorporate relevant population sensitivity indicators—linguistic isolation, educational attainment, unemployment, and poverty. CES 3.0 does not integrate race/ethnicity indicators, but does include an analysis of racial composition by census tract. Users can view the full CES map as well as individual indicator maps through OEHHA's website (**Figure 8**).

Framework 12. Environmental Justice Screening Method (EJSM)¹¹⁷

Developed by researchers Manuel Pastor, Rachel Morello-Frosch, and James Sadd in 2011, EJSM is a tool that identifies environmental justice communities based on measurements of cumulative impacts and social vulnerability. It uses 23 indicators to create a cumulative impacts score for census tracts and ranks them regionally within California rather than statewide. The authors note that though the tool can be used for statewide comparisons, it employs a regional focus to account for the fact that land use planning, industrial and transportation development, and environmental regulation are regionally rooted. The indicators, based on publicly available data, are organized into the following groups: hazard proximity and land use, air pollution exposure and estimated health risk, and social and health vulnerability.

In developing the tool, the researchers worked closely with scientists from the California Air Resources Board (CARB), which solicited and funded the analytical work involved. The development of the method also involved peer review from not only an external scientific peer review committee, but also CARB staff, scientists, and community stakeholders. Notably, development of the EJSM involved ground-truthing processes carried out by local residents and organizations in the Los Angeles area. These validation processes utilized local observation and data-gathering, including air monitoring to check data accuracy as well as the predictive value of the approach.

Framework 13. Cal-Adapt¹¹⁸

Cal-Adapt was designed to provide access to the wealth of data and information that is produced by California's scientific and research community on climate change impacts. Therefore, Cal-Adapt is not an assessment tool or set of indicators, but rather functions as a source of data. Users can explore charts, maps, and data of observed and projected climate variables for California based on two different emissions scenarios. The data available on this site is downloadable and is specific to various types of exposure, including extreme heat, sea level rise, and wildfires. Cal-Adapt is strong for its extensive database of climate impact projections, which have been used by other tools. The map feature allows visualization of CalEnviroScreen 2.0 census tracts, which can present climate projections for particular areas based on CES score. This has limited utility, however, since this version is now outdated.

Framework 14. California Healthy Places Index (HPI)^{119,108}

Developed by the Public Health Alliance of Southern California in 2018, HPI (formerly the Health Disadvantage Index) is a composite index that weighs and combines 25 community characteristics to identify cumulative health advantage in California. The index divides HPI indicators into eight Policy Action Areas: economic, education, transportation, social, neighborhood, clean environment, housing, and healthcare access. Users can also sort by decision support layers, which include a diverse set of climate vulnerability indicators. Individual HPI and decision support indicators are available for download along with the HPI map shapefile. HPI can be used for various applications, as data can be aggregated at various levels, including census tract, county, congressional district, and city (**Figure 9**). Custom scores can also be created based on a selection of multiple indicators.

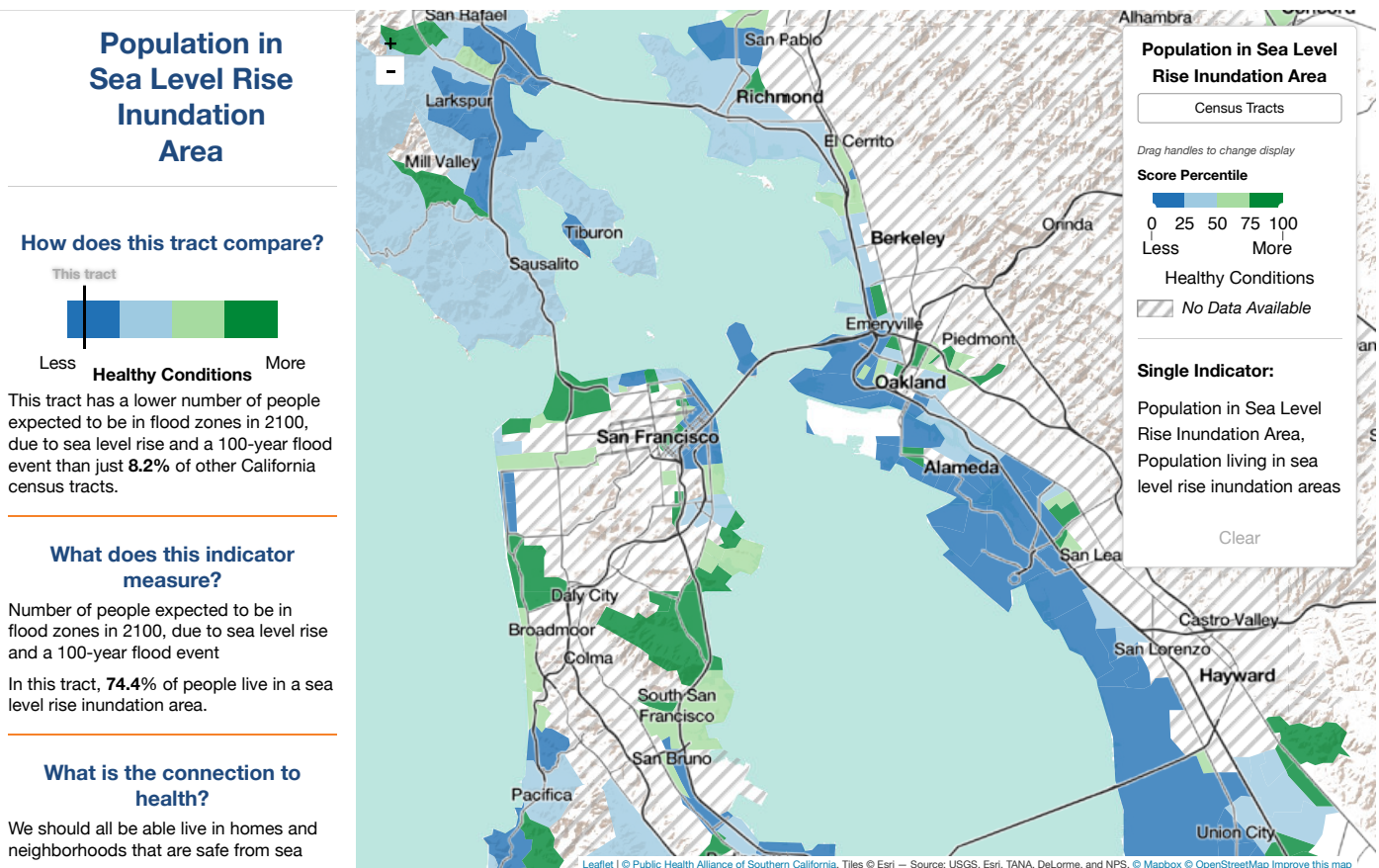


Figure 9 California Healthy Places Index (HPI) “Population in Sea Level Rise Inundation Area” map for the Bay Area.

Framework 15. California Building Resilience Against Climate Effects (CalBRACE) Climate Change and Health Vulnerability Indicators for California (CCHViz)¹⁰⁷

The CalBRACE Project of the California Department of Public Health provides resources and technical assistance for state and local public health departments to enhance resilience at the local and regional levels. In 2017, the project developed CCHViz, which are organized under three domains: environmental exposures, population sensitivity, and adaptive capacity. The data visualization platform offers several user-friendly features, including visualization of California counties based on the intersection of a select exposure variable and a population sensitivity variable, county snapshots that highlight how selected county compares to the state average for each indicator, and maps of single indicators (**Figure 10**). All data in figures and maps is available for download. This project summarizes Cal-Adapt climate change projections for various regions. CalBRACE also created Climate Change and Health Profile Reports for all California counties based on impacts at the climate region level.¹²⁰

Vulnerability

Visualize California Counties based on levels of both an exposure variable and a population sensitivity variable.

The plot illustrates the intersection of hazard (from an 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 top and right-most portions of the figure. Points are sized according to the population living in that county. Hover over points for the 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

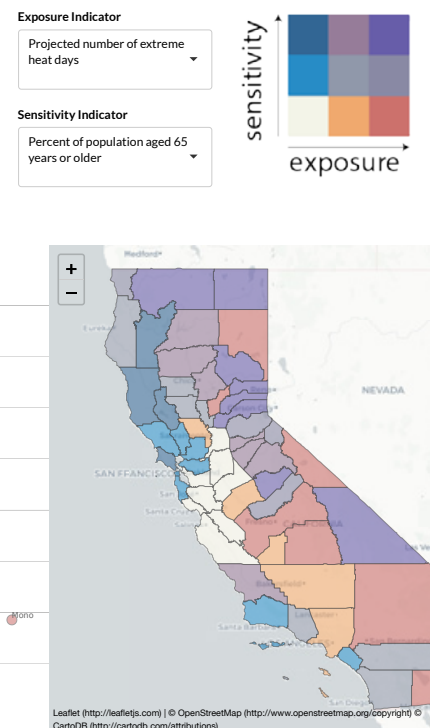


Figure 10 Climate Change and Health Vulnerability Indicators for California (CCHViz) data visualization platform.

Framework 16. 2018 Report: Indicators of Climate Change in California⁹

The 2018 version of the *Indicators of Climate Change in California* report, developed by OEHHA, presents 36 indicators that document some of the ways that climate change is occurring in California and its effects on the state's weather, environment, and wildlife. The indicators are scientifically based measurements that track trends in various aspects of climate change. The report highlights sources and characteristics, as well as strengths and limitations of the data for each indicator. Relevant indicators to community resilience include annual air temperature, extreme heat events, cooling and heating degree days, precipitation, drought, sea level rise, wildfires, vector-borne diseases, and heat-related mortality/morbidity. Overall, the tool is focused on natural systems impacts.

Framework 17. Indicators of Climate Change in California: Environmental Justice Impacts Report¹²¹

Created in 2010 at the request of CalEPA's Office of the Secretary, this report by OEHHA identifies four indicators to describe the disproportionate climate change impacts faced by environmental justice (EJ) communities. They are intended for use in better understanding climate change-related EJ concerns. The four indicators are air conditioner ownership and cost, farmworker exposure to extreme heat, exposure to urban heat, and vulnerability to wildfires. In developing the indicators, OEHHA only chose those for which there existed California-specific, community-level data. Consistent with the OEHHA's Indicators of Climate Change Report, this report highlights characteristics as well as strengths and limitations of the data for each indicator.

Framework 18. Social Vulnerability to Climate Change in California⁹⁸

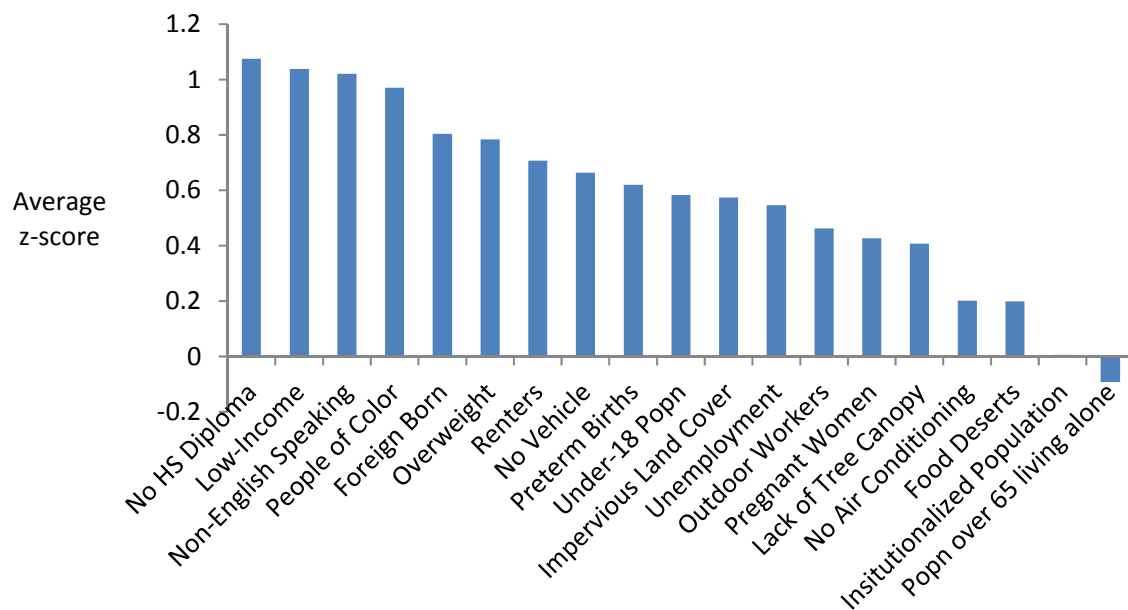


Figure 11 Contributing Factors in the Most Vulnerable Areas of the State (Social Vulnerability to Climate Change in California).

This study developed by Cooley et al. (2012) looks specifically at social vulnerability to climate change and frames climate risk as a function of exposure and vulnerability. The primary objective of the research was to identify areas within the state with heightened risk to projected climate impacts. The researchers developed a climate vulnerability index to indicate the social vulnerability of a region's population to climate-related harm. The index compiles 19 social vulnerability factors to create a single index. The data source for each factor is outlined in the report. The vulnerability index score maps are overlaid with maps of projected exposure to climate disturbances. According to the study's analysis, the factors that most significantly contributed to variability of scores include educational attainment, poverty, linguistic isolation, and race (**Figure 11**).

The development of this study was unique in its equitable community engagement process. A Project Advisory Committee made up of community-based organizations and government agencies provided input on analytical methods and availability of quality data used.

Framework 19. Energy Equity Indicators^{122,123}

In its Energy Equity Indicators Tracking Progress Report and Energy Equity Interactive Story Map, the California Energy Commission presents a set of nine energy equity indicators to evaluate progress for advancing SB 350 Low-Income Barriers Study recommendations. In addition to clean energy access and investment, the indicators also measure energy resilience, or the energy services that allow communities to use affordable energy even in the face of climate uncertainty. Examples of indicators highlighted include heat-related illness by county, local electricity reliability, and critical facilities.

QUALITATIVE REPORTS

Framework 20. California's Fourth Climate Change Assessment: Climate Justice Report¹⁸

This summary report on climate justice, released in 2018 as part of California's Fourth Climate Change Assessment, presents a literature review of climate science, adaptation strategies, and research gaps centered on the needs of the state's frontline communities. The report lists several social, economic, and environmental factors that impact climate vulnerability, including those relating to climate impact, as well as demographic and socioeconomic characteristics. It also identifies other factors such as having substandard living conditions, living in areas with lots of impervious surfaces and little tree cover, and lack of social capital.

REVIEW OF FRAMEWORKS: REGIONAL & LOCAL EXAMPLES

CITIES & REGIONS IN CALIFORNIA

Framework 21. Racial and Income Disparities in Relation to a Proposed Climate Change Vulnerability Screening Method for California¹⁰²

This 2013 study developed by English et al. in *The International Journal of Climate Change: Impacts and Responses* presents a screening method to identify populations at high risk from climate change impacts using population vulnerability and the effects of cumulative stressors (**Figure 12**). It also investigated whether racial/ethnic and income disparities affect climate change vulnerability. Metrics were chosen based on the literature and data availability at the census tract level for Fresno and Los Angeles counties. The study includes measures of exposure related to climate change, population sensitivity, and adaptive capacity. The study adds the Environmental Justice Screening Methodology (EJSM), an existing index that measures cumulative impacts.

