ASSESSING THE EQUITY IMPACTS OF HOUSEHOLD ELECTRIFICATION POLICIES ON SOUTHERN CALIFORNIA FAMILES

PREPARED FOR THE SOUTHERN CALIFORNIA GAS COMPANY

MAY 2021

Project Team:
Changyuan Pang
Henry Pines
Tim Smith
Dongxuan Zhao

Price School of Public Policy
University of Southern California

USC University of Southern California

ABOUT THE AUTHORS

CHANGYUAN PANG: Changyuan (Jack) Pang is a graduating Master of Public Policy student at the University of Southern California and is interested in transportation and public safety policies. He is a racing car driver and race team manager, competing in various Formula and Touring Car series. Jack attended Imperial College London and King's College London for his undergraduate Mathematics degree.

HENRY PINES: Henry Pines is a second year MPP student who originally hails from Brooklyn, NY. He studied Political Science and Theatre at American University in Washington, D.C. Prior to coming to USC, Henry worked as a paralegal at the law firms Bredhoff & Kaiser P.L.L.C. and Finkelstein Thompson LLP.

TIM SMITH: Tim is a native Californian and a graduate of California State University, Fullerton. Since graduating with his undergraduate degree in political science and economics, Tim has worked in higher education as an institutional researcher supporting Long Beach City College's program planning process, accreditation, grant applications, and evaluation processes. His policy interests include labor, employment, workforce, and economic development and is seeking new opportunities in federal or state bureaucracy.

DONGXUAN ZHAO: Dongxuan Zhao is a graduating Master of Public Policy student. She received her bachelor's degree from Indiana University Bloomington with a major in Environmental Management. Sustainable development. She is committed to promoting the sustainable utilization of resources and the preservation ecosystems as the primary conditions to maintain the harmonious development of human society.

ABOUT THE PRACTICUM PROJECT

This project was developed in accordance with the University of Southern California's Master of Public Policy degree at the Sol Price School of Public Policy. The program's capstone practicum project serves as a means of applying written, oral, and analytical skills in a consulting style environment. These professional experiences assist students in contextualizing coursework by fulfilling a request for research and data assistance from a corporate, nonprofit, or government client seeking better knowledge of critical public policy issues.

ACKNOWLEDGEMENTS

A special thanks to Juliet Musso, Ph.D. and Grace Bahng, Ph.D. of USC for their analytical and professional guidance through this project. We would also like to thank Evelyn Loya, MPP of SoCal Gas for her assistance navigating the energy policy ecosystem.

EXECUTIVE SUMMARY

This analysis details the socio-economic and environmental benefits of household electrification policies. These policies, largely spearheaded by local governments, involve changing the building code by either mandating or expressing preference for electric appliances over their natural gas counterparts. These policies come in many shapes and sizes with some requiring substantial updates to existing appliances while others merely express a preference that has no force of law. As of 2021, most electrification policies have been implemented in predominantly wealth communities in the San Francisco Bay region with only a few mandates and preferences in similar cities in the south.

The implementation of these policies comes at a critical point in time for Californians. The State of California faces two interlocking crises—an environmental crisis driven by climate change, and an affordability/income inequality crisis driven housing prices. The environmental crisis stems from a sustained increase in the average annual temperature across the state. The state has already faced considerable pollution challenges. Pesticide pollution threatens communities near agricultural centers in the San Joaquin Valley, Oxnard, and Santa Maria. The Los Angeles and Inland Empire region's sustained struggles with air pollution threatened residents with a mixture of pollutants from diesel vehicles, traffic, industrial production, and fires. The recent election of the Biden Administration has brought a new approach to environmental policy (Stein et al, 2021). More aggressive estimates of the cost of carbon, new plans to invest in clean technology, and a climate-focused foreign policy mirror California's approach taken after the passage of the 2006 Global Warming Solutions Act. This policy reflected one of the most prominent attempts to correct the externalities from pollution by capping and trading permits to pollute while using the profits to reinvest in vulnerable communities (Berkeley Law, 2020).

Simultaneously, the state faces considerable affordability challenges. A 2021 study of the minimum cost-of-living required to live each of the 50 states and the District of Columbia, found California was the third most expensive state behind only Hawaii and DC. Most prominent among these cost vectors is housing. The average Californian can expect to pay $15,600 annually in housing costs at minimum compared to just $6,500 in South Dakota (Glassmeir, 2021). While the new administration has promised to incentivize investments in housing, state policy makers have been less definitive (Marr et al, 2021). Attempts to rezone for transit-oriented development have failed in the state legislature leaving only minor changes to the zoning of accessory dwelling units to form the basis for much of California's housing policy (Capps, 2020; Dillon, 2021).

This paper dives deep into how a particular vector of environmental policy, electrification, impacts the cost of living in Southern California communities. Using an equity-based approach, we pay particular attention on regressive costs and progressive benefits. Specifically, if costs are distributed similarly across communities, low-income householders will face greater reductions in welfare then wealthier families. Offsets may include reductions in carbon emissions stemming from use of natural gas appliances.

The analysis conducted uses geographic and cost-benefit analyses to model the impacts of two types of electrification mandate on a set of typical California cities. To identify these typical cities, we develop three principal vulnerability indices that allowed for each of the state's 8,000 census tracts to be categorized by the scale of the social challenges. First, the social cost-of-living index, traces how likely a community is to meet basic standards of living. The index combines data from the U.S. Census Bureau to identify communities with acute food insecurity, limited access to health insurance, high transportation and housing burdens, and childcare costs. These cost-of-living challenges approximately 32% of the Southern California Gas Company (SoCalGas) service area with Black and Latino residents representing a disproportionate total of the vulnerable population. Second, the social mobility index identifies the rate at which middle class residents pass on their earnings to subsequent generations. This index finds Black residents are substantially more likely to live in communities with limited social mobility. Third, the environmental risk index identifies risk across three categories of pollution: air pollution, industrial pollution, and traffic pollution. Categorizing these risks finds that over 40% of urban residents and 24% of rural residents face the most acute pollution challenges in the state; a burden that falls disproportionately on Latino families.

The scale of these challenges becomes most stark when examining the intersection of social vulnerability and pollution risk. In total 15% of the SoCalGas service population live in the most polluted and most socially vulnerable census tracts in the state. These tracts are concentrated in dense urban centers like South-Central Los Angeles and the urban basin of the Inland Empire. Not all of these challenges are the same. As previously mentioned, inland communities particularly in the Inland Empire and San Joaquin Valley face higher rates of air pollution while coastal communities have far less. Rural/agricultural communities are substantially more burdened by pesticide pollution while urban communities face pollution from industrial activities and traffic.

The burden of these environmental and social challenges disproportionately falls on residents of color. 60% of Black families and 64% of Latino families in the SoCalGas service area live among the top half most polluted and most vulnerable census tracts in the state compared to just 28% of White families. The results of this analysis lead us to select nine cities from different quadrants of the intersection of social vulnerability and environmental risk. These cities include Visalia in Tulare County, Oxnard in Ventura County, Lancaster, Compton, Claremont, and Santa Monica in Los Angeles County, Laguna Beach in Orange County, Fontana in San Bernardino County, and Palm Desert in Riverside County.

The effect of electrification policies, therefore, must be considered in the context of these affordability and environmental challenges. The cost-benefit analysis identifies the likely changes resulting from mandating a switch from natural gas to electric appliances under both an all-housing electrification mandate and a new housing only electrification mandate. The results indicate that despite considerable reductions in carbon emissions, policymakers should not expect residents to switch appliances of their own accord.

While new home construction is not made substantially more expensive by using all-electric appliances, the positive environmental effects of such a policy are far smaller since those cities tend to be built out. A policy requiring homes to retrofit for all-electric appliances will have greater environmental benefits but is far more expensive. Furthermore, much of the pollution facing dual-crisis communities stems from industrial pollution, pesticides and other chemicals used in agriculture, and traffic—none of which will be touched by a potentially costly electrification policy. The common costs accrued across both low-income and high-income homes represents a regressive tax where the burden of the tax represents a higher portion of household income for a low-income family then a high-income family.

Table of Contents

I. ISSUE OVERVIEW

UNDERSTANDING THE DUAL CRISES

Recent changes to local building codes have brought renewed focus to the role of natural gas in residential households. These policies are bought to pass under the assumption that use of natural gas to power appliances introduced more pollution and greater carbon emissions then electricity. Electrification policies, as they are called, take many forms, but have yet to extend beyond a core of wealthy cities in the San Francisco Bay area.

The inclusion of such environmental considerations into building codes comes at an auspicious time for California families. The state faces two sometimes competing crises. Climate change threatens to bring considerable changes to the local climate. The Los Angeles Basin has already warmed past the 2 degrees Celsius of warming that scientists warn will cause catastrophic environmental damage. The effects of such changes are often dramatic. between droughts, wildfires, poor air quality, poor environmental quality, and rising sea levels. Federal, state, and local governments have all pledged to take significant action to address California's role in the climate crisis.

Additionally, Californians face crippling affordability challenges. California is among the top five most expensive states to live in with housing costs comprising the bulk of the additional costs. The average Californian needs to earn a lot more money to afford the same housing than their counterpart in a different part of the nation. The economic struggles that many Californians face are particularly acute for California's Black and Latino communities, which face high costs and a lack of social mobility that make it difficult for children to earn as much as their parents.

This section details the principal features of electrification policies in California, placing them in the context of the climate crisis and the associated state and local responses. Additionally, the depth of California's affordability issues are also explored – a crisis whose intersection with environmental degradation form the principal research questions answered throughout this paper.

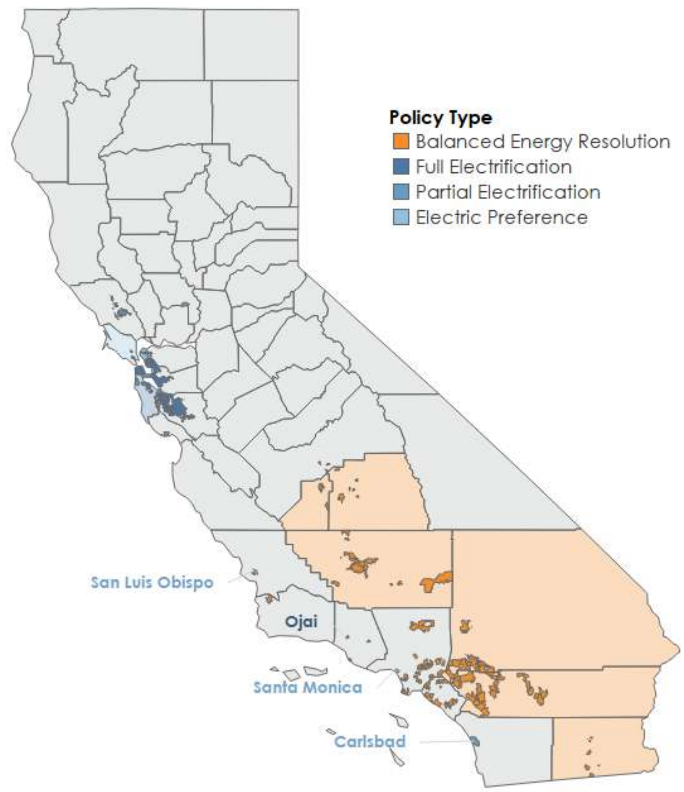
Local Electrification Policies:

While state and federal policies have focus on broad market-based regulation and investments, California local governments have taken often diverging approaches to electrification with some proposing progressively restrictive electrification measures while others reaffirm their commitment to household natural gas. As seen in figure 3, the San Francisco Bay has been a hub for municipal electrification policies since Berkeley passed an ordinance restricting natural gas connections to new buildings in 2019 (Berkeley, California, Municipal Code § 12.80). However, the lack of consistency in these proposals calls into question the level of consensus on the best approach to regulating household emissions.

The most common mechanism used by cities to regulate household natural gas emissions has been through building codes. So called "reach codes" set building standards that exceed the state's minimums by employing a variety of incentives and coercive measures (DiChristopher, 2020). The most restrictive of these were the Bay area cities of Mountain View, Oakland, San Francisco, and Saratoga. These cities required full electrification of new construction without exceptions for nonresidential buildings or stoves and cooktops.

However, these cities still restrained from requiring electrification of existing construction. Much of the remaining 38 cities who have adopted reach codes have either required all electric construction of new buildings with substantial exemptions or have merely expressed an electric- preference (Gough, 2021; Newsome, 2019). Only two cities have implemented any regulation on existing infrastructure: Healdsburg which requires electrification of appliances except gas cooking and fireplaces and San Carlos which requires electrification upgrades during major remodels. Only six of the 42 cities/counties with an electrification policy have a population greater than 100,000 residents and thus represent only 11% of the state's population. Additionally, only four are in Southern California (Carlsbad, San Luis Obispo, Ojai, and Santa Monica) with none located in the Inland Empire or San Joaquin Valley region (Gough, 2021).

FIGURE 1: CITIES/COUNTIES WITH AN ELECTRIFICATION POLICY AND BALANCED ENERGY RESOLUTIONS (Gough, 2021; SoCal Gas, 2021)



Running counter to these trends towards electrification are cities and counties who have passed "balanced energy resolutions." These resolutions, while not legally binding, express a preference towards maintaining natural gas connections. These municipalities represent large portions of Southern California especially in the urban core of the Inland Empire and the southern tip of the San Joaquin Valley (SoCal Gas, 2021). These communities represent approximately 23% of the state's population with large counties like Riverside and San Bernardino housing over 4.5 million residents (U.S. Census Bureau, 2019d).

Environmental Justification for Local Electrification:

While natural gas is more affordable, it is also one of several energy sources that contribute to climate change through the release of methane. In 2017, approximately 41 million tons of GHGs, or nearly 10% of California's total annual GHG emissions, came from the combustion of residential and commercial natural gas (California Air Resources Board, 2019). Residential appliance leakages contributed to an estimated 15% of the state's total natural gas-related CH_4 emissions (Fischer et al., 2018). While CH_4 emissions can come from natural sources, in the Los Angeles Basin, most CH_4 emissions come from fossil fuel sources (Hopkins et al., 2016). This suggests a tension between affordability and the need to reduce greenhouse gas emissions on the other. To the extent that lawmakers cannot address climate change, high temperatures will further stress California's electricity grid, resulting in a continuation of the state's history as home to some of the nation's highest electricity prices (Bryce, 2020).

Household electrification will create environmental impacts in two directions. Homes using all-electric appliances consume significantly more electricity than homes that are not electrified. Electricity production from Southern California Edison (SCE) emits 0.024 MT of CO2e/MWh (*Our Sustainability Goals*, 2019). As SCE invests more in renewable energy and decarbonizes the electricity is provides, the environmental impact of using all-electric appliances will lessen over time. The other way is effects emissions is by lowering CH_4 emissions from burning natural gas. Natural gas usage can be measured in many ways, but one of the most common measures is a therm—a measure of natural gas usage over time. The EPA calculates that each therm of natural gas used results in 0.0053 MT CO_2/therm (US EPA, 2018).

A few existing analyses have examined the environmental effects of household electrification. The research firm Energy + Environmental Economics (E3), estimates that fully electrified homes have 30-56% lower annual emissions than a mixed-fuel home (Mahone, et al. 2019).

Financial Cost of Local Electrification Policies: However, despite these environmental impacts many local policy makers point to the substantial price differentials between natural gas and electricity. In September 2020, the average cost of a single kilowatt hour of electricity was $0.20. The cost for an equivalent unit of natural gas was only one third the cost at approximately $0.05 (Bureau of Labor Statistics, 2020). These cost differentials are compounded by high energy costs in California. Californians pay approximately 45% more for electricity than the national average. Even natural gas is 37% more expensive in California then the national average (Bureau of Labor Statistics, 2020).

Financial analysts note four primary household appliances that would need replacing if a consumer were to fully electrify their home: cooking stoves/ovens, clothes dryers, furnaces, and water heaters. Approximately 64% of homes in the Pacific region have a natural gas water heater followed by 54% of homes with a natural gas furnace, 46% with a natural gas stove, and 25% with a natural gas clothes dryer (Office of Energy Consumption and Efficiency Statistics, 2018). Consumers who opt not to purchase premium appliances can expect to pay less on average for electric appliances then comparable natural gas appliances. This however may not amount to cost savings local mandates require replacements before old appliances have fully depreciated. These older homes may also have additional costs for retrofits. A 2019 report found that a typical single-family home built before 1978 would incur an additional $4,256 in retrofit costs if forced to upgrade (Mahone, et al. 2019). These costs may create substantial differentials in the economics of electrification when disaggregating between communities with relatively old development and communities with new construction or construction build in the past forty years.

The Environmental Crises: Global warming is an existential threat to California. Even though statewide emissions have decreased faster than expected—the state still faces numerous threats from wildfires, extreme heat, and sea-level rise. Some parts of California have already seen local temperatures rise above 2° Celsius—the threshold for catastrophic warming (Mooney & Muyskens, 2019). Emissions, frequently produced during human activities, threaten to accelerate these changes while simultaneously worsening pollution that threatens human health. California's primary emissions sources include:

- **Industrial activity:** Industrial activity, including the production of energy is one of the largest sources of GHG emissions in California, comprising 24% of all total emissions in 2017 (California Air Resources Board, 2019). Activities such as oil refining, manufacturing, agriculture, and construction are critical portions of the state's economy, but all contribute to pollution and greenhouse gas emissions. Manufacturing continues to play a large role and has intersected with the development of the Los Angeles metropolitan area in particular, since Los Angeles County zoned the East Side for industry and the west side of the city for single family homes (Deverell & Hise, 2006).

- **Traffic:** The largest source of emissions in California is the transportation sector, comprising 41% of all California's emissions (California Air Resources Board, 2019). While California's emissions in general have dropped below 1990 levels in accordance with AB 32, earlier than the law mandated, transportation emissions went up while emissions from other sources went down (Barboza, 2019). Between personal vehicles, and the large amount of heavy-duty truck traffic that moves through the state, researchers have been able to track incredibly high concentrations of pollution near roadways like the I-10, I-5, and I-405 freeways through Los Angeles (McDonald et al., 2014). Recent attempts to address transportation emissions through planning-based adjustments have just gotten started with the implementation of SB 743 in 2020 (Senate Bill No. 743, 2013)

- **Energy Production:** While energy production in California has grown progressively greener, the state still receives a substantial portion of its emissions from natural gas. Natural gas fired power plants produce particulate matter that can have deleterious effects on the health of people who live nearby particularly those in low-income communities (To et al., 2020). Increased particulate pollution can lead to a higher incidence of asthma in a community (Brandt et al., 2014). Complicating the situation further, recent research has shown that natural gas burning stoves are correlated to an increase in child asthma as well (Logue et al., 2014).

- **Topography:** California's topography also contributes to substantial air pollution problems. Pollution remains in areas like the Los Angeles Basin, between incoming air from the Pacific Ocean, trade winds, and the rings of mountains preventing the pollution from dispersing. Coastal areas tend to have better air quality, ocean access and wealthier residents (Figure 2). There are going to be a larger number of high heat days, sea levels will rise along California's coast, and scientists expect fire season to continue to get more intense in the coming years (Krishnakumar & Kannan, 2020).

In addition to the small number of cities with electrification policies, both the federal and state governments have taken steps to solve the climate crisis.

Federal Climate Policy: The Biden Administration's new infrastructure plan envisions a much larger role for the federal government in spurring the electrification of America. This represents a complete turnaround from the Trump administration which expressed doubt about the utility and likelihood of electrification efforts (Wheeler, 2020). The Biden plan sets aside large amounts of money for building up electric vehicle infrastructure, which will increase the burden on the grid. The plan also subsidizes the development of clean energy which could lower the carbon intensity of the electricity power utilities sell. The Plan also goes along with Biden's call for "Congress to adopt an "Energy Efficiency and Clean Electricity Standard" that would set specific targets to cut how much coal- and gas-fired electricity power companies use over time" (Stein et al., 2021).

State Climate Policy: California's climate policy toolbox can be broadly summarized through the framework of the World Bank's "Four Pillars of Decarbonization." These pillars articulate four broad policy goals recommended to reach full decarbonization. Included are:

1. **"Decarbonization of Electricity Generation:"** this pillar emphasizes the need to convert large-scale energy grids to renewable sources such as nuclear, solar, wind, or geothermal (Fay et al. 2015, pg. 29).

2. **"Electrification:"** this pillar articulates policy goals related to reduction of GHGs from household and industrial sources through broadscale electrification of households and transportation infrastructure (Mahone et al. 2018, pg. 8; Fay et al. 2015).

3. **Increasing Energy Efficiency:** this pillar refers to broad policy goals related to updating the energy efficiency of existing infrastructure whether household or industrial (Fay et al. 2015).

4. **Land Management and Preservation:** this pillar articulates the need to preserve and rebuild natural environments that capture carbon such as forests (Fay et al. 2015).

The California Energy Commission articulated a fifth pillar in its 2018 report on mitigation scenarios:

5. **"Reduce non-combustion GHGs:"** this pillar emphasizes the need to reduce greenhouse gasses from non-energy related sources such as dairy production, soil and forest carbons, and gas leaks (Mahone et al. 2018, pg. 8).

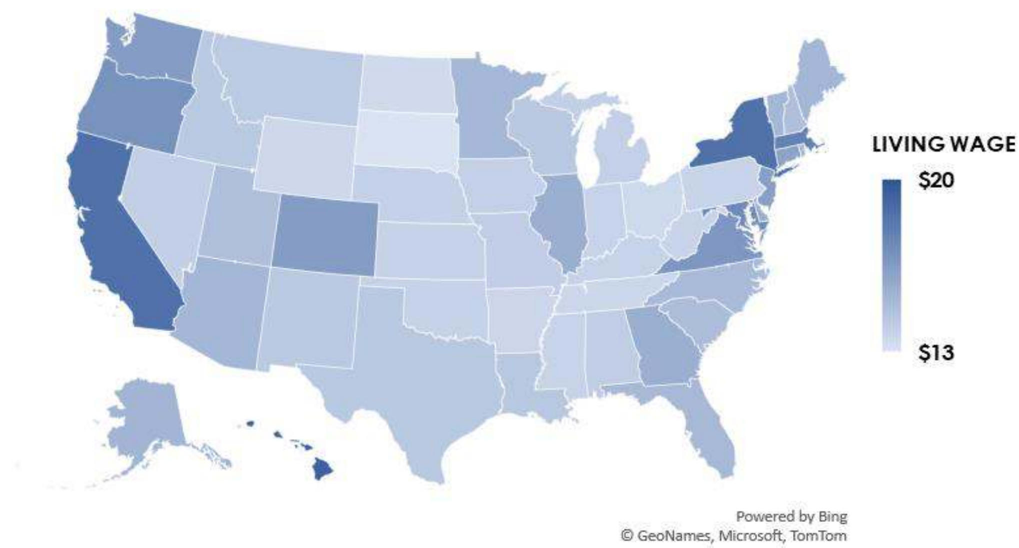
California's signature climate change policy was passed in 2006 by Governor Arnold Schwarzenegger. **AB32**, also known as the **California Global Warming Solutions Act of 2006**, set the state's first GHG reduction goal to 1990 levels by 2020. The state gave the California Air Resources Board (CARB) broad authority to scope, design, and implement equitable health-conscious and economically viable policy solutions in dialog with state energy agencies (Berkeley Law, 2020). By 2013, CARB introduced the state's first cap-and-trade program which effectively capped carbon emissions and required the state's largest industrial emitters to purchase tradable permits for emissions (California Air Resources Board, 2008). Subsequent policies like SB100 mandated that California's energy mix be 100% renewable by 2045 (SB 100, 2018). The program has thus far reduced GHG emissions to 1990 levels in 2016 while generating $9.5 billion for the state's Greenhouse Gas Reduction Fund (California Air Resources Board, 2020; Berkeley Law, 2020). This prompted legislators to set a new goal of reaching 40% of the 1990 levels by 2030 in **SB32** (Berkeley Law, 2020).

Calculating the cost of carbon, however, has been a challenge for CARB and other interested governments. This measure is usually known as the social cost of carbon and is a measure that "represents the economic cost associated with climate damage (or benefits) that results from the emission of an additional ton of carbon dioxide" ("CO2")(Ricke et al., 2018). After the failure of Waxman-Markey in 2009 to institute a national cap-and-trade program, the state of California instituted one via a Cap-and-Trade scheme in 2013 (Solutions, 2020). The state issues a limited number of carbon allowances to heavily polluting facilities in an auction. The number of allowances decreases 5% every year, resulting a steady increase in auction price, year over year (Solutions, 2020). CARB announced that the most recent price per metric ton of CO2 was $16.68 (California Air Resources Board, 2020a). The Obama Administration Interagency working group came to say that the social cost of carbon is $51 after reviewing the science and the evaluating the potential economic effects of climate change (Marten & Newbold, 2012). Many scientists believe that that price is too low and insufficiently captures the costs of climate change—it is not uncommon to see estimates over $100 as an estimate of the SCC.

In 2017, CARB's Climate Scoping Plan articulated the need to "switch from natural gas to electricity – where feasible" (California Air Resources Board, 2017, pg. ES11). This hole in California's climate policy was particularly important given the scale of GHG emissions from residential emissions of natural gas (California Air Resources Board, 2017, pg. ES11). Despite providing few particulars, CARB identified a series of potential actions that highlighted the state's supporting role in electrification. Passive actions such as "evaluat[ing] and set[ing] targets," through "public process[es]" likely better suited for local governments than state bureaucrats (California Air Resources Board, 2017, pg. 69).

