The Los Angeles 100% Renewable Energy Study

Chapter 10. Environmental Justice

FINAL REPORT: LA100—The Los Angeles 100% Renewable Energy Study

March 2021

maps.nrel.gov/la100

Los Angeles Department of Water & Power

NREL Transforming ENERGY

The Los Angeles 100% Renewable Energy Study

FINAL REPORT: The Los Angeles 100% Renewable Energy Study

Chapter 10. Environmental Justice

March 2021

Lead Authors of Chapter 10: Garvin Heath,[1] Jaquelin Cochran[1]

Procedural Justice and Deployment-Based Environmental Justice: Emma Tome,[2] Meghan Mooney[1]

Air Quality and Public Health-Based Environmental Justice: Dylan Hettinger,[1] Vikram Ravi[1]

[1] National Renewable Energy Laboratory
[2] Consultant

Suggested Citation—Entire Report

Cochran, Jaquelin, and Paul Denholm, eds. 2021. *The Los Angeles 100% Renewable Energy Study*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-79444. https://maps.nrel.gov/la100/.

Suggested Citation—Chapter 10

Hettinger, Dylan, Jaquelin Cochran, Vikram Ravi, Emma Tome, Meghan Mooney, and Garvin Heath. 2021. "Chapter 10: Environmental Justice." In *The Los Angeles 100% Renewable Energy Study*, edited by Jaquelin Cochran and Paul Denholm. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-79444-10. https://www.nrel.gov/docs/fy21osti/79444-10.pdf.

Los Angeles Department of Water & Power

NREL Transforming ENERGY

The Los Angeles 100% Renewable Energy Study

Produced under direction of the Los Angeles Department of Water and Power by the National Renewable Energy Laboratory (NREL) under ACT Agreement 18-39, LADWP Ref: 47481.

Los Angeles Department of Water & Power

NREL Transforming ENERGY

Context

The Los Angeles 100% Renewable Energy Study (LA100) is presented as a collection of 12 chapters and an executive summary, each of which is available as an individual download.

- The **Executive Summary** describes the study and scenarios, explores the high-level findings that span the study, and summarizes key findings from each chapter.
- **Chapter 1: Introduction** introduces the study and acknowledges those who contributed to it.
- **Chapter 2: Study Approach** describes the study approach, including the modeling framework and scenarios.
- **Chapter 3: Electricity Demand Projections** explores how electricity is consumed by customers now, how that might change through 2045, and potential opportunities to better align electricity demand and supply.
- **Chapter 4: Customer-Adopted Rooftop Solar and Storage** explores the technical and economic potential for rooftop solar in LA, and how much solar and storage might be adopted by customers.
- **Chapter 5: Utility Options for Local Solar and Storage** identifies and ranks locations for utility-scale solar (ground-mount, parking canopy, and floating) and storage, and associated costs for integrating these assets into the distribution system.
- **Chapter 6: Renewable Energy Investments and Operations** explores pathways to 100% renewable electricity, describing the types of generation resources added, their costs, and how the systems maintain sufficient resources to serve customer demand, including resource adequacy and transmission reliability.
- **Chapter 7: Distribution System Analysis** summarizes the growth in distribution-connected energy resources and provides a detailed review of impacts to the distribution grid of growth in customer electricity demand, solar, and storage, as well as required distribution grid upgrades and associated costs.
- **Chapter 8: Greenhouse Gas Emissions** summarizes greenhouse gas emissions from power, buildings, and transportation sectors, along with the potential costs of those emissions.
- **Chapter 9: Air Quality and Public Health** summarizes changes to air quality (fine particulate matter and ozone) and public health (premature mortality, emergency room visits due to asthma, and hospital admissions due to cardiovascular diseases), and the potential economic value of public health benefits.
- **Chapter 10: Environmental Justice** (this chapter) explores implications for environmental justice, including procedural and distributional justice, with an in-depth review of how projections for customer rooftop solar and health benefits vary by census tract.
- **Chapter 11: Economic Impacts and Jobs** reviews economic impacts, including local net economic impacts and gross workforce impacts.
- **Chapter 12: Synthesis** reviews high-level findings, costs, benefits, and lessons learned from integrating this diverse suite of models and conducting a high-fidelity 100% renewable energy study.

Table of Contents

List of Figures

List of Tables

Key Findings

The City of Los Angeles identified environmental justice as both a key motivation for the study and an intended outcome for the transition to 100% renewable electricity. This chapter's environmental justice analysis helps characterize some of the potential procedural and distributional justice aspects of the transition. In particular, three areas of distributional justice are reviewed: technology deployment of customer rooftop solar, air pollutant concentrations (fine particulate matter and ozone), and air-quality-related health impacts (emergency room visits from asthma, cardiovascular-related hospital admissions, and premature mortality). In addition, we review qualitatively additional impacts that affect quality of life in ways not quantified in LA100.

How is environmental justice addressed by the LA100 study?

1. The LA100 study was guided by definitions of environmental justice codified in California[1] and federal policy and aimed to follow procedural justice[2] and distributional justice principles in its approach to community engagement and analysis of scenario outcomes.
2. Procedural justice principles motivated the regular release to the LA100 Advisory Group of interim study findings, elicitation, and inclusion of LA100 Advisory Group feedback, updates to LA100 analytical approaches in response to feedback, and hosting and participating in community meetings to inform the public of study findings and gain a better understanding of public priorities for an energy transition. The public has vocalized many priorities; how competing priorities will be evaluated and/or incorporated into implementation plans has not yet been identified. Deliberative polling and participatory budgeting are examples of public engagement that empower residents in decision-making.
3. Distributional justice principles guided the analysis of technology deployment and air quality and related public health impacts in relation to disadvantaged community designations, which are based on present-day CalEnviroScreen scores in Los Angeles, as specified in the August 2017 City Council Motion. Half of the city's census tracts are identified as disadvantaged communities, comprising one quarter of the state's total.
4. Analysis of distributional justice in terms of technology deployment focuses on customer-sited solar adoption as an example. A full environmental justice analysis of not just customer-solar adoption, but also adoption of building energy efficiency and electrification of electric appliances and vehicles, among others, would require details on policy and program implementation, which were beyond the scope of this study. Nevertheless, the adoption levels of these technologies will be important facets of energy justice outcomes. This initial environmental justice analysis is intended to provide high-

[1] Defined as "the fair treatment and meaningful involvement of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies" ("AB-1628 Environmental Justice, 2019-2020," https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200AB1628).

[2] Shelley Welton and Joel Eisen, "Clean Energy Justice: Charting an Emerging Agenda," *Harvard Environmental Law Review* 43: 308–371. https://harvardelr.com/wp-content/uploads/sites/12/2019/08/43.2-Welton-Eisen.pdf.

level context for LADWP's own ongoing policy and program development, implementation, and evaluation.

How is customer rooftop solar distributed in Los Angeles under LA100 scenarios?

1. Significant growth in rooftop solar occurs in all scenarios across the city, in both disadvantaged and non-disadvantaged communities (DAC/non-DAC), as identified by the State of California by its CalEnviroScreen score. There is significant potential for solar in disadvantaged tracts. The distribution of solar between DAC and non-DAC census tracts in future scenarios remains similar to today. In 2020, 35% of customer rooftop solar is sited in disadvantaged communities, rising to 37%–41% by 2045 under the LA100 projections. (For reference, approximately half of the census tracts in LA are DAC.)
2. The LA100 study, however, does not capture many distinctions between disadvantaged and non-disadvantaged households that could be important to rooftop solar projections, including homeownership, rooftop quality, income, and access to financing. Therefore, policy actions to prioritize disadvantaged communities could focus on analyzing these types of factors that would lower barriers to realizing potential economic benefits of solar, as well as non-rooftop alternatives such as community solar and virtual net metering.[3]

How do power plant eligibility and electrification levels in end-use sectors affect pollutant concentrations in disadvantaged and non-disadvantaged communities?

1. In the 2012 Baseline, census tracts designated through their CalEnviroScreen scores by the State of California as disadvantaged communities (DAC) have, on average, higher mean concentration of $PM_{2.5}$ but lower mean concentration of summertime ozone compared to non-DAC tracts. In all evaluated LA100 scenarios (year 2045), the relative patterns of pollutant concentration experienced by DAC and non-DAC tracts persists; that is, all future scenarios show higher concentrations of $PM_{2.5}$ and lower concentrations of ozone in DAC tracts compared to non-DAC tracts.
2. Relative to the Baseline (2012), annual-average, population-weighted concentration of $PM_{2.5}$ decreases by a total of about 0.39–0.56 $\mu g/m^3$ (3.3%–5.2%) in all LA100 scenarios in 2045 on average throughout the City of LA. $PM_{2.5}$ concentration reduction is similar for DAC census tracts as compared to non-DAC tracts for the evaluated LA100 scenarios. (Note that by far the largest monetary damages from air pollution-related health effects results from prolonged exposure to $PM_{2.5}$.)
3. By contrast to the $PM_{2.5}$ results, population-weighted, summertime concentrations of ozone increase by a total of about 4.2–5.3 parts per billion (ppb) (10%–13%) in all evaluated LA100 scenarios relative to the Baseline (2012). (While counterintuitive, the scientifically well-established chemistry of ozone formation means that the reductions in NOx emissions from LA100 scenarios lead to increases in ozone concentration given the current composition of the atmosphere in LA; see Chapter 9 for details). Projected ozone

---

[3] Chapter 5 ranks potential locations for ground-mount solar that could support community solar and virtual net metering programs.

concentration in 2045 for DAC tracts increases slightly more compared to that for non-DAC tracts (e.g., +13% in DAC versus +10% in non-DAC in the Early & No Biofuels – High scenario).

How do health impacts measured in LA100 differentially affect disadvantaged and non-disadvantaged communities?

1. On balance, air pollution-related health effects decrease citywide under LA100 scenarios compared to the baseline in 2012, including both DAC and non-DAC census tracts alike (see Chapter 9). Yet within the citywide benefits, all comparisons among future LA100 scenarios evaluated in the year 2045 yield greater change in health endpoints for DACs as compared to non-DACs for all four endpoints investigated. The differences between DAC and non-DAC are not large in many cases. Further, the 95% confidence level was not reached in our statistical analysis in most cases, which means that we cannot say that there is a difference between DAC and non-DAC that might not have occurred by chance.
2. All LA100 scenarios evaluated indicate improvements in two health indicators—premature mortality and cardiovascular disease—compared to the Baseline (2012). Annual premature mortality reduces by a total of 72 deaths in non-DAC tracts and 76 deaths in DAC tracts in the Early & No Biofuels – High scenario compared to the Baseline (2012). Cardiovascular-related hospital admissions reduce by a total of 38 in DAC tracts (34 in non-DAC tracts) in the same scenario comparison.
3. However, owing to the aforementioned increase from 2012 in ozone concentration in LA100 scenarios, the number of annual asthma-related emergency room visits increases in both tract categories in the two comparisons made to the Baseline (2012) (Early & No Biofuels – High and SB100 – Moderate) (9.8–21 additional visits in DAC tracts versus 1.4–9.3 additional visits in non-DAC tracts). Asthma-related emergency room visits are statistically significantly different between DAC and non-DAC tracts for most scenario comparisons, with DAC tracts seeing, on average, greater increases in incidences.
4. In terms of isolating the contributions of different sectors to the evaluated health effects by comparing amongst evaluated LA100 scenarios in 2045, the greatest improvements observed are from increased levels of electrification of end-use sectors (such as residential and commercial buildings, transportation), as opposed to differences in power sector generation technology type and fuel use. The trend observed whereby the greater the electrification, the greater the improvement in health overall, is likely to continue with higher levels of electrification.

What other, non-quantified impacts of LA100 scenarios could be beneficial to disadvantaged communities?

1. Residents of disadvantaged communities near the LADWP in-basin power plants, the Ports of LA and Long Beach, major roadways, and those living or working in buildings with electrified water or space heating or other appliances have several types of benefits expected as a result of LA100 scenarios in addition to those quantified and reported above.

2. These benefits include reductions in air-pollution-related health effects from lower concentrations of more local pollutants (in contrast to regional air pollutants like ozone and fine particulate matter) contributed by changes to LADWP in-basin power plants, and electrification of the operation of the Ports and light-duty vehicles on major roadways. The concentrations of these other pollutants, such as nitrogen dioxide and toxic and hazardous air pollutants, were not quantified in LA100 because they involve chemistry, health effects, and near-source scales not modeled. Thus, the health benefits quantified in LA100, in this respect, should be viewed as an underestimate.
3. LA100 did not model indoor air quality, where improvements could be experienced from reduced use of indoor combustion equipment replaced with electric appliances.
4. In addition, in various ways, all of the LA100 scenarios should also reduce noise, visual, and odor nuisance from affected sources (like vehicles) and facilities.

Summary: All communities will share in the benefits of the LA100 scenarios—but improving equity in participation and outcomes would require intentionally designed processes, policies, and programs.

Disadvantaged communities (as defined by CalEnviroScreen scores) could expect to see many benefits in a clean energy transition, including reduced local and regional air pollution, improved indoor air quality from electrification, reduced vulnerability to climate change and improve health outcomes. Ensuring prioritization of these neighborhoods, however, is not an inevitable result of the power-system transition. A just, equitable clean-energy future would require intentionally designed decision-making processes and policies/programs that prioritize these communities.

Example actions to support prioritization of environmental justice could include:

- **Participation in Decision-Making**: Identifying barriers to procedural justice can inform improvements to who is included in decision-making, how decisions get made, and what resources are needed to enable parity of participation.
- **Energy infrastructure**: LA100 shows strong potential for electrification, efficiency, demand response, and rooftop solar in disadvantaged communities—but the modeling does not capture real-world experiences and barriers to adoption. Actions to prioritize environmental justice include:
  - Improved data collection and modeling on characteristics that could inform the design and evaluation of electrification, efficiency, demand response, and solar programs (e.g., differences in household size, appliance age, mobility options, access to smart energy devices)
  - More comprehensive representation of benefits (e.g., indoor air quality, improved resilience to extreme weather events with energy efficiency upgrades)
  - Policy designs that target barriers to these programs and related concerns (e.g., the potential for prioritization of benefits to lead to gentrification; impact of stranded costs on low-income customers who do not electrify or adopt rooftop solar; barriers specific to renters)
  - Metrics for success and process for course-correction established in collaboration with stakeholders. One gap in environmental justice metrics is a method to align forward-looking modeling with retrospective-based tools such as CalEnviroScreen. While CalEnviroScreen scores are useful as benchmarks, there is a need to evaluate options for their potential future effects prior

to implementation. Aligning forward-looking models with CalEnviroScreen metrics can enable flagging of potential deficiencies and the creation of optimal solutions toward improvement within the recognized CalEnviroScreen framework, as well as tracking of progress with granularity and frequency not now available through CalEnviroScreen.

- **Jobs**: While not reviewed in this chapter, identifying workforce needs for each energy technology identified in the study has important implications for potential future hiring and training needs. The city could facilitate programs for in-demand occupations that may be hard to fill and other high-quality jobs. The city could also include in clean energy program design some of the workforce objectives sought by the community. For example, some in the public requested solar installations within disadvantaged communities as a way to support clean energy jobs that do not require long commutes.
- **Health benefits**: Electrification of transportation, building end uses, and the Ports of Los Angeles and Long Beach provide significant air quality and related public health benefits. Hence, a prioritization of disadvantaged communities as first immediate beneficiaries of localized air quality improvements would include a focus on electrification. But electrification can be hindered by increasing electricity rates. Toward the end of the 100% renewable energy transition, the cost of decarbonizing the power sector, if reflected in increased rates, could lead to public pressure to reduce the pace of electrification. Further analysis could consider options that maintain decarbonization and improved health as a goal, but with a better understanding of the interaction between the costs of power system decarbonization, pace of electrification, and rate design.
    - In addition, quantifying neighborhood-level impacts could be an important component of an evaluation of LA100 with regard to achieving outcomes beneficial to disadvantaged communities. For example, the design and evaluation of any electric vehicle incentives could be coupled with analysis of local air quality benefits, especially in neighborhoods along roadways that suffer high local pollution. As another example, LA100 results suggest value to reliability in building new, state-of-the-art combustion turbines at current thermal generating stations sites fueled by renewable electricity-derived fuels (such as hydrogen) and operated less frequently compared to natural gas today. One step that LADWP and the City can consider to prepare for this change is to establish expectations of anticipated neighborhood environmental impacts, monitor these impacts, and revise operating protocols as needed.

Important Caveats

1. Analyzing how to prioritize benefits related to technology deployment to environmental justice neighborhoods requires information on future rates and policy and program design and implementation, which will occur after the completion of this study. Nevertheless, the study provides data on potential outcomes, which could help guide policy design. A near-term focus on participatory justice can support a process to design and monitor the policy implementation.
2. Due to methodological incommensurability between CalEnviroScreen and our air quality-health impacts modeling approach, our analysis could not follow the approach used in CalEnviroScreen. This is because CalEnviroScreen is a retrospective tool based on sparsely measured data whereas LA100 looks toward the future using highly resolved models that produce sometimes slightly different metrics than those defined in CalEnviroScreen.

3. Air quality modeling, and thus the analysis of public health effects resulting from changes to air pollutant concentrations, focused on analyzing both High and Moderate load electrification projections of the SB100 and Early & No Biofuels scenarios. Selection of these scenarios provides a high/low bookend to air pollutant emissions amongst the full set of LA100 scenarios. In addition, when evaluated in carefully selected pairs, analysis of these two scenarios allows for the isolation of changes to the power sector (by holding electrification levels constant) and to electrification levels (by holding power sector eligibility criteria constant). Results for the other LA100 scenarios are likely to fall in between those for SB100 and Early & No Biofuels.
4. Owing to a focus on modeling emissions changes to LA100-affected sources (as opposed to all sources of air pollutants in LA), our estimates of concentrations are not predictions of future concentrations in an absolute sense, but rather should only be used in the context of comparing results among the evaluated LA100 scenarios.
5. The analysis in this chapter identifies whether there are statistically significant differences between DAC and non-DAC tracts for the health and air pollutant concentration indicators. However, even when differences between non-DAC and DAC tracts are not statistically different, they may have practical significance, and vice versa (some statistically significant differences are not practically significant). Importantly, health modeling (Chapter 9) indicates that the city as a whole benefits from the emission reduction measures resulting from LA100 scenarios with regard to exposure to ozone and $PM_{2.5}$ and a subset of their related health effects.
6. With the addition of premature mortality, the environmental health endpoints modeled in this study align with those used in CalEnviroScreen. Yet, there are many other environmental health endpoints, and the pollutants that cause them, not modeled in this study, and thus this chapter does not represent a complete environmental health analysis of all of the potential health benefits of LA100 scenarios. In this way, the results reported here underestimate the potential health benefits of LA100 scenarios and their associated monetary benefits. LA100 focused on regional pollutants and did not model pollutants directly emitted that have high local spatial gradients in concentration, nor their associated health effects. For instance, reducing the use of combustion at LADWP in-basin power plants also reduces many pollutants directly emitted, such as NOx and a host of hazardous air pollutants, that have more local effects. *Ultimately this study underestimates the potential health benefits of the LA100 scenarios, especially for nearby residents and neighborhoods.*

1 Introduction

The Los Angeles 100% Renewable Energy Study is a pathbreaking effort to model a transition to a clean energy and mobility future for the City of Los Angeles. After the study, LADWP and the community will determine how to make investments in new infrastructure to support a clean energy future, and these decisions may have differential impacts on residents and ratepayers. The environmental justice analyses of this chapter help characterize the potential procedural and distributional aspects of this transition in order to aid LADWP and its stakeholders in designing policies and programs and investing in infrastructure to support equitable, reliable, and affordable access to clean energy.

This chapter includes specific foci on technology adoption as well as air quality and public health benefits. By evaluating model outcomes inside and outside disadvantaged communities in Los Angeles, we develop a first estimate of how benefits from each LA100 scenario might be distributed, including projections for customer-adopted rooftop solar and localized health impacts from changes in air quality. This analysis marks only the beginning of efforts that impact environmental justice, including community engagement, decision-making, planning, and policymaking.

Often, the justice implications of energy transitions are sidelined relative to the urgent need to address climate change.[4] Energy justice considerations include access to economic benefits, including employment in growing energy sectors, equity in bearing the costs of energy transition (that rates be "just and reasonable"), and in the local environmental impacts of energy siting.[5] LADWP and the LA City Council demonstrated unique foresight in requesting an environmental justice analysis before development occurs.

The focus in LA on environmental justice is now mirrored at the federal level. The new federal administration has signaled a strong interest in addressing the climate crisis while stimulating economic development and delivering environmental justice. As part of a January 2021 executive order, the Biden administration directed federal agencies to develop environmental justice screening tools and ensure that 40% of the benefits from federal investments go to disadvantaged communities.[6] A working group is set to deliver recommendations by May 2021 on how these communities will be defined and investments disbursed.[7]

---

[4] Shalanda H. Baker, "Fighting for a Just Transition: Climate Change Mitigation Does Not Guarantee Social Justice. To Avoid Deepening Inequalities, Clean Energy Transitions Must Prioritize Communities over Profit," *NACLA Report on the Americas* 52 (2): 144–51, https://doi.org/10.1080/10714839.2020.1768732.
[5] Shelley Welton and Joel Eisen, "Clean Energy Justice: Charting an Emerging Agenda," *Harvard Environmental Law Review* 43: 308–371. https://harvardelr.com/wp-content/uploads/sites/12/2019/08/43.2-Welton-Eisen.pdf.
[6] "Executive Order on Tackling the Climate Crisis at Home and Abroad," (White House, January 27, 2021), https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/.
[7] Jean Chemnick, "How Biden's Environmental Justice Order Might Work," *Scientific American* (reprinted from E&E News, February 16, 2021), https://www.scientificamerican.com/article/how-bidens-environmental-justice-order-might-work/.

Environmental and Energy Justice

In the United States, environmental justice is rooted in a long history of activism, research, and policy development with the aim of reducing the disproportionate environmental burdens faced by disadvantaged communities, and communities of color in particular. The 1970s and 1980s included several studies that highlighted the disproportionate environmental burdens faced by poor communities of color living near toxic facilities and waste sites. The First National People of Color Environmental Leadership Summit in 1991 and the seventeen principles laid forth in its Declaration are widely credited with formalizing and growing the environmental justice movement in the United States. Broadly, these principles advocate for recognizing diversity in relationships to the environment and rectifying the harms that have resulted from disenfranchising marginalized groups over time.

Environmental justice was formally recognized in federal policy with Clinton's 1994 Executive Order 12898, which defined environmental justice principles in federal regulatory practice. Environmental justice is also codified in California state policy, as "the fair treatment and meaningful involvement of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies."[8]

Environmental justice frameworks encompass fairness in the distribution of both environmental benefits and burdens. "Energy justice" is similarly concerned with the benefits and burdens of energy services, across the full life cycle of production, consumption, and waste. There are three core justice tenets in the energy justice literature:[9]

- **Procedural Justice**: the ability of people to be involved in decision-making procedures around energy system infrastructures and technologies.
- **Distributional Justice**: the distribution of benefits and burdens across populations.
- **Recognition Justice**: understanding the historical and present basis for social inequalities and the acknowledgment or dismissal of marginalized and deprived communities in relation to energy systems.