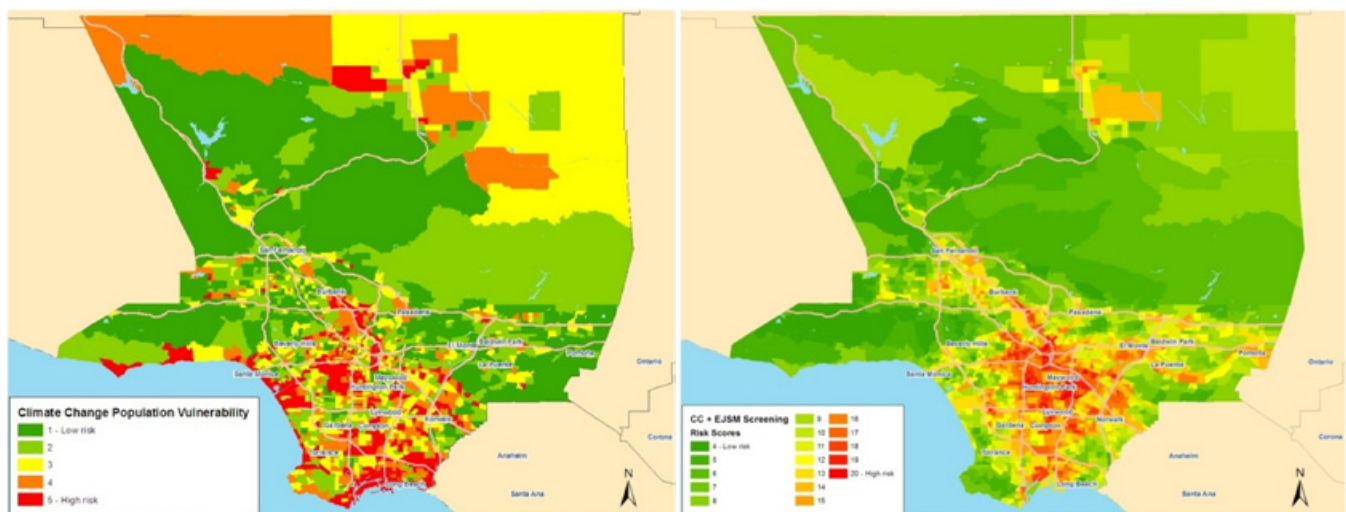


Figure 12 Left: Climate Change Population Vulnerability Scores by census tract;
Right: Cumulative Impacts Plus Climate Change Vulnerability Scores, both for Los Angeles County.

Framework 22. Community Indicators for Flood Risk¹²⁴

The Association of Bay Area Governments (ABAG) and the San Francisco Bay Conservation and Development Commission (BCDC) developed community indicators for flood risk as part of the Adapting to Rising Tides project. An advisory committee of community advocates and other experts selected indicators. It should be noted that qualitative factors that may affect risks (e.g., community cohesion and social capital) are not included. Data sources used originate primarily from the 2010–2014 American Community Survey, and are all publicly available. The 10 indicators are language, access to a vehicle, housing cost burden, race and ethnicity, education, housing tenure, transportation cost burden, income, and age.

CASE STUDY

LOCAL EXAMPLES FROM OTHER STATES: EXTREME HEAT

Framework 23. Heat Vulnerability in Denver¹²⁵

This map, developed by the City and County of Denver (Colorado) Department of Public Health & Environment evaluates Denver's vulnerability to extreme heat in the context of relevant interconnected socioeconomic, health, and environmental conditions (**Figure 13**). The analysis is at the census tract level and creates a heat vulnerability score, a composite measure of individual maps showing population information and indicators in the following categories: the built environment, including impervious surface and tree canopy; demographics, including vehicle access and race; and human health, including ambulatory disabilities and adult diabetes. The accompanying methodology describes the publicly available data sources, which were standardized to allow comparison, aggregation, and scoring.

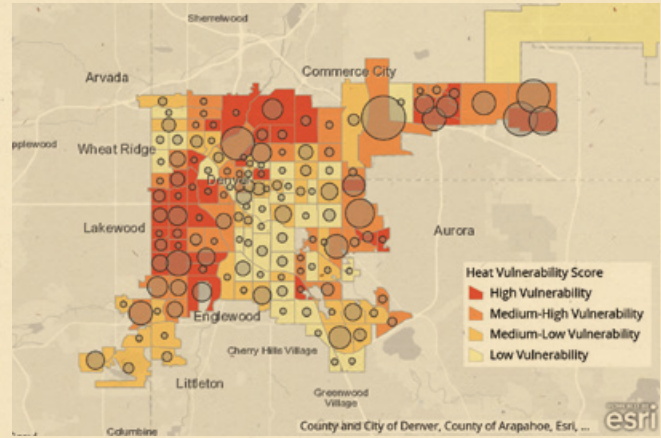


Figure 13 Heat Vulnerability Scores by census tract for Denver.

Framework 24. Heat Vulnerability Index Philadelphia¹²⁶

This study mapped a Heat Vulnerability Index to identify vulnerability at the block level in Philadelphia (**Figure 14**). The index aggregated the following indicators representing demographics of high-risk populations (all publicly available from the 2015 American Community Survey): age (65 years and older), race (all non-white), socioeconomic status (poverty rate), educational attainment (less than high school), and living alone. Tree count by block group was also used as an indicator. Combining this data, the team developed a cumulative vulnerability scoring system to create a comprehensive map of the city of Philadelphia.

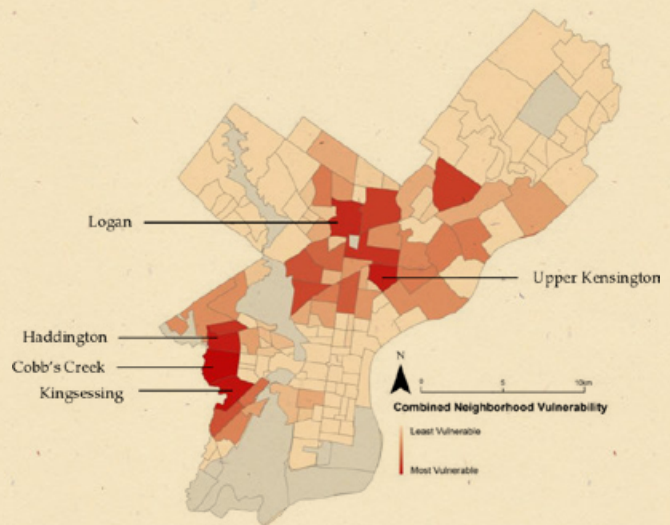


Figure 14 Map showing cumulative vulnerability scores for heat vulnerability and lack of street trees by neighborhood in Philadelphia. Gray areas are areas with no data.

REVIEW OF FRAMEWORKS: INDIVIDUAL CLIMATE IMPACTS

SEA LEVEL RISE & COASTAL FLOODING

Framework 25. Surging Seas Risk Zone Map^{104,127}

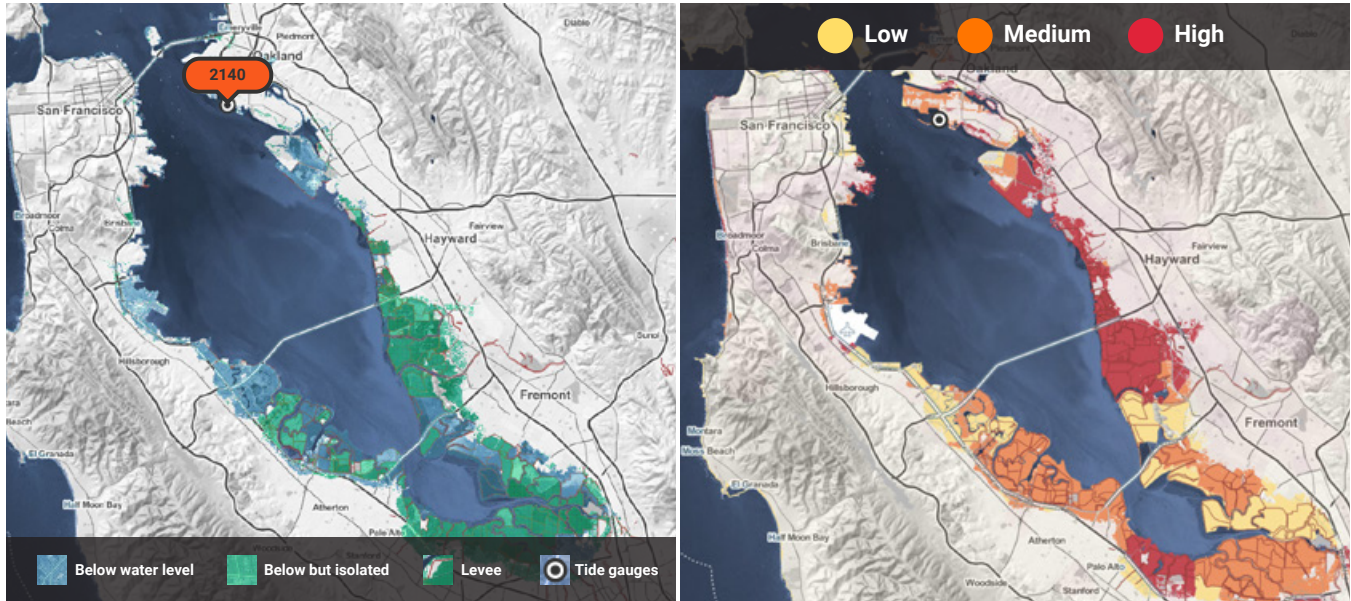


Figure 15 *Left:* Surging Seas sea level rise projection map under unchecked pollution scenario and at water level of 3 feet (marker shows that sea level rise reaches 3 feet in Alameda in 2140; *Right:* Social Vulnerability Index (SVI) map; both for the Bay Area.

Developed by Climate Central, this tool aims to provide various stakeholders with accessible, science-based information to understand and respond to risks of sea level rise and coastal flooding. The toolkit includes maps, sea level and flood risk projects, and potential impacts for population, land, and other variables (**Figure 15**). The tool includes a description that lists the full citation for each sea level model, key assumptions, and data sources. The user-friendly interface allows visualization of multiyear risk of flooding above selected water levels, coastal flood days, land below selected water levels by city council, and housing exposed to flooding. The social vulnerability index available is derived from the SoVI®.

Framework 26. Risks of Sea Level Rise to Disadvantaged Communities in the United States¹⁰³

In this 2013 report, researchers used both the SoVI® and output from a sea level rise coastal property model that evaluates the threats of flooding and the efficiency of adaptation responses to pinpoint areas that may face disproportionate impacts of sea level rise (Figure 16). The underlying methodologies of these approaches are cited for reference. It also identifies areas where socially vulnerable populations would face disproportionate adaptation costs. The analysis finds that many socially vulnerable communities fall within the coastal zone at risk of sea level rise.

Framework 27. When Rising Seas Hit Home: Hard Choices Ahead for Hundreds of U.S. Coastal Communities¹⁰⁰

The Union of Concerned Scientists published this report in 2017 to identify which communities will become chronically inundated during this century and when that will happen. Chronically inundated communities are defined as those coastal communities that experience flooding once every other week (on average), or on 10 percent or more of its land area, excluding wetlands and areas protected by federal levees. The analysis and data sources underlying the approach are articulated as part of the series of maps (Figure 17).

Framework 28. Coastal Resilience California¹²⁸

Coastal Resilience California is a program led by the Nature Conservancy to examine nature-based coastal flood risk reduction solutions. The program is made up of a four-step approach, a mapping tool, and a network of hazard mitigation and climate adaptation planning professionals. The online mapping tool allows visualization of sea level rise and coastal hazard projections (2010-2100) along the state's coast. In addition, the tool allows evaluation of interventions including the economics of nature-based adaptation strategies, future habitat changes, and considerations for community or regional planning. Statewide and regional projections are displayed with links to the accompanying exposure data and technical reports.

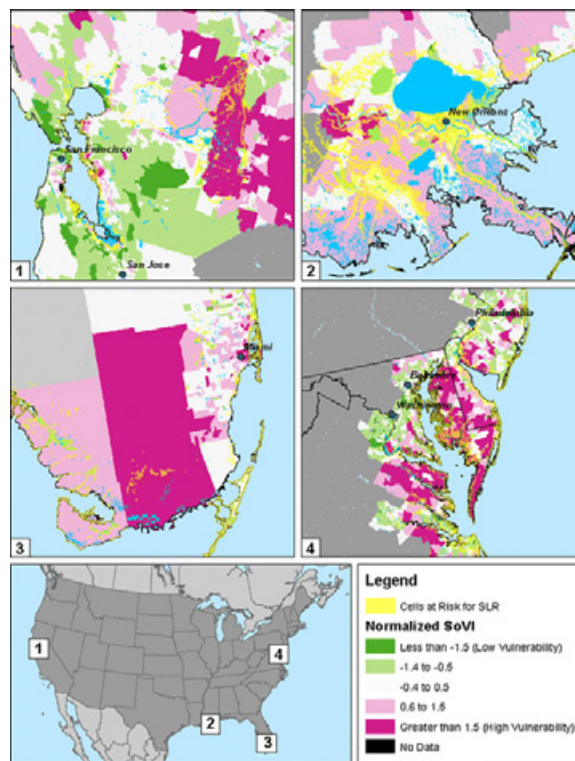


Figure 16 Maps of four regions of the U.S. showing exemplary sea level rise risk areas with high social vulnerability under a scenario with no adaptation.

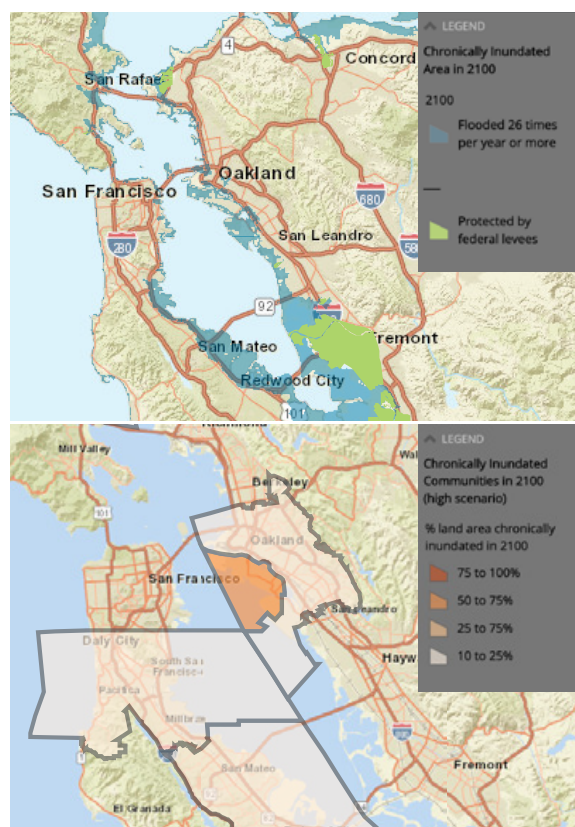


Figure 17 Top: Chronically Inundated Areas in 2100; Bottom: Percent Land Area Chronically Inundated in 2100.

HEAT

Framework 29. Urban Heat Island Index for California (UHII)^{129,130}

In 2012, the California Environmental Protection Agency was directed by the state to create an Urban Heat Island Index. In 2015, the agency released *Creating and Mapping an Urban Heat Island Index for California*, which quantifies the extent (duration) and severity (magnitude) of urban heat islands at the city level and includes interactive maps that allow for visualization of the urban heat island effect for California's urban areas at the census tract level. The study can help identify and prioritize areas for adaptation efforts such as urban greening, cool roofs, and pavements. Downloadable individual maps and data files are available through CalEPA.

Framework 30. California Heat Assessment Tool (CHAT)^{109,131}

Sponsored by the California Natural Resources Agency under the 2018 California Fourth Climate Change Assessment and developed by consulting firm Four Twenty Seven, this tool is intended to help public health and planning practitioners better prepare for extreme heat events. Indicators are available by census tract and are grouped into four categories: projected changes to heat health events, social vulnerability, health, and environment. They have also been compiled into the Heat Health Action Index, a composite score intended to represent total heat and health vulnerability. An accompanying technical document provides a description of the methods, findings, and limitations of the tool.

Framework 31. Mapping Community Determinants of Heat Vulnerability¹⁰⁰

This 2009 study analyzes 10 factors for vulnerability to heat-related morbidity/mortality (**Figure 19**). The factors include several demographic characteristics and household air conditioning variables, as well as vegetation cover and diabetes prevalence. The study outlines the data sources, vulnerability variables, and level of aggregation of the data sets that were used in the analysis. According to the analysis, four of the variables explain the majority of the variance in the variables: social/environmental vulnerability, social isolation, air conditioning prevalence, and proportion elderly/diabetes.

Framework 32. The 2006 California Heat Wave: Impacts on Hospitalizations and Emergency Department Visits⁹⁹

This 2008 study examined the number of hospitalizations and emergency department visits by age and race/ethnicity during the 2006 California heat wave (**Figure 20**). The study articulates the sources of the data in the materials and methods section. The results reveal that emergency department visits for heat-related causes increased across California during the heat wave. The Central Coast region, which includes San Francisco, was especially impacted, and children and the elderly were found to be at greatest risk. This study suggests that a useful indicator to understand climate vulnerability is heat-related morbidity and emergency department visits.