The Affordability Crisis: Affordability issues have led many to question whether California will continued to sustain the high levels of population growth it experienced throughout the twentieth century. **According to the Massachusetts Institute of Technology (MIT), a Californian must earn more than residents of 49 other states to meet basic living standards, behind only the District of Columbia and Hawaii.** By comparison, basic living standards require that the average single Californian without children would need to earn more than $18.66 per hour compared to only $14.01 in Texas, $14.90 in Minnesota, and $12.61 in South Dakota. These differentials are not the same, however, across all household spending categories. For example, Californians face lower medical and transportation costs then Texas, Minnesota, and South Dakota. While California's tax burden is considerably higher than many other states, it is housing that forms the starkest differential. The Massachusetts Institute of Technology estimates that the average Californian spends a minimum of $15,200 annually on housing compared to just $9,300 in Texas, $8,600 in Minnesota, and $6,500 in South Dakota (Glassmeier, 2021).

FIGURE 2: MINIMUM WAGE REQUIRED TO MEET BASIC LIVING STANDARDS FOR A SINGLE ADULT BY STATE (Glasmeier, 2021)



These figures ignore the considerable differences in housing and other living expenses in different corners of the state. **A single-childless adult in Marin, San Francisco, and San Mateo Counties, needs to earn more than $28.00 per hour ($58,240 annually) compared to just $13.20 ($27,460 annually) in Modoc County in the far northern corner of the state.** An average Bay area resident can expect to pay anywhere from $17,560 annually in housing costs in Contra Costa to $26,300 in Marin. Southern California shows many of the same challenges. The living wage in Santa Barbara County sits at $23.33 per hour compared to only $15.25 in neighboring Kern County. The housing price differentials are staggering. The average single childless adult living in Santa Barbara can expect to pay over $20,200 in housing costs annually compared to just $8,500 for a similarly situated adult in Kern (Glasmeier, 2021).

FIGURE 3: MINIMUM WAGE REQUIRED TO MEET BASIC LIVING STANDARDS FOR A SINGLE ADULT BY COUNTY (Glasmeier, 2021)

These expansive differences in the cost of living across California contribute to the state's widening income inequality. Eighteen percent of California children live in poverty, while 8.4% of the state's households face food insecurity severe enough to receive federal food stamps. These gaps grow when factoring the race of the household. Fifteen percent of Black Californians, 15% of Native Californians, and 13% of Latino Californians receive federal SNAP benefits compared to just 5% of their White and Asian neighbors. Twenty percent of Black Californians and 18% of Latino Californians live below the poverty line, compared to just 9% of White Californians. Note, further, that the federal poverty line is measured at an annual income of $12,880, which represents only 22% of the living wage required to meet basic subsistence in Marin, San Francisco, and San Mateo Counties (Glasmeier, 2021). The discrepancy between federal poverty numbers and the county cost of living illustrates another issue for policy makers: traditional measures of socio-economic need fail to appropriately capture the depths of California's affordability crisis. A wage three times the federal poverty limit may not meet traditional measures of need, but in many parts of the state, an annual income of $38,000 is far short of the most basic standards of living (Assistant Secretary for Planning and Evaluation, 2020; Glasmeier, 2021).

The new Biden administration has committed to tackling affordability issues both by increasing incomes and increasing housing supply. The inclusion of an expansion of the earned income and child tax credits in the American Rescue Plan are estimated reduce the number of children in poverty in California by 1.6 million (Marr et al., 2021). Biden's subsequent infrastructure program includes $213 billion in affordable housing grants so long as cities relax exclusionary zoning regulations. While the bill has yet to pass, the inclusion of the grants represents a seismic shift in the federal government's approach to affordability in high-cost states (Ackerman and Friedman, 2021).

Such actions at the federal level, however, have not been met with the same urgency at the state level. Small regulatory changes have been attempted to increase the housing supply. In 2017, a state law relaxed rules around accessory dwelling units (ADUs); small apartments in a backyard or garage commonly known as granny-flats (Capps, 2021). However, these small successes have been met with far more dramatic defeats. A 2020 attempt to update California's zoning laws to encourage transit-oriented development failed to garner any of the nine Democrats representing Los Angeles County in the state senate and died by three votes (Dillon, 2020). An attempt to increase local governments' authority to enact rent control failed with nearly 60% of the vote in the 2020 general election (Weber, 2020).

The complexity of the crisis necessitates analyzing the price effects of any housing policy particularly in the high-cost counties along the Southern coast and Bay area. Should a policy increase housing prices by more than they their offsets, it is likely to exacerbate existing inequities that have contributed to California's ongoing affordability issues.

RESEARCH QUESTIONS AND EVALUATIVE CRITERIA

The remainder of this report will answer two principal questions about the intersection of affordability and environmental risk:

- Where are the communities with the most acute economic needs and the communities most vulnerable to environmental threats?
    - Is there an overlap between these low-income communities and the environmentally vulnerable communities?
    - Are these "dual crisis" communities more prevalent in inland areas or near the coasts; more urban or rural?
    - How many "dual crises" communities are in jurisdictions who have legislated limits to current or future natural gas connections?

- How are costs and benefits (financial, environmental, etc.) distributed between advantaged and disadvantaged communities when state and local jurisdictions mandate or incentivize full household electrification? How do these costs and benefits compare to the status quo?
    - Are these costs and benefits distributed equitably between low-income or environmentally vulnerable communities and more privileged communities?
    - How are these costs and benefits distributed geographically? Do inland or coastal communities pay more, rural or urban communities?

These questions are principally based on conceptions of equity for which we define in three ways:

1. **Socioeconomic equity:** electrification can only be equitable if disadvantaged communities have an equivalent or greater share of the benefits and an equivalent or smaller share of the costs. This principal of equity is based on the concept of marginal utility in which an otherwise equivalent benefit given to advantaged and disadvantaged communities represent a greater return for low-income families due to the relatively higher share of a low-income family's income the benefit represents. For these purposes, due to the legacy of systemic racism and the high correlation between race and social mobility, we incorporate race as a primary disaggregation for analysis.

2. **Environmental equity:** electrification can only be equitable if communities most disadvantaged by the environmental effects of pollution and climate change are the ones most likely to benefit. As with socioeconomic equity, this equity principal relies on concepts of marginal utility. A small reduction in pollution across all communities in a region is likely to have greater benefit to communities already inundated with pollution then those with comparatively fewer pollution issues. We define this by disaggregating outcomes across four pollution risk categories defined in the methodology section.

3. **Socio-political equity:** for this criterion we consider the political and social inequities between coastal communities and inland communities as well as urban and rural communities. This disaggregation reflects the oft discussed inequities in political power between coastal urban centers like Los Angeles and San Francisco and rural and inland communities. An equitable proposal will not see a disproportionate scale of benefits go to politically advantaged communities over those with less institutionalized authority.

Subsequent responses to these research questions will disaggregate impacts across communities along each equity scale, first by comparing the frequency of environmental and social vulnerability across divides and second by selecting a group of case cities representing different cross sections of the equity divide. These methods are detailed in the subsequent methodology section.

II. METHODOLOGY

This report uses two principal methodological approaches. First, the report identifies the size, scope, scale, and location of environmental and social need using an analysis of pollution and socio-economic data across California's 8,000 census tracts. The methodology for this analysis begins on page 17. Second, using cities identified in the geographic analysis, the report estimates the typical household costs and benefits of a local electrification mandate across both financial and environmental impacts. The methodology for this analysis begins on page 22 and is followed by several strengths and limitation of this methodological approach (page 27). Additional details about both analyses are included in the technical appendix starting on page 55. For more information on data sources see page 53.

IDENTIFYING VULNERABLE COMMUNITIES

Answering the first research question required the completion of three principal tasks. To establish the **"where"** of the research question, the analyst required a chosen set of geographic boundaries. For this purpose, the report uses five geographic levels for comparison and analysis. These include the state of California, the SoCal Gas service area, the climate regions assessed in California's Fourth Climate Change Assessment report (shown in Figure 4), a selection of sample cities (selection process to be detailed later), and census tracts (Bedsworth et al., 2018). Most principal among these, however, are **census tracts**. Census tracts are the second smallest geographic unit of analysis defined by the United States Census and represent the principal proxy for the communities called for in the research question (U.S. Census, 2019a). These geographic shapes divide California into 8,034 communities of approximately 5,000 residents each (U.S. Census, 2019b). All data used for this analysis is collected at this tract level and aggregated to the state, regional, and city levels.

FIGURE 4: CALIFORNIA CLIMATE REGIONS
(Bedsworth et al., 2018)

Second, the research question required evaluative standard for identifying communities with the "**most acute economic needs."** For this purpose, the analysis prompted the creation of a **social-vulnerability index** based on the framework established by the State of California's CalEnviroScreen program (Blumenfeld and Zeise, 2018). Social-vulnerability indices are measures of compound effects of multiple thematic variables into a single community risk factor (Cutter, Boruff, and Shirley, 2003). These indices allowed us to compare the aggregated challenges and risks across communities through a single continuous value. The socio-economic indices include:

- **Social Cost of Living Index:** this measure examines the ease with which residents of a community are achieving basic standards of living. This is defined by using a basket of demographic factors that mirror the five of the cost categories identified in the Massachusetts Institute of Technology's Living Wage Calculator for California (Glasmeier, 2021). These five cost categories are detailed in table 1. Using data from CalEnviroScreen and the United States Census, a score was calculated based on how far a given census tract falls from the statewide average across each of the five measures. These were weighted based on the total portion of a single parent's budget they consume annually and add them together accordingly. Tracts in the top quartile of scores were flagged as those with the "**most acute"** cost-of-living challenges.

TABLE 1: SOCIAL COST OF LIVING INDEX CATEGORIES

Category	Min. Cost	Weight	Proxy Variable
Food	$5,574	10%	SNAP Recipient Rate *Source: U.S. Census Bureau*
Health	$8,323	15%	Health Insurance Rate *Source: U.S. Census Bureau*
Transportation	$8,987	16%	Average Commute Time *Source: U.S. Census Bureau*
Children	$10,641	19%	Households with Children *Source: U.S. Census Bureau*
Housing	$22,440	40%	Housing Burden *Source: CalEnviroScreen*
TOTAL	$55,965	100%	

- **Social Mobility:** this measure gauges the degree to which social factors impede a community's ability to meet basic living standards across generations. Based on data created by the Opportunity Insights project at Harvard University, the upward mobility score looks at the wages earned by the children of middle-income families by their mid-30s. This value differentiates communities most likely to meet cost-of-living challenges posed to the next generation from those falling further behind. Additionally, this index provides an effective means of examining the aggregated impacts of systemic racism, incarceration, educational inequities, etc., that often limit communities' earnings potential and weaken the mechanisms that have historically moved them out of poverty (Chetty et al., 2020a). As with the social cost-of-living index, the social mobility score is calculated based on how far a community falls from the statewide average. **Communities with scores in the highest quartile are determined to have the "most acute" social mobility challenges.**

Third, the research question requires the analysis to identify the communities **"most vulnerable to environmental threats."** As with the socio-economic distress indices, the environmental risk index uses data produced for CalEnviroScreen to identify threats from pollution. Methodological concerns with CalEnviroScreen led to the development an alternative statistical index using the same data (for more detail on the methodological process, see the technical appendix). Instead of measuring eleven environmental threats across two separate indices like CalEnviroScreen, this index uses six pollution risk measures across one index. CalEnviroScreen collected data across various state, local, and federal sources, and equivalent Mexican sources to account for pollution in border communities (Blumenfeld and Zeise, 2018). These pollution risks include:

- **Air Quality:** this measure accounts for air pollution across three pollutants: diesel pollution, the concentration of particulate matter 2.5 micrometers or smaller (PM2.5), and ozone concentration – all of which are known to be hazardous to human health.

- **Industrial Pollution:** industrial pollution includes ground and air pollutants resulting from agricultural and production-related activities. These include toxic pesticides and toxic air pollutants from heavy industry.

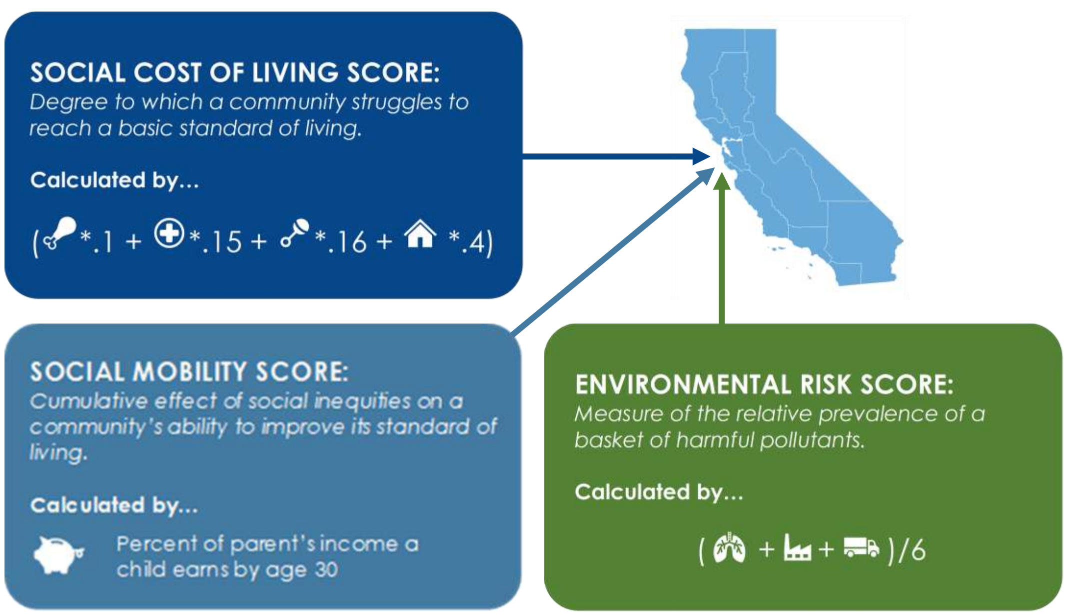
- **Traffic:** traffic pollution measures the average traffic volume in a census tract allowing for an account for both the risks of exhaust-related pollution (Blumenfeld and Zeise, 2018).

TABLE 2: ENVIRONMENTAL RISK INDEX CATEGORIES

Category	Measures
Air Quality	Diesel exhaust Particulate matter less than 2.5 mm (PM2.5) Oxone concentration
Industrial Pollution	Pesticide concentration Toxic release from facilities
Traffic	Traffic congestion

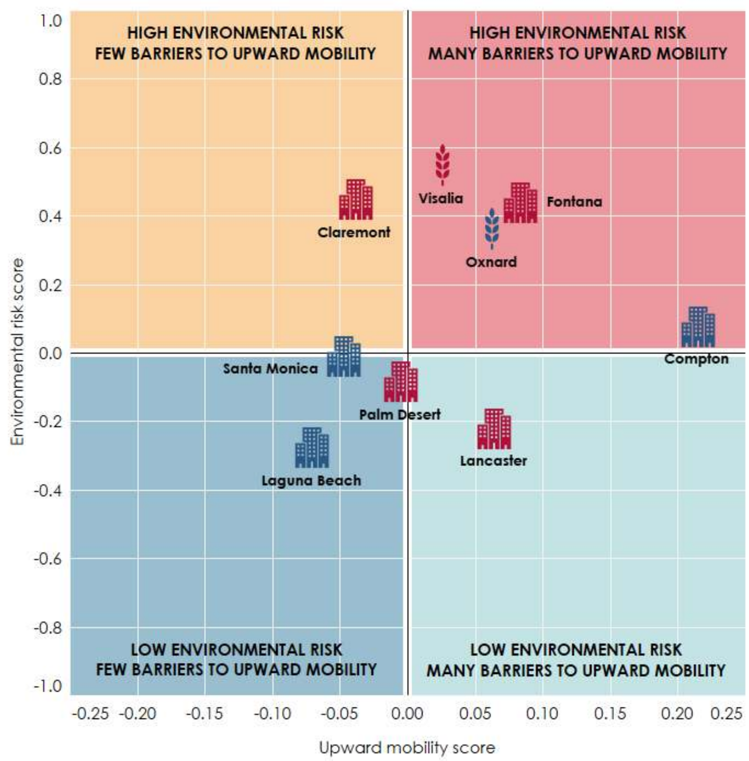
Details on how these concentrations were measured are included in the technical appendix. As with the socio-economic measures, these risks are calculated based on how far the concentration of a given pollutant in a census tract is from the statewide average. **The top quartile represents the communities "most vulnerable" to environmental threats.**

FIGURE 5: MEASURES OF ENVIRONMENTAL AND SOCIAL DISTRESS



This identification process enabled this analysis to examine how risk accumulates from both environmental and socio-economic sources. Using the top quartiles of all three social-vulnerability indices, the analysis can quantitatively identify "**dual crisis communities**," **or those communities that face acute challenges from both socio-economic stresses and environmental risk.** This intersectional perspective led to the creation of two matrices to identify cities that represent the diverse array of communities impacted by the two core risk factors. These matrices were constructed by plotting a city's average environmental risk score against the average social mobility and social cost-of-living scores. Since both socio-economic indices are highly correlated, the insights from both matrices follow a similar pattern.

FIGURE 6: CITIES BY AVG. ENVIRONMENTAL RISK AND SOCIAL MOBILITY SCORE



After reviewing where California cities fall across these intersections, it became clear that each quadrant includes cities with a set of distinct characteristics. Modeling a state or regional impact of an electrification policy would represent an unlikely venue for such policies to be implemented and miss unique costs and benefits accrued to each category of city. **As such, nine cities were selected to serve as case studies for the intersections of socio-economic and environmental risk as well as urban/suburban vs. agricultural and coastal vs. inland divides.** These cities are displayed in figures 6 and 7 and detailed below:

- **Compton** is a mid-sized community in central Los Angeles County with acute cost-of-living issues and substantial barriers to upward mobility. As a predominantly urban community (represented by the building icon), Compton has significant traffic congestion issues and toxic release from industrial facilities. However, Compton is closer to the coast than many other communities in the analysis (represented by the blue color). As a result, it has less ozone pollution than communities further inland.

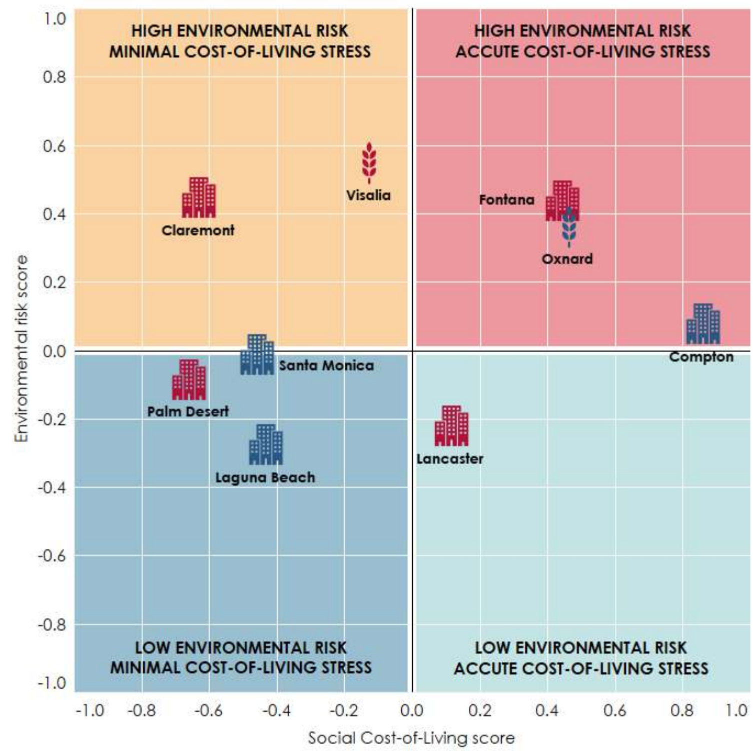
- **Claremont** is an upper-middle-income community in the San Gabriel Valley portion of Los Angeles County. Claremont is among the four cities selected with relative economic privilege, few cost-of-living stresses, and comparatively high upward mobility. As a suburban inland community (represented by the red color), Claremont has substantial air pollution issues with relatively high traffic congestion.

- **Fontana** is a low-income community at the southern tip of San Bernardino County. As with Compton, Fontana has substantial cost-of-living challenges and limited upward mobility. Its location between the 10 and 210 freeways and inland location makes it among the most threatened from air pollution and traffic congestion. Yet as a predominantly suburban community, Fontana has limited pollution from pesticides. The Fontana city council approved a balanced energy resolution in May 2019 (Lewis, 2019).

- **Laguna Beach** is a small wealthy city in coastal Orange County. As a coastal suburban community, Laguna Beach has limited air pollution and limited pollution from predominantly agricultural sources. The concentration of wealth makes it among the least economically distressed communities in the sample.

- **Lancaster** is a mid-sized community in the Antelope Valley portion of north Los Angeles county. As with many inland communities, Lancaster has substantial ozone pollution issues but few other environmental threats. As a suburban community, it has little pollution from pesticides and toxic release from industrial facilities. Its location on the periphery of Los Angeles county means few traffic congestion issues and minimal PM2.5 pollution.

FIGURE 7: CITIES BY AVG. ENVIRONMENTAL RISK AND SOCIAL COST-OF-LIVING SCORE



- **Oxnard** is a low-income agricultural community along the Ventura County coast. Like Santa Maria and Salinas to the north, Oxnard is among a few coastal agricultural communities with high pesticide pollution but relatively good air quality and limited traffic congestion. It is predominantly low income with substantial cost-of-living stresses and significant barriers to upward mobility.

- **Palm Desert** is a wealthy resort community in the Coachella Valley region of Riverside County. Its relatively wealth means few affordability challenges and relatively high upward mobility. Unlike similar inland communities, however, Palm Desert has few pollution challenges with minimal PM2.5 pollution and little pollution from agricultural sources. Riverside County approved a balanced energy resolution in December 2019 (Southern California Gas Company, 2019).

- **Santa Monica** is a wealthy coastal community along the Los Angeles County coast. While it has economic challenges, Santa Monica is plagued by traffic congestion despite its good, coastal, air quality. Santa Monica is the only city in the sample that has approved an electrification ordinance through a local preference code passed in September 2019 (Newsome, 2019).

- **Visalia** is a low-income agricultural community in Tulare County in the San Joaquin Valley. Despite having fewer cost of living challenges than its Los Angeles, Orange, and Inland Empire neighbors, Visalia has substantial upward mobility issues. As with Oxnard, Visalia has significant pesticide pollution, and the air pollution issues of other inland communities.

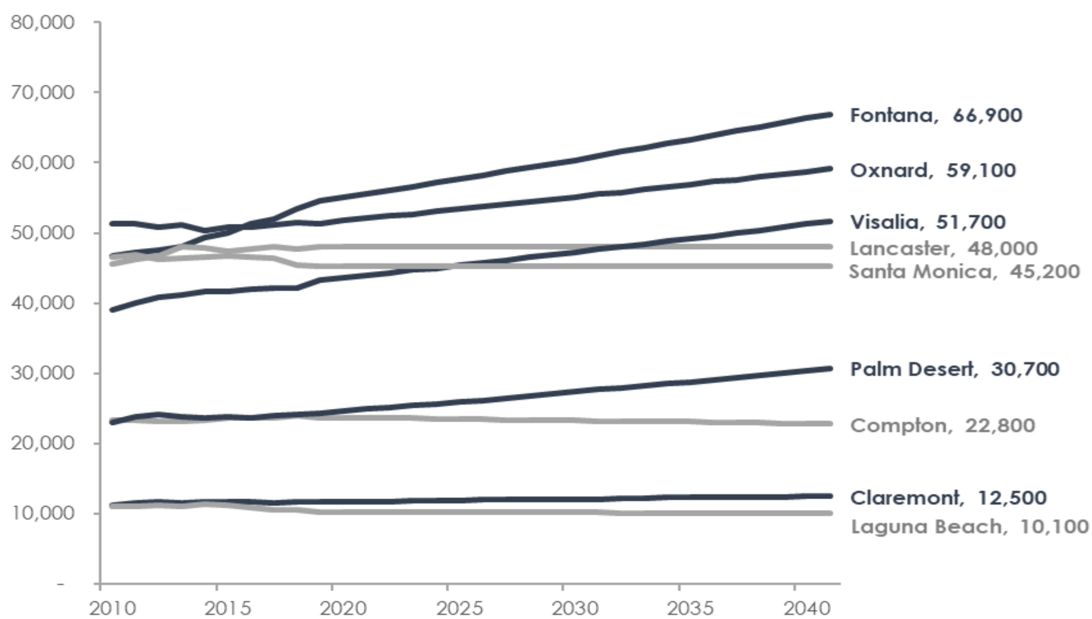
The diversity of these communities allowed the analysis to examine how the scale of financial and environmental tradeoffs attributable to electrification policies differ across different spectrums of environmental and social privilege.

COST-BENEFIT ANALYSIS

The cost-benefit analysis models the impacts of two types of electrification mandates on each of the nine cities identified in the previous section. **The first scenario is the indicative of the most common type of electrification mandate: a ban on natural gas infrastructure on all new home construction.** This is largely based on the policy implemented by the City of Berkeley in January 2020 in which all new construction was required to be all electric with no exceptions for cooking (Berkeley, California, Municipal Code § 12.80). **The second scenario is as of April 2021 uncommon, but likely to be discussed as the risks of climate change become more apparent. Total residential electrification would require full electric appliances for all new construction as well as retrofits and new appliances for all existing infrastructures.** For this purpose, the analysis assumes the policy is implemented starting in year zero. This model tracks these impacts over 20 years with a discount rate of 3.2%.

