LA County Climate Vulnerability Assessment

Technical Methodologies and Resources

October 2021

LA County CVA Technical Methodologies and Resources

The technical methodologies for the Social Vulnerability Assessment, Physical Vulnerability Assessment, and Cascading Impacts Assessment are provided below for insights into the assessment approach, methods, data sources.

Part 1: Social Vulnerability Assessment Methodology

Part 2: Physical Vulnerability Assessment Methodology

Part 3: Cascading Impacts Assessment Methodology

Part 1: Social Vulnerability Assessment Methodology

Buro Happold developed the approach for and evaluated social vulnerability for Los Angeles County's Climate Vulnerability Assessment. Methods, analysis, and assumptions are presented here. This section describes the methodology used for the Los Angeles County Social Vulnerability Assessment (SVA) Social Sensitivity Index. The aim of the assessment is to evaluate sensitivity and adaptive capacity as well as their relationships to climate exposures. Analysis results are presented in the form of maps, tables, and other visuals and drew upon the findings of the Desktop Review, Climate Hazards Assessment, and available datasets and information.

Social Sensitivity Index

The definition and scope of social vulnerability is broad and capturing its nuanced complexity is not easy. Social vulnerability can be assessed qualitatively, quantitatively, or using a combination of both. Explaining or identifying social vulnerabilities using quantitative data requires one to select indicators based on relevance and availability. Oftentimes, the data is disaggregated geographically, so the indicators are combined into an index or score to understand the cumulative effect of multiple factors that lead to increased vulnerability within a given region.

Indicator selection process

Plans, reports, and tools were reviewed as part of the Desktop Review to identify a set of key indicators that would be considered for the Social Sensitivity Index. Most frameworks included indicators in each of the following broader demographic categories: income/wealth, age, housing, mobility, health, race/ethnicity, education, community (social cohesion), and occupation. Indicators that were common across these resources and available at the census tract level were considered for the final index. The full suite of selected indicators is presented in the table below along with a description of the data and its source.

Table 1. Table of Indicators Included in the Social Sensitivity Index

Indicator	Description	Source
Children	Percent children 18 and under	American Community Survey, 5-Year Estimates, 2018, Table S0101
Older adults	Percent persons 65 and over	American Community Survey, 5-Year Estimates, 2018, Table S0101
Older adults living alone	Percent of households in which the householder is 65 and over who and living alone	American Community Survey, 5-Year Estimates, 2018, Table S2501
Limited English	Percent limited English speaking households	American Community Survey, 5-Year Estimates, 2018, Table S1602
No high school diploma	Percent of persons 25 and older without a high school diploma	American Community Survey, 5-Year Estimates, 2018, Table S1501
Female	Percent female	American Community Survey, 5-Year Estimates, 2018, Table S0101
Female householder	Percent of households that have a female householder with no spouse present	American Community Survey, 5-Year Estimates, 2018, Table B11011
Asthma	Age-adjusted rate of emergency department visits for asthma	CEHTP and OSHPD

Cardiovascular	Age-adjusted rate of emergency department visits for heart attacks per 10,000	CEHTP and OSHPD
Disability	Percent of persons with either mental or physical disability	American Community Survey, 5-Year Estimates, 2018, Table S1810
No health insurance	Percent of persons without health insurance	American Community Survey, 5-Year Estimates, 2018, Table S2701
Living in group quarters	Percent of persons living in (either institutionalized or un-institutionalized) group quarters	American Community Survey, ACS 2018 5-Year Estimates
Mobile homes	Percent of persons living in mobile homes	American Community Survey, 5-Year Estimates, 2018, Table S2504
Rent burden	Percent of renters paying more than 30 percent of their monthly income on rent and utilities	American Community Survey, 5-Year Estimates, 2018, Table B25070
Renters	Percentage of renters per census tract	American Community Survey, 5-Year Estimates, 2018, Table S2503
Median income	Median household income of census tract	American Community Survey, 5-Year Estimates, 2018, Table S2503
Poverty	Percent of the population living in a family earning below 100% of the federal poverty threshold	American Community Survey, 5-Year Estimates, 2018, Table S1701
Households without vehicle access	Percent of households without access to a personal vehicle	American Community Survey, 5-Year Estimates, 2018, Table S2504
Transit access	Percent of population residing within a ½ mile of a major transit stop	Healthy Places Index, SCAG
Outdoor workers	Percentage of outdoor workers - agriculture, fishing, mining, extractive, construction occupations	American Community Survey, 5-Year Estimates, 2018, Table S2401
Unemployed	Percent of the population over the age of 16 that is unemployed and eligible for the labor force	American Community Survey, 5-Year Estimates, 2018, Table S2301
Foreign born	Percent of the total population who was not born in the United States or Puerto Rico	American Community Survey, 5-Year Estimates, 2018, Table B05001
Library access	Each tract's average block distance to nearest library	LA County ISD (calculated as each tract's average block distance to nearest library)
No internet subscription	Percent of the population without an internet subscription	American Community Survey, 5-Year Estimates, 2018, Table S2801
Voter turnout rate	Percentage of registered voters voting in the 2016 general election	USC, California Statewide Database, General Elections Data
Black	Percent identifying as non-Hispanic Black or African American	American Community Survey, 5-Year Estimates, 2018, Table B03002
Hispanic Latinx	Percent identifying as Hispanic or Latino	American Community Survey, 5-Year Estimates, 2018, Table B03008
Tribal and Indigenous	Percent identifying as non-Hispanic American Indian and Alaska native	American Community Survey, 5-Year Estimates, 2018, Table B03003

Asian	Percent identifying as non-Hispanic Asian	American Community Survey, 5-Year Estimates, 2018, Table B03004

Constructing the Index

The team selected a Principal Component Analysis (PCA) based model to index indicators and create an overall score for mapping and analysis. Broadly speaking, PCA is a statistical method used for extracting information from, and reducing multicollinearity in, data sets with many variables. This approach is the best fit for its credibility, flexibility, and ability to account for the interactions between different indicators. For these reasons, PCA-based models can be particularly useful at uncovering geographical inequities while minimizing any potential redundancies or user biases across indicators. Dr. Cutter and the Hazards and Vulnerability Research Institute at University of South Carolina, where the Social Vulnerability Index (SoVI®) was created, popularized this approach to social vulnerability.[1] The institute offers a SoVI® Recipe, which the Los Angeles County Social Sensitivity Index was largely based on.

Prior to the analysis, the team verified the data's suitability for PCA through the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy (MSA) and Bartlett's Test of Sphericity.[2] The KMO test measures the proportion of common variance among indicators and produces an MSA between 0 and 1. Higher values show better suitability, and the MSA for the LA CVA set of indicators was 0.87. Once the data was verified, the following steps were taken to create the index:

1. Removed census tracts with a population of 0
2. Normalized all variables
3. Verified accuracy of the data set with descriptive statistics. Any remaining missing values were replaced with the variable's mean value
4. Standardized input variables using z-score standardization (mean of 0 and standard deviation of 1)
5. Performed the PCA using varimax rotation
6. Examined and chose resulting factors based on scree plot results (Figure 1) and variance (according to the Kaiser Criterion)
7. Calculated index score by using all selected component scores into an additive model. Combined the chosen factors in an additive model resulting in a PCA-based index score comprised of 6 components, which together account for 67.19% of the variation (Figure 2).