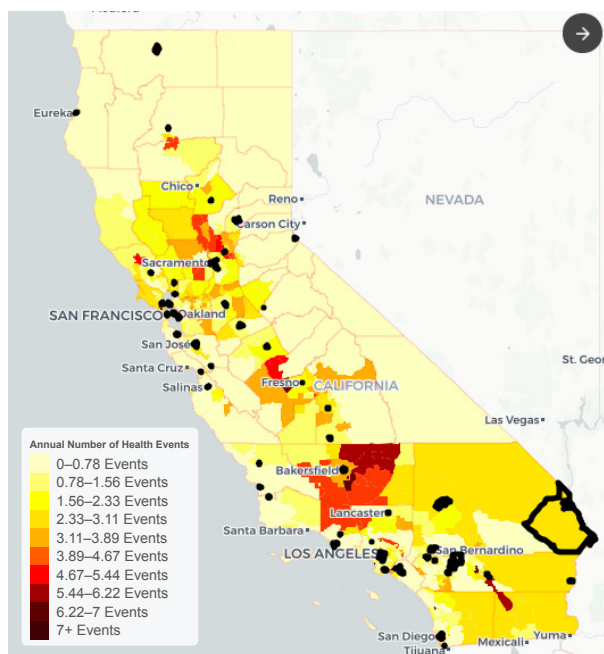


Figure 18 California Heat Assessment Tool (CHAT) Heat Health Action Vulnerability Index map (based on annual number of heat health events expected 2041-2060). Bold black outlines indicate high-priority census tracts based on selected vulnerability indicators.

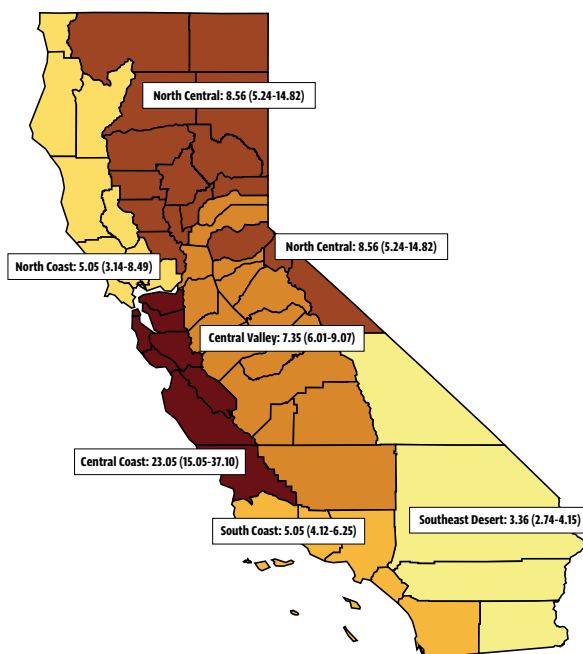


Figure 20 Map showing rate ratios for emergency department visits for heat-related illnesses during the July 15 to Aug. 1 heat wave, compared with a reference period (2006 California Heat Wave).

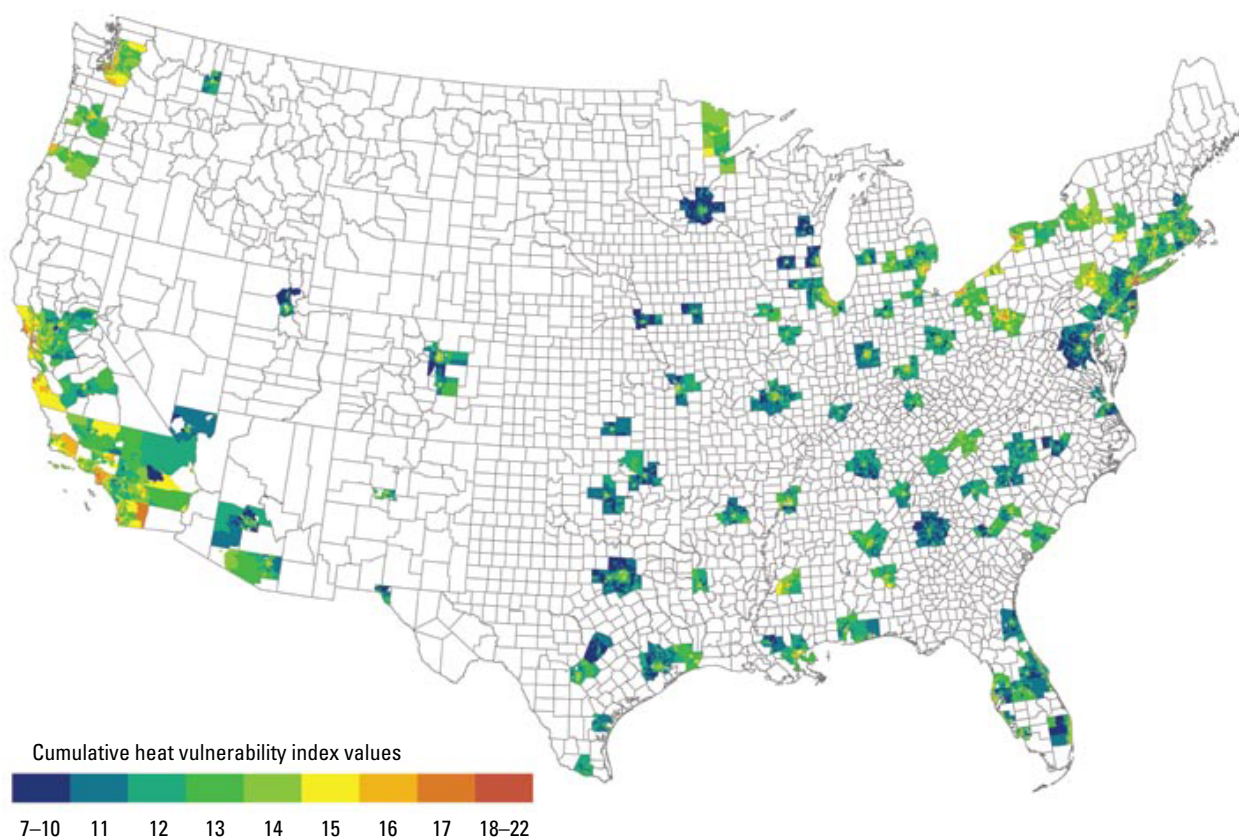


Figure 19 National map of Cumulative Heat Vulnerability Index by census tract.

WILDFIRE THREAT/SMOKE

Framework 33. California Department of Forestry and Fire Protection (CAL FIRE) Characterizing the Fire Threat to Areas and Communities in California^{105,106}

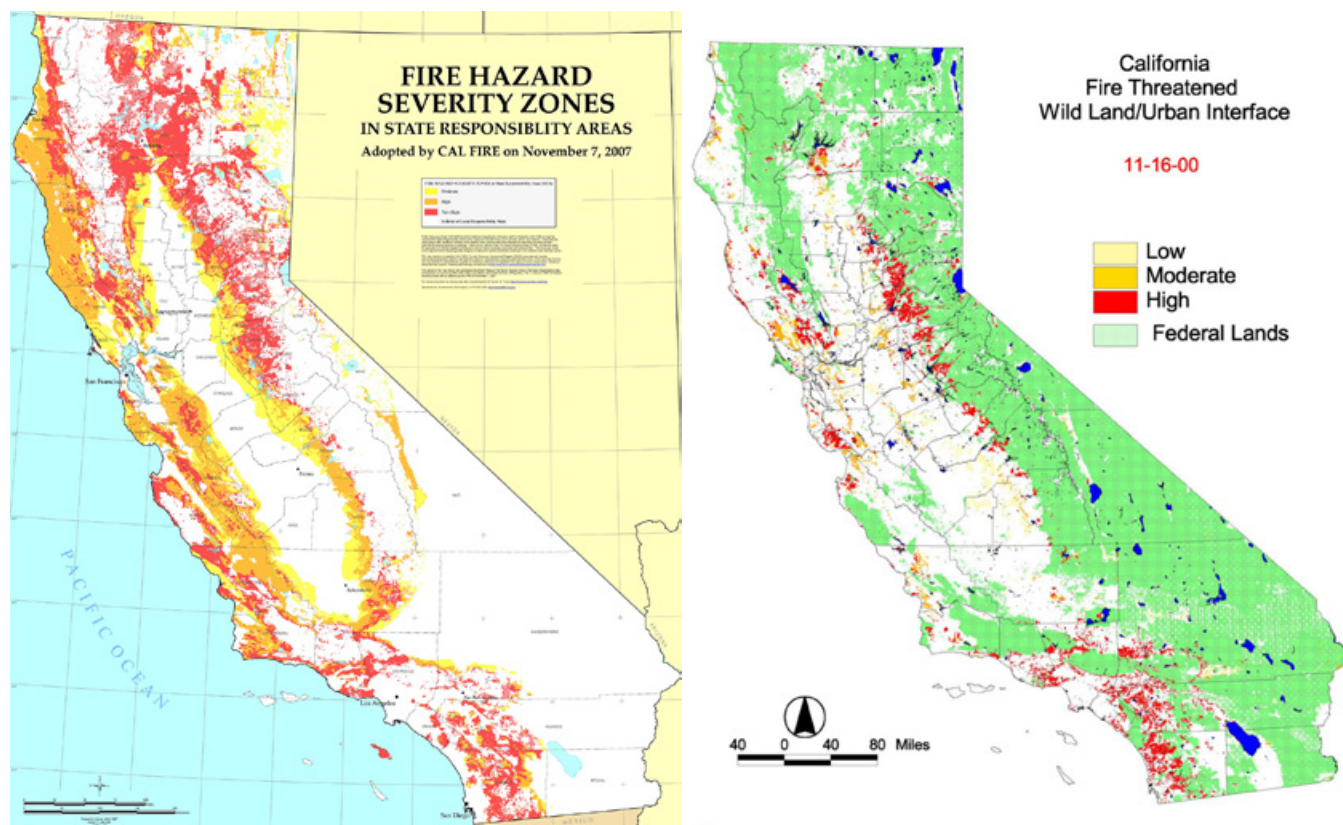


Figure 21 Left: Fire Hazard Severity Zones in State Responsibility Areas; Right: California Fire Threatened Wildland/Urban Interface (both from the California Department of Forestry and Fire Protection's Fire Resource and Assessment Program).

CAL FIRE's Fire Resource and Assessment Program (FRAP) provides various maps to identify communities that are currently at high risk of damage from wildfire (**Figure 21**). The Fire Hazard Severity Zone map, developed in 2007, supports identification of populations currently living in very high wildfire risk areas. The Wildland-Urban Interface map identifies particularly vulnerable communities within the wildland-urban interface, the area where housing and vegetation mix. It is important to note that these maps reveal current risk, but are not reflective of the ways risk will change based on future climate projections

Framework 34. Community Health Vulnerability Index (CHVI)^{132,133}

EPA scientists developed the Community Health Vulnerability Index (CHVI) in 2017 to help identify communities with a higher health risk from wildfire smoke. The tool, released as part of the report *Community Vulnerability to Health Impacts of Wildland Fire Smoke Exposure* is intended to help health officials center on at-risk populations living in areas with poor air quality. The index uses several factors that determine vulnerability to the health consequences of poor air quality, including asthma prevalence, percent of population 65 years of age or older, and poverty.

DROUGHT

Framework 35. U.S. Drought Monitor¹³⁴

Produced through a collaborative effort between the National Drought Mitigation Center at the University of Nebraska-Lincoln, the U.S. Department of Agriculture, and the National Oceanic and Atmospheric Administration, the U.S. Drought Monitor consists of an online interactive mapping tool that identifies areas of drought throughout the nation (labeled by intensity and duration of impact), downloadable data sets, and a weekly regional drought summary. The summary map categorizes each area into one of five intensity groups: D0 being areas that are not experiencing drought, but are abnormally dry; D1 being the least intense category of drought; and D4 being the most intense category of drought. The summary map and data sets are updated weekly.

Through it primarily relies on a combination of five drought indicators and local reports from hundreds of on-the-ground observers, the Drought Monitor also utilizes additional indicators like winter snowfall and river basin precipitation where needed to more accurately capture drought conditions. The producers of the Drought Monitor caution decision makers against using it to infer specifics about local conditions, maintaining that it provides a broader-picture look at drought conditions throughout the nation and should not be used to replace local assessments.

Framework 36. California Palmer Drought Severity Index (PDSI)¹³⁵

In order to monitor and assess the state of the Earth's climate in near real-time for decision makers at all levels, the National Oceanic and Atmospheric Administration's National Centers for Environmental Information have been updating climate data trends and updating several drought indices, among which the Palmer Drought Severity Index (PDSI) is commonly used in the United States. The PDSI suggests that in the winter of 2013-14, California experienced its most severe drought conditions since records began 122 years ago.

REVIEW OF FRAMEWORKS: SENSITIVITY FACTORS

Framework 37. Identifying and Mapping Community Vulnerability¹³⁶

This 1999 report by a Florida International University International Hurricane Research Center researcher discusses socioeconomic factors associated with increased disaster risk. The factors are organized into the following mutually inclusive groups: economic and material resources, including housing quality, homelessness, and domestic service jobs; human or personal resources, including health and physical ability, age, and household living arrangements; family and social resources, including institutional and kinship embeddedness, migrant agricultural workers, and tourists; and political sources, including relation to community decision makers (which encompasses housing tenure), unincorporated/rural areas, and politically marginalized groups. The author ultimately argues for the development and use of geographic information system (GIS)-integrated Community Vulnerability Maps, which show the concentration and distribution of especially vulnerable groups, as well as for local grassroots involvement in disaster response planning.

Framework 38. Regional Opportunity Index (ROI)^{137,138}

Using census tract data and a combination of “people” and “place”-based indicators relating to education, economy, housing, mobility/transportation, health, and civic life, the UC Davis Center for Regional Change Regional Opportunity Index (ROI) assesses factors driving community and regional opportunity and well-being (**Figure 22**). The appendix outlines the metrics, description of the data, and the data source used in the ROI. The index, which includes an online mapping tool, is intended to help banks, policymakers, and advocates identify the most vulnerable communities for investment and policy efforts.

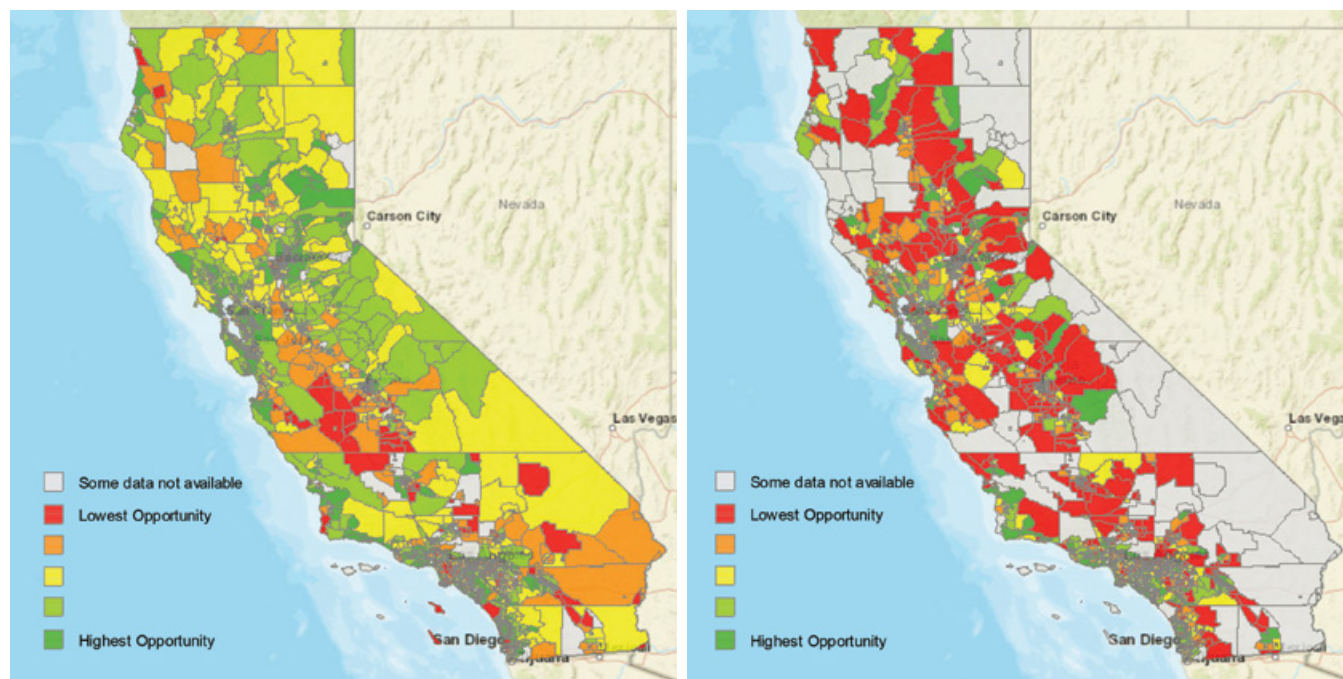


Figure 22 Left: Map showing Regional Opportunity Index (ROI), People component; Right: Map showing ROI, Places component, both for 2014.