These justice tenets, while addressed separately in this chapter, are interwoven. For example, inequitable access to opportunity (distributional justice) could inhibit one's ability to participate in decision-making that has direct influence over resource allocation decisions (procedural justice). Or, if the framing of an issue ignores or omits marginalized perspectives and needs (recognition injustice), this then makes it all the more challenging to even identify where distributional injustices may be occurring. In the energy sector, legal requirements for rates to be "just and reasonable" embed justice considerations in negotiations over rate design.

Other proposed energy justice frameworks take a broader view that encompass human rights and dignities, capabilities, and the role of energy in ensuring fruitful and productive lives. A rights-based approach to energy justice includes (1) the right to healthy, sustainable energy production,

---

[8] "Assembly Bill No. 1628," https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200AB1628.

[9] Sanya Carley and David M. Konisky, "The Justice and Equity Implications of the Clean Energy Transition," *Nature Energy* 5: 569–577 (2020), https://doi.org/10.1038/s41560-020-0641-6.

(2) the right to the best available energy infrastructure (3) the right to affordable energy and (4) the right to uninterrupted energy service.[10]

In August 2017, the Los Angeles City Council passed a motion requiring that LADWP, in its research efforts to achieve 100% renewable energy, incorporate "the CalEnviroScreen into each research area, and as the context for any analysis, study, and/or recommendation" and "the prioritization of environmental justice neighborhoods as the first immediate beneficiaries of localized air quality improvements and greenhouse gas reduction."[11] The LA100 study, which emerged from the City Council motion, has aimed to adhere to the procedural and recognition tenets of environmental justice, as well as California's commitment to "meaningful involvement" through the public LA100 Advisory Group meeting process and community outreach activities. To address to the distributional tenets of environmental justice, the LA100 study compares outcomes inside and outside CalEnviroScreen-defined "disadvantaged communities" for technology deployment of customer rooftop solar and air quality and health benefits.

Whether the City Council's environmental justice goals for LADWP's energy transition are achieved hinges upon policy design and implementation decisions that fall outside the scope of this analysis. LADWP continues to elicit and respond to stakeholder feedback, applies equity metrics to the policies and programs it is developing, and uses those metrics to adjust its implementation plan. This analysis considers the procedural and distributive aspects of community engagement and planning activities to date as it relates to the LA100 study, alongside distributional implications of scenario outcomes.

Context within LA100

This chapter is part of the Los Angeles 100% Renewable Energy Study (LA100), a first-of-its-kind power systems analysis to determine what investments could be made to achieve LA's 100% renewable energy goals. Figure 1 provides a high-level view of how the analysis presented here relates to other components of the study. See Chapter 1 for additional background on LA100, and Chapter 1, Section 1.9, for more detail on the report structure.

---

[10] Diana Hernández, "Sacrifice Along the Energy Continuum: A Call for Energy Justice," *Environmental Justice* 8 (4): 151–156 (August 18, 2015), https://doi.org/10.1089/env.2015.0015.

[11] City Council Motion #3 16-0243, August 1, 2017. https://www.ladwp.com/cs/idcplg?IdcService=GET_FILE&dDocName=OPLADWPCCB689139&RevisionSelectionMethod=LatestReleased

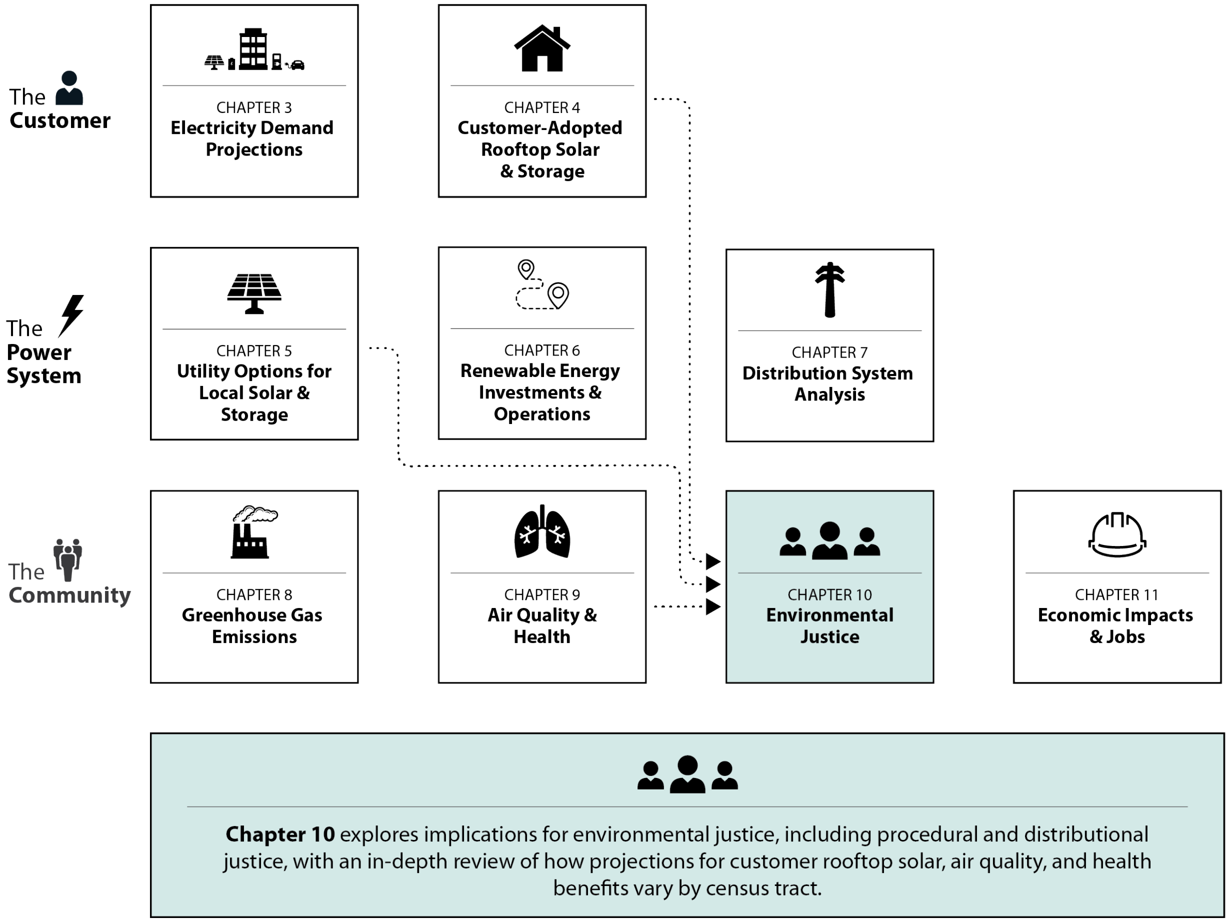

Figure 1. Overview of how this chapter, Chapter 10, relates to other components of LA100

Chapters 4, 5, and 9 provide data and analysis that serve as inputs to the environmental justice results in this chapter.

2 Procedural Justice

The *processes* LADWP and the City of LA implement to ensure that they remain aware of and responsive to the energy system's impacts on and opportunities for the most historically impacted and vulnerable communities will be instrumental to whether and how just outcomes are realized. Before discussing the range of distributional outcomes modeled by LA100 scenarios, we begin our discussion of environmental justice in the context of the LA100 study by discussing procedural justice-related actions taken and lessons learned to date, in order to inform post-LA100 policy design and implementation processes.

One way in which procedural justice can be interpreted is as "parity of participation," which considers the quality and extent of public engagement. Arnstein's Ladder is a classic conceptual model of public engagement, based on Sherry Arnstein's landmark 1969 paper, "A Ladder of Citizen Participation," which critically evaluated participation models used in federal social programs.[12,13] Blue et. al (2019) place Arnstein's ladder in a contemporary context, learning from the increasing embrace of participatory initiatives in mainstream planning and applying it to local policy responses to climate change.[14] To explain why certain groups remain marginalized, occupy different ladder rungs, or are able to move among them, Blue et al. connect Arnstein's ladder to principles of recognition (who is included and heard), redistribution (who gets what), and representation (how do we decide who gets what) (Figure 2), and their underlying cultural, economic, and political forms. They apply Nancy Fraser's synthesis of these justice elements as "parity of participation" – which defines justice as "social arrangements that permit all (adult) members of society to interact with one another as peers." While Arnstein's ladder characterizes the *political* drivers of procedural justice, economic and cultural dimensions are also influential. Fraser's framework acknowledges the many factors—inside and outside how public participation activities themselves are structured—that might influence engagement in, and the outcomes of, these initiatives.

[12] Sherry R. Arnstein, "A Ladder Of Citizen Participation," *Journal of the American Institute of Planners* 35 (4): 216–24 (1969), https://doi.org/10.1080/01944366908977225.

[13] The rungs may be summarized as follows: *Manipulation*: citizen support is engineered through their enrollment in rubberstamp advisory committees with limited or no access to complete information, technical support, and decision-making power; *Therapy*: Citizen discontent is treated as a pathology, and participation is oriented toward influencing and changing citizen feelings and attitudes; *Informing*: a one-way flow of information, from officials to citizens, with no feedback or negotiating power; *Consultation*: informs citizens and elicits opinions but offers no assurance that concerns or ideas will be taken into account; *Placation*: "citizens may plan or advise, but powerholders retain the ability to judge the legitimacy or feasibility of that advice." The degree of placation is dependent on whether citizens have high-quality technical assistance, and how well the community has been organized to press for their priorities; *Partnership*: power is redistributed through negotiation, and parties agree to share planning and decision-making responsibilities; *Delegation*: citizens have dominant decision-making authority over a specific plan or program; Citizen *Control*: citizens govern a program and make decisions regarding all policy/managerial aspects.

[14] Gwendolyn Blue, Marit Rosol, and Victoria Fast, "Justice as Parity of Participation: Enhancing Arnstein's Ladder Through Fraser's Justice Framework," *Journal of the American Planning Association* 85 (3): 363–76 (2019), https://doi.org/10.1080/01944363.2019.1619476.

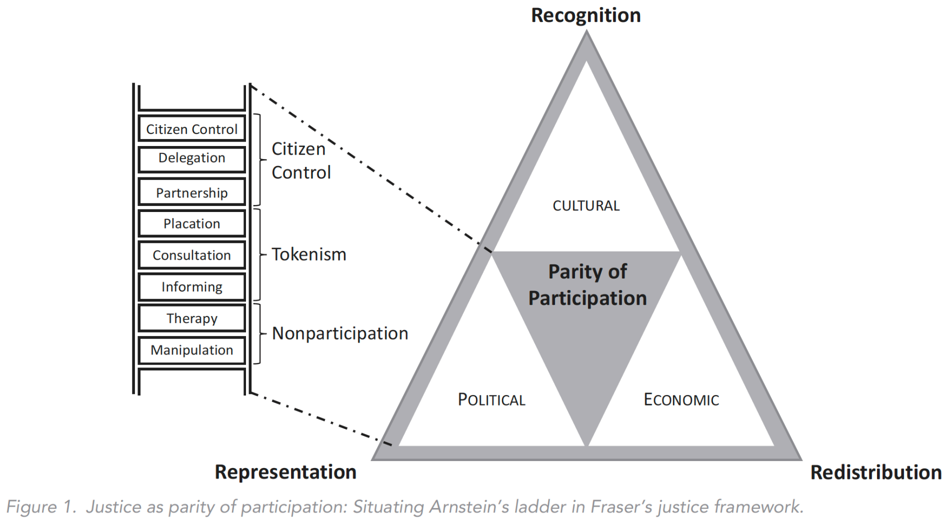

Figure 2. Justice as parity of participation

Reproduced from Blue et. al. 2019

The LA100 study does not use this framework (Figure 2) to analyze different forms of injustice that create barriers to parity of participation, but we include the framework as an acknowledgment that assessing procedural justice more fully is beyond the scope of LA100.

In the following section, we discuss specific aspects of the LA100 study that affect procedural justice. Later in this section, we survey additional approaches to public engagement that LADWP could consider employing to advance its environmental justice aims.

2.1 The LA100 Study in Context of Procedural Justice

To better understand the LA100 study in the context of procedural justice, this section describes the role and engagements of two groups specific to the Study—the LA100 Advisory Group and NREL. Not summarized in this chapter are ways in which LADWP addresses procedural justice across its activities more broadly—including, for example, the role of the LADWP Board of Commissioners in representing the public, the utility's long-standing public participation process in its Strategic Long-Term Resource Planning, and its approach to community outreach generally.

LA100 Advisory Group

To support the LA100 study, LADWP formed an advisory group comprised of representatives from environmental groups, neighborhood councils, academia, key customers, city government, business and workforce groups, and utilities. The LA100 Advisory Group members did not receive compensation and committed to participate on average 8 hours per quarter. During the course of the study, several members representing environmental justice withdrew from the committee; others remained.[15] The purpose of the LA100 Advisory Group was to provide input

[15] For example, an early LA100 Advisory Group member stepped away from the group when its representatives expressed a lack of confidence in LADWP based on decisions it made about Intermountain Power Plant (personal communication, July 8, 2020).

and feedback. For example, the Advisory Group guided the development of the scenarios, which underpin questions that the study addresses. The quarterly meetings of the Advisory Group were open to the public, with all presentations and meeting notes published on LADWP's website.[16]

LADWP kept the Advisory Group discussions as part of the LA100 study purposefully distinct from its planning process (Strategic Long-Term Resource Plan), which was put on hold until the study's completion. LADWP did this to make sure the LA100 study was seen as an independent, third party effort. While LADWP did link the LA100 study outcomes with its Strategic Long-Term Resource Plan, as discussed in Chapter 1, LADWP did not use the LA100 Advisory Group meetings to identify specific mechanisms by which feedback for the LA100 study would be linked to future decision-making.

As LADWP continues to develop strategies for engaging the public in its transition planning, it can evaluate and communicate transparently the specific requests made of the public and the decisions that it will inform. Utility rulemaking processes may be particularly challenging for public stakeholders to participate in when highly technical.

While stakeholder meetings and community feedback can provide useful forums for informing the public of study findings and answering questions, stakeholder processes can become taxing for participants, especially when uncompensated for their time.

In the context of this procedural justice discussion, we do not assume that more public participation is necessarily best suited to address all decision-making related to LADWP's transition planning. For instance, many aspects of power system modeling do not require local public engagement to yield credible first potential action steps on new generation procurement as long as the optimization criteria are mutually agreed upon at the outset. LADWP retains a staff of expert analysts to evaluate, plan, and inform decisions made by LADWP's Board of Commissioners. Nevertheless, LADWP can evaluate areas of its implementation and program and policy development that might be better served through different forms of engagement with the public.

NREL

NREL's role in the LA100 study is to provide objective and scientifically robust information about potential pathways to 100% renewable electricity, not to provide recommendations or directly participate in decision-making. NREL's modeling can inform LADWP and the general public of the potential outcomes and costs of each scenario pathway but does not define or identify what would be "just" or "equitable" given lack of consensus of what that would mean.

Still, no research process is value neutral. While LADWP established the clear long-range goal of 100% renewable energy by 2045, the potential pathways considered within NREL modeling were determined by a scenario selection process that incorporated a range of subjective stakeholder input and pathway preferences from the LA100 Advisory Group. NREL then applied

---

[16] "100% Renewable Energy Study," LADWP, https://www.ladwp.com/ladwp/faces/ladwp/aboutus/a-power/a-p-cleanenergyfuture/a-p-renewableenergystudy.

a variety of physical, economic, and social assumptions necessary to model complex technology adoption dynamics.

The LA100 study is the first of its kind to integrate customer and power system modeling at this scale of complexity, based on actual customer and distribution network data. The space of energy justice policy and programs is evolving just as rapidly as the power system. It would be extraordinarily challenging to decisively conclude, a priori, which aspects of the modeling would be most informative to a participatory process. Hence some features of the scenario design and modeling may not produce the full information needed for stakeholder discussions. However, LADWP can expand upon and integrate public participation in its existing equity-oriented programs and data collection initiatives to ensure that as it determines its first steps toward energy transition, there are well-structured opportunities for targeting energy transition benefits toward communities of need.

NREL has facilitated procedural justice objectives by providing information to the public and receiving feedback on the study and making study findings accessible and relevant to groups participating in discussions with LADWP. Also, at several stages, LADWP and NREL conducted direct outreach with representatives of environmental justice groups, as well as the broader community, including with Spanish translation. In the following section, we highlight where this public feedback directly influenced the study scope in effort to encourage more of a "partnership" form of procedural justice.

2.2 Integrating Public Feedback in the LA100 Study

To ensure we were hearing a broad range of community ideas, interests, and questions, NREL engaged with the public during meetings organized by LADWP (specific to LA100 and LADWP Board meetings), as well as incorporated feedback heard during other public events. These meetings occurred toward the end of the study, at which point the scenarios and scope of analysis were set. For context, note that these meetings occurred virtually during the pandemic, during which hardship and internet connectivity could have adversely affected involvement.

Broadly, listening sessions with environmental justice representatives and discussions during community outreach meetings explored several themes:

- Vision and framing
- Decision-making process
- Community engagement
- Outcomes

Some of these themes can be addressed by analysis in the study, some by community outreach associated with the study, and some by LADWP and others after the completion of the study.

Vision and Framing

Several community members emphasized the importance of framing the question before the City in terms of objectives that reflect environmental justice, such as, "What is a just transition and what would it look like?" "What does it look like to build an energy system that prioritizes public health?" To this, one of the community members cited the decision to retire LADWP's once-through cooling plants as an example of prioritizing public health and the environment in how the city generates energy. In contrast, the member cited redundancies in the system that require must-run plant operations as an example of prioritizing reliability over public health, even amidst investments in clean energy.

In these meetings, the Jemez principles of environmental justice were suggested to serve as the basis for the entire study.[17] Members also suggested making sure the vision was clear and tangible, which would allow the public to understand the concrete changes instead of vague promises.

NREL's actions in response: LADWP currently operates its in-basin generators to provide both energy and reliability services such as spinning reserves to address unexpected failures. Provision of spinning reserves from these generators requires them to be operating at part-load, producing emissions, even when they are not needed for energy. An important part of reducing emissions from these facilities is to provide reliability services from non-emitting resources. To respond to community concern, LA100 accomplishes this via the use of in-basin batteries and rapid-response demand response, both of which can respond at rates much faster than conventional generators.

In addition, during community outreach meetings, NREL began discussions with the public with a focus on visions related to climate change, low electricity bills, jobs, public health, etc. NREL also encouraged the community during outreach sessions to share ideas on their vision in order to document these for LADWP (as described in the Outcomes section, below). NREL's role does not including changing the focus of the study, as set forth in City Council motions and by LADWP, such as to optimize outcomes to support public health above other community goals.

Decision-Making Process

Many community and LA100 Advisory Group members mentioned the importance of being able to participate in decision making, beginning with addressing what it means to have broad, diverse, and robust engagement and facilitate deep understanding, which does not happen through PowerPoint or in meetings where passionate voices dominate. They noted that identifying the decision-making structure is a critical early step.

Similarly, LA100 Advisory Group members requested a process for decision-making that does not just result in a political battle, where who carries the most political weight gets their desired outcome. They requested that the decision-making process be constructed to ensure that what is important to community members be listened to and reflected in *how* decisions get made. Several Advisory Group and community members, through listening sessions and Advisory Group meetings, suggested specific approaches to decision-making, including:

- Ground the discussion in what is best from an environmental justice perspective
- Aim for a clear, fact-based story that would appeal to people on both left and right. For example, a proposal that considers aggressive decarbonization but with off-ramps to save costs if necessary, or a commitment to upgrade to a specific clean technology as soon as cost effective, as anticipated in a given year.

[17] "Jemez Principles for Democratic Organizing," meeting hosted by Southwest Network for Environmental and Economic Justice, Jemez, New Mexico, December 1996, https://www.ejnet.org/ej/jemez.pdf.

- Reflect in the decision-making process the learnings from the years-long effort of the LA100 Advisory Group to understand the issues
- Identify the steps and associated timeline that the City of LA/LADWP must take for all scenarios, and provide status of where they are.

Suggestions were made for the study to identify the three to five things that the City of LA can do to make the transition more equitable. Many people have a general sense of what to be mindful of, so providing specific information would be most useful. In addition, it was suggested to be specific about which investments are needed for disadvantaged communities to be part of the solution, which would also help in the visioning about what this study would mean for one's community.

NREL's actions in response: The tension between 100% renewable energy by 2030 versus pathways that consider the cost of carbon mitigation has dominated many discussions in the LA100 Advisory Group and the competing priorities do not match any single scenario. Solutions that blend elements of both are possible. We identify, for example, investments that could achieve deep but not complete power-sector decarbonization by 2030 and areas of greatest uncertainty associated with accelerated timescales to help identify sources of risk and alternatives that could maintain optionality. In addition, NREL has identified from within the analyses of this chapter which investments contribute to improved outcomes for DAC communities (Section 7).

Community Engagement

LA100 Advisory Group members have made many specific suggestions to improve community engagement. For example, members suggested that we not begin with the technical, but instead start with the vision and then explain how the technical informs options. They also relayed specific goals for community engagement, which included getting them excited about the study, communicating how the study affects them, identifying how they can participate and have a voice, and sharing information on how the community can reduce their electricity bills through energy efficiency and low-income programs. Many LA100 Advisory Group members also noted the insufficiency of environmental justice representation in the Advisory Group.

NREL's actions in response: NREL prioritized community engagement at different points in the study (e.g., outreach meetings with environmental justice groups and the broader community) to ensure that we heard a diversity of voices beyond those shared from the LA100 Advisory Group. These discussions also informed how we communicate the study results. We prepared a variety of materials (including our interactive website and introductory videos and explanatory materials) to facilitate communication of the study by community groups to their colleagues and networks. NREL's direct engagement with the public has been guided by LADWP (e.g., regarding frequency of meetings, composition of the LA100 Advisory Group) but is independent in terms of *what* NREL communicates.