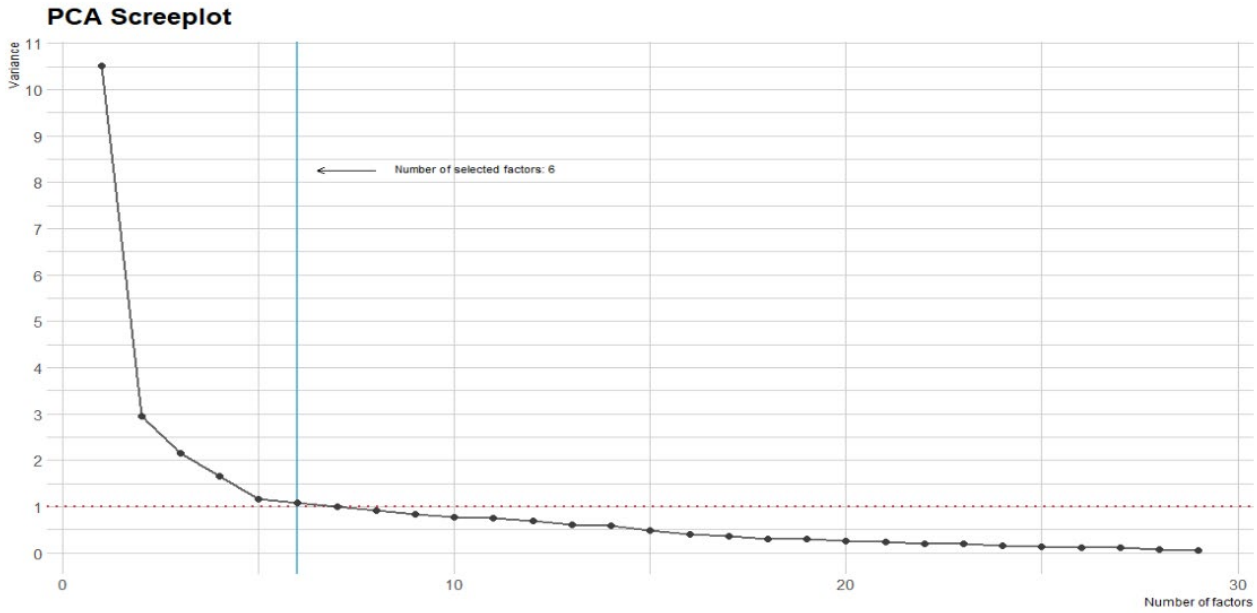

Figure 1. PCA Scree Plot Used for Factor Analysis

Table 2: Selected Factors with Variance Explained, Cumulative Variance Explained, and Top Loaded Variables (>+/-0.5)

Factor	Variance Explained	Cumulative Variance Explained	Indicator(s)	Loading
Factor 1	36.2%	36.2%	Renters	0.9
			Households without vehicle access	0.77
			Poverty	0.71
			No internet subscription	0.56
			Voter turnout rate	-0.59
			Median income	-0.76
Factor 2	10.2%	46.4%	Foreign born	0.89
			Limited English	0.77
Factor 3	7.4%	53.8%	Cardiovascular	0.94
			Asthma	0.59
Factor 4	5.7%	59.5%	Outdoor workers	0.84
Factor 5	4.0%	63.5%	Older adults living alone	0.94
Factor 6	3.7%	67.2%	Children	0.86

Note: It should be emphasized that at its core, a PCA-based model is a relative measure of variation across a selected subpopulation. Indicators that have lower weighting (or factor loadings) don't contribute as much to the overall index. However, this does not imply that these indicators contribute less to a person or communities' sensitivity, rather that they are less useful in uncovering geographic patterns of disparity across the region.

Within the context of the CVA, this means that there is less variation across census tracts in the County. One example of such an indicator is gender. Women experience gender discrimination which can contribute to climate sensitivity. However, most census tracts have a gender ratio that is close to even and variation is more minimal across the County when compared to other indicators. Because of this, indicators are also examined individually in the Social Vulnerability Assessment, analyzed using non-spatial techniques, and supplemented with qualitative data.

Constructing the social vulnerability maps

The social vulnerability maps are composed of two input layers: the social sensitivity index and a hazard exposure layer. The approach for mapping these overlays is largely based on the Integrated Vulnerability Assessment Framework which was developed by the National Centers for Coastal Ocean Science's (NCCOS).[3] In this approach, both input layers are broken into low, moderate, and high categories and then aligned in a three-by-three matrix. The result is that each census tract withing the County falls into one overall relative risk category.

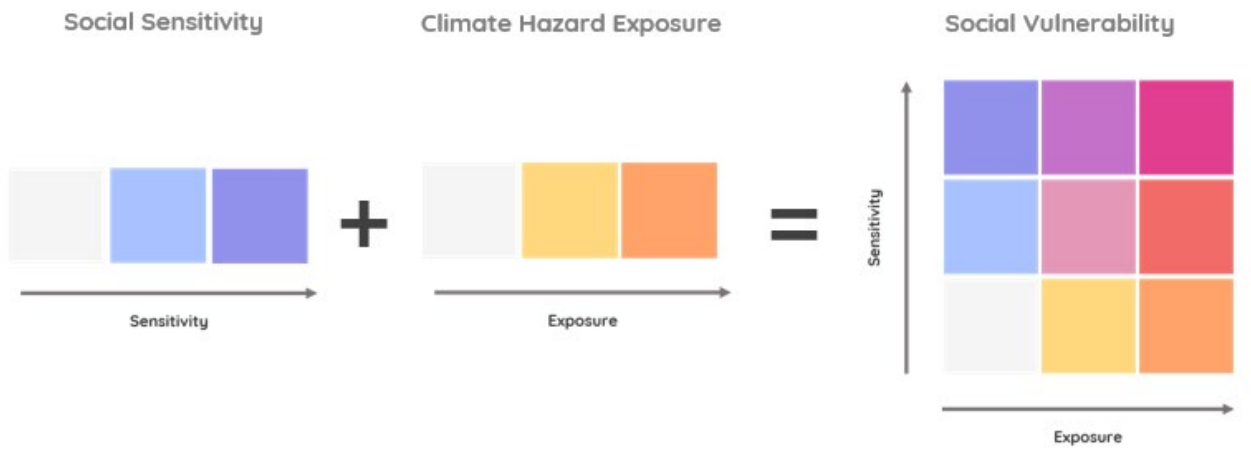

Figure 2: Overview of social vulnerability components

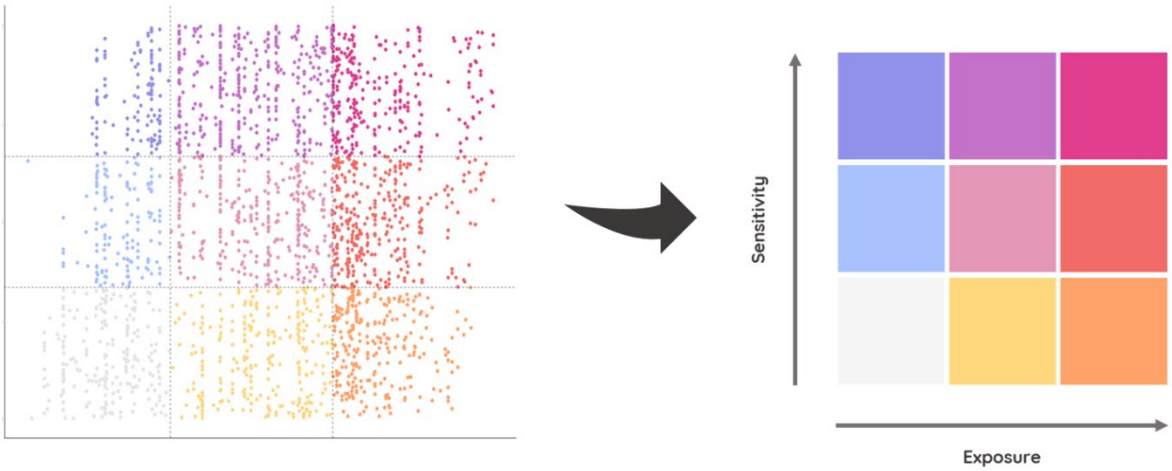

Figure 3. Example of how census tracts (left) are categorized into the social vulnerability matrix (right).

In total, five distinct climate hazards were mapped against social sensitivity at the County scale. Where applicable and available, both baseline and RCP 8.5 mid-century scenarios were presented. Each of the hazards were relatively and spatially categorized into low, moderate, and high groups. For extreme heat, wildfire, and precipitation, equal interval breaks were used for the cut off points. Historic baseline level cut off points were maintained for 2050 projections. For extreme heat, wildfire, and precipitation, grid level data (6km x 6km) were spatially joined with census tracts using area weighted averages. Cut off points were generated from the grid level data to maintain consistency with the original data source and physical vulnerability analysis. For the PCA-based social sensitivity index, low, moderate, and high classifications were assigned to each census tract based on their placement in three quantile breaks.

Once both layers, the climate hazard and the social sensitivity index, were classified, they were overlaid on a single map to create a 3x3 matrix of colors and relative vulnerability levels. Census tracts with a population of zero were omitted from the analysis. The resulting social vulnerability maps are summarized below.

Table 3. Summary Table for the Social Vulnerability Maps.

