Southern California Regional Energy Needs Assessment

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As a land grant institution, the UCLA Luskin Center for Innovation acknowledges the Gabrielino and Tongva peoples as the traditional land caretakers of Tovaangar (Los Angeles basin, Southern Channel Islands) and that their displacement has enabled the flourishing of UCLA.

DISCLAIMER

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EXECUTIVE SUMMARY

Southern California varies geographically in its climate and sociodemographic factors, and its energy needs reflect this important variation. In this study, we analyze these regional differences in energy needs. In doing so, we identify geographic and vulnerability trends to enable policymakers to target priority areas for support in order to advance climate and equity goals.

Specifically, we assess how energy indicators, vulnerability indicators, and energy program adoption varies across Los Angeles, Orange, Santa Barbara, and Ventura counties. Energy indicators include electricity consumption, carbon-free energy supply, and greenhouse gas emissions. Vulnerability indicators include disadvantaged community status, median income, and the number of high heat days predicted to be experienced by mid-century. Energy programs assessed include solar, electric vehicles, electric vehicle charging stations, and energy storage. To assess regional variation, we gathered, mapped, and analyzed data on these indicators. We find:

Electricity consumption, carbon-free energy supply, and greenhouse gas emissions vary across the study region.
Per capita electricity consumption varied geographically, likely because it is influenced by a variety of socioeconomic, housing, and environmental factors that also vary across the region. The share of carbon-free electricity used to meet energy demand also differed across the region, as this depends on the electricity provider. The study region is served by 16 different electricity providers, which vary in their size, governance structure, and importantly, the share of carbon-free resources used to generate electricity for their customers. Electricity-related greenhouse gas emissions are a function of both electricity consumption and carbon-free energy supply, and therefore also vary greatly across the region. Much of Santa Barbara and Ventura counties have low greenhouse gas emissions regardless of per capita consumption because the primary electricity providers in those counties use 100% carbon-free electricity generating resources. Los Angeles and Orange counties saw higher variation in greenhouse gas emissions as the electricity providers in these regions differed more in their carbon-free electricity supply. To reduce greenhouse gas emissions in the electricity sector, it is important to both reduce electricity consumption and increase the share of carbon-free electricity generating resources.

Vulnerability and energy program adoption varied across the four counties.
In terms of vulnerability, Los Angeles County had the highest average disadvantaged community score, the lowest median income, and is projected to see the most high heat days in mid-century. In terms of program adoption variation, Ventura County had the highest per capita solar adoption rates, Los Angeles County had the highest per capita storage adoption rate, and Orange County had the highest per capita electric vehicle adoption and electric vehicle charging stations.

Areas that will see more future high heat days are currently supplied by lower amounts of carbon-free energy.
There is a slight relationship between the future number of high heat days predicted to be experienced by each census tract by mid-century

and current share of carbon-free energy. This has implications for meeting climate goals, as areas with more high heat days will have greater energy demands in the future yet are meeting those needs with more polluting resources. These communities may be important to target with programs that reduce energy consumption, and therefore customer electricity bills and greenhouse gas emissions, to support both climate and equity goals.

Energy indicators vary most strongly by median income.
Higher median income was associated with higher electricity consumption, higher greenhouse gas emissions, and greater shares of carbon-free energy. This means that in areas with a higher median income, the higher greenhouse gas emissions are likely driven by higher levels of consumption rather than the share of carbon-free energy provided. This underscores the importance of reducing electricity consumption in order to reduce greenhouse gas emissions.

Median income was the strongest predictor of energy program adoption.
Median income was strongly associated with solar, electric vehicle, and storage adoption: the higher the median income of the census tract, the higher the uptake of these energy programs. Census tracts classified as less "disadvantaged" also tended to adopt these programs at higher rates, although the relationship was not as strong as with median income.

Electric vehicle charging stations were reasonably evenly spread across the region.
We examined the relationship between each the number of electric vehicle charging stations and the census tract's vulnerability characteristic and found no discernable trend between a census tract's disadvantaged community score, median income, or the future number of high heat days and the number of electric vehicle charging stations. Other energy programs could look to the successes in electric vehicle charging investments to ensure more equitable and geographically even adoption.

1. INTRODUCTION

California's energy sector faces a number of challenges, such as power shut-offs to prevent wildfires, and blackouts from extreme energy demand, all while undergoing a carbon-free transformation. With climate change, the energy sector will continue to face new challenges like increasing demand to meet air conditioning needs as the number of extreme heat days increases.

This is likely to cause energy bills to increase, exacerbating the strain on the state's most economically and environmentally vulnerable. On top of that, many people are struggling to pay electric bills as a result of increased unemployment and other widespread economic stress caused by the pandemic.

Assessing geographic variation in critical indicators during this transformation for the energy sector can help to inform policymakers and community leaders on regional energy needs. This can help to inform policy decisions on investments in energy infrastructure and programs, to ensure that they are equitable and effectively advance environmental goals. This study therefore assesses how energy use, community vulnerability, and clean energy technology adoption vary across four Southern California counties: Los Angeles, Orange, Santa Barbara, and Ventura. This study is conducted by the UCLA Luskin Center for Innovation (LCI) in collaboration with the Los Angeles Cleantech Incubator to support work funded by the California Energy Commission.

To achieve this objective, LCI gathered data from a variety of sources. These data were cleaned and transformed into a usable format and analyzed spatially using geographic information system software, ArcGIS, descriptively using Microsoft Excel, and statistically using STATA as appropriate. In this report, we detail the methods, findings, and recommendations resulting from the analysis.

We first assess geographic differences in energy use indicators. To do so, we estimate per capita electricity consumption by census tract across the region. We then assess regional differences in clean energy supply. We use these two analyses to examine regional differences in electricity-related greenhouse gas emissions.

Next, we assess how differences in per capita energy consumption, clean energy supply, and greenhouse gas emissions intensity vary along community vulnerability dimensions. We use three measures of community vulnerability, including CalEnviro Screen's Disadvantaged Community data, future high heat days, and median income.

Then, we assess geographic differences in clean energy technology adoption used to meet community energy needs, including electric vehicle purchases, charging infrastructure, rooftop solar, and energy storage. We analyze how adoption of these programs vary along the previously assessed vulnerability dimension. Finally, we conclude with a discussion of findings and recommendations.

2. BACKGROUND

In this study, we assess four Southern California counties: Los Angeles, Orange, Santa Barbara and Ventura. Table 1 summarizes the population of these counties and their total residential energy needs, and Figure 1 provides a map of these counties.

TABLE 1: Comparison of Counties' Population and Electricity Demand

County	Population	Annual Residential Electricity Demand (MWh) (2019)[1]
Los Angeles	10,059,057	19,562,555
Orange	3,168,044	6,661,246
Santa Barbara	444,819	768,515
Ventura	847,145	1,761,251

FIGURE 1: Map of Counties in This Study

[1] "Electricity Consumption by County," California Energy Commission (2021). http://www.ecdms.energy.ca.gov/elecbyutil.aspx

TABLE 2: Comparison of Types of Electricity Providers

	IOU	POU	CCA
Ownership	Private, for-profit	Public, nonprofit	Public, nonprofit
Electricity generation	✓	✓	✓
Electricity transmission and delivery	✓	✓	X*
Billing	✓	✓	X*
Energy program administration	✓	✓	✓

*The affiliate IOU provides these services for the CCA customers.

Seventeen different electricity providers serve customers across Los Angeles, Orange, Santa Barbara, and Ventura counties. Collectively, these providers served a population of over 14 million people in our study area with a combined 28.7 million MWh in 2019. These electricity providers fall into three categories: investor-owned utilities (IOUs), publicly owned utilities (POUs), and community choice aggregators (CCAs). IOUs are private, for-profit entities that provide electricity generation, transmission and delivery, and billing services for their customers, in addition to administering energy programs like energy efficiency and rooftop solar. POUs provide their customers with the same services as IOUs, however, they are public, nonprofit entities. CCAs are a relatively new type of electricity provider. Like POUs, they are public and nonprofit entities. However, they only provide electricity generation services on behalf of their customers. That is, they choose which electricity resources (e.g., solar, wind, or natural gas) to purchase on behalf of their customers. The IOU continues to provide electricity transmission and delivery, as well as billing services. CCAs do administer their own energy programs. Table 2 summarizes the differences between these types of electricity providers.

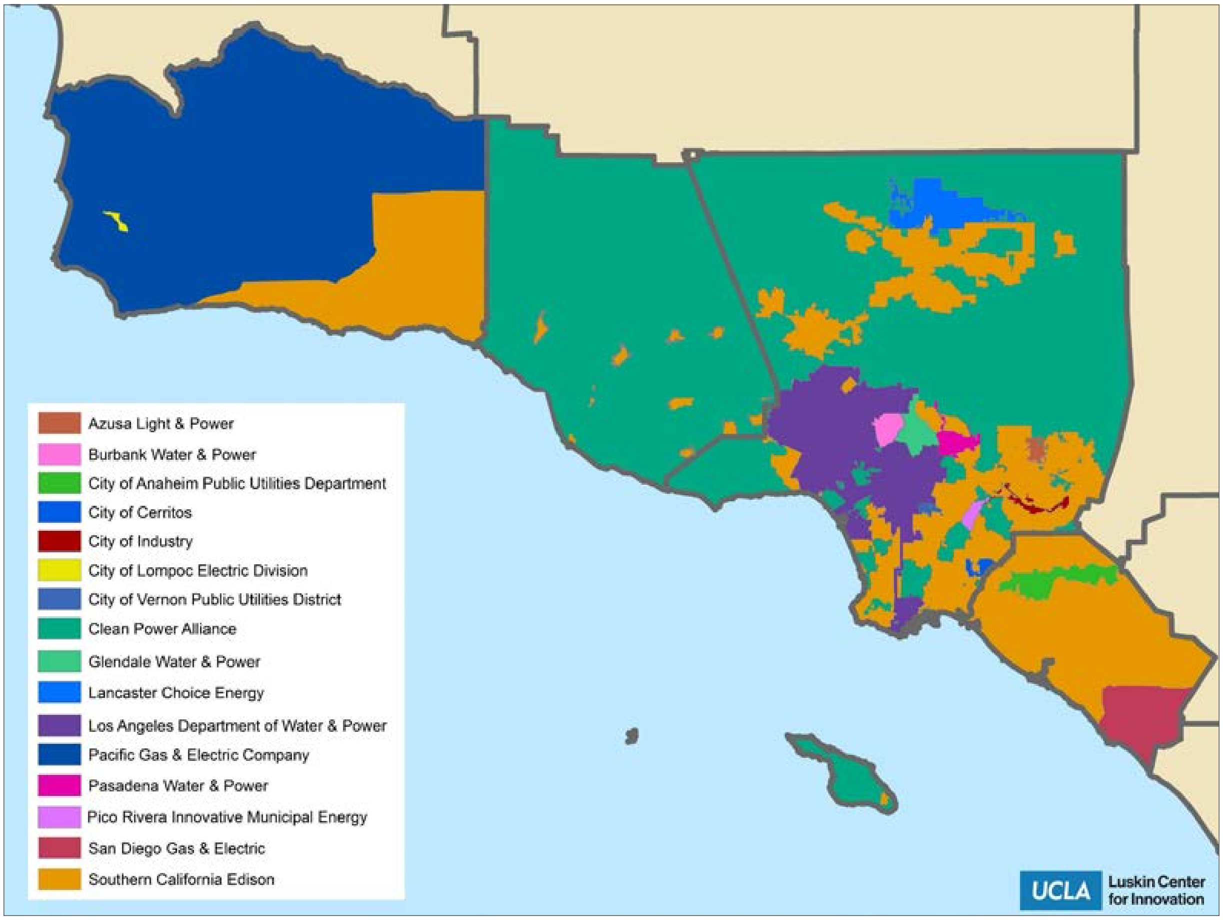
CCAs are emerging rapidly across the state — almost a third of the state's population has a CCA as an electricity provider option. Currently, the IOU Pacific Gas & Electric (PG&E) serves the majority of northern and western Santa Barbara County, with the IOU Southern California Edison serving much of the rest. This will change in 2021, with the cities of Buellton, Carpinteria, Goleta, Guadalupe, Santa Maria, Solvang, and Unincorporated Santa Barbara County joining the Central Coast Community Energy CCA. Cities located in PG&E territory joined in January 2021 and those currently located in Southern California Edison territory will join in October 2021.[2] The City of Santa Barbara will launch its own single-city CCA in May 2021.[3] After this, no part of Santa Barbara County will receive electricity generation services from PG&E or Southern California Edison. The City of Lompoc Electric Division, a POU, serves a small area in the western part of Santa Barbara County.

The CCA Clean Power Alliance, shown in light blue in the Figure 2 map, serves almost all of Ventura County and much of Los Angeles County. This CCA serves the unincorporated areas and 31 other cities across both counties. Clean Power Alliance allows member cities and counties to choose between three default electricity products, described more in section 3.2. Southern California Edison serves a few cities in Ventura County and Los Angeles counties that have not joined Clean Power Alliance. The POU Los Angeles Department of

[2] "2021 Enrollment" (2021). Central Coast Community Energy. https://3cenergy.org/2021-enrollment/

[3] "Community Choice Energy FAQs" (2021). City of Santa Barbara. https://www.santabarbaraca.gov/gov/depts/pw/fem/greenenergy/community_choice_energy_faqs.asp

FIGURE 2: Map of Electricity Providers in This Study



Water and Power is the second-largest electricity provider by physical territory size in Los Angeles County after Clean Power Alliance and serves the City of Los Angeles. There are seven other single-city POUs and two single-city CCAs in Los Angeles County. Two more single-city CCAs, Baldwin Park Resident Owned Utility District and Pomona Choice Energy launched after the start of this study in October 2020.[4,5]

Most of Orange County is served by Southern California Edison. The southern corner of the county is served by the third main IOU in California, San Diego Gas & Electric. One POU serves the city of Anaheim. Four cities have already voted to form a CCA in Orange County, with a number of additional cities considering forming or joining a CCA. Figure 2 illustrates where these electricity providers are located across these four counties.

Table 3, next page, lists the electricity providers in our region of study, their type, in which counties they serve customers, and the annual electricity in megawatt-hours (MWh) delivered to customers.

[4] "FAQs" (2021). Pomona Choice Energy. https://pomonachoiceenergy.org/about/faqs/
[5] "FAQ" (2021). BPROUD. https://bproud.baldwinpark.com/index.php/style/style1

TABLE 3: Regional Electricity Providers

Electric Utility Name	Type	Counties With Service Territory (In This Study)	Annual Residential Electricity Demand (MWh) (2019)[6]
Azusa Light & Water	POU	Los Angeles	83,487
Burbank Water and Power	POU	Los Angeles	254,823
City of Anaheim Public Utilities District	POU	Orange	567,180
City of Cerritos	POU	Los Angeles	0
City of Industry	POU	Los Angeles	145
City of Lompoc Electric Division	POU	Santa Barbara	59,198
City of Vernon Public Utilities Department	POU	Los Angeles	320
Clean Power Alliance	CCA	Los Angeles, Ventura	8,986,112
Glendale Water & Power	POU	Los Angeles	351,453
Lancaster Choice Energy	CCA	Los Angeles	545,556
Los Angeles Department of Water and Power	POU	Los Angeles	7,388,604
Pacific Gas & Electric*	IOU	Santa Barbara	28,014,177
Pasadena Water & Power	POU	Los Angeles	308,884
Pico Rivera Innovative Municipal Energy	CCA	Los Angeles	212,059
Southern California Edison*	IOU	Santa Barbara, Ventura, Los Angeles, Orange	27,324,324
San Diego Gas & Electric*	IOU	Orange	5,859,611
*The territories of these utilities extend beyond these four counties.			

6 IOU and POU annual residential electricity demand from "Electricity Consumption by Entity." California Energy Commission (2021). http://www.ecdms.energy.ca.gov/elecbyutil.aspx. CCA annual residential electricity demand from "Power Content Labels" (2019). California Energy Commission.

3. REGIONAL ENERGY ASSESSMENT

In this section, we analyze the geographic differences in clean energy consumption, greenhouse gas emissions intensity of electricity consumption, and per capita energy consumption for the region. Understanding how these three energy indicators vary across the region — and interact with each other — can help inform both policies and decisions on which areas to target to increase progress toward environmental goals.

A person's electricity needs vary by a number of factors, such as the climate zone they are located in, the age of the building they live in, and other lifestyle characteristics. When available, we use consumption data provided by the electric utilities and estimate electricity consumption based on the socioeconomic, housing, and climate characteristics of the census tract. For more information on electricity consumption per capita, see Appendix F.

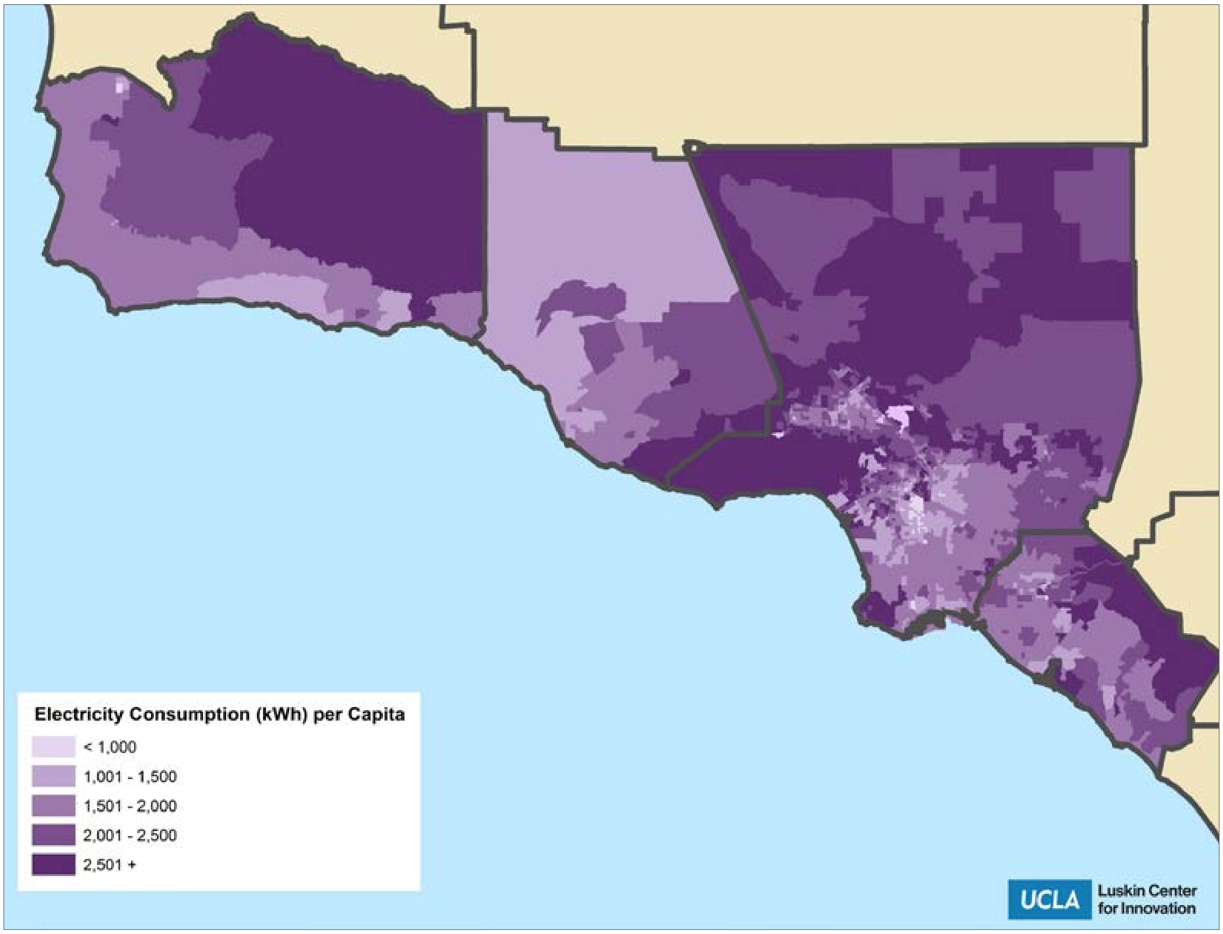
We then document both the renewable and carbon-free energy content associated with the electricity providers in the region. This allows us to assess how clean energy supply, and therefore progress toward the state's renewable energy goals, varies for customers across the region. In this analysis, we use data from the California Energy Commission's Power Content Labels. This data provides the share of each electricity-generating resource used by the providers in the region.

Electricity-related greenhouse gas emissions are a function of a customer's electricity consumption and what type of resources their provider uses to meet their needs. Building on the two previous analyses, we therefore can assess regional differences in electricity-related greenhouse gas emissions. Using greenhouse gas emissions factors from the Intergovernmental Panel on Climate Change and the California Air Resources Board, we estimate the per-kWh emissions intensity of each electricity provider. We then calculate the per capita emissions intensity based on the average energy consumption for each census tract and its associated electricity provider's power content. For more information on how greenhouse gas emissions per capita were estimated, see Appendix G.

3.1 Electricity Consumption

The results of our estimated average per capita residential electricity consumption are visualized in Figure 3. Areas of high consumption are found in the northeastern half of Santa Barbara County, southeastern Ventura County, areas in the southwestern and parts of northern Los Angeles County, and northeastern Orange County. Areas of low consumption are found in southern Santa Barbara County, northern Ventura County, south central Los Angeles County, and parts of southwestern Orange County. However, consumption varies greatly across the region and subregional consumption patterns are not especially pronounced. This could be in part because electricity consumption is influenced by a variety of factors: household size, how hot the region is, and more.

FIGURE 3: Electricity Consumption (kWh) per Capita[7]



Source: Figure created by UCLA Luskin Center for Innovation (2021). Electricity consumption data sources described in Appendix F.

3.2. Clean Energy Supply

In 2018, California passed Senate Bill 100[8], expanding and accelerating the previous version of the state's renewable energy targets, also known as the renewables portfolio standard. This bill requires that 100% of the electricity sold to customers be generated from renewable or carbon-free resources. Renewable energy resources include solar, wind, biomass, geothermal, and small hydroelectric. In this report, we refer to carbon-free energy resources as including renewable energy resources, large hydroelectric, and nuclear. In 2019, electricity providers were required to have 25% of their electricity come from renewable resources.

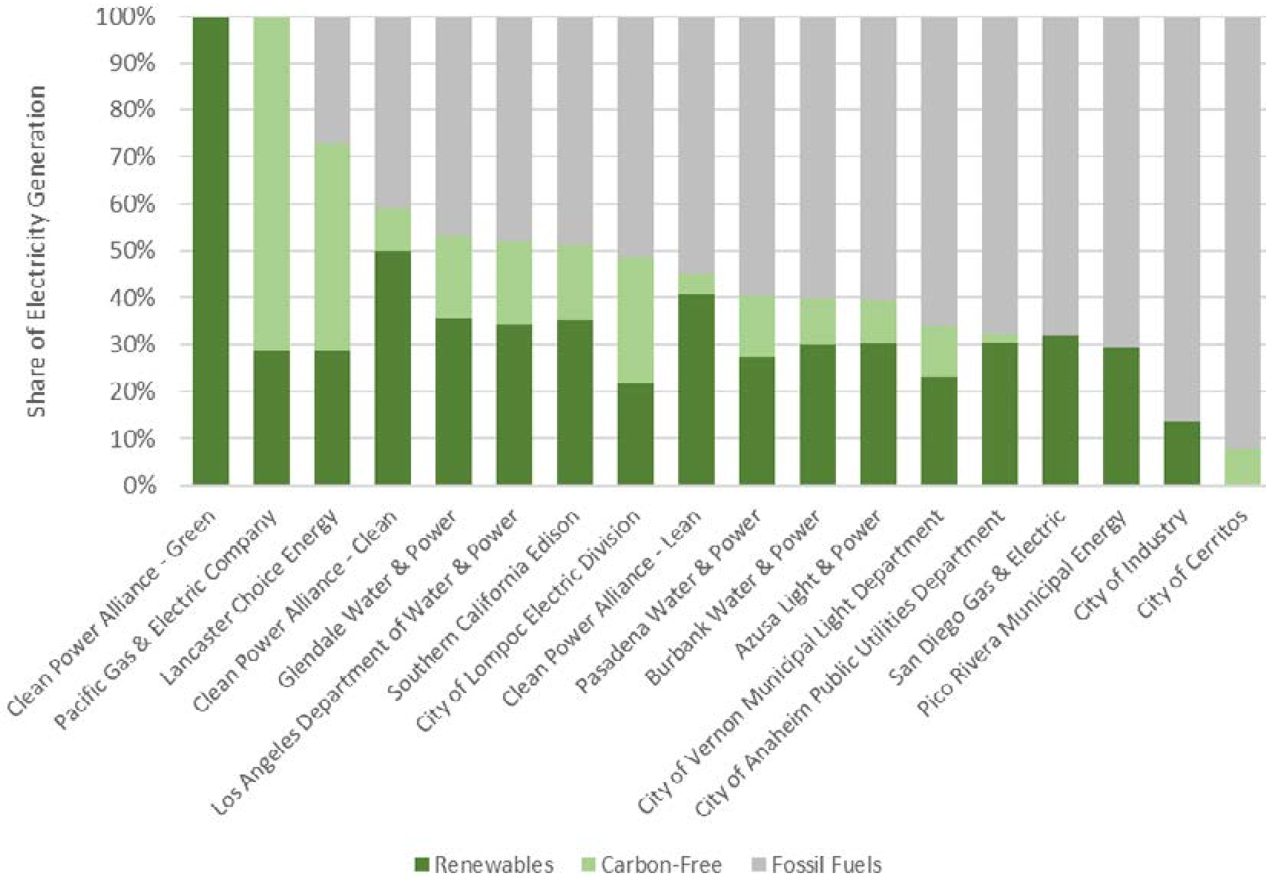
Figure 4 compares the power content, or the share of each type of electricity generating resource, for each electricity provider in our region in 2019.[9] Providers with the greatest total share of carbon-free energy are on the left, and those with the least are on the right. The dark green illustrates the share of renewable energy; the light green illustrates the additional share of carbon-free energy, and the gray illustrates the share from other electricity sources including natural gas,

[7] County-level maps can be found in Appendices A-D.

[8] https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB100

[9] The most recently available data was used when possible for each electricity provider. Data for Clean Power Alliance was available for 2020, for all other electricity providers 2019 data was used.

FIGURE 4: Comparison of the Power Content of Electricity Providers Across the Region



coal, and unspecified power. Clean Power Alliance allows its member cities and counties to choose how much carbon-free energy to offer their customers among three options named Green, Clean, and Lean. Clean Power Alliance's Green option had 100% renewable energy. In 2019, PG&E provided customers with 100% carbon-free electricity: 29% from renewable energy and 71% from large hydroelectric and nuclear. Lancaster Choice Energy and Clean Power Alliance's Clean option are the next highest carbon-free electricity providers in the region, with 73% and 62% carbon-free electricity, respectively. City of Cerritos and City of Industry had the lowest share of carbon-free energy in the region.

We then compare the share of carbon-free energy provided to each census tract by each type of electricity provider in the region, summarized in Table 4. CCAs offered the greatest share of carbon-free energy on average, with 68.9%. POUs offered the least amount of carbon-free energy in this region, with 49.7%.

Some of these electricity providers serve customers across different counties. We therefore compared how the average amount of carbon-free energy varies by county in our region by taking the average of all the county's census tracts, summarized in Table 5.

TABLE 4: Share of Carbon-Free Energy by Electricity Provider Type

Electricity Provider Type	Average Share of Clean Energy
CCA	68.9%
IOU	51.6%
POU	49.7%

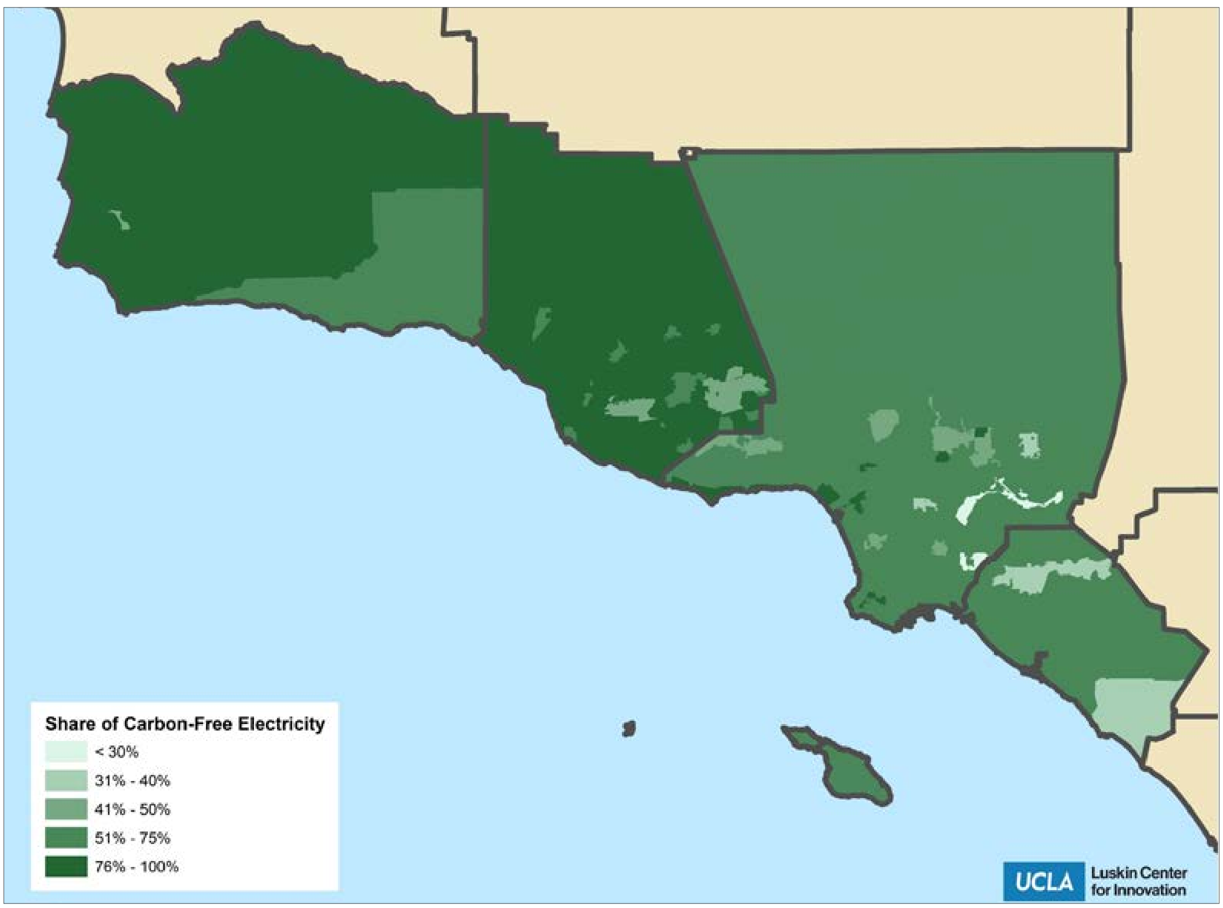
Ventura County has the highest average, with over 80% of its electricity coming from carbon-free energy resources. This is in part because almost all of Ventura County is served by Clean Power Alliance, which allows its members to choose to offer 100% renewable energy as the default option to their customers. The following Clean Power Alliance members in Ventura County chose to do this: Ojai, Oxnard, Thousand Oaks, the City of Ventura, unincorporated Ventura County. Orange County has the lowest average share of clean energy in the region, with under 50%.