Outcomes

A final theme of comments from the community and LA100 Advisory Group members includes specific outcomes related to investments. Specific examples include:

- Just transition—coupling energy justice with larger themes of economic change and addressing systems of oppression
- Low-income efficiency programs to keep electricity affordable and accessible and keep the burden of higher electricity rates of transitioning to clean energy off the poor
- Low-income solar programs to make clean energy visible and to make this transition feel inclusive
- Distribution grid upgrades that account for potentially higher electricity loads in low-income areas, so that the physical system is not a barrier to more equitable electricity use
- Assistance to renters to participate in solar, efficiency, and electrification programs
- Reduced environmental impacts at end-of-life of technologies, such as batteries
- Increased public charging for cars and bikes in high-density areas, such as apartments, commercial zones
- Global leadership by meeting the 100% target ahead of others
- Affordable rates
- Clean air, including for those located near power facilities
- Alternatives to combustion turbines, such as demand response
- Jobs close to where people live (e.g., rooftop solar installations in their neighborhoods) and information on career pathways

NREL's actions in response: NREL documented these outcomes here for public awareness and to serve as basis for post-study decision-making among the community. For example, the study provides information on how the scenarios align with many outcomes of interest (e.g., least cost, fastest decarbonization, most jobs). LADWP could then devise a decision-making process to consider which set of goals or outcomes to prioritize, how to weigh the attributes of each scenario pathway toward these goals (including scenario blends), and how this process would determine concrete near and long-term steps.

2.3 Procedural Justice in Pathway Selection

With the conclusion of the LA100 study, LADWP has the opportunity to consider how to involve its stakeholder community in decision-making over pathways to 100% renewable electricity. Having established the broad goal of 100% renewable energy by 2045, precisely *how* the utility will go about implementing potential changes identified by the scenarios remains to be determined.

Citizen engagement and empowerment could be effective routes toward durable and equitable energy system changes. In public processes, decision-makers must identify the appropriate level of engagement and trust to place in public opinion. Increasing the number of public hearings or expanding notice-and-comment rulemakings may not be sufficient for ensuring widespread support for renewable energy transitions. LADWP could employ new institutional structures in which more impactful citizen participation can occur.[18]

---

[18] Shelley Welton, "Decarbonization in Democracy," *UCLA Law Review* 67 (1): 56–121 (2020).

Public deliberative processes could aid LADWP in ensuring that the needs and perspectives of residents in the city are meaningfully incorporated in its decisions. Fung (2003) provides a typology of "mini-publics" to distinguish among different approaches. An *educative forum* aims to improve public knowledge and awareness, *participatory advisory panels* improve public knowledge and align policy with considered preferences, *participatory problem-solving collaborations* facilitate ongoing creative problem solving among the state and public sphere, and *participatory democratic governance* directly incorporates citizen voices in setting policy agendas.[19] Table 1 provides examples of these participatory governance styles from LADWP and elsewhere.

Table 1. Participatory Governance Styles: LADWP and Other Examples

Participatory Governance Style	City of LA and LADWP Examples	Other Examples (Fung 2003)
Educative Forum	Community meetings and presentations, Community assemblies through the Office of Climate Emergency Mobilization	Deliberative polling
Participatory Advisory Panel	LA100 Advisory Group	Oregon Health Decisions, Citizen Summit
Participatory Problem-Solving Collaboration	Community Partnership Grants Program, Neighborhood Councils	Citizen Summit, Neighborhood Planning Initiative
Participatory Democratic Governance		Participatory budgeting

The advisory group approach taken for LA100 most closely resembles a participatory advisory panel approach. LADWP conducts routine consumer satisfaction surveys and analyzes data for its Equity Metrics Data Initiative. Using the details of the LA100 scenarios, LADWP could develop a robust and informative public survey that allows all ratepayers to weigh in on their preferred energy transition pathway. LADWP could gauge and report on their customers' energy resource preferences and integrate these preferences into long-term planning.

There is some precedent for such an approach: in Texas, utilities were required to survey consumers on their energy values and preferences as part of integrated resource planning in the early 2000s. Regulators implemented a deliberative polling process to guide integrated resource planning, which allowed informed opinions to be elicited from the public.[20] An advisory group developed a balanced set of survey questions. Survey and focus group participants were sampled from the public, informed of the tradeoffs among options, and registered their opinions over issues related to their values and needs as ratepayers and preferences for their utilities' generation mix, rates, and energy efficiency programs. The core findings—that there was wider

[19] Archon Fung, "Survey Article: Recipes for Public Spheres: Eight Institutional Design Choices and Their Consequences," *Journal of Political Philosophy* 11 (3): 338–367 (2003), https://doi.org/10.1111/1467-9760.00181.
[20] R.L. Lehr, W. Guild, D.L. Thomas, and B.G. Swezey, *Listening to Customers: How Deliberative Polling Helped Build 1,000 MW of New Renewable Energy Projects in Texas* (NREL, 2003), https://www.nrel.gov/docs/fy03osti/33177.pdf.

public support for renewables and energy efficiency than expected—in part led to Texas' rapid expansion of wind energy resources.

Participatory budgeting is another approach to publicly engaged decision-making over energy and environment. In Fresno, the Transformative Climate Communities implementation process included a participatory budgeting component that solicited community input on funding priorities for clean transportation, affordable housing, and local renewable energy.[21]

In determining how to engage the public in scenario decision-making and implementation, LADWP could also draw upon its existing network of local organizations funded through its Community Partnership Outreach Grants program.[22] Local nonprofit organizations receive grants for publicizing LADWP energy and water programs and providing program enrollment assistance. This existing network of local organizations and supporters could help LADWP refine existing programs and develop a more participatory approach to meeting its energy efficiency, building decarbonization, and clean transportation goals. It could have the ancillary benefit of increasing public awareness of LADWP programs and the importance of energy and water conservation.

[21] Alex Karner, Keith Brower Brown, Richard Marcantonio, and Louis G. Alcorn, "The View from the Top of Arnstein's Ladder: Participatory Budgeting and the Promise of Community Control," *Journal of the American Planning Association* 85 (3): 236–254 (2019), https://doi.org/10.1080/01944363.2019.1617767.
[22] "Non-Profit Opportunities," LADWP, https://www.ladwp.com/ladwp/faces/ladwp/commercial/c-savemoney/c-sm-rebatesandprograms/c-sm-rp-non-Profitopportunities.

3 Distributional Justice

The remainder of this chapter will evaluate distributional justice from two perspectives: technology deployment (Section 4) and air quality and public health impacts (Section 5). Both analyses employ CalEnviroScreen as much as possible, which is described further in this section.

3.1 California Environmental Health Screening Tool (CalEnviroScreen)

The California Community Environmental Health Screening Tool, or CalEnviroScreen, is a regulatory tool developed by the California Office of Environmental Health Hazard Assessment (OEHHA) in order to scale environmental justice factors statewide and define "disadvantaged communities" in California. It translates the science of "cumulative impacts" – whereby socioeconomically vulnerable populations are also more vulnerable to negative environmental health impacts – into a scientific methodology and screening tool used in policy and program implementation. Several other environmental justice screening tools predated CalEnviroScreen, including the U.S. Environmental Protection Agency's EJScreen.[23]

The CalEnviroScreen methodology identifies census tracts that have relative socioeconomic and environmental disadvantage as compared to other tracts in the state based on the most recent measures of each indicator (Faust et al. 2017). Twenty environmental and socioeconomic indicators (Table 2) are scaled, weighted, and combined to yield a composite score for each of California's 8,035 census tracts. The top 25 percent highest-scoring tracts are termed "disadvantaged communities."[24] Nearly half of the census tracts in the city of LA are so-determined as disadvantaged communities (494 tracts, comprising almost one quarter of the state's disadvantaged tracts) (Figure 3). Twelve tracts in the city of LA have a population too small to yield scores for the "Population Characteristics" composite indicator, yet have very high pollution burdens, so are classified by OEHHA as disadvantaged communities.[25]

[23] "EJSCREEN: Environmental Justice Screening and Mapping Tool," U.S. EPA, last updated January 22, 2021, https://www.epa.gov/ejscreen.

[24] "Designation of Disadvantaged Communities Pursuant to Senate Bill 535 (De León)" California Environmental Protection Agency. April 2017. https://calepa.ca.gov/wp-content/uploads/sites/6/2017/04/SB-535-Designation-Final.pdf.

[25] *Designation of Disadvantaged Communities Pursuant to Senate Bill 535 (De León)* (California Environmental Protection Agency, April 2017), https://calepa.ca.gov/wp-content/uploads/sites/6/2017/04/SB-535-Designation-Final.pdf.

Table 2. CalEnviroScreen Criteria

Pollution Burden	**Population Characteristics**
Exposures Air quality: Ozone[a] Air quality: $PM_{2.5}$[a] Diesel PM emissions Drinking water contaminants Pesticide use Toxic releases from facilities Traffic density	Sensitive populations Asthma[a] (emergency department visits) Cardiovascular disease[a] (emergency department visits for heart attacks) Low birth weight infants
Environmental Effects	**Socioeconomic Factors**
Cleanup sites Groundwater threats Hazardous waste generators and facilities Impaired water bodies Solid waste sites and facilities	Educational attainment Housing-burdened low-income households Linguistic isolation Poverty Unemployment

[a] Indicators that are directly affected by LA100-modeled sectors and scenarios and considered in this analysis

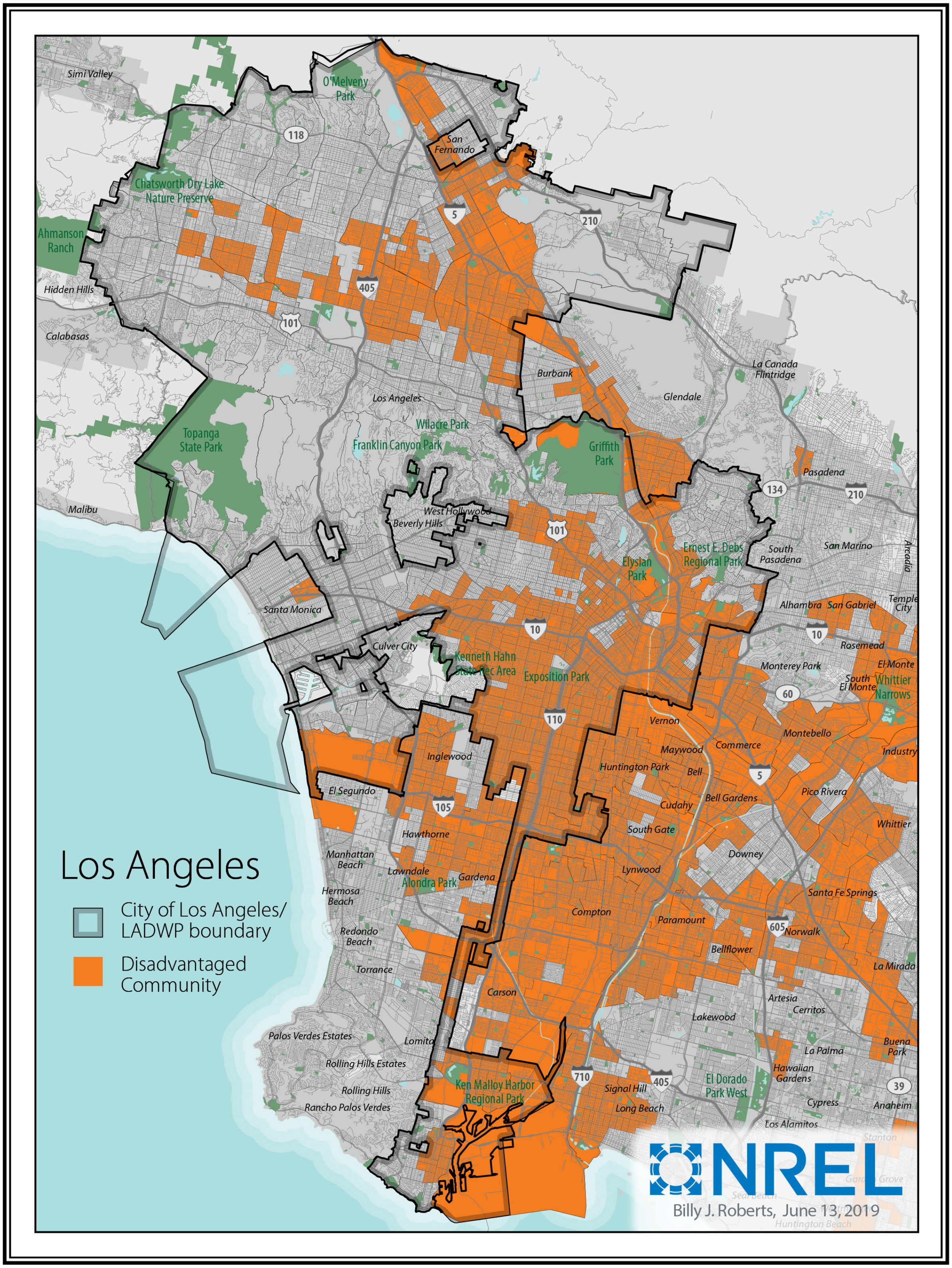

Figure 3. Census tracts that are disadvantaged communities in Los Angeles, as determined by CalEnviroScreen Score and OEHHA definition (score > 75)

CalEnviroScreen was developed as part of the implementation of SB 535, which stipulates how revenues from California's Cap and Trade program (also known as the Greenhouse Gas Reduction Fund) would be invested in California communities. CalEnviroScreen designations have since been incorporated into several areas of California energy and environmental policy, including greenhouse gas reduction fund expenditures (SB535), energy research and development (SB693), and low-income energy programs (AB327, SB350). California policy requires that at least 25% of the proceeds from the Greenhouse Gas Reduction Fund (GGRF) be spent inside, and an additional 10% benefitting, disadvantaged communities. Relatedly, the U.S. EPA's EJScreen has been identified by the Biden Administration as the starting point to develop a new "Climate and Environmental Justice Screening Tool," which will support the Justice40 Initiative, which aims to direct 40% of certain federal investments such as clean energy and transit to disadvantaged communities.[26]

3.2 Applying CalEnviroScreen to LA100 Scenarios

This analysis uses CalEnviroScreen and its disadvantaged community designations in two ways. First, disadvantaged community (DAC) and non-disadvantaged community (non-DAC) tract populations are used as a spatial category for evaluating results from technology deployment models and the air quality and related public health metrics evaluated. LA100 technology adoption models did not incorporate any policy-driven spending or investment constraint aimed at increasing participation or technology adoption within disadvantaged communities. Our analysis reveals currently expected adoption rates, with which stakeholders can consider where to apply policy support to seek different outcomes.

Second, changes to factors closely related to CalEnviroScreen's air quality and public health criteria are presented. Some of these criteria correspond relatively closely to outputs from LA100 models. Others would require additional modeling, including sectors not covered by this study, to yield credible estimates of changes to specific criteria. Thus, only a subset of outcomes from CalEnviroScreen indicators are analyzed in this study: two air quality and two public health outcomes, as shown in Table 2. In addition, even though not a CalEnviroScreen indicator, premature mortality is also analyzed for its environmental justice implications.

Note that due to methodological incommensurability between CalEnviroScreen and our air quality-health impacts modeling approach, our analysis could not produce adjusted CalEnviroScreen scores. See Section 5 for elaboration and results of the analysis we were able to perform.

Figure 4 displays the distribution of California census tracts by CalEnviroScreen score. While for the state as a whole there is a declining frequency (count) of census tracts as CalEnviroScreen score increases, for LA County and city of LA the opposite trend is observed. Figure 4 shows a more granular view of the statement made above, that the city holds approximately a quarter of all DACs in the state yet only accounts for approximately 10% of the total population of

[26] "Fact Sheet: President Biden Takes Executive Actions to Tackle the Climate Crisis at Home and Abroad, Create Jobs, and Restore Scientific Integrity Across Federal Government," White House, January 27, 2021, https://www.whitehouse.gov/briefing-room/statements-releases/2021/01/27/fact-sheet-president-biden-takes-executive-actions-to-tackle-the-climate-crisis-at-home-and-abroad-create-jobs-and-restore-scientific-integrity-across-federal-government/.

California. In addition, there are almost as many highly disadvantaged tracts (CalEnviroScreen score > 90%) in the city of LA as there are in the rest of California.

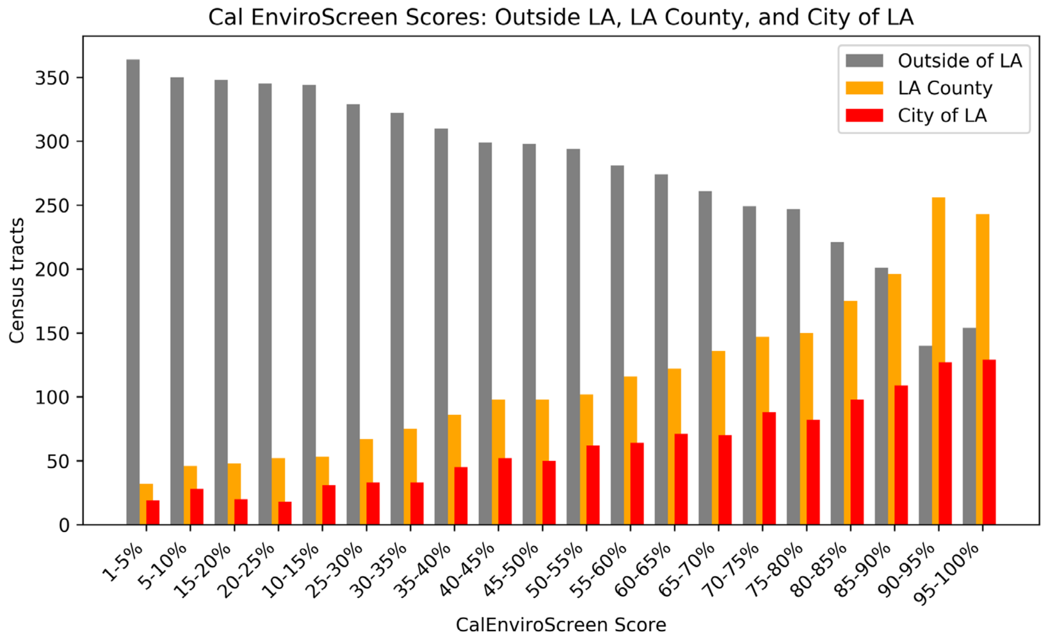

Figure 4. Comparison of count of census tracts by CalEnviroScreen score for all of California outside LA County (in grey), inside LA County (in orange), and inside the city of LA (in red)

Perfectly equitable CalEnviroScreen scores would see even counts of census tracts across bins. There are almost as many highly disadvantaged tracts (CalEnviroScreen > 90%) in the city of LA as there are in the rest of California.

CalEnviroScreen does not directly incorporate racial characteristics into its definition of disadvantaged communities. California's Proposition 26 prohibits any affirmative-action type policies, whereby racial criteria may influence any government funding or hiring decisions. However, definitions of environmental justice, and the history of environmental justice struggles, are tightly connected to experiences of environmental racism, and disproportionate harms experienced by race. Analysis of CalEnviroScreen criteria statewide has also shown that concentrations of Latino/a populations are one of the strongest determinants of environmental disadvantage.[27] Figure 5 illustrates the racial composition of each census tract in LADWP in order of CalEnviroScreen score.

[27] Raoul S. Liévanos, "Retooling CalEnviroScreen: Cumulative Pollution Burden and Race-Based Environmental Health Vulnerabilities in California," *International Journal of Environmental Research and Public Health* 15 (4): 762 (2018), https://doi.org/10.3390/ijerph15040762.

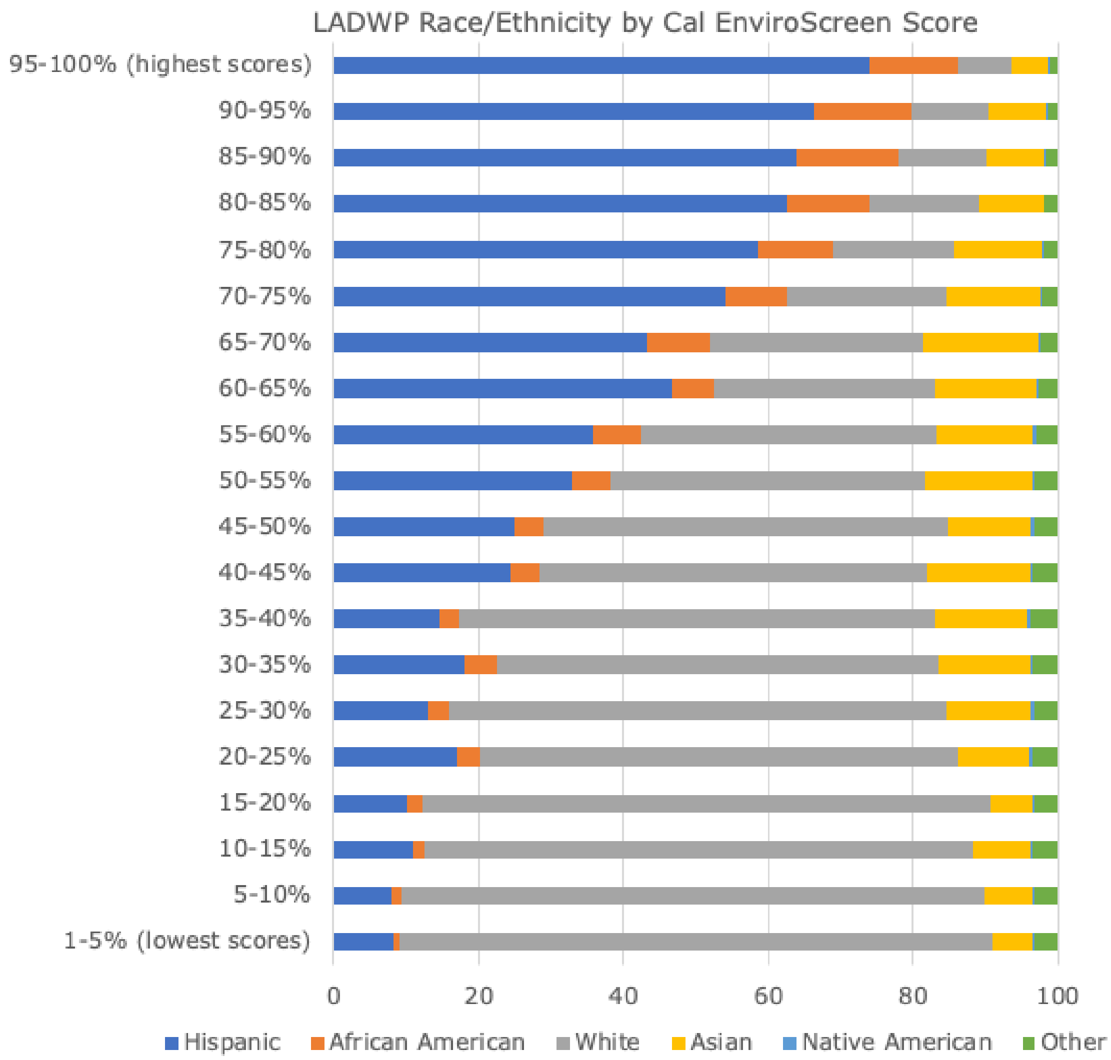

Figure 5. Race and ethnicity in the city of LA by CalEnviroScreen score

City populations are grouped by 5% CalEnviroScreen interval, and racial compositions of each subgroup (as represented on the x-axis) is based on data from the 2010 Census and reported as part of the CalEnviroScreen supplemental data.