Projected housing growth was highly significant to this analysis. Based on data from the United States Census, the analysis assumes that each of the nine cities in the analysis will grow at a rate consistent with their growth in the previous year. Using the ratio of houses to population in 2018, the analysis calculated a projected growth in housing units with each additional resident. These projections are shown below. Four cities were projected not to grow either because existing space inhibits additional

FIGURE 8: PROJECTED GROWTH IN HOUSING UNITS BY CITY



population, or because of falling demand. The remaining cities were projected to grow, with Fontana growing the fastest of any city in the analysis (U.S. Census, 2019e).

Financial Costs and Benefits: The model financial impact assumes that four principal household appliances are targets of electrification: stoves/ranges, clothes dryers, furnaces, and water heaters. All four of these appliances were present in least 76% of Pacific region homes, with a varying balance between natural gas and electric options (Office of Energy Consumption and Efficiency Statistics, 2015).

TABLE 3: BALANCE OF NATURAL GAS AND ELECTRIC APPLIANCES

Appliance	Natural Gas	Electric	None
Stove/Range	46%	43%	11%
Clothes Dryer	25%	51%	24%
Furnace	54%	31%	15%
Water Heater	64%	35%	0%

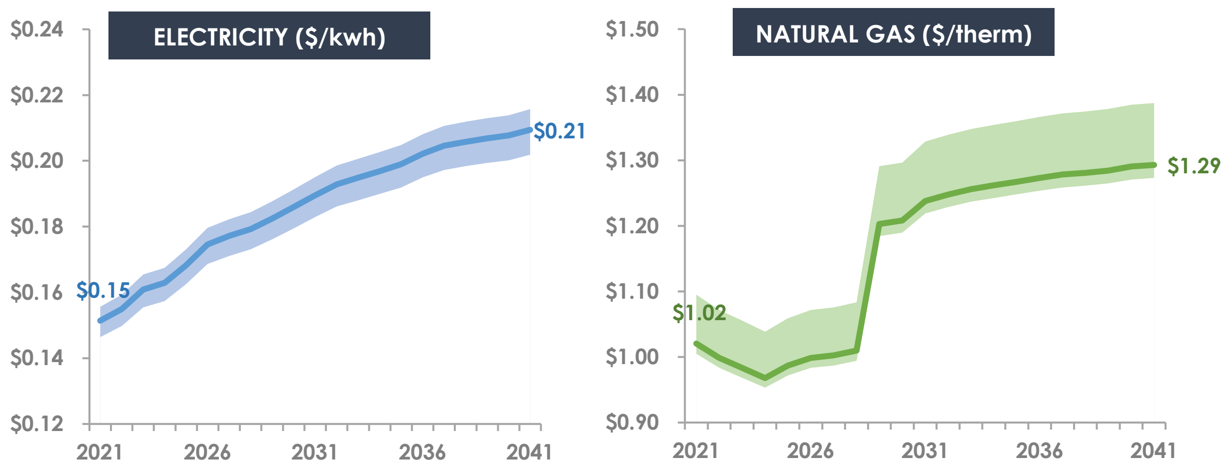
Modeling the costs required incorporation of three principal categories of costs and benefits. First was the purchase of electric appliances and the resulting savings from not purchasing natural gas appliances. For new homes both costs and savings occur in the year of the homes purchase, as the new homeowner would want to have these appliances available upon moving in. For existing homes, the savings from natural gas appliances do not occur until electric appliances need replacement. This is due to the concept of **sunk costs;** natural gas appliances purchased without the context of the electrification mandate are ultimately not considered as homeowners are essentially forced to eat the costs of previously purchased appliances. Additional appliance purchases were added to the analysis based on the replacement rate of natural gas and electric appliances. In general, natural gas appliances had a longer life cycle then comparable electric appliances, however no life cycle was short enough for a consumer to purchase an appliance more than once in the twenty-year span. Assumed prices and lifecycles of appliances come from the Energy Information Administration's survey of existing appliance stock.

Second was the additional cost of electricity. This calculation required two components. First, the average electricity and natural gas usage for each appliance was calculated based on the average annual energy usage of Pacific region homes in the EIA's 2015 survey of appliance usage (U.S. Energy Information Administration, 2019). Second, projections of energy cost were calculated using projections from the U.S. Department of Energy's National Renewable Energy Laboratory. These energy price projections are shown in figure 9. NREL projects steady increases in both natural gas and electricity costs over the next 20 years with small differentials by county (National Renewable Energy Laboratory, 2020). Tulare county is expected to have the highest electricity prices among those in the sample, while San Bernardino County is expected to have the highest natural gas prices. The differential between the cost of running appliances on natural gas versus electricity were subsequently categorized based on whether the total was positive or negative.

An analysis by Energy + Environmental Economics ("E3"), a consulting group, found that most California homes built before 1978 would require retrofits for electric appliances amounting to approximately $4,256 per home (Mahone, et al. 2018). These costs were subsequently applied to all homes built before 1980 based on the U.S. Census Bureau's estimates of housing age in each city (U.S. Census Bureau, 2019d).

FIGURE 9: ENERGY PRICE PROJECTIONS

Note: The shaded areas represent the range based on the 6 counties included in our analysis



Environmental Benefits: There are only a few large electric and gas utilities in the state of California: Pacific Gas & Electric ("PG&E), Southern California Edison ("SCE"), Southern California Gas Co. ("SoCalGas"), and San Diego Gas and Electric (SDG&E). All of them are regulated by the California Public Utilities Commission and report to the Energy Information Agency (EIA), and the Environmental Protection Agency. SCE's product is electricity, which it sells to customers by the kilowatt-hour. SoCalGas sells natural gas and on customer bills charges in therms—a measure of the heat content that "is equal to 100 cubic feet of natural gas (*What Is a Therm?*, 2021). Customers typically use about 468 therms per year in California (Rockzsfforde, 2015).

After determining the amount of energy used by a natural gas or electric appliance, the amount of GHGs being emitted was calculated based on the level of carbon intensity—depending on the carbon intensity of the fuel used to produce that energy. SCE released the carbon intensity of each MWh it produces. In 2020, SCE produced 0.24 MT of CO2 equivalent for every MWh and has a goal of producing 0.11 MT of CO2e per MWh by 2030 (*Our Sustainability Goals*, 2019). This represents a 56.4% decrease over ten years represented in the analysis as a 5.64% increase annually. Conversely, natural gas is a fossil fuel, so the emissions factor of natural gas usage per therm is steady. Additionally, the analysis uses an estimate of the carbon emissions from natural gas calculated by the EPA of about 0.0053 metric tons of CO2e per therm (US EPA, 2018). This estimate is in CO2 equivalent, which adjusts the emissions from natural gas in terms of CO2. Methane, or CH4 is widely estimated to have 25 times the warming effect of CO2 and emissions in terms of CO2e captures that adjustment (California Air Resources Board, 2020b).

After finding the emissions per unit consumed, the next task was to find how much of each energy source each city in the sample were projected to use during the study period in addition to projecting household energy use. Household energy usage is calculated by the Energy Information Association on a county level. To conduct city-level analysis, adjustment was required. After pulling the number of households in the county and in the city, the analysis calculates the percentage of households in the county that the city under examination comprises. Next, the analysis applied the percentage of households in the county that belong to a certain city to the energy usage of that city. This assumption enabled to a city-level analysis.

TABLE 4: COUNT OF CITY HOUSEHOLDS AS A PERCENT OF COUNTY POPULATION

CITY	HOUSEHOLDS	COUNTY	HOUSEHOLDS	CITY AS A % OF COUNTY
Claremont	11,763	Los Angeles	3,579,329	0%
Compton	23,658	Los Angeles	3,579,329	1%
Fontana	55,068	San Bernardino	2,180,085	3%
Laguna Beach	10,221	Orange	1,118,110	1%
Lancaster	48,075	Los Angeles	3,579,329	1%
Oxnard	51,751	Ventura	291,512	18%
Palm Desert	24,652	Riverside	857,148	3%
Santa Monica	45,301	Los Angeles	3,579,329	1%
Visalia	43,602	Tulare	151,603	29%
California	14,366,336		14,366,336	100%

Next, to understand, the impact of the two policies, the analysis calculated the household level consumption for each city. To find household level consumption, the city level consumption is divided by the number of households in a given city. From an average household consumption is assumed without eliminating outliers, which is impossible in already aggregated data. This process enabled the analysis of the estimated energy usage per household.

When deciphering the amount of natural gas appliance use in California, it became clear that the balance of appliance energy sources could significantly affect the analysis. A sensitivity analysis accounted for the possible impact of homes using different energy sources for different appliances, in determining the percentage of households that run on all-electric appliances. Many households already use electric appliances. These data indicates that a maximum of 35% of households are all-electric, since 65% of homes have at least a gas-powered hot water heater. By altering how much of the city is all electric, the relative intensity of natural gas use by mixed-fuel homes is raised.

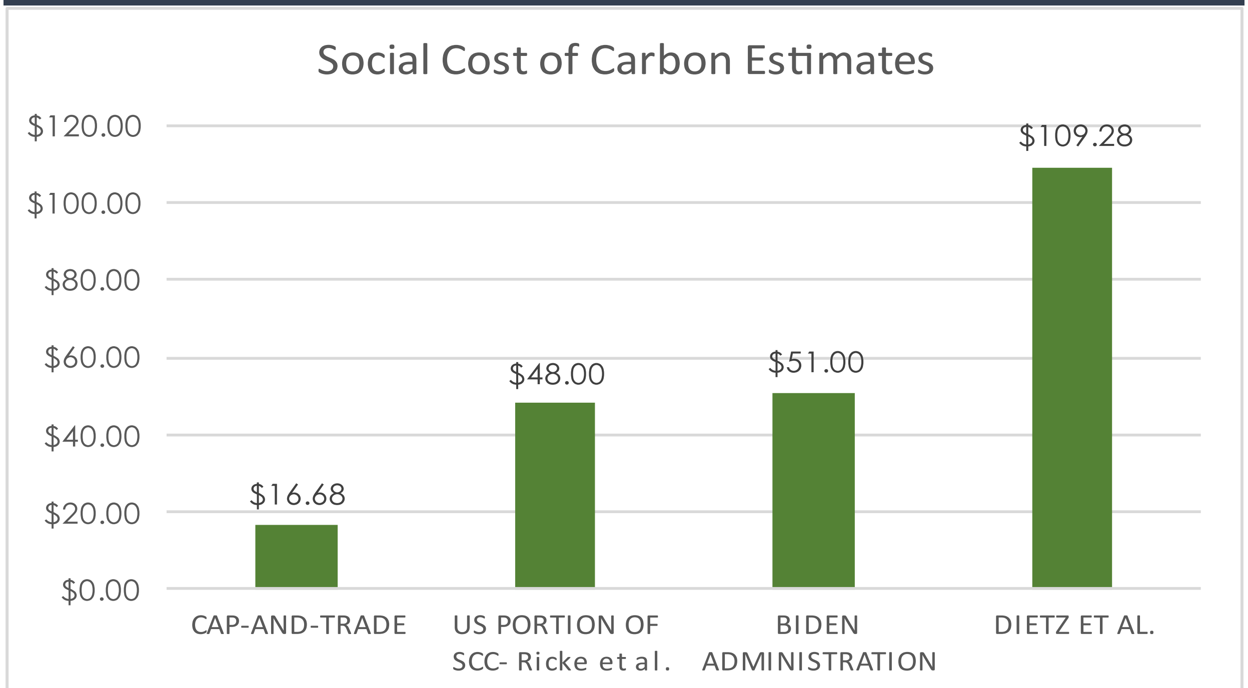
Social Cost of Carbon Calculation: Additionally, a value of the social cost of carbon was required in order to adequately quantify the monetary impacts of climate change. The economy does not price carbon emissions, but CO2 and other GHGs cause significant negative externalities, most notably, climate change. Higher social costs of carbon indicate higher estimations of the negative impacts of climate change (Dietz et al., 2020).

Estimates of the social cost of carbon vary. California's current Cap-and-Trade regime has priced each metric ton of CO2e at $16.68 (California Air Resources Board, 2020). In contrast, the Biden administration has reinstituted the Obama administration's $51.00 per metric ton. An attempt to estimate a global price on carbon and establish what each country should pay showed that the U.S. should price each metric ton of carbon at $48 per metric ton (Ricke et al., 2018). The high-end estimate comes from Dietz et al., who based their estimation on the carbon price required to prevent the world from warming past 1.5°Celsius.

California's a Cap-and-Trade Program is "a key element of California's strategy to reduce greenhouse gas (GHG) emissions". In 2006, California passed AB 32 which requires California to lowers its GHG emissions to 1990 levels by 2020. California achieved this goal in 2016, four years ahead of schedule (Barboza, 2018). The goal is to drive to 40% below 1990s levels by 2030. The program began in earnest in 2013 and gives out an ever-decreasing supply of carbon allowances, which are then auctioned off. By decreasing the supply of allowances, you increase the price of the allowance. The most recent allowance yielded a carbon price of $16.68 per metric ton (California Air Resources Board, 2020a). The Cap-and-Trade program started in 2013 and has been giving out fewer allowances each year. California conducts an auction every quarter and entities with high emitting facilities bid on the allowances. Prices vary slightly but have continued to progress in a general upward trend.

Upon reentering the White House, the Biden administration reasserted a social cost of carbon of $51 per Metric of CO2 equivalent for federal cost-benefit analysis. This is based on work completed by the interagency working group during the Obama administration. The Interagency Working Group brought together scientists and professionals in climate science and economics to arrive at the price of $51 per hour. This will form the upper bound of the sensitivity analysis of the social cost of carbon. There are other estimates that the proper social cost of carbon in United States might be $48 (Ricke et al., 2018).

FIGURE 10: SOCIAL COST OF CARBON ESTIMATE $2020



A high-end estimate comes from an evaluation based on keeping global emissions to less than 1.5 C. With that goal in mind, a group of scholars estimated that a social cost of carbon necessary to lower global emissions would be above $100 per metric ton (Dietz et al., 2020).

STRENGTHS AND VULNERABILITIES

This methodological approach has several core advantages. By using data from CalEnviroScreen, the analysis utilizes a dataset vetted by a robust regulatory process regularly reviewed by diverse stakeholders through a recognized comment period. While the analysis articulated in the appendix illustrates potential weaknesses in the specific mechanics of CalEnviroScreen, the data sources themselves are robust and vast. Additionally, multidimensional social vulnerability indices are widely used across disciplines to assess social needs in individual communities. The Centers for Disease Control and Prevention use a similarly constructed social vulnerability index to target vaccine distribution to vulnerable communities (Centers for Disease Control and Prevention, 2021). Using this method in conjunction with recognized and accepted data sources creates a robust means of assessing local social and environmental vulnerabilities.

However, it is important to understand the liabilities of using such an analysis. Census tracts are among the smallest units of analysis available from the U.S. Census, but their size is still comparatively large. Tracts range in size around an average of 5,000 residents with some being considerably larger in geographic size to reach that threshold. As such, these constraints limit the ability of this analysis to assess differences *within* census tracts; leading to the potentially weak assumption that all people within a census tract face the same social and environmental circumstances. This may not be a safe assumption especially in tracts that cover vast geographic areas. Pollution risks for example, could be concentrated around a particular farm or a military base leading to high environmental risk scores for the entire tract rather then just the most impacted communities. Similar issues stem from recording social factors like the financial burdens of childcare. While the data used to estimate the distribution of childcare costs across communities by making inferences through the simple number of families with children, the data cannot tell us about added costs from for example, a lack of supply of childcare or health costs born from poor nutrition. As such, it is likely that the analysis understates the costs of childcare.

The cost benefit analysis also displays considerable strengths. First, by using robust data sources from respected government databases, the analysis aligns with similar studies conducted for state and regional clients. Housing data collected from the U.S. Census, energy pricing estimates from the respected Department of Energy's National Renewable Energy Lab, and appliance balances, usages, and costs from the U.S. Energy Information Administration allow the analysis to rest on stable footing.

However, this cost-benefit analysis does have several important liabilities. First, a lack of data on the potential efficiency improvements of household appliances limits projections of the energy costs for both natural gas and electric appliances. If electricity usage improves for electric appliances, the result could be a reduction in the comparative cost of running electric appliances over natural gas appliances. Additionally, limited data prohibited the modeling the number of current natural gas appliances that would ultimately be replaced within the twenty-year span of the model. This means that estimates of the cost savings for existing homes may be understated as it is only able to estimate the lifecycle costs for the electric appliances purchased at the point of the policy's implementation.

III. RESULTS

IDENTIFYING VULNERABLE COMMUNITIES

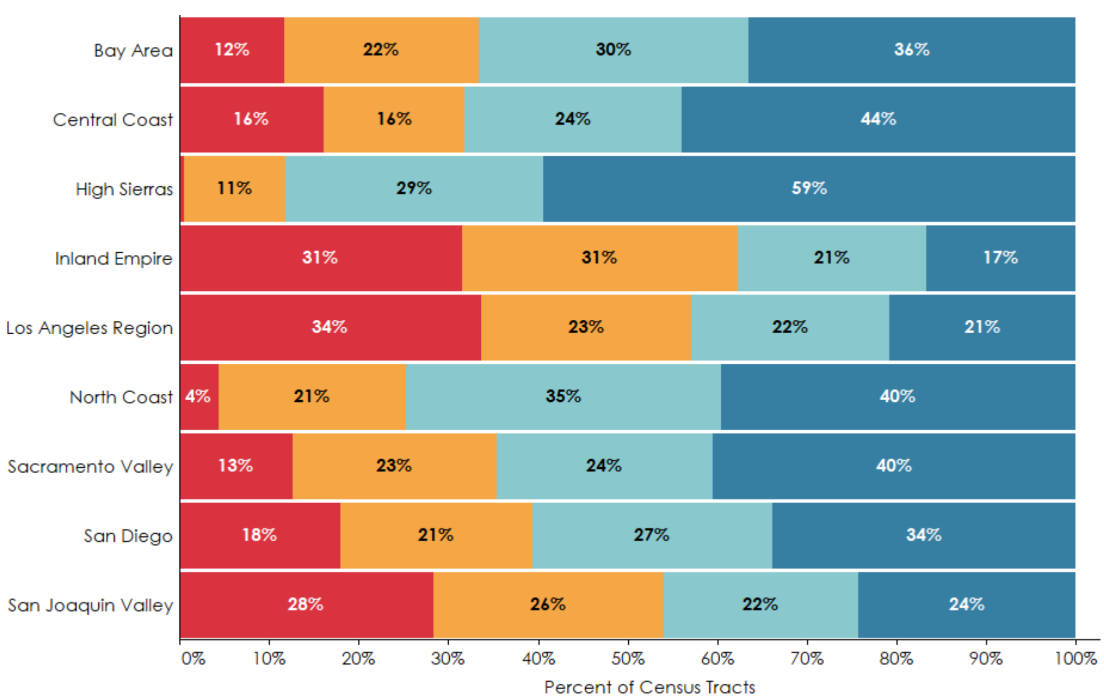
Where are the communities with the most acute economic needs?

The geographic analysis revealed that socio-economic vulnerability is present in virtually every corner of the state including the area served by SoCal Gas. The first index used to classify these, the social cost-of-living index, helped identify which communities had the greatest difficulty affording basic needs. These tracts represented a disproportionate percentage of Los Angeles, Inland Empire, and San Joaquin Valley census tracts as shown in figure 11 below. Communities with the highest proportion of tracts with the least acute affordability challenges were found in the High Sierra, Central Coast, Sacramento Valley, and Bay Areas. (A map of the full state can be found in appendix figure A1)

The second index, the social mobility index, helped identify communities that have had the greatest struggle maintaining and growing intergenerational wealth. This index showed many of the same patterns with the Inland Empire, Los Angeles, and San Joaquin Valley regions containing a disproportionate number of socially immobile tracts. However, this metric also identified considerable social mobility challenges in the North and Central Coast regions, which do not contain similarly stark rates of social vulnerability (see Figures A2 and A3 in the appendix for more detail). The subsequent sections will detail the prevalence of social cost-of-living challenges and social mobility within SoCal Gas' service area while also measuring equity gaps across racial groups. For a full map of all social cost-of-living scores see appendix figure A6.

FIGURE 11: PERCENTAGE OF CENSUS TRACTS BY REGION AND SOCIAL COST-OF-LIVING VULNERABILITY CATEGORY

MOST VULNERABLE ■ MORE VULNERABLE ■ LESS VULNERABLE ■ LEAST VULNERABLE ■

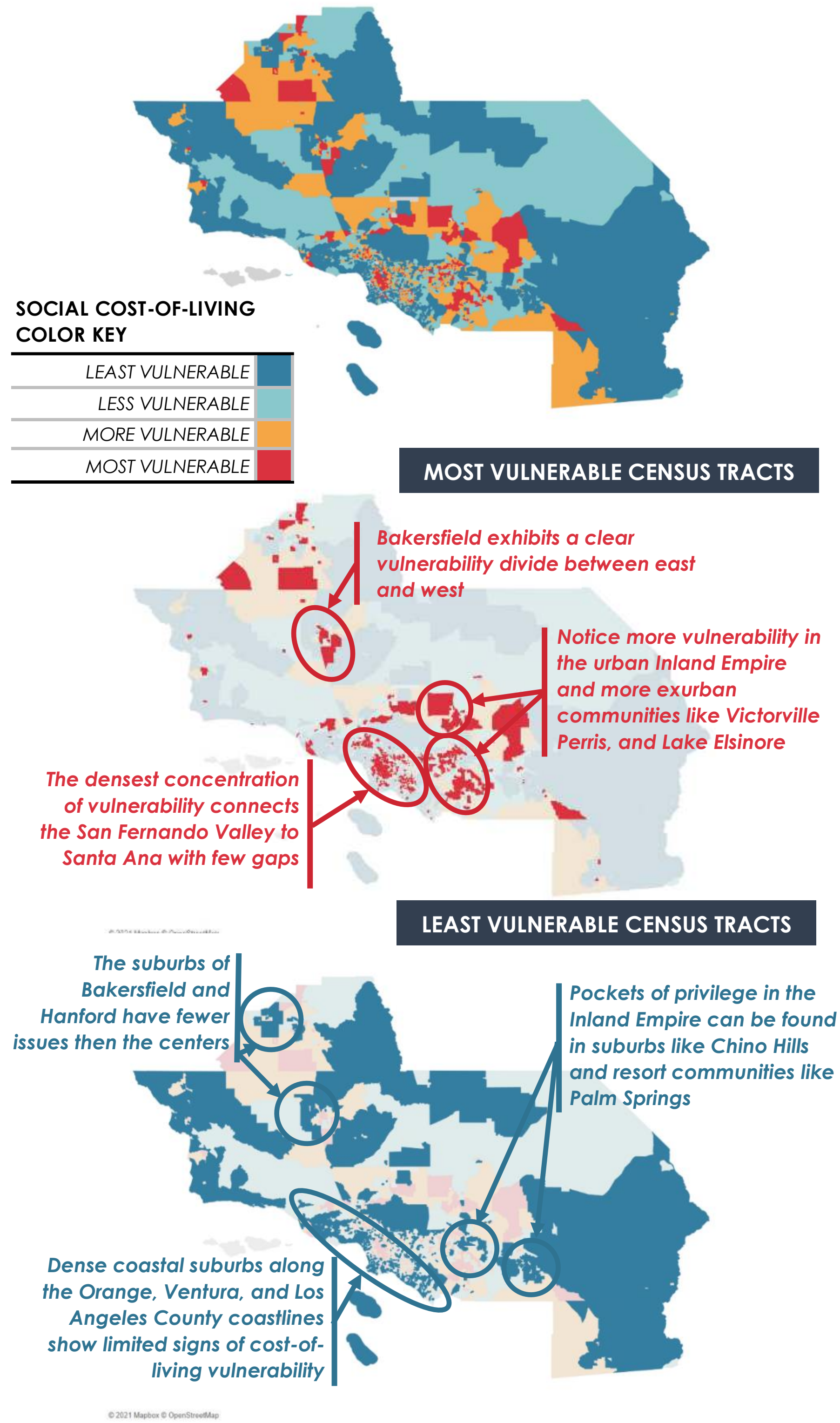


Social Cost-of-Living: In total, 32% of SoCalGas customers live in a census tract with the most acute cost-of-living challenges. An additional 26% of customers live in a tract with higher-than-average affordability issues compared to the just 19% who live in tracts with the least acute cost-of-living issues. These challenges most burden urban residents. In total, 26% of urban Californians live a census tract with the most acute cost-of-living issues compared to just 8% of rural Californians. Much of this urban vulnerability concentrated in South-Central Los Angeles, the eastern San Fernando Valley, central Orange County, San Bernardino and its surrounding cities, and exurban communities like Lake Elsinore, Oxnard, and Hemet. Rural vulnerability was most acute in the High Desert communities between Victorville and Palmdale. Vulnerability is also prevalent in the rural band of tracts east of Bakersfield and the tracts surrounding Tulare as shown in figure 12.