Framework 39. California Poverty Measure (CPM)¹³⁹

The California Poverty Measure (CPM) is a joint research effort between the Public Policy Institute of California and the Stanford Center on Poverty and Inequality. Introduced in 2013, it is different from the U.S. Census Bureau's official poverty measure in that it takes into consideration a region's cost of living as well as available benefits from social safety net programs like the federal Earned Income Tax Credit (EITC) and CalFresh. The CPM's interactive maps are particularly useful as they allow the user to filter by county, as well as by state assembly, state senate, and U.S. congressional district. All data is available for download in a variety of formats.

Framework 40. Applying Social Determinants of Health

Indicator Data for Advancing Health Equity¹⁴⁰

The Bay Area Regional Health Inequities Initiative (BARHII) Data Committee developed this report in 2015 to help local health departments use a social determinants of health framework to improve community health. The report identifies indicators to illustrate the effects of social determinants of health on inequitable health outcomes. The committee narrowed down a list of 300 potential indicators to a final list of 15 indicators grouped into four domains: economic, including income distribution and foregoing health care; service, including violent crime; social, including educational attainment and voter participation; and physical, including alcohol and food access. A key strength of this report is that the factors can be analyzed and monitored by local health departments with data sources and methodology described in detail for each indicator.

REVIEW OF FRAMEWORKS: ADAPTIVE CAPACITY FACTORS

Framework 41. The Racial/Ethnic Distribution of Heat Risk-Related Land Cover in Relation to Residential Segregation¹⁴¹

This 2013 study explains the effects of social inequalities on disparities in heat risk-related land cover (HRRLC) characteristics (**Figure 23**). HRRLC conditions are considered to be present when at least half the population experience the absence of tree canopy and at least half of the ground is covered by impervious surface. The methodology cites the data sources and articulates the approach of the analysis.

The results indicate that non-Hispanic blacks, non-Hispanic Asians, and Hispanic were more likely to live in HRRLC conditions. Within each of these groups, HRRLC conditions increased as degrees of segregation increased. The researchers state that adaptation strategies for extreme heat events should explicitly address racial/ethnic disparities in HRRLC through inclusion of an environmental justice framework.

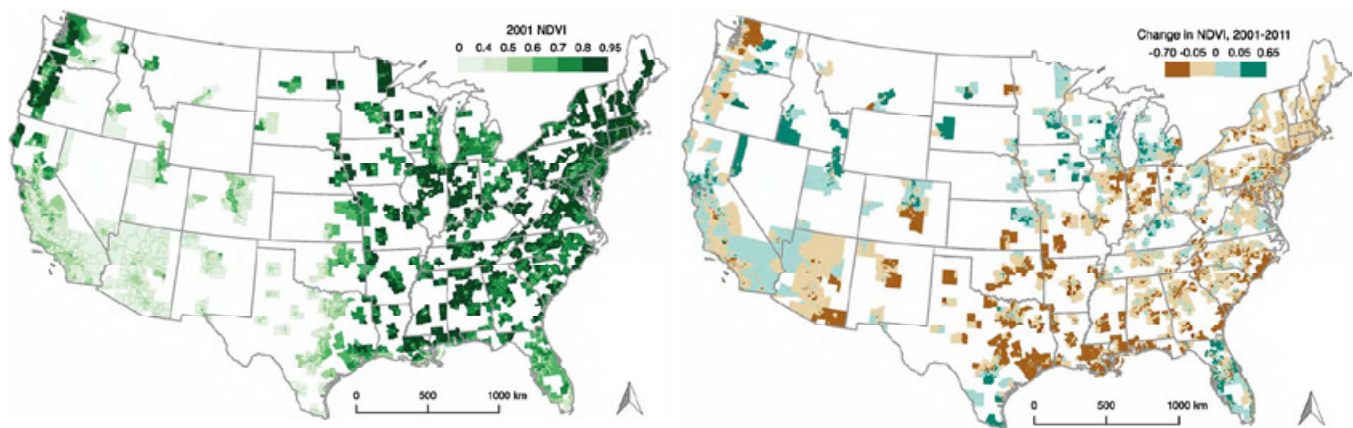


Figure 23 Maps showing the distribution of greenness at the census tract level across the U.S. *Left:* 2001 Distribution of Greenness; *Right:* Change in Greenness Between 2001 and 2011 (Race, Ethnicity, Income Concentration, and 10-Year Change in Urban Greenness in the U.S.).

Framework 42. Race, Ethnicity, Income Concentration, and 10-Year Change in Urban Greenness in the United States¹⁴²

This 2017 study examines how inequalities in urban greenness have changed over time. Data sources are cited in the methods and materials section. The study estimates 2001 and 2011 greenness throughout the contiguous United States and finds that urban areas with a higher proportion of racial/ethnic minorities lost more greenness between the years of 2001 and 2011. The study points to a need for policies to increase greenness in low-income communities of color.

TABLE 1

COMPARISON TABLE OF INDICATORS, ORGANIZED BY ELEMENTS OF CLIMATE VULNERABILITY

Table 1 provides a high-level snapshot of the frameworks and compiles an inventory of indicators contained across each of the frameworks in this review. This offers a view of the most commonly used indicators across frameworks. A checked box means that the indicator is included in the framework. The indicators on the left-hand column are divided into three categories (explained below) and are listed in descending order according to frequency of inclusion (indicated by the number under “Total” column). The “Data” column to the right of the “Total” column indicates the frequency of inclusion of that indicator across quantitative frameworks only (not qualitative reports), reflecting the extent of data availability for that indicator.

Indicator Categories

- **Exposures** are the biological, chemical, or physical stimuli, including climate hazards, that can impact communities.
- **Sensitivity** captures how intensely communities are affected by climate hazards and other climate stimuli.
- **Adaptive Capacity** describes a community’s ability to recover from or adjust to climate exposures.

[Category definitions adapted from U.S. Global Change Research – Climate and Health Assessment 2016]

Framework Types

- **Mapping Frameworks** are indicator sets that include interactive maps and features that characterize climate vulnerability geographically.
- **Indicator Sets** identify specific indicators for understanding climate vulnerability using quantitative data. These sets do not include maps.
- **Qualitative Reports** are climate vulnerability reports based on non-numerical data.

TABLE 1

COMPARISON TABLE OF INDICATORS, ORGANIZED BY ELEMENTS OF CLIMATE VULNERABILITY

Mapping Frameworks																								Indicator Sets (No Map)				Qualitative Reports													
National				State				Local																																	
	BRIC	Casey et al. (urban greenness)	CHVI	CRSI	Martinich et al. (SLR)	SoVI	Surging Seas Risk Zone Map	SVI	UCS Rising Seas	Cal-Adapt	CALBRACE CCHViz	CalEnviroScreen	CEC Energy Equity Indicators	CEC Social Vulnerability to Climate Change in CA	CHAT	Coastal Resilience California	CPM	HPI	Knowlton et al. (2006 CA heat wave)	Declet-Barreto et al. (urban vegetation effects on heat exposure)	English et al. (climate change vulnerability screening tool)	Heat Vulnerability Denver	Heat Vulnerability Index Philadelphia	ROI	UHI Index for California	ABAG Community Indicators Flood Risk	BARHII	EJSM	Jesdale et al. (heat risk-related land cover)	OEHHA Indicators of Climate Change	OEHHA EJ Indicators	PDSI	Reid et al. (heat vulnerability)	APHA	CA 4th Assessment	CAP Social Cohesion	CAP Disaster in the Making	EPA Mapping Vulnerability of Health to Extreme Heat	"Morrow (IDing & mapping vulnerability)"	NEJAC Resilience in EJ Industrial Waterfront Areas	
			✓	✓			✓		✓	✓	✓	✓			✓	✓		✓	✓	✓	✓			✓				✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

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TABLE 2

RELEVANT VULNERABILITY INDICATORS FOR INDIVIDUAL CLIMATE IMPACTS

Table 2 lists the indicators that are mentioned in relation to specific exposures according to the frameworks reviewed in this report. The table is divided by indicator category. This gives a sense of which indicators are relevant across multiple exposures and which contribute to vulnerability to a particular climate impact.

TABLE 2A: SENSITIVITY

	HEAT	WILDFIRE THREAT	FLOOD RISK	AIR QUALITY	DROUGHT
SENSITIVITY	Race/ethnicity	Race/ethnicity	Race/ethnicity	Race/ethnicity	Race/ethnicity
	Poverty	Poverty	Poverty	Poverty	Poverty
	Linguistic isolation	Linguistic isolation	Linguistic isolation	Linguistic isolation	Agricultural workers
	Asthma	Unemployment	Asthma	Asthma	Diabetes
	Children	Children	Children	Children	Food insecurity
	Elderly	Elderly	Elderly	Elderly	Social safety net programs
	Educational attainment	Educational attainment	Educational attainment	Educational attainment	
	Disability	Disability	Disability	Unemployment	
	Employment	Industrial/hazardous sites	Industrial/hazardous sites	Industry/hazardous sites	
	Outdoor workers	Outdoor workers	Housing quality	Outdoor workers	
	Elderly living alone	Elderly living alone	Housing affordability	Cardiovascular disease	
	Cardiovascular disease	Energy costs	Housing tenure	Obesity	
	Energy costs		Social safety net programs	Diabetes	
	Food insecurity		Food insecurity		
	Obesity		Unoccupied housing		
	Diabetes				
	Urban heat island				
	Housing quality				
	Housing tenure				

TABLE 2B: ADAPTIVE CAPACITY

	HEAT	WILDFIRE THREAT	FLOOD RISK	AIR QUALITY	DROUGHT
ADAPTIVE CAPACITY	Emergency services/ responders	Emergency services/ responders	Emergency services/ responders	Tree canopy/green space	Emergency services/ responders
	Vehicle access	Vehicle access	Vehicle access		
	Tree canopy/green space		Transit access		
	Impervious surface cover		Medical facilities		
	Air conditioning		Number of roadways		
			Flood insurance		
			Telecommunications access		



DATA GAPS AND KNOWLEDGE LIMITATIONS



MOST CLIMATE PROJECTIONS ARE AVAILABLE AT STATEWIDE SCALE AND REFLECT REGIONAL TRENDS

In terms of level of data available, the climate projections analyzed in this review are applied at a statewide or national scale. Some statewide projections (e.g., drought, urban heat island) may not accurately capture local conditions, and therefore should not replace local assessments. Although exposures are available consistently across the state, the extent also varies depending on the specific type of exposure. For example, data for populations living in sea level rise inundation areas is specific to coastal communities along the Pacific Ocean (particularly Los Angeles, Monterey, Ventura, and Santa Barbara counties) and along the San Francisco Bay.

CENSUS TRACT-LEVEL ANALYSIS IS MOST FEASIBLE AND ALSO PRESENTS CHALLENGES

For the sensitivity and capacity indicators, the majority of data applied in the frameworks were presented at either the census tract or county level. Notably, two frameworks: Heat Vulnerability Philadelphia, (Framework 24) and Jesdale et al.'s study on heat risk-related land cover and racial distribution (Framework 41) refine their analysis to the census block group level, which offers a more granular reflection of local

conditions. However, aggregation at the census tract or county level appears to be the smallest possible scale for a framework that integrates multiple data sources. Unfortunately, census tract-level analysis does present challenges for use in regional or local efforts. Moreover, the use of data available at the census tract level for some regions is imprecise in illustrating exposures and

impacts at the community scale. This is particularly apparent in rural areas where issues like smaller population and low reporting may result in inaccuracies. For example, emergency room visits for asthma and cardiovascular disease do not capture visits to local or community health clinics, which is more likely the type of medical care sought in rural communities.

LIMITS OF RELYING ON QUANTITATIVE DATA ALONE

These sampling limitations underline the dangers of relying solely on quantitative data to illustrate and depict local conditions. In fact, many stakeholders interviewed for this report reinforced the importance of complementing information derived from data trends and mapping tools with experiential knowledge of community needs. A strong example of this is the process of developing the Cumulative Environmental Vulnerability Assessment (CEVA) used in the San

Joaquin Valley, which combined community members' environmental knowledge derived from participatory mapping workshops with the San Joaquin Valley Cumulative Health Impacts Project.¹⁴³

The following sections further highlight factors that are not fully or accurately captured in existing quantitative approaches due to data gaps. Despite data limitations, these factors should be considered in the ways climate adaptation plans and programs are designed.

CLIMATE IMPACTS AND ENVIRONMENTAL EXPOSURES

REFLECTING FUTURE RISKS POSED BY CLIMATE CHANGE

Climate change will intensify the severity and frequency of extreme weather events. This means that the past is no longer an accurate predictor of the future. In order for exposure indicators to accurately reflect current and future risk, it is critical that indicators take both historical data and climate projections into account. This magnitude of risk also varies by the emissions scenario applied in modeling the severity of impacts. The ability to downscale specific climate projections varies by impact and scale, which can pose challenges for local or regional applications. Some data (e.g., urban heat island and urban drainage) is more appropriately generated and applied at a local scale.

The most recent modeling available through California's Fourth Climate Change Assessment (Framework 19) and Cal-Adapt (Framework 12) indicate that sufficient

data exists to project the following impacts: extreme heat, flood risk, wildfires, and drought. Air quality is the single exposure from this analysis for which there is not robust modeling to represent projected air quality conditions with climate change. Nevertheless, it is clear that climate change threatens to exacerbate poor air quality through multiple pathways. As it relates to extreme heat, higher temperatures accelerate chemical interactions between nitrogen oxide, volatile organic gases, and sunlight that contribute to increased ozone concentrations in urban areas.¹⁴⁴ Wildfire smoke also increases particulate pollution, which has been worsening in California over the past several decades.¹⁴⁵ Cooley et al. (Framework 17) is the only framework that includes air quality projections, but limits its analysis to respirable, fine particulate matter (PM_{2.5}), as the authors did not discern any apparent trend in ozone concentrations. Projected changes, however, in air quality from wildfires due to climate change was not considered.

ENVIRONMENTAL JUSTICE IMPLICATIONS OF CLIMATE CHANGE

Few studies in this review considered the environmental health implications of various climate impacts. For example, sea level rise poses additional threats to human health due to the flooding of hazardous sites. Releases of toxic chemicals from hazardous waste sites and industrial facilities into local air and floodwaters can occur accidentally or intentionally (e.g., to prevent explosions). Without this overlay, the way existing environmental justice issues will be exacerbated by climate change goes unconsidered in land use planning and zoning. The Climate Change Vulnerability Screening Method developed by English et al. (Framework 21), which considers existing pollution exposure and hazard proximity by integrating the Environmental Justice Screening Methodology (EJSM) (Framework 11), is one of the exceptions.¹⁰² The National Environmental Justice Advisory Committee (NEJAC) report (Framework 9) also reinforces the unique climate vulnerabilities among environmental justice communities in industrial waterfronts threatened by accidental release of hazardous substances from facilities and open-air industrial sites impacted by extreme weather events.¹¹⁴ As mentioned, ongoing research efforts are being undertaken through the Strategic Growth Council's (SGC) Climate Change Research Program to depict potential impacts of coastal flooding due to sea level rise on environmental justice communities.¹⁴⁶

COASTAL FLOODING RISK

Two studies highlight the limits of current estimates of flood risk. According to Shirzaei and Bürgmann, the current global projections of future sea level rise do not consider contributions from coastal subsidence in the development of inundation hazards maps.¹⁴⁷ This study analyzed and developed revised maps for the San Francisco Bay Area that account for the contribution of local land subsidence. Given ongoing land subsidence, the authors project that a much larger area will be vulnerable to inundation as compared to estimates considering sea level rise alone. This study implies the need for existing frameworks depicting risk of coastal flooding to account for land subsidence. In addition, Wing et al. use a new model to produce estimates of current and potential future flood exposure, which finds

that Federal Emergency Management Agency (FEMA) flood maps severely underestimate the magnitude of risk to the built environment and communities.¹⁴⁸

Despite these gaps, Coastal Storm Modeling System (CoSMoS) and sea level rise data available through Cal-Adapt do take local land subsidence into account, and therefore should be the preferred data source for related vulnerability assessments.