This report's analysis of the spatial distribution of technology deployment and estimated health and air quality changes provides some information to illustrate the distributional impacts of each LA100 scenario. However, this analysis marks only the start of comprehensively incorporating environmental justice principles into planning and utility decision-making. Local job creation and access to jobs will also play an important role in whether and how benefits from a renewable energy transition accrue to the most marginalized communities. Both of these topics are outside the scope of NREL's analysis in LA100.

3.3 Beyond CalEnviroScreen: Other Tools that Support Environmental Justice Analysis

While the City Council Motion authorizing LA100 guided NREL to focus on CalEnviroScreen as a key contextual indicator of socioeconomic and environmental disadvantage, several other data sources and mapping tools complement areas underemphasized by CalEnviroScreen measures. As discussed above, one key limitation to CalEnviroScreen is its omission of racial and ethnic data, which are central dimensions to understanding environmental justice and environmental racism. Another is its historical orientation; while CalEnviroScreen synthesizes cumulative harms emergent from the present-day location of polluting facilities and activities, and captures recent trends in poverty, unemployment, education, and housing burden, it does not incorporate measures of exposure or vulnerability to future changes in the climate. Finally, CalEnviroScreen does not include measures of energy burden. In this section, we briefly review these contextual factors in Los Angeles, all of which could bear on LADWP's planning decisions, and in some cases, have already been directly incorporated in LA100 modeling.

While CalEnviroScreen guides the state's investments under the Cap and Trade program, several other statewide tools provide more detailed analysis of socioeconomic disadvantage and climate vulnerability and adaptive capacity, which may be relevant to LADWP and the City's consideration of how to prioritize investments. The next sections provide further background on relevant, available tools and baseline information to inform readers of this report about a wider context of environmental justice issues in the city of LA.

3.3.1 Energy Burden

Similar to the definition of housing burden, energy burden is the average annual housing energy costs divided by the average annual household income, which when high can contribute to reduced social mobility and expendable income. Based on U.S. Census data, a U.S. Department of Energy/NREL-developed tool called the Low-Income Energy Affordability Data (LEAD)[28] provides census tract-level data on energy burden (and many other relevant factors). Figure 6 presents a screenshot of the tool.

[28] Ookie Ma, Krystal Laymon, Megan Day, Ricardo Oliveira, Jon Weers, and Aaron Vimont. 2019. *Low-Income Energy Affordability Data (LEAD) Tool Methodology*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-74249. https://www.nrel.gov/docs/fy19osti/74249.pdf. See also "Low-Income Energy Affordability Data (LEAD) Tool," DOE, https://www.energy.gov/eere/slsc/maps/lead-tool.

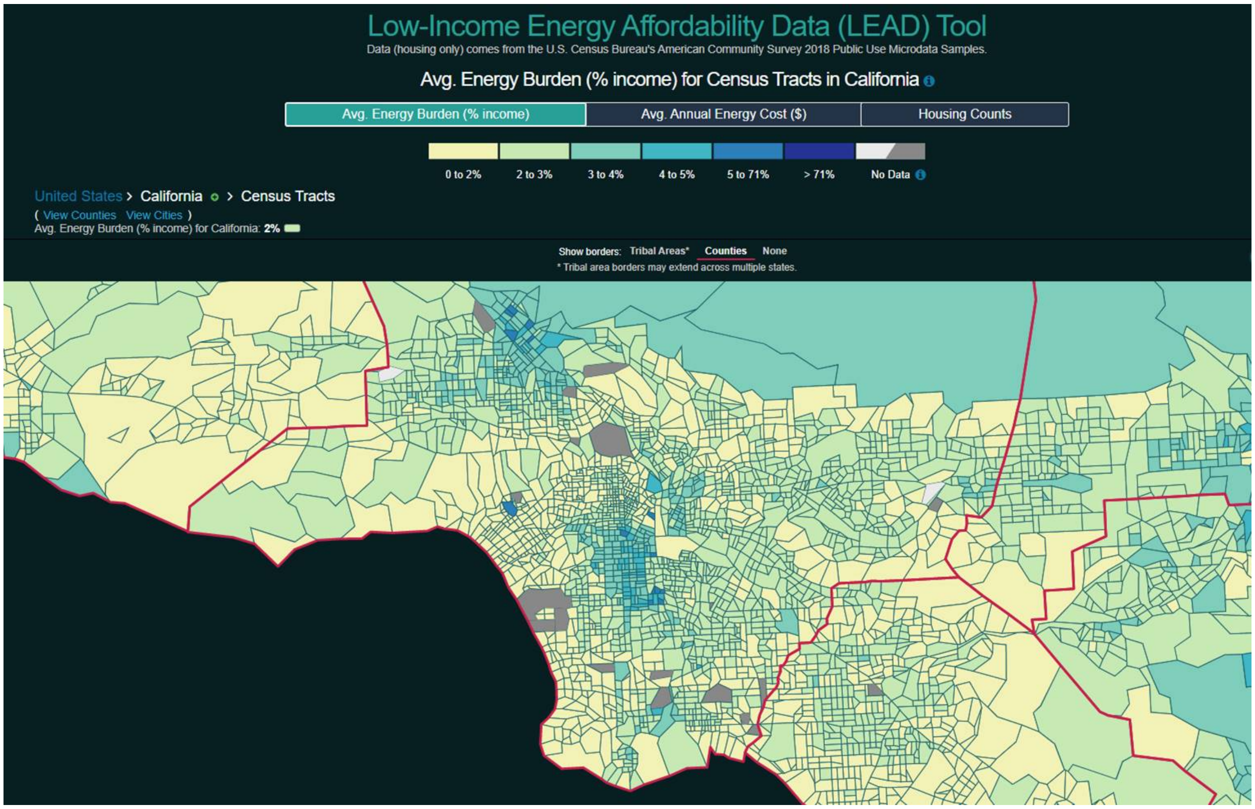

Figure 6. Screenshot from the U.S. Department of Energy's Low-Income Energy Affordability Data (LEAD) tool showing energy burden in Los Angeles (and surrounding) county census tracts

Source: https://www.energy.gov/eere/slsc/maps/lead-tool

3.3.2 Climate Exposure, Sensitivity, and Adaptive Capacity

The CalBRACE project (California Building Resilience Against Climate Effects) aids the state public health department in planning for and reducing health risks associated with climate change. CalBRACE and the Climate Change and Health Equity Program developed the CCHVIz tool (which visualizes data from Climate Change & Health Vulnerability Indicators for California, or CCHVI), which synthesizes data regarding climate change environmental exposures, population sensitivity, and adaptive capacity.[29] The indicators included in the CCHVIz tool are summarized in Table 3.

[29] Climate Change and Health Vulnerability Indicators for California, https://skylab.cdph.ca.gov/CCHVIz/.

Table 3. Climate Change and Health Vulnerability indicators included in the CCHVIz tool, including Comparison to CalEnviroScreen Indicators

			CalEnviroScreen
Environmental Exposures	Extreme Heat Days	Projected number of extreme heat days	
	Air Quality ($PM_{2.5}$)	Three-year annual mean concentration of particulate matter ($PM_{2.5}$)	Y
	Air Quality (Ozone)	Three-year ozone concentration exceedance above state standard	Y
	Wildfires	Percentage of population currently living in high-risk fire hazard zone	
	Sea Level Rise	Percentage of population living in 100-year flood zone and 55 inches of sea level rise	
Population Sensitivity	Children	Percentage of population aged 5 years or younger	Y
	Elderly	Percentage of population aged 65 years or older	Y
	Poverty	Percentage of population whose income in the past year was below poverty level	Y
	Education	Percentage of population aged > 25 years with less than high school educational attainment	Y
	Outdoor Workers	Percentage of population employed and ages > 16 years working outdoors	
	Vehicle Ownership	Percentage of occupied households with no vehicle ownership	
	Linguistic Isolation	Percentage of households with no one ages > 14 years speaking English	
	Physical Disability	Percentage of population with physical disability (ambulatory disability)	
	Mental Disability	Percentage of population with mental disability (cognitive disability)	
	Health Insurance	Percentage of population without health insurance	
	Violent Crime Rate	Number of violent crimes per 1,000 residents	
Adaptive Capacity	Air Conditioning	Percentage of households without air conditioning	
	Tree Canopy	Percentage of area not covered by tree canopy	
	Impervious Surfaces	Percentage of area covered by impervious surfaces	

From this list of indicators, environmental exposures not currently included in CalEnviroScreen include Extreme Heat Days, Wildfires, and Sea Level Rise. According to CCHVIz data, Los Angeles County will see an average of 33.5 extreme heat days per year between 2040 and 2060, and 61.6 by end of century (extreme heat days is defined as days above the 98th percentile of computed maximum temperature relative to a 1961–1990 baseline).[30]

Many factors contribute to heat-related mortality and morbidity, including physiologic susceptibility, home and immediate social environment, neighborhood microclimate and local social factors.[31] According to the 2009 Residential Appliance Saturation Survey (RASS) cited in CCHVIz, 34% of LA County households do not have air conditioning.[32]

About 8.2% of Los Angeles County's population lives in high wildfire risk areas, as defined by Cal Fire's Fire Hazard Severity Zones (Figure 7, next page).[33] This is lower than the statewide average of 11.2%.

In 2014 the Los Angeles County Department of Public Health held several local meetings and workshops,[34] and developed a Five-Point Plan to Reduce the Health Impacts of Climate Change, with a particular initial focus on reducing heat islands.[35] Increasing albedo and tree canopy cover, not addressed in the LA100 study, can cool Los Angeles neighborhoods by up to 2.3ºC during the day and 3.3ºC at night.[36]

---

[30] *Extreme Heat Days: Projected Number of Extreme Heat Days (Per Year)* (CalBRACE n.d.), https://www.cdph.ca.gov/Programs/OHE/CDPH%20Document%20Library/CHVIs/BRACE_ExtremeHeat_Narrative.pdf.
[31] *Climate Change and Health: Understanding How Global Warming Could Impact Public Health in California* (California Senate Office Of Research, 2018), https://sor.senate.ca.gov/sites/sor.senate.ca.gov/files/Public%20Health%20Climate%20Change%20LINKS_4%201126.pdf.
[32] "2009 and 2003 Residential Appliance Saturation Study (RASS)," CEC, https://web.archive.org/web/20190601194456/https://www.energy.ca.gov/appliances/rass/previous_rass.html.
[33] *Current Wildfire Risk: Percent of Population Currently Living in Very High Wildfire Risk Area* (CalBRACE n.d.), https://www.cdph.ca.gov/Programs/OHE/CDPH%20Document%20Library/CHVIs/WildfireZone_786_Narrative_11-8-2016.pdf.
[34] "LA Climate And Health Workshops," LARC, https://www.laregionalcollaborative.com/climateandhealth/
[35] *Mobilizing the Workforce to Address Climate Change: Los Angeles County Public Health Department Case Story* (California Department of Public Health, Office of Health Equity, 2018), https://www.cdph.ca.gov/Programs/OHE/CDPH%20Document%20Library/CalBRACE%20Case%20Stories/A-Climate-Health-Case-Story-LosAngeles-2rev2018.pdf.
"Framework for Addressing Climate Change in Los Angeles County," *Climate and Health Series* (Report 2), Los Angeles County Department of Public Health, 2014, http://publichealth.lacounty.gov/eh/docs/climatechange/FrameworkforAddressingClimateChange.pdf.
[36] Haider Taha, Ronnen Levinson, Arash Mohegh, Haley Gilbert, George Ban-Weiss, and Sharon Chen. "Air-Temperature Response to Neighborhood-Scale Variations in Albedo and Canopy Cover in the Real World: Fine-Resolution Meteorological Modeling and Mobile Temperature Observations in the Los Angeles Climate Archipelago," *Climate* 6 (2): 53 (2018), https://doi.org/10.3390/cli6020053.

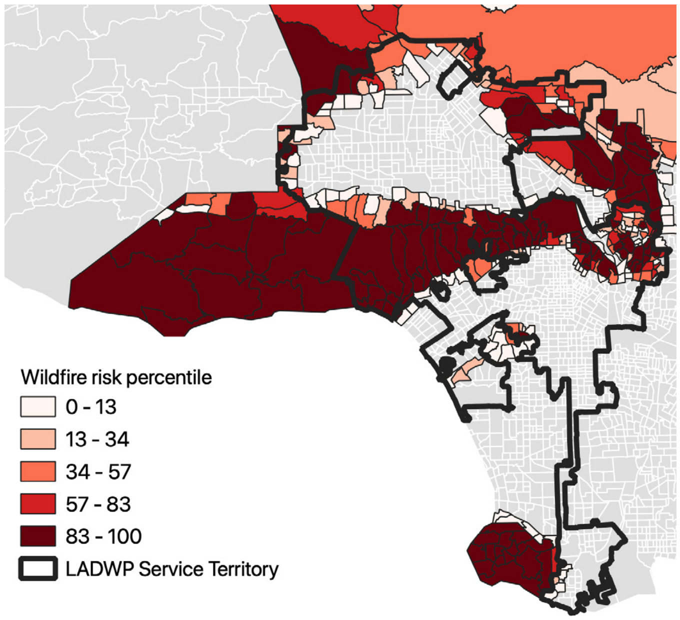

Figure 7. High wildfire risk areas: Share of population at high wildfire risk, scaled by percentile statewide

Climate Change Health Visualization, California Department of Public Health. Data Source: https://skylab.cdph.ca.gov/CCHVIz/_w_867f09df/session/d63157c39b41999362944db6930c34b1/download/downloadData?w=867f09df

3.3.3 Opportunity Areas

Many local technology deployment benefits may be realized through new housing construction, which is anticipated to include residential rooftop solar, high-efficiency appliances, state-of-the-art building envelopes, and electrified end uses. Several state tools evaluate where to direct federal and state investments in new housing construction. If these investments are directed toward disadvantaged communities, this could be a mechanism through which disadvantaged communities are prioritized, although this falls outside the direct purview of LADWP decision-making.

The Treasury Department's Tax Credit Allocation Committee (TCAC), in collaboration with the department of Housing and Community Development (HCD) produces Opportunity Area Maps to identify high and low-resource areas to inform decision-making in federal and state low-income housing tax credit programs.[37] These maps use CalEnviroScreen environmental indicators and a more robust set of socioeconomic indicators including educational proficiency, racial segregation, and access to jobs. Many low-resource areas overlap with CalEnviroScreen-designated disadvantaged communities.

[37] "2021 TCAC/HCD Opportunity Map," California State Treasurer's Office, https://belonging.berkeley.edu/2021-tcac-opportunity-map.

3.3.4 Healthy Places Index: Climate Vulnerability, Adaptive Capacity, and Current Resources

The California Healthy Places Index (HPI) captures perhaps the fullest range of economic, education, transportation, social, neighborhood, environment, housing, and healthcare access indicators.[38] HPI also includes transportation indicators (automobile access and active commuting), social indicators (two-parent households and voting), neighborhood indicators (alcohol access, park access, retail density, supermarket access), housing indicators (homeownership, housing habitability, housing burdens stratified by homeowners and renters, and crowded housing indicators), and rates of health insurance. HPI's Decision Support Layers include a range of additional health outcomes (some of which overlap with CCHVIz), health risk behaviors, climate change exposure, social vulnerability, and adaptive capacity; other disadvantage indicators, and race/ethnicity data.

CalEnviroScreen disadvantaged community tracts largely overlap with HPI's most disadvantaged tracts in Los Angeles, as seen in Figure 8.

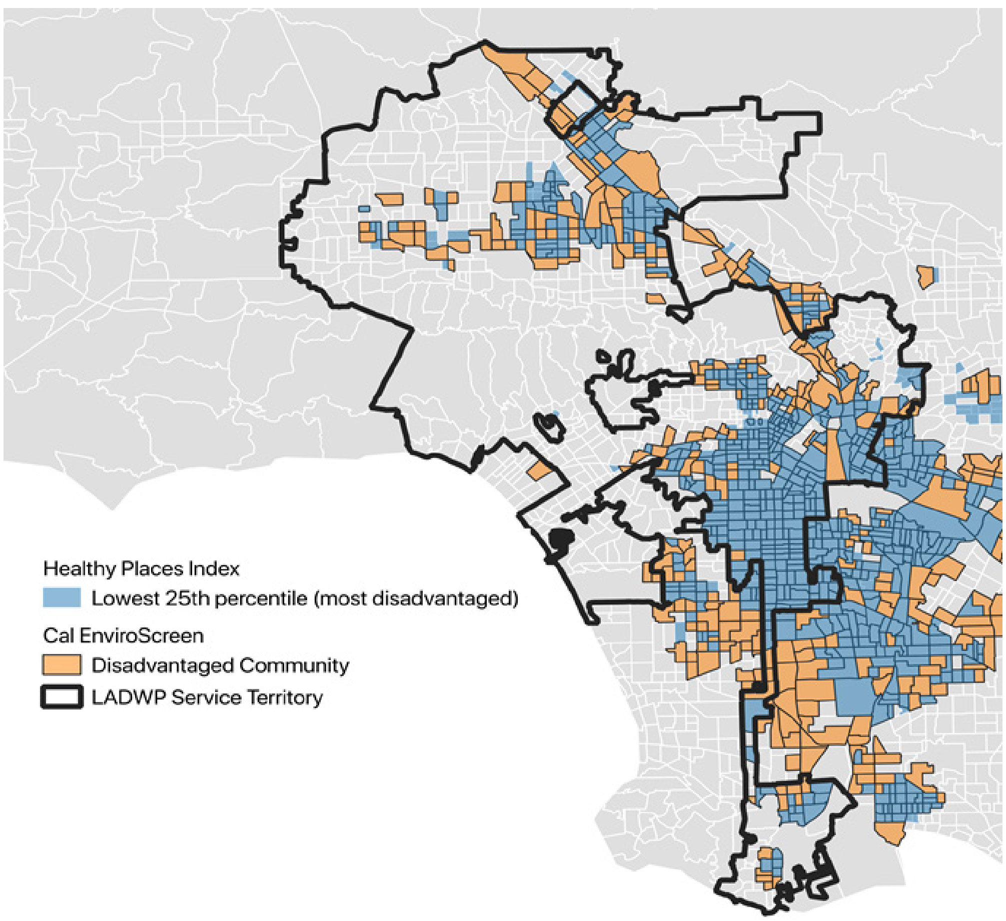

Figure 8. CalEnviroScreen vs. Healthy Places Index in Los Angeles

[38] "The California Healthy Places Index (HPI)," Public Health Alliance of Southern California, https://map.healthyplacesindex.org/.

As LADWP and its stakeholder community determines how best to prioritize LA's disadvantaged communities as part of transitioning to 100% renewable energy, the City could draw on some of these additional resources to characterize climate vulnerability and adaptive capacity, and appropriate policy responses.

4 Distributional Justice: Technology Deployment Analysis of Customer-Sited Rooftop Solar

Distributional justice analyses regarding technology deployment compare the share of clean energy adoption inside and outside disadvantaged communities. The purpose of this analysis in LA100 is not to define a fair outcome, or to model as a target an equal outcome. Instead, forward-looking evaluations of distributional justice can help identify factors that yield particular outcomes. Policymakers and the community can then use this information to decide what policies, if any, could produce results more in line with objectives.

We focus this analysis on customer rooftop solar adoption in disadvantaged communities, which many but not all LA100 Advisory Group members cited as important to energy justice. Other technologies, including energy efficiency upgrades and electrification of end uses, are not included due to modeling constraints. The customer electricity demand modeling (as described in Chapter 3) does not differentiate key data by income level or home size. Such data (e.g., technology adoption, age and type of appliance and plug loads) would be critical to understanding DAC and non-DAC distinctions for electrification and efficiency. This lack of modeling resolution also precludes meaningful energy bill or energy burden analysis for DAC and non-DAC households. Appendix B discusses those limitations in more detail and highlights opportunities for further research.

LA100's customer-sited rooftop solar model includes several premise-level characteristics to estimate a probability of adoption, including some socioeconomic characteristics such as income, sensitivity to prices, and parameters to capture the social diffusion of technology. In LA100, based on discussions with the study's Advisory Group, NREL's customer solar adoption model was not adjusted to prioritize adoption for DACs, but rather assumes that future adoption patterns will be informed by spatial trends in solar adoption to date, as well as projections of where it is economic to adopt solar based on electricity bill savings. Chapter 4 contains a detailed description of assumptions made in the adoption projections, which could serve as a reference in policy design.

This section examines the distribution of projected customer-sited solar adoptions by disadvantaged community status. This comparison of expected adoption rates under current policy conditions and prior adoption patterns can inform stakeholder consideration of whether the currently expected deployment, absent additional policy measures, achieves desired outcomes. But as will be noted, the modeling does not address all factors that influence adoption, so the chapter also notes considerations for environmental justice as implementation proceeds. Moreover, policy and program design could dramatically reshape where, when, and how these resources are adopted compared to what the study has projected.

More detail on the electrification and efficiency assumptions for each scenario and load projection may be found in Chapter 3. The five unique combinations of load and distributed generation projections are described in Chapter 4. Chapter 5 ranks potential locations for ground-mount solar, which can be used for community solar and virtual net metering programs, which are not addressed further in this chapter.

4.1 Customer Solar Deployment Inside and Outside Disadvantaged Communities

For this analysis, we associate customer-deployed distributed solar to a disadvantaged community if the agent adopting solar capacity is sited in a CalEnviroScreen-designated DAC tract. Some agents span more than one tract, but if at least one of these tracts is designated a disadvantaged community, that agent's installed solar capacity is assigned to the disadvantaged community category. Table 4 shows the distribution of agents having adopted solar in 2020, by sector and DAC status.

Table 4. Distribution of Agents Modeled for Having Adopted Customer-Sited Solar by 2020

	Commercial	Industrial	Residential	Total
Non-DAC	17,336 (39%)	549 (21%)	354,082 (62%)	371,967 (60%)
DAC	27,814 (41%)	2,046 (79%)	218,043 (38%)	247,903 (40%)

In 2020, the fraction of residential premises with a rooftop solar system is about 5.5% for all of Los Angeles. This fraction is 6.1% outside disadvantaged communities, and 4.3% inside of disadvantaged communities, as measured by count of rooftop solar systems relative to the number of premises in a tract. In 2020, 35% of distributed solar capacity (in all sectors) is in DACs (which comprise 40% of premises).

Table 5 shows the share of customer solar adoption in DACs in LA by LA100 load projections and rooftop solar adoption projections. In all scenarios, the DAC share of gross solar deployment increases relative to a 2020 baseline. The highest increase is under high distributed generation (DG) and high load projections, which are the conditions with the highest levels of building and vehicle electrification and customer rooftop solar.