In the aggregate, affordability challenges impact coastal Californians at the same rate as inland Californians. 25% of inland and coastal Californians live in one of the most vulnerable tracts. Similarly, 33% of Inland and 31% of coastal SoCalGas customers live in the most vulnerable communities. However, coastal communities show wide disparities within a comparatively smaller area. Through much of the

FIGURE 12: SOCIAL COST-OF-LIVING VULNERABILITY CATEGORY OF CENSUS TRACTS

SOCAL GAS SERVICE AREA



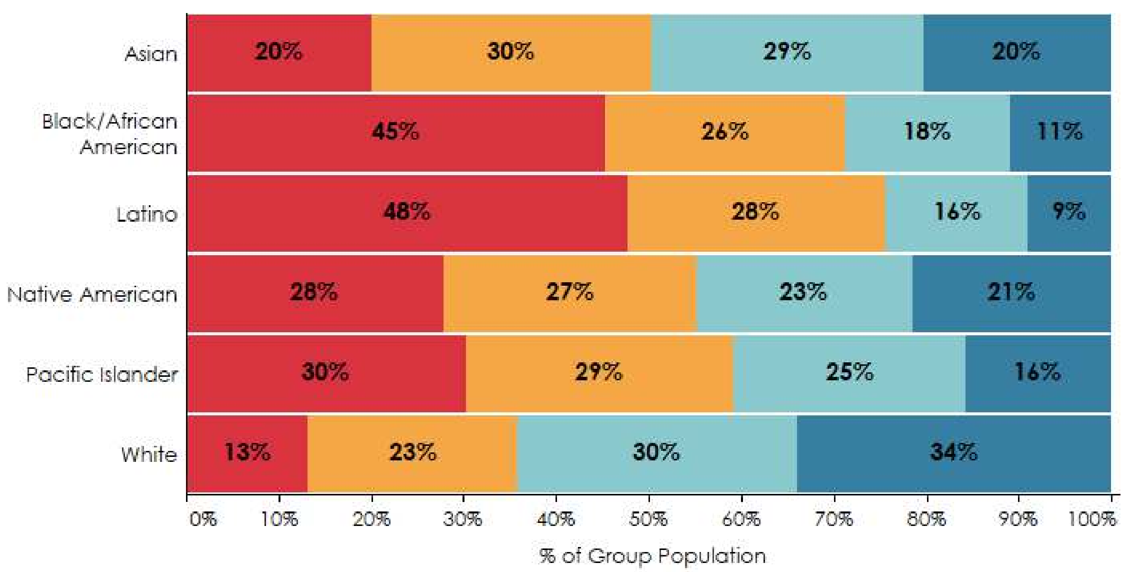
urban counties of Ventura, Los Angeles, and Orange, communities bordering the coast exhibited the least acute social cost-of-living vulnerability. This lays in contrast to the acute needs only a few miles inland. Communities like Compton, Westminster, and Santa Ana have some of the most acute social cost-of-living vulnerabilities despite being only miles away from privileged communities like the Palos Verdes Peninsula and Newport Beach. Most of the rural coastline of Santa Barbara and San Luis Obispo counties showed limited cost-of-living vulnerability. Pockets of vulnerability were identified in Santa Maria and the tract that houses Cal Poly San Luis Obispo; a largely residential university with students living on the support of parents and other family members.

People of color are more likely to live in the most vulnerable communities. 48% of Latinos and 45% of African American SoCal Gas customers live in the most vulnerable census tracts compared to only 13% of White customers. By contrast, 34% of White customers in SoCal Gas' service area live census tracts with the least acute cost-of-living challenges compared to just 11% of Black customers and 9% of Latino customers. **This amounts to an equity gap of 7% for Asian customers, 32% for Black customers, 35% for Latino customers, 15% for Native American customers, and 17% for Pacific Islander customers as shown in figure 13**.

FIGURE 13: PERCENTAGE OF RACIAL/ETHNIC POPULATION BY SOCIAL COST-OF-LIVING VULNERABILITY CATEGORY OF CENSUS TRACT

SOCAL GAS SERVICE AREA

MOST VULNERABLE ■ MORE VULNERABLE ■ LESS VULNERABLE ■ LEAST VULNERABLE ■

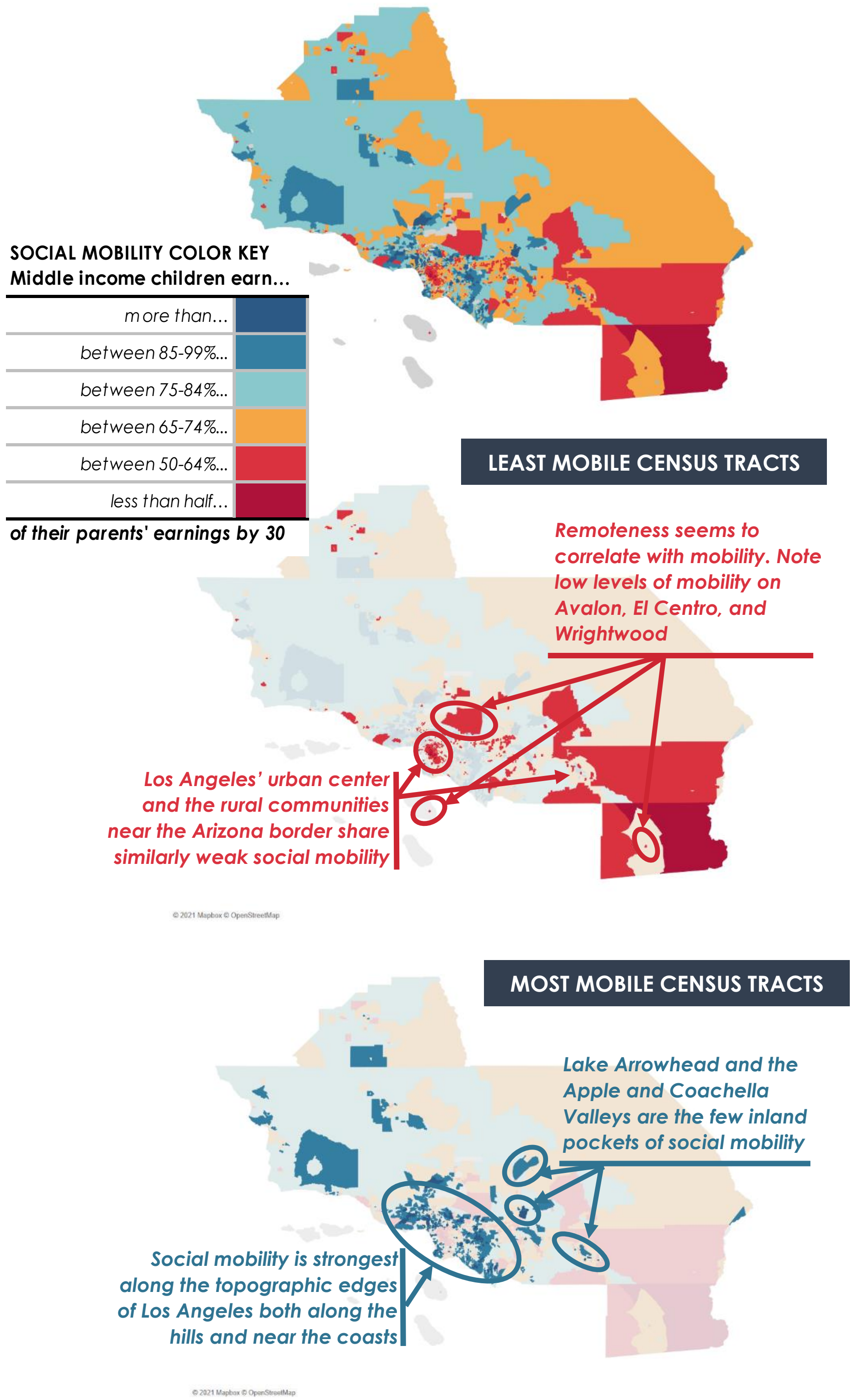


Social Mobility: In total, 11% of California census tracts housed middle income families with children earning less than 65% of their parents wages by age 30. Another 31% of tracts housed children earning between 65-74% of their parent's earnings, followed by an additional 58% earning 75% or more. Thirteen percent of SoCal Gas customers live in the least mobile census tracts. An additional 35% live in less mobile than average tracts, compared to 52% living in more mobile than average tracts (Chetty et al., 2020b).

Urban tracts were both more likely to be in the bottom tier of social mobility and the top tier with 13% of residents living in one of the least mobile tracts and 21% in the most mobile tracts. 6% of rural residents lived in least mobile tracts compared to just 12% in the most mobile tracts.

Urban social immobility was most pronounced in South-Central Los Angeles, San Bernardino and the exurbs of Ventura and Perris. Note, that unlike the social cost-of-living score, Santa Ana and the San Fernando Valley were not identified among the least mobile communities suggesting that these communities are on track to meet cost-of-living challenges with future generations. Rural social immobility was most prevalent in remote communities like Wrightwood, El Centro, and the vast desert lands east of the Salton Sea. Other pockets of limited

FIGURE 14: SOCIAL MOBILITY CATEGORY OF CENSUS TRACTS
SOCAL GAS SERVICE AREA



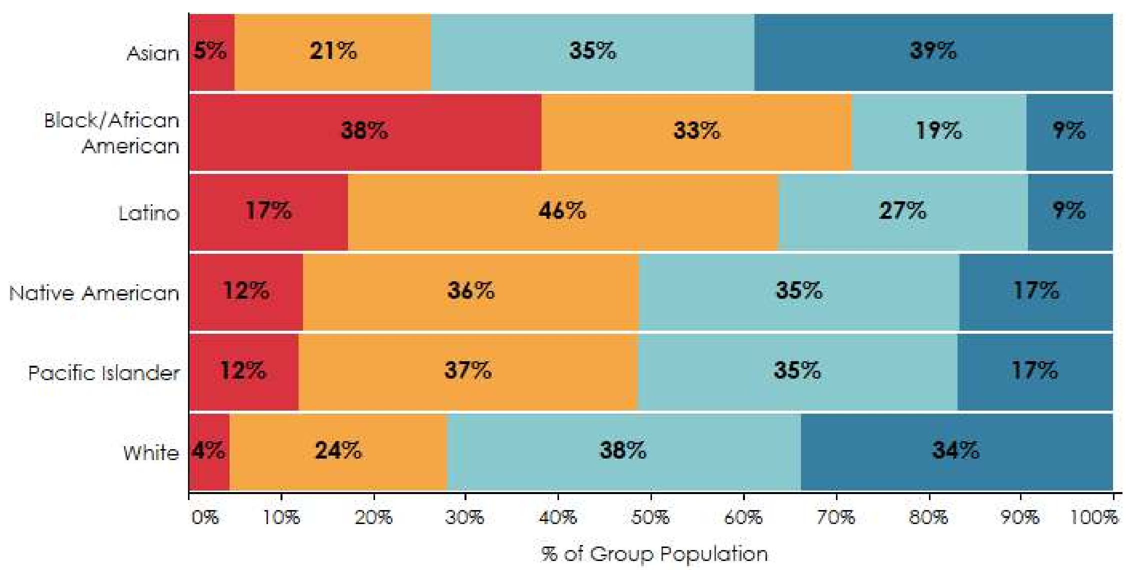
mobility were found in Avalon on Catalina Island and Tulare as shown in figure 14. While coastal and inland regions were home to approximately equal portions of residents in the least mobile census tracts lived in the most mobile tracts compared to just 9% of inland residents. Inland residents were substantially more likely to live in tracts that were less mobile then average (47% vs. 30%). The rims of Los Angeles were the most pronounced among upwardly mobile tract. This includes coastal communities across the South Bay, coastal Orange County as well as the exclusive hill communities around the Los Angeles Basin.

Black Californians in SoCal Gas' service area are substantially more likely to live in the least socially mobile census tracts. 38% of Black Californians live in the least mobile tracts compared to only 4% of White Californians. Asian customers are the most likely to live in the most mobile tracts with 39% of Asians living in the most mobile tracts compared to just 9% of Black customers. **This amounts to an equity gap of 1% for Asian customers, 34% for Black customers, 13% for Latino customers, 8% for Native American customers, and 8% for Pacific Islander customers as shown in figure 15.**

FIGURE 15: PERCENTAGE OF RACIAL/ETHNIC POPULATION BY SOCIAL MOBILITY CATEGORY OF CENSUS TRACT

SOCAL GAS SERVICE AREA

LEAST MOBILE ■ LESS MOBILE ■ MORE MOBILE ■ MOST MOBILE ■

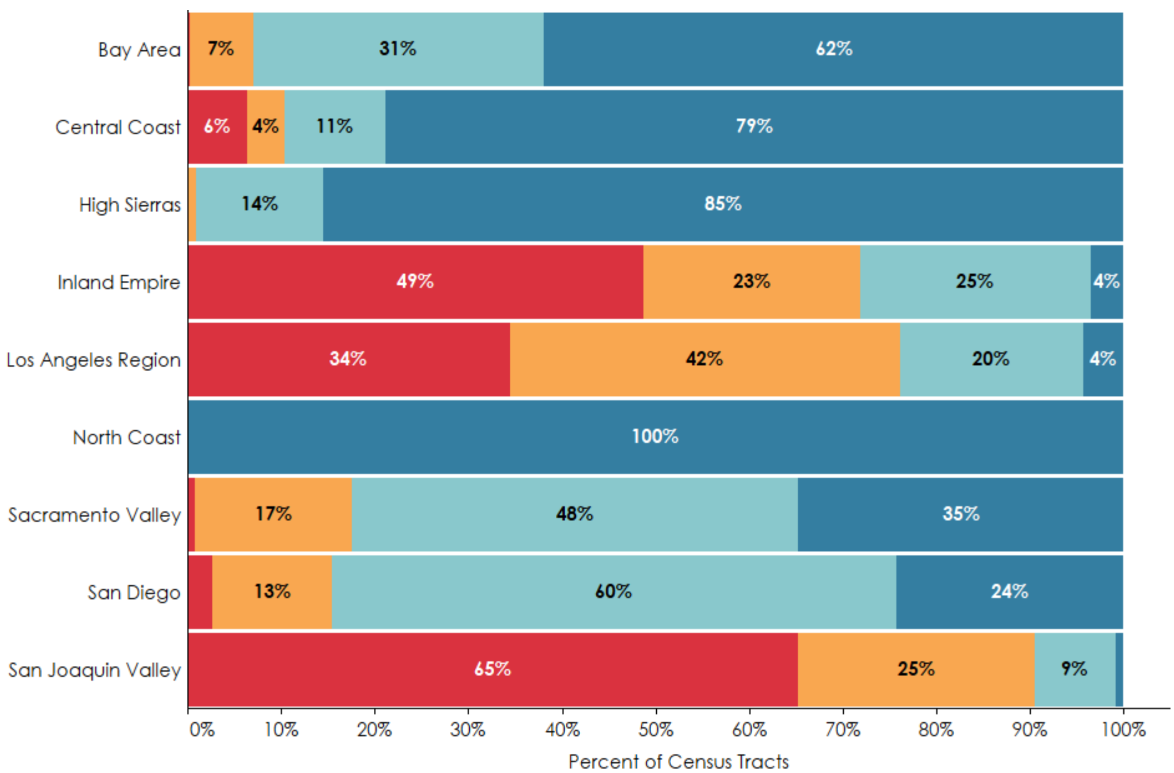


Where are the communities with the most environmental risks?

Unlike social vulnerability where most regions of the state all have shares of privileged and underprivileged communities, pollution risks are widely variable between regions of the state. The most burdened regions are the Inland Empire, Los Angeles, and in particular, the San Joaquin Valley, all of which have substantial portions of the population residing in the most polluted areas. Less than a third of tracts in these regions had a calculated pollution risk score less than the statewide average. By contrast, all tracts in the North Coast region and nearly all tracts in the High Sierras and Bay Areas fall below the state average (Blumenfeld and Zeise, 2018). (full state map available in appendix figure A4)

FIGURE 16: PERCENTAGE OF CENSUS TRACTS BY REGION AND POLLUTION RISK CATEGORY

MOST POLLUTED ■ MORE POLLUTED ■ LESS POLLUTED ■ LEAST POLLUTED ■



These discrepancies mirror differences in topography, industrial development, and population density particularly when examining the composite risk factors included in the pollution risk score. For a full map of all pollution scores see appendix figure A7.

- **Diesel Pollution:** Diesel pollution is most pronounced around transportation hubs. In the Los Angeles region and western Inland Empire region this includes the Ontario, Burbank, San Bernardino, and Los Angeles International airports, as well as the ports of Los Angeles and Long Beach. These locations serve as hubs of freight traffic throughout the region. Similarly, tracts with a heavy military presence also showed high rates of diesel pollution. Fort Irwin in San Bernardino county had the highest rates of diesel pollution in the state.

- **Drinking water pollution:** drinking water pollution showed few discernable geographic patterns. Since this index is calculated based on the water provided by local water districts, pollution across this vector is more a function of where a community gets its water then its immediate geography. On average, coastal Orange County, Long Beach, and the Palos Verdes Peninsula had better quality water than inland communities. In general, however water in Southern California had more pollutants than that of Northern California.

- **Ozone Pollution:** ozone pollution was most prevalent in inland communities particularly those separated from the coast by topography. This included much of Los Angeles County north and east of downtown Los Angeles.

- **Pesticide pollution:** concentration of toxic pesticides was nearly entirely concentrated in agricultural communities especially in the San Joaquin Valley, agricultural communities in Oxnard, Santa Maria, Salinas, and Imperial county.

- **PM2.5 pollution:** air pollution was most prominent in the most heavily populated valleys and basins of the state. This includes the San Joaquin Valley, the Los Angeles basin, and the most densely populated portions of the Inland Empire. The central Inland Empire near the cities of Ontario and Riverside had some of the worst air pollution in the state.

- **Toxic Release from Facilities:** the Los Angeles and Inland Empire regions contained much of the toxic release pollution in the state. Orange County contained the most polluted census tracts with much of the north eastern portion contaminated by the El Sobrante Landfill, Santiago Canyon Landfill, and manufacturing facilities along the 91 freeway (U.S. Environmental Protection Agency, 2019).

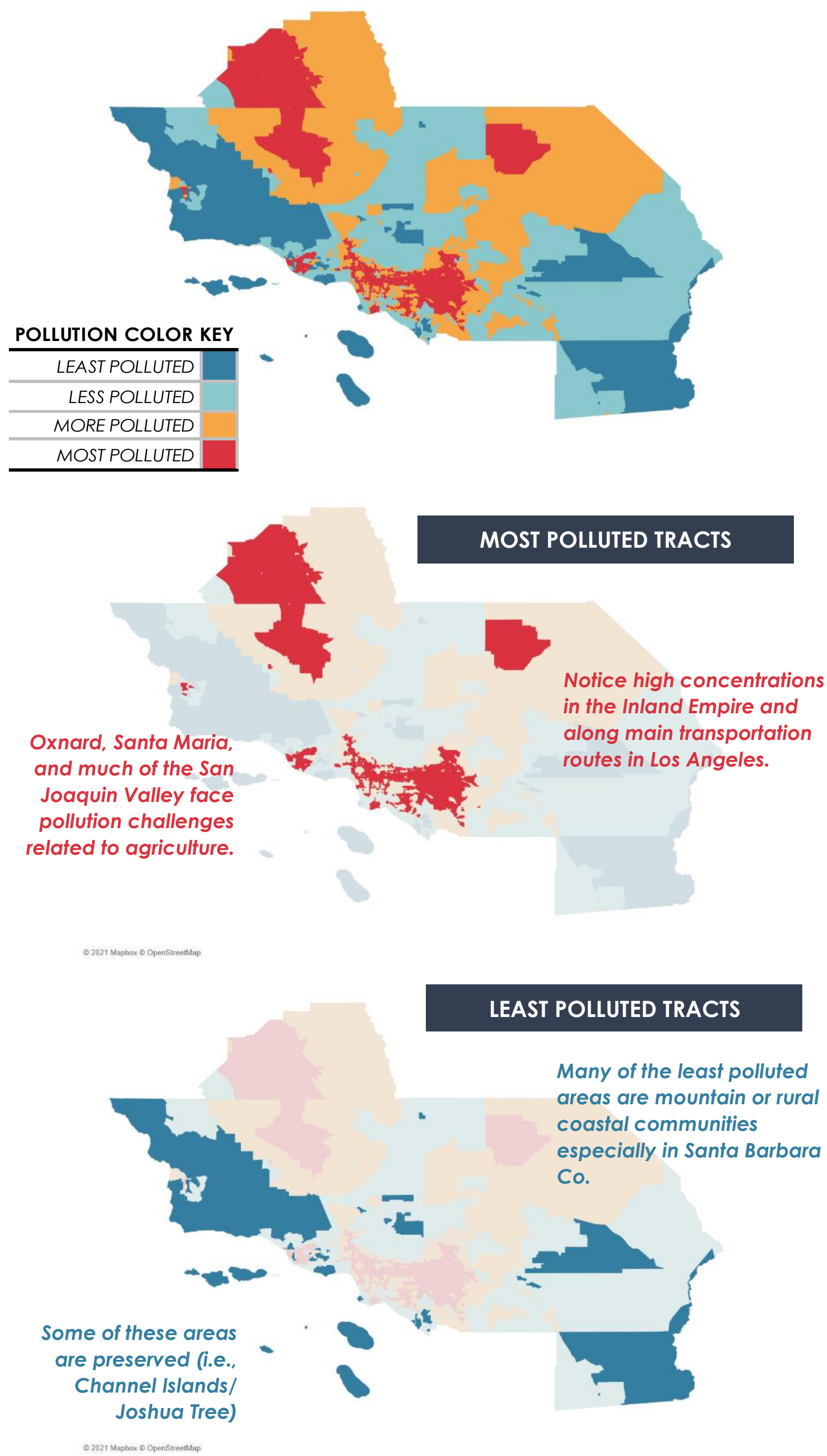
- **Traffic pollution:** traffic pollution is most densely concentrated along the major freeways of Los Angeles, San Diego, and Orange Counties as well as the Inland Empire and Bay area. However, the most pronounced traffic pollution was found outside of SoCal Gas' service area in the tracts with a considerable amount of border traffic with Mexico in San Diego.

The agglomeration of these pollution effects leads to the dense concentration of polluted tracts in the Los Angeles, Inland Empire, and San Joaquin Valley regions. Within the Southern California region served by SoCal Gas, the burden of pollution disproportionately falls on inland communities. 59% of Inland residents live in one of the most polluted census tracts compared to just 31% of coastal residents. These factors contribute to higher rates of pollution in urban communities as shown in figure 17.

Urban residents also face higher exposure to pollution. 40% of urban residents in the SoCal Gas region live in the most polluted census tracts compared to just 24% of rural residents. This was most pronounced along transportation corridors with heavy truck traffic such as the 60, 210, 110 and 10 freeways. Valley areas in Los Angeles and the entire urban Inland Empire are considerably more polluted than other parts of the state. This is likely the result of topography that holds more air pollution. Despite being mostly costal, central, and eastern Orange County holds many of the most polluted census tracts largely due to the toxic release previously mentioned. Among rural communities, agricultural areas surrounding Bakersfield, Visalia, Tulare, Oxnard, and Santa Maria face considerably more pollution. San Joaquin Valley tracts often face pollution threats from both agricultural production and the air quality of inland valleys.

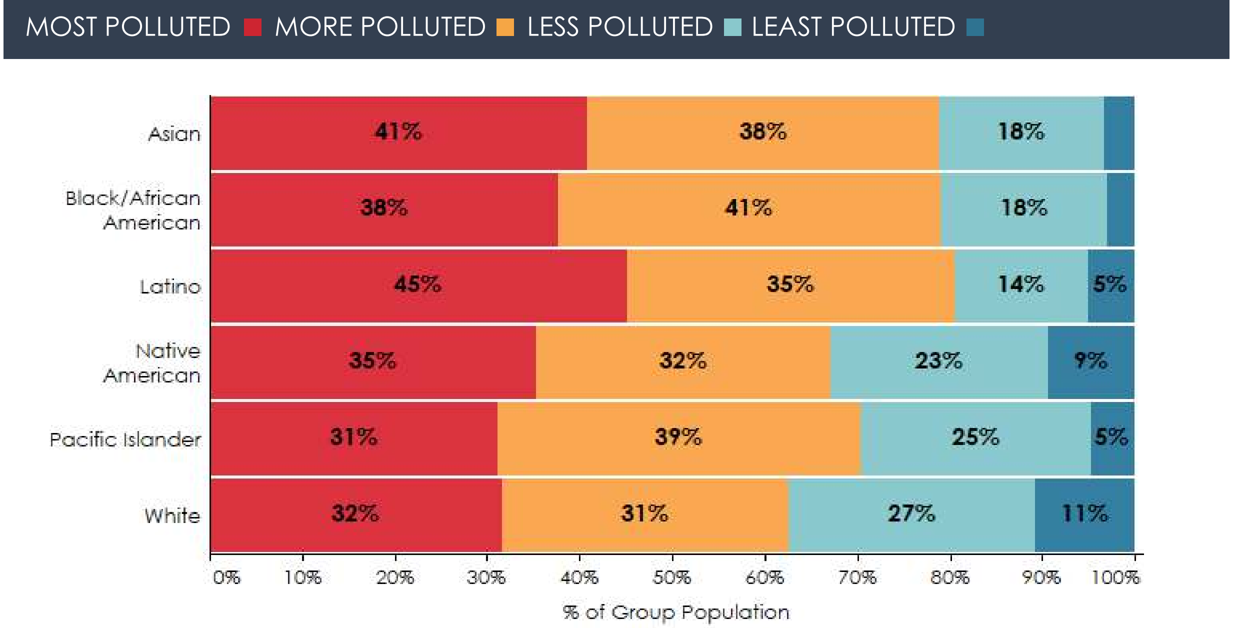
Even within these regions however, the burden of pollution is not equitably distributed between historically marginalized and White communities. Forty-five percent of Latinos in the SoCal Gas service area live in the most polluted census tracts in the state compared to just 32% of Whites. Asian and Black residents were also substantially more likely to live in census tracts with pollution above the statewide average with 41% of Asians and 38% of Black residents living in the most polluted tracts. In total, equity gaps were smaller than the socio-economic scores. **The equity gap was 9% for Asian customers, 6% for Black customers, 13% for Latino**

FIGURE 17: POLLUTION RISK CATEGORY OF CENSUS TRACTS
SOCAL GAS SERVICE AREA



customers, and 3% for Native American customers. There was no equity gap between Pacific Islander and White customers as shown in figure 18.