VULNERABILITY TO DROUGHT

The latest drought in California revealed the unique vulnerability of the San Joaquin Valley to water scarcity and long-term declines in groundwater reserves. For the past several decades, groundwater has been used faster than it is being replenished, which has contributed to increased pumping costs, dry wells, sinking lands, and declining reliability of this vital drought reserve. Beyond water scarcity, nitrate and arsenic contaminate groundwater and salinity accumulates in soil.¹⁴⁹ Drought impacts employment, water security, food security, and health of rural residents; these impacts and vulnerabilities are uneven and localized.¹⁸ Nevertheless, how social and physical processes interact to create drought vulnerability is poorly understood, especially with regards to disadvantaged communities.

One stakeholder interviewed for this report highlighted the California Statewide Groundwater Elevation Monitoring (CASGEM) program, which expands the current groundwater elevation monitoring to all of California's groundwater basins and allows identification of issues like overdraft occurring within a groundwater basin.¹⁵⁰ The University of California, Davis developed the California Water Sustainability Indicators Framework, which conceptualizes relevant indicators such as groundwater threats, nitrates, water quality, and water stress.¹⁵¹ Although there are implications of these environmental challenges to the valley's rural communities, the Climate Resilience Screening Index (CRSI) (Framework 1) and CalEnviroScreen (Framework 10) are the only frameworks that incorporate water indicators (drought, drinking water contaminants, and groundwater threats). Based on this review, frameworks that warrant further exploration in regard to groundwater quality and stress include the California Water Science Center Mojave Region Water Quality Studies and the Water Supply Stress Index (WaSSI) Ecosystem Services Model.^{152,153} In addition, there

is an ongoing project recently funded by the SGC to explore the environmental and socioeconomic impacts of climate change on San Joaquin Valley agriculture and disadvantaged communities in the context of a changing regulatory environment and water supply

reductions under the Sustainable Groundwater Management Act.¹⁵⁴ Further consultation with local advocates and researchers could support integration of drought impacts into climate vulnerability frameworks.

SENSITIVITY: PUBLIC HEALTH OUTCOMES

Overall, standardized health data such as mortality records, hospitalizations, emergency room visits, emergency distress calls, or outpatient visits is available to many health departments, which can be applied to map sensitive populations for such vulnerability assessments. However, using highly detailed morbidity/mortality data at the census tracts or even ZIP code level can pose challenges. In some scenarios, this may be caused by too few cases to adequately calculate rates, while in others the data may be considered protected health information due to privacy concerns.¹⁵⁵ Therefore, more detailed health outcomes data may be difficult to track.

CHANGES IN INFECTIOUS DISEASES

Air-, food-, vector-, and waterborne infectious disease risks are all impacted by climate change through multiple pathways, including warmer temperatures, precipitation changes, and sea level rise. Outdoor workers, low-income communities living in older housing and aging infrastructure, and those with chronic illnesses are uniquely susceptible to infectious diseases.¹⁵⁶ Although it is clear that the incidence, outbreak frequency, and distribution of many infectious diseases are generally expected to change as a consequence of climate change, there is limited regional information available to guide decision making. Monitoring protocols could be dramatically improved to model and map distribution of vectors based on anticipated changes in infectious disease risk. The American Public Health Association (APHA) (Framework 8) recommends changing the frequency of surveillance to detect changes in the presence of disease-carrying vectors and vector-borne diseases with increasing temperatures and changing precipitation patterns.

MENTAL HEALTH

Mental health-related indicators appeared in several of the frameworks reviewed in this report. While some framed it as a preexisting health condition susceptible to damage, others incorporated availability of mental health services as a measure of adaptive capacity. Mental health as a vulnerability indicator is difficult to capture in a metric. (It should be noted that mental health is not interchangeable with mental or cognitive disabilities, which is a separate indicator that a larger number of frameworks in this review utilized.) The California Healthy Places Index (HPI) (Framework 13) is the only framework in this review that includes mental health as a quantitative vulnerability indicator.¹¹⁹ It includes “mental health not good” as a “health outcomes” decision support layer. The data source is the Centers for Disease Control and Prevention’s (CDC) 500 Cities project, which measures the “percent of adults aged ≥18 years who report 14 or more days during the past 30 days during which their mental health was not good.”¹⁵⁷

SENSITIVITY: SOCIOECONOMIC FACTORS

EMPLOYMENT IN JOBS IMPACTED BY CLIMATE CHANGE

Existing climate vulnerability frameworks center on risks to residential communities, overlooking the multitude of social, economic, and health impacts of climate change on workers. For example, the Thomas Fire on the Central Coast substantially affected agricultural workers, most of whom could not afford to stop working despite health impacts from poor air quality. Many lacked knowledge regarding health risks and faced challenges obtaining protective gear.¹⁸ In addition to outdoor workers broadly, other sectors vulnerable to economic losses due to climate impacts include agricultural, tourism, and domestic workers. Most frameworks in this review derived data regarding outdoor workers through the American Community Survey (ACS), which includes those employed in the farming, fishing, forestry, construction, and extraction industries. Solely relying on this data source, however, ignores impacts to vulnerable workers in the informal economy, which includes domestic workers (e.g., nannies, home health aides, housekeepers, gardeners, and cooks), lawn/garden care, and day laborers.¹⁸ The Social Vulnerability Index (SoVI®) (Framework 3) incorporates a more expansive definition of vulnerable workers by including employment in service industry, transportation, and public utilities and specifically identifies service industry employment as a significant component contributing to the variance of the data.¹¹⁰ It is difficult to encapsulate loss of employment and livelihood impacts into a quantitative metric, although various studies quantify the broader economic implications of climate disasters on vulnerable industries. This is the impetus for a recently funded project through SGC to quantify financial and health costs of understudied climate impacts across California—workplace morbidity/mortality, wages, and unemployment.¹⁵⁸

HOMELESSNESS

Homeless communities suffer from disproportionate levels of chronic disease and lack access to housing, making them especially susceptible to climate impacts. In terms of acute climate events, extreme heat is

understood to be especially dangerous for homeless people due to barriers accessing cooling services, water, food, and shelter. Often occupying areas near creeks or rivers, homeless people are also especially vulnerable to flooding.⁵¹ Access to post-disaster social safety net programs for repair or replacement costs are also restricted for unhoused people living in nontraditional housing such as tents.¹⁵⁹ Data sources are unclear based on the few frameworks in this review that list homelessness as an indicator. Its relative absence from climate vulnerability frameworks may be due to the fact that accurate data on homelessness tends to be sparse. Data also tends to be inconsistent across different regions, which can partially be attributed to varying definitions of homelessness.

IMMIGRATION STATUS

Several frameworks in this review, as well as stakeholders interviewed for this report, identify immigration status as an important indicator for understanding climate vulnerability. U.S. citizenship is required for FEMA assistance, underlining the way immigration status directly affects an individual's capacity to respond to climate disasters.⁵¹ The APHA report on climate health equity (Framework 8) names indirect effects of immigration status on climate vulnerability. For example, in its discussion of the 2017 Sonoma County fires, the report identifies fear of immigration enforcement as a major barrier that prevented undocumented immigrants and their families from accessing postfire assistance, even in cases where such assistance was available. It goes on to list other immigration-related factors that affect vulnerability, including language barriers; discomfort or lack of familiarity with law enforcement, county government, and mainstream aid organizations; and employment in sectors disproportionately impacted by climate disasters.⁵¹ Despite its established connection to climate vulnerability, this indicator only showed up in one of the quantitative frameworks in this review, the Regional Opportunity Index (ROI) (Framework 38), which included percentage of adults who are U.S. citizens based on ACS data.¹³⁷ Given its nature, immigration status is difficult to accurately capture as a metric, so its relative absence from quantitative frameworks is unsurprising.

ISSUES FACING RURAL COMMUNITIES

There are key distinctions in data availability in rural areas as compared to urban centers. Air conditioning prevalence data from the ACS, for example, is limited to larger cities and unavailable for rural areas. This is largely due to low population, which poses data collection issues related to statistical sampling and privacy considerations. Ultimately, this limits understanding of how climate vulnerability differs in rural areas as compared to urban areas. In fact, most of the data used in vulnerability mapping is derived from densely populated areas. This not only impacts rural communities, but other underserved communities as well, including Native American tribes and undocumented migrant workers.¹¹⁵

SOCIAL CAPITAL

Social capital is reflected in the networks and relationships that create trust, reciprocity, mutual aid, and cooperation in a society. Community resilience during extreme weather events is bolstered when people are represented by elected officials, receive culturally appropriate information, and can access network and resources to respond. Therefore, social capital refers to elements that contribute to cohesion, political involvement, and isolation. Although many elements of social capital are not rigorously measured, various metrics described in this review represent contributing factors. For example, social cohesion is supported by physical infrastructure that enables connectivity and relationships such as sidewalks, community centers, and parks. Cohesiveness and resilience during disasters is also strengthened by the presence of community institutions such as community-based organizations, nonprofits, and faith-based organizations.¹¹¹ Political participation is often estimated by voter turnout. Isolation is associated with particular demographic characteristics that can be measured, including those living in rural areas, institutionalized populations, and those with limited English proficiency.¹⁸

DISPLACEMENT

Displacement pressures compounded by the current housing crisis alongside climate impacts threaten to destabilize the social fabric cultivated in neighborhoods.

Moreover, climate disasters exacerbate preexisting housing and economic instability by accelerating gentrification through the destruction of housing stock as well as intensifying social isolation when communities are separated. Therefore, it is important to retain and foster cohesion in vulnerable areas in order to avoid displacement. Although it is difficult to fully reflect the interacting forces that contribute to displacement, housing affordability and tenure are metrics that partially capture this risk. The Bay Area Regional Health Inequities Initiative (BARHII) (Framework 40) identifies gentrification as an indicator, citing “individual and housing characteristics” as potential indicator measurements.¹⁴⁰ The Urban Displacement Project has developed maps depicting rent, migration by race and income, and demographic change to reflect mobility patterns associated with gentrification and displacement for the San Francisco Bay Area and Southern California.¹⁶⁰ In order to partly address this gap, SGC has funded a project to estimate the relationship between displacement pressures and California’s climate mitigation investments in order to create tools that state agencies can use to predict and mitigate the displacement impacts of future investments.¹⁶¹

HOUSING CHARACTERISTICS

Other housing characteristics such as housing quality and home crowding worsen climate vulnerability and associated adverse health outcomes. This is largely because people living in substandard housing are less protected during climate disasters. For example, moisture introduced by flooding coupled with poor ventilation can aggravate household mold and indoor air pollution leading to respiratory illness, nausea, and fatigue.¹⁴⁰ Studies also reveal that people living in older housing are more susceptible to hospitalization associated with extreme heat, which is likely caused by lack of insulation or air conditioning.^{18,51} Public housing is often prone to structural damage, resulting in the displacement of residents to temporary shelters or homelessness.¹³⁶ In general, however, housing quality data tends to be inconsistent across the state in terms of scale, and indicators vary across frameworks. For example, unlike other regions, San Francisco uniquely tracks annual housing violations (per 1,000 residents) at the block group level.⁵¹ The Baseline Resilience

Indicators for Communities (BRIC) (Framework 2) and CRSI (Framework 1) capture construction quality of housing stock using data on age of residential housing, the scale of which is limited at the county level.^{91,95} CRSI and HPI (Framework 13) use percent of homes with inadequate plumbing and kitchen facilities available through federal Housing and Urban Development (HUD) data also limited to the county level.

Crowded housing increases vulnerability to infectious and communicable diseases like tuberculosis. However, as mentioned above, infectious disease risk is outside the scope of this report due to data limitations. Several frameworks incorporate measures of home crowding by comparing estimates of rooms and occupants per household.^{96,119,140} CRSI (Framework 1) takes a higher-level approach and incorporates housing density as a proportion of housing units by county size.⁹⁵

Finally, evidence suggests that mobile homes are far more likely to be destroyed during extreme weather events like hurricanes and tornadoes.¹³⁶ About 4 percent of California's population lives in mobile homes, which equates to approximately 500,000 residents.¹⁶² Mobile home parks often house already vulnerable communities, including farmworkers, elderly people and other low-income communities. However, post-disaster assistance funds for rent, repair, or replacement costs are often inaccessible to mobile home residents due to formal ownership verification requirements.¹⁵⁹ Just three frameworks in this review incorporate mobile homes, but none are California-specific.^{91,95,96} This is likely because these types of destructive weather events are historically a rare occurrence in the state. However, these communities may become an increasing priority to protect in light of the growing intensity of wildfires, extreme storms, and flood risk in the state.

SEGREGATION

Segregation captures the way low-income communities of color are often left out of land use planning and decision making. These vulnerable communities also lack access to critical assets like hospitals, clinics, grocery stores, and other infrastructure. Geographic segregation is worsened by inequalities in the distribution of public, federal, and state investments across neighborhoods. Although incomplete, one measure connected to this trend is income inequality, which is derived from the Gini coefficient.¹⁸

INSTITUTIONALIZED POPULATIONS

Institutionalized populations include those in hospitals, inpatient rehabilitation facilities, nursing homes, prisons, group homes, college dormitories, and other similar facilities. These populations are often isolated from family members and not integrated into social networks outside of their facilities.¹¹⁵ This reality, in conjunction with the fact that many are already dependent on their institutions for everyday needs, means that they are also largely dependent on the quality of hazard response of their institutions. In cases where institutions are inadequately prepared for disasters, individuals who are institutionalized are at heightened risk.¹⁸ In some cases, institutions endanger occupants by refusing to carry out evacuation processes. This is often the case, for example, faced by incarcerated people, who are among the most vulnerable to climate hazards. In addition to representing one of the most socially neglected populations, prison inmates are vulnerable due to lack of resources for adaptive capacity like air conditioning.

The unique vulnerability of institutionalized populations to climate change is often overlooked, and as a result, there are few frameworks that incorporate the use of this indicator. However, some do incorporate specific subgroups of institutionalized populations. BARHII (Framework 40) accounts for percent of population that is incarcerated and the SoVI® (Framework 3) identifies percentage of people living in nursing facilities.^{140,110} Several other frameworks in this review include an institutionalized population-related indicator because they utilize SoVI®, but the extent of incorporation is limited to “population living in nursing facilities.” The California Energy Commission’s *Social Vulnerability to Climate Change in California* report (Framework 17) derives data for the indicator “residents living in institutions” from the ACS, though it also identifies it as one of two indicators that did not contribute to the overall vulnerability scores.⁹⁸

HARD-TO-COUNT COMMUNITIES

The Public Policy Institute of California (PPIC) offers interactive maps that highlight hard-to-count communities across the state. This characterization offers insight on particular demographics that may not be accurately estimated by census data. PPIC identifies

the following hard-to-count communities: African Americans, Latinxs, Native Americans, undocumented immigrants, young children, renters, residents in overcrowded or “low visibility” housing (e.g., garages, trailers, or basements), and residents with limited high-speed Internet connections.¹⁶³

GENDER AND SEXUALITY

Gender-related indicators like women, gender, and gender inequality are widely understood to be important climate sensitivity indicators and are discussed in several of the qualitative reports in this review. For example, the APHA (Framework 8) discusses the ways in which the social, health, and economic effects of climate change put women at heightened risk of disease, sexual violence, poor mental health, and death, among other adverse outcomes.⁵¹ Among the quantitative tools, indicator sets, and frameworks, however, gender-related

indicators are much harder to find. Of those included in this review, two frameworks include gender-related indicators: BRIC (Framework 2), which contains a “gender income inequality” indicator, and SoVI®, which contains a “gender” indicator.^{91,110}

It should also be noted that neither of these data sets examine the specific vulnerabilities faced by queer, transgender, and gender nonconforming people. Even among the qualitative reports in this review, there is lack of discussion surrounding the specific vulnerabilities faced by queer, transgender, and gender nonconforming people, who face increased marginalization in society and whose unique needs are often left out of emergency response protocols and shelter policies.⁵¹ The APHA report on climate health equity is the only report that names some of the specific climate vulnerabilities faced by the LGBTQ community.