Figure 5 visualizes how this share of carbon-free energy supply varies across the region. Darker green areas indicate that customers in those areas receive electricity generated by higher shares of carbon-free energy. The darkest green areas are in northern Santa Barbara County and much of Ventura County. These areas are served by PG&E and Clean Power Alliance's 100% renewable energy option, respectively. A handful of cities

TABLE 5: Share of Clean Energy by County

County	Average Share of Clean Energy
Los Angeles	54.6%
Orange	48.1%
Santa Barbara	67.5%
Ventura	86.2%

FIGURE 5: Clean Energy Supply Across the Region[10]



Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from California Energy Commission (2019).

[10] County-level maps can be found in Appendices A-D.

throughout Los Angeles County are also dark green; customers in these cities also receive 100% renewable energy from Clean Power Alliance (Green). Northern Los Angeles County receives electricity from Clean Power Alliance's 50% renewable energy option. The City of Los Angeles, served by the Los Angeles Department of Water and Power, and much of Orange County are the medium shade of green: both receive 40% carbon-free electricity.

3.3 Greenhouse Gas Emissions

Energy resources like coal and natural gas emit greenhouse gas emissions when generating electricity. As the name suggests, carbon-free energy resources do not emit greenhouse gases. As described in the previous section, the use of these resources varies by electricity provider and therefore varies across the region. We estimate a per-unit greenhouse gas emissions factor for each electricity provider. We measure greenhouse gases in metric tons of carbon dioxide equivalent (MTCO2e) per megawatt-hour (MWh) of electricity.

Clean Power Alliance (Green) and PG&E had the lowest emission factors in the region — 0 MTCO2e per MWh. This is because they both used 100% carbon-free electricity-generating resources. Anaheim Public Utilities District had the highest per-unit greenhouse gas emissions intensity of the electricity providers in the region. This is because 53% of its electricity came from coal — the highest share in the region. Pasadena Water & Power, the second-highest greenhouse gas emitter per-unit, had the second-highest share of coal at 41%.

We use these electricity provider emission factors to estimate electricity-related per capita greenhouse gas emission across the region. We apply the relevant electricity provider's per-unit emission factor to the average annual per capita electricity consumption in each census tract.

FIGURE 6: Greenhouse Gas Emissions Intensity Among Electricity Providers

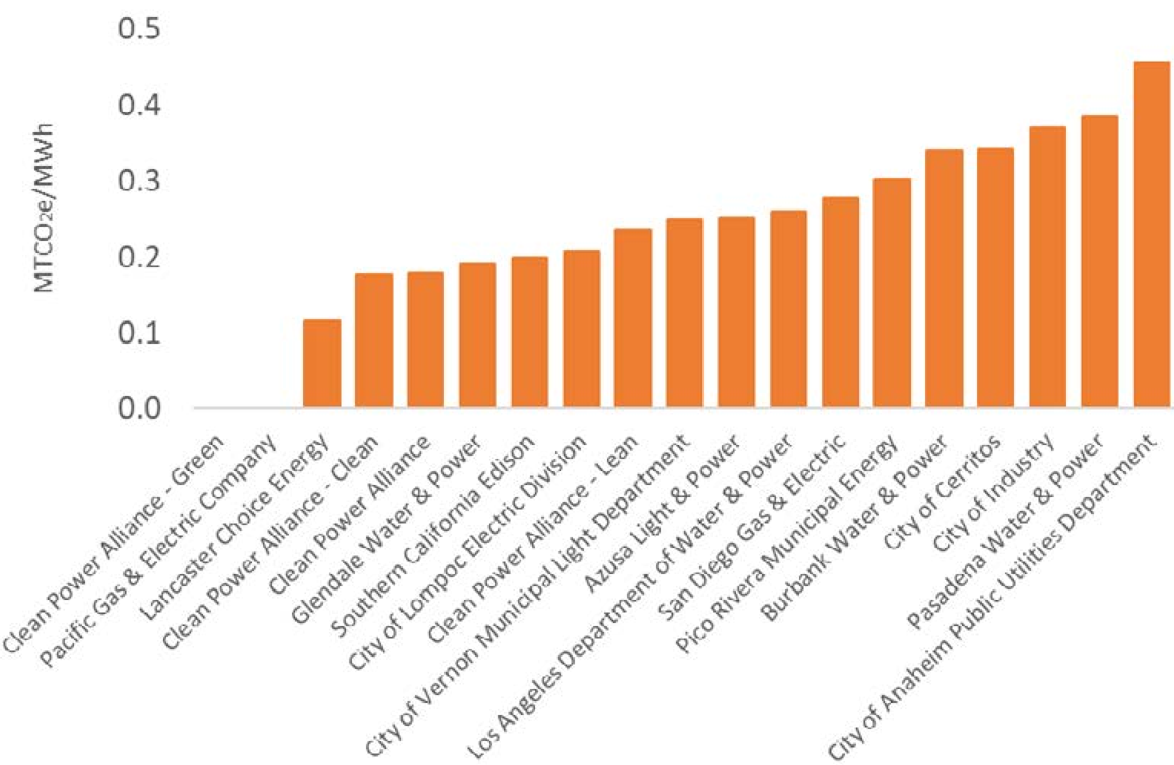
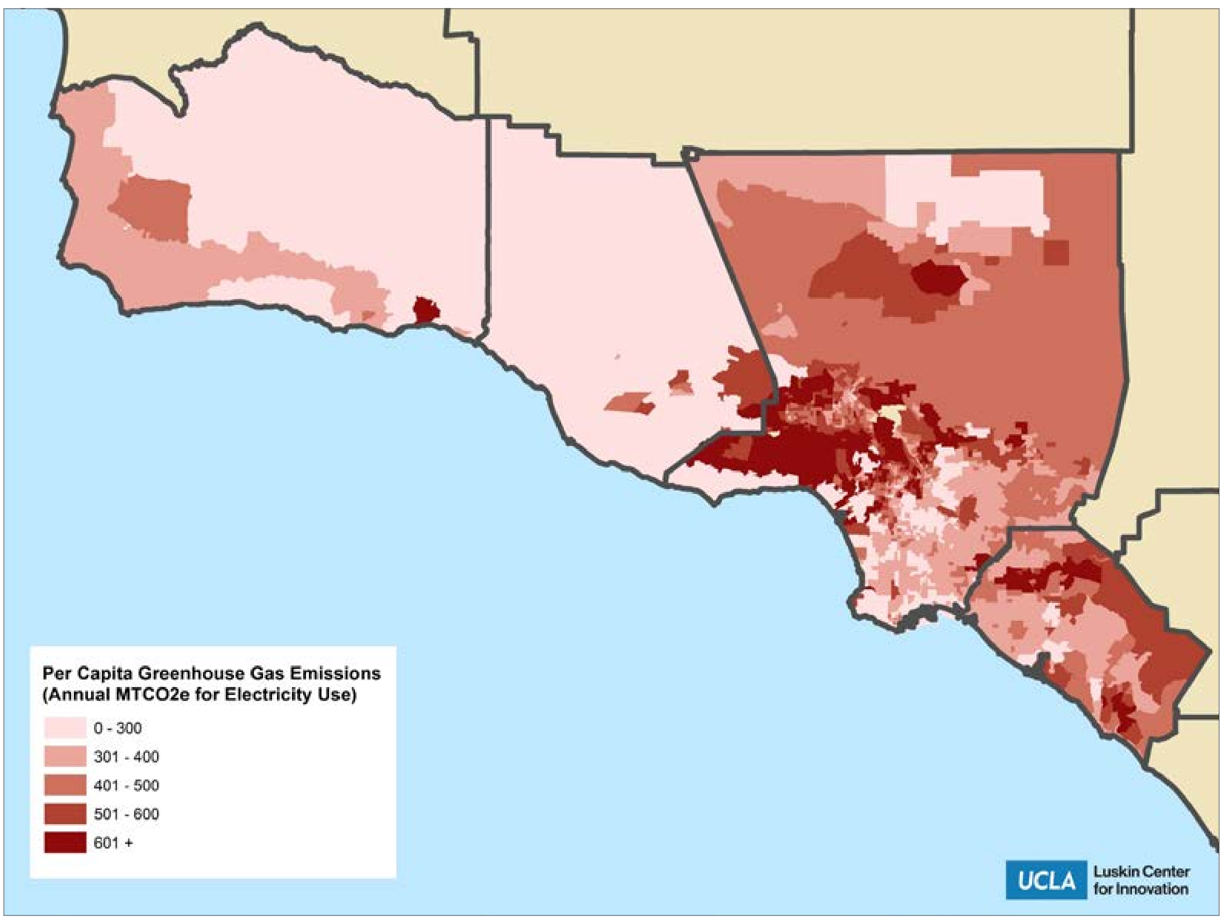


Figure 7 visualizes the differences in electricity-related greenhouse gas emissions across the region. Per capita greenhouse gas emissions are very low in the majority of Santa Barbara and Ventura counties. This is primarily driven by the clean energy supply of the electricity providers in this region. Northern Santa Barbara County is served by PG&E, which provided its customers with 100% carbon-free energy in 2019. Much of Ventura County is enrolled in Clean Power Alliance's 100% renewable energy option. Because these utilities' per megawatt hour emission factor in these areas is 0, the associated greenhouse gas emissions are 0 regardless of how much electricity is consumed. This is similarly the case in the western coastal area of Los Angeles County, which is also enrolled in Clean Power Alliance's 100% renewable energy option, even though this area had high levels of per capita consumption. Areas in south central Los Angeles County also have low emissions. Even though the electricity is not 100% carbon-free, per capita electricity consumption is low in these areas.

Per capita greenhouse gas emissions are higher and vary more around Los Angeles County and northwestern Orange County, reflecting the variation in both electricity provider power content and average per capita electricity consumption.

FIGURE 7: Greenhouse Gas Emissions Intensity Across the Region[11]



Source: Figure created by UCLA Luskin Center for Innovation. See Appendix G for greenhouse gas emissions methodology.

[11] County-level maps can be found in Appendices A-D.

4. VULNERABLE COMMUNITIES

We assess communities across the region along three measures of vulnerability: disadvantaged community score, median income, and average future days above 90 degrees Fahrenheit. We then assess how the three previously estimated energy indicators (electricity consumption, greenhouse gas emissions, and clean energy supply) vary along these measures of vulnerability. Examining trends in the communities that are most economically and environmentally vulnerable is important to understanding how to address inequities in these areas.

We first examine where the state-classified "disadvantaged communities" are in the region. This is determined by data from the CalEnviroScreen, developed by the California Office of Environmental Health Hazard Assessment.[12] This tool assesses census tracts across the state on a variety of environmental and sociodemographic factors in order to determine which areas are especially vulnerable. Census tracts are given standardized scores, with higher scores indicating that a community is more vulnerable. Census tracts in the top 25% of scores are classified as "disadvantaged communities" or DACs. Thirty-five percent of the census tracts in the region we assessed are classified as DACs.

We then examine median income data for census tracts across the region. While median income is one of the factors included in the DAC score, we examine this economic vulnerability indicator independently. The California Air Resources Board identifies priority populations for California Climate Investment funding based on both their DAC score and median income.[13] We use median income data from the U.S. Census (2019 American Community Survey five-year estimates).

Finally, we examine areas of the region especially vulnerable to the adverse effects of climate change. We identify which census tracts will experience the most high-heat days, as these census tracts will likely experience increased energy needs for air conditioning. We used the variable "days above 90 degrees Fahrenheit" to define high-heat days. We identified the projected annual number of days above 90 degrees Fahrenheit in mid-century (2035 - 2065) using projected climate data from Cal-Adapt. We used the four models that are considered priority models for California (HadGEM2-ES; CNRM-CM5; CanESM2; MIROC5) to calculate these estimations.

Among the four counties assessed, census tracts in Los Angeles County had the highest average DAC score, lowest median income, and highest number of future high heat days, suggesting that there are higher rates of vulnerable communities in LA County than in other counties in the region. Census tracts in Santa Barbara County had the lowest average DAC score and the lowest number of future high heat days. Orange County had the highest median income. Table 6 summarizes these vulnerability indicators across the region.

12 "CalEnviroScreen 3.0" (2018). California Office of Environmental Health Hazard Assessment. https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-30

13 The California Air Resources Board defines priority populations as "residents of: (1) census tracts identified as disadvantaged by California Environmental Protection Agency per SB 535; (2) census tracts identified as low-income per AB 1550; or (3) a low-income household per AB 1550." California Air Resources Board (2018). "Funding Guidelines."

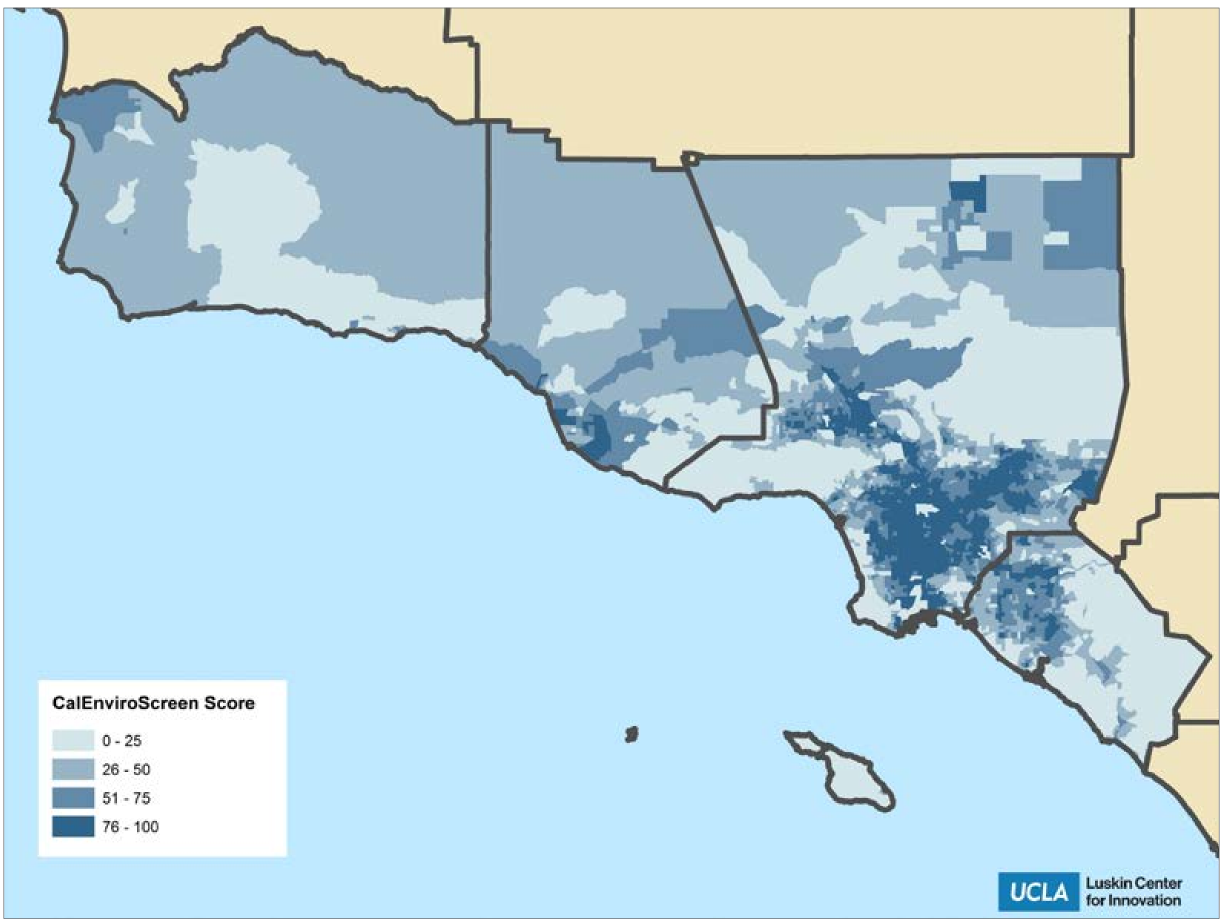
TABLE 6: **County Comparison of Measures of Vulnerability**

County	Average DAC Score	Median Income	Average Future Days Above 90 Degrees
Los Angeles	65.1	$68,044	70.6
Orange	41.3	$90,234	45.2
Santa Barbara	26.6	$74,624	12.3
Ventura	36.1	$88,131	45.8

4.1 Disadvantaged Communities

Figure 8 illustrates the variation in DAC scores across the region, with darker colors indicating a higher DAC score (and therefore a "more disadvantaged" community). As seen in the map, the highest concentration of high-scoring DACs is in southern Los Angeles County.

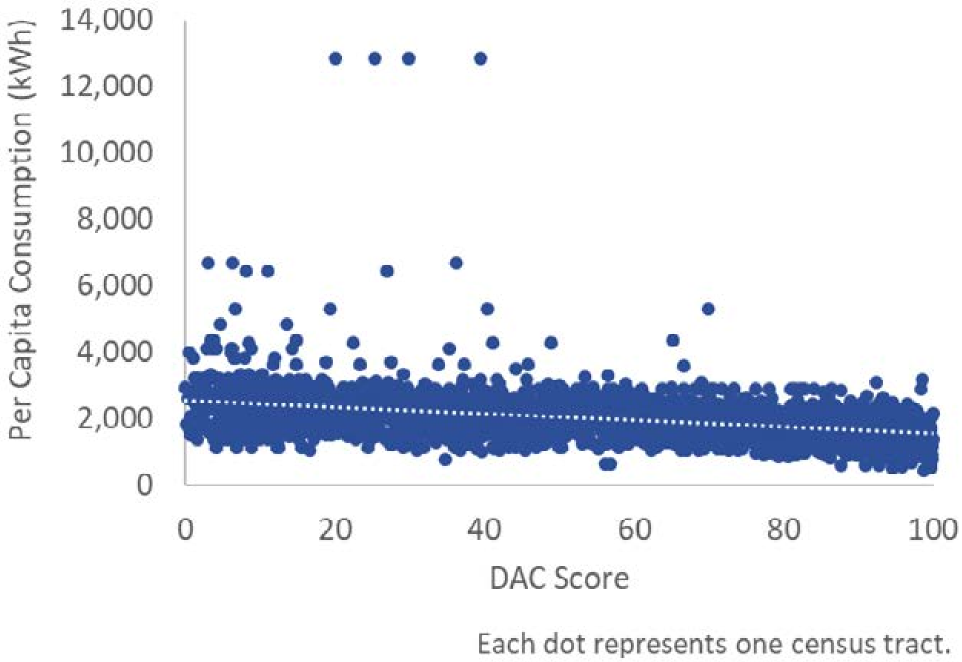
FIGURE 8: **Disadvantaged Communities Across the Region**[14]



Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from California Office of Environmental Health Hazard Assessment (2018).

[14] County-level maps can be found in Appendices A-D.

FIGURE 9: Comparison Between DAC Score and Electricity Consumption



Source: California Office of Environmental Health Hazard Assessment (2018). Electricity consumption data source is described in Appendix F.

Figure 9 shows the relationship between each census tract's DAC score and its average per capita electricity consumption (kWh). The white dashed line indicates that there is a slight negative relationship: As the DAC score increases, the average per capita electricity consumption decreases. This is statistically significant. For every 10-point increase in DAC score, per capita electricity consumption decreases by 100 kWh on average. In other words, more vulnerable communities tend to consume less electricity.

We find that there is not a strong relationship between each census tract's DAC score and its average greenhouse gas emissions per capita. Greenhouse gas emissions are a function of electricity consumption and the share of clean energy provided by an electricity provider. While we did find a higher DAC score was associated with less electricity consumption, this trend does not appear as strongly when looking at greenhouse gas emissions, suggesting that this is more dependent on other factors, such as the community's electricity provider. Similarly, we find there is not a strong relationship between each census tract's DAC score and the share of clean energy provided by its electricity provider. The share of clean energy provided depends on a DAC's electricity provider.

The share of DACs within an electricity provider's territory varies. Pico Rivera Municipal Energy's service territory has the highest share of DACs at 79%. The City of Cerritos, City of Lompoc Electric Division, PG&E, and San Diego Gas & Electric have no DACs in their service territory in the region we studied. It is important to note that PG&E, San Diego Gas & Electric, and Southern California Edison serve a territory beyond the four counties studied and the share of DACs illustrated here does not reflect the share of DACs found within their entire service territories.

FIGURE 10: Share of DAC Census Tracts in Each Electricity Provider's Territory

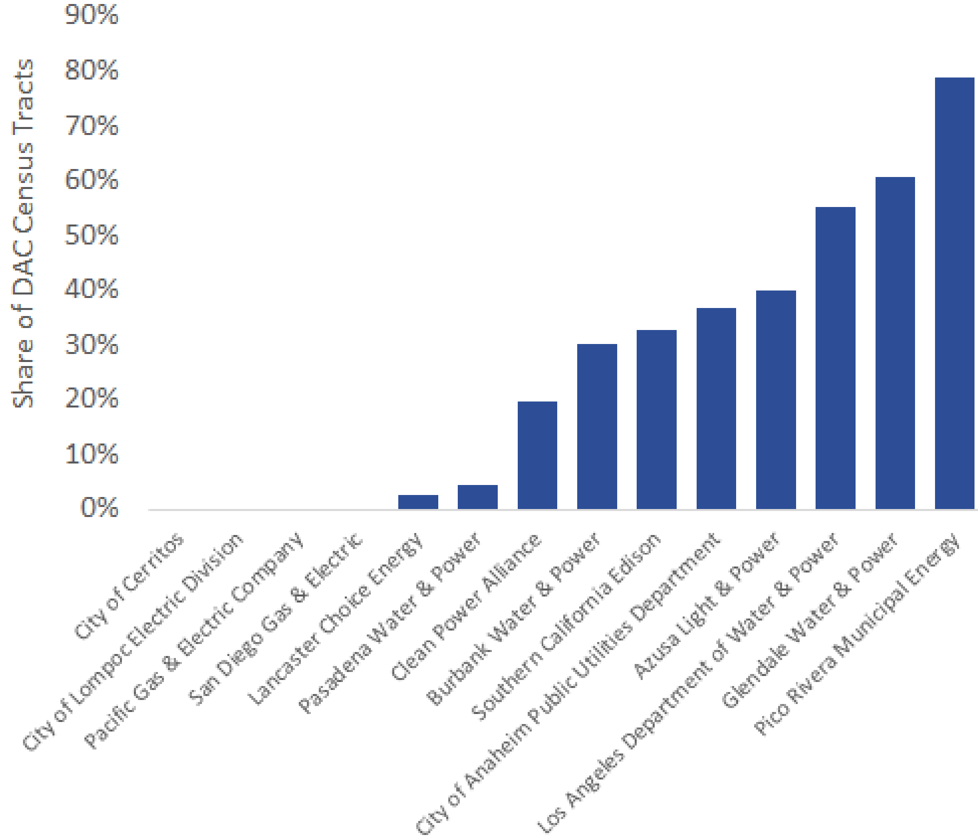


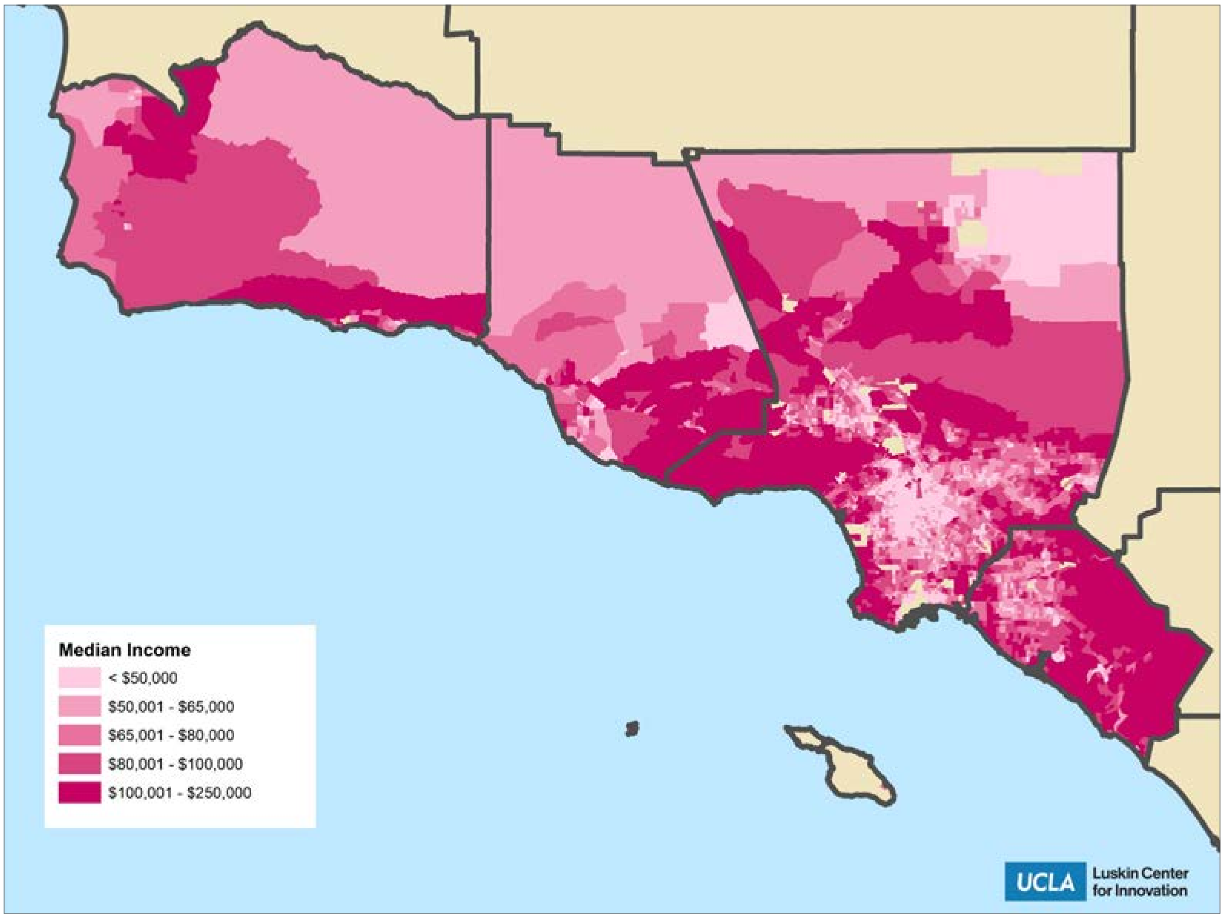
TABLE 7: Number of DAC and Non-DAC Census Tracts by Electricity Provider

Electricity Provider	Number of DAC Census Tracts	Number of Non-DAC Census Tracts	Share of DAC Census Tracts
Azusa Light & Water	4	10	40%
Burbank Water & Power	6	20	30%
City of Anaheim Public Utilities Department	22	60	37%
City of Cerritos	0	10	0%
City of Lompoc Electric Division	0	11	0%
Clean Power Alliance	151	767	20%
Glendale Water & Power	23	38	61%
Lancaster Choice Energy	1	37	3%
Los Angeles Department of Water and Power	482	873	55%
Pacific Gas & Electric	0	27	0%
Pasadena Water & Power	1	22	5%
Pico Rivera Municipal Energy	15	19	79%
San Diego Gas & Electric	0	36	0%
Southern California Edison	410	1,249	33%
All Census Tracts	1,117	3,196	35%

4.2 Median Income

Figure 11 illustrates the variation in median income across the region, with darker colors indicating a higher median income. Census tracts in lighter colors have a lower median income and are therefore more likely to be considered financially vulnerable. As seen in the map, the highest concentration of high-scoring DACs is in southern Los Angeles County. The largest clusters of census tracts with lower median incomes can be found in southern Los Angeles County, similar to what was seen in the DAC map. Other clusters of census tracts with lower median incomes are found in northern Orange County and the farthest northeastern corner of Los Angeles County.

FIGURE 11: Median Income Across the Region[15]



Source: Figure created by the UCLA Luskin Center for Innovation. Data from U.S. Census (2019).

Figure 12, next page, shows the relationship between the median income of each census tract and its average per capita electricity consumption (kWh). There is a slightly positive relationship between the two variables. As median income increases, per capita electricity consumption increases. This is statistically significant: For every $10,000 increase in median income, per capita electricity consumption increases by 89 kWh. Put simply, wealthier communities tend to consume more electricity per person.

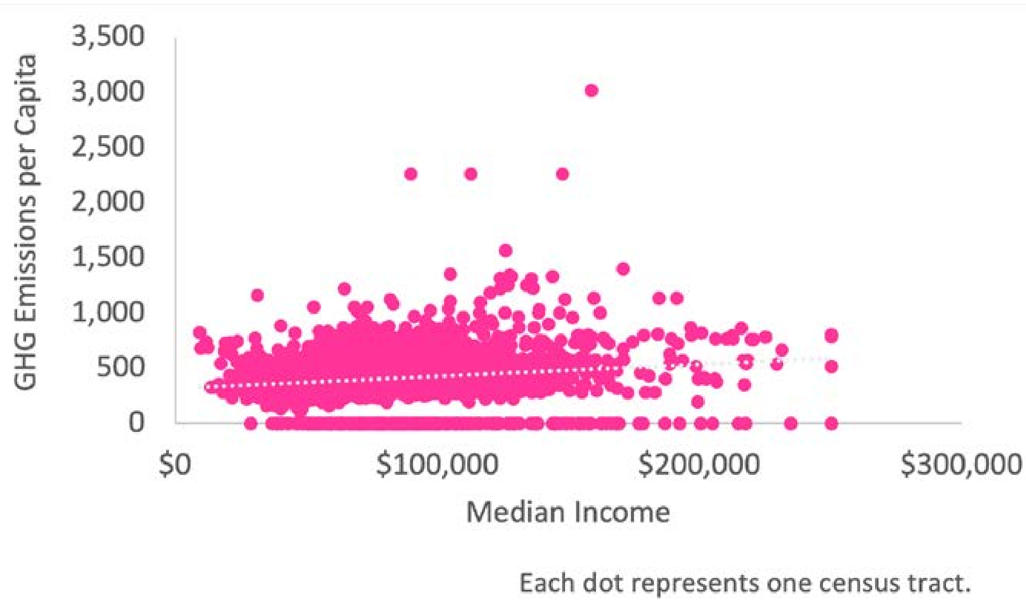
[15] County-level maps can be found in Appendices A-D.

FIGURE 12: Comparison Between Median Income and Electricity Consumption

Source: Median income data from the U.S. Census (2019). Electricity consumption data source is described in Appendix F.

Figure 13 shows the slightly positive relationship between the median income of each census tract and its average per capita greenhouse gas emissions. As median income increases, per capita greenhouse gas emissions also increase. This is statistically significant: For every $10,000 increase in median income, per capita greenhouse gas emissions increase by 10.8 MTCO2e. This makes sense considering that income was strongly associated with greater electricity consumption.

FIGURE 13: Comparison Between Median Income and Greenhouse Gas Emissions



Source: Median income data from the U.S. Census (2019). Greenhouse gas emissions data source is described in Appendix G.

Next, we examine the relationship between median income and share of clean energy, illustrated in Figure 14. Clean energy is slightly higher in areas with higher median incomes, seeming to contradict the previous finding that greenhouse gas emissions intensity was also greater in higher median income areas. This suggests that the trend that electricity consumption is higher in areas with higher median income is driving this trend. This relationship is statistically significant: For every $10,000 increase in median income, share of clean energy increases by 0.46%.