FIGURE 18: PERCENTAGE OF RACIAL/ETHNIC POPULATION BY POLLUTION RISK CATEGORY OF CENSUS TRACT
SOCAL GAS SERVICE AREA



Where do social vulnerabilities and environmental risks meet?

The intersection of social vulnerability and pollution reveals the depth of the challenges faced by Southern Californians. Nearly half of all census tracts in the Inland Empire, Los Angeles, and San Joaquin Valley regions face above average levels of social vulnerability and pollution. These "dual crisis" tracts represent any tract that falls among the more and most vulnerable categories for both pollution and social cost-of-living (A map of the full state can be found in appendix figures A8 and A9).

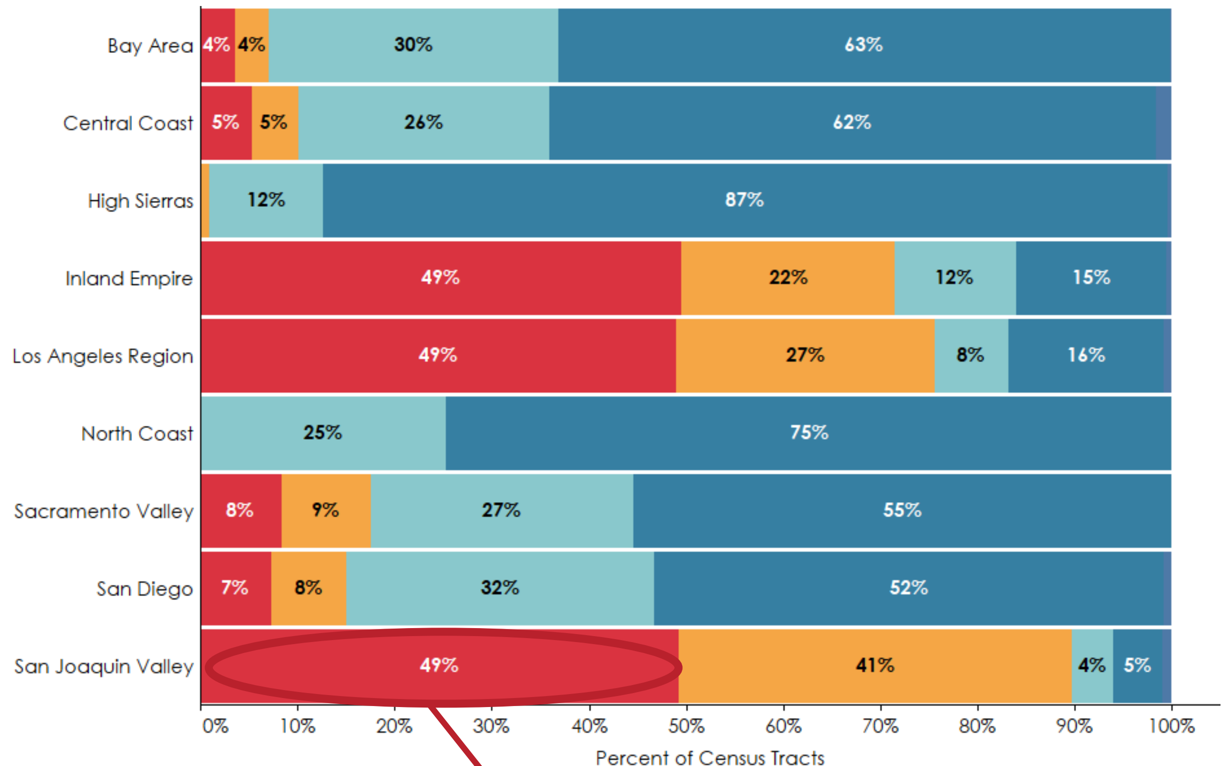
When looking deeper into these dual crisis communities, the analysis found that nearly 20% of tracts in the Inland Empire, Los Angeles, and San Joaquin Valley regions fall in the most vulnerable categories of both pollution and social cost-of-living as seen in figure 19. These challenges are most acute in the San Joaquin Valley. 49% of tracts face a dual crisis. An additional 41% face considerable pollution challenges despite fewer social cost-of-living challenges. Only 5% of San Joaquin Valley tracts face neither undue pollution nor social vulnerability challenges. This reflects the true scale of pollution in the Central Valley. As previously noted, 90% of tracts face above average levels of pollution; a crisis that is clearly more burdensome for the region's socially vulnerable families. Similarly, urban areas like the Bay Area, have considerably fewer "dual crisis" communities with over 63% of tracts falling among the least vulnerable and least polluted tracts in the state. Despite similar patterns of development to Southern California, San Diego faces considerably fewer challenges then other parts of the region. Only 7% of San Diego census tracts fall among the dual crisis categorization while over 52% fall among the least threatened tracts. These figures mirror the intersection of social mobility and pollution shown in the appendix in figure A10.

FIGURE 19: PERCENTAGE OF CENSUS TRACTS BY REGION AND THE INTERSECTION OF POLLUTION AND SOCIAL COST-OF-LIVING CATEGORIES

SOCAL GAS SERVICE AREA

MORE POLLUTED/MORE VULNERABLE (DUAL CRISIS) ■ MORE POLLUTED/LESS VULNERABLE ■

LESS POLLUTED/MORE VULNERABLE ■ LESS POLLUTED/LESS VULNERABLE ■



WITHIN THE "DUAL CRISIS" tracts, the Los Angeles, Inland Empire, and the San Joaquin Valley regions had the highest proportion of tracts in the most acute categories of environmental and social distress. Nearly 20% of the tracts in these regions fell among the most polluted and most vulnerable tracts in the state.

	most polluted/most vulnerable	either pollution or vulnerability is severe	more polluted/more vulnerable
Bay Area	0%	1%	2%
Central Coast	2%	2%	1%
Inland Empire	**19%**	**24%**	**7%**
Los Angeles Region	**14%**	**25%**	**10%**
Sacramento Valley	0%	3%	5%
San Diego	1%	4%	3%
San Joaquin Valley	**17%**	**25%**	**7%**

The true scale of the dual environmental and social vulnerability crisis can be seen when examining the populations of each intersectional category in the SoCal Gas service area. As seen in figure 20, 15% of SoCal Gas customers live in the most socially vulnerable, most polluted census tracts, more than any other group. This accounts for over 3,135,000 residents throughout the region. By contrast, only 3% of residents live in the least polluted, least vulnerable census tracts accounting for fewer than 700,000 residents.

FIGURE 20: PERCENTAGE OF POPULATION BY SOCIAL COST-OF-LIVING VULNERABILITY AND POLLUTION RISK OF CENSUS TRACT
SOCAL GAS SERVICE AREA

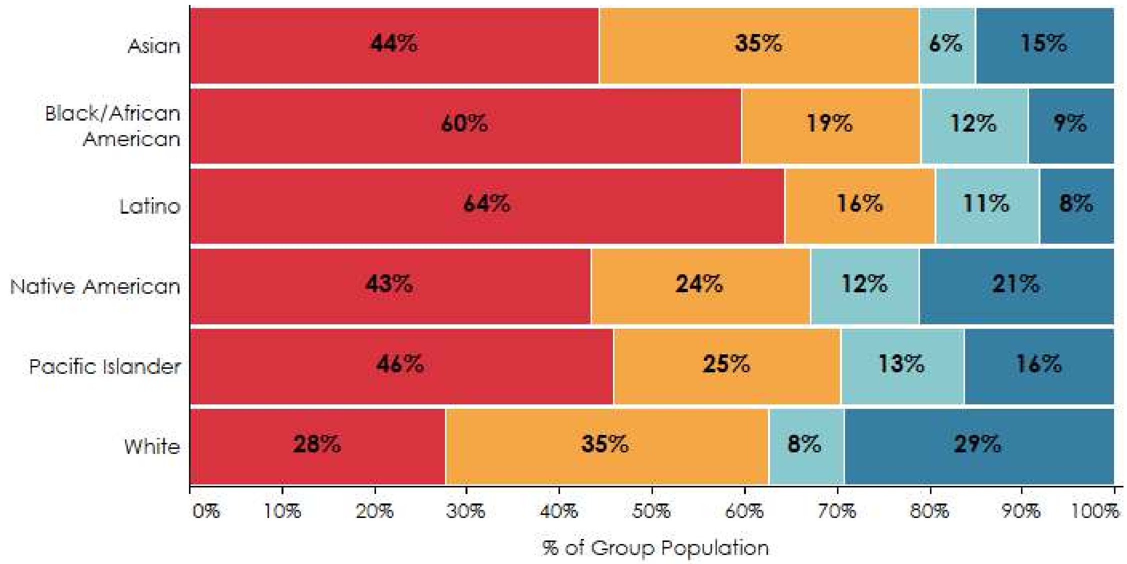
In total, 60% of Black/African American customers and 64% of Latinos live in dual crisis communities. The equity gap between these groups and White residents is staggering. 16% for Asian customers, 32% for Black customers, 34% for Latinos, 15% for Native Americans, and 18% for Pacific Islanders as shown in figure 23. (See appendix figure A12 for social mobility disaggregation).

FIGURE 23: PERCENTAGE OF POPULATION BY THE POLLUTION AND SOCIAL COST-OF-LIVING VULNERABILITY CATEGORIES OF CENSUS TRACT

SOCAL GAS SERVICE AREA

MORE POLLUTED/MORE VULNERABLE ■ MORE POLLUTED/LESS VULNERABLE ■

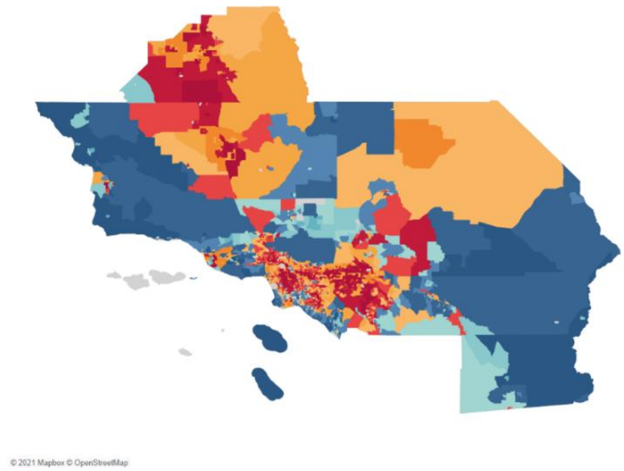
LESS POLLUTED/MORE VULNERABLE ■ LESS POLLUTED/LESS VULNERABLE ■



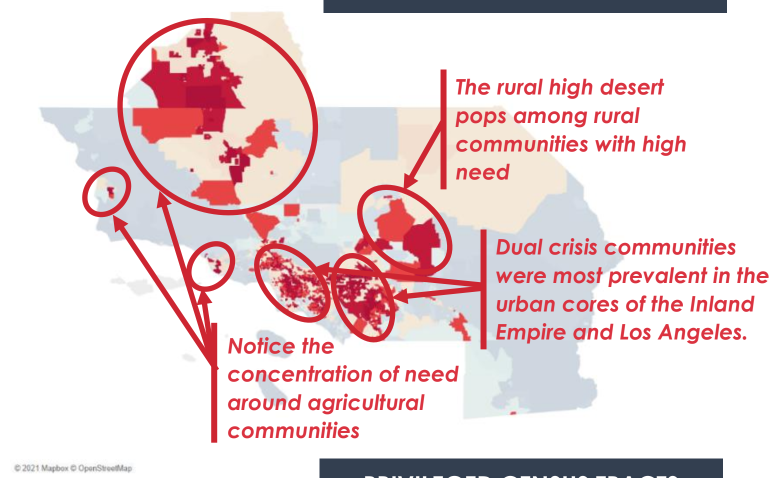
This is divide is reflected in the geography of the two indices. 51% of urban census tracts meet the criteria of "dual crisis" compared to only 22% of rural census tracts. These tracts are found predominantly in Los Angeles, Orange, Riverside, San Bernardino, Kern, Tulare, and Kings counties. South Central Los Angeles, Central Orange County, and much of the dense urban corridors of San Bernardino and Riverside counties fall among the most polluted/most vulnerable census tracts. Among rural areas, the farming communities around Tulare, Santa Maria, Visalia, and the eastern exurbs of Bakersfield face the most acute pollution and social vulnerability challenges. Other communities like the San Gabriel and San Fernando Valleys face less acute shades of the same issues. This same scale of concern can be found in the high desert communities of the Lucerne Valley south of Barstow.

Both inland and coastal areas face similar scales of social vulnerability and pollution. Forty-seven percent of coastal communities and 53% of inland communities meet the "dual crisis" categorization. However, as previously identified, the coastal areas show the starkest contrast in need. The least polluted/least vulnerable communities are predominantly found in San Luis Obispo and Santa Barbara counties. Small concentrations of privilege dot South Orange County while many of the preserved lands of the eastern Inland Empire face few challenges. In total, most of the less vulnerable/less polluted tracts are found along the wealthy coastal communities of Orange, Ventura, and Los Angeles county and virtually all of San Luis Obispo and Santa Barbara counties. The Coachella Valley leads into an eastern Inland Empire that is largely free of concentrated cost-of-living challenges and pollution. Despite this, few people live in many of these tracts meaning the balance of the Inland Empire's struggles fall in the urban core as shown in figure 22.

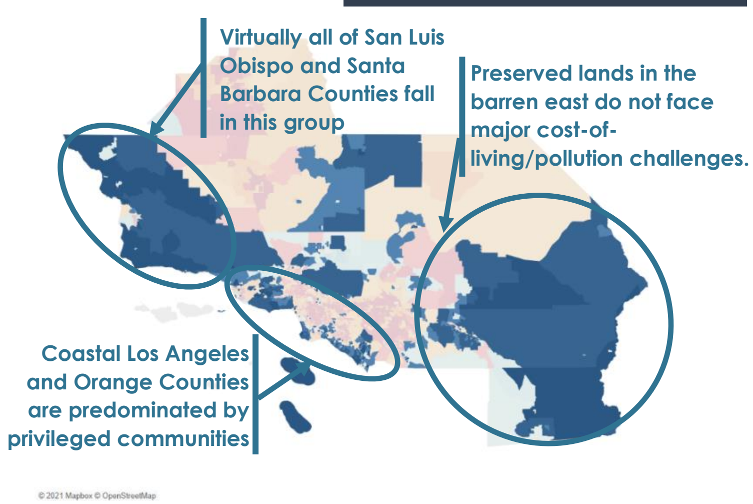
FIGURE 22: POLLUTION RISK CATEGORY OF CENSUS TRACTS | SOCAL GAS SERVICE AREA



DUAL CRISIS CENSUS TRACTS



PRIVILEGED CENSUS TRACTS



COST-BENEFIT ANALYSIS

This portion of the analysis uses the cities identified in the previous analysis as case studies to see how a mandate to change from natural gas to electric appliances would impact affect families' pocketbooks both in literal financial costs and benefits and in reduction of carbon emissions. The analysis showed that that high electricity costs and needed retrofits were the main reason why converting existing homes is cost prohibitive. In total, costs electrify existing homes ranged from -$5,600 to -$7,100 over 20 years, despite substantial reductions in CO2 emissions. In contrast, electrifying new homes had a positive benefit, because due to large cost savings accrued by not purchasing natural gas appliances, which are more expensive than their electrical counterparts.

What are the cost-of-living impacts of electrification?

The cost-benefit analysis of the financial impacts of electrification policies revealed that mandating household electrification was only financially advantageous for new homeowners, and not by a substantial enough margin to expect major shifts in purchasing behavior without government intervention. The largest benefits were cost savings from the purchase of natural gas and natural gas appliances. Across the four most used natural gas appliances, the average family already living in one of the nine analyzed communities could expect to save $2,100 in the purchase of natural gas appliances and $3,600 in natural gas bills across the 20 years of the analysis. These benefits accrue to approximately $285 annually with savings primarily occurring in later years.

These savings were slightly larger for existing homes; however, this is likely an overstatement. Due to the lack of accessible data, the analysis is unable to project the depreciation and replacement rate of existing natural gas infrastructure. This leads to a slightly higher savings for natural

FIGURE 24: PER UNIT NET PRESENT VALUES OF COSTS AND BENEFITS FOR EXISTING HOMES
AVERAGE OF ALL CITIES DISTRIBUTED OVER 20 YEARS

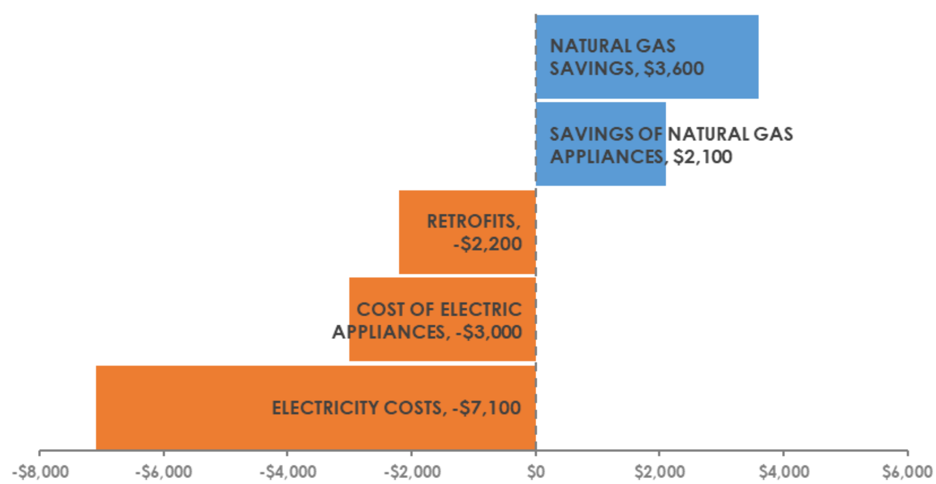
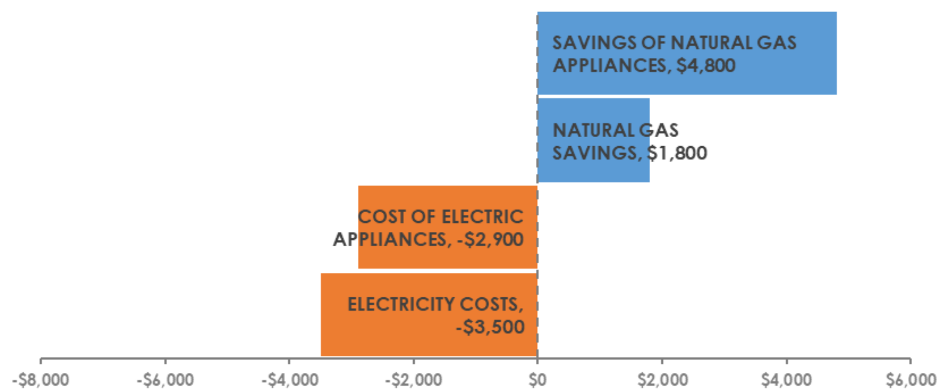


FIGURE 25: PER UNIT NET PRESENT VALUES OF COSTS AND BENEFITS FOR NEW HOMES
AVERAGE OF ALL CITIES DISTRIBUTED OVER 20 YEARS



gas prices for existing homes then savings for new homes where purchased appliances can be attributed to the year of a house's construction. The differences in the cost of natural gas and electric appliances are largely attributable to differences in the replacement rate. Natural gas appliance savings were slightly higher among new homeowners at $4,800 over twenty years. Meanwhile natural gas savings were slightly lower at $1,800 over twenty years.

FIGURE 26: PER UNIT NET PRESENT VALUE BY SCENARIO
NOTE: THESE COSTS/BENEFITS ARE DISTRIBUTED OVER 20 YEARS

City	New Houses	Existing Housing	Both New and Existing Housing
Claremont	$200	-$7,600	-$7,100
Compton	-	-$7,200	-$7,200
Fontana	$400	-$5,300	-$4,300
Laguna Beach	-	-$8,000	-$8,000
Lancaster	-	-$5,900	-$5,900
Oxnard	$300	-$7,000	-$6,100
Palm Desert	$300	-$5,600	-$4,500
Santa Monica	-	-$6,900	-$6,900
Visalia	$100	-$6,400	-$5,400

FIGURE 27: TOTAL NET PRESENT VALUE BY SCENARIO
NOTE: THESE COSTS/BENEFITS ARE DISTRIBUTED OVER 20 YEARS

City	New Houses	Existing Housing	Both New and Existing Housing
Claremont	$182,700	-$89,244,300	-$89,061,700
Compton	-	-$169,413,200	-$169,413,200
Fontana	$4,489,700	-$293,700,600	-$289,210,900
Laguna Beach	-	-$81,772,400	-$81,772,400
Lancaster	-	-$281,582,700	-$281,582,700
Oxnard	$2,241,200	-$361,998,400	-$359,757,200
Palm Desert	$2,073,700	-$139,119,800	-$137,046,000
Santa Monica	-	-$313,521,700	-$313,521,700
Visalia	$929,300	-$280,883,300	-$279,954,000

However, these benefits are offset by substantial financial costs. The primary cost driver was electricity costs. When compared to the natural gas savings these costs replace, consumers will spend an additional $3,400 above the baseline. Across existing homes, electricity costs amount to an additional $7,100 across 20 years. Similarly, electricity costs total $3,500 per new home over 20 years. These, however, cannot be fully offset by natural gas savings. In total, new households will pay an additional $1,700 over 20 years. Electric appliances cost approximately $2,900 over 20 years for both new and existing homes. These cost differentials in energy prices are largely a reflection of how the analysis categorized new and existing housing stock. Since costs are calculated for existing housing stock starting in the first year, existing homes accrue more costs from the high cost of electricity usage then homes purchased mid-way through the twenty-year period. It is likely that these energy costs will accrue to a level equal to existing housing by the time they reach their twentieth year. For more details on these categorizations see, the technical appendix.

Retrofit costs are only born on existing homes built before 1978. Some cities have considerably older housing stock leading to important differentials in housing retrofit costs across cities. Laguna Beach had the oldest housing stock with 78% of its homes built before 1978. This is illustrated in the high cost of electrification for existing homes in Laguna Beach at $8,000 per home over 20 years. Similar patterns can be seen in Claremont and Compton where 75% and 66% of housing stock respectively was built before 1978. No city showed a positive return on investment for electrifying existing housing infrastructure on finances alone.

These costs and benefits lead to a largely net negative financial return to electrification. Across all nine cities in the analysis, new homes showed small positive returns, however the scale of these returns are so small that they may disappear with the inclusion of unattributed costs. A new homeowner in Fontana can expect a return of $400 spread over 20 years or $20 per year. In total, new residents of Fontana can expect a collective return of $4.5 million, the largest of any city in the analysis. Four cities in the analysis show no growth – as such no benefits are projected for Compton, Laguna Beach, Lancaster, and Santa Monica. Fontana is projected to grow the fastest with an additional 11,800 housing units by 2040. The remaining cities are all projected to grow at lower rates, with Claremont growing slowest with an additional 745 housing units by 2040. In total, when summing these benefits together with the costs born on existing housing, no city shows positive financial returns to fully electrifying homes.

Additionally, the regressive structure of these financial costs means that while wealthy communities like Laguna Beach and poorer communities like Compton have comparable cost amounts, the burden is substantially more punishing for residents of Compton. In Compton like other communities with considerable social cost-of-living vulnerabilities, the value of a dollar can do more to help residents meet critical needs then that same dollar in a wealthier community like Laguna Beach. This **marginal utility of income** illustrates that while costs may look the same across all communities, the impacts will not be equitably felt.

What are the environmental impacts of electrification?

The environmental analysis focused on the emissions reductions that home electrification will cause. The charts below have been created with the assumption that 35% of homes are already all-electric, and the SCC is $109.28, the high-end estimate (Dietz et al., 2020).

On a per home basis, new homes prevent an average of $615 of CO2e emissions in cities where new homes are being electrified. As with the financial analysis, the housing tenure of new homeowners effects the amount of emissions eliminated from transitioning to electric. New homes purchase in the first year of the policy have equivalent emissions reduction to existing homes. Homes purchased in one of the subsequent 20 years will have equivalent costs once they reach 20-years old in the years after the scale of our analysis. This leads to a substantially larger benefit from removing natural gas appliances in existing homes as benefits are accrued for the full 20 years of the analysis. As previously mentioned, benefits accrued to existing homes do not matter for cities that are either fully developed or expecting limited growth. Benefits however, can be accrued in these cities by electrifying existing homes.