Layers	Measure	Time frames	Spatial Join	Breaks
Social Sensitivity + Extreme Heat	95th percentile daily maximum temperature	Baseline, RCP 8.5 Mid-Century	Weighted average	Equal interval
Social Sensitivity + Wildfire	Annual hectares burned	Baseline, RCP 8.5 Mid-Century	Weighted average	Equal interval
Social Sensitivity + Inland Flooding	FEMA floodplain hazard designations	Baseline	NA	1% and 0.2% Annual Chance Flood Zones
Social Sensitivity + Coastal Flooding	2.5-foot level, 100-year storm event	Mid-Century	NA	Lower and Upper Half of Depth Values

Community-scale adaptive capacity

Additional layers that describe adaptive capacity and sensitivity through the built environment and natural systems (rather than populations) were also examined alongside hazards and social vulnerability. These layers provide additional context and insight, especially for areas where high vulnerability and exposure overlap.

Table 4: Community-scale Adaptive Capacity Layers

Layer	Definition	Source
Heat refuge	Using "acc med" which is cooling center accessibility when walking speed at 3.5 km/hr	Mikhail Chester, Publication: Household accessibility to heat refuges: Residential air conditioning, public cooled space, and walkability, 2017
Permeable surfaces	Percentage of land covered by surfaces that allow water to soak into the soil	Healthy Places Index, NLCD, 2011
Park Access	Percentage of the population living within walkable distance (half-mile) of a park, beach, or open space greater	Department of Parks and Recreation, Parks Needs Assessment, 2016
Thermal building performance	Building heat performance index (defined as the time elapsed for the indoor temperature to increase from 25 to 32°C)	Mikhail Chester, Publication: Building Thermal Performance, Extreme Heat, and Climate Change, 2016
Tree canopy	Percentage of land with tree canopy	SavATree Consulting Group, University of Vermont Spatial Analysis Laboratory, TreePeople, & Loyola Marymount University Center for Urban Resilience. Los Angeles

Community level social vulnerability analysis

To better support and inform local and departmental planning within Los Angeles County, census tract level data has been aggregated up to and aligned with the following administrative boundaries:

1. Countywide Statistical Areas (communities)
2. DRP Planning Areas
3. DPH Service Planning Areas
4. City of LA Community Planning Areas

It should be noted that since **census tracts are not always perfectly aligned with community and planning area boundaries**, aggregations may be approximate for some locations. Summary statistics that are presented at levels above census tract are aggregated up using a population weighted average. This helps preserve the true values of the community. Communities are also highlighted if they have any census tracts (populations) that reside within an area of high social vulnerability and high exposure.

Part 2: Physical Vulnerability Assessment Methodology

Buro Happold and ICF developed the approach for and evaluated physical vulnerability for Los Angeles County's Climate Vulnerability Assessment. The section includes supplemental information including approach and methodology, spatial data sources, scoring ranges and definitions, and final exposure, sensitivity, and vulnerability scores for each infrastructure type.

Infrastructure types and data sources

To prioritize infrastructure types as critical, an initial screen of datasets collected through the Desktop Review was conducted. The initial screening aimed to identify data on infrastructure types that are commonly considered to be the most sensitive to climate hazards and have critical community functions. Listed infrastructure types were evaluated against the following criteria using expert judgment and findings from the Desktop Review. These criteria include:

- Does the infrastructure have an important role in emergency response?
- Does the infrastructure have an important economic role for a large community?
- Does the infrastructure have an important role for socially vulnerable populations?
- Is the infrastructure important because of a lack of redundancy?

Meetings with County departments were held to ensure agreement with the proposed list of infrastructure types and to capture any additional insights that will enable preparation of datasets for the CVA analysis. Using this feedback from County departments, the list of infrastructure types was finalized to be included in exposure maps, summary statistics, and sensitivity and adaptive capacity matrices in the Physical Vulnerability Assessment.

Of the selected infrastructure types, most were evaluated spatially given LA County datasets. There were three infrastructure types (natural gas transmission and distribution, oil pipelines, and active permitted wells) that were not evaluated geospatially due to a lack of comprehensive and consistent data. Assumptions made for these infrastructure types are provided below. The following table includes the final list of infrastructure types evaluated spatially and the datasets used in the PVA.

Table 5: List of infrastructure types and spatial dataset descriptions

Infrastructure Category	Infrastructure Type	Dataset Description	Data Source(s)
Communications	Cell Towers	Data from the U.S. Department of Homeland Security that includes only government-owned cell towers	County of Los Angeles Location Management System

Infrastructure Category	Infrastructure Type	Dataset Description	Data Source(s)
Community and Other Facilities	Childcare/Child and Family Services	Aggregation of LA County Child Care and Child and Family Services including: • Family service centers • Crisis centers • Youth centers • Counseling centers • Foster care • Boys and girls clubs and clinics • Child care centers (does not include home-based daycare)	County of Los Angeles Location Management System
	Cooling Centers	Cooling centers within LA County including County cooling centers, LA city recreation centers, and LA city year-round pools. This data is from 2019.	County of Los Angeles Location Management System, Los Angeles County Chief Sustainability Office
	Cultural/Historic Resources	Properties listed on the National Register of Historic Places, classified as historic buildings, and depicted as points.	National Register of Historic Places - National Park Services
	Prisons and Jails	This is an aggregation of two datasets: "Correctional Facilities and Detention Facilities" • USCIS Detention Facilities • Los Angeles County Sheriff Correctional/Detention Facilities • Los Angeles County Sheriff Correctional/Detention Facilities Federal Bureau of Prisons "Probation Camps and Juvenile Halls" • Juvenile Halls • Probation Camps	County of Los Angeles Location Management System

Infrastructure Category	Infrastructure Type	Dataset Description	Data Source(s)
	Schools	This aggregated dataset includes data for: • Colleges and Universities • Early Childhood Education and Head Start • Private and Charter Schools • Public Elementary Schools • Public High Schools • Public Middle School • Special Curriculum Schools and Programs	County of Los Angeles Location Management System
Economic Centers	Job Dense Areas	Polygons of job rich areas, defined by job density per square mile (areas with more than 100,000 jobs/square mile)	Longitudinal Employer Household Dynamics program via US Census
Emergency Response	Emergency and Disaster Offices	Emergency centers within LA County, includes: • County Office of Emergency Management • Red Cross Emergency Centers • United Way Emergency Centers • Private Emergency Centers	County of Los Angeles Location Management System
	Fire Stations	Fire stations within LA County for both cities (e.g., Beverly Hills, Alhambra, City of Vernon) and LA County	County of Los Angeles Location Management System
	Sheriff & Police Stations	Police stations within LA County including: • County Sheriff's Department • Local police departments	County of Los Angeles Location Management System
Energy	Electricity Transmission Lines	Electricity transmission lines within LA County	California Energy Commission
	Oil Refinieries	Location of oil refiniries in Los Angeles County	County of Los Angeles Location Management System. Homeland Infrastructure Foundation Level Data (Homeland Security)
	Oil and Gas Wells	Locations of oil and gas wells in Los Angeles County	County of Los Angeles Location Management System. Homeland Infrastructure Foundation

Infrastructure Category	Infrastructure Type	Dataset Description	Data Source(s)
			Level Data (Homeland Security)
	Petroleum Terminals	Locations of petroleum terminals in Los Angeles County	County of Los Angeles Location Management System. Homeland Infrastructure Foundation Level Data (Homeland Security)
	Power Plants	Power plants within LA County including: • Hydroelectric plants • Solar plants • NG power plants and processing plants • Fossil Fuel Electric Power Generation • Wind turbines • Biomass plants (including municipal waste to energy plants)	Homeland Infrastructure Foundation Level Data (Homeland Security); US Energy Information Administration (for NG processing plants)
	Substations	Among the following institutions, those transmission and distribution substations within LA County: • SCE • LADWP • Other (including municipal-owned substations)	California Energy Commission
Housing for Sensitive Populations	Continuing Care, Residential Care, and Nursing Facilities	This dataset is an aggregation of 4 different datasets: • From CDSS: "Residential Care Facility for the Elderly" • From CDPH: "Continuing Care Facilities" and "Skilled Nursing Facilities"	CA Department of Social Services, CA Department of Public Health
	Publicly Subsidized Low-income Housing	This dataset includes two aggregated datasets: • Low Income Housing Tax Credit properties • "Other" properties where HUD programs were utilized such as Section 8 vouchers or rental assistance	U.S. Department of Housing and Urban Development (HUD)