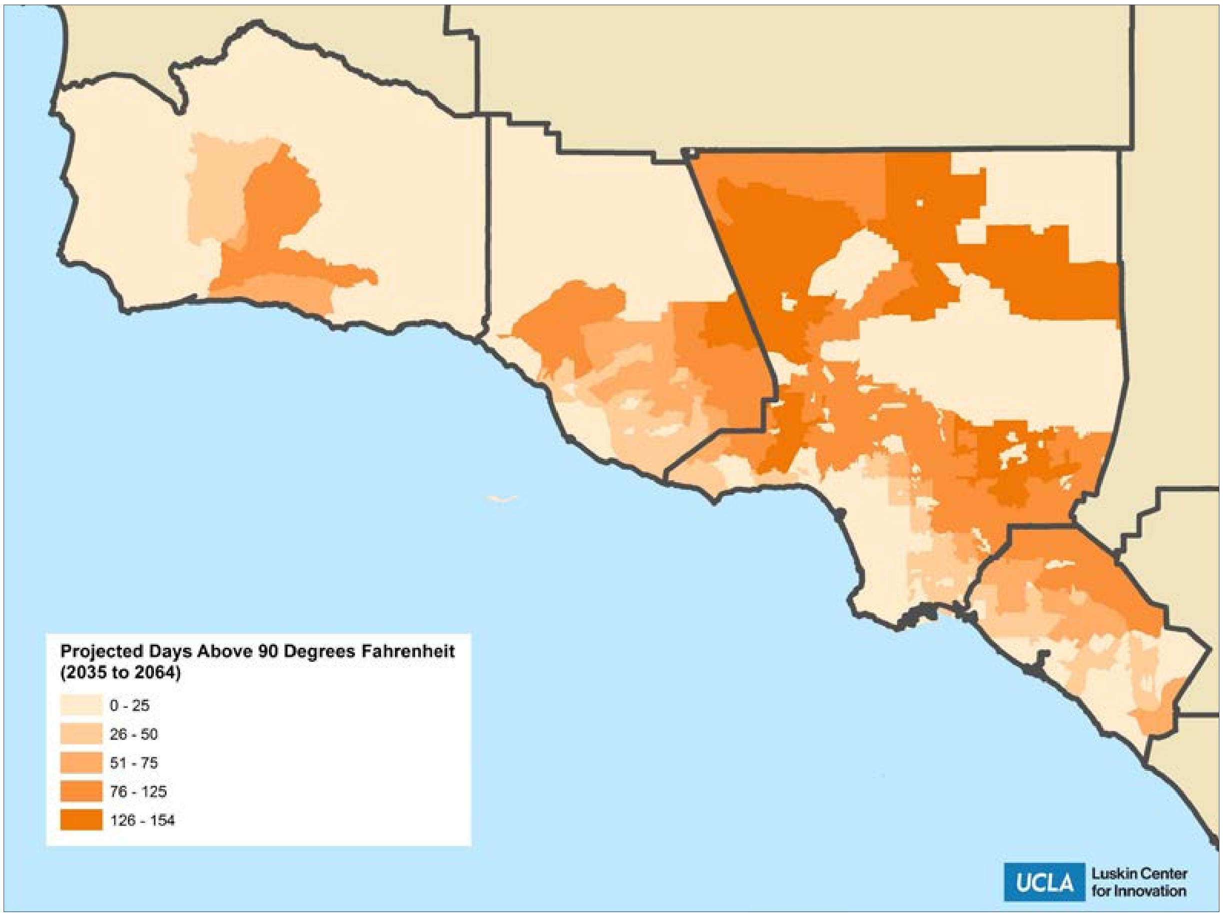
FIGURE 14: Comparison Between Median Income and Share of Clean Energy

Source: Median income data from the U.S. Census (2019). Clean energy data is from the California Energy Commission.

4.3 Future High Heat Days

Figure 15 illustrates the variation in future high heat days across the region, measured in annual days above 90 degrees Fahrenheit from 2035 to 2064. Darker colors indicate a greater number of future high heat days. As seen in the figure, the areas of the region likely to see the largest number of high heat days in the future are southern and southeastern Ventura County, inland and northwestern Los Angeles County, and northern Orange County.

FIGURE 15: Annual Future High Heat Days Projected in the Years 2035 to 2064 Across the Region[16]



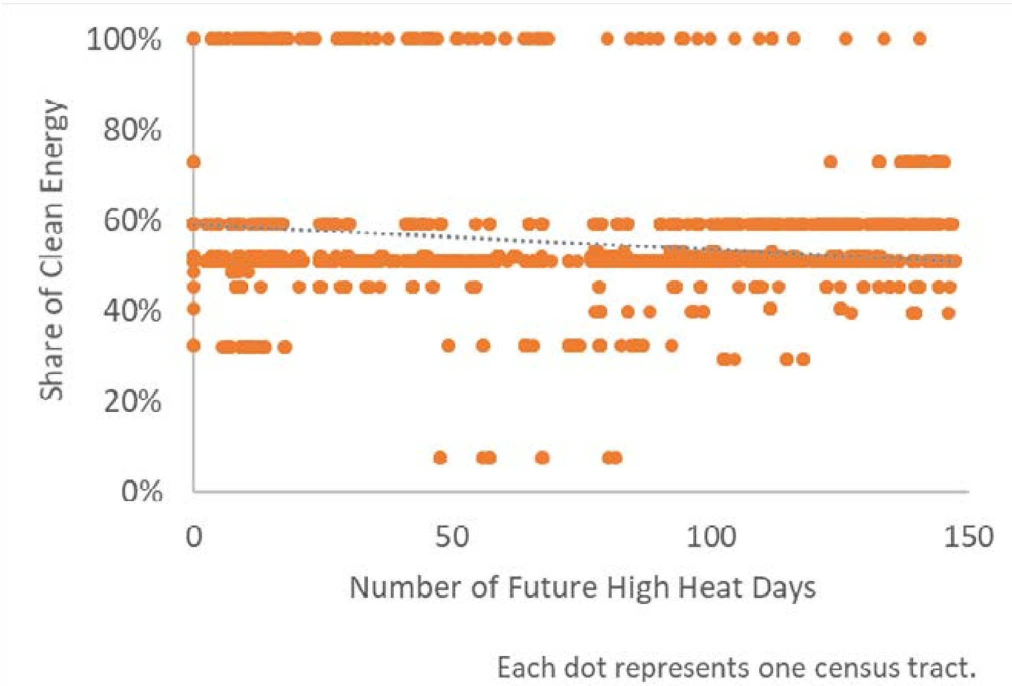
Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from Cal-Adapt (2020).

The relationship between each census tract's future number of high heat days and each energy indicator is very weak. There is a slight, positive correlation with per capita electricity consumption, as well as with greenhouse gas emissions. That means per capita consumption is higher in areas that will see more future high heat days. This makes sense, as the areas that will see more future high heat days are likely already some of the warmer areas of the region and already have higher energy needs and therefore generally higher electricity-related greenhouse gas emissions.

[16] County-level maps can be found in Appendices A-D.

At the same time, there is a weak, negative relationship with share of clean energy; census tracts with more future high heat days tend to be supplied with less clean energy (illustrated in Figure 16).

FIGURE 16: Comparison Between Future High Heat Days Projected in the Years 2035 to 2064 and Current Share of Clean Energy



Source: Cal-Adapt (2020) ad California Energy Commission (2019).

It is worth noting that this means areas that will likely experience greater increases in energy needs in the future also tend to live in areas with lower shares of clean energy. To attain climate goals, we need to figure out how to meet those increasing energy needs without increasing the carbon footprint or further burdening those vulnerable communities that also will be experiencing higher bills. These communities may benefit from greater targeting with programs like solar and storage, as well as energy efficiency, to offset/lower electric bill costs in the face of increasing electricity needs for air conditioning.

5. ENERGY PROGRAM ADOPTION

Energy programs can bring a variety of economic and environmental benefits to customers and communities, as well as to the electricity providers that administer them. In this section, we assess how adoption of four different energy programs has varied geographically across the region: residential rooftop solar, electric vehicles and their charging infrastructure, and energy storage.

We then assess how program adoption varies by previously described measures of community vulnerability. These programs are not meant to be comprehensive — a wide variety of other energy programs exist, such as energy efficiency — but rather representative of how the adoption of some of the major energy programs vary across the region.

We begin with residential solar installations. Rooftop solar generates clean electricity and often offsets the cost of electricity consumption for the household. The development of rooftop solar is possible through a number of different pathways. For example, utilities administer net energy metering programs. Additional examples include the low-income solar programs offered through the California Solar Initiative, a state program: Single-Family Affordable Solar Homes program (SASH) and Multifamily Affordable Solar Housing (MASH) program. To map solar adoption across the region, we use Stanford University's DeepSolar database.[17] This data was gathered using AI, machine learning, and Google Earth satellite imagery to identify all rooftop solar installations across the country. Data can be downloaded in an Excel file that aggregates the total number of residential rooftop solar installations per census tract, along with other related data.

Electric vehicles are growing in popularity as an alternative to traditional fossil fuel burning cars. They are much cleaner than gas-powered cars in terms of greenhouse gas emissions and local air pollutant emissions that are detrimental to human health. Increasingly, localities are passing laws to phase out the use of gas-powered cars in favor of exclusively using electric vehicles, including in California. In September 2020, Gov. Newsom signed an executive order that requires that all new car sales be zero-emission by 2035.[18] While there are costs associated with purchasing electric vehicles, programs exist to offer subsidies or rebates to customers purchasing electric vehicles to encourage their adoption and make them more accessible. For example, the California Clean Vehicle Rebate Project offers incentives of up to $7,000 for new electric vehicles.[19] The use of electric vehicles decreases the need to purchase gasoline — a cost savings for customers in many cases — but it is offset by an increase in electricity demand.

Next, we examine regional electric vehicles adoption and its associated charging infrastructure. Electric vehicle adoption data is from IHS Markit and includes vehicles sold from 2010 to 2018. Electric vehicle charging stations support the

[17] Yu, Jiafan; Wang, Zhecheng; Majumdar, Arun; and Rajagopal, Ram. (2018). "DeepSolar." Stanford University. http://web.stanford.edu/group/deepsolar/home

[18] Executive Order N-79-20. https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-text.pdf

[19] "Drive clean and save" (2021). California Clean Vehicle Rebate Program. https://cleanvehiclerebate.org/eng?utm_source=sce&utm_medium=referral&utm_campaign=utility&utm_content=logo_incentives

adoption of electric vehicles, as they provide utility to EV drivers. Electric vehicle charging station data is from the National Renewable Energy Laboratory API as of March 2021 and reported as point data (latitude and longitude).[20] We use ArcGIS to spatially aggregate the number of EV charging stations per census tract. We include all active public and private charging stations.

Finally, we look at the regional adoption of residential energy storage. Energy storage is emerging as a solution to some grid and resilience challenges. Senate Bill 700 (2018) allowed for energy storage systems to receive rebates through the self-generation incentive program (SGIP), administered by the California Public Utilities Commission. For energy storage data, we use SGIP data, reported by zip code. We include only residential, single-family, and multifamily electrochemical storage that has an interconnection date and has not been marked as canceled.

5.1 Solar

Although Los Angeles County has the highest absolute number of residential solar systems in the region, with 92,380 installed, it has the lowest per capita rate of adoption at 9.2 solar systems per 1,000 residents. Ventura County has the highest per capita rate of adoption with 17.6 solar systems per 1,000 residents. Orange County has the second-highest absolute number and per capita rate of adoption in the region.

Figure 17 illustrates the number of residential solar systems per census tract across the region. Darker yellow areas correspond with a higher number of installed residential solar systems. In Santa Barbara County, western coastal areas had fewer solar systems than the rest of the county. In Ventura County, the northern half of the county had fewer solar systems than the southern half. In Los Angeles County, the number of solar systems was fairly evenly distributed throughout the county, with few systems in the Angeles National Forest area in the middle of the county. The number of solar systems per census tract was also fairly evenly distributed in Orange County.

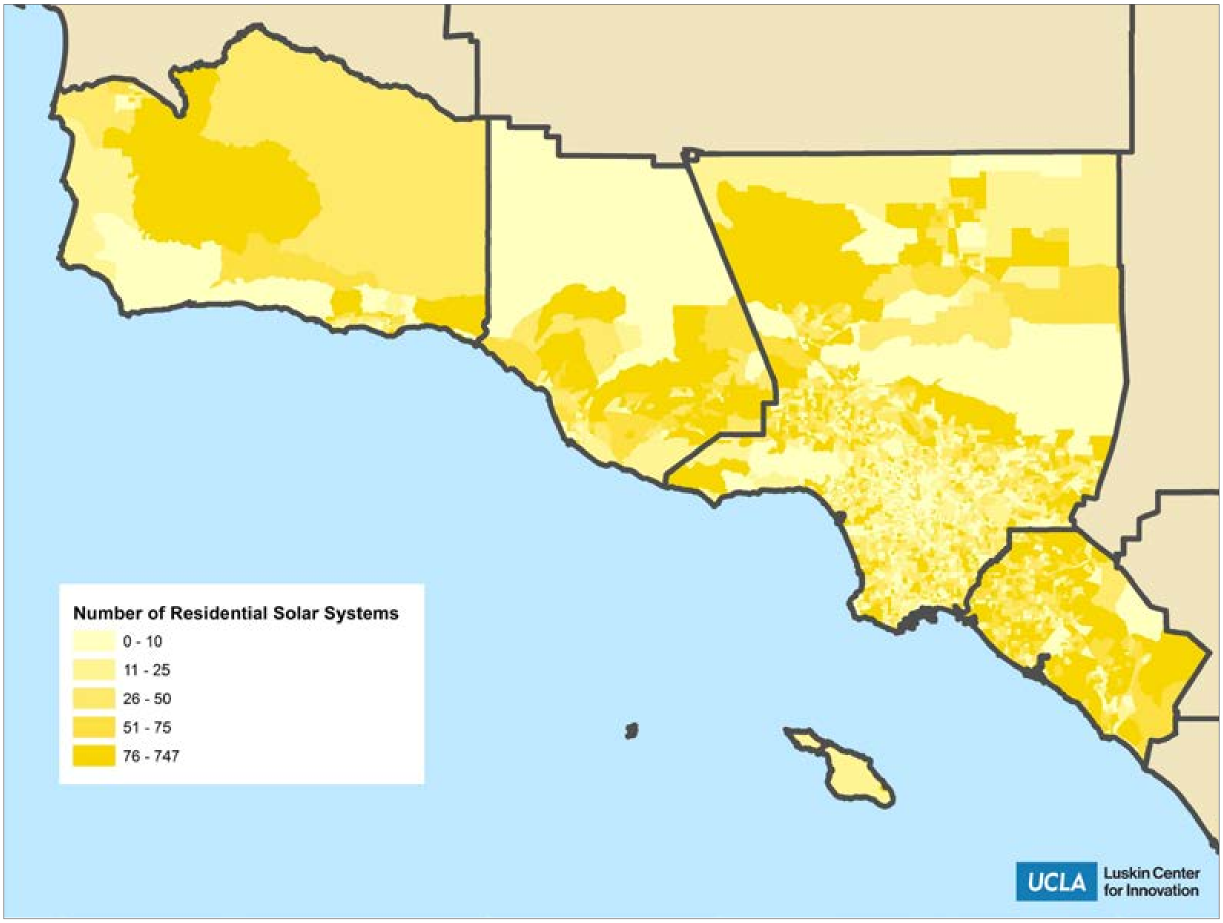
Figure 18 shows the relationship between each census tract's DAC score and the number of solar systems installed. There is a slight negative relationship: As the DAC score increases, the number of solar installations decreases. This is statistically significant: For every 10-point increase in DAC score, the number of solar installations decreases by 10. Less vulnerable communities tend to have more solar systems.

TABLE 8: Comparison of Solar Adoption by County

County	Total Number of Residential Solar Systems	Number of Residential Solar Systems per 1,000 Residents
Los Angeles	92,380	9.2
Orange	42,047	13.3
Santa Barbara	4,801	10.8
Ventura	14,908	17.6

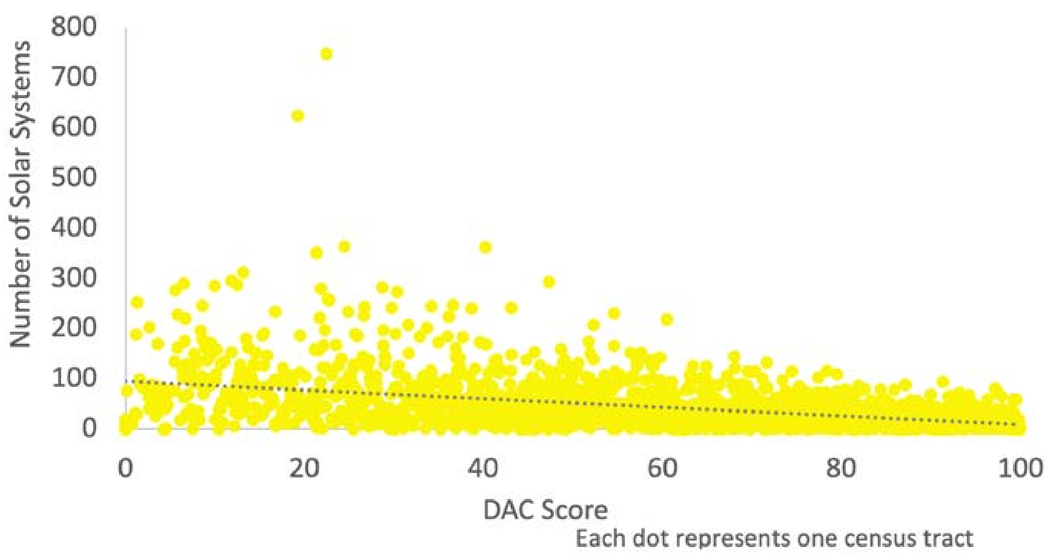
[20] National Renewable Energy Laboratory: Developer Network (2021). "All Stations API." https://developer.nrel.gov/docs/transportation/alt-fuel-stations-v1/all/

FIGURE 17: Residential Solar Systems Across the Region[21]



Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from Stanford University (2018).

FIGURE 18: Comparison Between DAC Score and Solar Adoption



Source: Stanford University (2018) and California Office of Environmental Health Hazard Assessment (2018).

[21] County-level maps can be found in Appendices A-D.

This trend appears even stronger when comparing the median income of a census tract to the number of solar systems installed, illustrated in Figure 19. Generally, the wealthier a census tract, the more solar systems are installed. We find this is also statistically significant: For every $10,000 increase in median income, the number of solar systems increases by 9.2, on average.

FIGURE 19: Comparison Between Median Income and Solar Adoption

Source: Stanford University (2018) and U.S. Census (2019).

5.2 Electric Vehicles

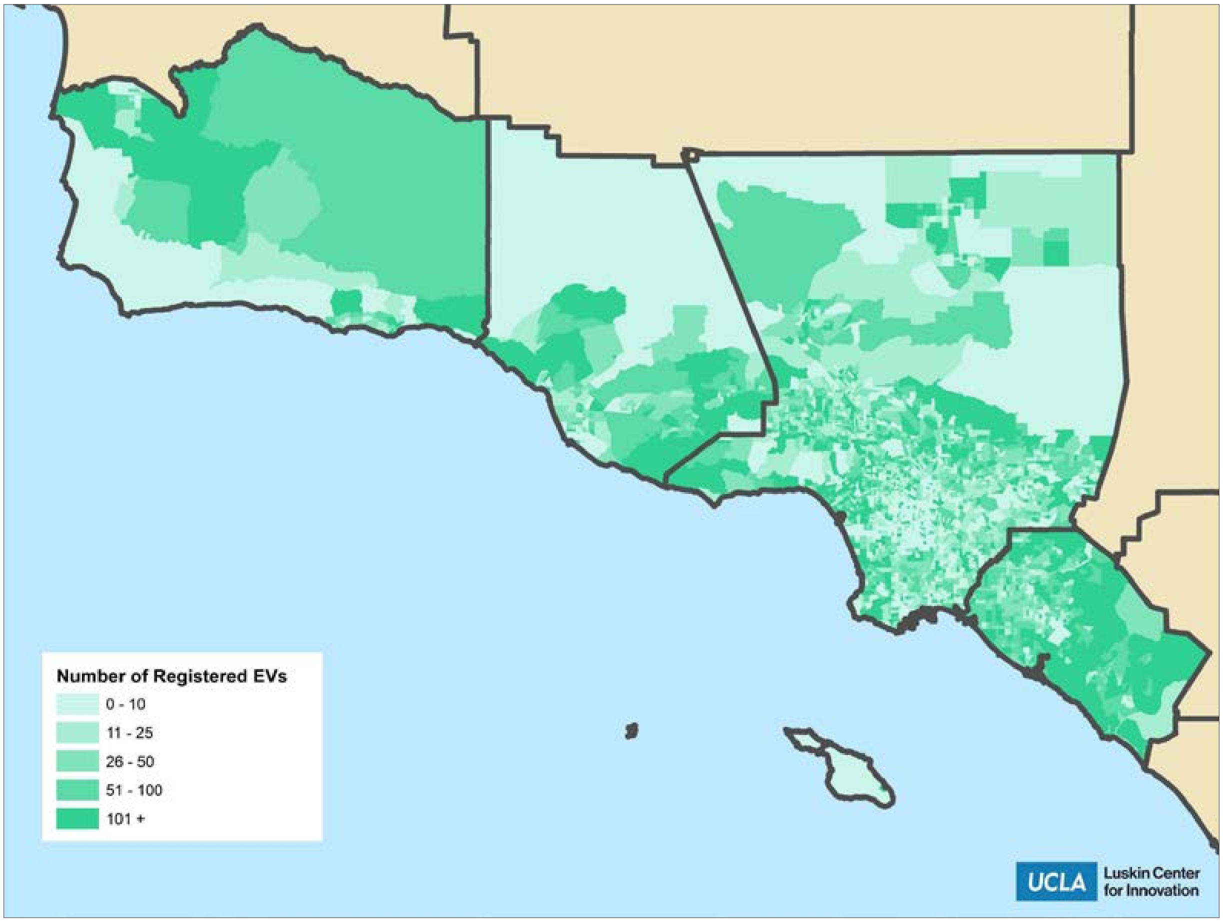
Table 9 compares the four counties' EV registration performance. Orange County has the highest per capita EV adoption rate, while Santa Barbara County has the lowest.

TABLE 9: Comparison of Electric Vehicle Registrations by County

County	Total Registered EVs	EVs per 1,000 Residents
Los Angeles	134,014	13.3
Orange	61,241	19.3
Santa Barbara	3,681	8.3
Ventura	10,087	11.9

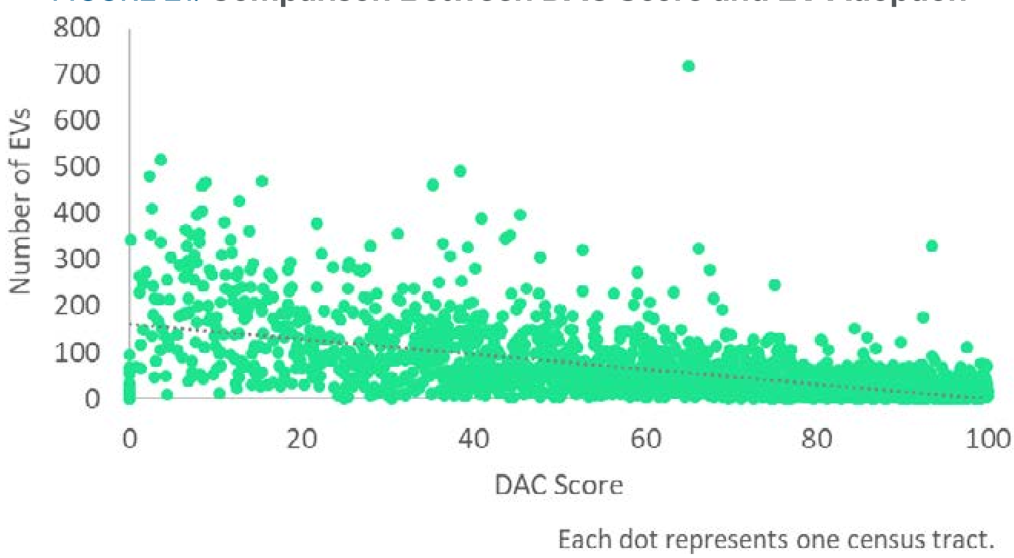
Figure 20 illustrates how the adoption of electric vehicles varies across the region. Darker colors indicate higher numbers of registered vehicles in that census tract. Electric vehicle adoption is high across much of Orange County.

FIGURE 20: Electric Vehicle Adoption Across the Region[22]



Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from IHS Markit (2018).

FIGURE 21: Comparison Between DAC Score and EV Adoption



Source: IHS Markit (2018) and California Office of Environmental Health Hazard Assessment (2018).

[22] County-level maps can be found in Appendices A-D.

Figure 21 shows the relationship between each census tract's DAC score and the number of registered EVs. There is a moderate negative relationship between the two. Census tracts with higher DAC scores had fewer EVs. This is statistically significant: For every 10-point increase in DAC score, the number of EVs registered in that census tract decreases by 16.4 on average.

Figure 22 shows the relationship between each census tract's median income and the number of registered EVs. We find that as the median income increases, the number of registered EVs increases. This is statistically significant: For every $10,000 increase in median income, the number of EVs registered in that census tract decreases by 16 on average.

FIGURE 22: Comparison Between Median Income and EV Adoption

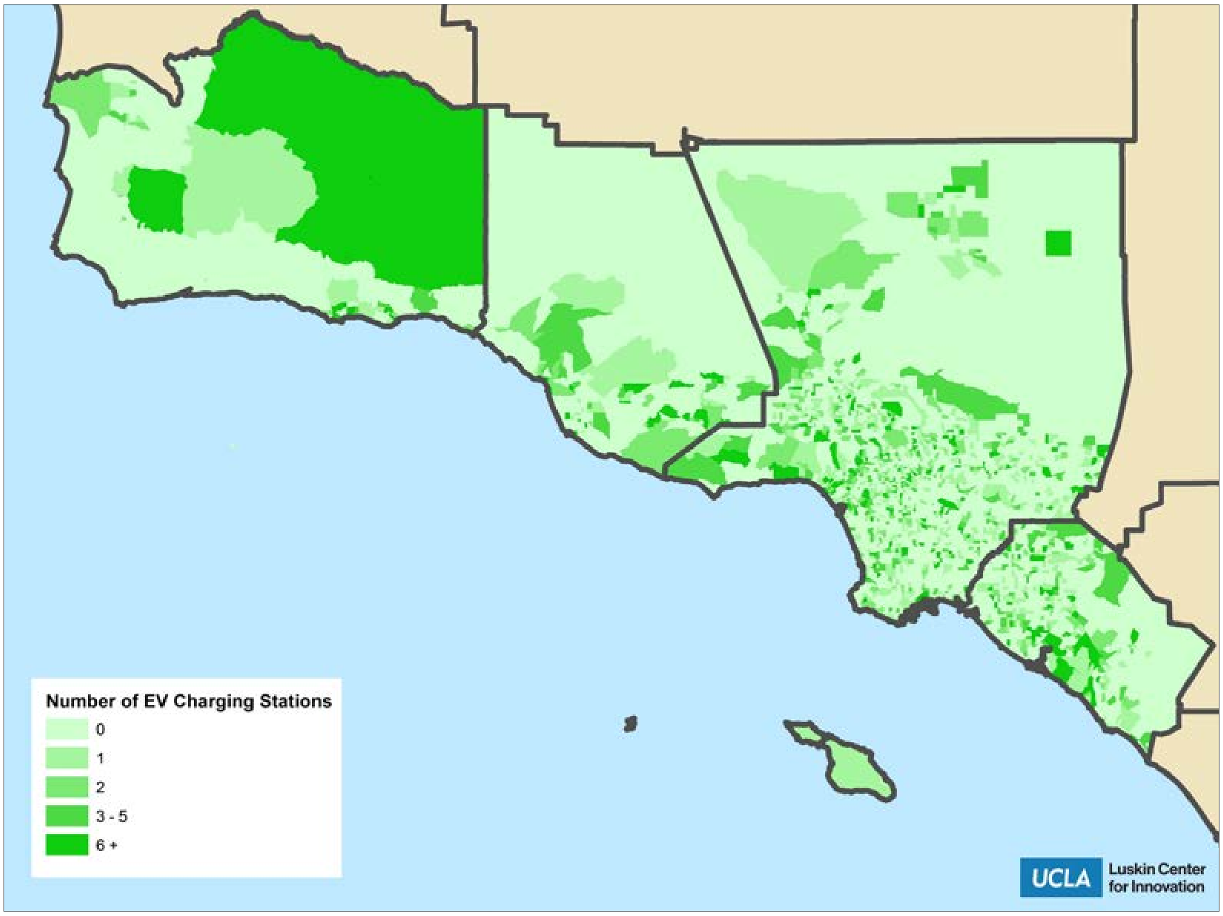
Source: IHS Markit (2018) and U.S. Census (2019).

Table 10 summarizes how the number of EV charging stations vary across the four counties in this study. Orange County has the highest per capita EV charging station rate, but the second-lowest charger-per-EV rate. On the flip side, Santa Barbara County had the highest number of EV charging stations per registered EV, but the lowest number of total EV charging stations in the county.

TABLE 10: Comparison of Electric Vehicle Charging Stations by County

County	Number of EV Chargers	Number of EV Chargers per 1,000 Residents	Number of EV Chargers per 1,000 Registered EVs
Los Angeles	3,246	0.32	24.2
Orange	1,397	0.44	22.8
Santa Barbara	152	0.34	41.3
Ventura	216	0.25	21.4

FIGURE 23: Electric Vehicle Charging Stations Across the Region[23]



Source: Figure created by UCLA Luskin Center for Innovation. Data from the National Renewable Energy Laboratory (2021).

Figure 23 illustrates the number of EV charging stations per census tract across the region. Darker green areas illustrate higher numbers of EV charging stations. The number of EV charging stations appears to be somewhat evenly spread across the southern half of Ventura and Los Angeles counties, and the northern two-thirds of Orange County. Fewer EV charging stations are available in the northern half of Ventura and Los Angeles counties, the eastern third of Orange County, and the western coastal regions of Santa Barbara County.

We examine the relationship between each the number of EV charging stations and the census tract's vulnerability characteristic and find no trends. There is no discernable trend between a census tract's DAC score and the number of EV charging stations. Similar to DAC score, the median income of a census tract does not appear to have a relationship with the number of EV charging stations, suggesting that EV charging stations are somewhat evenly distributed among census tracts with different DAC scores.

[23] County-level maps can be found in Appendices A-D.