Table 5. LA100 Modeling Results: Share of New Customer Solar Adoption, Inside and Outside Disadvantaged Communities

	2020 Capacity (MW)			2045 Capacity (MW)			
	DAC	**Non-DAC**	**DAC %**	**DAC**	**Non-DAC**	**DAC %**	**Increase in DAC Share of Solar, 2020–2045**
Early & No Biofuels, Limited New Transmission – Moderate	115	211	35%	1,464	2,153	40%	20%
Early & No Biofuels, Limited New Transmission – High				1,585	2,315	41%	17%
SB100 & Transmission Focus – Moderate				1,052	1,771	37%	5%
SB100 & Transmission Focus – High				1,171	1,952	37%	5%
SB100 – Stress				1,236	2,019	38%	8%

Figure 9 and Figure 10 show the cumulative adoption inside (orange) and outside (grey) disadvantaged communities, by scenario, sector, and year. The majority of distributed generation capacity is added in the residential sector. While there are increases in both DAC and non-DAC customer-sited rooftop solar (Table 5), disadvantaged communities adopt less new solar capacity than non-disadvantaged tracts, and the gap increases over time for residential. These figures show gross levels of added solar capacity by sector; a different perspective could be made by analyzing the amount of customer solar deployed as a fraction of a census tract's underlying technical or economic potential. With caveats, such an analysis is preliminarily explored in Appendix A.

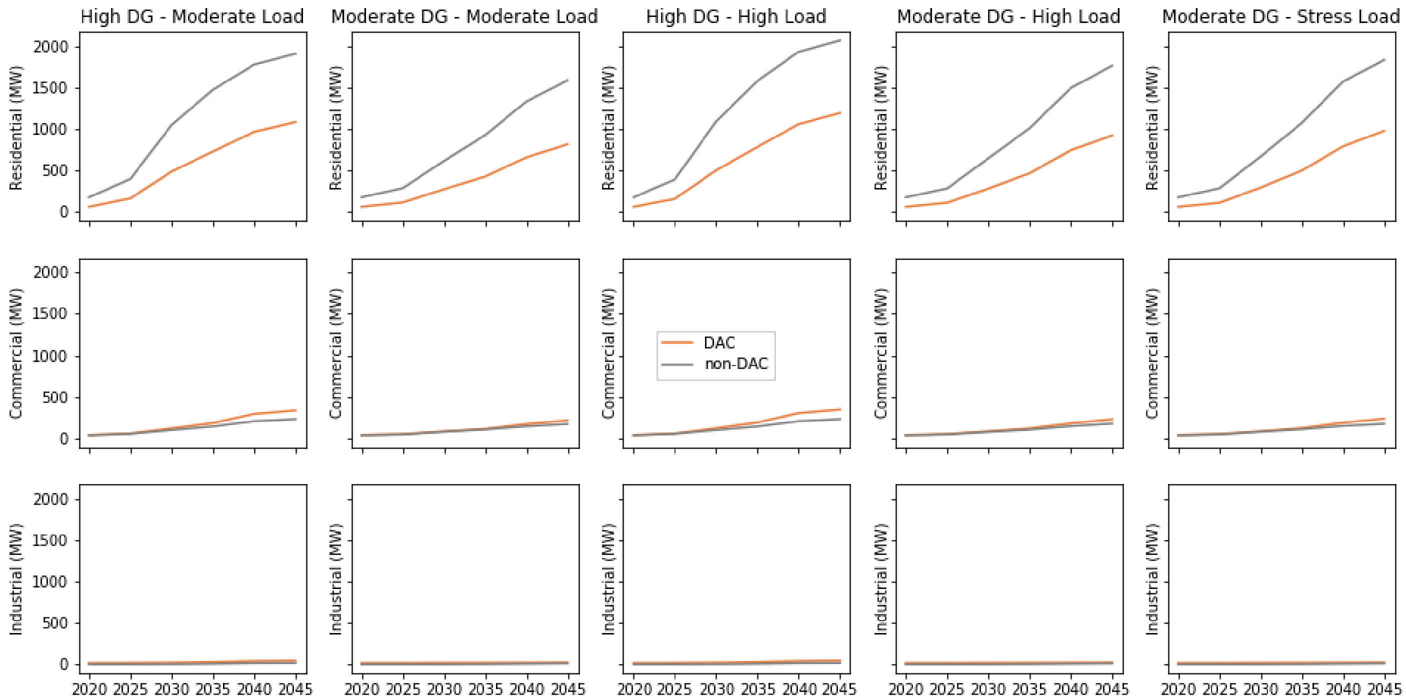

Figure 9. LA100 modeling shows non-disadvantaged community residential solar adoption surpasses disadvantaged community residential solar adoption in all scenarios

Moderate distributed generation (DG) refers to SB100 and Transmission Focus Scenarios. High DG refers to Early & No Biofuels and Limited New Transmission scenarios. The gap in gross adoption is more pronounced in High DG – High Load scenarios, but disadvantaged community solar adoption increases the most in High DG scenarios relative to a 2020 baseline.

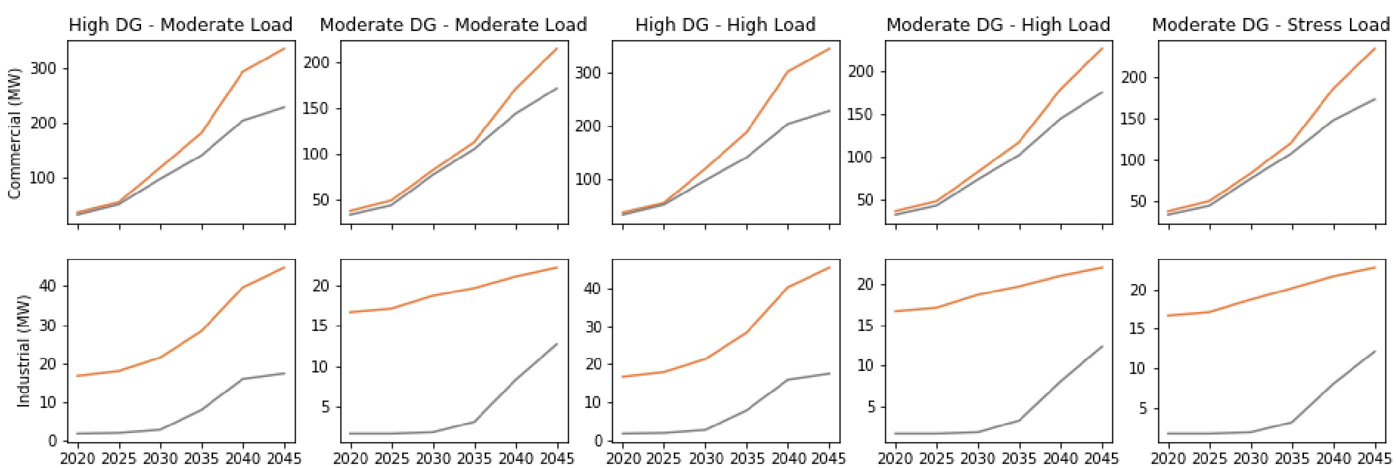

Figure 10. LA100 modeling results demonstrate a larger share of commercial and industrial solar adoption occurs in disadvantaged communities

Data shown is the same as in Figure 9, rescaled for visual clarity.

Compensation schemes differed among scenarios, producing some of the results seen. Net energy metering was used to drive higher adoption levels in Early & No Biofuels and Limited New Transmission, and net energy billing to produce the moderate adoption levels in SB100 and Transmission Focus. Thus, these changing adoption shares suggest that the compensation scheme for customer sited solar could be important for increasing the representation of DAC single- and multifamily homes with rooftop solar.

However, the customer adoption model does not capture income levels or retail tariffs that differentiate rates by income, which could likely change significantly in any case by 2045. Therefore, these data represent projections as if all customers face the same economic benefits and would therefore likely overestimate the value of rooftop solar to those who pay lower electricity rates.

The modeling also does not capture many other distinctions between DAC and non-DAC households that could be important to projections, including homeownership, rooftop quality, access to financing, timing of electricity demand (which affects economic value of projections that use net billing), and access to a competitive market, which can help secure lower bids.

In summary, significant growth in rooftop solar occurs in all scenarios across the city, in both DAC and non-DAC tracts. Both DAC and non-DAC communities have significant potential to adopt rooftop solar; therefore, policy actions to prioritize DAC communities could focus on addressing factors that would lower barriers to realizing the economic benefits, and they are discussed in the next section. Appendix A includes additional analyses that reflect distributional justice of the LA100 rooftop solar projections.

4.2 Energy Justice in a Distributed Energy Future

Customer-sited rooftop solar, while becoming progressively more widespread, has historically had limited reach in low-income communities. The primary barriers to adoption include home age (older homes often require electrical service panel upgrades or roof replacement to install solar), homeownership status (where renting or leasing may limit resident decision-making power and access to finance), and financing challenges (lack of funds to make an upfront investment).[39]

Home ownership is a central barrier to solar adoption among lower-income households. The share of low-income solar adopters has been increasing steadily over time, in part owing to policies aimed at incentivizing low-income adoption. Policies including solar leasing, property-assessed clean energy financing, and low- and medium-income-specific incentives may encourage parity in adoption among higher- and lower- income populations (O'Shaughnessy et al. 2020).

Still, relatively few non-homeowners live in jurisdictions where they have access to such policies. To date, the majority of non-rooftop solar clean energy offerings are opt-in premium rates for "100% clean energy." The Sacramento Municipal Utilities District uses its SolarShares

[39] Jeffrey J. Cook and Lori Bird, *Unlocking Solar for Low- and Moderate-Income Residents: A Matrix of Financing Options by Resident, Provider, and Housing Type* (NREL, 2018), NREL/TP-6A20-70477, https://www.nrel.gov/docs/fy18osti/70477.pdf.

program to comply with the California Energy Commission's new solar homes mandate, automatically enrolling new homeowners as subscribers. California investor-owned utilities are beginning to implement two disadvantaged community solar programs that provide a 20% bill discount for eligible participating ratepayers.[40]

LADWP has already implemented several solar energy programs, some aimed at increasing access to solar generation among low-income ratepayers (see Table 6). The net energy metering program is its most popular residential solar program. LADWP's Solar Rooftops program made it the first utility to build and collect energy from a residential PV program, paying ratepayers for leasing rooftop space, and was designed to increase solar access in underserved communities.[41]

LADWP's existing Feed-in-Tariff program for commercial generators is highly popular and is currently oversubscribed. The Green Meadows Recreation Center pilot project in Central LA includes rooftop and carport solar arrays, both grid-connected and island-able to support local resiliency needs.[42]

Table 6. LADWP's Solar Programs

	Compensation	Ownership	Customer Type	Current Enrollment / [pLAn / SLTRP goal]
Net Energy Metering	On-bill credit for excess generation. Solar Incentive program (discontinued)	Owned or leased from third-party company	Residential (owner-occupied single-family home)	130,000 systems
Solar Rooftops	Fixed-rate lease paid to homeowner for use of roof	LADWP owns the PV system and energy generated	Owner-occupied single-family home	400 systems [2 systems per month] (~600 by 2045)
Shared Solar (est. May 2019)	Subscription to purchase in-basin solar at a fixed rate	LADWP	Residential (apartment, condo, or single-family home)	13,000 enrolled customers
Feed-in-Tariff	Per-kWh payment to generator	Generator-owned resource	Commercial	150 MW [add 300 MW]

LADWP Briefing Book, 20192 (LADWP, 2020), https://s3-us-west-2.amazonaws.com/ladwp-jtti/wp-content/uploads/sites/3/2020/09/22092418/Briefing-Book-2019-20-Final-Online.pdf.

[40] *Alternate Decision Adopting Alternatives to Promote Solar Distributed Generation in Disadvantaged Communities* (California Public Utilities Commission, 2018), Rulemaking 14-07-002. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M216/K789/216789285.PDF.
[41] "LADWP Launches the Solar Rooftops Program Providing the Benefits of Solar Energy to More Angelenos," LADWP, https://www.ladwpnews.com/ladwp-launches-the-solar-rooftops-program-providing-the-benefits-of-solar-energy-to-more-angelenos/.
[42] *Power System Resiliency Update* (LADWP, January 22, 2020), Stakeholder Advisory Group, https://www.energy.gov/sites/prod/files/2020/03/f73/DRC%20SAG%20Meeting%20-%20LADWP.pdf.

LADWP releases data on some of these programs as part of its Equity Metrics Data Initiative, which tracks and reports on 15 metrics related to infrastructure investment, consumer incentive programs and services, procurement, and employment. Metrics related to LA100 include electric vehicle infrastructure investments, low-income and lifeline programs, the home energy improvement program and commercial direct install programs, and the consumer rebate program (see examples in Figure 11).

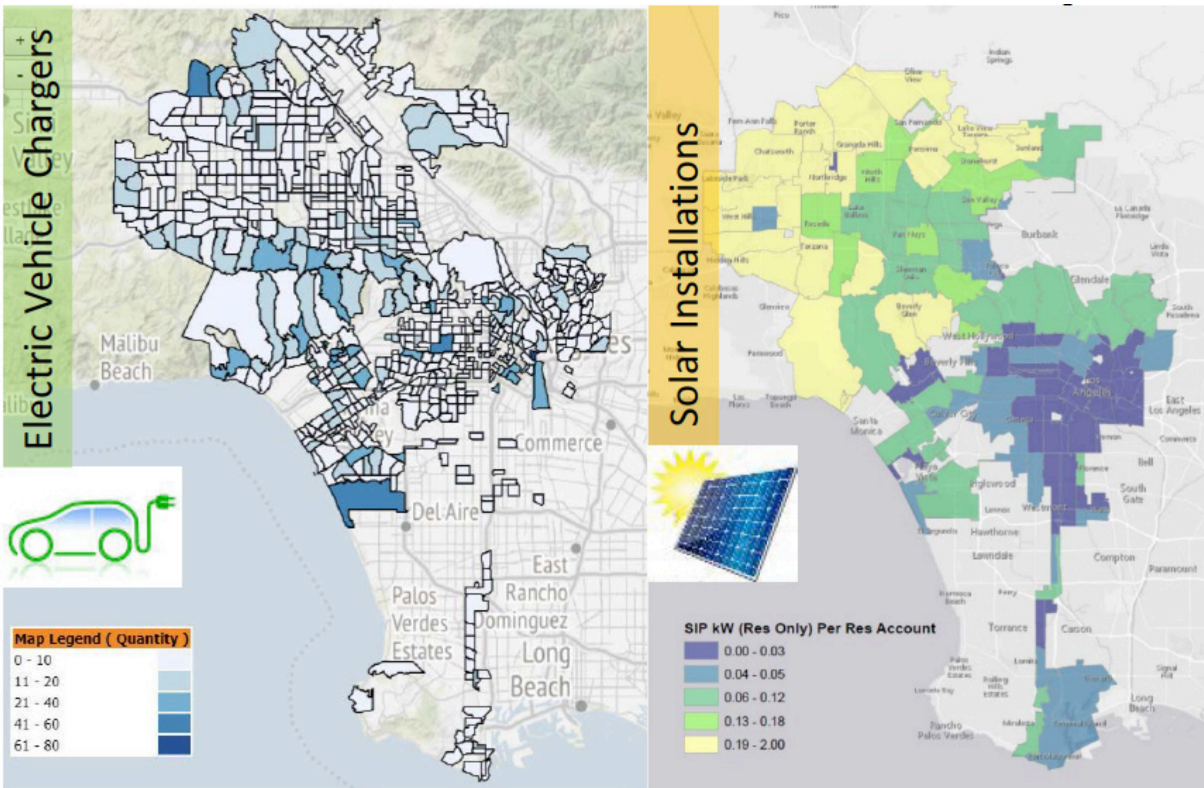

Figure 11. Example data communicated by LADWP from its September 2020 LA Equity Metrics presentation[43]

Figure 11 shows some of the data LADWP already collects related to electric vehicle charging stations and solar installations. At present, charging stations and solar installations are concentrated in northwest Los Aneles and the San Fernando valley. Rates of solar adoption per residential account are lowest in the southeastern parts of Los Angeles.

Apart from specific solar program offerings, distributed energy resource rate design will be a key driver of adoption. While LA100 net metering scenarios stimulate more widespread adoption than net energy billing, studies have found evidence for a cross-subsidy impacts to ratepayers compensated for solar generation, whereby households without the benefit of self-generation discounts pay a larger share of collective grid expenses.[44] This amount was recently estimated as roughly $100 per customer per month for Pacific Gas & Electric and Southern California Edison

[43] "Equity Metrics Data Initiative (EMDI) Update, September 2020."
[44] Erik Johnson, Ross Beppler, Chris Blackburn, Benjamin Staver, Marilyn Brown, and Daniel Matisoff. "Peak Shifting and Cross-Class Subsidization: The Impacts of Solar PV on Changes in Electricity Costs," *Energy Policy* 106 (July): 436–444 (2017), https://doi.org/10.1016/j.enpol.2017.03.034.

customers.[45] While net metering policies may result in regressive cost-shifting, a recent review of value of solar methods suggests that net metering rates may still *undervalue* the total benefits from distributed generation, when other avoided utility costs and environmental, health, and social benefits are included.[46] However, it should be noted that values of solar are particularly sensitive to estimates of greenhouse gas liability costs (the cost of negative externalities due to climate change).

In order to address and avoid further burdening low-income ratepayers unable to afford the upfront investment in residential solar, LADWP could consider the joint impact of its bill assistance, energy efficiency, demand response, and electrification programs. LADWP has had a commercial demand response program since 2015, and launched its residential power savers program in summer of 2020, offering a $125 incentive to households enrolling their smart thermostat.[47] As utility models transition from selling electricity generated offsite to providing energy services from a mix of distributed and utility-scale energy resources, equity considerations stretch well beyond net energy metering rates alone.[48]

This distributional analysis could only formally evaluate solar adoptions by disadvantaged community status. Follow-up research could include distributional justice implications for efficiency and electrification. As LADWP considers the findings from the LA100 study in developing its programs, it might build on the analysis herein to assess the cost-effectiveness of investments in energy efficiency, electric vehicle charging infrastructure, and local solar generation, and evaluate cases in which comparable financial investments might yield different private bill savings and public health/air quality benefits.

Equity considerations have long been raised in the context of policy debate over feasible decarbonization pathways, particularly when it comes to accessing the benefits of new low-carbon transportation and energy options. If utility policy does not proactively address equity matters, some warn of the emergence of a "new rift in America: one class that employs increasingly sophisticated gadgets to manage its energy use, save money, and gain an attendant sense of participation in collective problem-solving; and a second class that cannot afford such technologies and pays mounting electric bills caused by the need to decarbonize the grid."[49]

These concerns serve to underline the significance of LADWP's leadership in pursuing a rapid and equitable transition. Utility governance models were not originally designed for a distributed energy system with customer-generators, demand response technology, and widespread access to

[45] Karl Dunkle Werner. *Assessment of Residential Net Metering Subsidies*. Brattle Group. Presented at the CRRI 32nd Annual Western Conference, June 27, 2019. https://brattlefiles.blob.core.windows.net/files/16671_assessment_of_residential_net_metering_subsidies.pdf.

[46] Value of solar components may include energy production costs, electricity generation capacity costs, fuel costs, environmental costs, ancillary voltage control benefits, solar integration costs, market price reduction benefits, economic development value or job creation, health liability costs, and value of increased security.
Koami Soulemane Hayibo and Joshua M. Pearce. "A Review of the Value of Solar Methodology with a Case Study of the U.S. VOS," *Renewable and Sustainable Energy Reviews* 137: 110599 (March 2021). https://doi.org/10.1016/j.rser.2020.110599.

[47] "Power Savers FAQ," LADWP, https://enrollmythermostat.com/faqs/ladwp/.

[48] Shalanda H. Baker. "Chapter 4: The Energy Justice Stakes Embedded in the Net Energy Metering Policy Debates," *Northeastern University School of Law Research Paper* 351 (2019), https://ssrn.com/abstract=3400405.

[49] Shelley Welton. 2017. "Clean Electrification," *University of Colorado Law Review* 88 (3): 571–652.

battery storage. Rate and incentive design is rapidly evolving to accommodate these shifts, and some policy experts suggest that these domains may be areas where new governance models could be explored, based on partnership, delegated power, or citizen control.[50]

4.3 Changes in Energy Burden

The prior analysis primarily evaluates equity in terms of the spatial distribution of a given technology in communities bounded by census tract geographies. However, achieving spatial parity in community-wide technology adoption does not ensure that ratepayers will be impacted equitably under a transition to 100% renewable energy. A thorough evaluation of the equity-related implications of LADWP's transition to 100% clean energy could include the differential affordability impacts faced by technology adopters and non-adopters.

California's joint agency Senate Bill 100 report acknowledges the potential affordability impacts of a transition to clean energy, and the importance of assessing how expenditures associated with rapid decarbonization will be realized in retail energy rates.[51] One common metric for evaluating rate impacts is energy burden (see Section 3.3.1 and Figure 6, above), or the percentage of income a given household spends on energy-related costs. Energy poverty is a related concept rooted in a rights-based approach to energy justice and describes a state of household energy deprivation that limits social and material necessities for full participation in society.[52]

Energy assistance programs such as the federal Weatherization Assistance Program (WAP) and bill assistance programs such as the Low-Income Home Energy Assistance Program (LIHEAP) can address energy burden and energy poverty issues, and can function as protective factors to reduce low-income ratepayer vulnerability during energy transitions.[53] Yet even with access to short-term bill relief or subsidized programs designed to improve building performance and reduce energy expenses, the expenses incurred by transitioning to 100% renewable energy may have disparate impacts on lower-income consumers.[54] Energy rates and consumer-facing costs and benefits could also be important components of the long-run equity and affordability of LADWP's energy transition. Energy burden could be considered as a metric for targeting of efficiency or renewable generation incentives or programs.

---

[50] Archon Fung. 2003. "Survey Article: Recipes for Public Spheres: Eight Institutional Design Choices and Their Consequences," *Journal of Political Philosophy* 11 (3): 338–67. https://doi.org/10.1111/1467-9760.00181.
[51] SB 100 Joint Agency Report, 2021, https://www.energy.ca.gov/sb100#anchor_report.
[52] Dominic J. Bednar and Tony G. Reames, "Recognition of and Response to Energy Poverty in the United States," *Nature Energy* 5: 432–439 (March 2020), https://doi.org/10.1038/s41560-020-0582-0.
[53] Sanya Carley, Tom P. Evans, Michelle Graff, and David M. Konisky, "A Framework for Evaluating Geographic Disparities in Energy Transition Vulnerability," *Nature Energy* 3 (8): 621–627 (2018), https://doi.org/10.1038/s41560-018-0142-z.
[54] Shelley Welton, "Grid Modernization and Energy Poverty," *North Carolina Journal of Law and Technology* 18 (4) (May 2017), https://ssrn.com/abstract=2993976.