Infrastructure Category	Infrastructure Type	Dataset Description	Data Source(s)
	Temporary and Supportive Housing for People Experiencing Homelessness	This dataset is an aggregation of 4 different LA County homeless housing datasets: • Winter Shelters: This emergency shelter program provides low-barrier, safe and supportive shelter, food and comfort to homeless individuals. Source: Los Angeles Homeless Services Authority. • Family Motels: Motels used as crisis housing for families. The use of motel vouchers provides a safe, low-barrier and supportive 24-hour residence to families experiencing homelessness, while they either self-resolve their homelessness or are assisted with connections to other programs and resources to find a permanent place to live. Source: Los Angeles Homeless Services Authority. • Current Interim Housing: This data shows existing shelters and other forms of interim housing. Here, people experiencing homelessness have a safe, warm place to sleep at night and receive services to help them secure housing. There are currently 177 sites countywide with 7,132 beds available. This data does not represent the entire universe of funded interim housing because it does not include motels funded by the County of Los Angeles or the Los Angeles Homeless Services Authority and used as interim housing. • Current Supportive Housing: Supportive housing is not for the majority of people experiencing homelessness, but rather for the smaller subset of people with disabling conditions who have been homeless for long periods of time. For people in this group, it offers a permanent place to live and intensive, onsite services, such as mental health services, benefits counseling and case management. This representation only includes project-based developments. It does not include subsidized housing in private apartments, which accounts for more than	LA County / Los Angeles Homeless Services Authority

Infrastructure Category	Infrastructure Type	Dataset Description	Data Source(s)
		half of all supportive housing available in Los Angeles County.)	
Medical Facilities and Emergency Response	Hospitals and Medical Centers	Hospitals within LA County including: • Medical centers • Urgent care centers • Hospitals	County of Los Angeles Location Management System
	Medical Clinics	Medical clinics including: • Acute Psychiatric hospital • Adult Day Healthcare • Alternative Birthing Center • Chemical Dependency Recovery Hospital • Chronic Dialysis Clinic • Congregate Living Health Facility • Correctional Treatment Center • General Acute Care Hospital • Hospice • Intermediate Care Facility • Intermediate Care Facility - DD/H/N/CN/IID • Other • Pediatric Day Health and Respite Care Facility • Primary Care Clinic • Psychology Clinic • Rehabilitation Clinic • Skilled Nursing Facility • Surgical Clinic	California Health Human Services
	Mental Health Providers	Mental health providers within LA County, including: • Outpatient • 24-hour care facilities • Day services	County of Los Angeles Location Management System
Natural Resources	Beaches	Filtered from a comprehensive dataset of parks and open space.	County of Los Angeles Department of Parks and Recreation.
	Parks and Open Space	Comprehensive park areas, including, but not limited to: • City parks	County of Los Angeles Department of Parks and Recreation.

Infrastructure Category	Infrastructure Type	Dataset Description	Data Source(s)
		• County parks • State parks • National forests/parks • Protected areas	
	Streams and Rivers	Location of streams and rivers in Los Angeles County	Los Angeles County Internal Services Department
Transportation	Airports	Locations of airports: • Agua Dulce Airpark • Bob Hope Airport • Brackett Field • Catalina Airport • Compton Woodley Airport • El Monte Airport • General WM J Fox Airfield • Jack Northrop Field • L.A. Palmdale Regional Airport • Long Beach Airport • Los Angeles International Airport • Santa Monica Municipal Airport • Van Nuys Airport • Whiteman Airport • Zamperini Field	Southern California Association of Governments (SCAG)
	Bridges	Bridges within LA County	Caltrans
	Bus Lines and Stops	Routes and stops for bus systems with ridership above 10M annually or County-owned/County partner bus systems: • Antelope Valley Transit Authority • Foothill Transit • LADOT • LA Metro • Long Beach Transit • Palos Verdes Peninsula Transit Authority • Santa Clarita Transit • Santa Monica Big Blue Bus	AVTA/Foothill/LADOT/LA Metro/Long Beach Transit/PVPTA/Santa Clarita Transit/Santa Monica Big Blue Bus
	Disaster Routes	Primary and secondary disaster routes	County of Los Angeles Location Management System

Infrastructure Category	Infrastructure Type	Dataset Description	Data Source(s)
	Highways	California State Highway Network	Caltrans
	Metro Lines and Stations	Metro routes and stations within LA County	LA Metro
	Metrolink Lines and Stations	Metrolink routes and stations within LA County	Metrolink
	Ports	Footprints of the following: • Port of Long Beach • Port of Los Angeles	Caltrans
	Tunnels	Tunnels within LA County	Federal Highway Administration (FHWA)
Waste	Hazardous Waste Disposal/ Superfund Sites	Aggregation of two datasets: LA County Hazardous Waste Sites • Los Angeles County Sheriff San Dimas Station • Los Angeles County Sanitation District Waste Site (in Whittier) • City of Los Angeles Bureau of Sanitation - Nicole Bernson Safe Center EPA Superfund sites	LA County/EPA
	Solid Waste	Solid waste sites within LA County, including: • Landfills • Dumps • Transfer stations • Compost facilities • Recycling facilities	California Solid Waste Information System (SWIS) database
Water	Dams and Debris Basins	Locations of dams and debris basins in Los Angeles County	County of Los Angeles Location Management System
	Groundwater Recharge Basins / Spreading Grounds	Location of groundwater recharge basins and stormwater spreading grounds operated by the Los Angeles County Department of Public Works.	Los Angeles County Department of Public Works

Infrastructure Category	Infrastructure Type	Dataset Description	Data Source(s)
	Injection Wells	Active injection wells along seawater barriers: • Alamitos • Dominguez • West Coast	LA County Public Works
	Lakes and Reservoirs	Reservoirs (both County and cities): • Sewage Treatment Pond • Disposal • Aquaculture • Storage (non-earthen) • Storage (earthen) • Treatment Lakes: • Intermittent • Perennial	County of Los Angeles Location Management System
	Small Water Systems	Location of small water suppliers that may be at risk of drought and water shortage vulnerability in Los Angeles County	California Natural Resources Agency. California Department of Water Resources.
	Storm Drain System	Storm drain system within LA County, specifically: • Open channels • Gravity Mains • Lateral Lines • Pump Stations	Los Angeles County Department of Public Works
	Wastewater Treatment/ Reclamation Facilities	Aggregation of LA County Sanitation District dataset and EPA Wastewater Treatment Facilities within LA County area: • Wastewater treatment plants and reclamation plants • Pumping plants	LA County Sanitation District/EPA
	Water Distribution (Aqueducts)	Secondary canal features within the water delivery system	California State Geoportal

Infrastructure Category	Infrastructure Type	Dataset Description	Data Source(s)
	Water Treatment Plants	Aggregated dataset includes locations of the following Water Treatment Plants: • DWP Los Angeles Aqueduct Filtration Plant • DWP well fields that treat groundwater • MWD Water Treatment Plants • Municipal and Community Water Treatment Plants • Additional treatment plants classified under the SDWIS in the following categories: ◦Community: Serves at least 15 service connections used by year-round residents or regularly serves 25 year-round residents. ◦Non-Transient Non-Community: Serves at least the same 25 non-residential individuals during 6 months of the year. ◦Transient Non-Community: Regularly serves at least 25 non-residential individuals (transient) during 60 or more days per year.	EPA Safe Drinking Water Information System Drinking Water Branch, MWD, DWP

Unmapped infrastructure types

This PVA did not spatially assess three of the 49 critical infrastructure types because the datasets were not comprehensive or consistent across LA County. These infrastructure types include natural gas transmission and distribution, oil pipelines, and active private and permitted wells. Although a spatial assessment could not be completed, we approximated the locations of this infrastructure based on public knowledge of their location, visual estimation based on other maps, and using similar facility types as proxies. For these three infrastructure types, these location assumptions served as the foundation for the exposure analysis. Refer to Table 11 for the estimated exposure scores for each of these facility types.

PVA scoring methodology

Vulnerability is defined as a function of exposure and sensitivity. To develop vulnerability scores, we took the following steps:

- We first evaluated **exposure** across each infrastructure type. For extreme heat and wildfire, exposure is the projected change for each climate hazard between a historical baseline and mid-century. For inland and coastal flooding, exposure refers to the areas with either current or projected likelihoods of flooding. Most infrastructure types were evaluated using GIS to overlay spatial projections of exposure with the locations of critical facilities. For those unmapped infrastructure types, exposure scores were estimated based on location assumptions. Ultimately, each infrastructure type was scored low, moderate, or high for each climate hazard.