5.3 Energy Storage

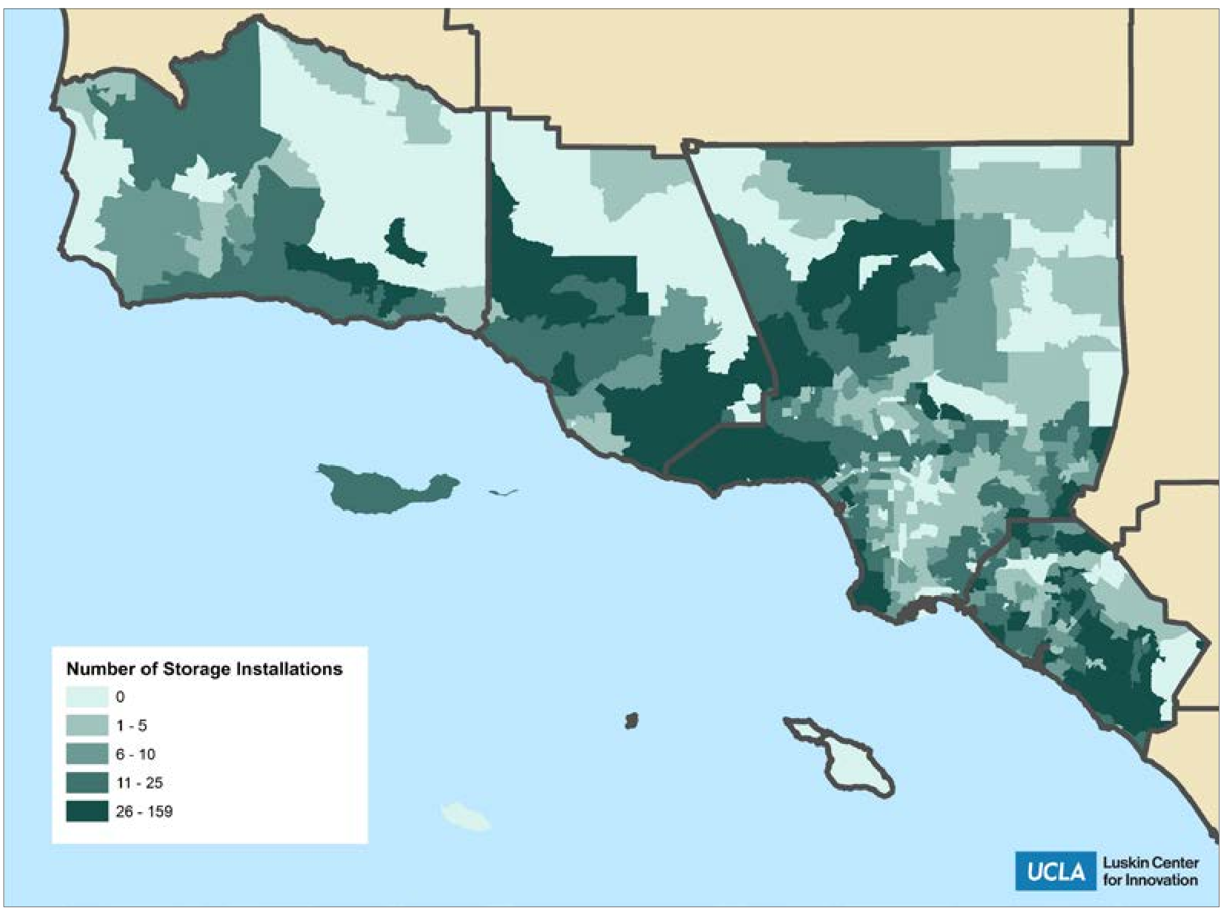
Energy storage adoption is occurring at similar rates across the region. Los Angeles County has the highest per capita storage adoption rates at 0.23 per 1,000 residents, while Orange County has the lowest per capita storage adoption rate at 0.18 per 1,000 residents.

TABLE 11: Comparison of Energy Storage Adoption by County

County	Number of Energy Storage Installations	Energy Storage Installations per 1,000 Residents
Los Angeles	2,336	0.23
Orange	582	0.18
Santa Barbara	88	0.20
Ventura	175	0.20

Figure 24 illustrates how energy storage installations vary across the region. Darker blue areas indicate a higher number of storage installations in that zip code. Storage adoption rates are lowest in northern Ventura County, and in southern, central and much of the northwestern part of Los Angeles County.

FIGURE 24. NUMBER OF RESIDENTIAL STORAGE INSTALLATIONS ACROSS THE REGION[24]

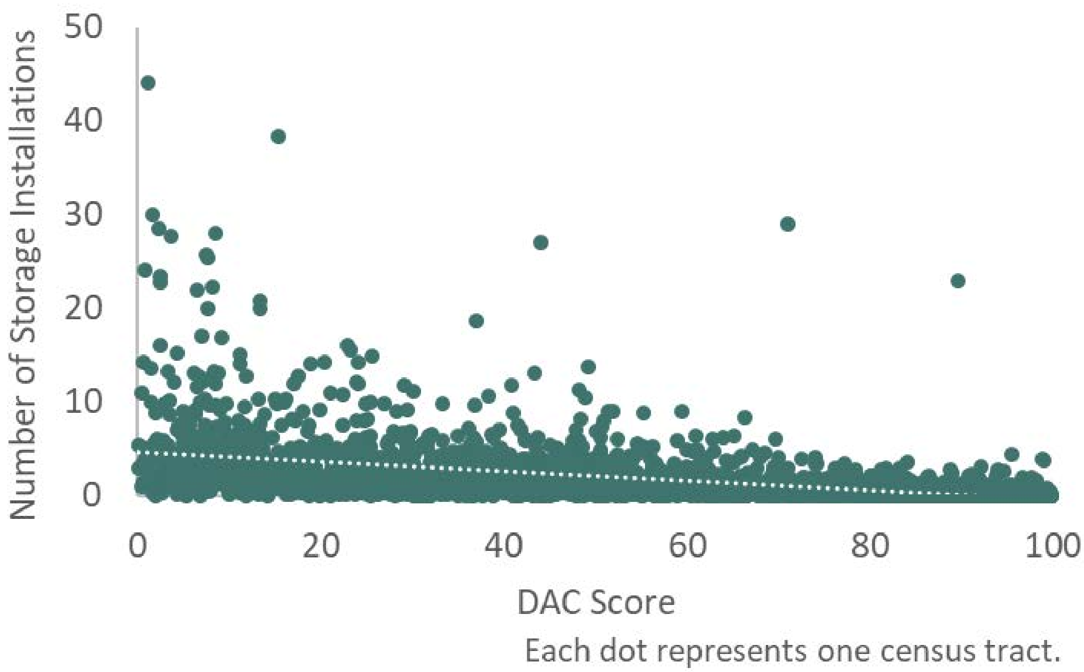


Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from SGIP Program Statistics (2021).

[24] County-level maps can be found in Appendices A-D.

Figure 25 shows the relationship between each census tract's DAC score and the number of storage installations. There is a moderate negative relationship between these two variables. The higher a census tract's DAC score, the fewer storage installations in that census tract. This is statistically significant: For every 10-point increase in DAC score, the number of storage installations decreases by 0.5 on average. Essentially, higher-scoring DACs tend to have fewer storage installations.

FIGURE 25: Comparison Between DAC Score and Energy Storage Adoption



Source: SGIP Program Statistics (2021) and California Office of Environmental Health Hazard Assessment (2018).

Figure 26 shows the relationship between median income and energy storage adoption. There is a moderate positive relationship; census tracts with a higher median income had more energy storage installations. This is statistically significant: For every $10,000 increase in median income, the number of storage installations increases by 0.4, on average. Consistent with what we have seen with other energy programs, wealthier communities tend to have more storage installations.

FIGURE 26: Comparison Between Median Income and Energy Storage Adoption

Source: SGIP Program Statistics (2021) and U.S. Census (2019).

There is no statistically significant relationship between the number of future high heat days and energy storage installations.

6. CONCLUSION

Energy needs, community vulnerability, and energy program adoption vary geographically among Los Angeles, Orange, Santa Barbara, and Ventura counties. Understanding this variation can help policymakers and local communities ensure we are continuing to make progress in the transition to clean energy, the reduction of greenhouse gas emissions, and the adoption of clean energy technologies through energy programs.

Importantly, understanding how energy indicators and energy program adoption vary along community vulnerability dimensions can inform decision-making. Specifically, this understanding can inform decisions about how to ensure benefits are distributed equitably across the region, and how to especially ensure that those areas most burdened by climate change are accessing the environmental benefits of the clean energy transition.

In terms of energy indicators, we find that electricity consumption per capita varies widely around the region, as it is dependent on a variety of socioeconomic, housing, and environmental characteristics. Furthermore, we find there is uneven progress throughout the region toward the 100% carbon-free energy goal. While some areas of the region, notably large portions of Santa Barbara and Ventura counties, have already achieved this goal, areas of Los Angeles and Orange counties are not quite there. Encouraging this transition to carbon-free electricity can help reduce the greenhouse gas impact of electricity consumption across the region. It is important to note that greenhouse gas emissions are a function of both clean energy supply and electricity consumption. To further reduce emissions, we should aim to both reduce per capita consumption (through energy efficiency programs for example), as well as increase clean energy supply.

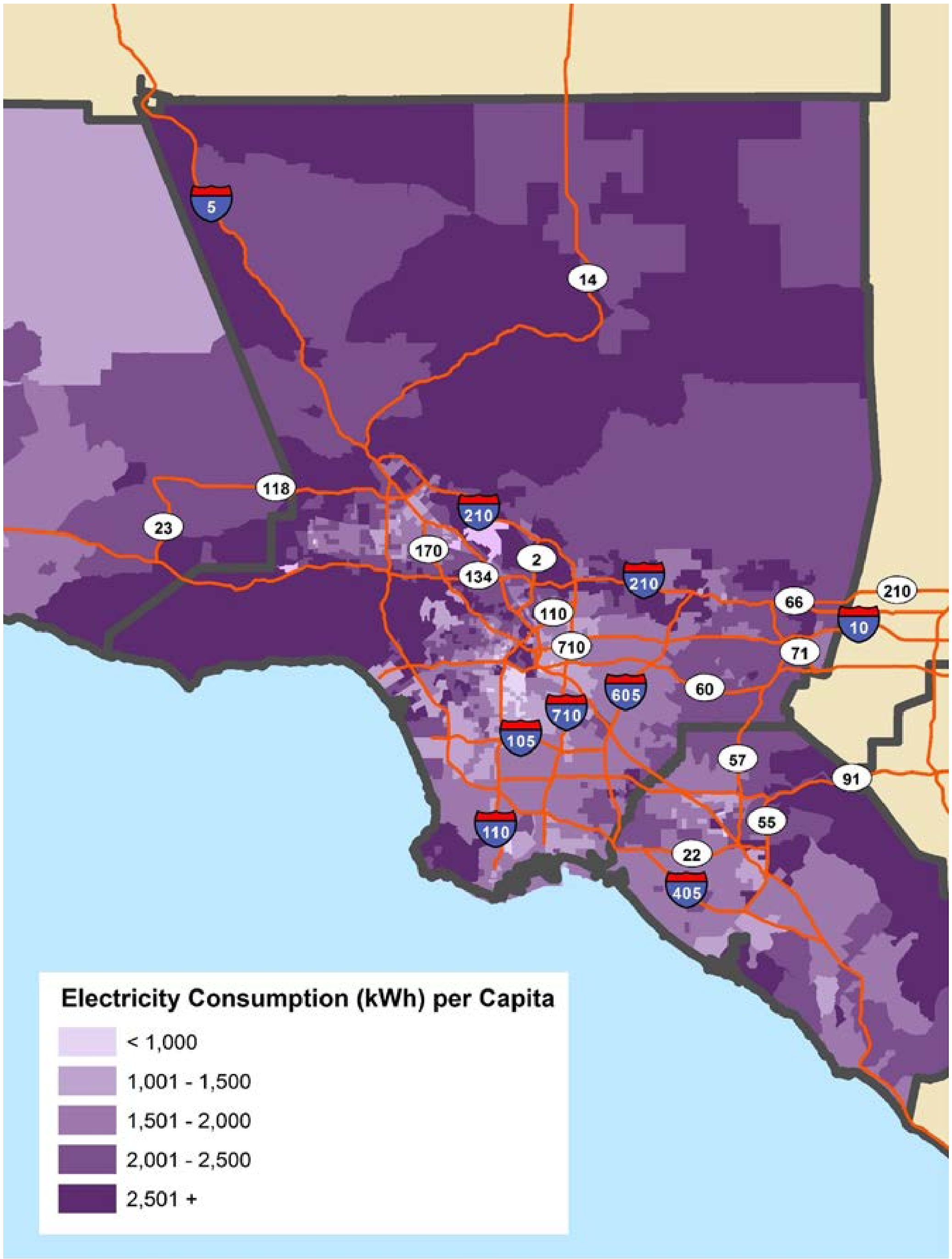
This will be especially true when considering the economically and environmentally vulnerable communities around the region. We find that community vulnerability also varies across the region for the indicators we assessed. Notably, there is a section of southern Los Angeles County and northern Orange County that have high DAC scores and low median incomes. Where this occurs in places with lower median incomes, these customers will face a disproportionate economic and environmental burden. Those facing increases in high heat days in the future will likely see their energy needs, and thus their energy bills, increase. Supporting programs in these areas that reduce electricity bills (such as energy efficiency, rooftop solar and energy storage), as well as rate assistance programs, could alleviate the burden on these communities as the effects of climate change increase.

We found that median income appears to be the strongest driver of energy program adoption. We found generally lower rates of energy program adoption in census tracts with a higher DAC score, although this relationship was often not as strong as it was with median income. Targeting lower income communities with outreach and additional financial support can help make the distribution of these programs more even across all areas. Counties as a whole varied in their adoption rates of these programs. Ventura had the highest per capita solar adoption rates (and the cleanest energy supply). Orange County had the highest per capita rates of both electric vehicles and charging stations. EV chargers were the only energy program indicator we assessed that did not have a relationship with any of the vulnerability indicators, suggesting that efforts to ensure their equal distribution across vulnerable and nonvulnerable communities have been successful. Lessons learned from this success could be used to inform more equitable distribution of other energy programs. All counties performed similarly well on storage adoption rates, although these were generally low across the region compared to other programs. Continued support for energy programs at the legislative and regulatory level can help bring additional environmental and economic benefits to the region.

APPENDICES

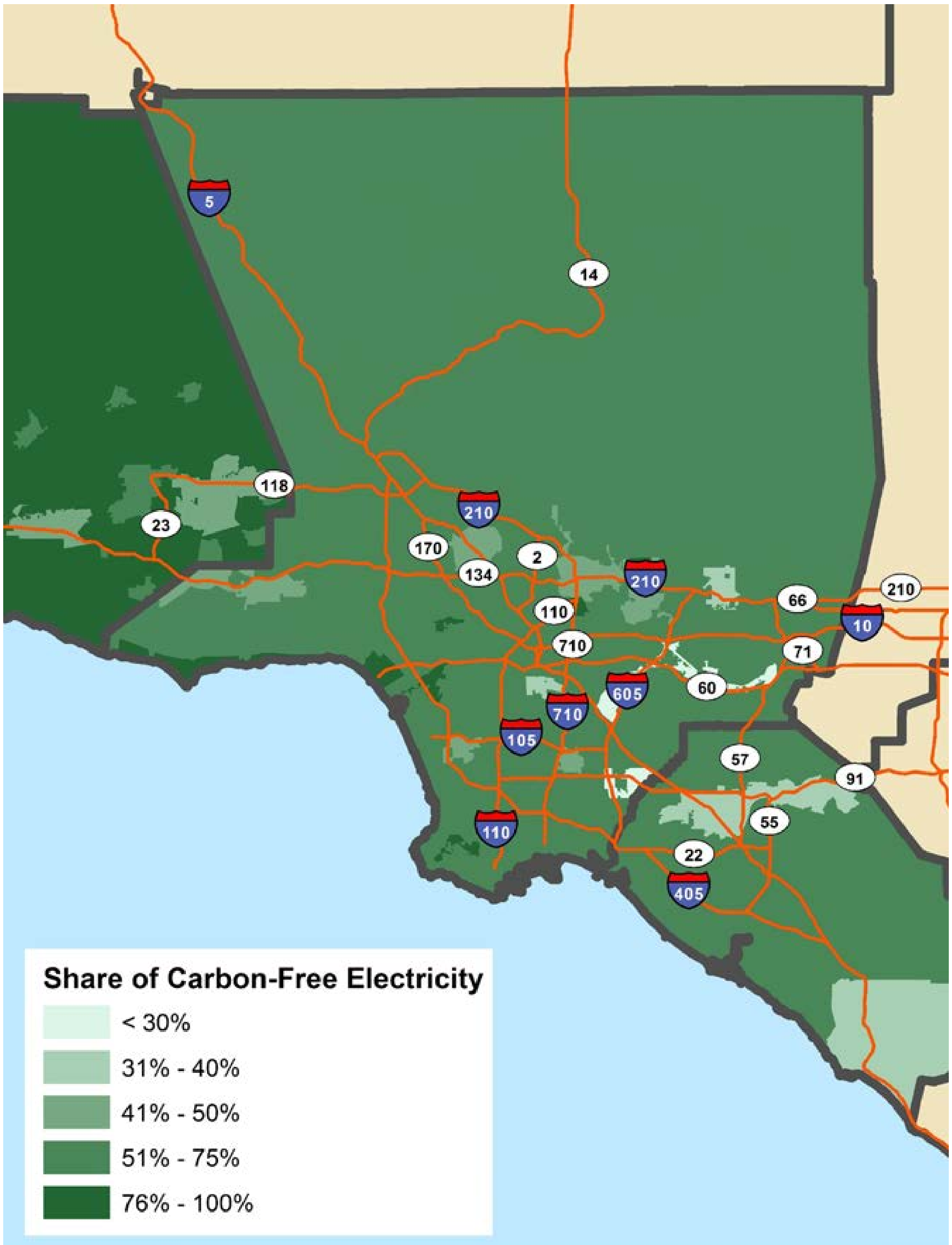
Appendix A: Los Angeles County Maps

FIGURE A-1: **Electricity Consumption (kWh) per Capita Across Los Angeles County**



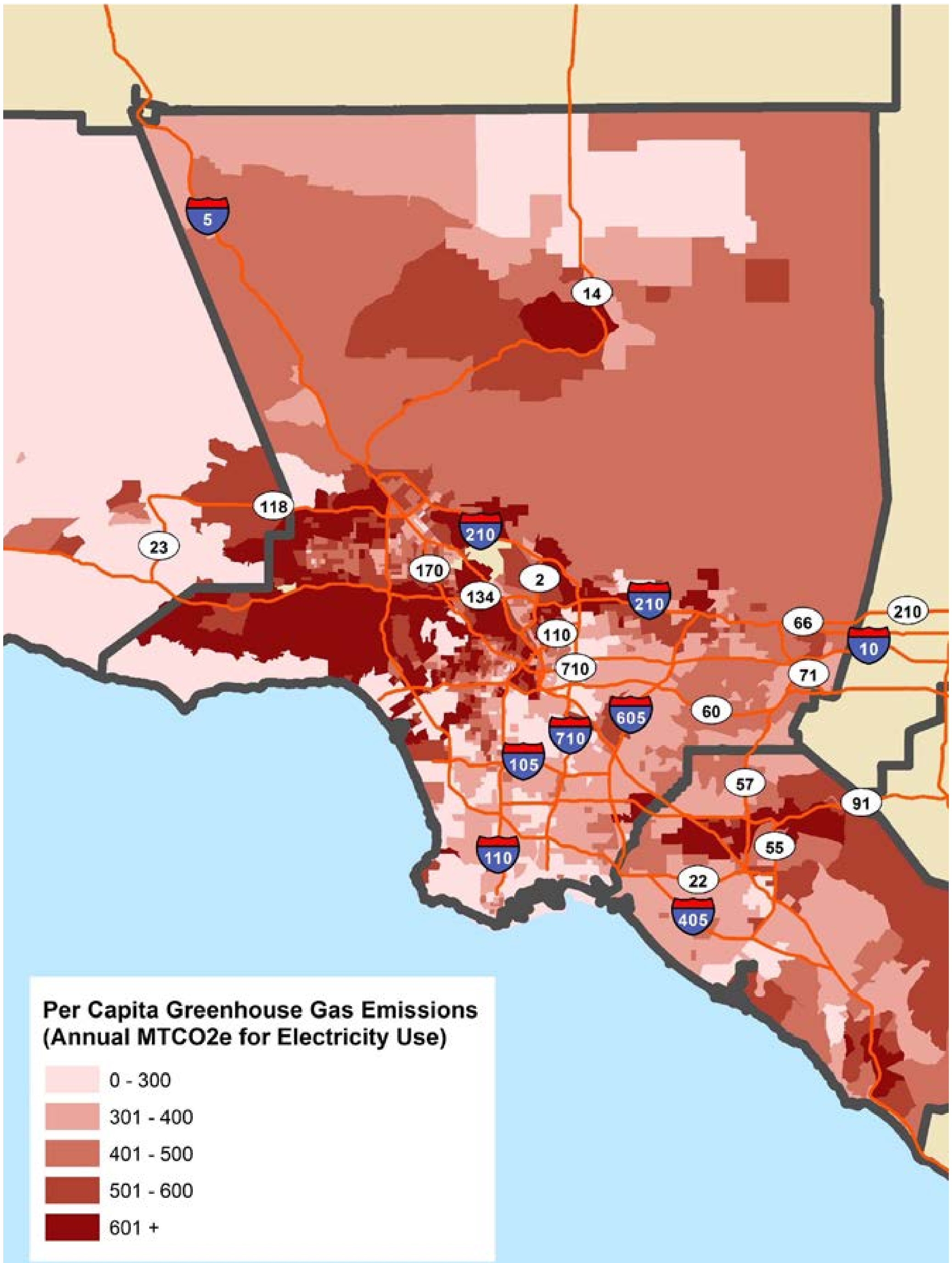
Source: Figure created by UCLA Luskin Center for Innovation (2021). Electricity consumption data sources described in Appendix F.

FIGURE A-2: Clean Energy Supply Across Los Angeles County



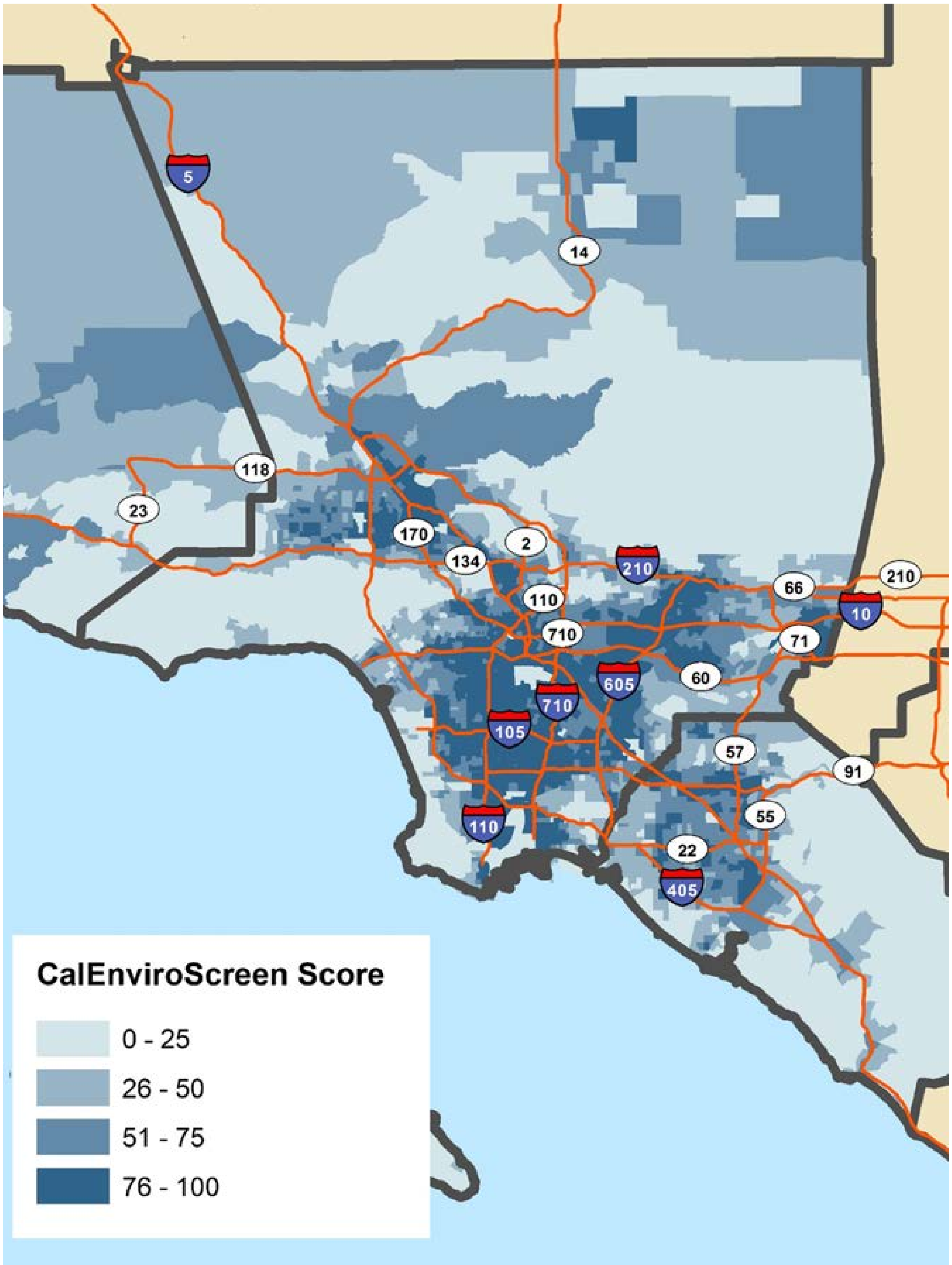
Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from California Energy Commission (2019).

FIGURE A-3: Greenhouse Gas Emissions Intensity Across Los Angeles County



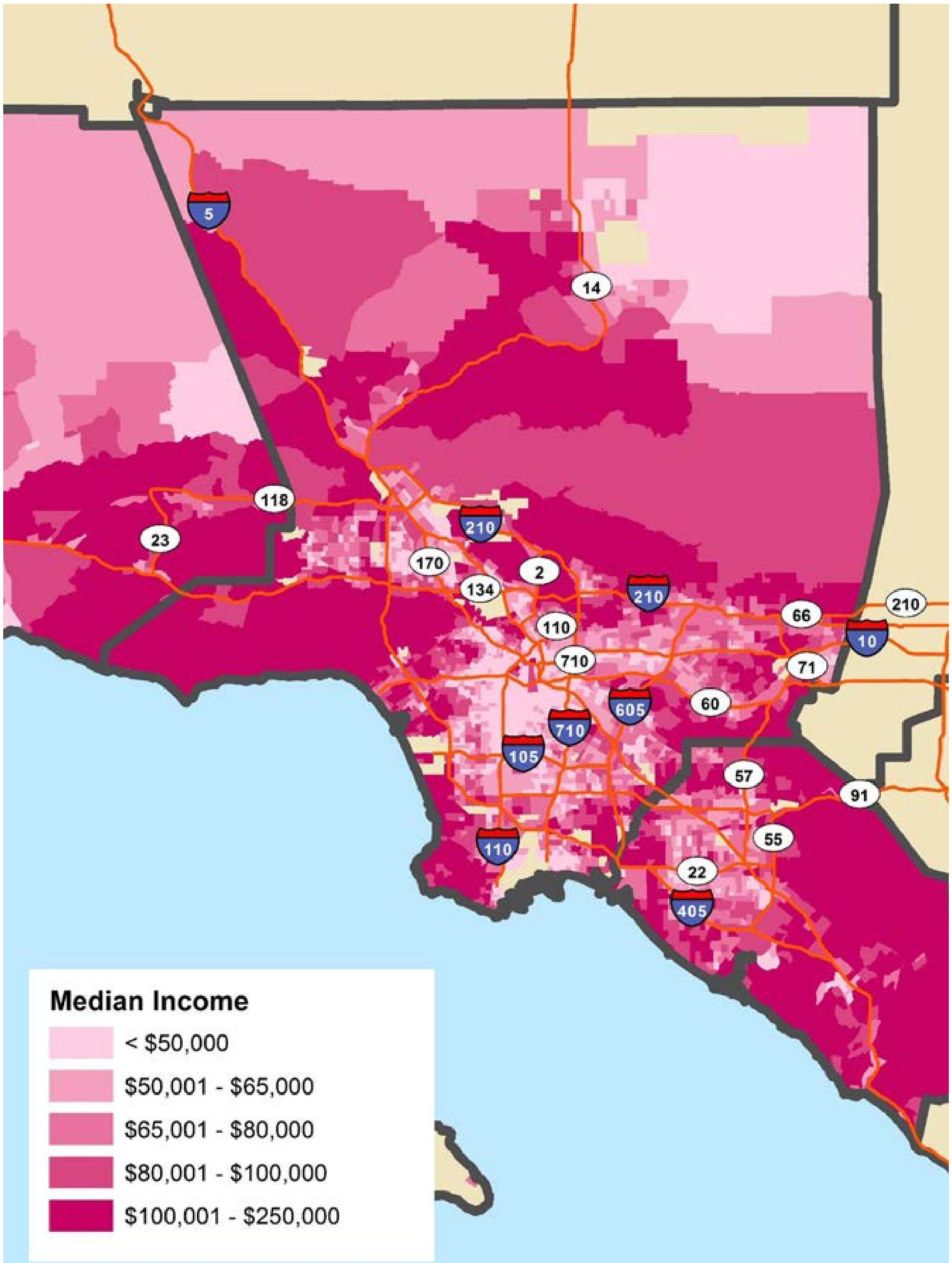
Source: Figure created by UCLA Luskin Center for Innovation. See Appendix G for greenhouse gas emissions methodology.