ADAPTIVE CAPACITY

AIR CONDITIONING

Access to cooling may be one of the most important factors in determining household-level adaptive capacity to extreme heat.¹⁶⁴ Studies of heat waves have identified lack of access to air conditioning as a significant risk factor for heat-related mortality.¹²¹ The California frameworks incorporating air conditioning as an indicator measure ownership, data of which is derived from the California Energy Commission’s Statewide Residential Appliance Saturation Study (RASS). This study also offers information on consumption based on dwelling type, dwelling age, and income. Most recently updated in 2009–10, it is important to note that this data may not accurately reflect current and future consumption trends. In addition, certain areas of the state not served by the participating electric utilities may not be adequately captured by the study.¹²¹

Furthermore, simply noting whether a household has air conditioning is not enough to understand the degree of vulnerability. Air conditioner ownership alone does not reflect factors that influence a household’s decision to use air conditioning for cooling (such as affordability).

Moreover, for low-income residents, higher energy burdens often make it prohibitively expensive to use air conditioning even if they have it. Multiple studies exemplify the influence of high electricity costs in limiting or preventing household air conditioning use.^{121,164} In addition, many vulnerable communities are unaware of programs to repair broken air conditioners and options for public assistance with electric bills during summer months.¹⁶⁴

FACILITIES THAT PROMOTE RESILIENCE: COOLING CENTERS & EVACUATION SHELTERS

Cooling centers and evacuation shelters locations generally include government-run senior centers, community centers, parks and recreation sites, and public buildings such as libraries. For those who do not have access to air conditioning, cooling centers are critical community assets that ensure all residents can seek relief during hot summer days. This is particularly important for regions like the Bay Area that have not historically experienced extreme heat, and therefore are not adequately equipped to respond. The California

Governor's Office of Emergency Services (Cal OES), based on local governments public data, provides online maps identifying the location of cooling centers across the state. Similarly, each of three investor-owned utilities offer lists and accompanying maps of designated cooling center locations.^{165,166} Evacuation shelters are generally designated by local government.

One limitation, similar to air conditioning, is that the mere existence of cooling centers and evacuation shelters does not imply that the facilities are accessible and utilized by a community's most vulnerable residents. For example, beaches in coastal regions are open to the public and offer the potential for relief, but are not always accessible to low-income residents who may not own a personal vehicle. For designated cooling centers and shelters to be effective, they must be accessible via public transportation, offered within walking distance of neighborhoods, and designed to meet community needs.¹⁶⁷

None of the frameworks in this review consider access to designated cooling centers as part of adaptive capacity. The HPI (Framework 13) includes park access as a neighborhood indicator, which is defined as percentage of the population living within walkable distance (half-mile) of a park, beach, or open space greater than one acre. A key distinction between these facilities is that cooling centers serve communities' ability to cope and respond to heat waves, while temporary shelters are relevant during climate disasters that involve evacuation like flooding and wildfires. Just two frameworks in this review incorporate availability of temporary shelters.^{91,95} In order to address these gaps, vulnerability maps could feature an overlay of the location of resilience facilities, allowing users to explore whether the places most vulnerable to particular climate impacts have sufficient access to community resources such as public cooling centers and evacuation shelters.

TRANSPORTATION

Transportation is separated into "vehicle access" and "transit access" in this review. While both help to capture adaptive capacity, they are distinct in terms of relevant infrastructure and differ in their strength as indicators. Public transit, an especially important mode of transportation for low-income residents, is dependent on bus routes, metro lines, and railways, and operates only on set routes, making its accessibility dependent on

a community's proximity to transit infrastructure. Data availability on public transit is not consistent across regions—the CRSI (Framework 1), for example, does not include it as a metric on the grounds that adequate data exists mainly for metropolitan areas. Vehicle access is not interchangeable with transit access. Most of "vehicle access" indicators use data on vehicle ownership. California's Fourth Climate Change Assessment's *Climate Justice Report* (Framework 19) describes the importance of vehicle ownership to one's ability to evacuate, even for those with access to transit.¹⁸ Still, there are limitations with this metric because vehicle ownership does not directly indicate the ability to evacuate. Whether or not the owner can afford gas and whether the vehicle is reliable are both important concerns.

ROADWAY INFRASTRUCTURE

Many stakeholders mentioned roads and choke points as important indicators of adaptive capacity, especially in the context of evacuation from mudslides and flooding. More specifically, the number and condition of roads making up evacuation routes directly impact whether people can quickly and safely escape harm's way. Stakeholders also mentioned the importance of considering the indirect effects of the condition, location, and accessibility of roads on community vulnerability, as choke points in one area inevitably cause cascade effects throughout the rest of the region, which can impact all aspects of people's lives, including access to work as well as to health care and other services.

Despite the wide-reaching impacts of road condition and accessibility, only two of the frameworks in this review include a metric related to roadways. The relevance of this metric depends on the climate impact. CRSI discusses number and miles of different types of roads (arterial, local), as well as access to highway entrances and exits to capture transportation infrastructure critical for responding to an acute climate event. The Surging Seas Risk Zone Map (Framework 25) lists miles of different types of roads that are projected to be covered by 3 feet of water, using the metric to paint a picture of what infrastructure is at risk.^{95,104} Another developing resource that could address this gap are the California Department of Transportation's Climate Change Vulnerability Assessment maps (currently available for select districts), which highlight transportation

infrastructure at risk from impacts such as sea level rise, storm surges, precipitation, and temperature.¹⁶⁸

GREEN SPACE

The definition of green space varies across frameworks. Data on vegetation and tree canopy coverage is well established through the National Land Cover data set. In addition to tree canopy, the California Healthy Places Index (Framework 13) includes park access as a neighborhood indicator, which is defined as percentage of the population living within walkable distance (half-mile) of a park, beach, or open space greater than 1 acre. This data is derived from the California Protected Areas Database (CPAD), which contains data on protected lands like small urban parks, large national parks, and forests owned by governments, nonprofits, and some private entities.

GOVERNMENT RESOURCES AND INFRASTRUCTURE

Government infrastructure and resources dedicated to climate adaptation planning is an important consideration in assessing the preparedness of a region to extreme weather events. This could be evaluated at the local or regional level by considering the existence and quality of climate action plans, dedicated staff working on relevant projects, and warning systems. Mapping efforts could integrate these elements as online links as a resource for users to connect climate vulnerability with government efforts in a city or region.

TELECOMMUNICATIONS ACCESS

Telecommunications access can significantly affect a community's capacity to respond to climate disasters. In the wake of an acute climate event, the ability to receive timely and reliable information about hazard risks, response plans (e.g., evacuations, shelter-in-place protocols, etc.), and availability of resources can be the difference between life and death. Only two of the quantitative tools in this review capture access to telecommunications systems as adaptive capacity indicators. The CRSI (Framework 1) includes a "Communications Infrastructure" indicator, which captures measures of cell phone, land mobile, and radio broadcast towers, as well as areas of no Internet coverage, among others.⁹⁵ BRIC (Framework 2) incorporates two separate indicators: "communications capacity," which measures percent of households with access to telephone service, and "high-speed Internet infrastructure," which measures percent of population with access to broadband Internet service.⁹¹ While the Surging Seas Risk Zone Map (Framework 25) also includes a telecommunications indicator, "FM radio transmitter sites," it frames the indicator in terms of infrastructure at risk rather than adaptive capacity.¹⁰⁴

It should also be noted that the literature generally lacks both consideration of and data for indicators measuring telecommunications access specifically for people with disabilities. Stakeholders stressed the significance of accessible emergency response materials and alerts for a community's adaptive capacity.



LESSONS LEARNED FROM DEVELOPMENT AND USE OF RELATED SCREENING INDICATOR SETS & TOOLS IN CALIFORNIA

WE CARRIED OUT INTERVIEWS WITH A DIVERSE SET OF STAKEHOLDERS TO CAPTURE EXPERTISE FROM THE FIELD AROUND KEY LESSONS LEARNED FROM THE DEVELOPMENT AND USE OF RELEVANT INDICATORS AND/OR MAPPING TOOLS. These findings represent a multitude of sector perspectives, including community advocates, local and state agency staff, and researchers. Stakeholders interviewed also represent diverse geographic regions, including Los Angeles, the San Joaquin Valley, the Central Coast, and the Bay Area. We learned insights regarding elements covering strengths and challenges of various tools, data limitations, recommendations for improving process and data application, helpful features, and important vulnerability factors to consider.

OVERARCHING THEMES

In evaluating how accurately existing climate vulnerability tools capture the varying impacts of climate exposures on diverse communities across the state, many stakeholders point to the same flaw—a **failure to demonstrate cascading hazards of climate disasters**. For example, there are wide-reaching impacts of only having one evacuation route that then becomes littered with choke points during evacuation. In such a situation, those affected are not only residents immediately and directly impacted by the disaster event, but also residents in the larger geographic area whose economic livelihood and access to certain services (e.g., health care, grocery stores) may be severely impacted.

Existing frameworks are limited in reflecting the cumulative impacts of multiple social vulnerabilities

While several existing interactive tools allow users to overlay multiple indicators and exposures, they generally do not capture the cumulative interactions between various elements of climate vulnerability, which stakeholders identified as important for informing climate resilience work. For example, poverty makes it more likely for an individual to live in an area with high pollution exposures, and higher exposure to pollution can also affect an individual's health in a way that makes it more difficult to break the cycle of poverty. However, many tools simply overlay these indicators without investigating the ways in which they cumulatively impact a community's vulnerability. CalEnviroScreen was highlighted as an example of a tool that *is* based on cumulative impacts.

Mapping approaches should capture resilience capacity in addition to risks

In addition to highlighting vulnerability hot spots, maps should also identify existing community assets, state programs, and other resources that address a community's specific vulnerabilities (e.g., cooling centers, evacuation shelters, government plans and resources, existing community organizing efforts). Using the adage "what gets measured, gets managed," one stakeholder noted that capturing existing assets allows for the creation and execution of bold climate solutions. Moreover, knowing which assets already exist allows for their creative utilization. Stakeholders also highlight the importance of infusing hope into the tools themselves, expressing that a failure to capture existing resilience capacity could make using the tool overwhelming for the general public. One way to do this is to clearly showcase existing adaptation efforts and their successes.

Community engagement processes are a critical component in the development of vulnerability tools

It is critical that tool development include active community engagement (whether via participatory mapping processes or incorporation of community feedback), as well as cross-issue involvement of community-based organizations working in labor, transportation, or public health for development of future tools.

Dangers of relying on a single framework to depict climate vulnerability

While acknowledging that screening tools can be helpful in informing cross-region comparisons or in focusing attention on particularly vulnerable areas or communities, many partners caution against relying on any single such framework or treating any framework as a "silver bullet." One stakeholder expressed the utility of tools including disclaimers that would specify the types of applications they are suitable for. Another stressed the need to use care when presenting screening tools to the public in order to avoid overwhelming those living in more vulnerable areas, as well as causing those living in less burdened areas to erroneously feel immune and therefore removed from climate adaptation efforts.

LESSONS LEARNED FROM CALENVIROSCREEN

Most stakeholders reflected on their experience with CalEnviroScreen (Framework 10), as it is the most widely applied screening tool in California environmental policy. They consistently point to **its sound scientific underpinnings and robust set of diverse environmental and socioeconomic indicators** as its strongest elements. Other highlights include its use of publicly available data and the accessibility of its mapping interface.

Most of the challenges posed by CalEnviroScreen relate to its application to identify disadvantaged communities for statewide funding purposes

There is a general sentiment that the application of CalEnviroScreen is overly political, with critiques of regional dynamics that emerged around designation of disadvantaged communities for state policy applications. One stakeholder even expressed discomfort with the term “disadvantaged communities” itself on the grounds that it fails to capture the underlying systems of oppression that are at the root cause of vulnerability and instead implies that the communities themselves are at fault.

CalEnviroScreen contains a multitude of relevant indicators, but gaps still remain

Although OEHHA has released separate analyses of race/ethnicity characteristics for both CalEnviroScreen 2.0 and CalEnviroScreen 3.0, the agency has excluded these characteristics from the tool itself post-CalEnviroScreen 1.0. This is because government entities may be restricted from considering race/ethnicity when making certain decisions due to civil rights laws including Title VI. The City Project has disputed this claim, however, arguing that excluding race/ethnicity indicators is misguided, prejudicial, and discriminatory.¹⁶⁹ One stakeholder also identified the tool’s inability to capture pollution burden faced by workers (e.g., domestic workers, migrant agricultural workers) as another shortcoming.

Finally, there are limits to using CalEnviroScreen as a tool to promote climate resilience when it is specifically designed to identify communities overburdened by the cumulative impacts of poverty and pollution.

The process of developing and updating CalEnviroScreen could include further community engagement and involvement of stakeholders

This could involve consultation with impacted community members as well as government agencies and community organizations working in diverse areas such as environmental science, environmental justice, labor, transportation, housing, health, etc.

Many recommend improving the application of CalEnviroScreen data in policymaking by examining its design as a resource allocation tool. Stakeholders generally acknowledge the power of the tool’s role in directing resources to overburdened communities, but some question whether inclusion of this funding element in its purpose is overall positive or negative in terms of meaningful impact in those communities. One concern is that the design of CalEnviroScreen as a resource allocation tool is largely what has driven the politicization of its application in a way that has led to 1) the omission of race/ethnicity indicators, and 2) the incorporation of indicators and methods to address regional dynamics. In order to address the former issue, OEHHA released a supplemental report to analyze the relationship between CES scores and race/ethnicity for informational purposes, which reinforced the trend that high rates of pollution disproportionately impact certain communities of color in California.¹⁷⁰

LESSONS LEARNED FROM OTHER TOOLS

Models for Community Engagement

Stakeholders expressed concerns in regard to the development of Cal-Adapt (Framework 12)—without any ground-truthing—as well as how inadequate publicity and outreach has led to practitioners’ distrust of the tool. Nevertheless, the Strategic Growth Council (SGC) is supporting research to build new features and targeted tools to increase data accessibility in Cal-Adapt in order to better support state agencies to execute climate resilience planning beyond the energy sector.¹⁷¹ As Cal-Adapt is improved, stakeholders highlighted several other actionable tools that leveraged strong community engagement and collaborative processes to inform their designs. Meaningful ground-truthing processes were involved in both the Environmental Justice Screening Methodology (EJSM) (Framework 11) and the California Environmental Vulnerability Assessment (CEVA) used in the San Joaquin Valley and Coachella Valley regions. Stakeholders also uplifted the collaboration between researchers and advocates, and the engagement of health equity professionals involved in the development of the EJSM and the California Healthy Places Index (HPI) (Framework 13).

Selection of Relevant Indicators

Stakeholders commended inclusion of individual indicators including: race (EJSM), voting (HPI), crime (CCHVIZ, Framework 14), clean energy jobs (Energy Equity Indicators, Framework 18), and impervious surfaces (CCHVIZ). One stakeholder also commended the ability to customize maps according to user needs in the Climate-Smart Cities tool.

Issues of Scale

While many stakeholders prefer a local or regional focus over statewide, frameworks like EJSM, while useful regionally, may have limited applicability at a statewide scale. Cal-Adapt is a data source that is widely applied among policymakers and practitioners working in climate adaptation. Stakeholders generally find it useful for larger-scale climate projections. However, the tool’s inclusion of just two climate scenarios and lack of a customization feature limits its application for smaller-scale analysis purposes. In fact, attempting to use the tool for neighborhood-level planning is an inappropriate use of climate projection science, since it loses reliability at the local level.