- We then evaluated **sensitivity** qualitatively based on literature, input from stakeholders, and expert knowledge. Similarly to exposure, each infrastructure type was scored low, moderate, or high for each climate hazard.
- Finally, we used the findings on exposure and sensitivity to develop an overall **vulnerability** score for each facility type. This analysis resulted in scores of low, moderate, or high vulnerability for each infrastructure type and hazard.

We describe the details of the approach for assessing exposure, sensitivity, and vulnerability in the subsections that follow.

Assessing exposure

We conducted our exposure assessment based on the projected changes for each climate hazard between a historical baseline (30-year timespan from 1976 to 2005) and mid-century (30-year timespan from 2036-2065) under an RCP 8.5 emissions scenario. The emphasis on change, rather than absolute values, acknowledges that facility managers, to some degree, are already aware of current vulnerabilities to climate hazards and, in some cases, are already grappling with how to address these vulnerabilities. To ensure proper adaptation planning, it is critical to understand where—and to what extent—current vulnerabilities will be exacerbated by climate change and where new vulnerabilities may arise.

We used the following variables to represent the evaluated climate hazards, as described in the Climate Hazard Assessment:

- **Extreme heat:** 95th percentile daily maximum temperature, or very hot events occurring in the warmest 5% of days in a year.
- **Wildfire:** Change in annual hectares burned per grid cell.
- **Inland flooding:** Federal Emergency Management Agency (FEMA) 1% and 0.2% annual chance flood. It is difficult to project change in flooding, as flood events are driven by a number of hydrological and hydraulic factors that are challenging to model on larger scales. However, FEMA floodplain maps are commonly used at a screening level as a proxy for the extent to which flooding may occur during more frequent or more severe flood events in the future.
- **Coastal flooding:** A 1% annual chance storm on top of 0.75 meters (about 2.5 feet) of sea level rise, which is the amount of sea level rise projected to occur in Los Angeles by mid-century.
- **Drought:** Since drought is a regional hazard, localized projection information is unavailable.

In order to identify exposure scores for each infrastructure type, three steps were taken:

- First, a definition for low, moderate, and high exposure was determined for each climate hazard.
- Second, that scoring approach was used to bucket infrastructure components for each infrastructure type into low, moderate, and high. For example, electricity transmission lines were overlaid with extreme heat to show that 22% of lines are in low exposure, 47% are in moderate exposure, and 31% are in high exposure areas.
- Third, the distribution in exposure percentages was evaluated through scoring rules for each climate hazard to determine overall scoring of low, moderate, or high exposure.

As mentioned above, the first step was to define definitions of low, moderate, and high for each climate hazard. For some hazard, this was determined based on the range of values observed across the County. For other

hazards, these were determined based on if infrastructure is within a certain zone or not. These definitions are provided below for each climate hazard.

Step 1

Extreme heat

Looking across all grid cells in the County, we identified the minimum and maximum changes in temperature. We then divided that range into three equal parts, and designated them as low, moderate, or high.

Table 6: Exposure scoring bins for extreme heat

	Change in temperature	*Historical baseline absolute value*	*Mid-century absolute value*
	Units: Degrees		
Low exposure	3.600 to 4.896	*78.6 to 91.2*	*82.3 to 95.4*
Moderate exposure	4.897 to 5.783	*79.0 to 102.0*	*84.0 to 107.7*
High exposure	5.784 to 6.670	*86.9 to 101.4*	*93.0 to 107.2*
Complete Range	3.600 to 6.670	*78.6 to 102.0*	*82.3 to 107.7*

Wildfire

We assigned a low score if the facility was outside of the combined fire state and federal protection responsibility or if change in area burned was less than or equal to zero. For facilities located in grid cells with a positive increase in area burned, we divided that range of values in half to determine the thresholds for moderate and high scores for changes in exposure.

Table 7: Exposure scoring bins for wildfire

Wildfire	**Change in annual average hectares burned**	*Absolute value at historical baseline*	*Mid-century absolute value*
	Units: Annual average hectares burned per grid cell		
Low exposure	-14.008 to 0 and Null	*0.8 to 44.8*	*0.2 to 44.3*
Moderate exposure	0.001 to 12	*2.3 to 42.2*	*53.5 to 2.4*
High exposure	12.001 to 23.367	*29.8 to 47.4*	*42.6 to 70.6*
Complete range	-14.008 to 23.367	*0.8 to 47.4*	*0.2 to 70.6*

Inland flooding

We assigned a low score if the facility was not in the floodplain, a moderate score if it was within the 0.2% annual chance floodplain, and a high score if it was within the 1% annual chance floodplain.

Table 8: Exposure scoring bins for inland flooding

	Flooding exposure
Low exposure	No value (outside floodplain)
Moderate exposure	0.2% annual chance floodplain

High exposure	1% annual chance floodplain

Coastal flooding

We assigned a low score if the facility was not in the coastal flooding zone, a moderate score if it was within the lower half of depth values, and a high score if it was within the upper half of depth values.

Table 9: Exposure scoring bins for coastal flooding

	Change in inundation depth
	Units: Feet
Low exposure	No value
Moderate exposure	0.003 to 3.930
High exposure	3.933 to 7.870
Complete range	0.003 to 7.870

Drought

We assumed moderate change in exposure for all facility types, given that drought is a regional hazard for which localized spatial projection information is unavailable.

Step 2

Based on the low, moderate, high exposure definitions, we assigned each infrastructure component with an exposure value given the six-by-six kilometer grid cell within the County where the facility lies. These values were rolled up into a set of values for each infrastructure type. For each infrastructure type and each climate hazard, percentages of exposed infrastructure was categorized into low, moderate, or high.

Scoring polygons, lines, and point data: To account for the percentage of exposed features, exposed facilities were counted according to the type of available data. Percentage of area was used for polygons, percentage of length was used for line data, and percentage of facilities/points was used for point data.

Step 3

Based on the percentages generated in step 2, we assigned low, moderate, and high designations at the infrastructure type level based on the following "rules" for exposure statistics:

- If more than 50% of facilities fell in the low bin, the score for the facility type score is low.
- If more than 50% of facilities fell in moderate or high bins, and of those, less than 1/3 fell in the high bin, the score for the facility type score is moderate.
- If more than 50% of facilities fell in moderate or high bins, and of those, more than 1/3 fell in the high bin, the score for the facility type is high.

Assessing physical sensitivity

The County conducted a qualitative assessment for sensitivity, drawing from literature, department meetings, expert knowledge, and existing County plans, such as the All-Hazards Mitigation Plan. Based on this information, the County assigned a sensitivity score of low, moderate, or high for each infrastructure type and hazard, using the following scoring rubric:

- Low: Facility may experience minimal damage and short-term disruptions lasting hours to days
- Moderate: Facility may experience substantial damage and be temporarily out of service for days to weeks
- High: Facility may experience severe damage and be out of service until repaired

In assessing the degree of impact to a facility, the County considered both the structure and function of facilities, including the broad range of services that the facility provides to people. It is important to note that this assessment makes an inherent assumption that today's sensitivity remains constant into the future. It is difficult to predict how technology, policy decisions, and other factors will evolve in the coming decades, and how sensitivity will change as a result. However, we do have information on how exposure may change in the future. Thus, the PVA assumes today's sensitivity overlaid with future exposure projections. This approach highlights where changes must be made to help lower sensitivity to mitigate the degree of impact and the disruption to our daily lives.

Assessing physical vulnerability change

The County combined exposure and sensitivity scores for each infrastructure type and climate hazard and developed overall vulnerability scores, using the approach below.

1. If exposure and sensitivity are the same, vulnerability is that score. For example, if exposure and sensitivity are low, vulnerability is low.
2. If 100% of the infrastructure type is in a low exposure bin, vulnerability is low.
3. If exposure is high and sensitivity is low or if exposure is low and sensitivity is high, vulnerability is moderate.
4. If exposure or sensitivity are moderate, vulnerability is the higher score between exposure and sensitivity.

The combination of these rules in this approach, are visually represented in Figure 16 below.