FIGURE A-4: Disadvantaged Communities Across Los Angeles County



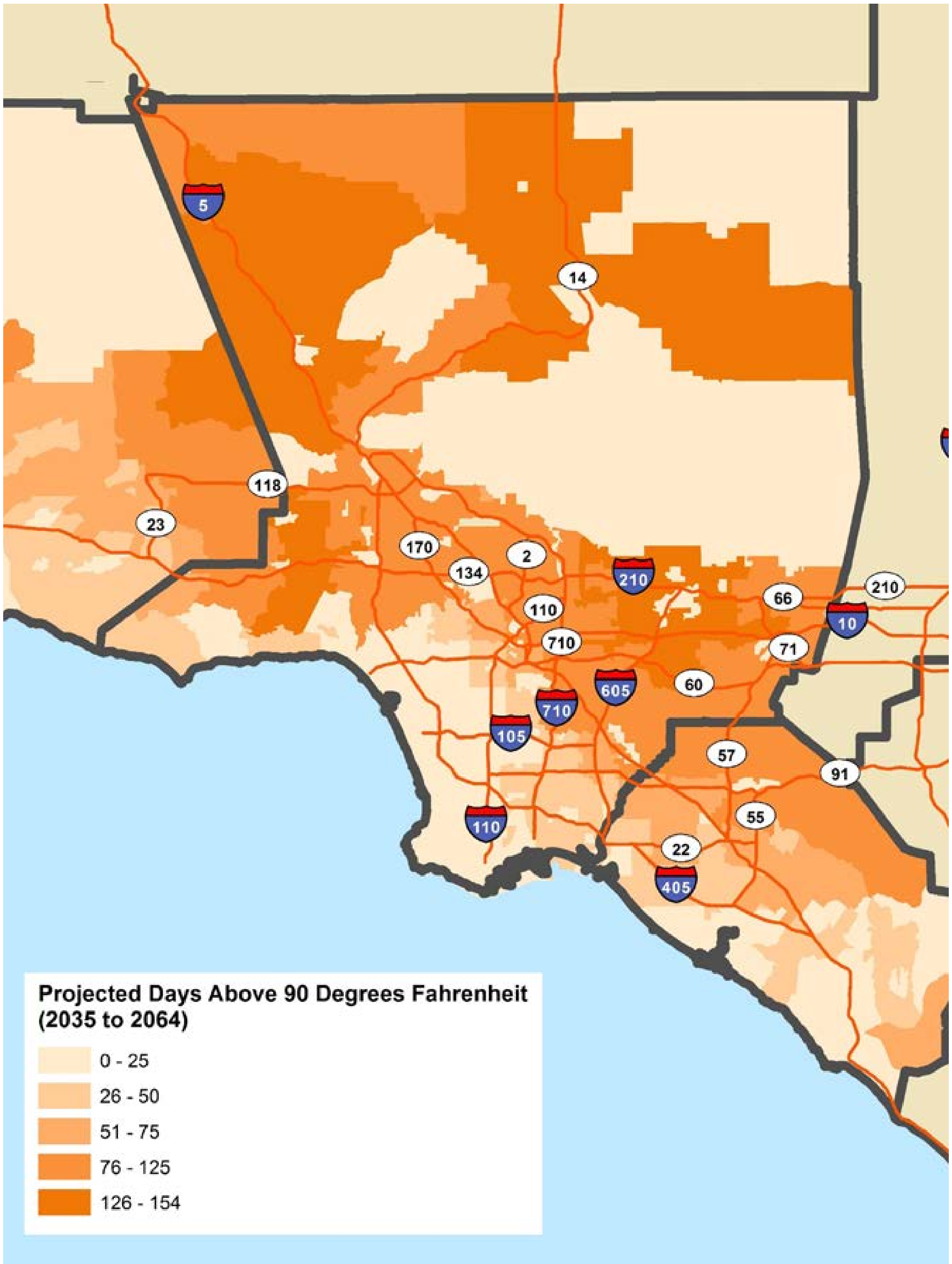
Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from California Office of Environmental Health Hazard Assessment (2018).

FIGURE A-5: Median Income Across Los Angeles County



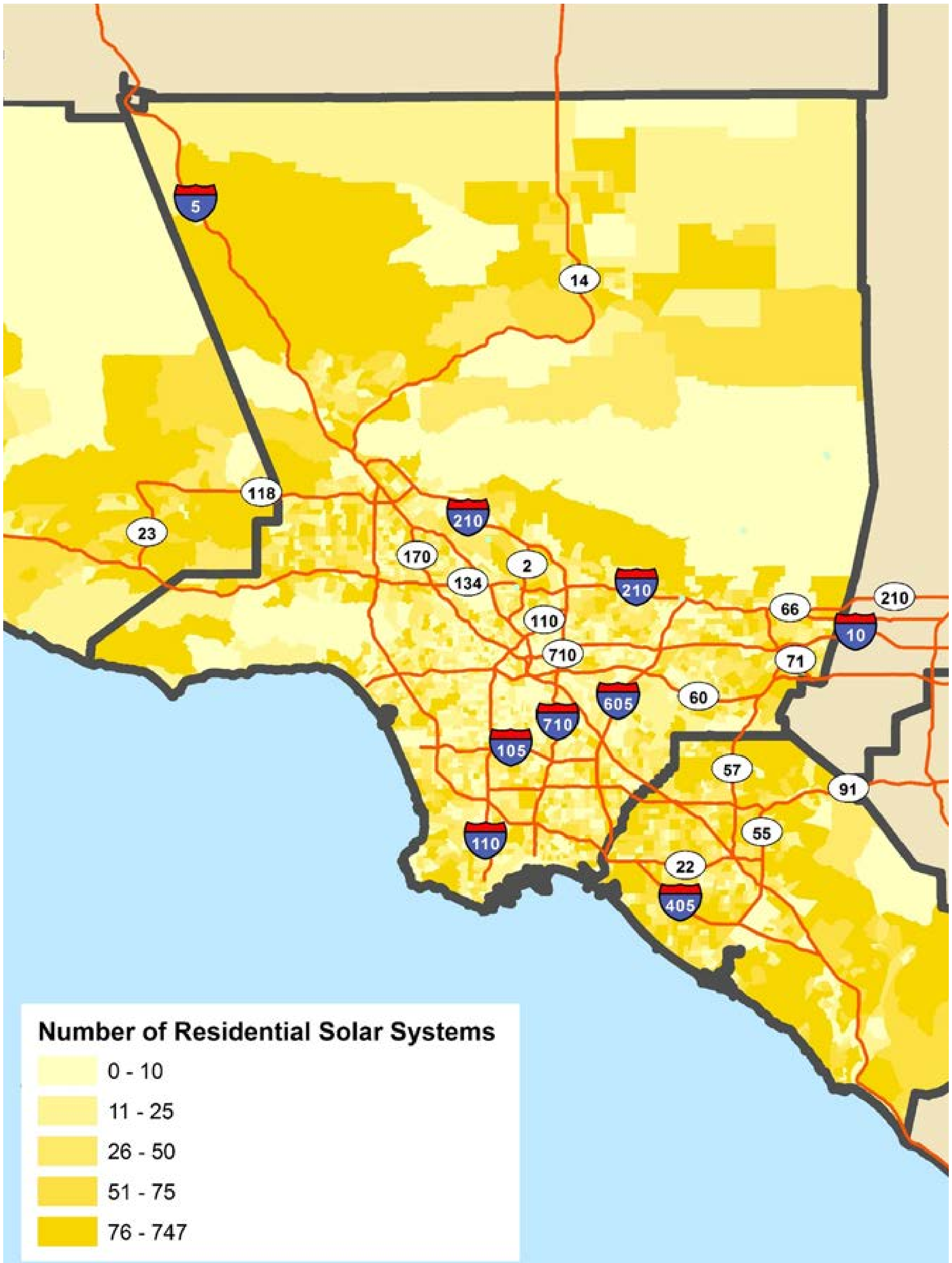
Source: Figure created by the UCLA Luskin Center for Innovation. Data from U.S. Census (2019).

FIGURE A-6: Annual Future High Heat Days Projected From 2035 to 2064 Across Los Angeles County



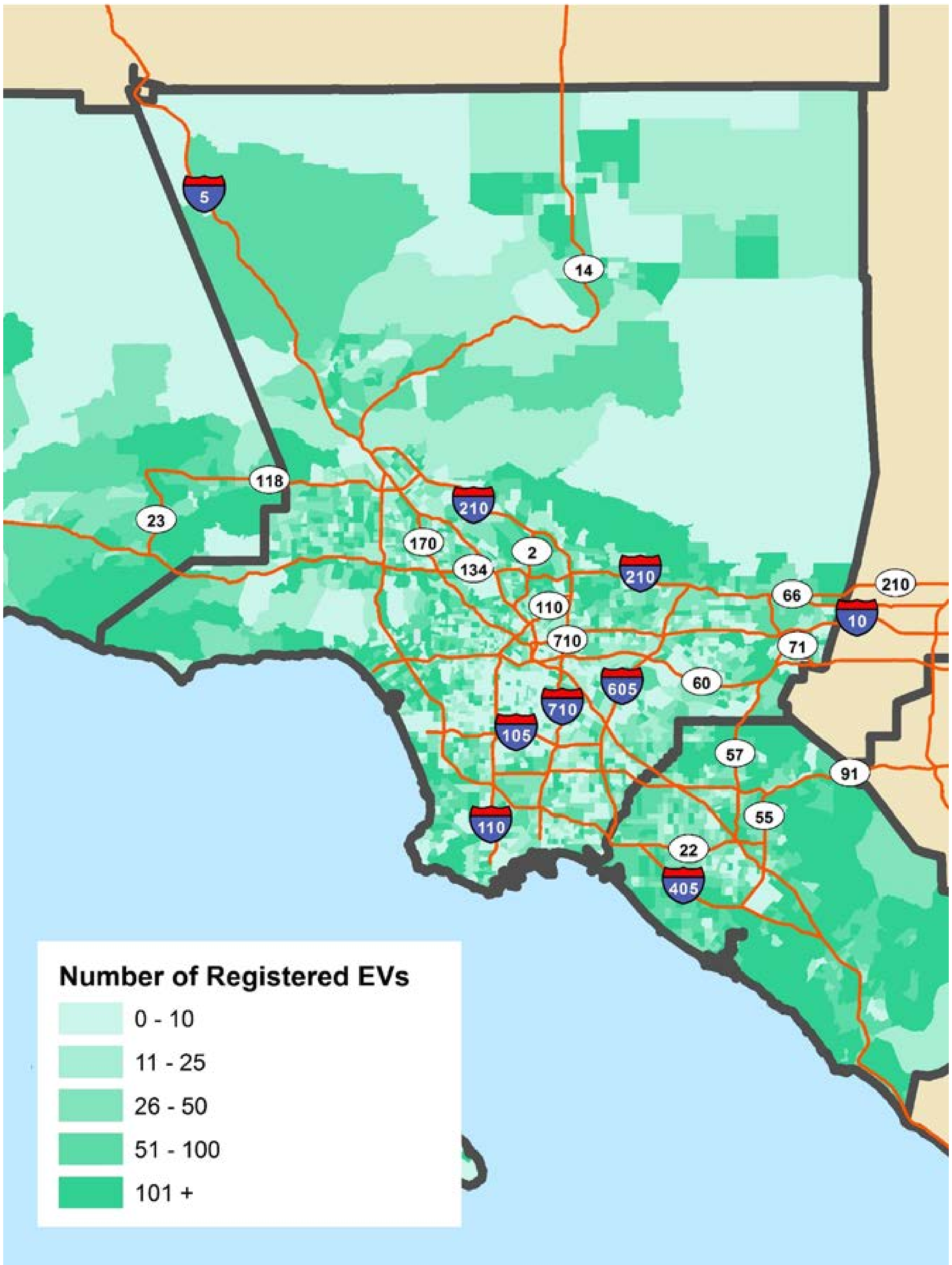
Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from Cal-Adapt (2020).

FIGURE A-7: **Residential Solar Systems Across Los Angeles County**



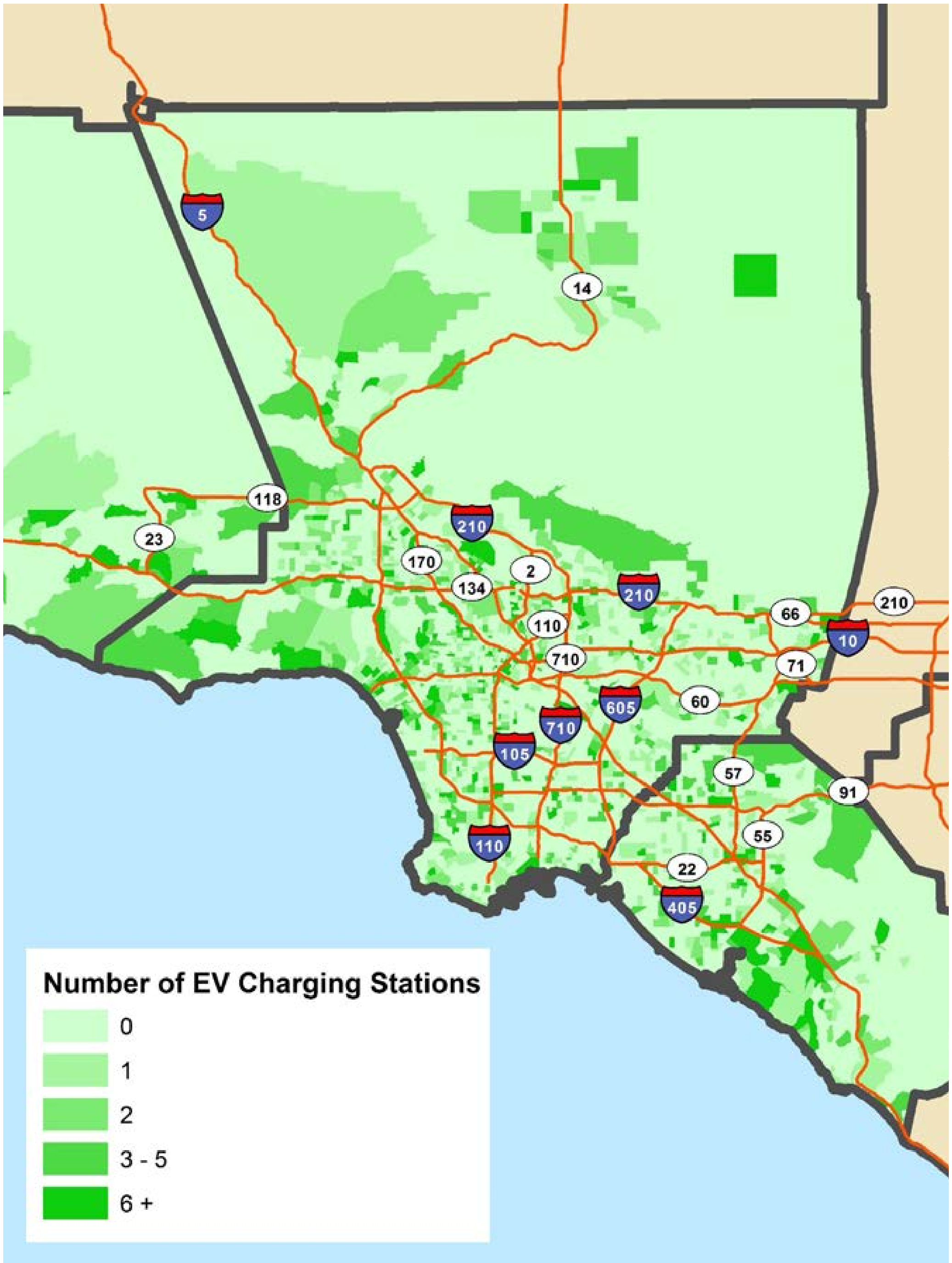
Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from Stanford University (2018).

FIGURE A-8: Electric Vehicle Adoption Across Los Angeles County



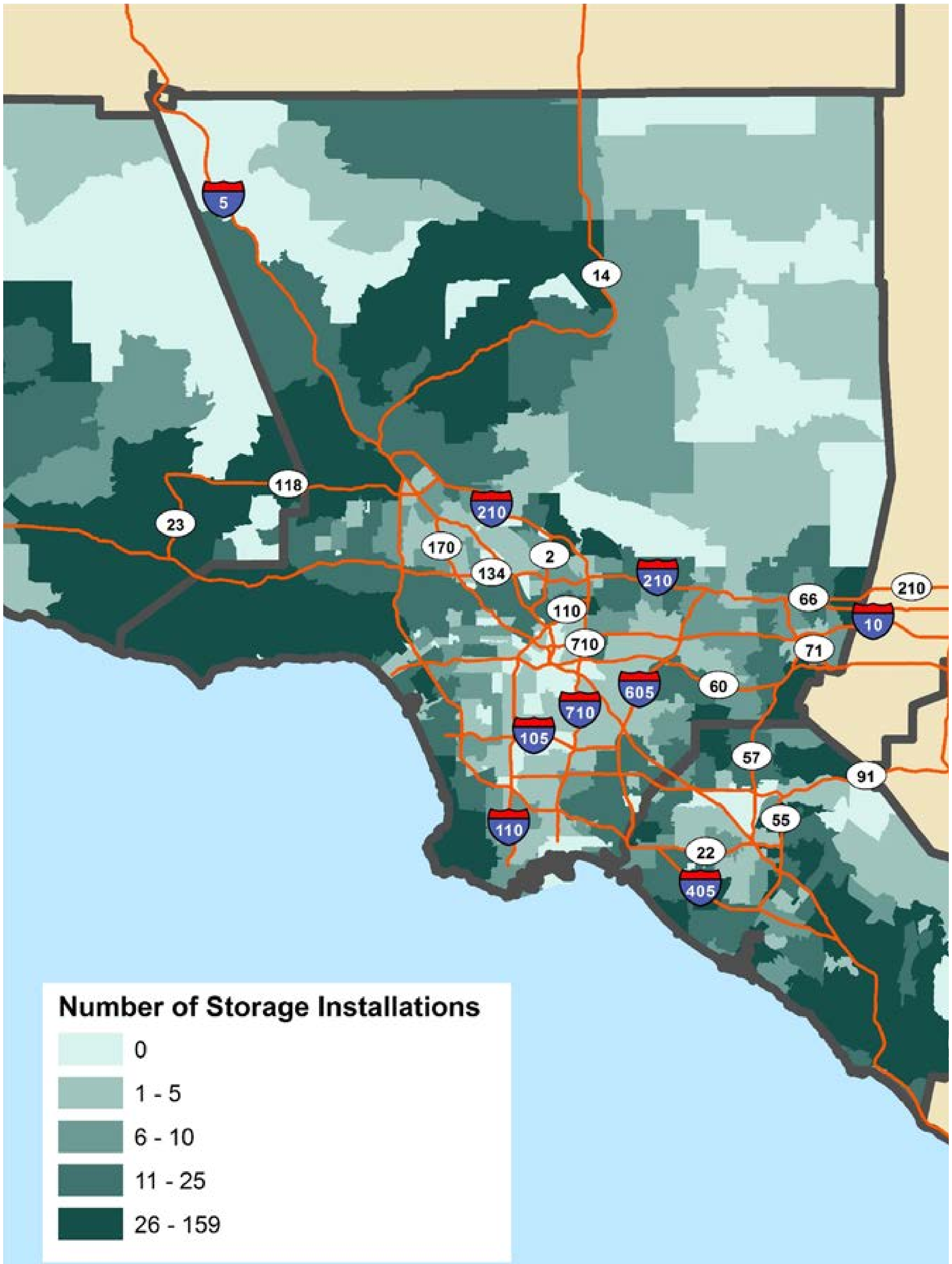
Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from IHS Markit (2018).

FIGURE A-9: **Electric Vehicle Charging Stations Across Los Angeles County**



Source: Figure created by UCLA Luskin Center for Innovation. Data from the National Renewable Energy Laboratory (2021).

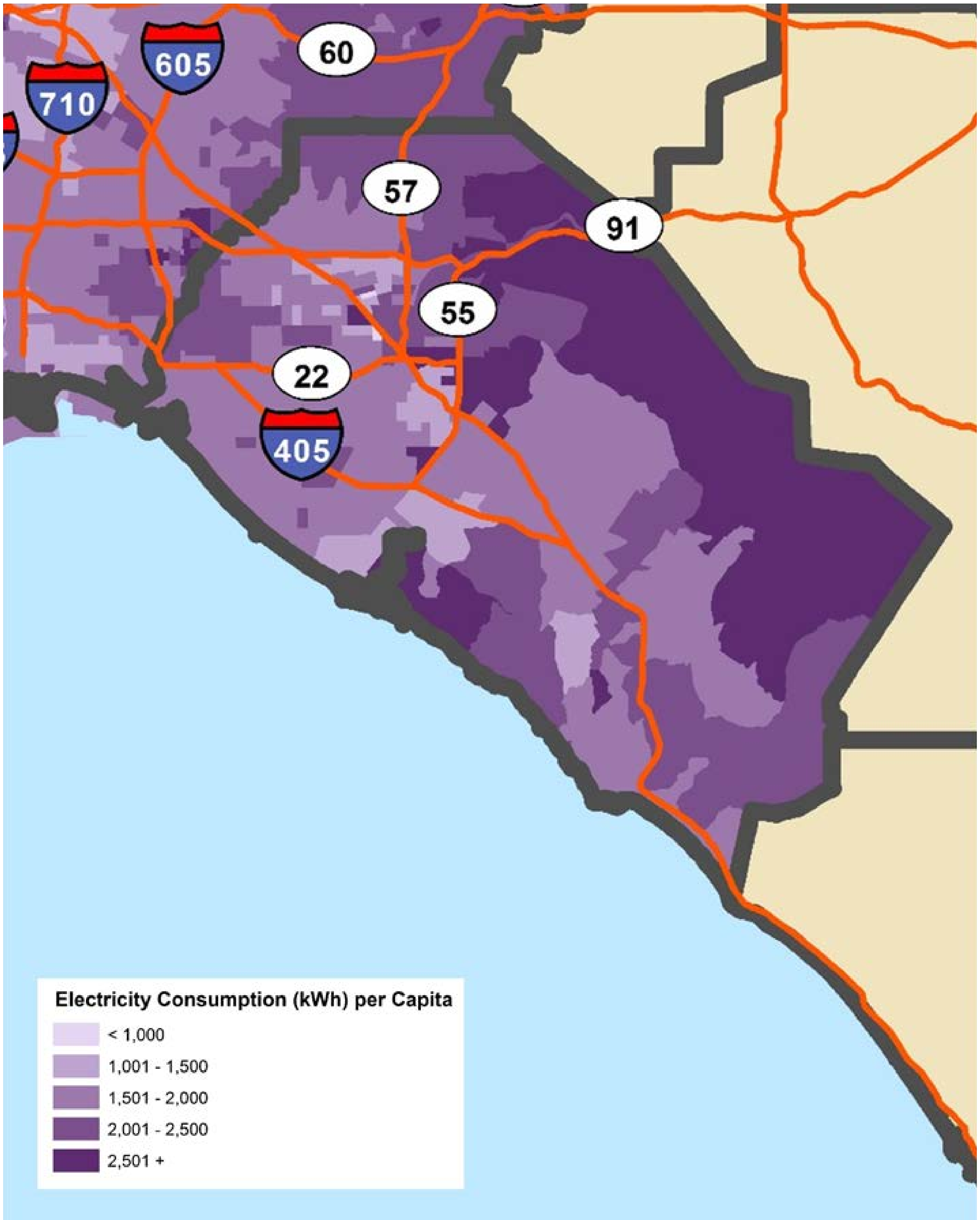
FIGURE A-10: Number of Residential Storage Installations Across Los Angeles County



Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from SGIP Program Statistics (2021).

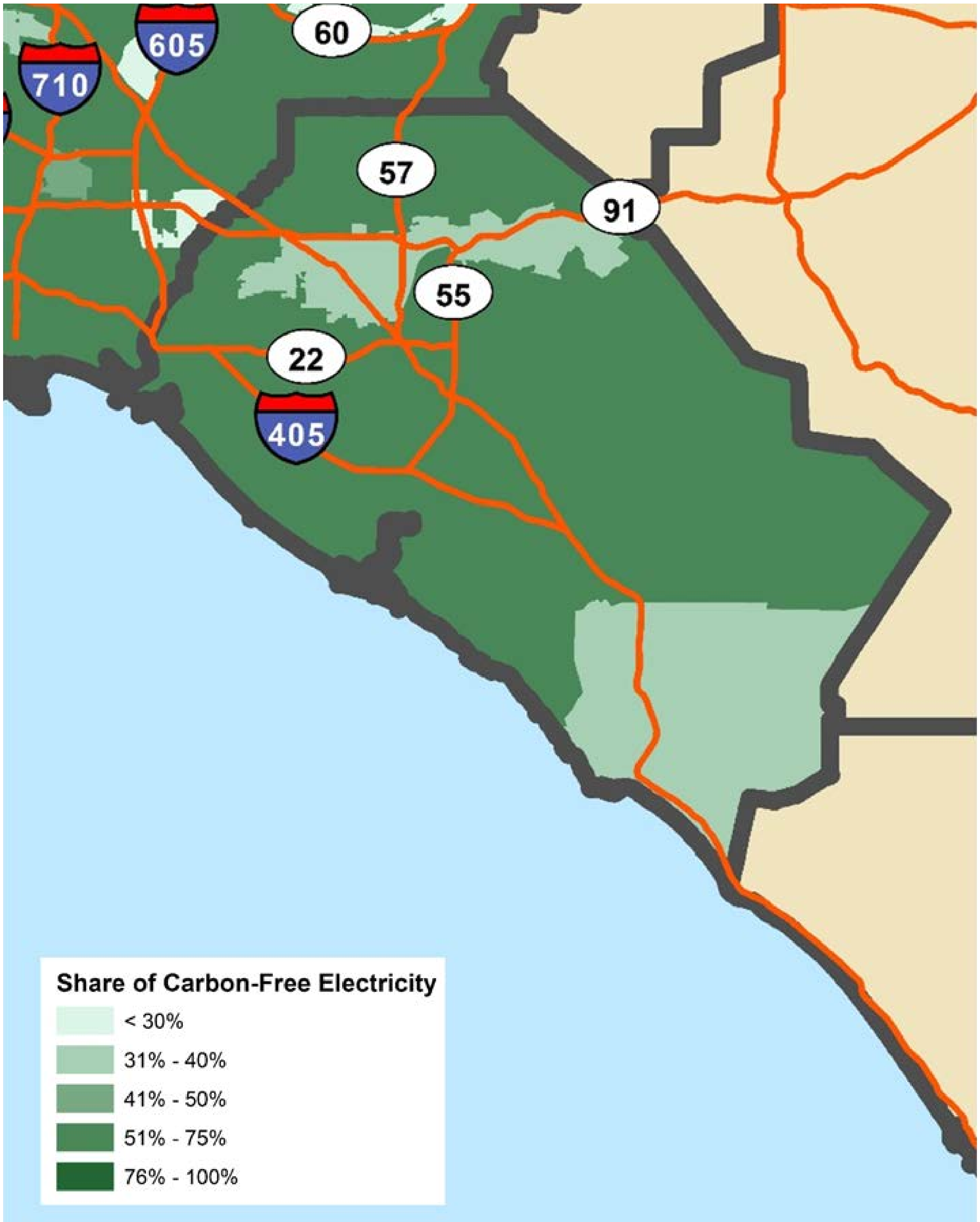
Appendix B: Orange County Maps

FIGURE B-1: **Electricity Consumption (kWh) per Capita Across Orange County**



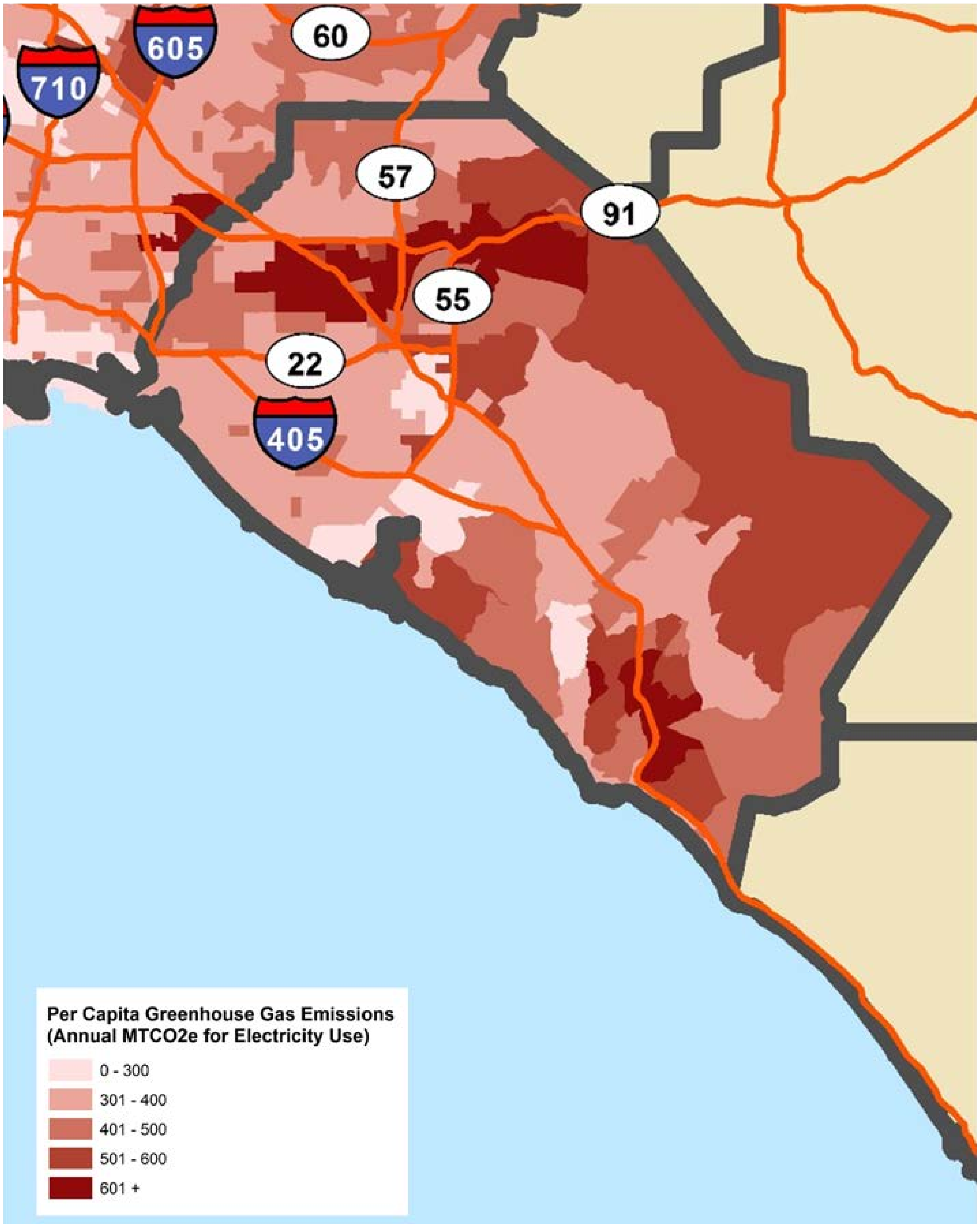
Source: Figure created by UCLA Luskin Center for Innovation (2021). Electricity consumption data sources described in Appendix F.