5 Distributional Justice: Air Quality and Public Health

As Los Angeles makes progress toward its decarbonization, clean transportation, and renewable energy goals, these economy-wide changes will likely impact some root-cause sources for many of the indicators included in the CalEnviroScreen. Some of these criteria correspond relatively closely to outputs from LA100 models. Others would require additional modeling, including outside the sectors covered by this study, to yield credible estimates of changes to specific criteria. Thus, as described in the introduction to this chapter, only a subset of the CalEnviroScreen indicators is analyzed in this study: two air quality and two public health indicators, as shown in Table 2.

However, even for these CalEnviroScreen indicators, where LA100 models would seem at first glance to provide results for the same issue, in the end the differences between a retrospective-based tool like CalEnviroScreen and a future-projection-based approach, and underlying models, like in LA100, are incommensurable. CalEnviroScreen has very specific definitions of their indicators based on what historical data are available; the models used in LA100 are wholly different in character – for instance, spatial and temporal resolution – and despite considerable effort to match them, in the end we could not. In addition, we investigated public health impacts of LA100 with an important additional indicator—premature mortality—which we also include in this environmental justice analysis for potential differential impacts (results on an additional indicator, heart attacks, are included in Appendix C).

More specifically, our environmental justice analysis approach is different from the approach followed in CalEnviroScreen for calculating and assigning scores for exposure to particulate matter with aerodynamic diameter of 2.5 micrometer or less ($PM_{2.5}$) and ozone (O_3). CalEnviroScreen assigned scores based on exposure to annual ambient concentration of $PM_{2.5}$ and summer-time exposure to O_3 by calculating the decile band to which a census tract belongs relative to mean concentrations in California. Given the scope of the project, our modeling domain covers only parts of Southern California, therefore, we do not have data on concentration changes for all of California. Similarly, there are some additional methodological incommensurability between our approach of estimating future change in health outcomes (from an estimated, future change in pollutant concentration) and the approach used in CalEnviroScreen for the two health indicators – cardiovascular hospital admissions and asthma-related emergency department visits. Furthermore, a key aspect of CalEnviroScreen methods for the health indicators was not described sufficiently in the CalEnviroScreen model documentation to be able to replicate (age-weighting). Therefore, we follow a different approach for both air quality exposure indicators and for sensitive population indicators.

Our future year (2045) air pollutant concentrations are based on modeled data. As reported in Chapter 9, we created detailed source-specific emissions inventories for various pollutants for a single future year–2045–for four future scenarios (SB100 – Moderate, SB100 – High, Early & No Biofuels – Moderate, Early & No Biofuels – High) and one current scenario which we call Baseline (based on South Coast Air Quality Management District (SCAQMD) data representing 2012). These include detailed emissions data for LA100-influenced sectors that leverage data from NREL's loads modeling teams (power generation, transportation, residential and commercial buildings, and ports), combined with emissions from the SCAQMD, both current (2012) and projected to 2031. (Note: 2012 is the latest year for which a source-oriented emissions inventory is available from SCAQMD. The reader is referred to Chapter 9 for more details on how the SCAQMD inventory is used in conjunction with other data and models to develop the 2045 emissions inventories for each LA100 scenario investigated).

To simulate the impact of emissions on the concentration of $PM_{2.5}$ and O_3 under these five scenarios, we use a three-dimensional, gridded, photochemical model called the Weather Research and Forecasting Model coupled with Chemistry (WRF-Chem version 3.7, Grell et al., 2005; Powers et al., 2017). The simulated model domain consists of three nested domains, with the innermost domain at a 2 km x 2 km grid cell size and covering most of the Southern California Air Basin. Detailed descriptions of the selected model chemistry, radiation scheme, microphysics scheme, and land-use data are available in Chapter 9 of this report. The output from the model includes gridded hourly concentrations of $PM_{2.5}$ and O_3, which is postprocessed to obtain the desired metric used in this chapter's environmental justice analysis: annual average concentration for $PM_{2.5}$ and summer mean of the daily 8-hour maximum concentration for O_3. Impacts of changes in the concentration of $PM_{2.5}$ and O_3 on public health are analyzed using a benefits assessment tool called Benefits Mapping and Analysis Program – Community Edition (BenMAP-CE) developed by the U.S. Environmental Protection Agency (Sacks et al., 2018). For a detailed description of the methodology followed for benefits assessment using BenMAP, readers may refer to Chapter 9 of this report. A schematic of the approach used in BenMAP analysis is shown in Figure 12.

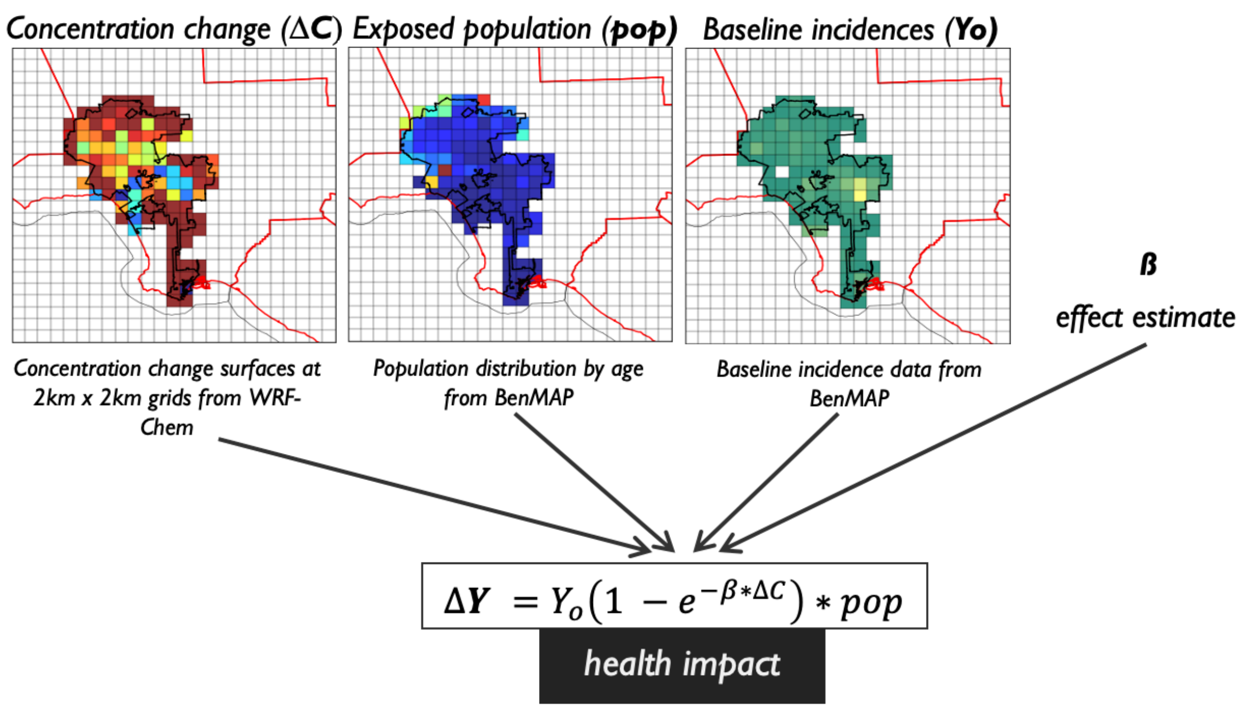

Figure 12. Schematic showing the approach used in BenMAP for calculating changes in health impacts (*ΔY*) due to a change in pollutant concentration by *ΔC*

Data on exposed population (*pop*), baseline incidences (Y_o), and the effect estimate (*β*, a measure of health benefits per unit change in pollutant concentration) are used from BenMAP databases. Change in concentration (*ΔC*) is gridded difference in ambient pollutant concentration for the scenarios selected for comparison, and it is based on WRF-Chem modeling as described in the text).

5.1 Analysis Approach

We consider two different sources of data for our environmental justice analysis – WRF-Chem model-derived annual average concentrations of $PM_{2.5}$ and summertime average of daily 8-hr maximum O_3, and BenMAP-derived changes in the incidences for select health endpoints. Our WRF-Chem modeling includes one month in each quarter: January, April, July, and October. We use data from all of these modeled months to calculate annual average concentration for $PM_{2.5}$, and the months of April, July, and October for calculating summertime O_3 concentration for the environmental justice analysis.[55] Summertime average of O_3 is calculated from a daily maximum of the 8-hr rolling mean for each grid cell. For each LA100 scenario, and for the Baseline scenario, our results report analysis of differences between DAC and non-DAC tracts.

For the public health analysis, the considered health endpoints include asthma-related emergency room (ER) visits, cardiovascular disease-related hospital admissions, and premature mortality.[56] It is important to remember here (as originally presented in Chapter 9) that the BenMAP output is based on the *changes* in pollutant concentration between a base scenario and a control scenario, and thus the health endpoints reported herein estimate a *change* in the incidence of the selected health endpoints, not absolute incidences. We combine changes in asthma-related ER visits due to O_3 with those due to $PM_{2.5}$ to produce a single asthma ER visit indicator for each grid cell. Changes in mortality values due to O_3 and $PM_{2.5}$ are likewise combined for each grid cell. We considered the following seven scenario comparisons for the public health analysis:

- Comparison of scenarios at the same load level to isolate the effects of power sector eligibility criteria:
    - SB100 – Moderate versus Early & No Biofuels – Moderate.
    - SB100 – High versus Early & No Biofuels – High.
- Comparison of scenarios with the same power plant/fuel eligibility but different load levels:
    - SB100 – Moderate versus SB100 – High.
    - Early & No Biofuels – Moderate versus Early & No Biofuels – High.
- Comparing different load levels with changing power plant/fuel eligibility: SB100 – Moderate versus Early & No Biofuels – High.
    - Current baseline versus future reference comparison: Baseline (2012) versus SB100 – Moderate.
    - Comparison of the high end-use electrification and hydrogen combustion scenario with the baseline: Baseline (2012) versus Early & No Biofuels – High. This was selected to quantify maximum potential benefits based on selected sources modeled.

The next section describes the methodology used for analysis of whether there are statistically significant differences in the spatial average of these five indicators (two pollutant concentrations and three health endpoints) among DAC versus non-DAC tracts in the city of LA.

---

[55] Although the summer season in Southern California extends from May through October, we use modeled April concentrations of O_3 as a surrogate for May concentrations.
[56] We also analyze nonfatal acute myocardial infarctions, results for which are included in Appendix C.

Statistical Analysis

Since DAC status is assigned to census tracts, the first part of our analysis approach requires the conversion of concentration and health endpoint values which have been modeled on a regular 2 km x 2 km grid (with 141 N-S rows and 129 E-W columns in the modeling domain) to census tracts. Census tracts are designed by the U.S. Census Bureau to contain approximately equal population but are not regular shapes. Some census tracts within a dense city like LA are small enough to be wholly contained within a 2 km x 2 km grid cell; others span several grid cells in whole or part. The approach we used differs slightly for concentrations as compared to health endpoints owing to the different models' outputs, where the approach to assigning a concentration to a grid cell uses weighted averaging but for health endpoints it is summing each grid cell's proportional contribution.

Incidence of disease is additive when considering the contribution from multiple grid cells to a given census tract. Therefore, the health endpoints were converted from the grid cells covering the city of Los Angeles to its 561 DAC and 607 non-DAC U.S. census tracts using population-weighted sums. Each grid cell wholly or partially contained within a census tract contributed to the tract total by multiplying the value of each health endpoint and population contained in each grid cell to the areal proportion of that grid cell contained within each tract, and summing across all grid cells (and portions thereof) that overlap a given census tract:

$$Endpoint_{tract} = \sum \left[\frac{Area_{part}}{Area_{tract}} \times \frac{Pop_{tract}}{Pop_{grid}} \times Endpoint_{grid} \right]$$

where $Endpoint_{tract}$ is the population-weighted total number of occurrences of each endpoint in a tract, $Area_{part}$ is the areal portion of each grid cell contained in each tract, $Area_{tract}$ is the total tract area, Pop_{tract} is the U.S. Census Bureau tract population, Pop_{grid} is the BenMAP modeled population per grid cell, and $Endpoint_{grid}$ is the health endpoint quantity (i.e., change in incidence of mortality or morbidity) in each grid cell. This arrangement weights the portions of each grid cell in each tract by the tract population as opposed to a simple area-based weighting which may produce erroneous estimates for some tracts.[57]

Contrary to disease incidence, concentrations of pollution are not additive, but rather represent the average over an area. Different weighted-average methods exist in the literature including, but not limited to, spatial averaging, nearest-neighbor, inverse distance weighting, and kriging. Previous work has shown that when the number of data points used to interpolate to a target spatial unit is large (which is the case here: there are about 400 grid cells covering 1,200 census tracts in the city of LA), these methods produce similar results (Wong, Yuan and Perlin, 2004). We average each tract's concentration weighted by the percentage of each overlapping grid cell and its population. The tract-specific total population (between age of 0 and 99)[58] were

[57] This result was observed for some larger tracts when using the area-weighted approach.

[58] Population used in this calculation comes from BenMAP which has population data only for the 0–99 age range. We acknowledge that this leaves out a small fraction of population (aged 100 years or more), but this is unlikely to change any conclusions from our analysis.

combined with the pollutant concentration to derive a population-weighted average concentration for each tract for O_3 and $PM_{2.5}$ using the following equation:

$$\mathrm{Conc}_{tract} = \frac{\sum \frac{Area_{part}}{Area_{tract}} \times Pop_{grid} \times Conc_{grid}}{\sum \frac{Area_{part}}{Area_{tract}} \times Pop_{grid}}$$

where $Conc_{tract}$ is the population-weighted average concentration of each pollutant in a tract, $Area_{part}$ is the areal portion of each grid cell contained in each tract, $Area_{tract}$ is the total tract area, Pop_{grid} is the population of the corresponding grid cell, and $Conc_{grid}$ is the concentration of the pollutant of the corresponding grid cell. This process was repeated for both exposure indicators (O_3 and $PM_{2.5}$) and for two census tract categories – DAC and non-DAC.

To determine whether there is a statistically significant difference between the values of each health endpoint and each pollutant concentration in DAC and non-DAC tracts, we performed an independent t-test. An independent t-test helps assess whether the differences between two data sets (here, each metric for DAC and non-DAC tracts) are due to chance or represent true differences (Kim 2015). An independent t-test methodically compares the means of two samples, from the same distribution, to produce a single number (a so-called p-value, or probability value) that represents the degree of difference. This number is then compared to a pre-determined level of significance—known as the alpha level—which provides a threshold used to determine if the calculated p-value represents differences in means that could be explained by chance alone. (Sometimes the t-test will indicate significance and sometimes it will indicate differences due to random chance in the sample selection.) In this study, we use an alpha level of 0.05, which means that if the p-value is less than 0.05 the differences between DAC and non-DAC metrics is likely (greater than 95%) not due to random chance and is therefore considered to be statistically significant.

The DAC and non-DAC tract groups in our analysis each include ~600 data points per data set, which is considered large for a t-test. Because a t-test is sensitive to large sample sizes (meaning, statistical significance is more commonly found with larger sample sizes than for small sample sizes[59]), a common practice is to repeat the t-test on limited samples of each data set, thereby reducing the size of each sample, and then use those limited samples to build a distribution of possible p-values. This process is known as bootstrapping. For each of the DAC and non-DAC tract groups, we select 50 samples from each group and repeat (bootstrap) the t-test 10,000 times. The median of the 10,000 bootstrapped samples is chosen to represent the p-value associated with the comparison of the two populations. We then compare this median p-value to the pre-set alpha level of 0.05 to determine whether the differences between DAC and non-DAC tracts are statistically significant.

[59] P-value is calculated from an intermediate value that is inversely proportional to the sample size. At sample sizes > 50–100 one can have statistical differences where there may not be a functional difference.

5.2 Results

5.2.1 Results on $PM_{2.5}$ and O_3 Concentrations

Population-weighted average concentrations of the two CalEnviroScreen exposure indicators are shown in Figure 13. In 2012, as indicated by the Baseline (2012) scenario output, DAC communities were exposed to about 12.7 μg/m^3 annual-average concentration of $PM_{2.5}$, which is approximately 2.0 μg/m^3 higher than the average concentration to which non-DAC communities are exposed. The population-weighted concentration of $PM_{2.5}$ decreases in all future scenarios modeled for all tracts throughout the city of LA, with a citywide decrease between 0.4 and 0.6 μg/m^3 depending on the scenarios. The DAC tracts' population-weighted $PM_{2.5}$ average concentration remains about 1.9–2.0 μg/m^3 higher than non-DAC tracts in all evaluated LA100 scenarios. Compared to the Baseline (2012), all future scenarios help DAC communities more, with a $PM_{2.5}$ concentration reduction slightly greater in DAC communities (0.42–0.62 μg/m^3) compared to decreases in non-DAC communities (0.39–0.56 μg/m^3) (Table 13 in Appendix C). This is also demonstrated in Figure 14, which shows the distribution of $PM_{2.5}$ concentration change in the four LA100 scenarios in the DAC and non-DAC tracts relative to the concentrations in the 2012 Baseline in corresponding tracts. In general, the two High load electrification scenarios result in larger reductions in both tract categories, where the tract mean reductions are about 0.2 μg/m^3 more than the two Moderate electrification scenarios. Overall, population-weighted $PM_{2.5}$ concentrations in DAC tracts decrease 3.3%–4.8% in future LA100 scenarios compared to the 2012 DAC tract concentration. Corresponding relative decrease (to 2012) in non-DAC tracts is slightly higher, with average decrements of 3.6%–5.2%. While these numbers may seem small, it is helpful to compare them to the annual exposure standards set by the U.S. EPA, which is 12.0 μg/m^3, thus these changes over the LA100 study period are considered significant especially in light of the challenges the LA metro area has had over decades in reducing $PM_{2.5}$ concentration.[60]

[60] To illustrate the difficulty in reducing ambient $PM_{2.5}$ concentrations, the average of the design values at six monitors in LA County (located in LA Downtown, Reseda, Compton, Pico Rivera, and two in Long Beach) from 2009 to 2013 was 11.7 μg/m^3, which changed to 11.2 μg/m^3 when averaged over 2015–2019 for the same monitoring sites (calculated from Table 6a of the $PM_{2.5}$ design value report available from the U.S. EPA available at https://www.epa.gov/sites/production/files/2020-05/pm25_designvalues_2017_2019_final_05_26_20.xlsx: "Table 6a. Site-Level Design Value History for the 2012 Annual PM2.5 NAAQS," last updated May 8, 2020).

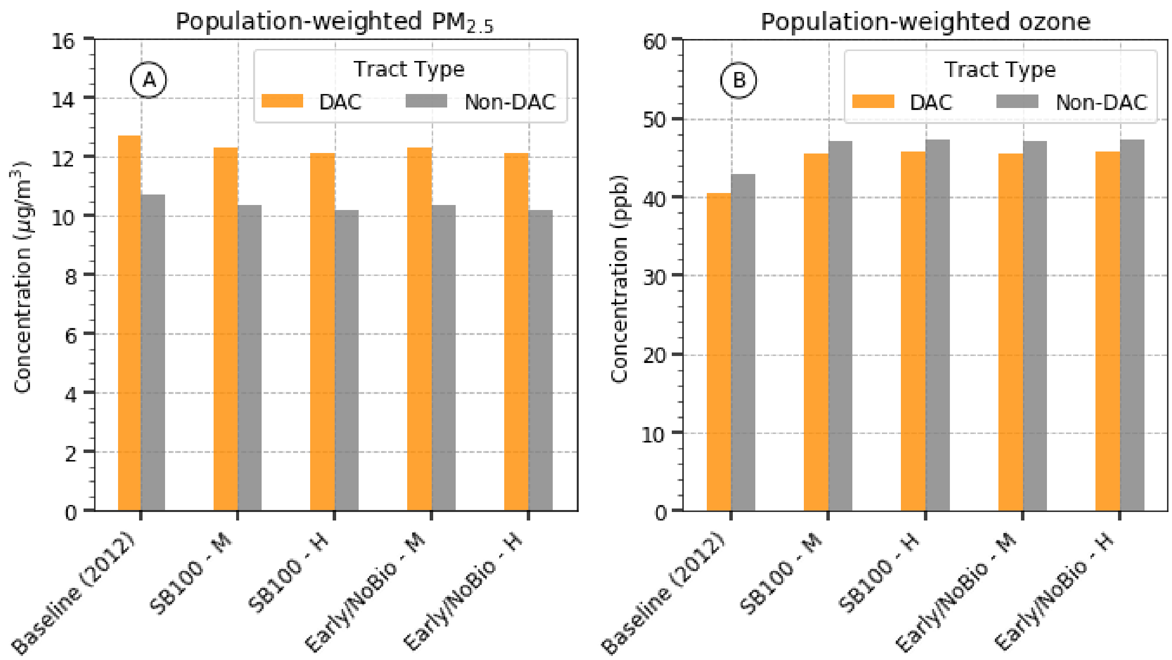

Figure 13. Population-weighted concentrations of $PM_{2.5}$ (annual average, frame A) and O_3 (summertime averaged daily 8-hr maximum, frame B) in DAC and non-DAC census tracts

These results and corresponding differences between DAC and non-DAC tracts are also shown in Appendix C, Table 12.

The results for ozone concentration are different than for $PM_{2.5}$, with a citywide increase in O_3 of about 4.6–4.8 ppb between baseline and future scenarios. Non-DAC communities are exposed to higher population-weighted O_3 concentration in all scenarios considered. This is partly attributable to the northwestern part of the city (San Fernando Valley region) being a mostly non-DAC set of tracts, where the highest ozone concentrations in the city are observed in the 2012 base case. The San Fernando Valley shows the highest O_3 concentration because of an accumulation effect in the atmosphere (where the San Fernando Valley is downwind of the city's emissions sources) and higher ozone production rate in that region. Mountains in the south and southwest of this area block the ocean, so the sea breeze flows from the west of the city into and through central Los Angeles where it picks up polluted air, and then into the valley. Ozone accumulates as it flows toward the San Fernando Valley. In addition, this area also has higher air temperature than other parts of Los Angeles, which leads to higher photochemical reaction rates for production of ozone (since these reaction rates increase with the air temperature).

As explained in greater detail in Chapter 9, owing to the non-linear response of O_3 to changes in emissions (especially NOx), and because of the current chemical composition of the atmosphere over LA, reductions in NOx emissions lead to increases in ozone concentration in the future scenarios. While DACs are exposed to lower ozone concentrations compared to non-DAC tracts, the population-weighted future O_3 concentration in DAC tracts increases slightly more compared to that for non-DAC tracts. Population-weighted O_3 concentration increases by 5.1–5.3 ppb in DAC tracts in the future scenarios relative to the Baseline (2012), whereas this increase is 4.2–4.4 ppb for non-DAC tracts (Table 13, Figure 25 in Appendix C). This increase in population-weighted ozone translates to 12.5%–13.1% increments relative to the Baseline (2012) scenario in DAC tracts, and an increase of 9.8%–10.2% in non-DAC tracts.