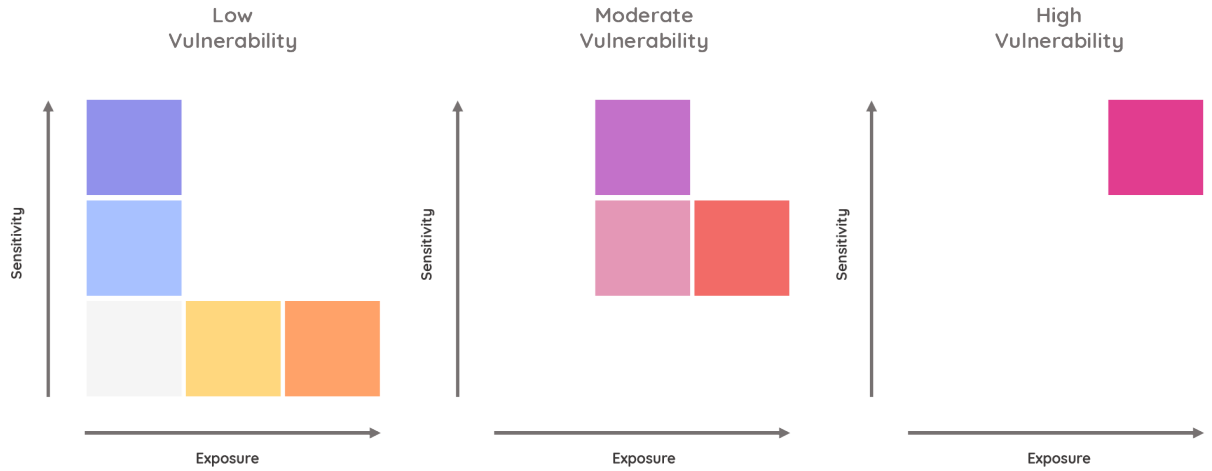

Figure 4: Physical vulnerability matrix by level of vulnerability

Below is an example of how the County scored vulnerability of electric transmission lines and extreme heat:

- Exposure: Scored "high" because majority (more than 50%) of assets are located in areas with moderate -to-high change in extreme heat, and of those, more than 1/3 fell in the high bin.
- Sensitivity: Scored "high" because of numerous and consequential ways in which transmission lines may be adversely affected. For example, extreme heat can cause overhead lines to sag, posing fire and safety hazards, and reducing efficiency; high ambient air temperatures may prevent adequate cooling during times of high demand. These impacts are linked to serious consequences for reliability and safety.
- Vulnerability: Following the fourth rule described above, change in vulnerability by mid-century is "high."

Scores by infrastructure type and climate hazard

The tables that follow show the final exposure, sensitivity, and vulnerability scores for each infrastructure type and hazard. For exposure, we also show the percent breakdown of infrastructure components within each type that are located within areas projected to experience low, moderate, or high changes in exposure to each hazard.

Exposure

Table 10 below shows the percent of facilities within each infrastructure type that fall within the low, moderate, and high exposure bins for each climate hazard, by mid-century, under RCP 8.5. Note that drought was not spatially evaluated and is not presented alongside the percentage breakdowns for other hazards.

Table 10: Percent breakdown of facilities within low, moderate, and high exposure bins**

Infrastructure Category	Facilities Type	Extreme Heat			Wildfire			Inland flooding			Coastal flooding			Drought		
		L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
Communications	Cell Towers	36%	43%	21%	64%	33%	2%	95%	5%	0%	98%	2%	0%	0%	100%	0%
Community Facilities	Childcare/Child and Family Services	38%	46%	17%	95%	5%	0%	93%	6%	1%	100%	0%	0%	0%	100%	0%
	Cooling Centers	32%	51%	17%	94%	6%	0%	93%	5%	1%	100%	0%	0%	0%	100%	0%
	Cultural/Historic Resources	22%	77%	2%	94%	6%	0%	92%	6%	2%	100%	0%	0%	0%	100%	0%
	Prisons/Jails	18%	45%	38%	73%	27%	0%	79%	16%	5%	100%	0%	0%	0%	100%	0%
	Schools	35%	51%	15%	94%	5%	0%	93%	6%	1%	100%	0%	0%	0%	100%	0%
Economic Centers	Job-Dense Areas	41%	52%	6%	98%	2%	0%	94%	5%	1%	100%	0%	0%	0%	100%	0%
Emergency Response	Emergency and Disaster Offices	28%	61%	12%	97%	3%	0%	93%	7%	0%	100%	0%	0%	0%	100%	0%
	Fire Stations	37%	49%	14%	90%	10%	0%	92%	6%	2%	98%	2%	0%	0%	100%	0%
	Sheriff & Police Stations	41%	52%	8%	92%	8%	0%	94%	5%	1%	100%	0%	0%	0%	100%	0%
Energy	Electricity Transmission Lines	22%	47%	31%	75%	22%	3%	63%	10%	27%	100%	0%	0%	0%	100%	0%
	Oil Refineries	89%	11%	0%	100%	0%	0%	100%	0%	0%	89%	11%	0%	0%	100%	0%

	Oil and Gas Wells	65%	23%	12%	95%	4%	1%	89%	2%	9%	90%	10%	0%	0%	100%	0%
	Petroleum Terminals	85%	10%	4%	100%	0%	0%	88%	6%	6%	85%	15%	0%	0%	100%	0%
	Power Plants	26%	34%	40%	91%	8%	0%	78%	17%	4%	98%	2%	0%	0%	100%	0%
	Substations	45%	44%	11%	92%	8%	0%	94%	3%	3%	97%	3%	0%	0%	100%	0%
Housing for Sensitive Populations	Continuing Care, Residential Care, and Nursing Facilities	29%	39%	32%	94%	6%	0%	96%	4%	0%	100%	0%	0%	0%	100%	0%
	Low-income Housing	29%	56%	15%	98%	2%	0%	90%	10%	0%	100%	0%	0%	0%	100%	0%
	Temporary and Supportive Housing for People Experiencing Homelessness	32%	54%	14%	97%	3%	0%	86%	13%	0%	100%	0%	0%	0%	100%	0%
Medical Facilities	Hospitals and Medical Centers	32%	55%	13%	95%	5%	0%	94%	6%	0%	100%	0%	0%	0%	100%	0%
	Medical Clinics	24%	53%	23%	95%	5%	0%	95%	4%	1%	100%	0%	0%	0%	100%	0%
	Mental Health Providers	35%	49%	16%	95%	5%	0%	91%	9%	0%	100%	0%	0%	0%	100%	0%
Natural Resources	Beaches	91%	10%	0%	78%	22%	0%	47%	13%	40%	77%	23%	0%	0%	100%	0%
	Streams and Rivers	13%	48%	39%	25%	64%	12%	86%	1%	13%	99%	1%	0%	0%	100%	0%
	Parks and Open Space	18%	45%	38%	22%	61%	17%	98%	0%	2%	100%	0%	0%	0%	100%	0%
Transportation	Airports	47%	20%	33%	80%	20%	0%	93%	0%	7%	100%	0%	0%	0%	100%	0%
	Bridges	24%	53%	23%	88%	11%	1%	83%	4%	13%	100%	0%	0%	0%	100%	0%
	Bus lines*	31%	52%	17%	95%	4%	1%	90%	8%	2%	100%	0%	0%	0%	100%	0%
	Bus stops*	39%	48%	13%	97%	3%	0%	90%	9%	1%	100%	0%	0%	0%	100%	0%
	Disaster Routes	22%	51%	26%	83%	15%	2%	87%	6%	6%	100%	0%	0%	0%	100%	0%