FIGURE B-2: Clean Energy Supply Across Orange County



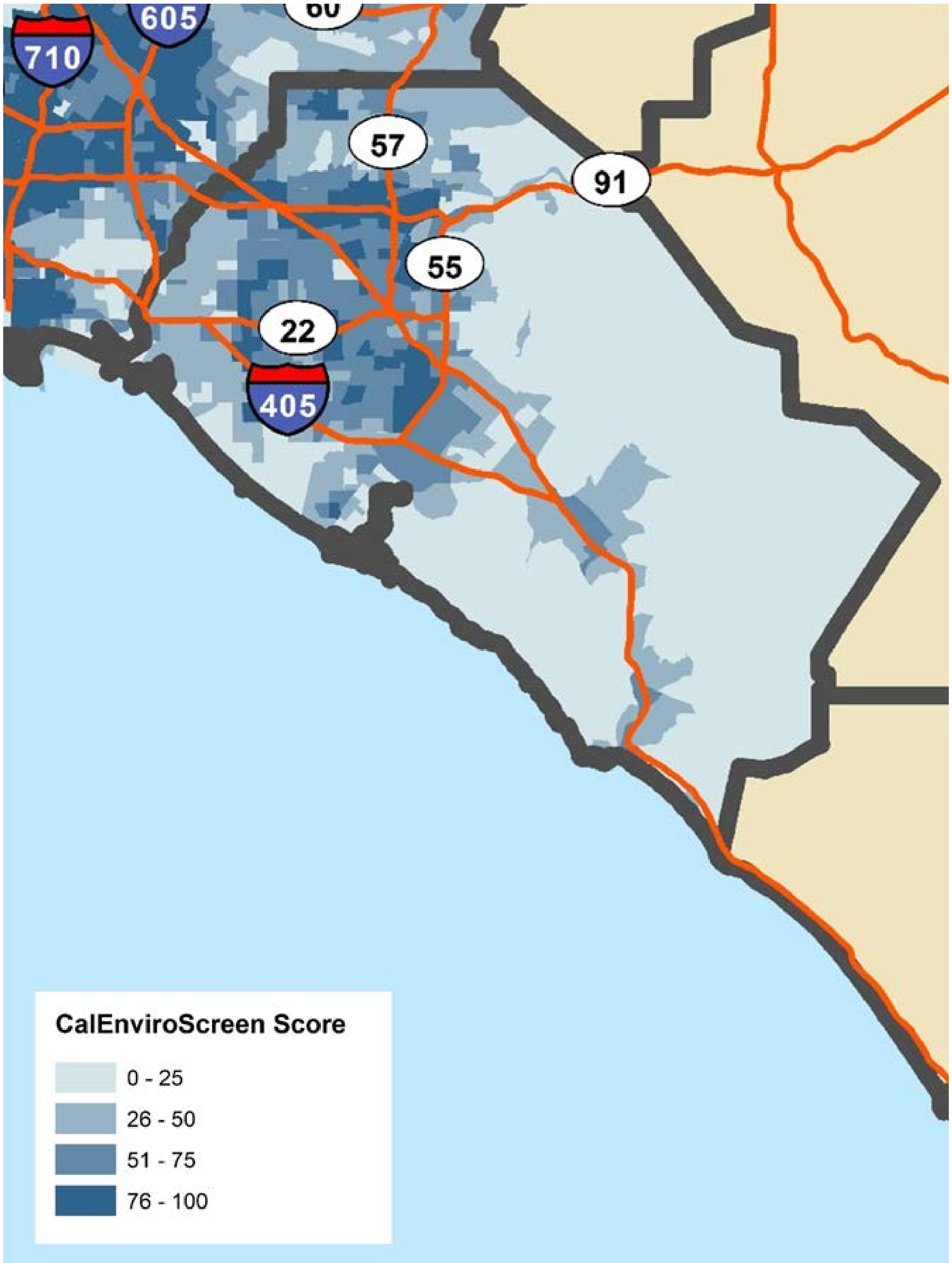
Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from California Energy Commission (2019).

FIGURE B-3: **Greenhouse Gas Emissions Intensity Across Orange County**



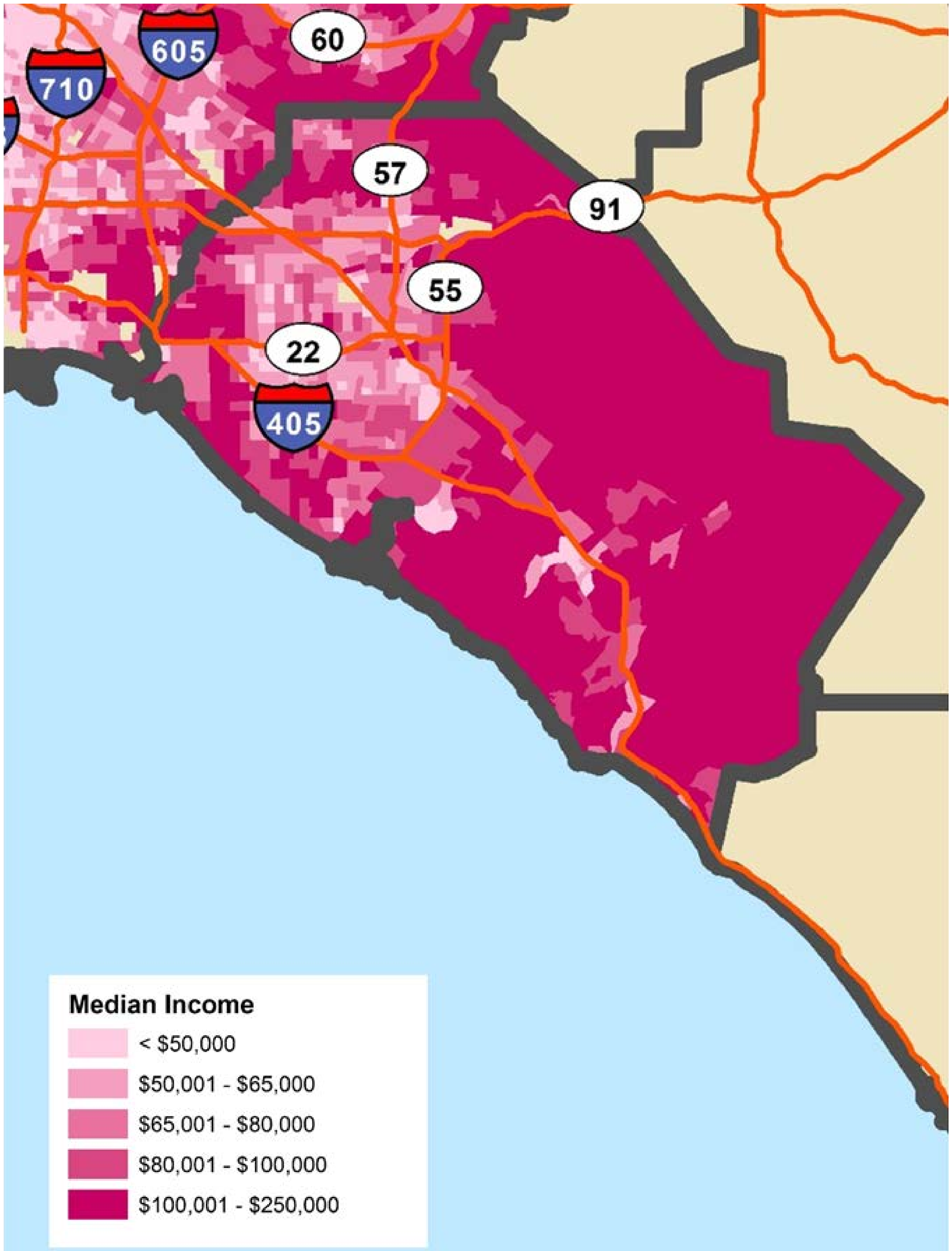
Source: Figure created by UCLA Luskin Center for Innovation. See Appendix G for greenhouse gas emissions methodology.

FIGURE B-4: Disadvantaged Communities Across Orange County



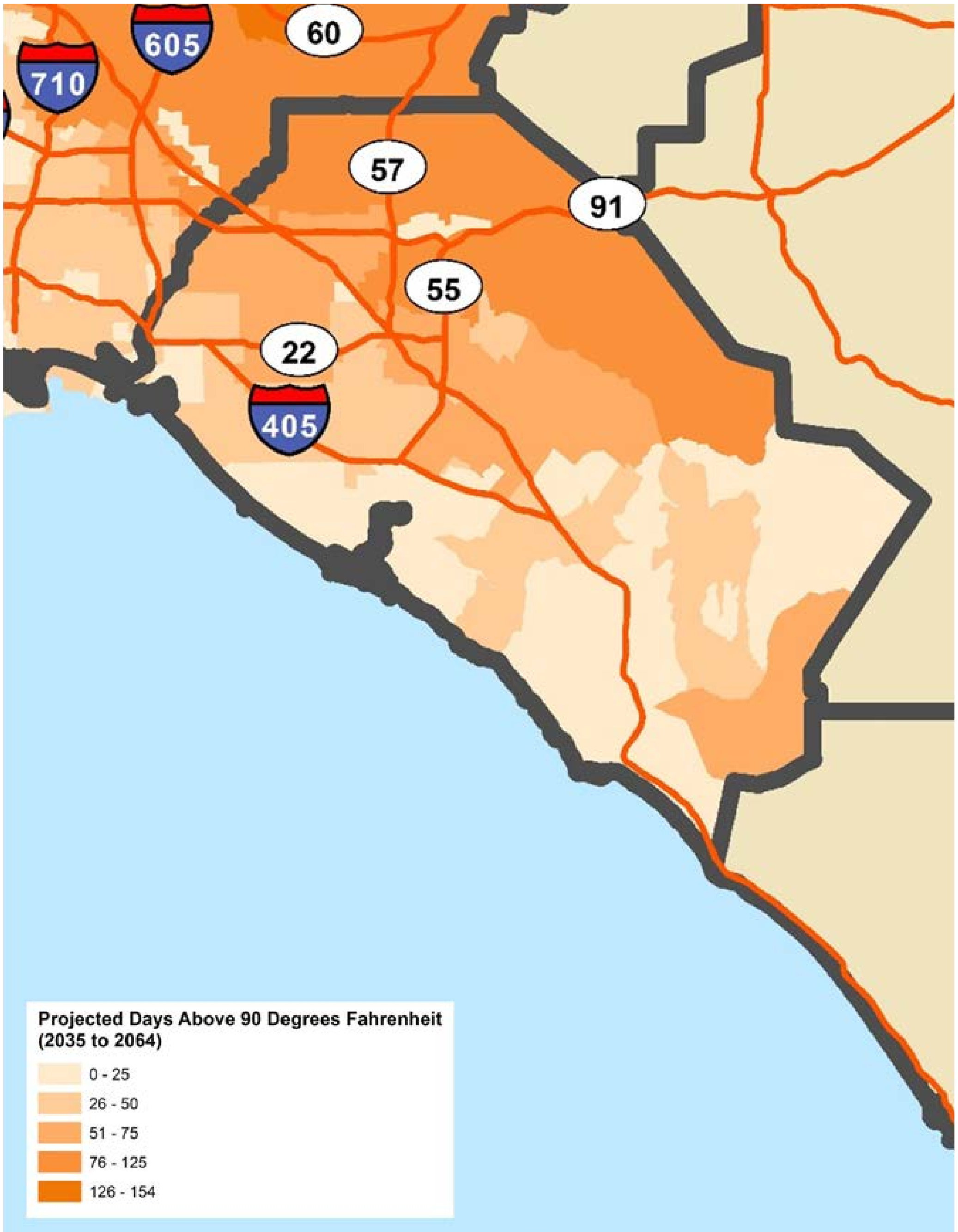
Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from California Office of Environmental Health Hazard Assessment (2018).

FIGURE B-5: **Median Income Across Orange County**



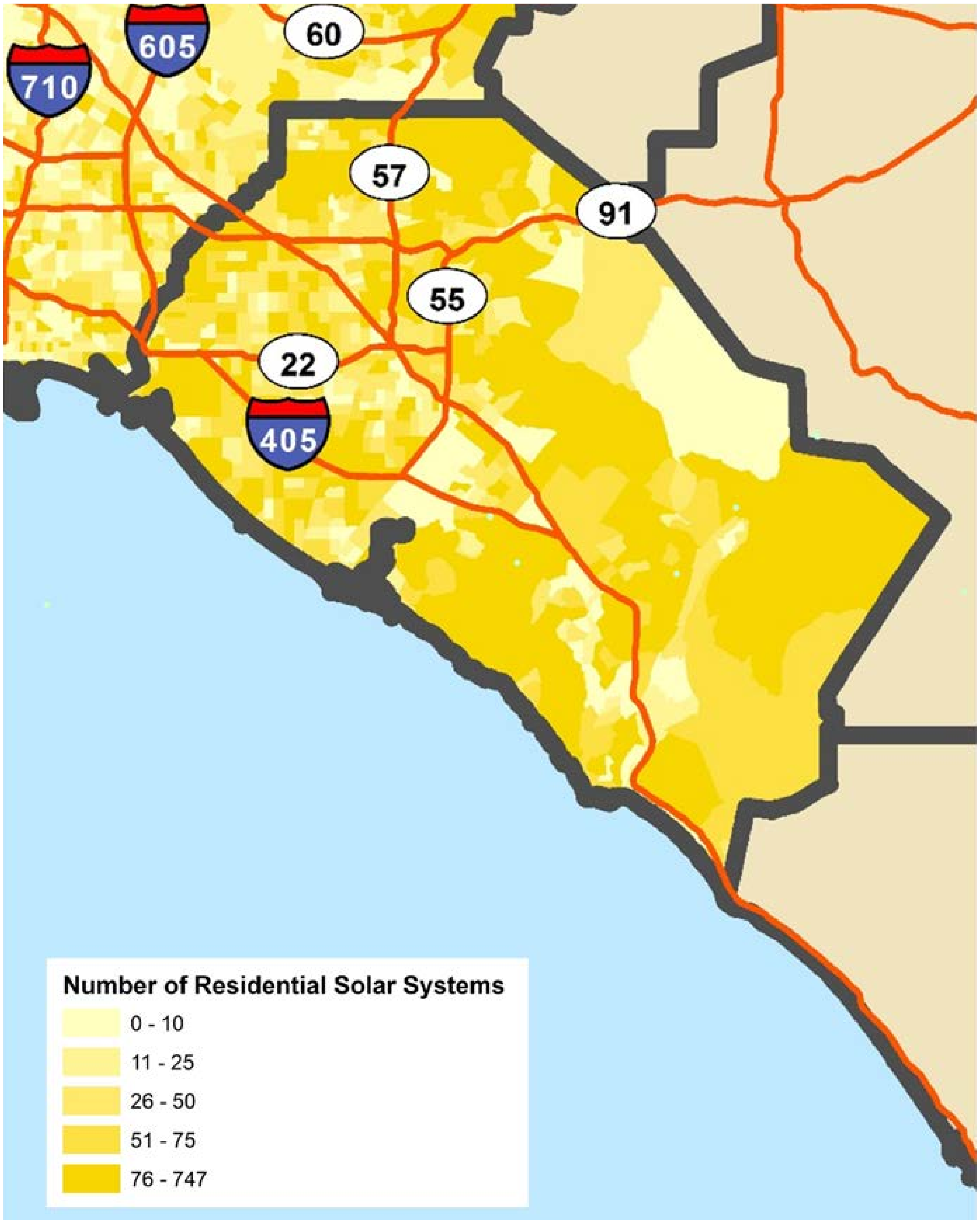
Source: Figure created by the UCLA Luskin Center for Innovation. Data from U.S. Census (2019).

FIGURE B-6: **Annual Future High Heat Days Projected From 2035 to 2064 Across Orange County**



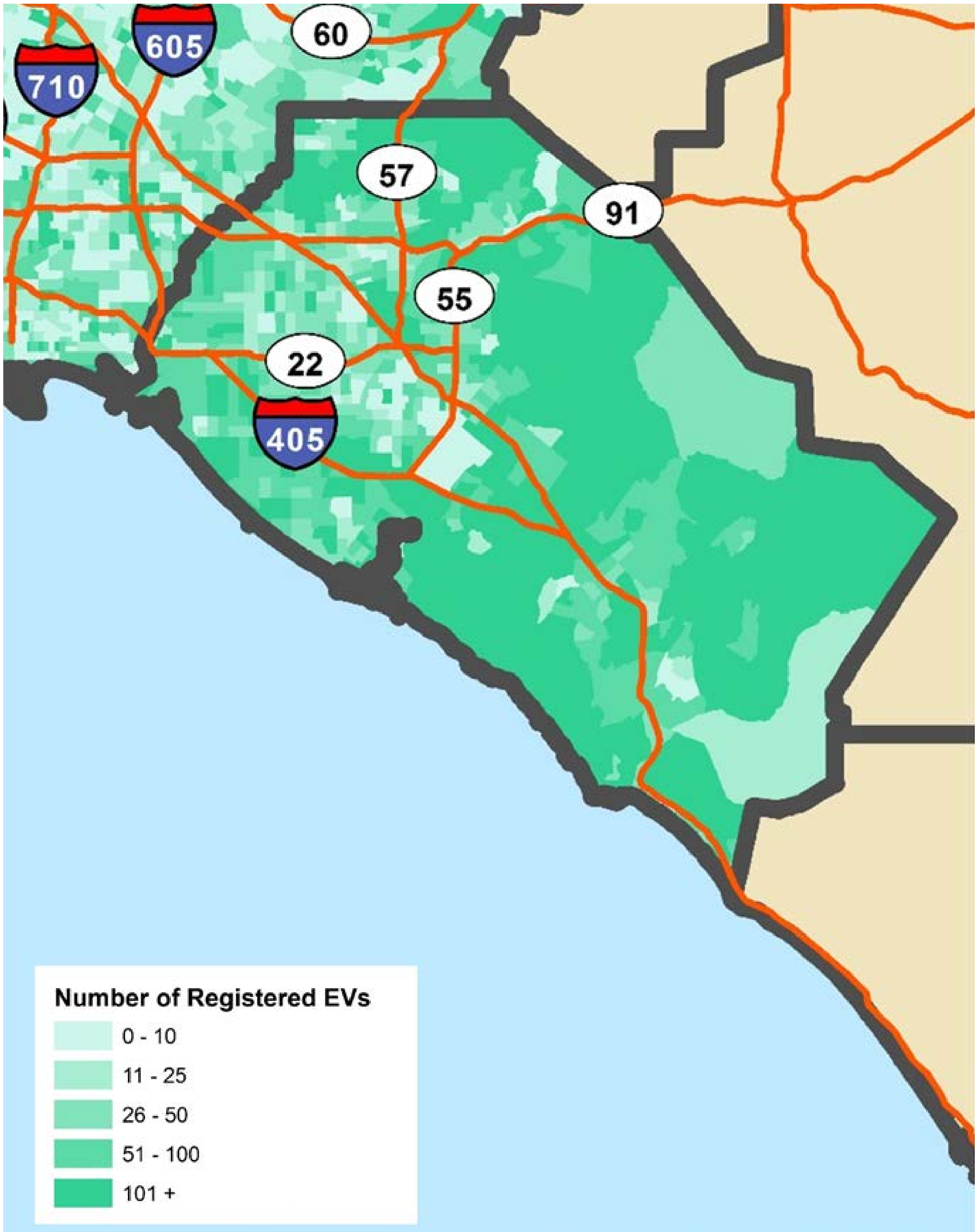
Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from Cal-Adapt (2020).

FIGURE B-7: Residential Solar Systems Across Orange County



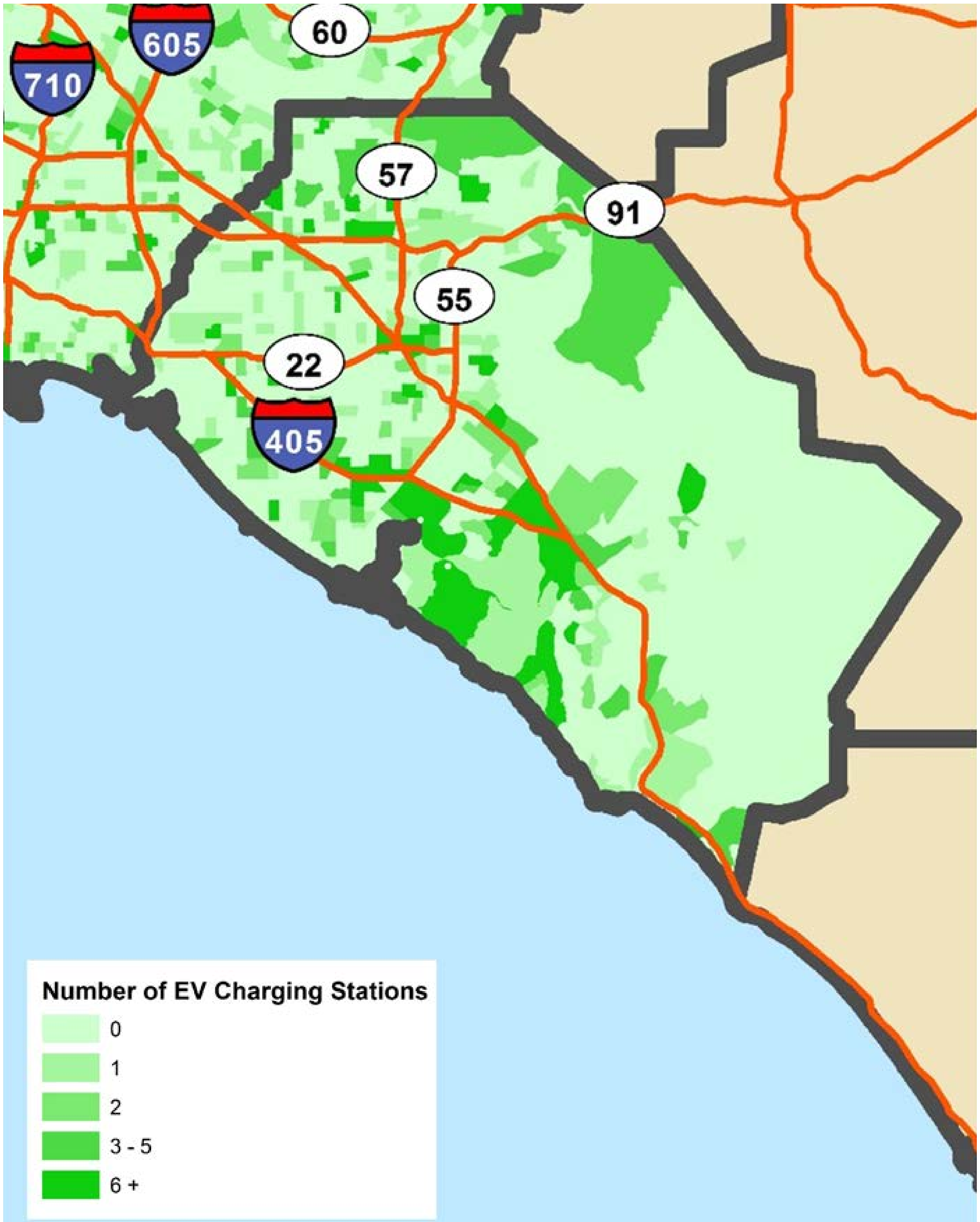
Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from Stanford University (2018).

FIGURE B-8: Electric Vehicle Adoption Across Orange County



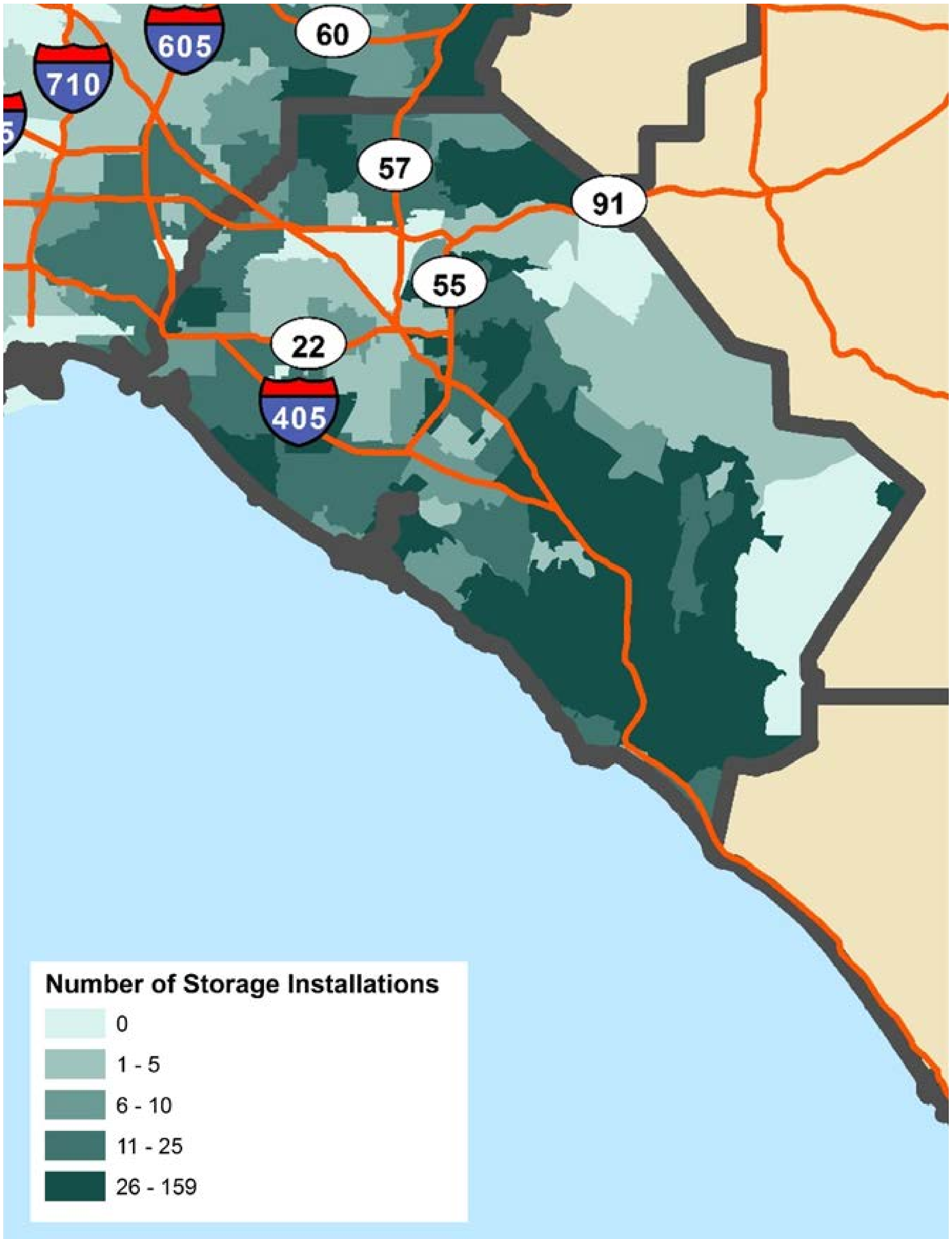
Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from IHS Markit (2018).

FIGURE B-9: **Electric Vehicle Charging Stations Across Orange County**



Source: Figure created by UCLA Luskin Center for Innovation. Data from the National Renewable Energy Laboratory (2021).

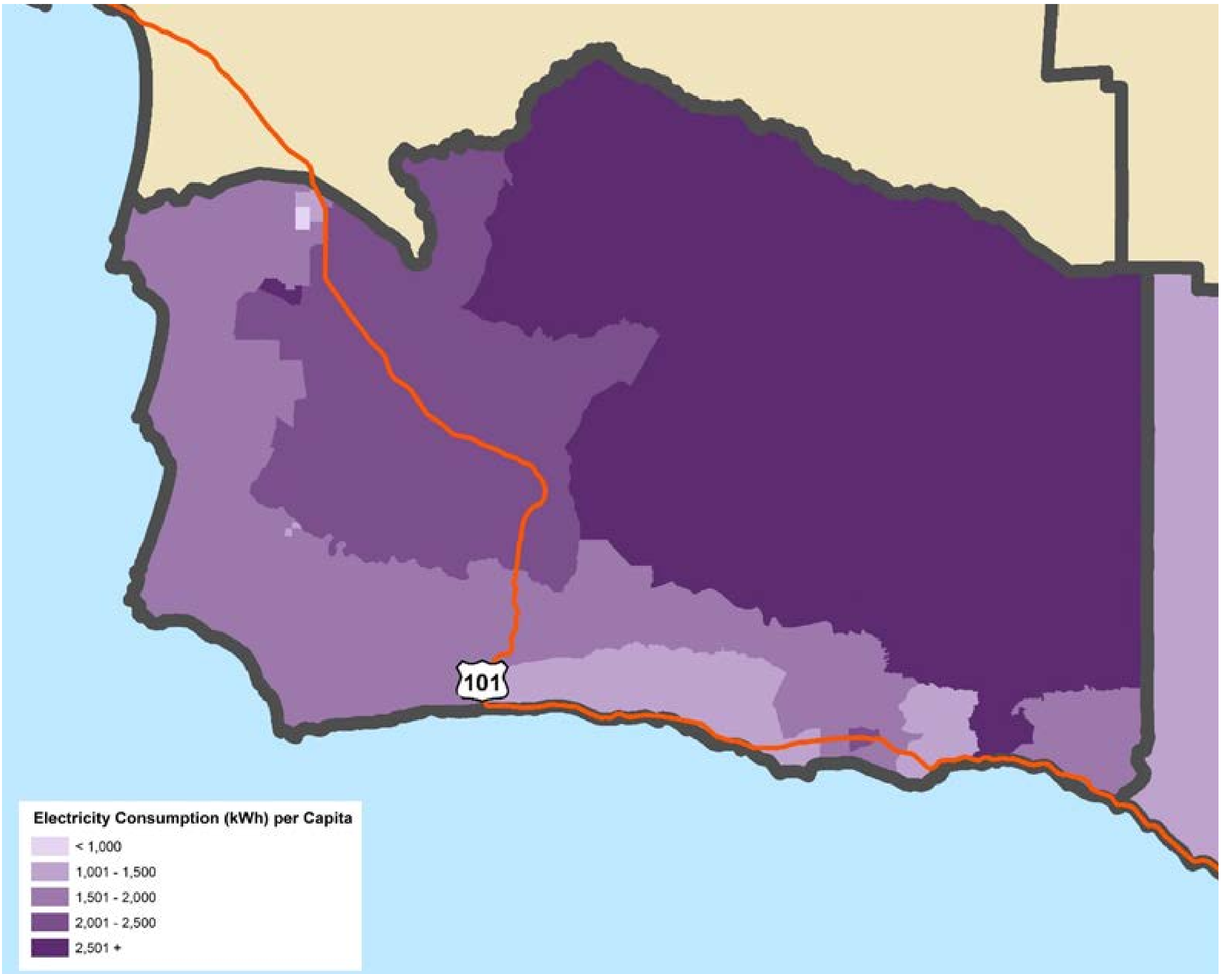
FIGURE B-10: Number of Residential Storage Installations Across Orange County



Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from SGIP Program Statistics (2021).