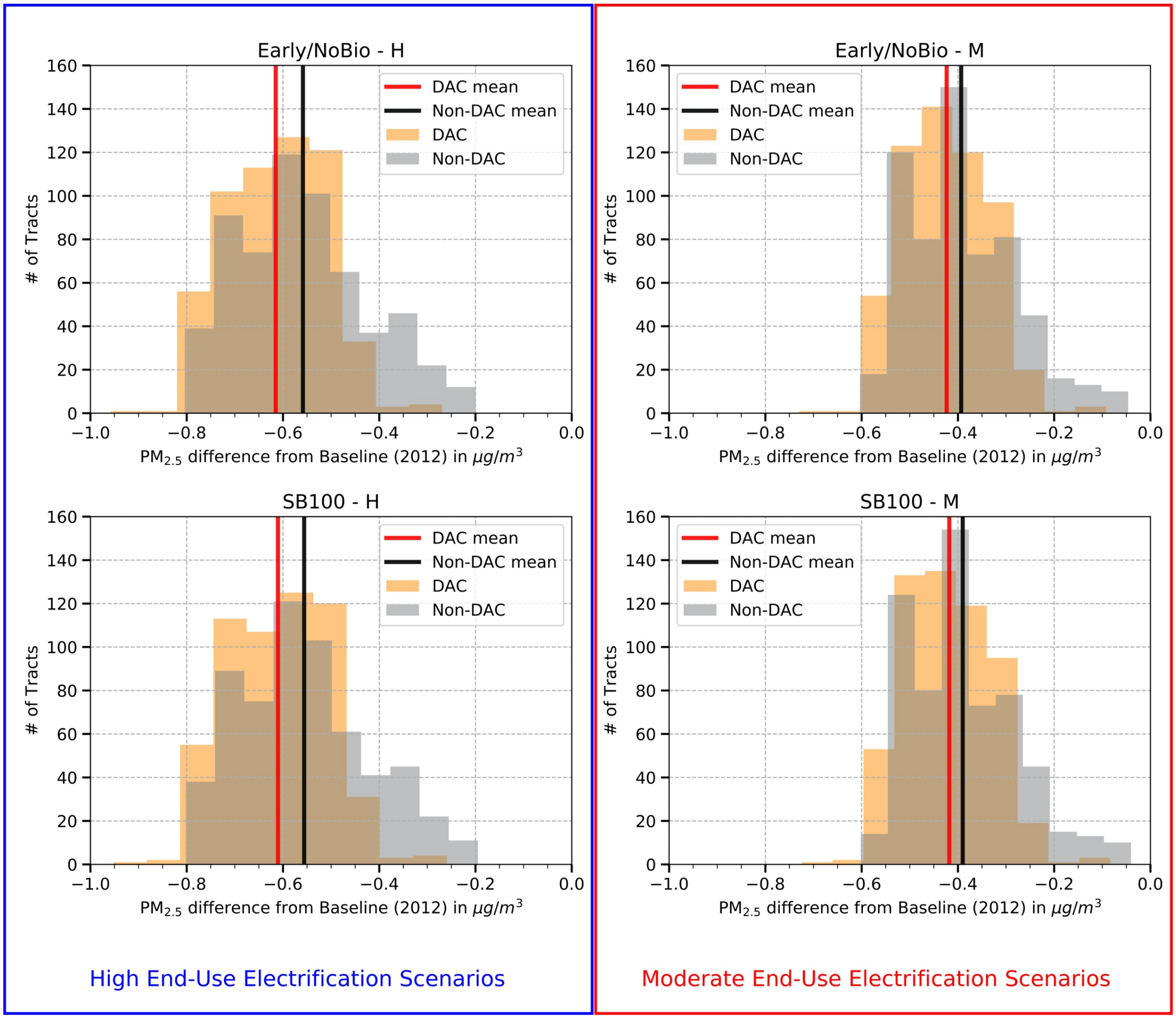

Figure 14. Histograms showing change in $PM_{2.5}$ concentration in DAC and non-DAC tracts in Los Angeles in the two High electrification scenarios (left panel) and the two Moderate electrification scenarios (right panel) relative to Baseline (2012)

In all evaluated future scenarios, the average decrease is larger in DAC tracts compared to non-DAC tracts, although the average DAC concentration is higher to start (Figure 13). Note that the reductions in the 2045 scenarios shown here are comparable to 0.6 µg/m3 decrease averaged over six monitors in LA County over a recent 6-year period.[60]

All five scenarios showed statistically (or nearly) significant differences between DAC and non-DAC tracts for the pollutants $PM_{2.5}$ and O_3 at an alpha level of 0.05 (Table 7). In all scenarios, $PM_{2.5}$ concentrations are, on average, higher for DAC tracts than non-DAC tracts. (Figure 15 and Appendix C, Figure 27). In all scenarios, higher concentrations of O_3 are found in the north/northwest regions of LA (Figure 16, geographic and physical conditions causing this elevated concentration are briefly discussed in the previous paragraphs of this section and in Chapter 9) and are, on average, higher for non-DAC tracts than DAC tracts (Appendix C, Figure

26). $PM_{2.5}$ concentrations in the base case (Baseline [2012] scenario) are highest in the southern part of the city, near the Port of Los Angeles. This area has the highest $PM_{2.5}$ concentration because of higher primary $PM_{2.5}$ emissions (which are directly emitted from various sources) and higher emissions of precursor pollutants (e.g., NOx) that form secondary $PM_{2.5}$ than other parts of the city.

Table 7. Comparison of DAC vs. Non-DAC Tract-Level Average O_3 and $PM_{2.5}$ Concentrations by Scenario

Scenario	Pollutant	DAC Tract Mean†	Non-DAC Tract Mean†	DAC Percentage Difference from non-DAC	t-Test Results (Median p-value)
Baseline (2012)	O_3	41 ppb	43 ppb	-5.6%	0.0081*
Early & No Biofuels – High	O_3	46 ppb	47 ppb	-3.2%	0.054
Early & No Biofuels – Moderate	O_3	46 ppb	47 ppb	-3.3%	0.047*
SB100 – High	O_3	46 ppb	47 ppb	-3.2%	0.052
SB100 – Moderate	O_3	46 ppb	47 ppb	-3.3%	0.048*
Baseline (2012)	$PM_{2.5}$	13 μg/m³	11 μg/m³	+19%	< 0.001*
Early & No Biofuels – High	$PM_{2.5}$	12 μg/m³	10 μg/m³	+19%	< 0.001*
Early & No Biofuels – Moderate	$PM_{2.5}$	12 μg/m³	10 μg/m³	+19%	< 0.001*
SB100 – High	$PM_{2.5}$	12 μg/m³	10 μg/m³	+19%	< 0.001[a]
SB100 – Moderate	$PM_{2.5}$	12 μg/m³	10 μg/m³	+19%	< 0.001*

Average concentrations by scenario and pollutant for 561 DAC and 607 non-DAC tracts in the city of LA, with associated independent t-test p-values (based on 10,000 bootstrapped subsample comparisons (n = 50 for each subsample). All scenarios show greater $PM_{2.5}$ concentrations for DAC tracts and greater O_3 concentrations for non-DAC tracts. †Average of tract population-weighted mean.

* Less than 5% probability that results are due to random chance. ‡Percent with respect to the total change.

Figure 15. Population-weighted concentrations of $PM_{2.5}$ (annual average) in Los Angeles census tracts

DAC tracts are outlined in black. All five scenarios show similar spatial distribution and exhibit statistically significant differences (at $p = 0.05$ level or lower) between DAC and non-DAC tracts, with DAC tracts having, on average, higher concentrations of $PM_{2.5}$.

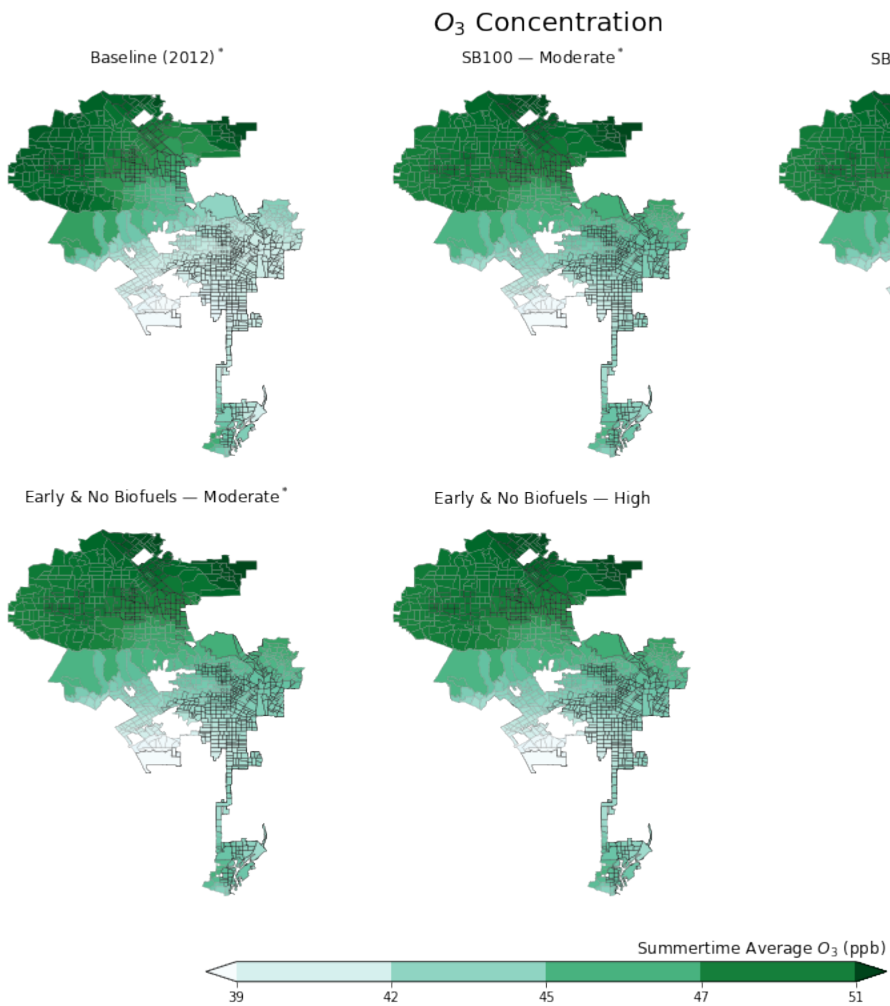

Figure 16. Population-weighted concentrations of O_3 (summertime average) in Los Angeles census tracts

DAC tracts are outlined in black. All five scenarios show similar spatial distributions, with non-DAC tracts having higher concentrations of O_3, primarily due to the increased concentrations in the San Fernando Valley (N/NW corner). Only the Baseline (2012) scenario and Early & No Biofuels – Moderate exhibit significant differences between DAC and non-DAC tracts at the 5% level (5% probability the differences in DAC and non-DAC are due to random chance).

Our environmental justice analysis here focuses on determining whether the concentrations of the two exposure indicators ($PM_{2.5}$ and O_3) from different scenarios are statistically significantly different between DAC non-DAC tracts. Results from this analysis are shown in Table 7. Earlier, we compared the population-weighted concentration of $PM_{2.5}$ and O_3 in Figure 13 and found that DAC tracts were exposed to higher population-weighted $PM_{2.5}$ concentration compared to non-DAC tracts. Our analysis suggests that the $PM_{2.5}$ difference is statistically significantly higher in DAC tracts in all scenarios, although in all future scenarios the DAC tracts are exposed to relatively lower $PM_{2.5}$ concentration compared to the Baseline (2012) simulations. It is interesting to note that for the other exposure indicator, O_3, which has a higher population-weighted concentration in non-DAC tracts compared to the DAC tracts, the DAC/non-DAC difference is statistically significant only for the Baseline (2012) and SB100 – Moderate scenarios. Population-weighted concentrations of O_3 are not statistically significantly different between DAC versus non-DAC tracts in any other future scenario (SB100 – High, Early & No Biofuels – Moderate, or Early & No Biofuels – High).

5.2.2 Public Health-Related Environmental Justice Results

We also considered the changes between different scenarios for the three health indicators: ER visits from asthma (Figure 17), cardiovascular-related hospital admissions (Figure 18), and premature mortality (Figure 19) to determine if statistically significant differences exist between DAC non-DAC tracts for each scenario. Table 8 and Table 9 summarize the results for these three health endpoints. Note that because we intend to quantify benefits from LA100 scenarios, results are reported as avoided incidence of a specific health endpoint, which means that negative values represent increases in estimated incidence. Also note that we include an additional health endpoint in our analysis in Appendix C: acute myocardial infarction (AMI, or heart attack).

SB100 Moderate versus SB100 – High, SB100 – Moderate versus Early & No Biofuels – High, and Early & No Biofuels – Moderate versus Early & No Biofuels – High show very similar effects for all health endpoints (Figure 17 – Figure 19). Only for a few endpoints and scenario combinations are the differences between impacts to DAC and non- DAC tracts statistically significantly different.

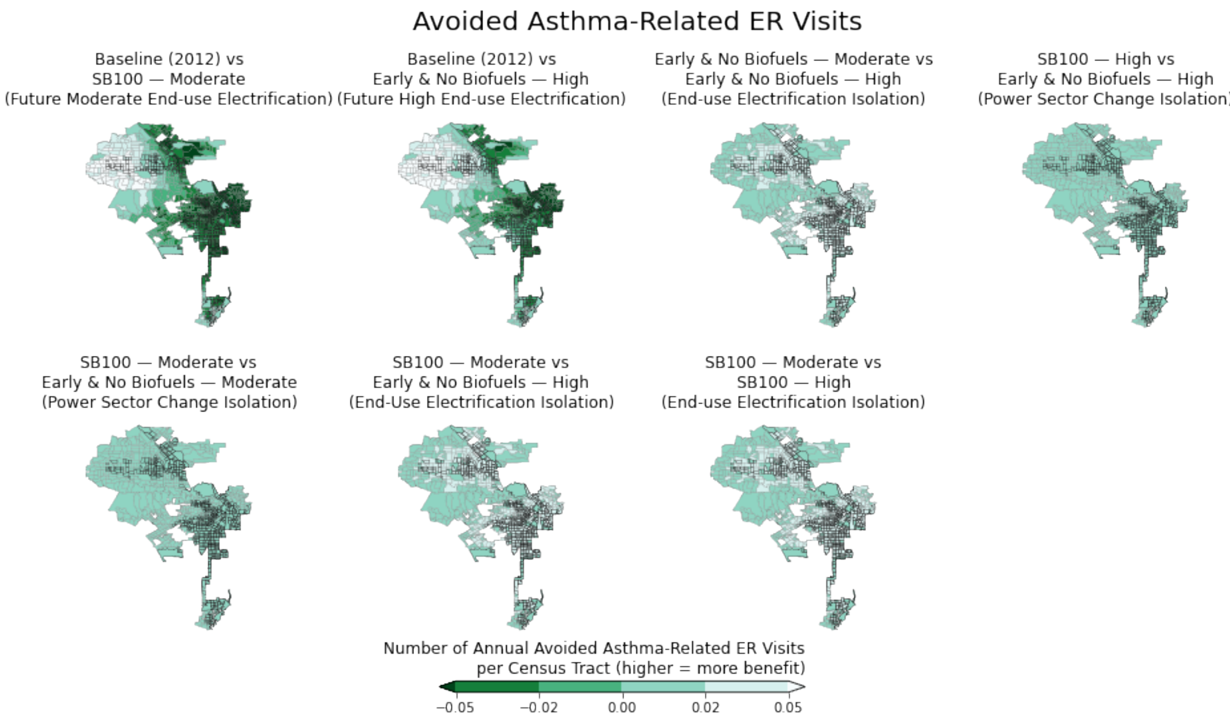

Figure 17. Population-weighted differences in annual number of avoided asthma-related emergency room (ER) visits in DAC and non-DAC Los Angeles census tracts in 2045

DAC tracts are outlined in black. Higher numbers on this scale translate to reduced incidences, which is a health improvement. Baseline (2012) versus SB100 Moderate and Baseline versus Early & No Biofuels – High comparisons show substantial spatial variation. All scenario comparisons exhibit statistically significant differences between DAC and non-DAC tracts, though SB100 High versus Early & No Biofuels – High is also just below our statistical threshold (median p-value of 0.058).

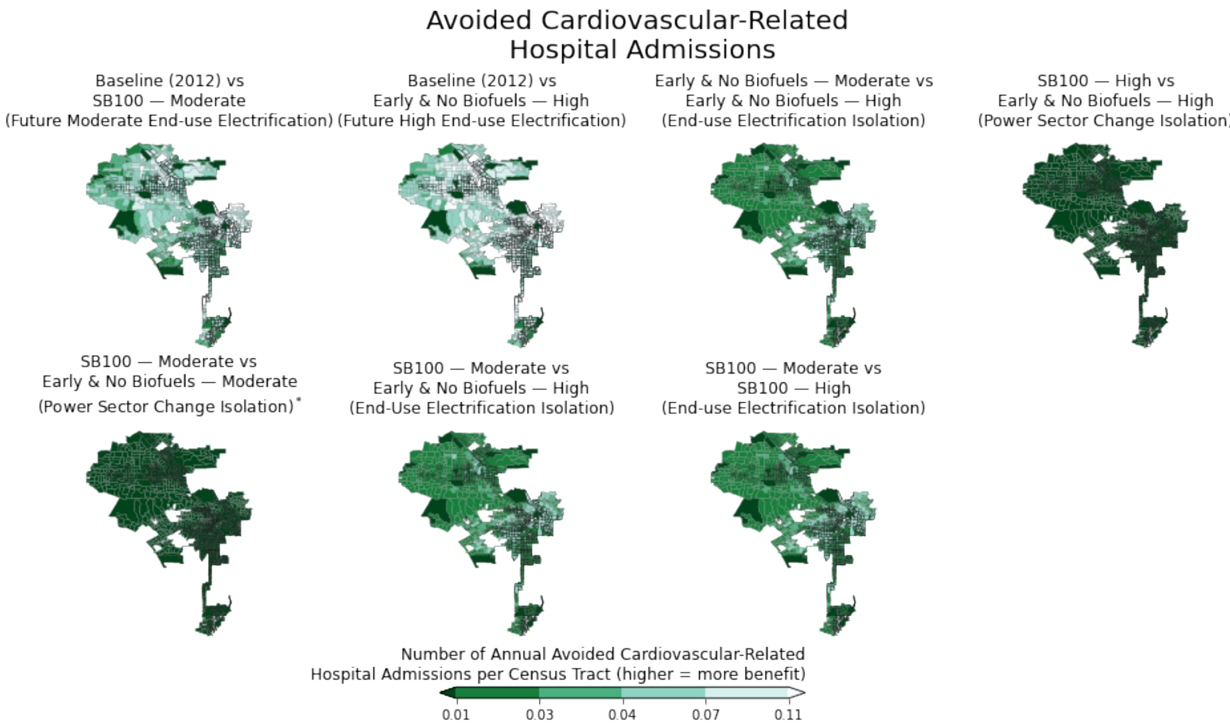

Figure 18. Population-weighted differences in number of annual avoided cardiovascular-related hospital admissions in DAC and non-DAC Los Angeles census tracts in 2045

DAC tracts are outlined in black. Higher numbers on this scale translate to reduced incidences, which is a health improvement. Baseline (2012) versus SB100 – Moderate and Baseline (2012) versus Early & No Biofuels – High comparisons show substantial spatial variation with the largest decrease in hospital admissions overall, yet the impacts are evenly distributed between DAC and non-DAC tracts (not statistically significantly different). Only SB100 – Moderate versus Early & No Biofuels – Moderate has a statistically significant difference between DAC and non-DAC tracts, yet it is not a substantial absolute difference. *Less than 5% chance differences in DAC and non-DAC are due to random sampling.

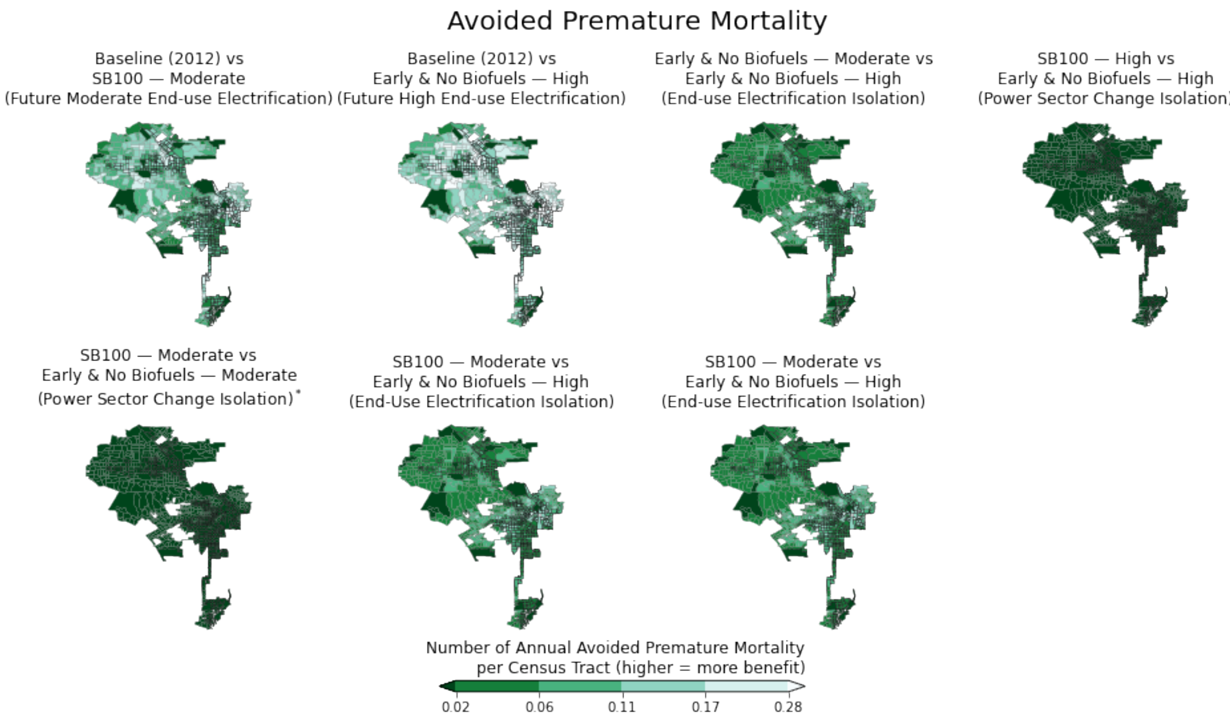

Figure 19. Population-weighted differences in number of annual avoided premature mortality in DAC and non-DAC Los Angeles census tracts in 2045

DAC tracts are outlined in black. Higher numbers on this scale translate to reduced incidences, which is a health improvement. Baseline (2012) versus Early & No Biofuels – High and Baseline (2012) versus SB100 – Moderate both show the greatest spatial variation and the largest decreases in mortalities among the scenario comparisons; however, the impacts are relatively evenly dispersed between DAC and Non-DAC tracts for all scenario comparisons (not statistically significantly different). *Less than 5% chance differences in DAC and non-DAC are due to random sampling.