The results reveal that new home electrification, by far the most popular policy implemented by cities in California provides small, potentially insignificant, benefits. Some cities that have implemented those policies, like Santa Monia, who are not expecting growth and will likely not see any carbon savings from electrifying new homes. Only cities that are expecting large amounts of population growth like Fontana do see positive impacts from electrifying new homes. In contrast, a policy pushing existing home electrification by replacing gas appliances with electric appliances generates substantial carbon savings. The most environmentally-friendly scenario combines both policies—with new homes and existing being electrified. Substantial savings stem from carbon reductions from a combined policy. However, even the high-end estimate of the potential carbon savings does not cover the cost of electrifying an existing home. Californians who choose to electrify their homes are likely ideologically motivated.

The analysis found similar per home savings in each city. This result is logical. Most of the cities in the sample are in Southern California, and since the analysis takes the average household, differences in individual consumption are smoothed out. In addition, families largely use their appliances in similar fashions. The per home savings carbon savings for Existing Home Electrification are the highest in any of the scenarios examined, which makes sense because it is a direct replacement of fossil fuel use with electricity.

Many of the cities that saw large, positive NPVs from electrification were poorer cities like Visalia, which are communities in the dual-crisis designation. These cities are cheaper to live and build in than wealthier coastal communities like Santa Monica and will see more environmental benefits in the aggregate from electrification policies.

FIGURE 28: PER UNIT NET PRESENT VALUE BY SCENARIO
NOTE: THESE COSTS/BENEFITS ARE DISTRIBUTED OVER 20 YEARS

City	New Houses	Existing Housing	Both New and Existing Housing
Claremont	$624	$1,197	$1,163
Compton	-	$1,176	$1,218
Fontana	$611	$1,197	$1,093
Laguna Beach	-	$1,189	$1,205
Lancaster	-	$1,196	$1,198
Oxnard	$617	$1,197	$1,124
Palm Desert	$608	$1,197	$1,081
Santa Monica	-	$1,196	$1,198
Visalia	$613	$1,197	$1,105

FIGURE 29: TOTAL NET PRESENT VALUE BY SCENARIO
NOTE: THESE COSTS/BENEFITS ARE DISTRIBUTED OVER 20 YEARS

City	New Houses	Existing Housing	Both New and Existing Housing
Claremont	$465,372	$14,076,108	$14,541,481
Compton	-	$27,813,374	$27,813,374
Fontana	$7,252,542	$65,894,237	$73,146,779
Laguna Beach	-	$12,147,979	$12,147,979
Lancaster	-	$57,480,576	$57,480,576
Oxnard	$4,544,105	$61,925,295	$66,469,400
Palm Desert	$3,677,787	$29,498,859	$33,176,646
Santa Monica	-	$54,157,075	$54,157,075
Visalia	$4,959,118	$52,174,113	$57,133,231

IV. CONCLUSIONS

To effectively frame our conclusion, it is important to address one question we chose not to answer: is electrification a good idea? This normative question may be effectively answered by either side of the debate depending on the scale and quality of the trade-off's policymakers are willing to accept. However, our analysis does contribute several critical factors policymakers should consider when evaluating electrification and its impacts on affordability:

1. **Financial returns alone will not be enough to entice consumers into switching from natural gas to electric appliances.** Even among homeowners where the net present value of costs and benefits was positive, the scale of benefits was so small that a minor change in our cost assumptions may result in a net negative outcome. Unless governments incentivize the purchase of electric appliances like they have through the federal ENERGY STAR rebate program, consumers are unlikely to make the switch on pure financial grounds alone. A mandate like an electrification policy will likely increase costs to consumers without responsive rebates or subsidies. This explains much of the income divide present in who has passed electrification mandates and who has passed balanced energy resolutions. The prohibitive costs of electrification are more affordable to wealthier coastal communities; communities that may also derive social benefits from engaging in eco-conscious decisions.

2. **Despite considerable pollution issues the scale of environmental challenges will not be enough to entice low-income families into replacing electric appliances.** Across all communities in our analysis, the net benefits from reduced carbon emissions are not enough to produce positive returns especially in communities with limited housing growth. This is due to two principal factors – existing housing forms the bulk of the housing stock in these communities. Given the prohibitive cost of retrofitting an existing home, the scale of the ecological benefits is too small to make up the difference. Without a substantial financial subsidy to low-income families, cities may inadvertently increase the cost of housing by limiting access to lower-cost cooking and heating fuels, and implicitly mandating retrofits to dated housing stock. Second, many of the low-income communities suffer from pollution unrelated to natural gas emissions. Compton and Fontana's heavy traffic pollution and industrial activity, Visalia and Oxnard's heavy pesticide pollution are ultimately unrelated to the emissions created by household natural gas use. Therefore, despite considerable ecological issues in these communities, electrification will not mitigate most pollution challenges in these communities despite the large returns to reducing pollutants in these communities.

V. APPENDIX

LITERATURE SOURCES

Ackerman, Andrew and Friedman, Nicole. (2021, April 7). "Biden's infrastructure plan seeks to ease housing shortage with looser zoning rules." *The Wall Street Journal*. https://www.wsj.com/articles/biden-seeks-to-ease-housing-shortage-with-looser-zoning-rules-11617796817

Assistant Secretary for Planning and Evaluation. (2020). "2020 Poverty Guidelines." *U.S. Department of Health and Human Services.* https://aspe.hhs.gov/2020-poverty-guidelines.

Barboza, T. (LA T. (2019). California's planet-warming emissions declined in 2017, even as its biggest pollution source keeps rising. *Los Angeles Times*, 1–7.

Bedsworth, Louise; Cayan, Dan; Franco, Guido; Fischer, Leah, and Ziaja, Sonya (2018) "Fourth climate change assessment." *State of California*. Retrieved from https://www.energy.ca.gov/sites/default/files/2019-11/Statewide_Reports-SUM-CCCA4-2018-013_Statewide_Summary_Report_ADA.pdf

Berkeley Law. (2020). "California climate policy fact sheet: cap and trade." *University of California, Berkeley*. https://www.law.berkeley.edu/wp-content/uploads/2019/12/Fact-Sheet-Cap-and-Trade.pdf.

Berkeley, California, Municipal Code § 12.80

Brandt, S., Perez, L., Künzli, N., Lurmann, F., Wilson, J., Pastor, M., & McConnell, R. (2014). Cost of near-roadway and regional air pollution-attributable childhood asthma in Los Angeles County. *Journal of Allergy and Clinical Immunology*, *134*(5), 1028–1035. https://doi.org/10.1016/j.jaci.2014.09.029

Bryce, R. (2020). *The High Cost of California Electricity Is Increasing Poverty*. FREOPP. https://freopp.org/the-high-cost-of-california-electricity-is-increasing-poverty-d7bc4021b705

California Air Resources Board. (2008). "Climate change scoping plan: a framework for change." *State of California*. https://ww2.arb.ca.gov/sites/default/files/classic//cc/scopingplan/document/adopted_scoping_plan.pdf

California Air Resources Board. (2017). "California's 2017 Climate Change Scoping Plan." *State of California*. https://ww2.arb.ca.gov/sites/default/files/classic//cc/scopingplan/scoping_plan_2017.pdf

California Air Resources Board. (2019). *GHG Current California Emission Inventory Data*. https://ww2.arb.ca.gov/ghg-inventory-data

California Air Resources Board. (2020a). *California Cap-And-Trade Program: Summary of California-Quebec Joint Auction Settlement Prices and Results* (Issue November). https://ww2.arb.ca.gov/sites/default/files/2020-08/results_summary.pdf

California Air Resources Board. (2020b). *GHG Global Warming Potentials*.

Capps, Kriston. (2021, March 25). "How California set off a backyard apartment boom." *Bloomberg CityLab*. https://www.bloomberg.com/news/articles/2021-03-25/can-granny-flats-fill-california-s-housing-gap

Centers for Disease Control and Prevention (2021) "CDC/ATSDR Social Vulnerability Index." *U.S. Department of Health and Human Services*. https://www.atsdr.cdc.gov/placeandhealth/svi/index.html

Chetty, Raj; Friedman, John; Hendren, Nathaniel; Jones, Maggie; and Porter, Sonya. (2020a) "The opportunity atlas: mapping the childhood roots of social mobility." *Opportunity Insights*. https://opportunityinsights.org/wp-content/uploads/2018/10/atlas_paper.pdf

Cutter, Susan; Boruff, Bryan; and Shirley, W. Lynn. (2003). "Social vulnerability to environmental hazards." *Social Science Quarterly.* 84(2).

Deverell, W., & Hise, G. (2006). *Land of Sunshine: an environmental history of metropolitan Los Angeles Land of Sunshine*. University of Pittsburgh Press.

DiChristopher, Tom (2020, July 8). "'Banning' natural gas is out; electrifying buildings is in." *S&P Global Market Intelligence.* Retrieved from https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/banning-natural-gas-is-out-electrifying-buildings-is-in-59285807

Dietz, S., Bowen, A., Doda, B., Gambhir, A., & Warren, R. (2020). *The Economics of 1.5 C Climate Change*. *August 2018*, 1–26.

Dillon, Liam. (2020, February 7). "L.A. versus S.F.: how the 'cultural divide' is determining housing policy in California." *The Los Angeles Times*. https://www.latimes.com/homeless-housing/story/2020-02-07/housing-bill-sb-50-bay-area-los-angeles-scott-wiener.

Fay, M., Hallegatte, S., Vogt-Schib, A., Rozenburg, J., Narloch, U., and Kerr, T. (2015). *Decarbonizing Development*. World Bank Group.

Fischer, M. L., Chan, W. R., Delp, W., Jeong, S., Rapp, V., & Zhu, Z. (2018). An Estimate of Natural Gas Methane Emissions from California Homes. *Environmental Science and Technology*, *52*(17), 10205–10213. https://doi.org/10.1021/acs.est.8b03217

Glassmeier, Amy. (2021). "Counties and metropolitan statistical areas in California." *Living Wage Calculator – Massachusetts Institute of Technology*. https://livingwage.mit.edu/states/06/locations.

Gough, Matt (2021, January 25). "California's cities lead the way to a gas-free future." *Sierra Club.* Retrieved from https://www.sierraclub.org/articles/2020/10/californias-cities-lead-way-gas-free-future

Hopkins, F. M., Kort, E. A., Bush, S. E., Ehleringer, J. R., Lai, C.-T., Blake, D. R., & Randerson, J. T. (2016). Spatial Patterns and Source Attribution of Urban Methane in the Los Angeles Basin. *Journal of Geophysical Research: Atmospheres*, *121*, 2490–2507. https://doi.org/10.1002/2015JD024429.Received

Krishnakumar, P., & Kannan, S. (2020, September 15). The worst fire season ever . *Los Angeles Times*. https://www.latimes.com/projects/california-fires-damage-climate-change-analysis/

Lewis, Tonia. (2019). "Resolution No. 2019" *City of Fontana, CA*. https://novus.fontana.org/AttachmentViewer.ashx?AttachmentID=16774&ItemID=12562

Logue, J. M., Klepeis, N. E., Lobscheid, A. B., & Singer, B. C. (2014). Pollutant exposures from natural gas cooking burners: A simulation-based assessment for Southern California. *Environmental Health Perspectives*, *122*(1), 43–50. https://doi.org/10.1289/ehp.1306673

Mahone, Amber; Khan-Lang, Jenya; Li, Vivian; Ryan, Nancy; Subin, Zachary; Allen, Douglas; De Moor, Gerrit; and Price, Snuller. (2018). “Deep decarbonization in a high renewables future.” *California Energy Commission.* https://www.ethree.com/wp-content/uploads/2018/06/Deep_Decarbonization_in_a_High_Renewables_Future_CEC-500-2018-012-1.pdf

Mahone, Amber; Khan-Lang, Jenya; Li, Vivian; Ryan, Nancy; Subin, Zachary; Allen, Douglas; De Moor, Gerrit; and Price, Snuller. (2018). “Deep decarbonization in a high renewables future.” *California Energy Commission.* https://www.ethree.com/wp-content/uploads/2018/06/Deep_Decarbonization_in_a_High_Renewables_Future_CEC-500-2018-012-1.pdf

Marr, Chuck; Cox, Kris; Hingtgen, Stephanie; Windham, Katie, and Sherman, Arloc. (2021, March 12). “American Rescue Plan Act Includes Critical Expansion of Child Tax Credit and EITC.” *Center on Budget and Policy Priorities*. https://www.cbpp.org/research/federal-tax/american-rescue-plan-act-includes-critical-expansions-of-child-tax-credit-and.

Marten, A. L., & Newbold, S. C. (2012). Estimating the social cost of non-CO 2 GHG emissions: Methane and nitrous oxide. *Energy Policy*, *51*, 957–972. https://doi.org/10.1016/j.enpol.2012.09.073

McDonald, B. C. (University of C. B., McBride, Z. (University of C. B., Martin, E. (University of C. B., & Harley, R. (University of C. B. (2014). High-resolution mapping of motor vehicle carbon dioxide emissions. *Journal of Geophysical Research: Atmospheres*, *May*, 5283–5298. https://doi.org/10.1002/2013JD021219.Received

Mooney, C., & Muyskens, J. (2019, September 8). Dangerous new hot zones are spreading around the world. *The Washington Post*, 1–41. https://www.washingtonpost.com/graphics/2019/national/climate-environment/climate-change-world/?nid=top_pb_signin

Newsome, Nikima S. (2019, September 10). “City of Santa Monica – City Council Minutes, September 10, 2019.” City of Santa Monica. http://santamonicacityca.iqm2.com/Citizens/FileOpen.aspx?Type=15&ID=1212

Our Sustainability Goals. (2019). Southern California Edison.

Ricke, K., Drouet, L., Caldeira, K., & Tavoni, M. (2018). Country-level social cost of carbon. *Nature Climate Change*, *8*(10), 895–900. https://doi.org/10.1038/s41558-018-0282-y

Rockzsfforde, R. R. (2015). Comparative Analysis of Utility Services & Rates in California California Public Utilities. *California Public Utilities Commision*, 1–28.

Rodriguez, Matthew and Zeise, Lauren (2017) “CalEnviroScreen 3.0” *California Environmental Protection Agency/Office of Environmental Health and Hazard Assessment*. https://oehha.ca.gov/media/downloads/calenviroscreen/report/ces3report.pdf

SB 100, SB No. 100 Chapter 2312, California Legislative Information (2018). https://leginfo.legislature.ca.gov/faces/billStatusClient.xhtml?bill_id=201720180SB1023%0D

Senate Bill No. 743, Pub. L. No. Senate Bill No. 743, 7 1 (2013). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201320140SB743

Solutions, C. for C. and E. (2020). *California Cap and Trade Program Overview*. C2es.Org. https://www.c2es.org/content/california-cap-and-trade/

Southern California Gas Company. (2019). "Riverside county joins 113 California local governments in voting to keep their natural gas choice." *PR News Wire.* https://www.prnewswire.com/news-releases/riverside-county-joins-113-california-local-governments-in-voting-to-keep-their-natural-gas-choice-300973420.html

SoCal Gas. (2021). "Local jurisdictions that support energy choice for their communities." *socalgas.com*. https://www.socalgas.com/energychoice

Stein, B. J., Eilperin, J., Laris, M., & Romm, T. (2021, April 1). White House unveils $2 trillion infrastructure and climate plan, setting up giant battle over size and cost of government. *Washington Post*. https://www.washingtonpost.com/us-policy/2021/03/31/biden-infrastructure-climate-plan/

To, T., Zhu, J., Stieb, D., Gray, N., Fong, I., Pinault, L., Jerrett, M., Robichaud, A., Ménard, R., van Donkelaar, A., Martin, R. V., Hystad, P., Brook, J. R., & Dell, S. (2020). Early life exposure to air pollution and incidence of childhood asthma, allergic rhinitis and eczema. *European Respiratory Journal*, *55*(2). https://doi.org/10.1183/13993003.00913-2019

U.S. Bureau of Labor Statistics (2020). "Average energy prices, Los Angeles-Long Beach-Anaheim-September 2020." *Bls.gov*. Retrieved from https://www.bls.gov/regions/west/news-release/averageenergyprices_losangeles.htm

U.S. Census Bureau. (2019a). "Glossary – Census Tracts." *Census.gov*. https://www.census.gov/programs-surveys/geography/about/glossary.html#par_textimage_13

U.S. Environmental Protection Agency. (2018). *Greenhouse Gases Equivalencies Calculator - Calculations and References | Energy and the Environment | US EPA*. 1–23. https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

U.S. Environmental Protection Agency. (2019). "Greenhouse gas emissions from large facilities." *Facility Level Information on Greenhouse Gasses Tool.* https://go.usa.gov/xHKcj.

What is a therm? (2021). Arcadia Power. https://welcome.arcadia.com/energy-101/energy-bills/what-is-a-therm

Wheeler, A. R. (2020). *Letter to Governor Newsom re: Executive Order establishing a goal of 100% zeo emission vehicle sales by 2035*. United States Environmental Protection Agency.

Weber, Shirley. (2020, November 3). "General Election State Ballot Measures." *California Secretary of State*. https://elections.cdn.sos.ca.gov/sov/2020-general/sov/58-ballot-measures.pdf.

DATA SOURCES

Geographic Analysis

Blumenfeld, Jared and Zeise, Lauren. (2018). "CalEnviroScreen 3.0 Data" *Office of Environmental Health and Hazard Assessment,* https://oehha.ca.gov/media/downloads/calenviroscreen/document/ces3results.xlsx.

Chetty, Raj; Friedman, John; Hendren, Nathaniel; Jones, Maggie; and Porter, Sonya. (2020b) "The opportunity atlas." *Opportunityatlas.*org. https://www.opportunityatlas.org/

U.S. Census. (2019b). "Hispanic or Latino Origin by Race." *American Community Survey*. https://data.census.gov/cedsci/table?q=hispanic&tid=ACSDT5Y2019.B03002&hidePreview=false

U.S. Census. (2019c). "Selected economic characteristics." *American Community Survey*. https://data.census.gov/cedsci/table?q=selected%20economic%20characteristics&g=0400000US06.140000&tid=ACSDP5Y2019.DP03&hidePreview=false

U.S. Census. (2019d). "Selected housing characteristics." *American Community Survey*. https://data.census.gov/cedsci/table?q=housing&tid=ACSDP5Y2019.DP04&hidePreview=false

U.S. Census Bureau. (2019e). "Total population." *American Community Survey*. https://data.census.gov/cedsci/table?q=population&g=0400000US06.140000&tid=ACSDT5Y2019.B01003&hidePreview=true

Cost-Benefit Analysis

National Renewable Energy Laboratory. (2020). "Levelized Cost of Energy – SLOPE: State and Local Planning for Energy." *U.S. Department of Energy*. https://gds.nrel.gov/slope/data-viewer?layer=lcoe.levelized-cost-of-electricity&year=2020&resolution=county&geography=G0600590

Office of Energy Consumption and Efficiency Statistics. (2018). "Table HC3.8 Appliances in homes in the South and West Regions, 2015" *U.S. Energy Information Administration.* https://www.eia.gov/consumption/residential/data/2015/hc/php/hc3.8.php

Navigant Consulting, Inc. (2018). "EIA – Technology Forecast Updates – Residential and Commercial Building Technologies – Reference Case" *U.S. Energy Information Administration*.

U.S. Census. (2019d). "Selected housing characteristics." *American Community Survey*. https://data.census.gov/cedsci/table?q=housing&tid=ACSDP5Y2019.DP04&hidePreview=false

U.S. Census Bureau. (2019e). "Total population." *American Community Survey*. https://data.census.gov/cedsci/table?q=population&g=0400000US06.140000&tid=ACSDT5Y2019.B01003&hidePreview=true

U.S. Energy Information Administration. (2019). "2015 Residential Energy Consumption Survey Data." *U.S. Department of Energy*. https://www.eia.gov/consumption/residential/data/2015/index.php?view=microdata

GLOSSARY OF TERMS AND ABBREVIATIONS

CalEPA – California Environmental Protection Agency

EIA – Energy Information Agency of the Federal Department of Energy

EPA – Federal Environmental Protection Agency

NREL – National Renewable Energy Laboratory of the Federal Department of Energy

GEOGRAPHIC ANALYSIS:

Coastal vs. Inland: All tracts in a coastal county were coded as "coastal" except in Los Angeles County. All tracts east of the 5 freeway north of the 210 freeway and tracts north of the 210 freeway east of the 5 freeway were coded as Inland. Coastal tracts are shown by the blue tracts on the right.

Urban vs. Rural: For the purposes of this analysis, we use an approximation of the U.S. Census's definition of a rural and urban community. Census tracts with a population density greater then approximately 300 people per square mile were coded as urban. The remainder were coded as rural. Tracts with artificially low densities (i.e. industrial areas) were coded as urban if surrounded by urban tracts. Urban tracts are shown in blue in the map on the right.

COST-BENEFIT ANALYSIS:

Existing Balance: A percentage indication of the current market share for natural gas appliances and electric appliances, and percentage those who do not own a particular appliance.

Costs: Typical cost of varying natural gas and electric appliances, in 2021 dollar.

Electricity Usage: Annual electricity usage in kwh, of one household on a particular piece of appliances. Note that natural gas appliances also cost electricity to run, hence the difference is used in electricity cost calculation.

Natural Gas Usage: Annual natural gas usage in MMBTU, calculated using the per usage consumption and an estimated 200 uses per year for residential stove/range and clothes dryer, and 400 uses annually for furnace and water heater.

Replacement Rate: How often different types of appliances needs to be replaced in households, unit in years.

Average Annual Maintenance: Annual maintenance cost for each type of appliance.

Discount Rate: Annual discount rate used in this analysis.

Natural Gas Price: Residential natural gas price in dollars per thousand cubic feet, based on historical data and prediction from 2021.

Electricity Price: Census data on per kWh electricity price in different counties. 2021 number is based on 2019 cost converted to 2021 dollars, the rest is projection.

Existing Housing: Number of existing households in the city.

New Housing: Sum of annual construction numbers from 2021.

Annual Construction: Number of new constructions that year, based on new construction rate projection.

All Housing: Number of all housing units, exiting plus new housing in the city.

Percent Built Before 1978: The percentage of existing housing built before 1978. This is significant because houses built after 1978 follows a more stringent set of housing codes, therefore might affect the cost of refit.

kWh: A commonly used metric of electricity usage on utility bills, which is equivalent to 1 kilowatt of power expended for an hour.

Therm: A unit of measurement of natural gas usage over time. One therm is equal to 0.1 MMBTU.

Social Cost of Carbon: A method to calculate the global warming and social impact of an additional metric ton CO_2 emitted into the atmosphere.

CO_2 equivalent: A post-adjustment figure that puts greenhouse gases that are not CO_2 in terms of CO_2, by calculating that greenhouse gas's global warming potential in relation to CO_2.

Retrofit: A household shifting their natural gas appliances to electric appliances.

All-Electric: A household whose only source of energy is electricity.

TECHNICAL DOCUMENTATION

Identifying Vulnerable Communities:
Assessing the environmental and social threats of individual communities required developing or adapting a methodology that could succinctly quantify a wide array of socio-environmental factors. One of the most prominent attempts at quantifying these community level effects came from California's Environmental Protection Agency (CalEPA). CalEnviroScreen was developed by CalEPA as a means of identifying communities that were the most susceptible to socioeconomic, health, and environmental hazards. The outputs of the project are significant to how resources are distributed across the state. SB535 (De León, 2012) mandated CalEPA identify at-risk communities – a classification that was subsequently used to distribute no less than 25% of California's carbon auction revenues under the mandates of AB1532 (Pérez, 2012).

CalEnviroScreen's methodology examines environmental, health, and socioeconomic threats across four categories. The first, pollution exposure measures a community's exposure to seven different airborne and consumption-based pollutants. These include ozone concentration, PM2.5 concentrations, diesel, drinking water contamination, concentration of high-hazard/high-volatility pesticides, toxic release from industrial or waste facilities, and traffic density. Second, environmental effects variables measure the presence of pollution producing or environmentally hazardous facilities such as solid waste sites, toxic cleanup sites, and hazardous waste facilities. Third, sensitive population indicators identify the concentration of people most vulnerable to high levels of pollution. These include persons with asthma, cardiovascular disease, and infants with low birthweights. The final category of variables measures the socioeconomic status of a community through factors such as poverty, linguistic isolation, unemployment, and educational attainment.