Individual Indicators vs. Index-Based Approach

The newest version of CCHVIZ makes it difficult to understand the relationship between indicators since they don’t compose a single index. Nevertheless, some index-based approaches are less than ideal because they don’t allow users to see what individual factors are driving the index’s cumulative score. (HPI is an example of a tool that both captures the way that indicators affect each other, but also provides disaggregated indicators and data).

USEFUL FEATURES

Many interviewees expressed enthusiasm for an indicator set and accompanying visualization platform with features that would allow for a more comprehensive understanding of climate resilience.

Reflecting Interaction of Multiple Factors

A consistent thread is the need for features that demonstrate the interplay between various impacts, vulnerability, and even adaptation factors. For example, one stakeholder offered developing a map that would allow users to hover over an area and easily access links to resources or programs that address the climate and vulnerability factors that are significant in that area.

Integrating Qualitative Information

The inclusion of qualitative data provides context and information beyond what quantitative data can provide. For example, data could be complemented by stories that describe current applications of the tool or explain the rationale behind the incorporation of specific indicators. They could also include explanations of the levels of certainty associated with specific climate impact projections and the levels of response necessary at each progressive stage of impact.

Depicting Indirect Effects

Interviewees also expressed the need for features that would show the indirect effects of climate impacts and vulnerabilities. For example, one stakeholder offered the idea of a map that shows not only areas where mudslides occur, but also areas that would be affected due to traffic caused by choke points in the area's major evacuation routes.

Additional recommendations for map-specific features focused on increasing accuracy in representation of on-the-ground conditions. This includes showing critical infrastructure, street names, and local landmarks like churches and markets; showing where people spend time instead of just where they live; and showing the geographic distribution of farmworkers, domestic workers, and others working in the informal economy.

Recommendations of helpful **logistical features** include:

- Step-by-step tutorial walking users through use of the tool
- Mobile-friendliness
- Options to view offline and in different languages
- Visual icons (rather than solely a map legend)
- Use of publicly accessible data (that retains a sufficient level of accuracy even for unincorporated areas)
- Interactive and easy-to-use feedback, zoom, and printing functions.
- Functions to:
 - Integrate data layers from other tools
 - Toggle between various levels of geographic focus when viewing the maps—by census tract, ZIP code, city, assembly district, etc.
 - Extract select data and share ready-made reports based off of that data
 - Import data sets
 - Turn individual indicators on and off
 - Clearly visualize cross-community and cross-region comparisons



POLICY APPLICATIONS



THE INTEGRATION OF CALENVIROSCREEN IN STATE AND LOCAL POLICYMAKING OFFERS KEY INSIGHTS AND LESSONS REGARDING THE WAY CLIMATE VULNERABILITY DATA, INDICATORS, AND FRAMEWORKS CAN SUPPORT ADAPTATION PLANNING IN CALIFORNIA. Many stakeholders in our interviews expressed the need to improve the way the wealth of information contained within various frameworks informs efforts to promote climate resilience across a variety of sectors. Knowledge regarding vulnerability hot spots, for example, can support policymakers in targeting programs to relevant populations and places. The following offers examples of key sectors and policies within which such frameworks could be applied.

ANTICIPATED USES OF INDICATORS IN KEY SECTORS

Climate adaptation is multi-sectoral: The far-reaching impacts of climate disasters require planning efforts to centralize resilience across a variety of fields. *Safeguarding California*, as the state's road map on climate resilience, outlines the activities that agencies are deploying to protect communities, infrastructure, services, and natural resources from climate impacts.¹⁷² We reviewed relevant sector plans as well as the Climate Justice Working Group recommendations to assess specific ways that climate vulnerability frameworks could inform adaptation planning and programs.⁸⁵

PUBLIC HEALTH

It is clear that climate change threatens the health and well-being of California's diverse population and poses challenges for advancing health equity. The California Department of Public Health (CDPH), the California Environmental Protection Agency (CalEPA), and the Office of Environmental Health Hazard Assessment (OEHHA) are leading the state through a diverse range of actions to reduce vulnerability and protect community health. CDPH already actively promotes the use of climate vulnerability frameworks like the California Healthy Places Index (HPI) and Climate Change and Health Vulnerability Indicators (CCHVIZ) for use by local, regional, and state agencies. OEHHA recently updated its Indicators of Climate Change report in 2018 to track climate trends in California. The Public Health sector plan in *Safeguarding California* highlights the opportunity for these types of frameworks to prioritize funding, community engagement, jobs, and services for communities facing disproportionate climate and health risks.

Local Health Department Outreach

CDPH engages local health departments around climate resilience planning in a variety of ways. The sector plan identifies opportunities in health department activities such as nutrition promotion programs and mental health centers. The agency plans to promote and disseminate *Climate Change, Health, and Equity: A Guide for Local Health Departments* to assist local health departments with integration of climate change and health equity work into traditional public health programs and core functions. They are also promoting resilience in community health clinics, nonprofit organizations, and community groups. With the assistance of CDPH, information derived from climate vulnerability frameworks like HPI and CCHVIZ can continue to support the ability of local health providers and departments to execute vulnerability assessments at the local and regional level. For example, CDPH could utilize data regarding heat vulnerability overlaid with designated cooling center locations to support local health departments to identify and reach vulnerable populations in need of access to cooling resources. Demographic information contained within these frameworks could also ensure the departments' outreach is culturally competent and accessible.

LAND USE AND COMMUNITY DEVELOPMENT

In the Land Use and Community Development sector, climate adaptation and resiliency efforts are currently being carried out by three entities, the Governor's Office of Planning and Research (OPR), the Department of Housing and Community Development (HCD), and the Strategic Growth Council (SGC). Many of the recommendations offered for this sector in *Safeguarding California* are focused on incorporating climate threats into the agencies' grant programs, as well as in the policy guidance they provide.

Climate Justice Strategy

Acknowledging that vulnerable populations bear a disproportionate burden of climate change, the state prioritizes protecting these populations. Several agencies are using different methods to work toward this goal. For example, CDPH has developed climate health profiles based on demographic and risk information, while OPR is providing technical guidance on how to meet new environmental justice requirements in the General Plan. The Land Use and Community Development sector plan in *Safeguarding California* highlights further opportunities for ensuring the implementation of a coordinated and robust climate justice strategy across various levels of government. Most of these next steps require cross-sector, cross-agency collaboration and are efforts to more clearly demonstrate the vulnerabilities of at-risk communities. The sector plan also explicitly directs the state to explore the use of frameworks that screen for health and vulnerability or that lay out access to community development opportunities, specifically to complement existing tools that identify disadvantaged communities.

Investments in Housing and Community Development

Various state grant programs incorporate climate adaptation. This includes the Affordable Housing and Sustainable Communities (AHSC) grant program, which funds transit-oriented development and selected programs that reduce greenhouse gas emissions, and the Transformative Climate Communities (TCC) program, which funds the development and implementation of neighborhood-level transformative climate community plans. TCC currently includes, as part of its Climate

and Adaptation Resilience scoring criteria, the identification and analysis of climate risks, exposures, and adaptation measures. Also listed is the inclusion of a process to identify and prioritize climate risks, exposures, and adaptation measures. Providing suggestions of relevant climate resiliency frameworks (e.g., California Healthy Places Index and Climate Change and Health Vulnerability Indicators) to help applicants meet these criteria could help strengthen state efforts to incorporate climate adaptation in its funding programs. TCC could also require applicants to cite data from a specific framework it deems most effective at meeting the comprehensive needs of the program.

EMERGENCY MANAGEMENT

Climate change impacts emergency preparedness, response, and recovery; therefore, it is critical to ensure community resilience against its destructive effects. The Governor's Office of Emergency Services (Cal OES) leads state disaster preparation, response, and recovery, with emphasis on incorporating climate risks into hazard mitigation planning, which encompasses strategies to reduce disaster losses and break the cycle of disaster damage.

Cal OES Office of Access and Functional Needs (OAFN)

Cal OES through its Office of Access and Functional Needs addresses emergency planning, response, and recovery needs for access and functional needs populations (e.g., people with disabilities, seniors, children, limited English proficiency, and transportation disadvantaged). OAFN has a web mapping tool that provides demographic information and outlines where resources like accessible transportation are located across the state. OAFN is looking to integrate an understanding of the way climate impacts will exacerbate risks to access and functional needs populations, and is working on incorporating those risks within all threat and hazard analysis conducted by the state. OAFN could better achieve this intent and increase whole community preparedness to disasters by coupling its demographic information and resources maps with climate vulnerability frameworks.

POLICY SPOTLIGHT

SENATE BILL 379

SB 379 (Jackson, 2015) requires local jurisdictions to address climate adaptation and resilience strategies as they revise local hazard mitigation plans or in the safety element of the General Plan. The law requires the update to include goals, policies, and objectives based on a vulnerability assessment identifying local climate change risks. Climate vulnerability frameworks on exposures, health risks, and priority populations could target proposed strategies with grounded evidence. The legislation explicitly names Cal-Adapt as a source of information to help cities and counties assess local vulnerabilities to climate change, but other frameworks could be useful to local jurisdictions looking to connect data from other sectors.

Hazard Mitigation Funding

Cal OES administers a variety of grant programs for disaster mitigation to both reduce disaster losses and protect communities and infrastructure from future damages. This includes the Hazard Mitigation Grant Program, which supports entities like state agencies and local governments, and the California Disaster Assistance Act, which supports repair, restoration, or replacement of damaged public property. Pre-Disaster Mitigation and Flood Mitigation Assistance are additional programs that provide funding for mitigation activities. Integration of climate vulnerability frameworks would enhance disaster response and recovery by identifying vulnerable populations, demonstrating how climate impacts will exacerbate existing conditions, and depicting physical risks to essential services and facilities. Therefore, these grant programs could be more strategically deployed by incorporating such frameworks.

Emergency Planning: Local Hazard Mitigation Plans

In addition to recovery efforts in the aftermath of disasters, Cal OES is also looking to incorporate climate considerations into emergency planning efforts at all levels. Current and future climate projections could inform emergency planning and investments. For example, Cal OES proposes revising its state guidance for Local Hazard Mitigation Plans to reflect climate risks and adaptation needs. This guidance could include examples of climate vulnerability frameworks that local entities could use to inform planning activities. Cal OES also is exploring the feasibility of integrating climate projections like sea level rise into its MyHazards and MyPlan tools.

TRANSPORTATION

A range of climate impacts pose threats to critical transport infrastructure like highways, roads, bridge supports, and airports. The Department of Transportation (Caltrans) is the agency responsible for operating the state's highways and rail lines.

Vulnerability Assessments of Infrastructure and Populations to Inform Transportation Planning

Caltrans is planning to assess the vulnerability of transportation assets by integrating climate change projections from Cal-Adapt with highways, seaports, airports, and rail, transit, bicycle, and pedestrian infrastructure. Vulnerability assessments of infrastructure could highlight potential operational issues related to congestion management and disaster response. Additional analysis of impacts on infrastructure alongside vulnerable populations (e.g., low-income, disabled, and elderly residents) with limited transportation access could also reveal potential evacuation inequities during climate disasters. Therefore, CalTrans plans to direct this data on vulnerable segments of the state's transportation system to Cal OES to enhance emergency preparedness. This information could inform improvements in public transportation systems to evacuate vulnerable people during climate disasters. For example, indicators capturing heat vulnerability such as urban heat islands could inform services to access cooling centers or design

POLICY SPOTLIGHT

SENATE BILL 1

SB 1 (Beall, 2018), the Road Repair and Accountability Act, provides \$5.4 billion annually to fund improvements to the state's transportation systems. SB 1 funds Adaptation Planning Grants, which support planning actions at local and regional levels that advance climate change efforts on the transportation system. The identification of vulnerable infrastructure and communities through use of climate vulnerability frameworks could improve targeting of this funding.

of transit hubs to promote shade, offer drinking water, and passive cooling.

ENERGY

California's energy infrastructure must be resilient to cope with disruptions from wildfires, storms, and floods; this is imminent as increasing frequency and severity of disasters due to climate change are devastating communities as a result of repeated infrastructure failures.¹⁷³ Since historical data is a poor predictor of future impacts, the energy sector is committed to advancing research on climate change projections.

The California Energy Commission (CEC) and the California Public Utilities Commission (CPUC) are the primary agencies advancing the resilience of the energy sector and are leading the state in connecting climate science to planning and investment decision making. The sector is also considering and prioritizing protections for vulnerable communities from climate threats. Energy resilience is promoted within a range of ongoing efforts, including customer-side renewable distributed generation, microgrid incentives, energy storage, energy efficiency, water efficiency, and demand response strategies.

Electric Program Investment Charge

CEC created the Electric Program Investment Charge (EPIC) in December 2011. The purpose of this program is to fund clean energy technology projects that will promote clean and renewable energy throughout California and improve air quality. The EPIC program has an annual funding of \$162 million that is collected from the customers of the three largest investor-owned utilities companies in California. These funds can be used for research and development, technology demonstration and deployment, and market facilitation. AB 523 (Reyes, 2017) targets a minimum of 35 percent of EPIC funding for technology demonstration and deployment for projects in low-income and disadvantaged communities. Funding opportunities within EPIC that promote community resilience include the EPIC Challenge: Accelerating the Deployment of Advanced Energy Communities program and past solicitations to deploy advanced microgrids in disadvantaged communities.^{174,175,176} Renewable energy technologies like on-site solar coupled with storage as well as microgrids provide the capability to provide on-site electricity in the event of a power outage. Alongside existing definitions of eligible communities, community vulnerability frameworks could inform strategic deployment of the funding of such programs to critical facilities located in places most impacted by climate disasters and associated power outages.

California Clean Energy Equity Framework

Energy Commission staff incorporated climate impacts in its energy equity indicators for SB 350 (De León, 2015). The associated story map published by the CEC highlights opportunities for applying this framework to inform the agency's energy efficiency investments (which can improve space cooling) by targeting areas that are currently impacted by and expected to experience vulnerability to heat-related illness (e.g., Central Valley and Southern California deserts). It also highlights the types of analysis that are possible by geographically overlaying low-income areas with high fire-threat areas to highlight hot spots of vulnerability that inform potential opportunities for technology deployment.

Low-Income Weatherization Program

The Department of Community Services and Development (CSD) administers the Low-Income Weatherization Program (LIWP), which offers free energy efficiency and solar programs to communities overburdened by poverty and pollution. CSD is committed to serving low-income and disadvantaged Californians with continued efforts to improve and innovate to reduce greenhouse gases and achieve multiple benefits, including lowering household energy burden, improving health and safety, and supporting local workforce development. CSD's programs are also a unique opportunity to promote community resilience, as low-income households are likely most vulnerable to the health and economic impacts of electricity shutoffs and power outages from climate change.¹⁷⁷ Coupled with energy efficiency measures and energy storage technology, solar access also promises improved household comfort, safety, stability, and resilience. Low-income communities tend to live in older buildings and use inefficient appliances, which contribute to higher energy use. High-performance, well-insulated buildings are more likely to maintain temperatures, allow residents to shelter in place longer due to extreme weather (e.g., heat waves, storms), and also contribute to economic stability. Therefore, LIWP could be further strengthened by using climate vulnerability frameworks to identify high-value resilience opportunities based on projected climate impacts within disadvantaged communities.

POLICY SPOTLIGHT

PROPOSITION 1

In efforts to support regional groundwater management for drought resiliency, the Water Board is funding projects that clean up and prevent contamination of groundwater used as a source of drinking water through the Proposition 1 program that reserves 20 percent of available funds for projects directly benefiting Disadvantaged Communities (DACs) and Economically Distressed Areas (EDAs).¹⁷⁸ This is an example of a policy application where integrating information derived from a climate vulnerability framework that highlights communities requiring resources for drought resiliency could help to ensure targeted action.

WATER

Climate change has already affected hydrological patterns in California, increasing risks from acute climate events and threatening the state's water resources. With these recommendations, the Department of Water Resources (DWR) and the State Water Resources Control Board (Water Board) lead efforts to build on previous adaptation work in the water sector to update and coordinate actions focused on different parts of the water cycle.