	Highways	26%	50%	24%	74%	20%	6%	95%	3%	2%	100%	0%	0%	0%	100%	0%
	Coastal highways*	67%	27%	6%	86%	14%	0%	96%	2%	2%	99%	1%	0%	0%	100%	0%
	Metro lines*	47%	53%	0%	100%	0%	0%	87%	12%	1%	100%	0%	0%	0%	100%	0%
	Metro stations*	41%	59%	0%	100%	0%	0%	88%	12%	0%	100%	0%	0%	0%	100%	0%
	Metrolink lines*	0%	74%	26%	93%	5%	1%	96%	1%	3%	100%	0%	0%	0%	100%	0%
	Metrolink stations*	0%	62%	38%	88%	12%	0%	88%	4%	8%	100%	0%	0%	0%	100%	0%
	Ports	100%	0%	0%	100%	0%	0%	0%	100%	0%	0%	100%	0%	0%	100%	0%
	Tunnels	23%	70%	8%	65%	30%	5%	98%	3%	0%	100%	0%	0%	0%	100%	0%
Waste	Hazardous Waste Disposal/ Superfund Sites	11%	79%	11%	89%	11%	0%	100%	0%	0%	100%	0%	0%	0%	100%	0%
	Solid Waste	18%	74%	7%	94%	6%	0%	97%	2%	1%	100%	0%	0%	0%	100%	0%
Water Systems	Dams and Debris Basins	8%	43%	49%	66%	34%	0%	96%	2%	2%	100%	0%	0%	0%	100%	0%
	Groundwater Recharge Basins / Spreading Grounds	6%	81%	13%	67%	33%	0%	90%	3%	7%	99%	1%	0%	0%	100%	0%
	Injection Wells	100%	0%	0%	100%	0%	0%	90%	0%	10%	100%	0%	0%	0%	100%	0%
	Lakes and Reservoirs	4%	38%	58%	67%	32%	1%	61%	1%	38%	100%	0%	0%	0%	100%	0%
	Storm Drain: Gravity Main*	35%	48%	17%	94%	6%	0%	100%	0%	0%	99%	1%	0%	0%	100%	0%
	Storm Drain: Lateral Lines*	38%	46%	16%	95%	5%	0%	100%	0%	0%	99%	1%	0%	0%	100%	0%
	Storm Drain: Open Channel*	23%	51%	25%	90%	10%	0%	100%	0%	0%	99%	1%	0%	0%	100%	0%
	Storm Drain: Stormwater Pump Stations*	72%	23%	5%	100%	0%	0%	82%	8%	9%	92%	8%	0%	0%	100%	0%

	Wastewater Treatment/Reclamation Facilities	64%	28%	8%	87%	13%	0%	91%	4%	5%	97%	3%	0%	0%	100%	0%
	Water Distribution (Aqueducts)	0%	0%	100%	37%	63%	0%	92%	2%	6%	100%	0%	0%	0%	100%	0%
	Water Treatment Plants	13%	55%	32%	80%	18%	2%	87%	9%	4%	100%	0%	0%	0%	100%	0%
	Small Water Systems	12%	44%	44%	74%	22%	4%	81%	12%	7%	100%	0%	0%	0%	100%	0%

**The County Facility analyzed exposure of these facility types and averaged them to determine exposure at the level of the facility type (e.g., Storm Drain System, Metro Lines and Stations, Metrolink Lines and Stations).*

***The County did not assess exposure for these facility types spatially, so there are no exposure statistics for them: Natural gas transmission and distribution, oil pipelines, active private/permitted wells*

Table 11: Exposure (E), sensitivity (S), and vulnerability (V) scoring by infrastructure type and hazard

Facilities Category	Facilities Type	Extreme Heat			Wildfire			Inland Flooding			Coastal Flooding			Drought		
		E	S	V	E	S	V	E	S	V	E	S	V	E	S	V
Communications	Cell Towers	M	M	M	L	H	M	L	M	M	L	M	M	M	L	M
Community and Other Facilities	Childcare/Child and Family Services	M	M	M	L	H	M	L	M	M	L	H	L	M	L	M
	Cooling Centers	M	M	M	L	H	M	L	M	M	L	H	L	M	L	M
	Cultural/Historic Resources	M	M	M	L	H	M	L	M	M	L	H	L	M	L	M
	Prisons and Jails	H	H	H	L	H	M	L	M	M	L	H	L	M	L	M
	Schools	M	M	M	L	H	M	L	M	M	L	H	L	M	L	M
Economic Centers	Job Dense Areas	M	M	M	L	H	M	L	M	M	L	H	M	M	L	M
Emergency Response	Emergency and Disaster Offices	M	M	M	L	H	M	L	H	M	L	H	L	M	L	M
	Fire Stations	M	M	M	L	H	M	L	H	M	L	H	M	M	L	M
	Sheriff & Police Stations	M	M	M	L	H	M	L	H	M	L	H	L	M	L	M
Energy	Electricity Transmission Lines	H	H	H	L	H	M	L	M	M	L	H	L	M	L	M
	Natural Gas Transmission and Distribution	M	M	M	L	M	M	L	M	M	L	M	M	M	L	M

Facilities Category	Facilities Type	Extreme Heat			Wildfire			Inland Flooding			Coastal Flooding			Drought		
		E	S	V	E	S	V	E	S	V	E	S	V	E	S	V
	Oil and Gas Wells	L	L	L	L	H	M	L	M	M	L	M	M	M	M	M
	Oil Pipelines	H	L	M	L	L	L	L	M	M	L	M	M	M	L	M
	Oil Refineries	L	L	L	L	H	L	L	H	L	M	H	H	M	M	M
	Petroleum Terminals	L	L	L	L	H	L	L	H	M	M	H	H	M	L	M
	Power Plants	H	M	H	L	H	M	L	H	M	L	H	M	M	M	M
	Substations	M	M	M	L	H	M	L	H	M	L	H	M	M	L	M
Housing for Sensitive Populations	Continuing Care, Residential Care, and Nursing Facilities	H	M	H	L	H	M	L	M	M	L	H	L	M	L	M
	Low-income Housing	M	M	M	L	H	M	L	M	M	L	H	L	M	L	M
	Temporary and Supportive Housing for People Experiencing Homelessness	M	M	M	L	H	M	L	M	M	L	H	L	M	L	M
Medical Facilities	Hospitals and Medical Centers	M	M	M	L	H	M	L	H	M	L	H	L	M	M	M
	Medical Clinics	M	M	M	L	H	M	L	H	M	L	H	L	M	L	M
	Mental Health Providers	M	M	M	L	H	M	L	M	M	L	H	L	M	L	M
Natural Resources	Beaches	L	L	L	L	L	L	L	M	M	M	H	H	M	M	M

Facilities Category	Facilities Type	Extreme Heat			Wildfire			Inland Flooding			Coastal Flooding			Drought		
		E	S	V	E	S	V	E	S	V	E	S	V	E	S	V
	Parks and Open Space	H	H	H	M	H	H	L	L	L	L	L	L	M	H	H
	Streams and Rivers	H	M	H	M	H	H	L	M	M	L	M	M	M	M	M
Transportation	Airports	H	M	H	L	H	M	L	M	M	L	H	L	M	L	M
	Bridges	M	L	M	L	M	M	L	H	M	L	H	L	M	L	M
	Bus Lines and Stops	M	M	M	L	M	M	L	M	M	L	M	L	M	L	M
	Disaster Routes	H	L	M	L	M	M	L	M	M	L	M	L	M	L	M
	Highways	M	L	M	L	M	M	L	M	M	L	M	L	M	L	M
	Metro Lines and Stations	M	H	H	L	H	L	L	H	M	L	H	L	M	L	M
	Metrolink Lines and Stations	M	H	H	L	H	M	L	H	M	L	H	L	M	L	M
	Ports	L	L	L	L	L	L	L	M	M	M	H	H	M	L	M
	Tunnels	M	L	M	L	L	L	L	H	M	L	H	L	M	L	M
Waste	Hazardous Waste Disposal/ Superfund Sites	M	L	M	L	H	M	L	M	L	L	H	L	M	L	M
	Solid Waste	M	L	M	L	H	M	L	M	M	L	M	L	M	L	M

Facilities Category	Facilities Type	Extreme Heat			Wildfire			Inland Flooding			Coastal Flooding			Drought		
		E	S	V	E	S	V	E	S	V	E	S	V	E	S	V
Water Systems	Active Private / Permitted Wells	M	L	M	L	H	M	L	L	L	L	M	M	M	H	H
	Dams and Debris Basins	H	L	M	L	M	M	L	H	M	L	M	M	M	L	M
	Groundwater Recharge Basins / Spreading Grounds	M	M	M	L	M	M	L	L	L	L	L	L	M	H	H
	Injection Wells	L	L	L	L	L	L	L	L	L	L	M	L	M	M	M
	Lakes and Reservoirs	H	M	H	L	H	M	L	M	M	L	L	L	M	H	H
	Storm Drain System	M	L	M	L	M	M	L	H	M	L	H	M	M	L	M
	Wastewater Treatment/Reclamation Facilities	L	M	M	L	L	L	L	H	M	L	H	M	M	M	M
	Water Distribution (Aqueducts)	H	M	H	M	M	M	L	M	M	L	M	L	M	H	H
	Water Treatment Plants	H	M	H	L	H	M	L	M	M	L	M	L	M	H	H

Part 3: Cascading Impacts Assessment Methodology

Bellwether Collaboratory, LLC analyzed infrastructure interdependencies and cascading impacts on critical lifelines and socially vulnerable populations for Los Angeles County's Climate Vulnerability Assessment. Methods, analysis, and results are presented here.