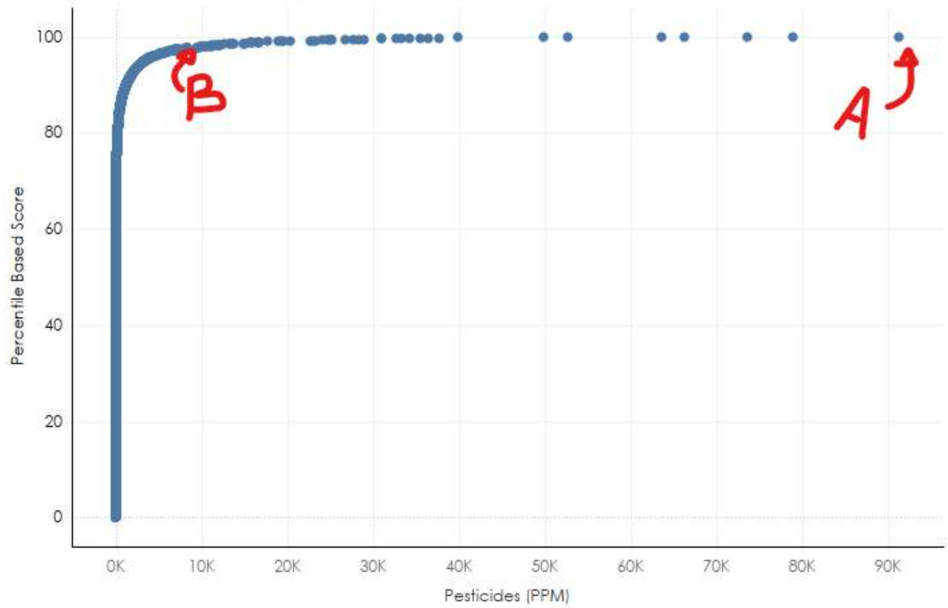
Each factor was measured using data from a vast array of geographically identifiable sources. These include, but are not limited to, the U.S. Census, the federal Environmental Protection Agency, the California Air Resources Board, and various environmental monitoring agencies within the federal and regional governments of Mexico. These data collection efforts are impressive and robust; drawing on a full-panel of sources to measure the impacts of socio-environmental threats that often do not follow traditional geographic boundaries.

CalEPA used a social-vulnerability index framework to highlight communities with compounded risks from pollution. These methods are regularly used by groups such as the Centers for Disease Control and Prevention to assess compound risks from a diverse panel of social factors. Since all these data are measured on different scales, CalEnviroScreen calculates the percentile of a particular census tract across the distribution of pollution exposure, environmental effects, sensitive population, and socioeconomic variables. These values are subsequently averaged together to find a pollution burden and population characteristic score which become the basis for CalEnviroScreen's determination of the most environmentally and socially vulnerable populations.

While this process is meticulously detailed in CalEnviroScreen's methodology handbook, several aspects of its methodology make it a flawed tool in identifying at-risk communities.

- **Use of Percentiles:** The CalEnviroScreen methodology relies on percentiles to calculate the aggregated risk from pollution. However, these percentile scores do not accurately control for asymmetrical distributions of pollutants across census tracts. The result is a method that places equal weight on census tracts with pollution several orders of magnitude smaller than that of the most polluted tracts. As shown in below, the CalEnviroScreen methodology places virtually the same weight on a census tract (B) with a pesticide pollution level one-ninth of the most polluted census tract (A). These issues are particularly impactful in areas with a high concentration of a single pollutant (Blumenfeld and Zeise, 2018).

FIGURE 1: Concentration of pesticides by percentile score



- **Nonrandom Duplication of Pollution Impacts:** CalEnviroScreen includes five environmental effects variables intended to model the effects of unobserved pollution. However, these variables inadvertently duplicate many of the effects measured in the pollution exposure variables. For example, the authors model threats to groundwater systems as any "hazardous substances, degrading soil or groundwater." However, CalEnviroScreen already measures the human impact of these pollutants through the drinking water quality index. This index measures water pollution through an analysis of drinking water sources, which in many cases will include groundwater. The result is a nonrandom bias in which pollutants measured by both the pollution exposure and environmental effects variables are weighted twice while those measured by only one variable series are not.

These methodological issues led us to question whether some communities may appear less vulnerable (or more) then the data suggests. As such, the team developed an alternative methodology using CalEnviroScreen data and some additional sources to create a more robust framework for identifying social vulnerability. Our analysis took two critical steps to correct for the weaknesses in CalEnviroScreen's methodology. First, we rescaled the pollution exposure variables using a z-score. A z-score is a measure of how far an individual value lies from the population average. The formula for z-scores is recounted below:

This score allowed us to measure how far a particular census tract was from the state's average level of pollution. As seen in figure 2, this method gave a far higher score for census tracts with exceptional pollution levels. Census tract A now has a pesticide score far more indicative of its distance from the mean level of pesticide pollution than was provided by the percentile method. We subsequently calculated the average of all individual pollution exposure scores to create an aggregate pollution exposure score. This differential is highlighted in the scores of a census tract in Ventura County shown in table 1.

FIGURE 2: Concentration of pesticides by z-score

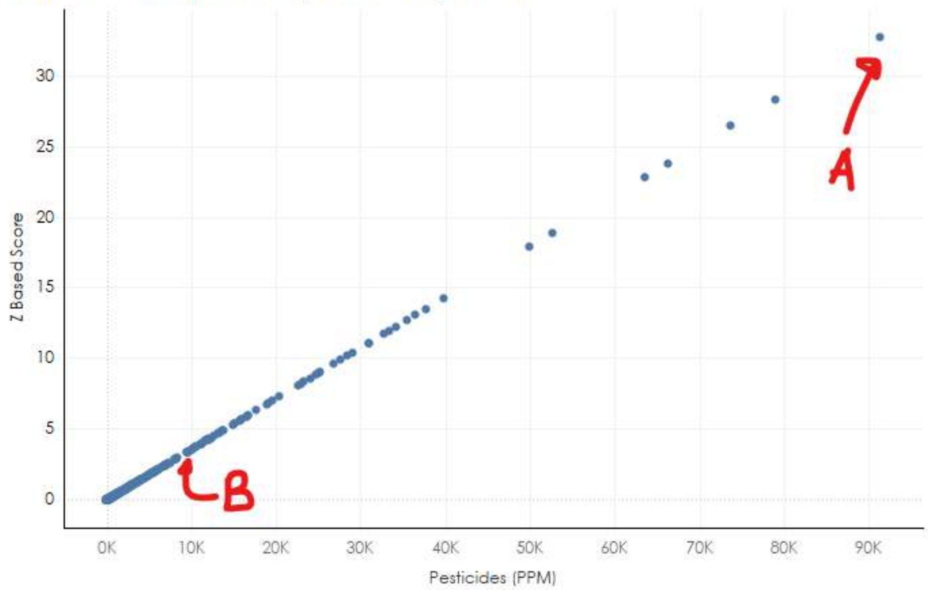


TABLE 1: Pollution Score for Census Tract - 06111004716 (Ventura County)					
Pollutants	Actual	Z-Score		Percentile	
		Raw	Scaled	Raw	Scaled
Ozone (ppm)	0.0	-0.3	1.2	40.5	1.3
PM 2.5 (µg/m3)	9.5	-0.3	1.2	40.9	1.3
Diesel (kg/day)	12.9	-0.4	1.1	38.5	1.2
Pesticides (lbs./sq mi)	91,316.2	32.8	34.3	100.0	3.2
Toxic Release (index)	284.6	-0.2	1.3	41.7	1.3
Traffic (vehicle km/hr.)	508.3	-0.5	1.0	31.6	1.0
Drinking Water (index)	644.8	0.7	2.2	72.6	2.3
Final Pollution Exposure Score		4.5	**6.0**	52.5	**1.7**

These averages did not include environmental effects variables due to the nonrandom bias identified previously. The quartiles formed the cutoffs for an ordinal scale of most to least polluted tracts. This scale allowed us to measure equity gaps between the most and least polluted tracts by comparing their demographic characteristics at the state and regional levels. This method was duplicated to create the social cost-of-living scores using a weighted average rather than the traditional average used in the pollution scoring.

Cost-Benefit Analysis: This study examines city and household-level emissions. Binding the natural gas usage of residents in a city and dividing that by the number of homes already present in the city, we were able to find the amount of natural gas used by each household and estimate the emissions from that. Since the county-level data on Natural Gas is in MMBtu, a measure of heat content. Emissions were measured in therms, which can be found by multiplying MMBtu by 10. A similar process was followed for calculating electricity usage. Electricity usage was tracked in kWh.

After finding the amount of electricity and natural gas that the city of interest used in a given year, we multiplied the emissions by the carbon intensity of that measurement. Further work will be needed to examine the particulate emissions from both power production and indoor natural gas use. It was then necessary to calculate total emissions and emissions per household, which might reveal substantial differences between electric retrofits plus all electric new housing and purely new electric home building.

First, we divided the amount of electricity consumption by the number of homes to find the electricity consumption per home in the base case. The next step was to divide total natural gas consumption by the number of homes, assuming that each existing home was a mixed-fuel home that made use of natural gas and electricity.

Then, after calculating how much use there was and how much per energy source per household, we applied the previously discussed carbon intensities of each energy source to the amount of usage, calculating both the total emissions and the per household emissions.

This created the baseline of emissions in a case where there is no mandate to electrify new buildings or retrofit existing ones. After creating the base case, the two alternative policies were examined: in one case, only new buildings were electrified while in the other alternative new buildings were electrified and one percent of the existing housing stock was retrofitted to be using all-electric appliances. Each scenario's emissions were evaluated in the manner described above, allowing us to evaluate the difference-in-difference in each scenario. Electric houses had no natural gas emissions, but increased electricity usage. The electricity emissions from electrified households were derived from the energy each type of appliance used over the course of a year.

To add another dimension to the analysis, we considered a 1% retrofit rate, where 1% of the houses in a given area would transition from mixed-fuel homes, which use both natural gas and electricity to all-electric appliances. While most proposals have focused on new construction, the city of San Carlos has required that "remodel projects that update more than 50% of the building to be all-electric" (Gough, 2021). Figures on the number of homes that update more than 50% of the building are difficult to come by, so we modeled a policy where 1% of households would be transitioning every year to project what a policy like that might accomplish. We assumed a constant rate of change year over year, though such a policy would likely change consumer habits.

For retrofits, we subtracted the number of retrofitted households from the total number of households and then used that to estimate lover natural gas usage. To simplify our assumptions, we assumed that each retrofitted house would be retrofitted with standard electric appliances and that all the appliances would be changed over at the same time. Each homeowner changes their appliances that their own pace, but a full retrofit scenario provides the clearest counterfactual.

These assumptions allowed us to find how energy use changed in each scenario. After finding the emissions, both the retrofit and new construction scenarios' emissions were valued by the social price of carbon. To estimate the value of the reduction, we subtracted the estimation of the changed emissions profile from the base scenario and then multiplied that by the social cost of carbon.

By testing each city's emissions and housing development with these three potential scenarios, we were able to lay out the potential environmental consequences of each policy course.

Our analysis of the financial impacts too much the same approach. The number of existing homes who would hypothetically need to convert from natural gas to electricity was calculated by multiplying the current balance of natural gas and electric appliances by the total number of homes in 2019. For existing homes, this was considered a one-time cost at year 0. For new homes, the same calculation was used every year a new home was constructed. The result was a different balance of costs and benefits for new and existing homes among appliance purchases. New homes showed a steady distribution of costs and benefits across all 20 years, while existing homes had concentrated costs in year 0 and some benefits and costs distributed at the end of an appliance lifecycle. Other related assumptions are detailed below:

REPLACEMENT RATE OF APPLIANCES
YEARS

Appliance	Natural Gas	Electric
Stove/Range	20	13
Clothes Dryer	13	13
Furnace	22	23
Water Heater	13	13

COST OF APPLIANCES
2021 DOLLARS

Appliance	Natural Gas	Electric
Stove/Range	$1,217	$955
Clothes Dryer	$713	$583
Furnace	$2,419	$1,080
Water Heater	$1,512	$648

ENERGY USAGE BY APPLIANCES

	Stove/ Range	Clothes Dryer	Furnace	Water Heater
Electricity used by electric appliances (khw/yr)	226.7	749.7	1374.2	2281.3
Natural Gas used by natural gas appliances (therms/yr)	25.3	18.8	142.5	167.8