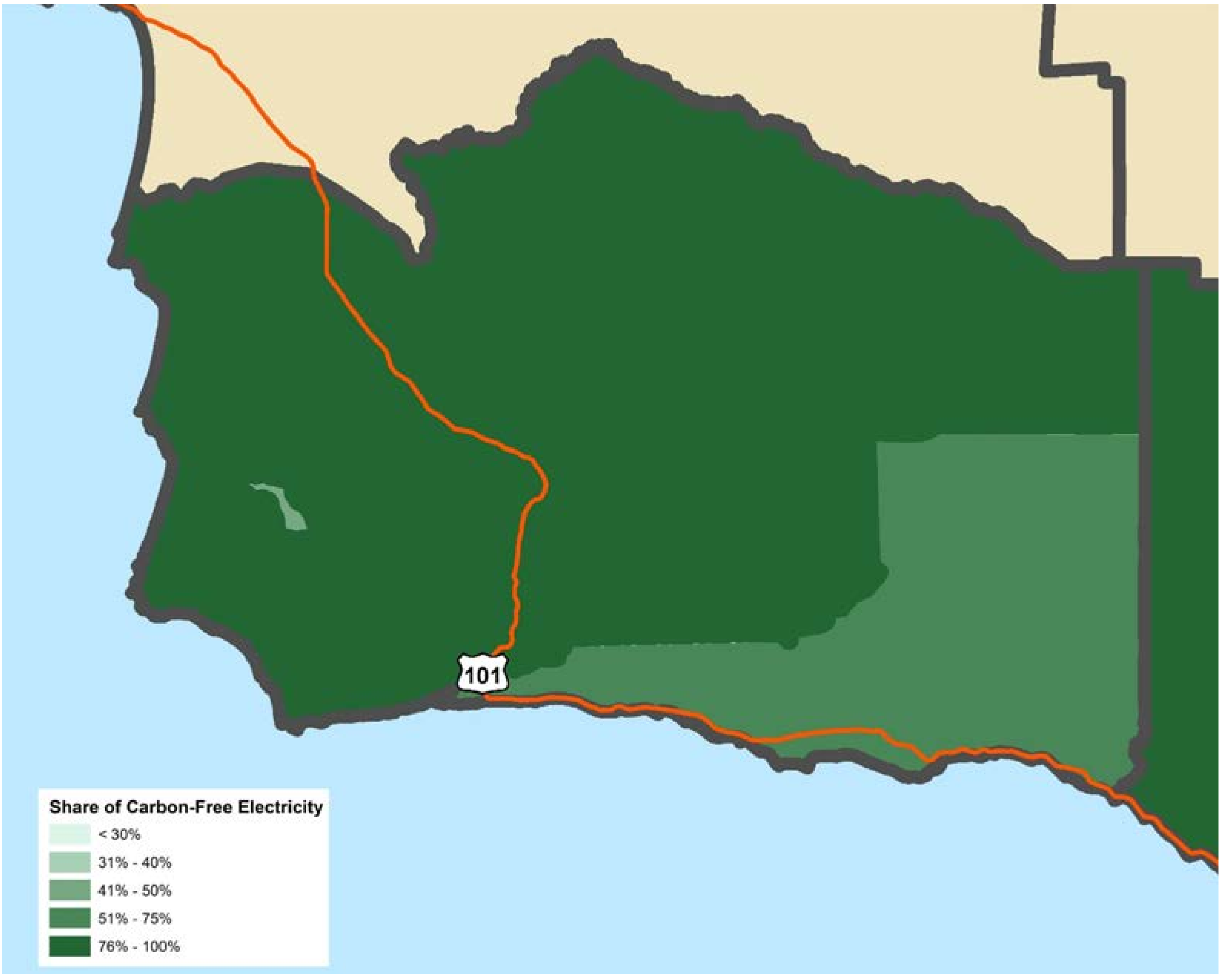
Appendix C: Santa Barbara County Maps

FIGURE C-1: **Electricity Consumption (kWh) per Capita Across Santa Barbara County**



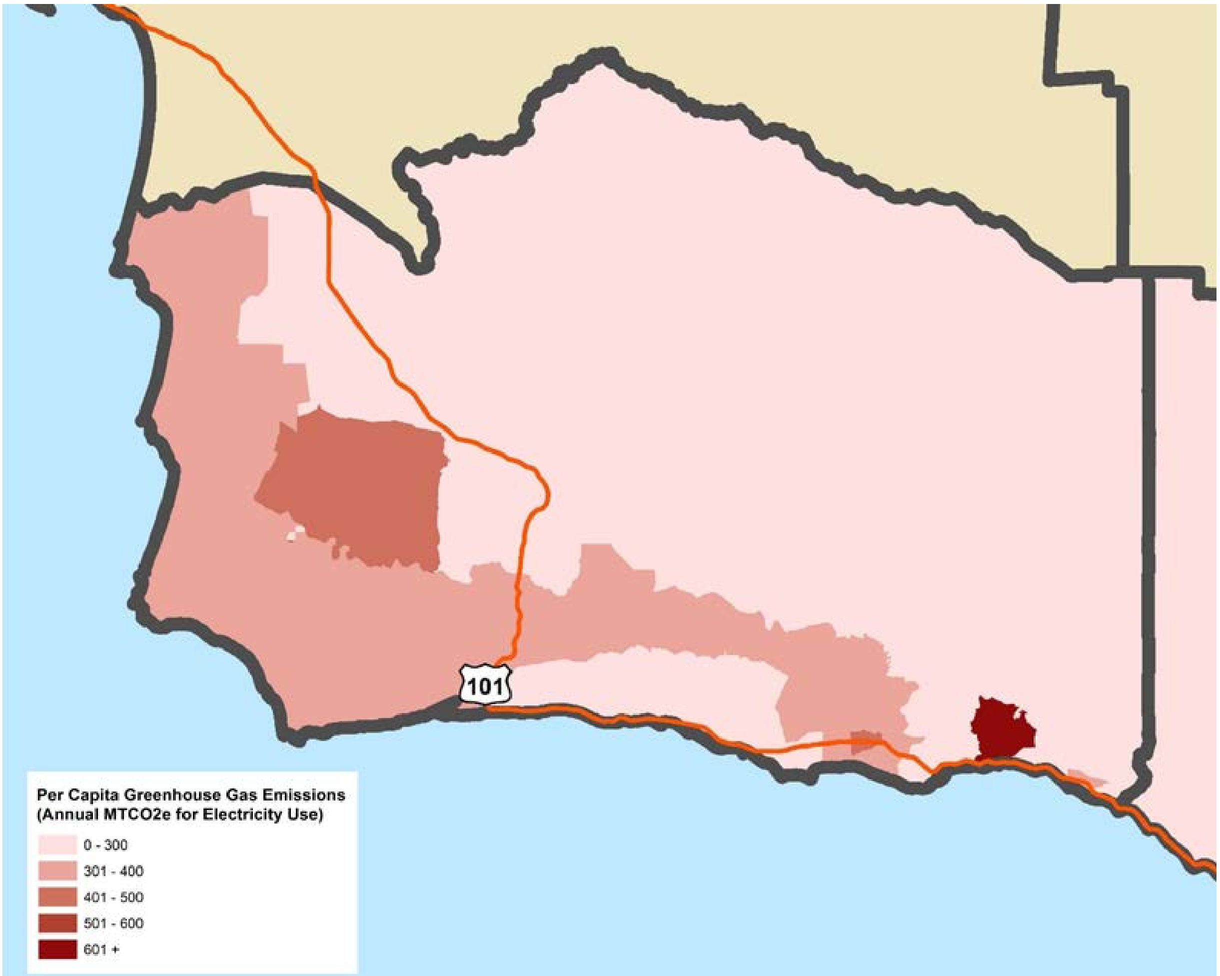
Source: Figure created by UCLA Luskin Center for Innovation (2021). Electricity consumption data sources described in Appendix F.

FIGURE C-2: Clean Energy Supply Across Santa Barbara County



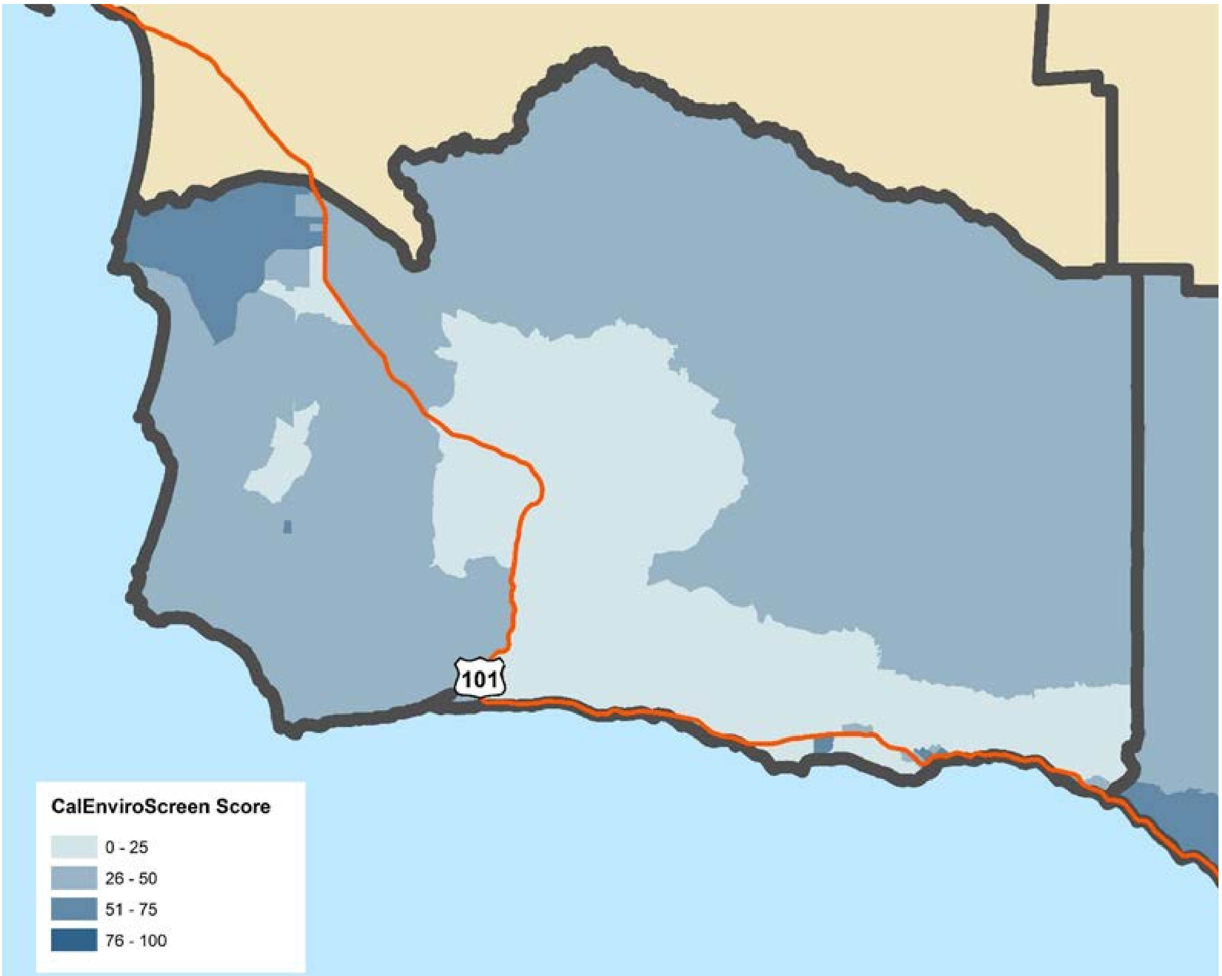
Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from California Energy Commission (2019).

FIGURE C-3: **Greenhouse Gas Emissions Intensity Across Santa Barbara County**



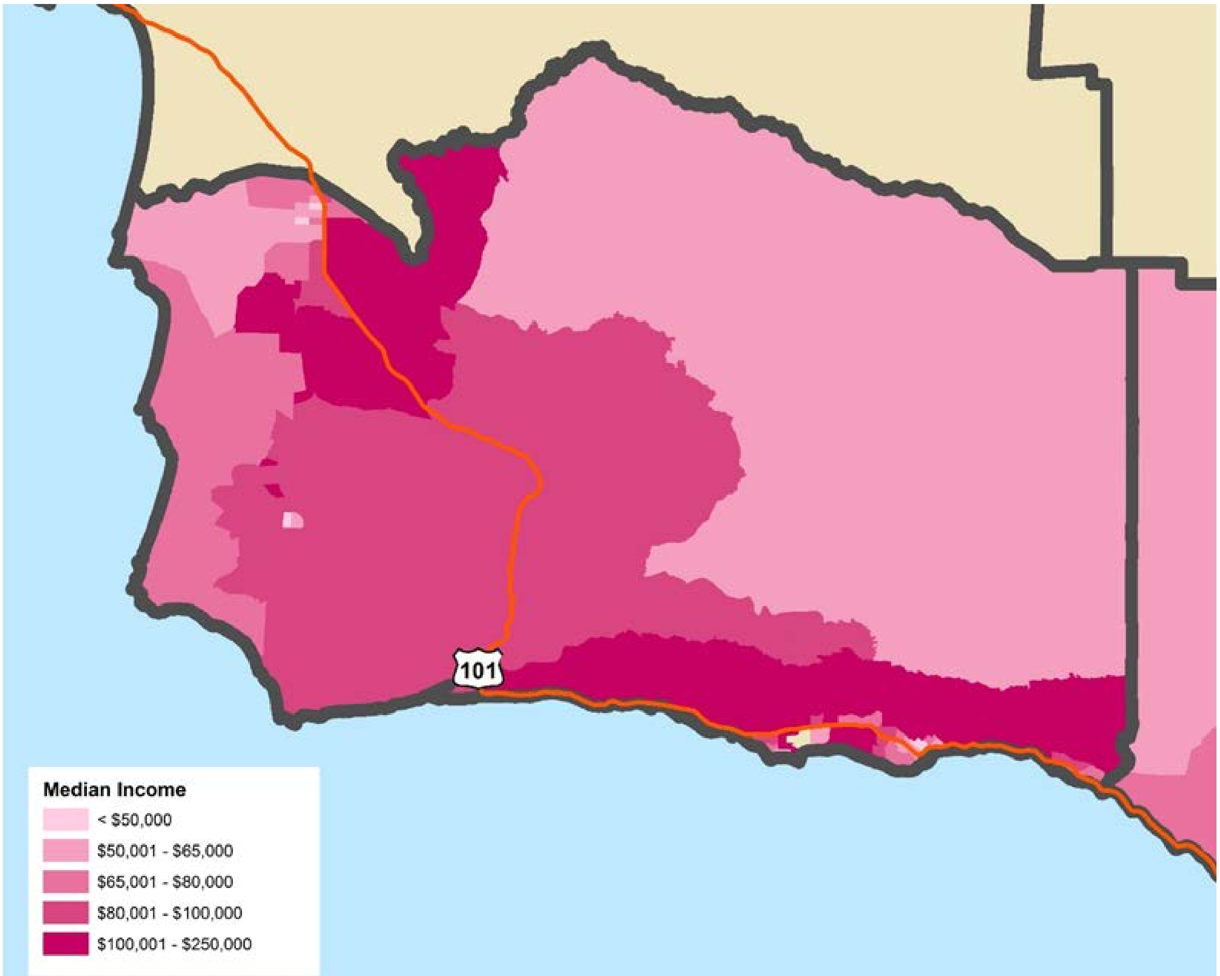
Source: Figure created by UCLA Luskin Center for Innovation. See Appendix G for greenhouse gas emissions methodology.

FIGURE C-4: Disadvantaged Communities Across Santa Barbara County



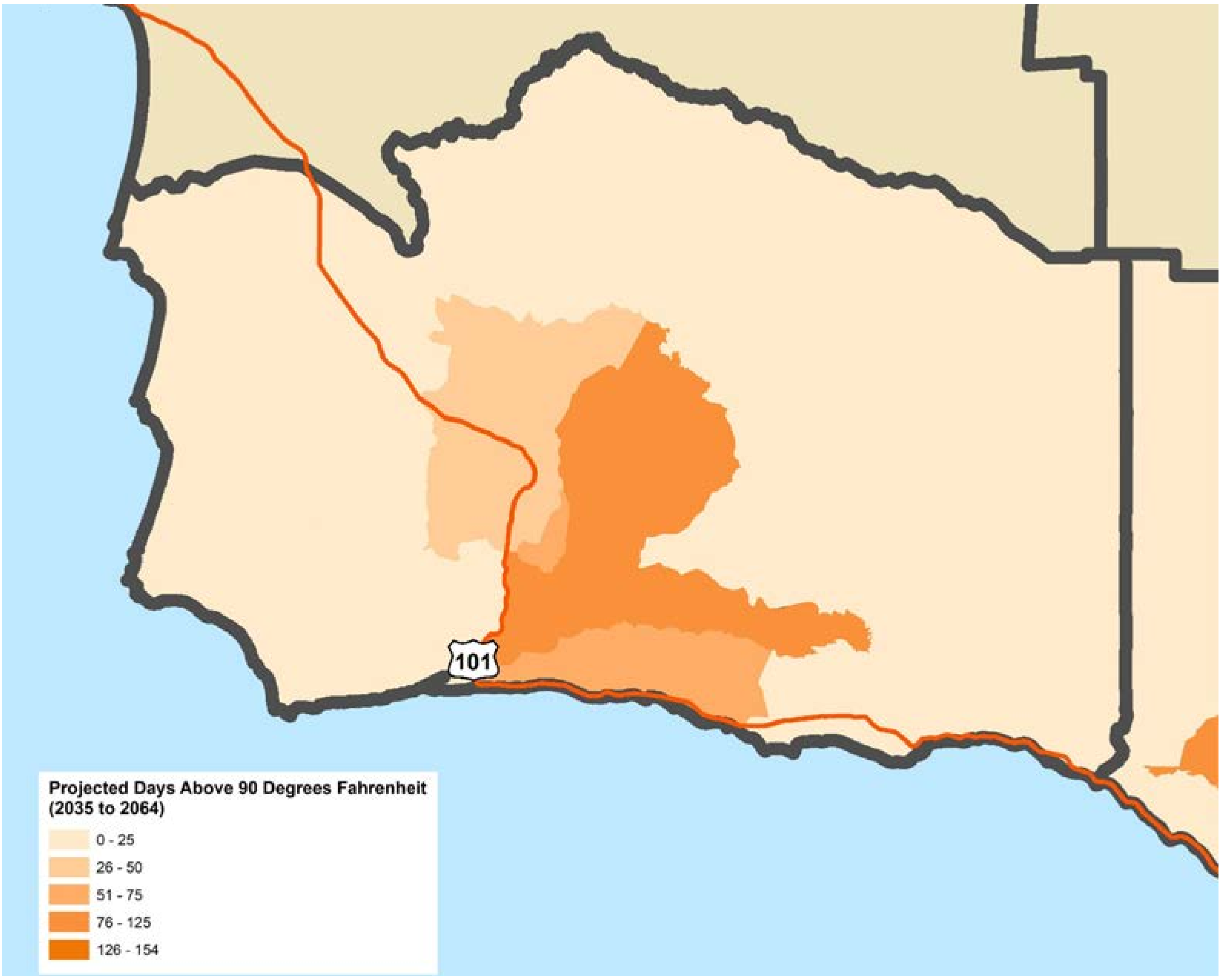
Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from California Office of Environmental Health Hazard Assessment (2018).

FIGURE C-5: **Median Income Across Santa Barbara County**



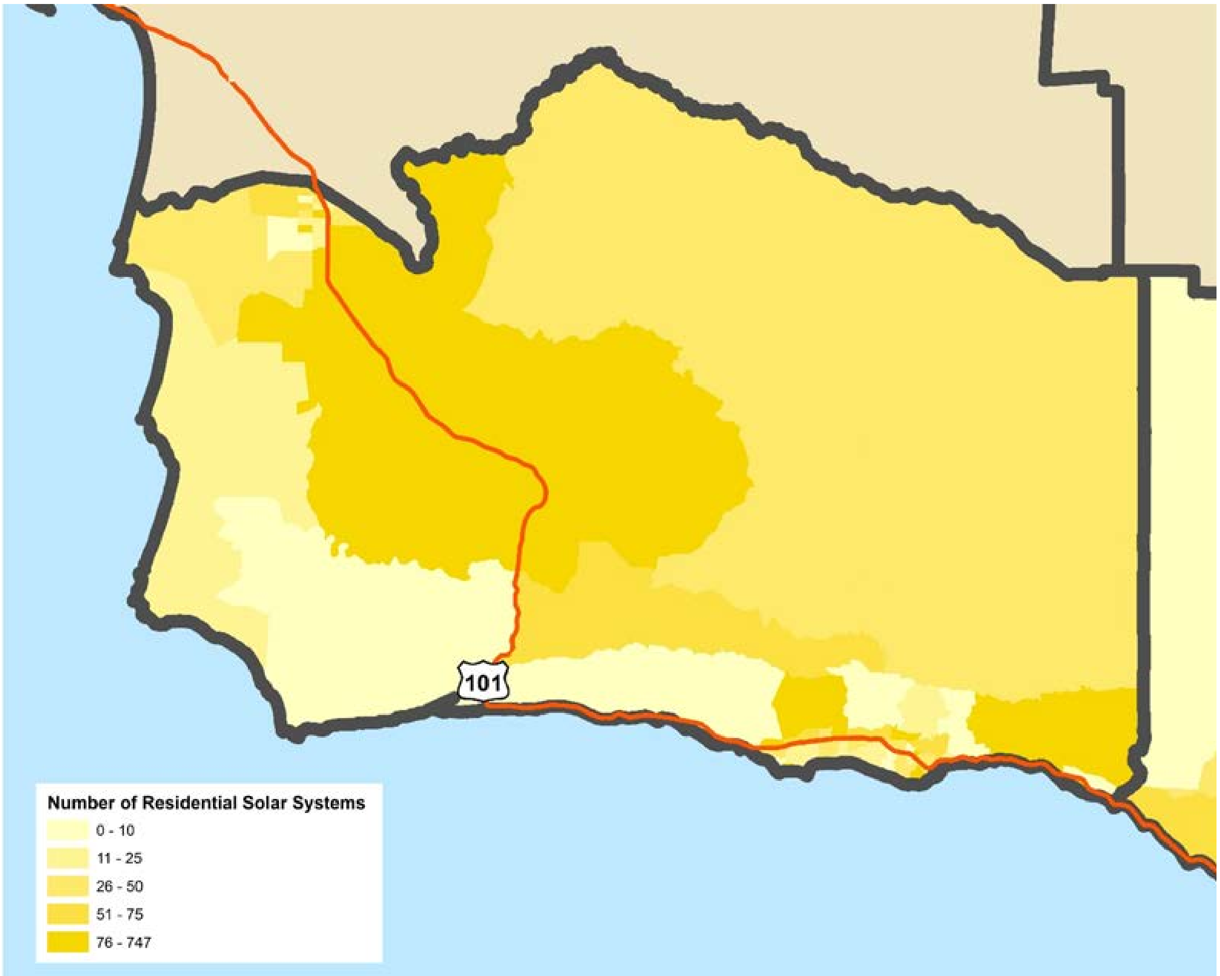
Source: Figure created by the UCLA Luskin Center for Innovation. Data from U.S. Census (2019).

FIGURE C-6: Annual Future High Heat Days Projected From 2035 to 2064 Across Santa Barbara County



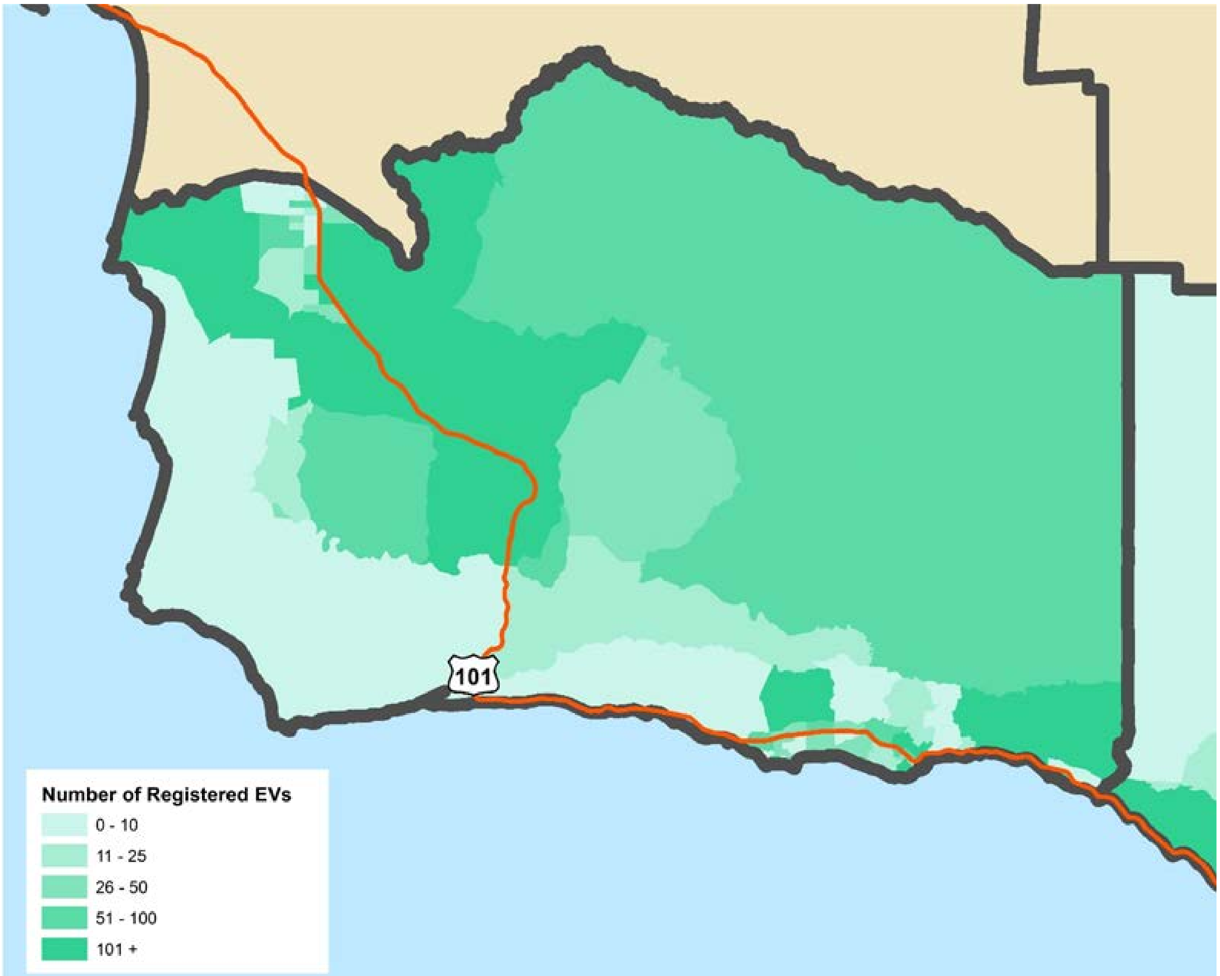
Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from Cal-Adapt (2020).

FIGURE C-7: Residential Solar Systems Across Santa Barbara County



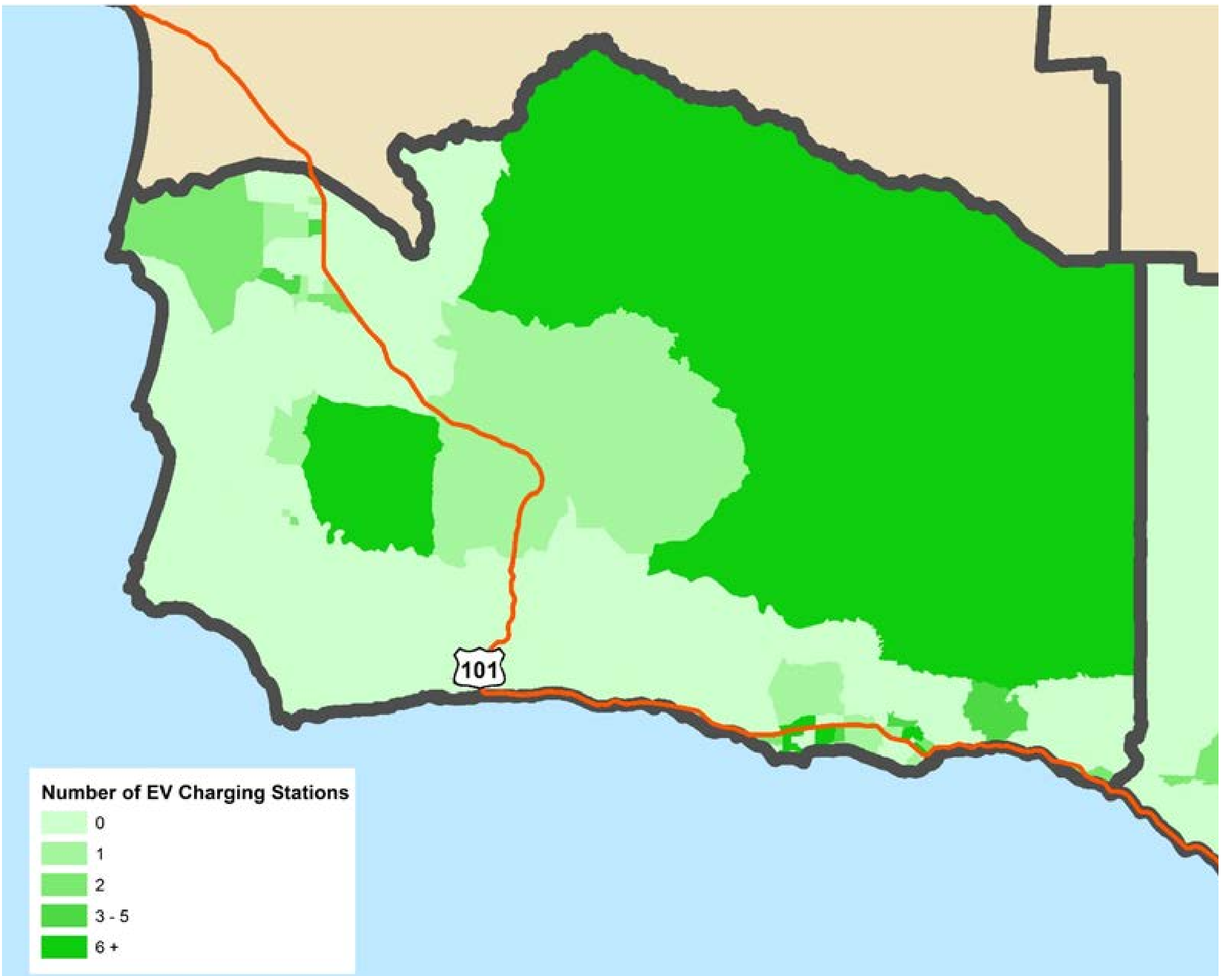
Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from Stanford University (2018).

FIGURE C-8: Electric Vehicle Adoption Across Santa Barbara County



Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from IHS Markit (2018).

FIGURE C-9: Electric Vehicle Charging Stations Across Santa Barbara County



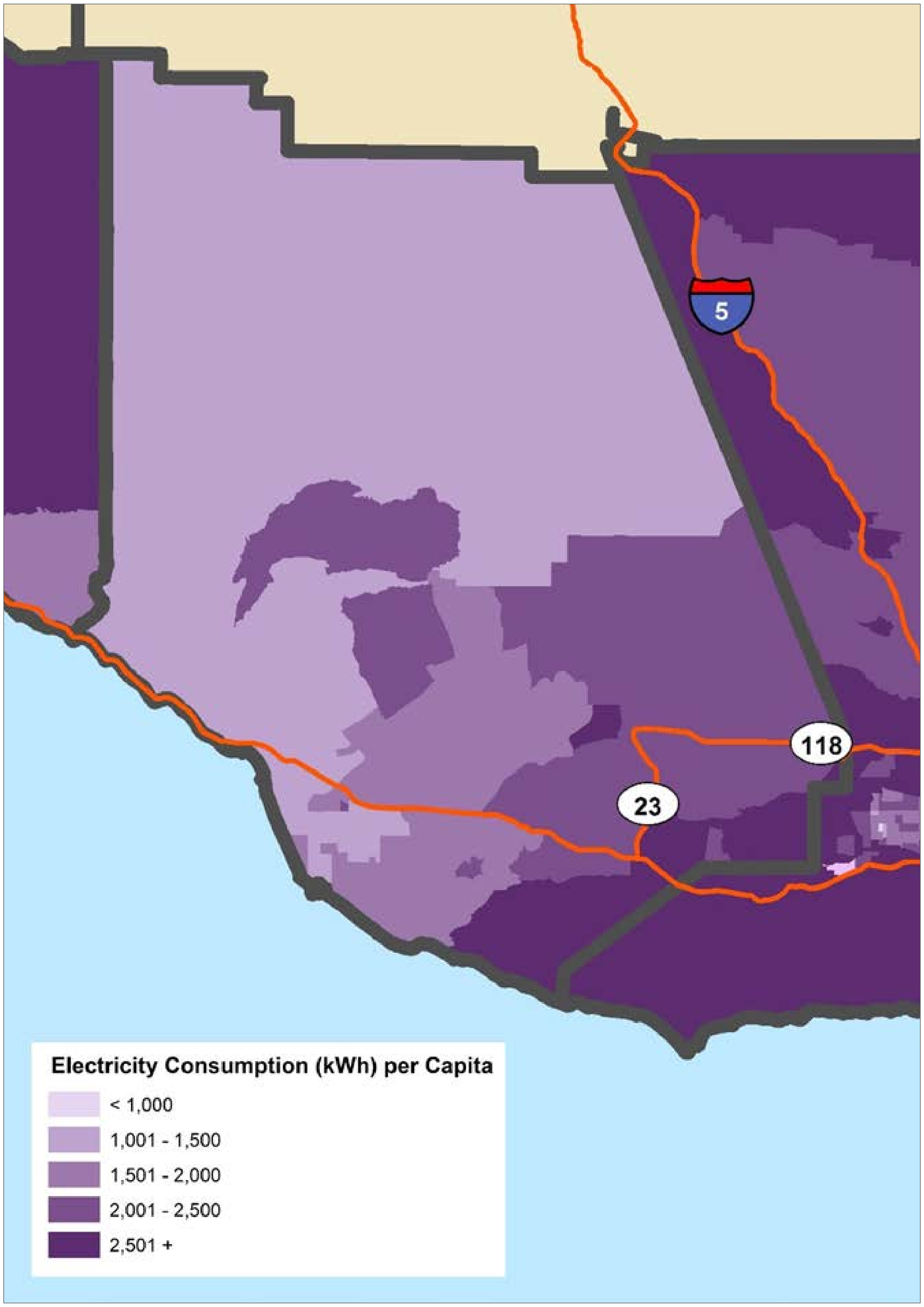
Source: Figure created by UCLA Luskin Center for Innovation. Data from the National Renewable EnergyLaboratory (2021).