Infrastructure interdependencies

Methods

To assess infrastructure interdependencies, interviews were conducted with 37 representatives from the following Los Angeles County departments, external agencies, non-profits, and industry associations:

- Los Angeles County Office of Emergency Management
- Los Angeles County Internal Services Department
- Los Angeles County Department of Public Health
- Los Angeles County Public Works
- Mayor's Director of Infrastructure, City of Los Angeles
- Los Angeles Metropolitan Transit Authority
- Los Angeles Regional Water Quality Control Board
- California State Water Resources Control Board
- Hospital Association of Southern California
- California Cable and Telecommunications Association
- CTIA (wireless communications industry association)
- Los Angeles County Business Federation
- Prevention Institute
- members of the CVA's Advisory Committee

The first draft of the infrastructure-interdependency map was created for California's Fourth Climate Change Assessment[iv] and funded by the California Energy Commission. Sources for that study included infrastructure managers and representatives of utilities, health service providers, academia, and city, county, state, and national agencies and departments including:

- Southern California Edison
- PG&E
- Southern California Gas Company
- Los Angeles Department of Water & Power
- Sempra Utilities
- California Public Utilities Commission
- Los Angeles Metropolitan Transit Authority
- City of Los Angeles Emergency Management Department
- Los Angeles County Office of Emergency Management
- Los Angeles County Department of Public Health
- Providence St. John's Health Center
- Children's Hospital L.A.

- City of Los Angeles, Mayor's Office of Resilience
- City of Santa Monica Chief Resilience Officer
- City of Santa Monica Office of Sustainability and the Environment
- ExteNet Systems
- Los Angeles Food Policy Council
- Los Angeles Regional Collaborative for Climate Action and Sustainability
- United States Geological Survey Earthquake Science Center
- USC Sea Grant
- UC Berkeley
- UCLA
- Union of Concerned Scientists
- Pacifico

In both cases, interviewees and workshop participants were asked about the dependencies and outputs of the following infrastructure sectors:

- water (for LA County interviews, includes wastewater and stormwater)
- power (includes electricity, diesel, natural gas, and gasoline)
- communications
- transportation
- emergency services
- public health
- health services

Their responses were summarized into a causal loop diagram using the online apps Elephant Builder and Kumu. These tools visualize and analyze systems maps, in which relationships between variables are represented by arrows (also known as "edges" or "connections") between nodes (or "elements").

Analysis

The resulting map was analyzed in three ways:

First, centrality metrics including degree, indegree, outdegree, betweenness, closeness, and eigenvector centrality were calculated using Kumu's social-network-analysis feature.

Second, a Python script was used to count the inter-sector connections, or the number of connections between nodes in each of the following categories: electricity, transportation, communications, water, public health and safety, and emergency services. Nodes were assigned to a category when the corresponding sector manages, or has some degree of control over, that variable. The category "water" also includes wastewater and stormwater infrastructure. The category "electricity" was used rather than "power" because the fossil-fuel sector was omitted in order to facilitate comparisons between the centrality metrics and the count of inter-sector connections. When fossil fuel is included, the results are in the same direction but stronger.

Third, a Python script was used to identify feedback loops. Duplicate loops were filtered out.

Results

The data behind the figures and conclusions presented in the report are shown here: centrality metrics (Table 12, Table 13, and Table 14), count of inter-sector connections (Table 15), and count of feedback loops (Table 16).

Table 12: Top ten nodes by outdegree

Node	Outdegree centrality
electrical power provision	22
highway system reliability	13
communications availability	11
workforce availability	10
diesel supply	10
potable water supply	6
emergency services provision	5
public health srvc provision	4
mobility and accessibility	4
state of good repair, bridges	3

Table 13: Top ten nodes by eigenvector

Node	Eigenvector centrality
community function	0.086
public health	0.047
workforce availability	0.043
emergency services provision	0.042
health services provision	0.037
public health srvc provision	0.034
first responder availability	0.032
cell site function	0.030
bus reliability	0.028
electrical grid function	0.027

Table 124: Top ten nodes by betweenness centrality

Node	Betweenness centrality
workforce availability	0.345
community function	0.269
highway system reliability	0.226
electrical power provision	0.214
electrical grid function	0.210
potable water supply	0.109
electrical power generation	0.096

diesel supply	0.094
water availability	0.088
wastewater treatment function	0.078

Table 135: Number of connections from nodes within one sector to nodes within another

Number of connections							
		FROM:					
		communications	electricity	emergency services	public health and safety	transportation	water
TO:	communications		5	0	0	1	0
	electricity	1		1	0	1	3
	emergency services	4	1		0	5	0
	public health and safety	3	3	6		4	4
	transportation	3	4	0	0		0
	water	3	4	0	0	2	

Table 146: Number of feedback loops

	loops up to 12 nodes long	**all loops (up to 38 nodes long)**
containing workforce availability	2,681	161,087
total	2,862	161,869

Human impacts

Methods

Information about the effects of infrastructure disruption on socially vulnerable populations was gathered through listening sessions (see Part 1B) and key informant interviews. An Institutional Review Board (IRB) exempt determination was obtained in advance of the engagement exercises.

Participants in listening sessions were service providers and advocates for the following populations: climate-exposed workers, people with disabilities and access challenges, people without reliable transportation, rural communities, and people experiencing homelessness. They were asked the following questions relevant to cascading impacts:

- When services are disrupted, how does it affect the day-to-day lives of the populations you work with?
- What are the issues/challenges that people face, or what can't they do anymore, when

- the power goes out (and it's hot? or there's a fire? or it's raining?)
- cell phones and internet don't work
- transit is delayed and/or highways are closed
- water is unavailable
- emergency services are unavailable
- community facilities are closed?

Results

The impacts of infrastructure disruption on services and socially vulnerable populations as gathered from listening sessions and key informant interviews are shown in Table 17.

Table 17: Impacts of infrastructure disruption on socially vulnerable populations

Sector	Service	Populations particularly affected
Communications	211	People with disabilities and access challenges
	Caregiving	Older adults
		People with disabilities and access challenges
	Cell phones	People experiencing homelessness
		Youth
	Evacuation	Older adults
	Evacuation notices	Rural communities
	Internet	People with disabilities and access challenges
	Landlines	Rural communities
Community facilities	Cooling centers	People experiencing homelessness
	DMV	People experiencing homelessness
	Food banks	People experiencing homelessness
	Homeless services	People experiencing homelessness
	Independent living centers	People with disabilities and access challenges
	Land	Indigenous communities
		Indigenous communities
	Libraries	People without internet access
	Mental healthcare	Low-income and BIPOC communities

		Older adults
		People with disabilities and access challenges
	Open space	Indigenous communities
	Parks	Low-income and BIPOC communities
	Sanitation	Day laborers and street vendors
		People experiencing homelessness
		People with disabilities and access challenges
	Shade/tree canopy	People experiencing homelessness
		People without access to reliable transportation
	Water fountains	People experiencing homelessness
	Worker centers	Day laborers
Electricity	Air conditioning	Older adults
		People with disabilities that compromise thermoregulation
	Cooking	Older adults
	Elevators	People with disabilities and access challenges
	Hydration	Communities using well systems
	Medical devices	Electricity-dependent populations
	Refrigeration	Low-income and low-food-access communities
		People taking medications that need refrigeration
Emergency services	Firefighting	Rural communities
	Paramedics	People experiencing homelessness
Housing	Sanitation	People experiencing homelessness
Transportation	Access to community facilities	People without access to reliable transportation
	Evacuation	People with disabilities and access challenges
		People without access to reliable transportation
	Hydration	Communities served by utilities with poor water quality
	Sidewalks	People with mobility impairments

		People with visual impairments
		People without access to reliable transportation
	Transit	Day laborers
		Low-income and BIPOC communities
		People experiencing homelessness
		People with disabilities and access challenges
		People with respiratory or cardiovascular illness
		People without access to reliable transportation
Water	Agriculture	Farmers, farmworkers, and people who are food insecure
	Hydration	Older adults
		People experiencing homelessness
		People with disabilities and access challenges
		People with mobility impairments

Endnotes

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