Preparing California for Flooding

Safeguarding California recommends that the state vigorously prepare California for flooding and directs the Department of Water Resources to incorporate or support the incorporation of projections of future hydrology and climate impacts in flood planning efforts, whether they are development of flood inundation maps, integration of flood models in Regional Flood Management Plans, or assessment of adverse impacts to health, industries, infrastructures, and ecosystems. The Central Valley Flood Protection Board has already begun incorporating climate impacts into their regional work, though this work has mostly been concerned

with financial aspects of preparation, like costs of flood management or investment strategies. Use of a more holistic framework that not only captures the effects of climate change on inundation risk, but also overlays data on social vulnerability, hazardous sites, and infrastructure could support other efforts to prevent and mitigate flood risk (e.g., Surging Seas Risk Zone Map).

Addressing Drought via Groundwater Protection

As the reliability of groundwater sources decreases due to climate change, communities already vulnerable to the effects of drought will face heightened risks. It is critical to protect communities from drinking water insecurity resulting from depleted or contaminated groundwater sources. One recommendation from the CJWG is to encourage the direct involvement of environmental justice communities as well as private well users in planning efforts.⁸⁵ Private well users are not mentioned in *Safeguarding California*, reflecting the way drinking water issues faced by these communities are often overlooked by agencies. Involvement in the development of a climate vulnerability framework that captures localized groundwater issues (e.g., through a ground-truthing process like the one undertaken during the development of the California Environmental Vulnerability Assessment) is one way to help planning efforts capture these communities' specific water-related vulnerabilities.

Improved Understanding of Climate Risks and Tool Development

More effective water management calls for tools that model the effects of climate change at smaller scales. For this reason, various agencies are working to further state understanding of climate risks and to develop improved tools. For example, DWR, drawing from the Fourth Climate Change Assessment, is standardizing the selection of climate change scenarios across its programs and for local water management efforts, including the Proposition 1 Water Storage Investment Program. The sector plan also identifies specific plans that further help to coordinate water-related adaptation efforts. The DWR will be releasing a completed Vulnerability Assessment and Adaptation Plan that analyzes the State Water Project, and together with the CEC and the Natural Resources Agency will update water-related climate projections used in Cal-Adapt to make it more useful for local planning. In addition, the Public Utilities Commission is developing a new tool that assesses urban water resilience. Existing climate resilience frameworks that characterize water-related risks like flooding and drought (e.g., Surging Seas Risk Zone Map and the U.S. Drought Monitor) may help to inform development of new tools.

FORESTRY AND GREENING

Human activities like fire suppression and those contributing to climate change have degraded California's forests. Because forests throughout the state vary widely in their ecological characteristics and ownership type (forests in California are managed by the federal, state, and local governments, as well as private landowners), *Safeguarding California's* recommendations present a suite of strategies designed to improve resilience rather than a one-size-fits-all solution. CAL FIRE, the U.S. Forest Service, and the Natural Resources Agency are among the agencies carrying out these strategies.

Urban Tree Canopy Coverage

Safeguarding California's Forestry sector plan directs the state to continue investing in urban forestry to enhance the health of current urban forests and expand urban tree canopy statewide. The next steps identified mostly focus on supporting local efforts, including helping

POLICY SPOTLIGHT

PROPOSITION 68

Passed in June 2018, Proposition 68 is a \$4 billion bond measure aimed at protecting California's water, parks, and natural resources, while bolstering climate adaptation, resilience, and social equity statewide. It invests in efforts to mitigate climate-intensified disasters (e.g., wildfire, floods, and drought) by investing in local water infrastructure projects, fire protection, natural lands, and forest restoration. An equity provision requires that 15–20 percent of the bond funds be directed to projects in low-income communities. In addition, \$725 million in bond revenue is reserved for parks in “park-poor” neighborhoods.¹⁷⁹ Although the definition of “park poor” is consistent with an existing grant program, indicators such as urban heat island, tree canopy, and impervious surfaces could be overlaid with eligible communities based on statute in order to further target these funds to promote resilience benefits during extreme heat events or flooding.

local governments identify optimal locations for green infrastructure and increased tree canopy cover in high-priority areas, collecting and sharing canopy coverage data with local governments, and funding urban tree planting and green infrastructure projects where they yield multiple benefits. Ongoing actions by the state that address this goal include funding urban forestry projects as well as providing research and technical support for urban forestry management through programs like CAL FIRE's Urban and Community Forestry Program and the Regional Urban Foresters. *Safeguarding California* names several frameworks as resources to guide incorporation of community greening, including the California Environmental Protection Agency's Urban Heat Island maps, California Building Resilience Against Climate Effects' (CalBRACE) tools on tree canopy cover and impervious surfaces, and the Trust for Public Land's Climate-Smart Cities tool.

Foster Fire-Adapted Communities

Another recommendation for the Forestry sector is to foster fire-adapted communities through local planning and fire preparedness. Several of the actions identified as next steps for this recommendation are concerned with the wildland-urban interface. This includes helping local and tribal governments to incorporate policies that discourage development in the wildland-urban interface in planning documents, developing local fire readiness plans, and understanding the effects of climate change on the risks posed by fires to lives, homes, and critical infrastructure. Currently, CAL FIRE tracks vegetation clearing in the wildland-urban interface. The agency also inspects defensible spaces on State Responsibility Areas, areas for which it has a legal responsibility to provide fire protection. Execution of some of the next steps regarding fire adaptation along the wildland-urban interface could likely benefit from tools that help to characterize risks to populations and infrastructure along the state's wildland-urban interface (e.g., CAL FIRE Fire Hazard Severity Zones maps and California Fire Threatened Wild Land/Urban Interface map.)

OCEAN AND COAST

State agencies including the Ocean Protection Council, Natural Resources Agency, Coastal Commission, and State Lands Commission along with regional agencies along the coast and inland delta are taking action to assess the risks and reduce the impacts of climate change. They continue to study and plan for community impacts on economic livelihoods, coastal access and recreation, and the well-being and safety of coastal communities.

Protecting Coastal Communities

The sector plan explicitly states its goals to reduce hazards and increase the resilience of coastal communities, infrastructure, development, and other resources. Climate vulnerability frameworks on sea level rise impacts and social vulnerability integrate climate risks into planning in various ways. The data highlights communities facing unequal burdens from climate risks and those with insufficient resources to respond to these risks, which can be incorporated into various coastal grants and local adaptation programs. This includes the San Francisco Bay Conservation and Development Commission's Adapting to Rising Tides program, which

POLICY SPOTLIGHT

EXECUTIVE ORDER N-05-19

Directed by an Executive Order issued by Gov. Gavin Newsom in January 2019, CAL FIRE identified priority fuel reduction projects that could protect communities vulnerable to wildfires.¹⁸⁰ The order explicitly directs CAL FIRE to prioritize the most at-risk communities and consider social vulnerability factors and other access and functional needs challenges. Socioeconomic characteristics considered by CAL FIRE include poverty levels, residents with disabilities, language barriers, residents over 65 or under 5 years of age, percent non-white, and households without a car. Based on a combination of wildfire risk, existing plans, and socioeconomic characteristics, CAL FIRE identified 35 priority projects covering more than 200 communities, including areas near Big Sur, Orinda, Aptos, Woodside, Los Gatos, the city of Redding, and Butte County.¹⁸¹

is a community-based planning program along the entire San Francisco Bay shoreline, or the state Coastal Conservancy's Climate Ready Program, which provides funds and technical assistance to local communities to assess climate impacts and plan for adaptation.

Vulnerability Assessments

This information can also be integrated into grants and funding for community-based vulnerability assessments. The sector plan identifies the importance of extending frameworks to communities to equip them with the ability to assess vulnerability and inform appropriate action and response. Thus, agencies responsible for coastal protection are looking to incorporate input into vulnerability assessments from residents, beach users, local businesses, and

other relevant stakeholders through workshops and community events. Existing frameworks can continue to be strengthened as the relevant agencies map coastal infrastructure and vulnerable assets, such as water and wastewater infrastructure, energy infrastructure, ports, tourism, and fishing sites. For example, the sector plan highlights how sea level rise projections overlaid with hazardous material cleanup sites on the coast in high flood risk areas could inform priority remediation to prevent contamination during flooding.

OTHER RELEVANT EFFORTS

STRATEGIC GROWTH COUNCIL CLIMATE CHANGE RESEARCH PROGRAM

The Strategic Growth Council Climate Change Research Program represents a prime opportunity for working with other nonprofits, academic institutions, and public agencies to advance the development of indicators. In particular, 10 research projects were recently awarded funding through the program's first round solicitation, several of which will increase data accessibility to support vulnerable communities. Many of the projects aim to address research gaps and strengthen frameworks to depict community vulnerability to climate impacts in California. A second round solicitation announcing \$17.1 million was released on Oct. 9, 2018.

Round 1 awardees focusing on protecting vulnerable communities include:

- **The Future of San Joaquin Valley Agriculture Under Climate Change and SGMA.** A team of research scientists, engineers, and agricultural economists are investigating the environmental and socioeconomic impacts of climate change on San Joaquin Valley agriculture and disadvantaged communities in the context of a changing regulatory environment and water supply reductions under the Sustainable Groundwater Management Act.
- **Sea Level Rise, Hazardous Sites, and Environmental Justice in California.** This project brings together a multidisciplinary project team to examine the potential impacts of coastal flooding due to sea level rise (SLR) on disadvantaged communities in California, improve public knowledge about flood risks from SLR, and promotes more systematic consideration of hazardous sites and vulnerable populations.
- **Examining the Unintended Effects of Climate Change Mitigation: A New Tool to Predict Investment-Related Displacement.** This research estimates the relationship between displacement pressures and California's climate mitigation strategies, policies, and the investments made possible by the Cap and Trade program in order to create tools that state agencies can use to predict and mitigate the displacement impacts of future investments.
- **Increasing Data Accessibility and Climate Resilience Planning Support Through Cal-Adapt.** Researchers are leveraging the existing Cal-Adapt web application tool by conducting needs assessments and outreach efforts to help identify new data sets, design and build new features and targeted tools for the application that more thoroughly addresses stakeholder needs beyond the energy sector, and assist state agencies and others with developing actionable plans to adapt to changing conditions.
- **Measuring the Impacts of Climate Change on Vulnerable Communities to Design and Target Protective Policies.** Researchers are quantifying financial and health costs of understudied climate

impacts across California—workplace morbidity/mortality, wages, unemployment, household energy expenditures, reproductive and prenatal risks, air pollution exposure, inadequate housing quality, and wildfire readiness. Researchers will forecast potential costs due to increases in the number of extreme heat days and create two accessible online mapping tools to inform state agencies, nonprofits, local governments, and community members.

COMMUNITY ENGAGEMENT IN DECISION-MAKING PROCESSES

Many sector plans identify the importance of providing pathways for meaningful community engagement in state agency decision-making processes around climate adaptation and resilience. Climate vulnerability frameworks point to a range of populations and regions that are most vulnerable to particular climate impacts. This information can support outreach efforts to ensure that relevant residents and community groups are integrated and empowered in planning processes. California's Fourth Climate Change Assessment notes that there are significant limits to most mapping tools, especially because they are often not vetted with local communities.¹⁸

Current and future processes to geographically map hot spots or develop frameworks could, therefore, be enhanced through citizen and community science projects that add a narrative or qualitative component to climate science. This is echoed by various reports that reiterate the importance of building on community knowledge by providing frontline community members with opportunities to support information-gathering, research, analysis, and review.^{44,85,182} For example, the Public Health sector plan highlights the U.S. EPA *Smoke Sense* study, which will support determining the extent to which exposure to wildland fire smoke impacts community health and productivity.¹⁸³ The SB 1000 Toolkit produced by the California Environmental Justice Alliance (CEJA) offers a wide range of community engagement strategies and techniques that can be modeled by decision makers looking to communicate and enhance vulnerability frameworks with local community residents.¹⁸⁴



ENDNOTES

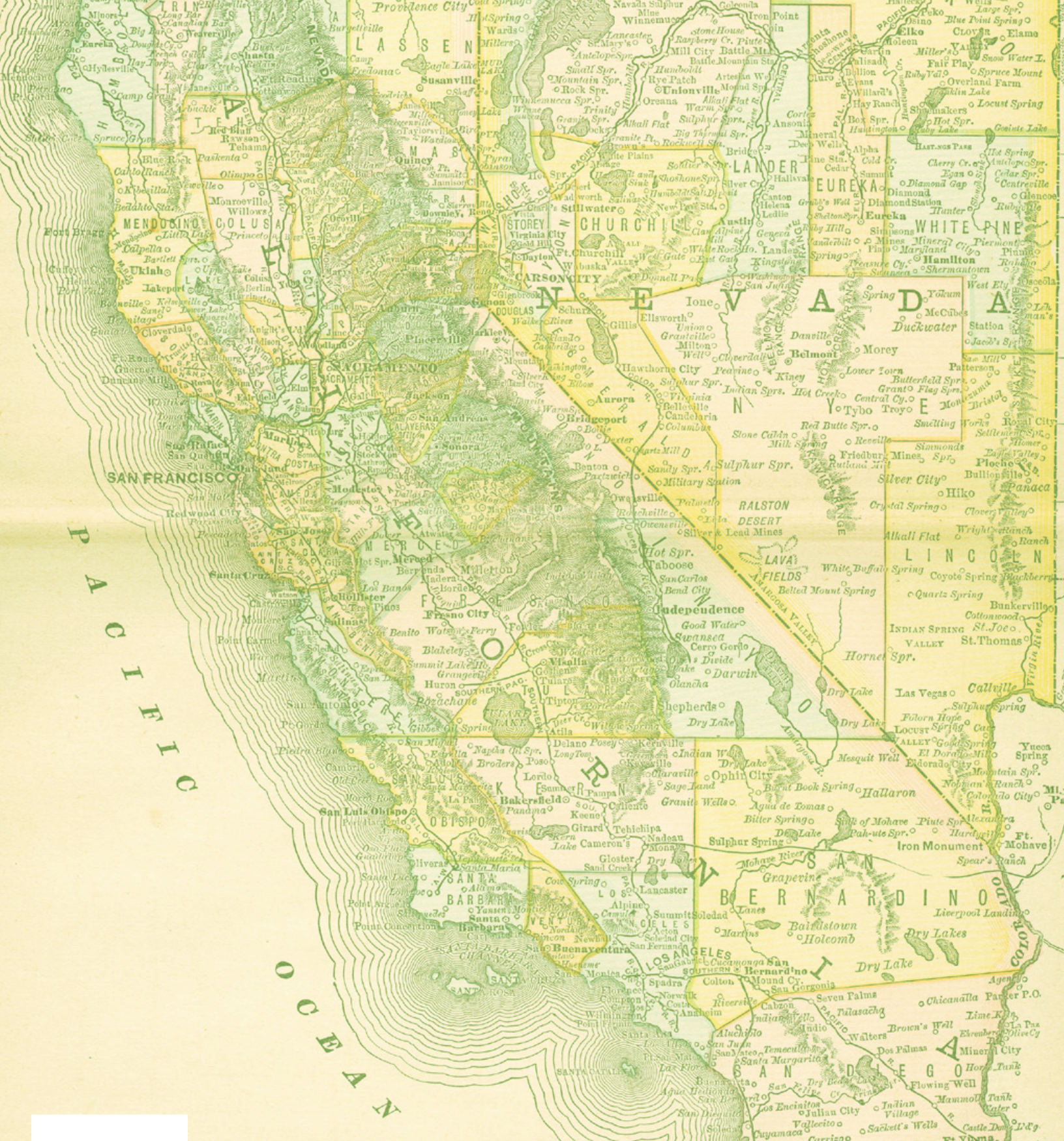
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All people have a right to a clean and healthy environment in which their communities can live, work, learn, play, and thrive. Toward this vision, APEN brings together a collective voice to develop an alternative agenda for environmental, social, and economic justice. Through building an organized movement, we strive to bring fundamental changes to economic and social institutions that will prioritize public good over profits and promote the right of every person to a decent, safe, affordable quality of life, and the right to participate in decisions affecting our lives. APEN holds this vision of environmental justice for all people. Our work focuses on Asian and Pacific Islander communities. www.apen4ej.org