FIGURE C-10: Number of Residential Storage Installations Across Santa Barbara County

Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from SGIP Program Statistics (2021).

Appendix D: Ventura County Maps

FIGURE D-1: **Electricity Consumption (kWh) per Capita Across Ventura County**

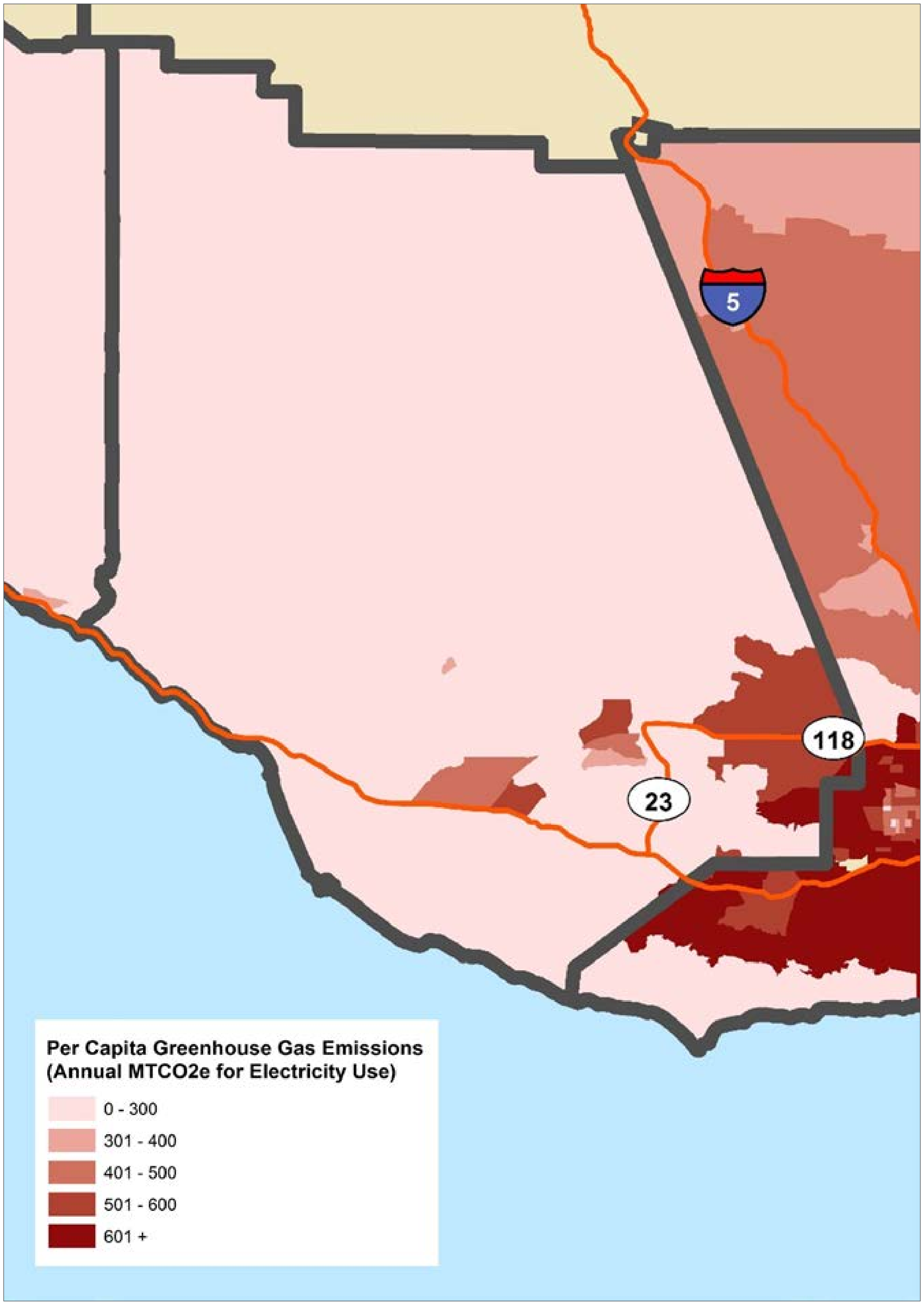


Source: Figure created by UCLA Luskin Center for Innovation (2021). Electricity consumption data sources described in Appendix F.

FIGURE D-2: Clean Energy Supply Across Ventura County

Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from California Energy Commission (2019).

FIGURE D-3: **Greenhouse Gas Emissions Intensity Across Ventura County**



Source: Figure created by UCLA Luskin Center for Innovation. See Appendix G for greenhouse gas emissions methodology.

FIGURE D-4: **Disadvantaged Communities Across Ventura County**

Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from California Office of Environmental Health Hazard Assessment (2018).

FIGURE D-5: **Median Income Across Ventura County**

Source: Figure created by the UCLA Luskin Center for Innovation. Data from U.S. Census (2019).

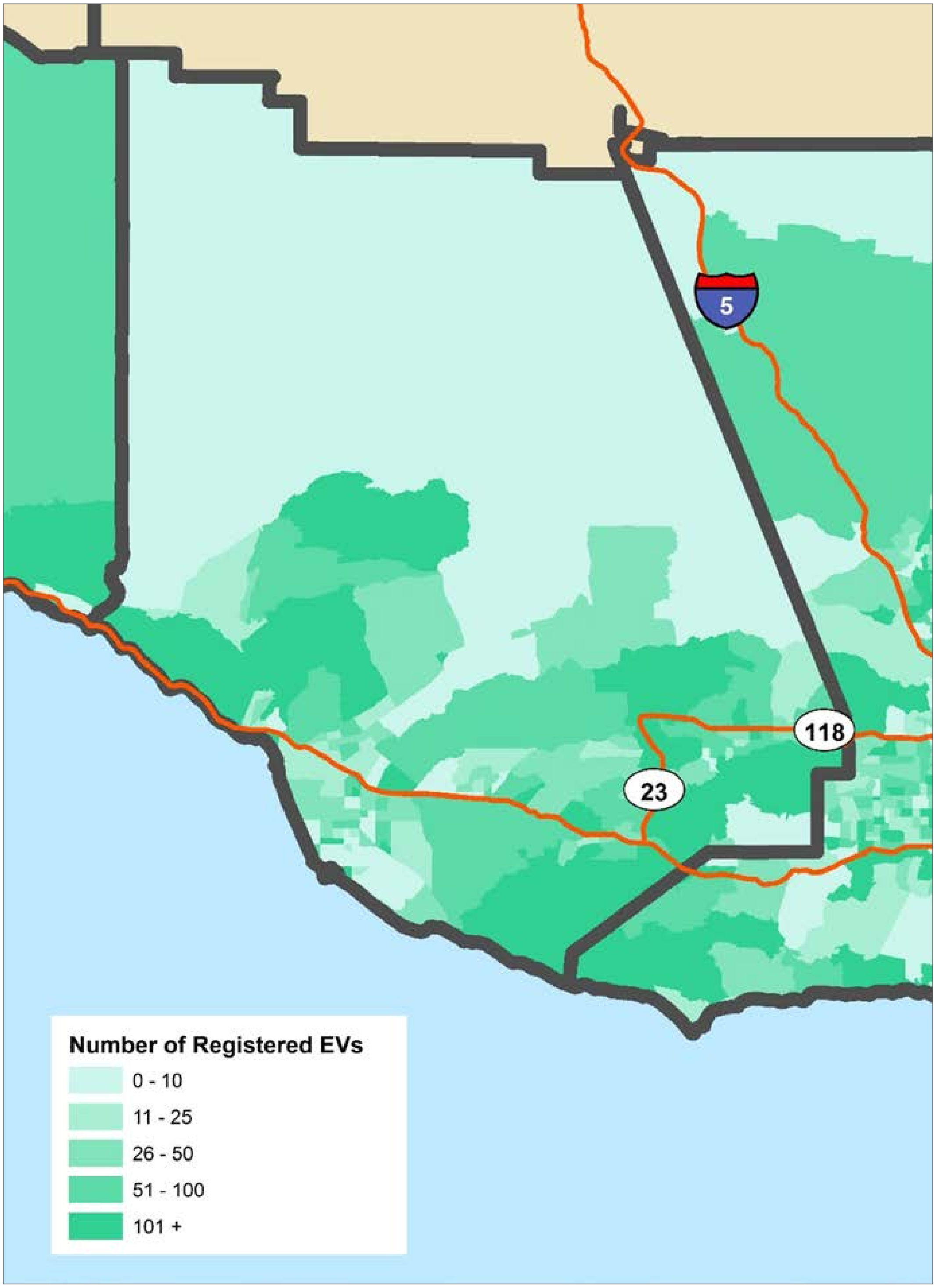
FIGURE D-6: Annual Future High Heat Days Projected From 2035 to 206 Across Ventura County

Source: Cal-Adapt (2020).

FIGURE D-7: Residential Solar Systems Across Ventura County

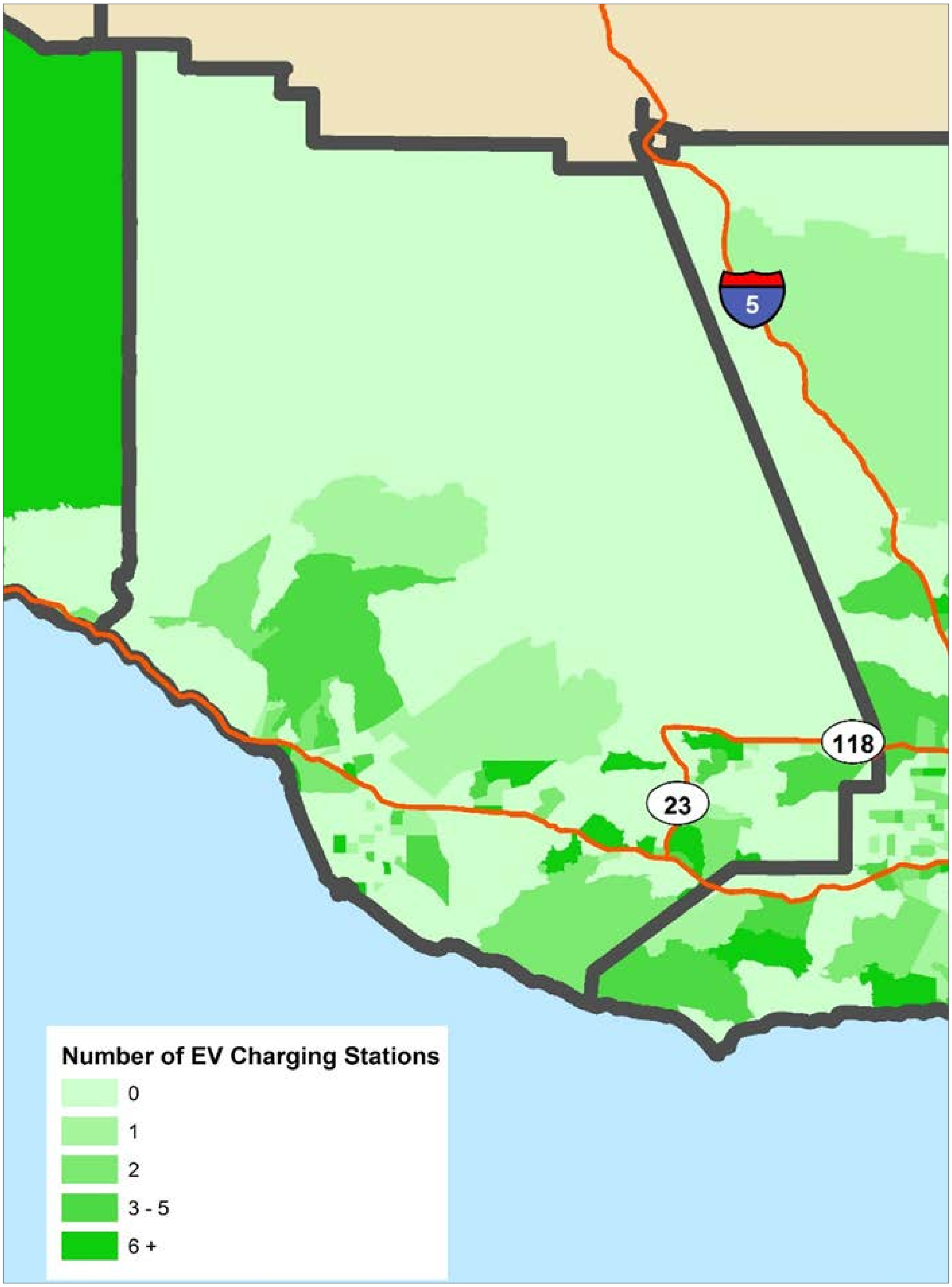
Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from Stanford University (2018).

FIGURE D-8: **Electric Vehicle Adoption Across Ventura County**



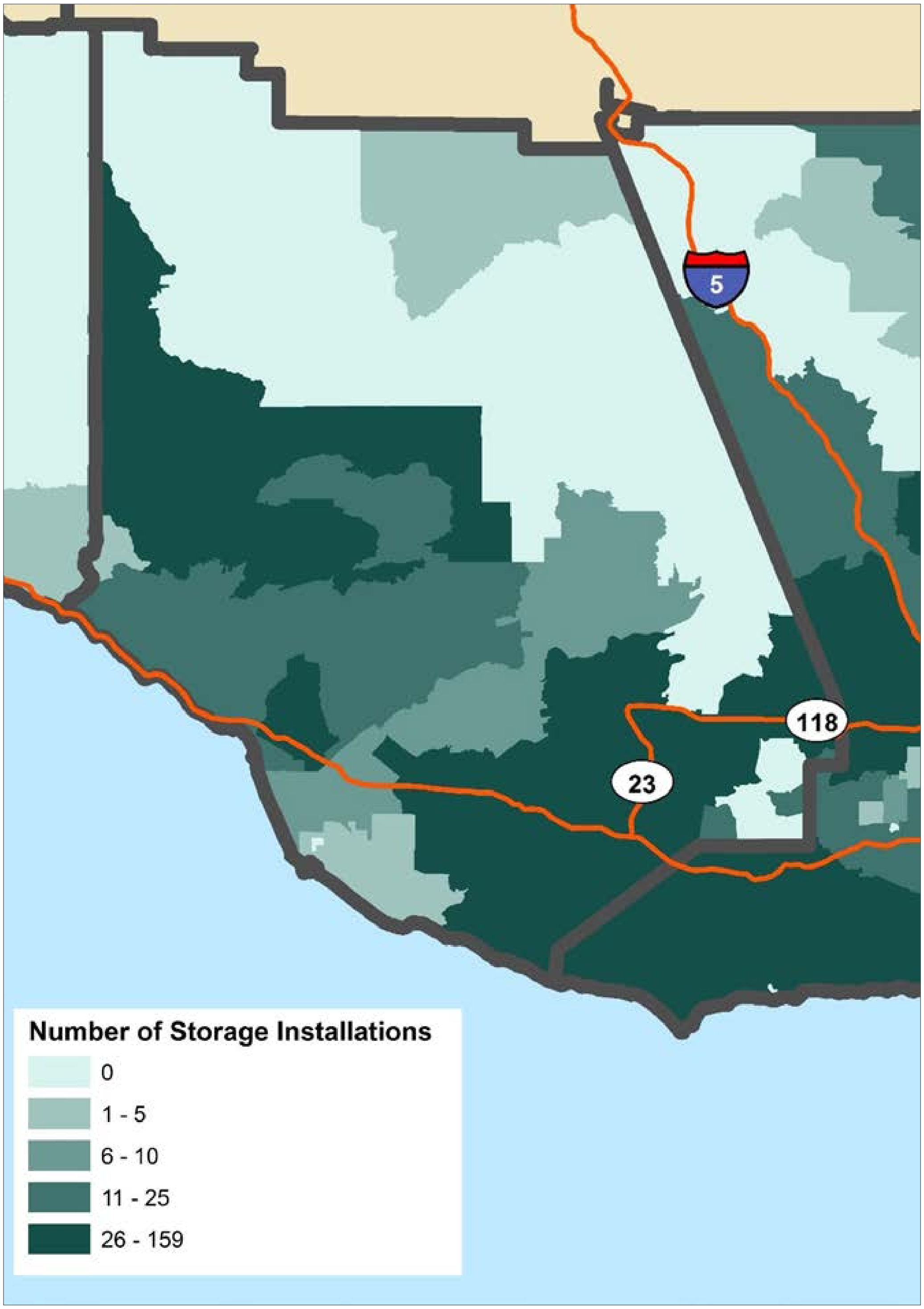
Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from IHS Markit (2018).

FIGURE D-9: Electric Vehicle Charging Stations Across Ventura County



Source: Figure created by UCLA Luskin Center for Innovation. Data from the National Renewable Energy Laboratory (2021).

FIGURE D-10:. Number of Residential Storage Installations Across Ventura County



Source: Figure created by UCLA Luskin Center for Innovation (2021). Data from SGIP Program Statistics (2021).

Appendix E: Underlying Data and Shapefile Sources

Shapefiles

"CA County Boundaries" (2019). California Open Data Portal
https://data.ca.gov/dataset/ca-geographic-boundaries/resource/b0007416-a325-4777-9295-368ea6b710e6

"CA Places Boundaries" (2019). California Open Data Portal
https://data.ca.gov/dataset/ca-geographic-boundaries/resource/436fc714-831c-4070-b44b-b06dcde6bf18

"California Electric Utility Service Areas" (2020). California Energy Commission (Note: for POUs and IOUs)
https://cecgis-caenergy.opendata.arcgis.com/datasets/b95ca182aa254c3db8ad4d92bd32a73c_0/explore?location=34.867732%2C-118.628270%2C7.82

"TIGER/Line Shapefile, 2018, 2010 nation, U.S., 2010 Census 5-Digit ZIP Code Tabulation Area

(ZCTA5) National" (2018). U.S. Census Bureau
https://catalog.data.gov/dataset/tiger-line-shapefile-2018-2010-nation-u-s-2010-census-5-digit-zip-code-tabulation-area-zcta5-na

"CalEnviroScreen 3.0 Data and Additional Materials" (2018). California Office of Environmental Health Hazard Assessment
https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-30

"USA Freeway System" (2019). ArcGIS
https://www.arcgis.com/home/item.html?id=91c6a5f6410b4991ab0db1d7c26daacb

Regional Energy Assessment Data Sources

Electricity Consumption
See Appendix F.

Clean Energy
"Power Content Labels" (2019). California Energy Commission.
https://www.energy.ca.gov/programs-and-topics/programs/power-source-disclosure/power-content-label

Greenhouse gas emissions
See Appendix G.

Community Vulnerability Data Sources

Disadvantaged Communities
"CalEnviroScreen 3.0" (2018). California Office of Environmental Health Hazard Assessment.
https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-30

Median Income
"American Community Survey: Table S1901" (2019). United States Census Bureau.
https://www.census.gov/acs/www/data/data-tables-and-tools/subject-tables/

Future High Heat Days
"Days above 90 degrees Fahrenheit in mid-century (2035 - 2065)" (2020). Cal-Adapt.
https://cal-adapt.org/data/

Energy Program Adoption Data Sources

Solar
Yu, Jiafan; Wang, Zhecheng; Majumdar, Arun; and Rajagopal, Ram. (2018). "DeepSolar." Stanford University
http://web.stanford.edu/group/deepsolar/home

Electric vehicle registrations
"Electric vehicles sold from 2010 to 2018" (2018). IHS Markit.

Electric vehicle charging stations
National Renewable Energy Laboratory: Developer Network (2021). "All Stations API."
https://developer.nrel.gov/docs/transportation/alt-fuel-stations-v1/all/

Storage
"SGIP Program Statistics" (2021). Self Generation Incentive Program.
https://sites.energycenter.org/sgip/statistics

Appendix F: Electricity Consumption Estimation Methodology

Due to the private nature of the data, energy consumption data is challenging to find at a spatially disaggregated scale. Accordingly, LCI developed a method for estimating energy consumption at the zip code level when data were unavailable. For IOUs and CCAs, electricity consumption data is publicly available online. Additionally, electricity consumption data was received for Burbank Water and Power through a public information request. Data for all other POUs was estimated using the electricity consumption methodology described in this section. Table F-1 summarizes whether electricity consumption data was available or estimated for each electric utility in our study region.

TABLE F-1: Source of Electricity Consumption Data for Each Electricity Provider

Electricity Provider	Electricity Consumption Data
Azusa Light and Water	Estimated by LCI
Burbank Water and Power	Received via public information request
City of Anaheim Public Utilities District	Estimated by LCI
City of Cerritos	Estimated by LCI
City of Industry	Estimated by LCI
City of Lompoc Electric Division	Estimated by LCI
City of Vernon Public Utilities Department	Estimated by LCI
Clean Power Alliance	Publicly available from IOU
Glendale Water and Power	Estimated by LCI
Los Angeles Department of Water and Power	Estimated by LCI
Lancaster Choice Energy	Publicly available from IOU
Pacific Gas & Electric	Publicly available on website
Pasadena Water & Power	Estimated by LCI
Pico Rivera Innovative Municipal Energy	Publicly available from IOU
Pomona Choice Energy	Publicly available from IOU
Southern California Edison	Publicly available on website

LCI first identified potential variables that could predict electricity consumption through a literature review. Table F-2 summarizes the literature review.

TABLE F-2: Literature Review

Variable	Studies Using
Building Age	Fell et al. (2014), Poyer and Williams (1993)
Building Characteristics	Burke et al. (2012), Druckman and Jackson (2008), Fell et al. (2014), Jamasb and Meier (2010), Sultana et al. (2018)
Climate	Baker et al. 1989, Fell et al. (2014), Poyer and Williams (1993), Sultana et al. (2018)
Education	Brounen et al. (2013), Sawtelle (1993), Sultana et al. (2018)
Employment	Sawtelle (1993)

Variable	Studies Using
House Size	Baker and Blundell (1991), Baker et al. (1989), Burke et al. (2012), Poyer and Williams (1993)
Household Size	Baker and Blundell (1991), Baker et al. (1989), Fell et al. (2014), Jamasb and Meier (2010), O'Neill and Chen (2002), Poyer and Williams (1993), Sultana et al. (2018)
Housing Tenure	Baker and Blundell (1991), Baker et al. (1989), Burke et al. (2012), Fell et al. (2014), Jamasb and Meier (2010), Sawtelle (1993)
Income	Baker and Blundell (1991), Brounen et al. (2013), Fell et al. (2014), Jamasb and Meier (2010), O'Neill and Chen (2002), Poyer and Williams (1993), Baker et al. (1989), Sawtelle (1993), Sultana et al. (2018)
Race/Ethnicity	Poyer and Williams (1993), Sawtelle (1993)
Type of Heating	Baker and Blundell (1991), Fell et al. (2014), Jamasb and Meier (2010)

We gathered data on these indicators from the sources identified in Table F-3. Data from the U.S. Census used 2019 American Community Survey (ACS) 5-Year Estimates.

TABLE F-3: Indicator Sources

Indicator Category	Indicator Name	Detail About Indicator	Source
Socioeconomic	Education	Population 25 plus who has a high school degree or higher, population 25 plus with a bachelor's degree or higher	U.S. Census Table S1501
	Household Size	Average Household Size	U.S. Census
	Income	Median Household Income	U.S. Census Table S1901
	Unemployment	Labor Participation Rate 20 to 64 years old	U.S. Census Table S2301
Housing Characteristics	Age of Building	Median Year Structure Built	U.S. Census Table B25035
	Household Size	Average Household Size	U.S. Census
	Housing Tenure	Owner Housing Tenure; Renter Housing Tenure	U.S. Census
	Dwelling Size	Number of Units (1 unit, 2 or more units, mobile and other)	U.S. Census Table S2504
	Dwelling Size	Number of bedrooms (Percent No beds, Percent 1 bed, Percent 2-3 beds, Percent 4 or more beds)	U.S. Census Table S2504
	Utilities	Electricity for Heating	U.S. Census Table S2504
Climate	Climate Zone	Climate Zone	California Energy Commission[1]
	High Heat Days	Number of High Heat Days (Above 90 degrees Fahrenheit) in 2016 [Historical Extreme Heat Days >90 degrees F]	U.S. Center for Disease Control

[1] "Building Climate Zones by ZIP Code" (2021). California Energy Commission https://www.energy.ca.gov/media/3560

We converted any indicators at the zip code level, including IOU electricity consumption data, to the census tract level. We used a zip code to census tract crosswalk.[2] For electricity consumption data, we took total residential electricity consumption by zip code and converted it to electricity consumption per capita within that zip code. We used that per capita estimate for all census tracts within that zip code. We then ran a lasso model, a type of statistical analysis, to see which combination of variables was optimal to predict electricity consumption using the actual electricity consumption data we had. The results of this analysis identified the following seven variables to estimate electricity consumption.

TABLE F-4: Indicators Used in the LCI Electricity Consumption Model

Socioeconomic Characteristics	Percent of Population 25 or higher with a bachelor's degree or higher
	Unemployment
Housing Characteristics	Average Household Size
	Owner Housing Tenure
	Median Structure Age
Climate Characteristics	Climate zone
	High Heat Days

We then used this data for each census tract without electricity consumption data to estimate per capita consumption.

References

Baker, P., Blundell, R., & Micklewright, J. (1989). Modelling Household Energy Expenditures Using Micro-Data. *The Economic Journal*, *99*(397), 720. doi: 10.2307/2233767

Baker, P., & Blundell, R. (1991). The Microeconometric Approach To Modelling Energy Demand: Some Results For Uk Households. *Oxford Review of Economic Policy*, *7*(2), 54–76. doi: 10.1093/oxrep/7.2.54

Brounen, D., Kok, N., & Quigley, J. M. (2013). Energy literacy, awareness, and conservation behavior of residential households. *Energy Economics*, *38*, 42–50. doi: 10.1016/j.eneco.2013.02.008

Burke, T., & Ralston, L. (n.d.). *Household Energy Use: Consumption and Expenditure Patterns 1993-2012*. *Household Energy Use: Consumption and Expenditure Patterns 1993-2012*. CRC for Low Carbon Living. Retrieved from http://www.lowcarbonlivingcrc.com.au/sites/all/files/publications_file_attachments/rp3001_household_energy_use_consumption_and_expenditure_patterns_1993-2012.pdf

Druckman, A., & Jackson, T. (2008). Household energy consumption in the UK: A highly geographically and socio-economically disaggregated model. *Energy Policy*, *36*(8), 3177–3192. doi: 10.1016/j.enpol.2008.03.021

Fell, H., Li, S., & Paul, A. (2014). A new look at residential electricity demand using household expenditure data. *International Journal of Industrial Organization*, *33*, 37–47. doi: 10.1016/j.ijindorg.2014.02.001

[2] "HUD USPS ZIP Code Crosswalk Files" (2021). Office of Policy Development and Research. https://www.huduser.gov/portal/datasets/usps_crosswalk.html

Jamasb, T., & Meier, H. (2010). *Household Energy Expenditure and Income Groups: Evidence from Great Britain*. *Household Energy Expenditure and Income Groups: Evidence from Great Britain*. University of Cambridge.

O'Neill, B., & Chen, B. (2002). Demographic Determinants of Household Energy Use in the United States. *Population and Development Review, 28*, 53-88. Retrieved from www.jstor.org/stable/3115268

Poyer, D. A., & Williams, M. (1993). Residential energy demand: additional empirical evidence by minority household type. *Energy Economics*, *15*(2), 93–100. doi: 10.1016/0140-9883(93)90027-o

Sawtelle, B. A. (1993). Income elasticities of household expenditures: a US cross-section perspective. *Applied Economics*, *25*(5), 635–644. doi: 10.1080/00036849300000008

Sultana, S., Pourebrahim, N., & Kim, H. (2018). Household Energy Expenditures in North Carolina: A Geographically Weighted Regression Approach. *Sustainability*, *10*(5), 1511. doi: 10.3390/su10051511

Appendix G: Greenhouse Gas Emissions Estimation Methodology

For all electricity generating resources except where noted, we use the Intergovernmental Panel on Climate Change's (IPCC) median direct emissions factors.[3] These are reported in gCO2eq/kWh, which we then convert into MTCO2e/kWh. These are summarized in Table B-1. We use the California Air Resources Board emission factor for 'unspecified' power.[4] Absent an emission factor for energy reported as 'other', we assume that electricity was generated by unspecified power, and therefore use that emission factor. These emission factors are summarized in Table G-1.

TABLE G-1: Emissions Factor by Electricity Generating Resource Type

Resource	Emissions Factor (MTCO2e/kWh)	Source
Renewable Energy	0	IPCC
Biomass and Biowaste	0	IPCC
Geothermal	0	IPCC
Small Hydroelectric	0	IPCC
Solar	0	IPCC
Wind	0	IPCC
Coal	0.76	IPCC
Large Hydroelectric	0	IPCC
Natural Gas	0.37	IPCC
Nuclear	0	IPCC
Other	0.428	N/A
Unspecified	0.428	ARB

For each electricity provider, we use the 2019 California Energy Commission Power Content Labels, which report the share of each electricity generating resource used to provide electricity to their customers. We multiply the power content by the emissions factors to estimate a weighted average emission factor for each electricity provider.

We then multiply the relevant electricity provider's emission factor for each census tract by the average per capita electricity consumption in that census tract (See Appendix F for more detail about how we estimated electricity consumption per capita). The result is the annual average electricity-related greenhouse gas emissions per capita for that census tract.

[3] Source: Schlömer S., T. Bruckner, L. Fulton, E. Hertwich, A. McKinnon, D. Perczyk, J. Roy, R. Schaeffer, R. Sims, P. Smith, and R. Wiser, 2014: Annex III: Technology-specific cost and performance parameters. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-iii.pdf#page=7

[4] "Electric Power Entity Reporting Requirements Frequently Asked Questions (FAQs) for California's Mandatory GHG Reporting Program" (2021). California Air Resources Board. https://www.arb.ca.gov/cc/reporting/ghg-rep/ghg-rep-power/epe-faqs-2020.pdf

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