ADDITIONAL DATA AND VISUALS

FIGURE A1: CALIFORNIA CENSUS TRACTS BY SOCIAL COST-OF-LIVING CATEGORY

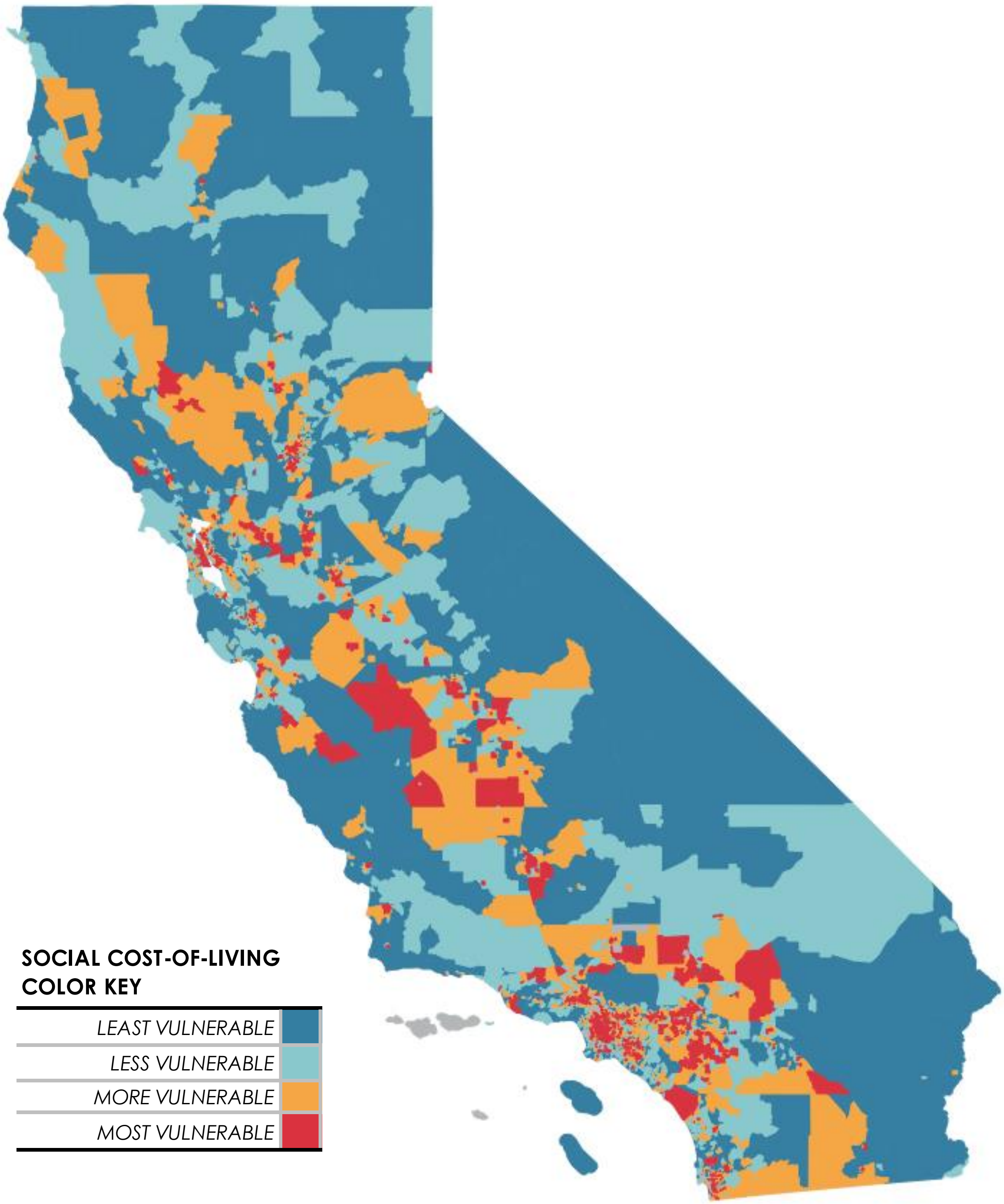


FIGURE A2: CALIFORNIA CENSUS TRACTS BY SOCIAL MOBILITY CATEGORY

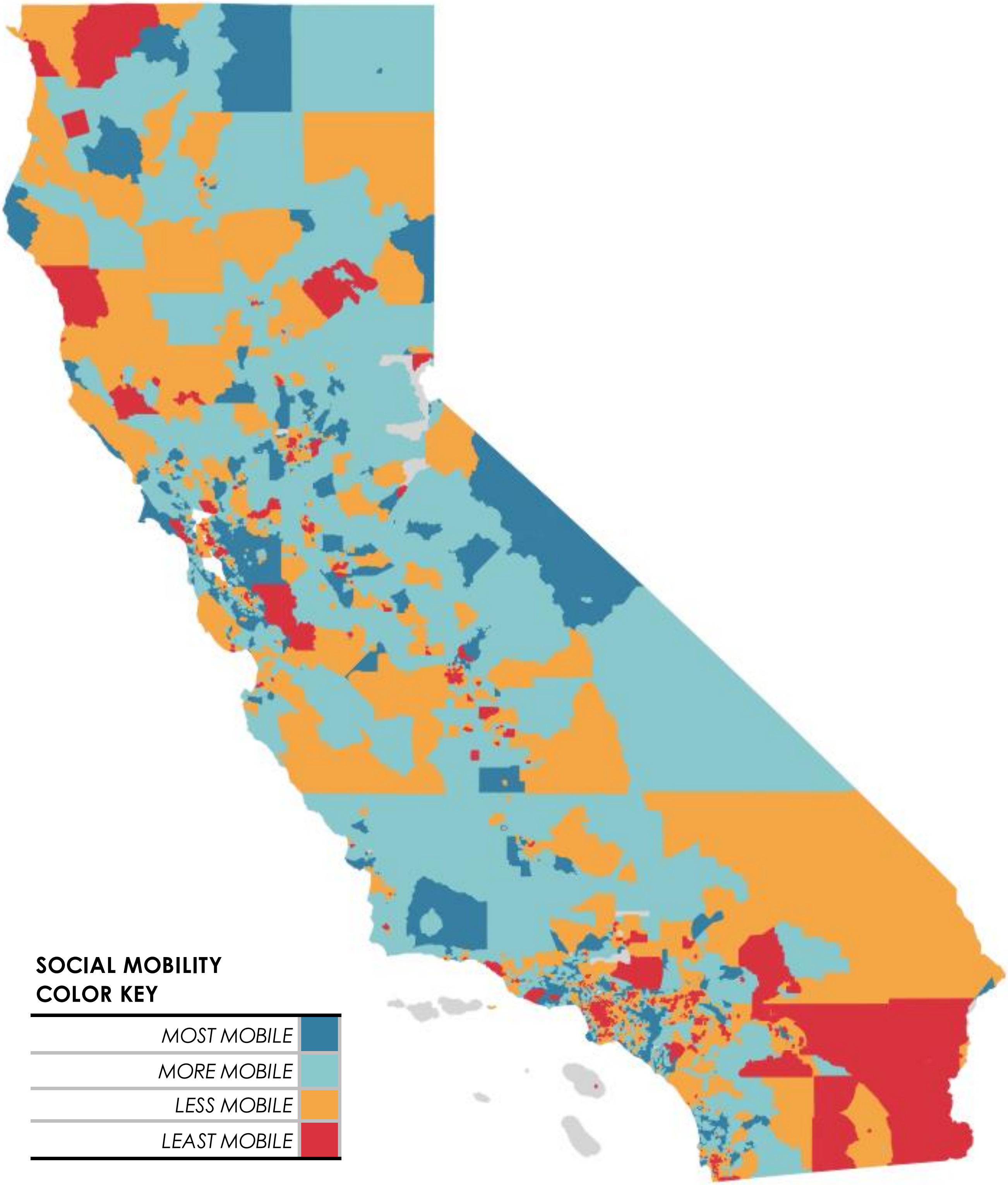


FIGURE A3: PERCENTAGE OF CENSUS TRACTS BY SOCIAL MOBILITY CATEGORIES

SOCAL GAS SERVICE AREA

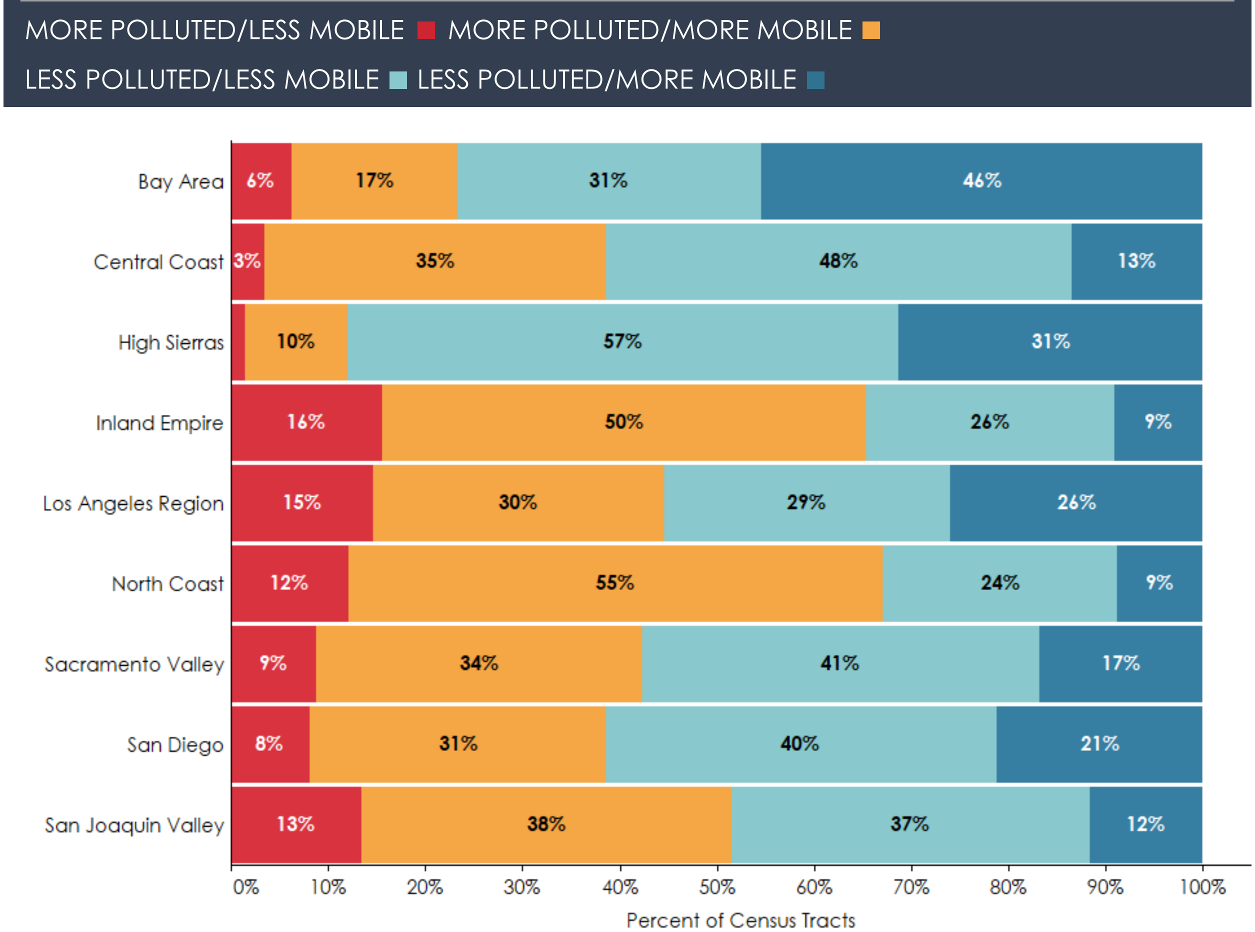


FIGURE A4: CALIFORNIA CENSUS TRACTS BY POLLUTION RISK CATEGORY

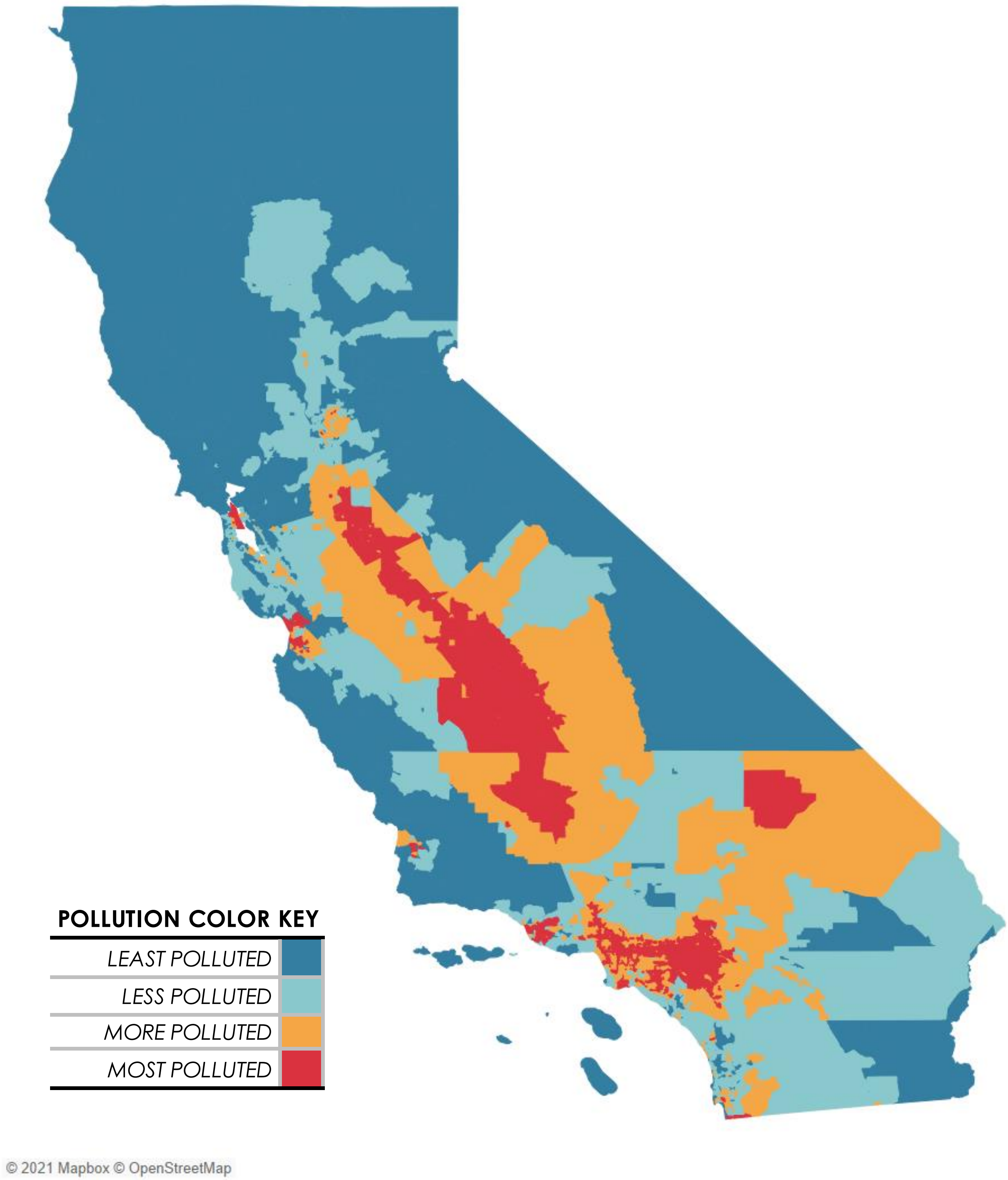


FIGURE A6: SOCIAL COST-OF-LIVING RISK SCORES

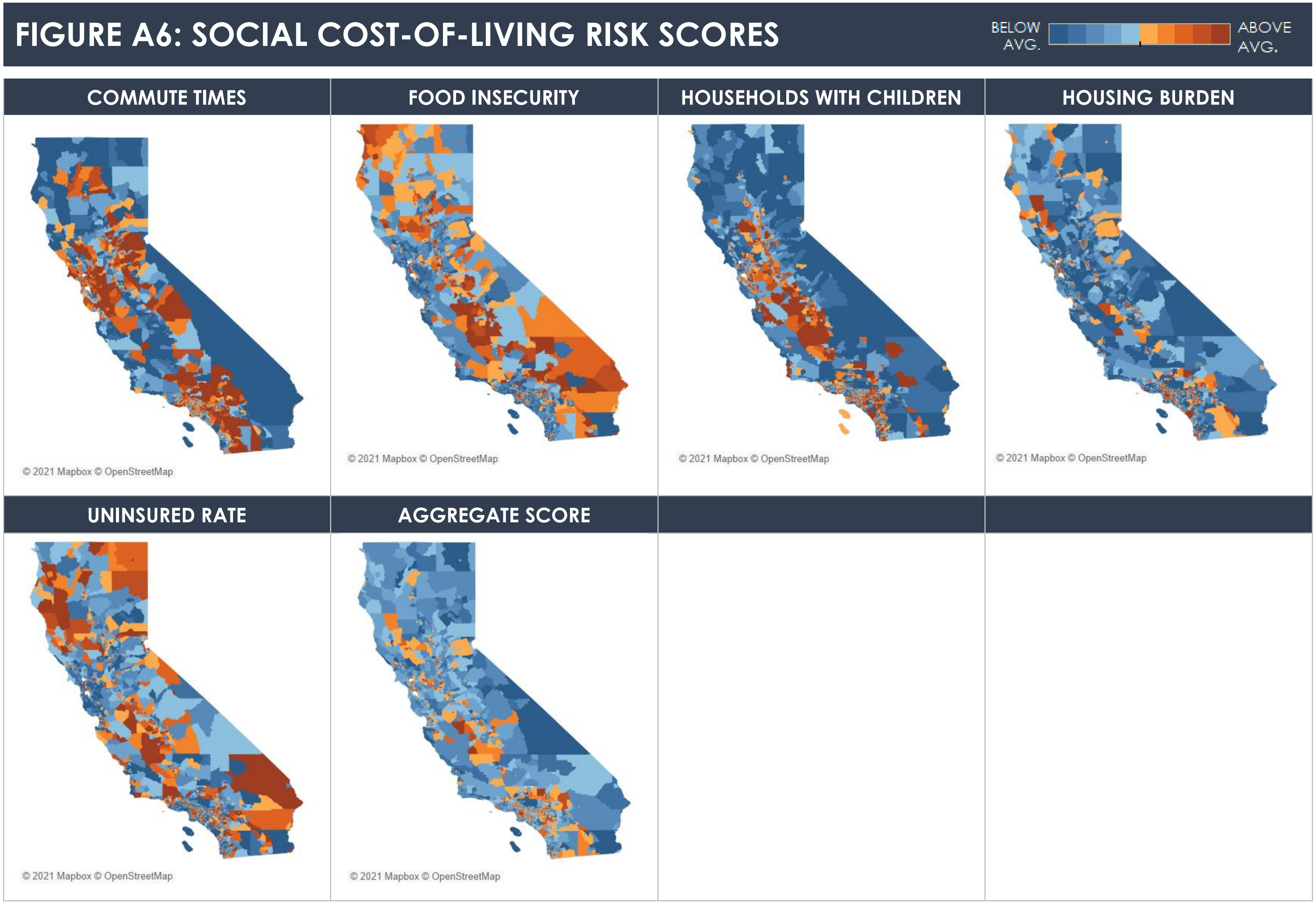


FIGURE A7: POLLUTION RISK SCORES

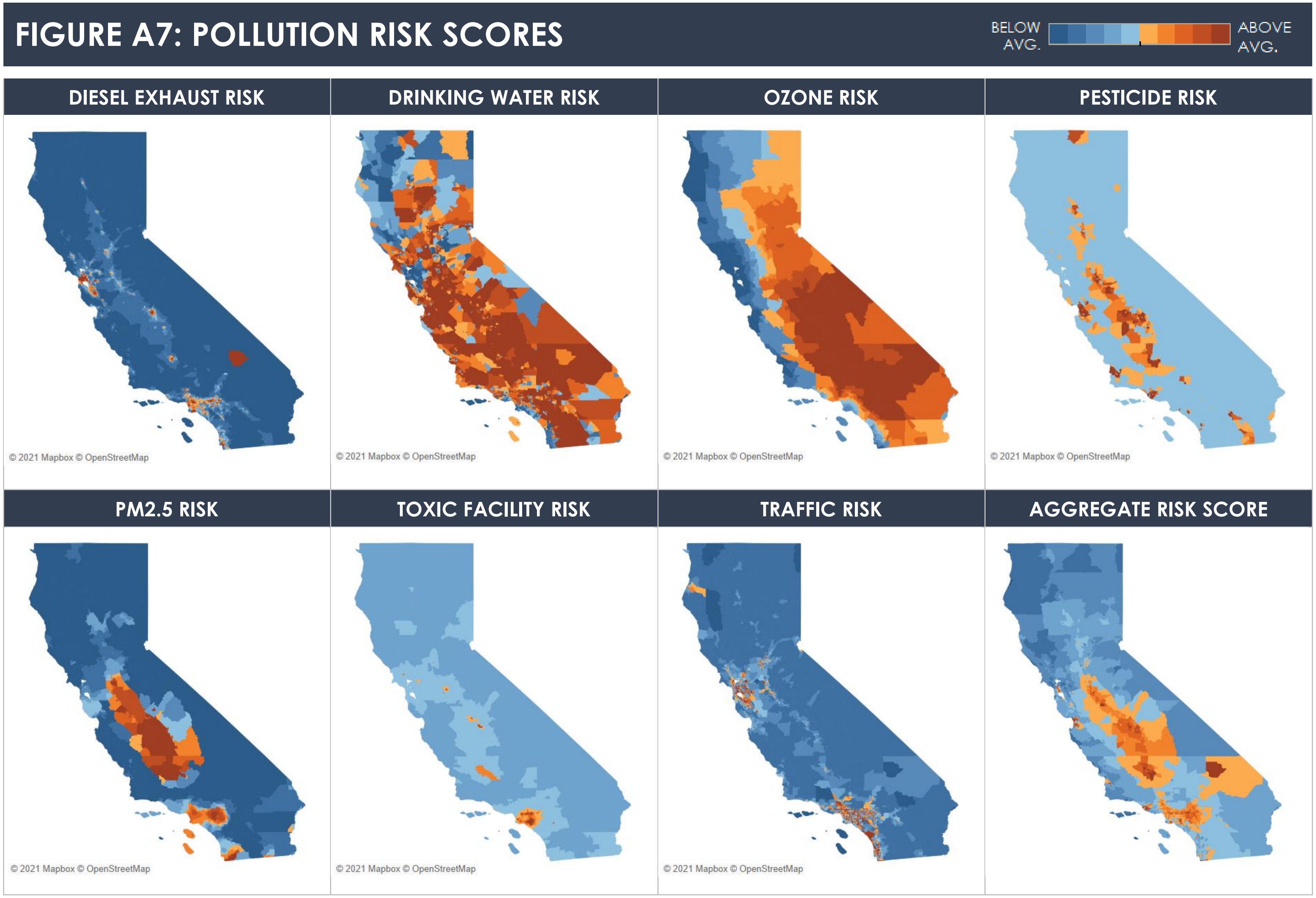


FIGURE A8: CALIFORNIA CENSUS TRACTS BY THE INTERSECTION OF POLLUTION RISK AND SOCIAL COST-OF-LIVING CATEGORIES

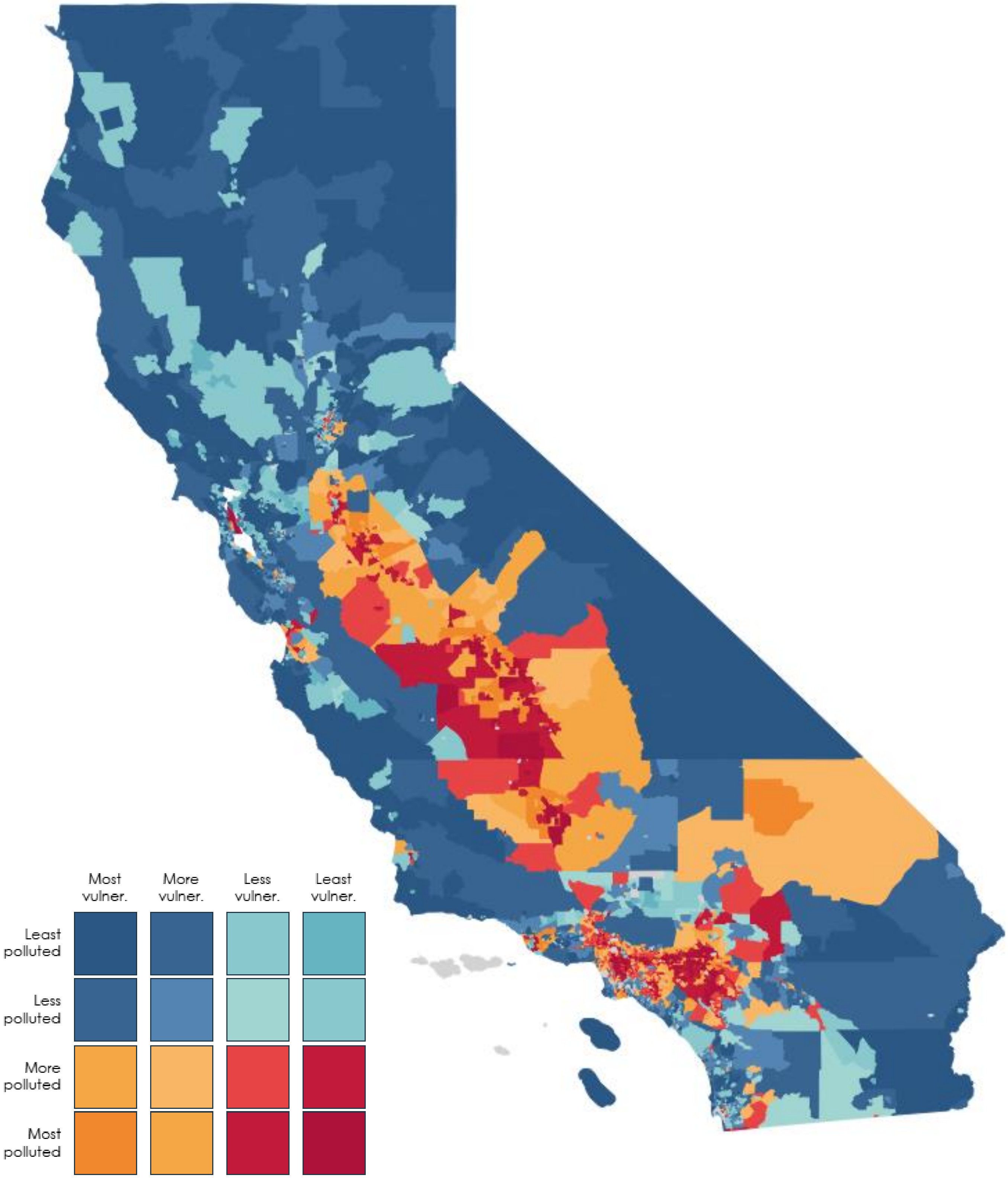


FIGURE A9: CALIFORNIA CENSUS TRACTS BY THE INTERSECTION OF POLLUTION RISK AND SOCIAL MOBILITY CATEGORIES

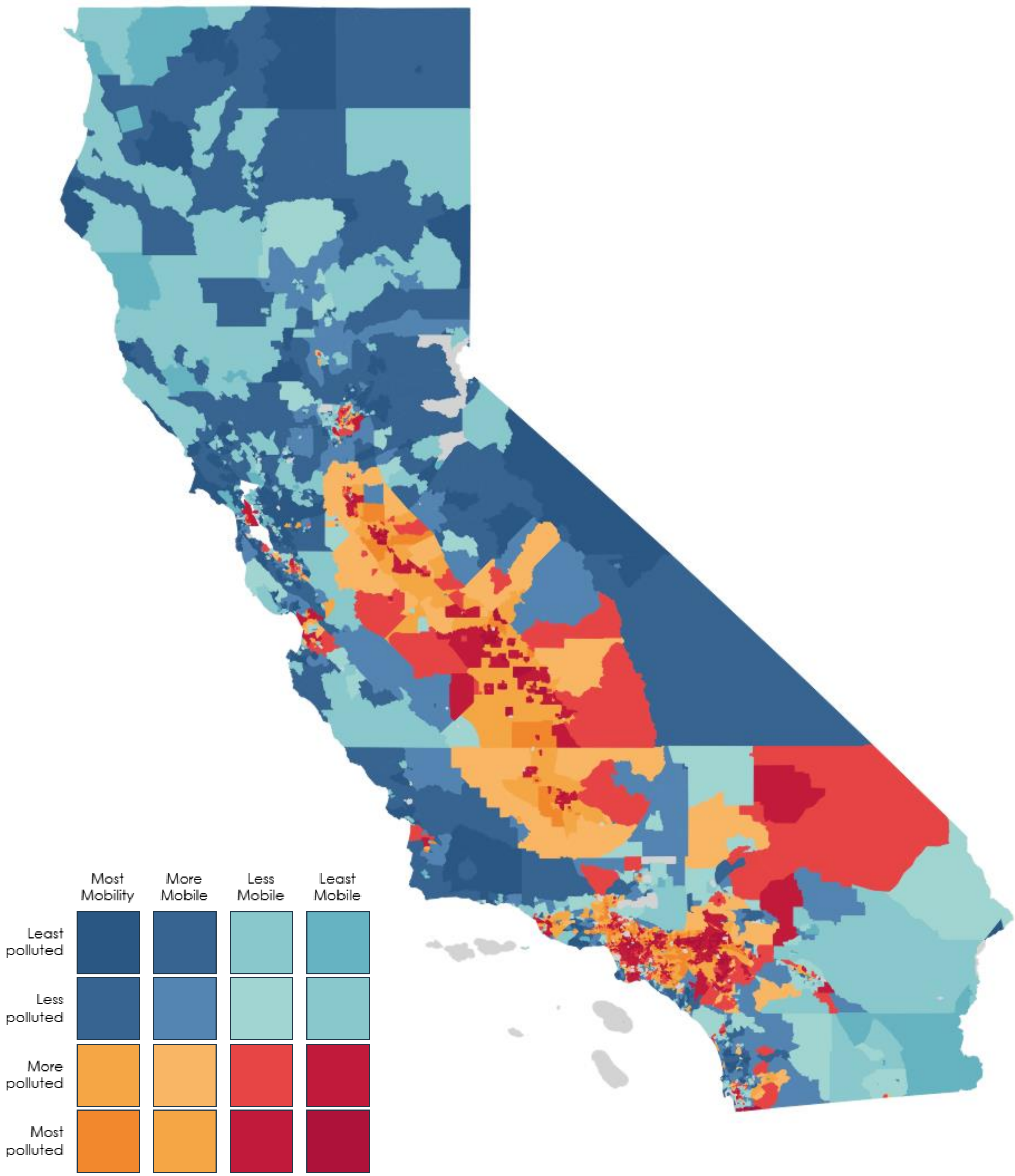
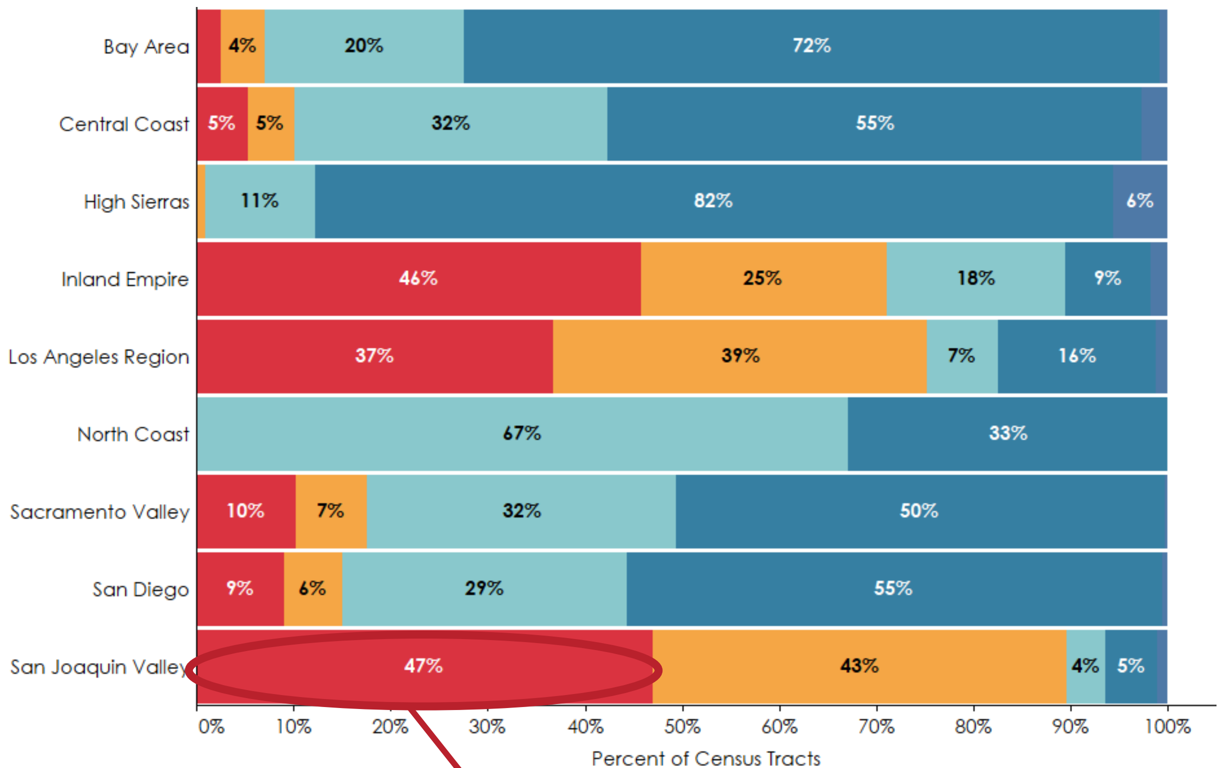


FIGURE A10: RACE AND INCOME DEMOGRAPHICS OF CENSUS TRACTS BY SOCIAL MOBILITY AND POLLUTION RISK

SOCAL GAS SERVICE AREA

MORE POLLUTED/LESS MOBILE ■ MORE POLLUTED/MORE MOBILE ■

LESS POLLUTED/LESS MOBILE ■ LESS POLLUTED/MORE MOBILE ■



WITHIN THE "DUAL CRISIS" tracts, the Los Angeles, Inland Empire, and the San Joaquin Valley regions again, had the highest proportion of tracts in the most acute categories of environmental and social mobility. One in ten tracts in these regions has the lowest rates of mobility and highest incidence of pollution in the state.

	most polluted/least mobile	either pollution or mobility is severe	more polluted/least mobile
Bay Area	0%	1%	2%
Central Coast	0%	3%	2%
Inland Empire	**8%**	**29%**	**11%**
Los Angeles Region	**6%**	**18%**	**13%**
Sacramento Valley	0%	4%	7%
San Diego	1%	3%	5%
San Joaquin Valley	**10%**	**27%**	**11%**

FIGURE A11: RACE AND INCOME DEMOGRAPHICS OF CENSUS TRACTS BY SOCIAL MOBILITY AND POLLUTION RISK

SOCAL GAS SERVICE AREA

	more mobile		less mobile		
	less polluted	more polluted	less polluted	more polluted	Total
Hispanic/Latino	**24%**	**36%**	**54%**	**66%**	**47%**
White (non-Hispanic)	**56%**	**38%**	**29%**	**16%**	**32%**
Asian	13%	19%	6%	7%	12%
Black/African-American	3%	3%	8%	9%	6%
Unknown/Other	4%	3%	3%	2%	3%
Total	100%	100%	100%	100%	

24% overrepresentation of Whites in less polluted/less vulnerable tracts

6% overrepresentation of Whites in more polluted/less vulnerable tracts

7% overrepresentation of Latinos in less polluted/more vulnerable tracts

19% overrepresentation of Latinos in more polluted/more vulnerable tracts

	more mobile		less mobile		
	less polluted	more polluted	less polluted	more polluted	Total
$0 - $24K	**12%**	**15%**	**22%**	**22%**	**18%**
$25K - $49K	**14%**	**16%**	**23%**	**24%**	**19%**
$50K- $74K	14%	15%	17%	18%	16%
$75K - $99K	12%	13%	13%	13%	13%
$100K - $149K	19%	18%	14%	14%	16%
$150K+	**29%**	**23%**	**11%**	**10%**	**18%**

11% overrepresentation of those making more than $150K in less polluted/less vulnerable tracts

5% overrepresentation of those making more than $150K in more polluted/less vulnerable tracts

4% overrepresentation of those making less than $50K in less polluted/more vulnerable tracts

4% overrepresentation of those making less than $25K in more polluted/more vulnerable tracts

FIGURE A12: RACE AND INCOME DEMOGRAPHICS OF CENSUS TRACTS BY SOCIAL COST-OF-LIVING VULNERABILITY AND POLLUTION RISK

SOCAL GAS SERVICE AREA

	less vulnerable		more vulnerable		
	less polluted	more polluted	less polluted	more polluted	Total
Hispanic/Latino	**24%**	**31%**	**55%**	**62%**	**47%**
White (non-Hispanic)	**57%**	**44%**	**27%**	**18%**	**32%**
Asian	11%	17%	8%	11%	12%
Black/African-American	3%	5%	7%	7%	6%
Unknown/Other	4%	4%	3%	2%	3%
Total	100%	100%	100%	100%	

25% overrepresentation of Whites in less polluted/less vulnerable tracts

12% overrepresentation of Whites in more polluted/less vulnerable tracts

8% overrepresentation of Latinos in less polluted/more vulnerable tracts

15% overrepresentation of Latinos in more polluted/more vulnerable tracts

	less vulnerable		more vulnerable		
	less polluted	more polluted	less polluted	more polluted	Total
$0 - $24K	**13%**	**13%**	**21%**	**22%**	**18%**
$25K - $49K	**15%**	**14%**	**22%**	**23%**	**19%**
$50K- $74K	14%	14%	17%	18%	16%
$75K - $99K	12%	13%	13%	13%	13%
$100K - $149K	18%	19%	14%	14%	16%
$150K+	**28%**	**26%**	**11%**	**10%**	**18%**
Total	100%	100%	100%	100%	100%

10% overrepresentation of those making more than $150K in less polluted/less vulnerable tracts

8% overrepresentation of those making more than $150K in more polluted/less vulnerable tracts

8% overrepresentation of those making less than $25K in less polluted/more vulnerable tracts

4% overrepresentation of those making less than $50K in more polluted/more vulnerable tracts

FIGURE A13: PERCENTAGE OF RACIAL/ETHNIC POPULATION BY THE COMBINATION OF POLLUTION AND SOCIAL MOBILITY CATEGORIES OF CENSUS TRACT

SOCAL GAS SERVICE AREA

MORE POLLUTED/LESS MOBILE ■ MORE POLLUTED/MORE MOBILE ■

LESS POLLUTED/LESS MOBILE ■ LESS POLLUTED/MORE MOBILE ■