For the health indicators, changes in incidences of avoided asthma-caused ER visits are statistically significantly different between the DAC and non-DAC tracts for all scenarios compared (Table 8). Although we find that the difference between DAC and non-DAC tracts is statistically significant, the overall changes in asthma-related ER visits are sizeable only for SB100 – Moderate versus SB100 – High, Early & No Biofuels – Moderate versus Early & No Biofuels – High, and SB100 – Moderate versus Early & No Biofuels – High among the future scenarios (Table 9).

We find that changes in premature mortality between DAC and non-DAC tracts are statistically significantly different for the SB100 – Moderate versus Early & No Biofuels – Moderate scenarios (Table 8), but practically the same (with a total of 0.59 annual avoided mortalities in DAC and 0.34 annual avoided mortalities in non-DAC) (Table 9). We find that the DAC versus non-DAC changes in premature mortality are not statistically significantly different for any of the other scenarios compared and any benefits are statistically similar for the populations in the two tract categories compared. Changes in cardiovascular hospital admissions for DAC and non-DAC are statistically significant for the two moderate level end-use electrification scenarios compared in our analysis (SB100 – Moderate versus Early & No Biofuels – Moderate).

We find that while there are benefits to the city of LA through a decrease in the incidences of premature mortality and cardiovascular hospital admissions (although asthma-induced ER visits increase when compared to the 2012 baseline), these benefits generally do not preferentially occur in DAC tracts; rather, they benefit the city population as a whole.

Table 8. Summary of the Statistical Analysis for the Three Health Endpoints to Assess whether the Differences between DAC and Non-DAC Tracts in Annual Avoided Incidence are Statistically Significant, based on Health Modeling Results for a Single Future Year (2045)

A positive number in the *Mean* columns indicate that the respective health endpoints decrease (i.e., are avoided) and a negative number indicates an increase (i.e., more incidences).

Compared Scenarios		Health Endpoint	Mean per Census Tract of Annual Avoided Incidence† in DAC Tracts	Mean per Census Tract of Annual Avoided Incidence † in Non-DAC Tracts	DAC Percentage Difference from Non-DAC	t-Test Results (Median p-Value)
Baseline (2012)	SB100 – Moderate	Premature mortality	0.084	0.079	6.7%	0.44
Baseline (2012)	Early & No Biofuels – High	Premature mortality	0.14	0.12	13%	0.32
Early & No Biofuels – Moderate	Early & No Biofuels – High	Premature mortality	0.050	0.040	26%	0.12
SB100 – High	Early & No Biofuels – High	Premature mortality	0.00061	0.00042	47%	0.14
SB100 – Moderate	Early & No Biofuels – High	Premature mortality	0.051	0.040	27%	0.11
SB100 – Moderate	Early & No Biofuels – Moderate	Premature mortality	0.0010	0.00056	88%	0.0023*
SB100 – Moderate	SB100 – High	Premature mortality	0.050	0.040	26%	0.11
Baseline (2012)	SB100 – Moderate	ER visits (asthma)	-0.037	-0.015	140%	0.011*
Baseline (2012)	Early & No Biofuels – High	ER visits (asthma)	-0.018	-0.0023	674%	0.046*

Compared Scenarios		Health Endpoint	Mean per Census Tract of Annual Avoided Incidence† in DAC Tracts	Mean per Census Tract of Annual Avoided Incidence † in Non-DAC Tracts	DAC Percentage Difference from Non-DAC	t-Test Results (Median p-Value)
Early & No Biofuels – Moderate	Early & No Biofuels – High	ER visits (asthma)	0.019	0.013	46%	0.0020*
SB100 – High	Early & No Biofuels – High	ER visits (asthma)	0.00034	0.00021	64%	0.045*
SB100 – Moderate	Early & No Biofuels – High	ER visits (asthma)	0.019	0.013	47%	0.0015*
SB100 – Moderate	Early & No Biofuels – Moderate	ER visits (asthma)	0.00055	0.00024	129%	< 0.001*
SB100 – Moderate	SB100 – High	ER visits (asthma)	0.019	0.013	47%	0.0017*
Baseline (2012)	SB100 – Moderate	Hospital admissions (cardiovascular)	0.046	0.040	15%	0.26
Baseline (2012)	Early & No Biofuels – High	Hospital admissions (cardiovascular)	0.068	0.057	20%	0.17
Early & No Biofuels – Moderate	Early & No Biofuels – High	Hospital admissions (cardiovascular)	0.022	0.017	29%	0.069
SB100 – High	Early & No Biofuels – High	Hospital admissions (cardiovascular)	0.00027	0.00017	55%	0.12

Compared Scenarios		Health Endpoint	Mean per Census Tract of Annual Avoided Incidence† in DAC Tracts	Mean per Census Tract of Annual Avoided Incidence † in Non-DAC Tracts	DAC Percentage Difference from Non-DAC	t-Test Results (Median p-Value)
SB100 – Moderate	Early & No Biofuels – High	Hospital admissions (cardiovascular)	0.022	0.017	30%	0.064
SB100 – Moderate	Early & No Biofuels – Moderate	Hospital admissions (cardiovascular)	0.00046	0.0002	95%	0.0016*
SB100 – Moderate	SB100 – High	Hospital admissions (cardiovascular)	0.022	0.017	30%	0.066

Mean difference in combined O_3 and $PM_{2.5}$ health endpoint incidences by scenario comparisons for 561 DAC and 607 non-DAC tracts, with associated independent t-test p-values. Negative values indicate the compared scenario (column 2) results in a higher value than the source scenario (column 1), i.e., the endpoint counts increase. †Average of tract area-weighted mean. *Less than 5% chance results are due to chance.

Table 9. Summary of Citywide Health Endpoint Totals for DAC and Non-DAC Tracts

Compared Scenarios		Health Endpoint	Citywide Total of Annual Avoided Incidence in DAC Tracts	Citywide Total of Annual Avoided Incidence in Non-DAC Tracts	DAC Percentage of City Total*
Baseline (2012)	SB100 – Moderate	Premature mortality	47	48	50%
Baseline (2012)	Early & No Biofuels – High	Premature mortality	76	72	51%
Early & No Biofuels – Moderate	Early & No Biofuels – High	Premature mortality	28	24	54%
SB100 – High	Early & No Biofuels – High	Premature mortality	0.34	0.25	58%
SB100 – Moderate	Early & No Biofuels – High	Premature mortality	29	24	54%
SB100 – Moderate	Early & No Biofuels – Moderate	Premature mortality	0.59	0.34	64%
SB100 – Moderate	SB100 – High	Premature mortality	28	24	54%
Baseline (2012)	SB100 – Moderate	ER visits (asthma)	-21	-9.3	69%
Baseline (2012)	Early & No Biofuels – High	ER visits (asthma)	-9.8	-1.4	88%
Early & No Biofuels – Moderate	Early & No Biofuels – High	ER visits (asthma)	11	7.8	57%
SB100 – High	Early & No Biofuels – High	ER visits (asthma)	0.19	0.13	60%
SB100 – Moderate	Early & No Biofuels – High	ER visits (asthma)	11	8.0	58%
SB100 – Moderate	Early & No Biofuels – Moderate	ER visits (asthma)	0.31	0.14	68%
SB100 – Moderate	SB100 – High	ER visits (asthma)	11	7.8	58%

Compared Scenarios		Health Endpoint	Citywide Total of Annual Avoided Incidence in DAC Tracts	Citywide Total of Annual Avoided Incidence in Non-DAC Tracts	DAC Percentage of City Total*
Baseline (2012)	SB100 – Moderate	Hospital admissions (cardiovascular)	26	24	52%
Baseline (2012)	Early & No Biofuels – High	Hospital admissions (cardiovascular)	38	34	53%
Early & No Biofuels – Moderate	Early & No Biofuels – High	Hospital admissions (cardiovascular)	12	10	54%
SB100 – High	Early & No Biofuels – High	Hospital admissions (cardiovascular)	0.15	0.11	59%
SB100 – Moderate	Early & No Biofuels – High	Hospital admissions (cardiovascular)	12	10	55%
SB100 – Moderate	Early & No Biofuels – Moderate	Hospital admissions (cardiovascular)	0.26	0.14	64%
SB100 – Moderate	SB100 – High	Hospital admissions (cardiovascular)	12	10	55%

* Percent with respect to the total change.

5.3 Important Caveats

1. Due to methodological incommensurability and differences in data sets between CalEnviroScreen and our air quality-health impacts modeling chain, our analysis could not follow the approach used in CalEnviroScreen. This is because CalEnviroScreen is a retrospective tool based on sparsely measured data whereas LA100 looks toward the future using highly resolved models that produce sometimes slightly different metrics than those defined in CalEnviroScreen.
2. The CalEnviroScreen definition of DAC versus non-DAC tracts is partially based on recent yet historical concentrations of the two air pollutant exposure indicators and the incidences of the three health indicators relative to the whole of California. Our analysis tracks and models change in air quality only in part of California, yet we rely on the current CalEnviroScreen designation of tracts for our distributional justice analyses and assume that this current classification does not change in the modeling year (2045).
3. Air quality modeling, and thus the analysis of public health effects resulting from changes to air pollutant concentrations, focused on analyzing both High and Moderate load electrification projections of the SB100 and Early & No Biofuels scenarios. Selection of these scenarios provides a high/low bookend to air pollutant emissions amongst the full set of LA100 scenarios. In addition, when evaluated in carefully selected pairs, analysis of these two scenarios allows for the isolation of changes to the power sector (by holding electrification levels constant) and to electrification levels (by holding power sector eligibility criteria constant). Results for the other LA100 scenarios are likely to fall in between those for SB100 and Early & No Biofuels.
4. Owing to a focus on modeling emissions changes to LA100-affected sources (as opposed to all sources of air pollutants in LA), our estimates of concentrations are not predictions of future concentrations in an absolute sense, but rather should only be used in the context of comparing results among the evaluated LA100 scenarios.
5. The analysis in this chapter identifies whether there are statistically significant differences between DAC and non-DAC tracts for the health and air pollutant exposure indicators. However, even when differences between non-DAC and DAC tracts are not statistically different, they may have practical significance, and vice versa (some statistically significant differences are not practically significant). Importantly, public health modeling (Chapter 9) indicates that the city as a whole benefits from the emission reduction measures resulting from LA100 scenarios with regard to exposure to ozone and $PM_{2.5}$ and a subset of their related health effects.
6. Several issues impacting local neighborhoods adjacent to LA100-affected sources like LADWP-owned power plants as well as the roads that electrified light-duty vehicles travel on and changes to indoor air quality resulting from energy efficiency and electrification of appliances in buildings are addressed in Section 6.
7. With the addition of premature mortality, the environmental health endpoints modeled in this study align with those used in CalEnviroScreen. Yet, there are many other environmental health endpoints, and the pollutants that cause them, not modeled in this study, and thus this chapter does not represent a complete environmental health analysis of all of the potential health benefits of LA100 scenarios. In this way, LA100

underestimates the potential health benefits of LA100 and its monetary benefits. LA100 focused on regional pollutants and did not model the local concentration nor their associated health effects. For instance, reducing the use of combustion at LADWP in-basin power plants also reduces many pollutants directly emitted, such as NOx and a host of hazardous air pollutants, that have more local effects. *Ultimately this study underestimates the potential health benefits of the LA100 scenarios, especially for nearby residents and neighborhoods.*

5.4 Conclusion—Environmental Justice of Air Quality and Public Health Impacts

In this work, we analyze the environmental justice aspects of pollutant exposure and related health endpoints to the census tracts identified by OEHHA as disadvantaged communities in the city of Los Angeles based on CalEnviroScreen scores.

We find that with regard to ozone concentration, disadvantaged communities experience lower concentrations now and under all future scenarios than their non-DAC counterparts. Conversely, our analysis indicates that the disadvantaged communities are currently exposed to disproportionately higher level of $PM_{2.5}$ pollution, compared to the non-DAC counterparts and this remains true for all future scenarios. Thus, the LA100 scenarios do not disproportionately benefit or worsen DAC and non-DAC distinctions in exposure to either pollutant across any of the scenarios.

These results are a direct result of the air quality modeling analysis reported in Chapter 9. It was found in that analysis that $PM_{2.5}$ concentrations decrease citywide (for both DAC and non-DAC tracts) from baseline to all future scenarios, and thus provide health benefits (as summarized below). Ozone concentrations on the other hand increase through most of the city (barring the northwestern part of San Fernando Valley where the concentrations decrease), yielding increased health incidences. Increased ozone concentration may seem counterintuitive since emissions of ozone precursor pollutants (principally, nitrogen oxides) decrease considerably as a result of LA100-related emission reductions. However, this results from a scientifically well-established phenomenon for Los Angeles based on the current ratio of pollutants in the LA atmosphere (see Chapter 9 for further discussion of this phenomenon and air quality modeling results). The disproportionate burden for non-DAC tracts with regard to ozone results mainly from conditions in the San Fernando Valley.

Comparisons across scenarios meant to isolate the contribution of certain sectors (comparing with constant load levels or with constant power plant eligibility criteria) do not identify specific sectors or scenarios where the concentration results differ significantly between DAC and non-DAC tracts. Similar spatial patterns of concentration are experienced by DAC and non-DAC communities. And again, the relative patterns of DAC vs. non-DAC that exist today are maintained through all future scenarios.

In the future, Early & No Biofuels – High, the scenario with the greatest emission reductions (resulting from high end-use electrification and low power plant emissions), offers maximum population-weighted $PM_{2.5}$ concentration reduction in the DAC communities compared to the 2012 baseline. In the Early & No Biofuels – High (the scenario with maximum emission reductions from high electrification in the end-use sectors and hydrogen combustion in LADWP owned power plants), the DAC tracts experience a 4.8% reduction in population-weighted $PM_{2.5}$ concentration in 2045 compared to the Baseline (2012), which is a representative simulation for current conditions where the average DAC tract $PM_{2.5}$ concentration is 12.7 $\mu g/m^3$. In the Early & No Biofuels – High scenario, the population-weighted average concentration of $PM_{2.5}$ decreases in non-DAC tracts, too, but the decrease is slightly larger (5.3% reduction compared to the Baseline (2012) where average $PM_{2.5}$ concentration is 10.7 $\mu g/m^3$). Because the Early & No Biofuels – High scenario assumes high end-use electrification and restricts LADWP-owned power plants to combust only hydrogen, the modeled results show the largest benefits in terms of reduced $PM_{2.5}$ concentration. In general, for all future scenarios modeled, $PM_{2.5}$ reductions in DAC tracts is 3.3%–4.8% compared to the Baseline (2012), and the corresponding reduction is 3.6%–5.2% in the non-DAC tracts.

Among future scenarios, Early & No Biofuels – High has the largest average increase in O_3 concentrations compared to the Baseline (2012) scenario across all tracts (13% increase in the mean summertime 8-hour maximum O_3 concentrations) with statistically significant differences between DAC tracts (tract average increase of 5.3 ppb) and non-DAC tracts (tract average increase of 4.4 ppb). Early & No Biofuels – Moderate, SB100 – Moderate, and SB100 – High showed similar increases of O_3 concentration compared to the Baseline (2012) (12%–13% increase in the mean summertime 8-hour maximum O_3 concentrations) and similar disparities between DAC and non-DAC tracts (average increase of 5.1–5.3 ppb and 4.2–4.4 ppb across DAC and non-DAC tracts, respectively).

The two concentration indicators in CalEnviroScreen affect human health from their inhalation in many ways. In Chapter 9, we modeled three potential health effects from $PM_{2.5}$ and ozone among the many potential health effects: asthma, cardiovascular disease, and premature mortality. Both $PM_{2.5}$ and ozone affect asthma as well as premature mortality; these health effects are reported as the sum of contributions from both pollutants. Asthma effects are measured in emergency department visits and cardiovascular disease in hospital admissions.

In this chapter, we have analyzed the differences in the future changes to health effects that result from exposure to ozone and $PM_{2.5}$ for the DAC versus non-DAC census tracts in the city of Los Angeles. We used statistical analysis to discern whether differences observed could be due to random chance, setting a confidence threshold of 95% for when we deem differences statistically significant. There are several scenario and indicator combinations that show statistically significant differences between DAC and non-DAC tracts, though sometimes statistically significant differences are not substantively different. Note also that for health effects, the methods applied require *comparisons* of scenarios and do not report absolute measures of health effect incidence.

All comparisons among future LA100 scenarios yield greater health benefits (avoided health effects) for DAC as compared to non-DAC tracts for all three endpoints investigated. However, for many of the comparisons, the 95% confidence level was not reached, which means that we cannot say that there is a difference between DAC and non-DAC tracts that might not have occurred from random chance. All evaluated LA100 scenarios show larger absolute benefits in the future when compared to the Baseline (2012) than when isolating a particular sector's emissions as in the comparisons between LA100 scenarios in 2045.

In summary, our analysis indicates that emissions reductions in the source sectors affected by LA100 does not benefit non-DAC tracts differentially compared to DAC tracts, which have historically been at disadvantage. The City of LA benefits as a whole for all health indicators considered in all future scenarios compared. For premature mortality and cardiovascular-related hospital admissions, from 2012 baseline to 2045, health incidence reduces; for asthma, the opposite is true, which is due to ozone concentration increases owing to LA100 scenarios (see Chapter 9 for explanation of this finding). Differences between scenarios are relatively smaller than the changes seen from the Baseline (2012) to 2045. (These results are further corroborated in Chapter 9.)

The City Council Motion authorizing the LA100 study emphasized prioritization of environmental justice communities as the first immediate beneficiaries of localized air quality improvements. Within the context of the how the LA100 scenarios were defined, it appears that investment in electrification of transportation, appliances in residential and commercial buildings, as well as the Ports of Los Angeles and Long Beach provide significantly greater air quality and related public health benefits than does the specific path to 100% renewable energy by LADWP-owned power generation facilities.

6 Distributional Justice: Qualitative Discussion of Selected Potential Impacts to Local Communities of Additional Changes Resulting from LA100 Scenarios

In February 2019, Mayor Garcetti announced the retirement of LA's remaining once-through cooling natural gas generation. This decision occurred in the middle of the LA100 study and was incorporated into the LA100 generation and load modeling, and subsequently into the air quality and public health modeling (see Chapter 9). However, there are several implications of LA100 scenarios with regard to use of the LADWP in-basin fossil-fuel power facilities that are not addressed in the regional air quality modeling reported in this chapter that are worth raising qualitatively here, including neighborhood nuisance issues (odor, noise, visual impacts), heat island, and local air quality. In addition, electrification of light-duty vehicles and building appliances, as well as some energy efficiency measures like building weatherization, can also affect residents in ways not quantified in LA100.

6.1 Issues Related to Changes to LADWP Power Plant Facilities

Impacts of changes to the LADWP power plant facilities modeled in the LA100 study have been quantified with regard to GHG emissions (Chapter 8), air quality and public health (Chapter 9), and economic impacts and jobs (Chapter 11). This chapter also addressed potential differential impacts to disadvantaged communities of air quality and resultant public health effects from the regional air pollutants examined in Chapter 9, ozone and $PM_{2.5}$, as well as analyzed customer rooftop solar deployment. This section attempts to qualitatively address topics that fall outside the scope of the aforementioned chapters and sections: so-called nuisance issues of noise and visual impacts; heat island; and more localized air quality impacts not addressed in Chapter 9.

It is important to reiterate that all LA100 scenarios use the existing in-basin generation sites for new infrastructure, including batteries, fuel cells and/or combustion turbines fueled with renewably derived fuels, in different mixes depending on the scenario. These will continue to be industrial sites, with visual impacts including transmission infrastructure and exhaust stacks. We do not anticipate a net reduction in the area occupied by the existing plants, as batteries and renewable fuel infrastructure can take up considerable area.

Renewably fueled combustion turbines are relatively expensive to operate (as compared to natural gas generators), so the LA100 study relies on these facilities primarily during periods of peak demand or low output from wind and solar resources. There will be many days, particularly in the spring, when generation from these units will not be needed and thus they will sit idle. Yet, in this study, they are necessary infrastructure to ensure reliability of the grid, and thus while idle, they will be ready to be turned on in case of an emergency, such as a big transmission failure. While idle, there will be significant reduction in noise from these sites, and these periods will occur more frequently than today.

Depending on their fuel, when operated, renewably fueled combustion turbines will produce emissions at rates equal to or less than the cleanest, state-of-the-art natural gas plant. For instance, when hydrogen is burned (as is allowed for all LA100 scenarios), emissions factors are cut to zero for CO, SOx, VOC (which includes most hazardous air pollutants, otherwise known as local toxics), and PM, whereas NOx and ammonia emissions are assumed to be emitted at the current regulatory limit, which is approximately the average rate reported for the four in-basin LADWP power plants in 2019 (see Appendix D of Chapter 9). However, their decreased operation will result in significantly lower overall emissions (-72% to -100% for NOx and PM) on an annual basis compared to today (Table 9).

Table 9. Annually averaged daily NOx and PM emissions in 2045 (metric tons per day) and percent reduction from the 2012 Baseline from LADWP power plants for the LA100 scenarios modeled for air quality impacts (excerpted from Tables 9 and 10 in Chapter 9)

	NOx	PM
2012 Baseline	0.54	0.24
SB100 – M	0.15 (-72%)	0.03 (-87%)
SB100 – H	0.15 (-72%)	0.03 (-87%)
Early/NoBio – M*	0.05 (-91%)	0.00 (-100%)
Early/NoBio – H*	0.04 (-93%)	0.00 (-100%)

*Early & No Biofuels only allows hydrogen combustion by 2045, which is assumed to have zero PM emissions.

In addition to the emissions reductions from the power plants resulting from LA100 scenarios as compared to today, to the extent that LADWP electrifies its on-site heavy maintenance vehicles and auxiliary equipment, most of which are currently fueled with diesel, there will be additional air pollutant emission reductions, as well as noise reduction.

In all, those living in proximity to the in-basin power plants should experience significant reductions in exposure to air pollutant emissions from the LADWP facilities. The local benefits of these emission reductions were not quantified within the LA100 study because the air quality modeling was aligned with the two pollutants included in CalEnviroScreen, ozone and $PM_{2.5}$. These two pollutants are more regional in character, owing to the fact that they are both formed in the atmosphere rather than directly emitted. Reducing (as in SB100) or eliminating (as in all other LA100 scenarios) combustion of natural gas at LADWP-owned power plants also reduces many pollutants directly emitted, such as NO_2 and a host of hazardous air pollutants, that have more local effects. LA100 did not model the local concentration of those pollutants nor their associated health effects, and in this way, likely underestimated the potential health benefits of the LA100 scenarios especially for nearby residents and neighborhoods. A different air quality modeling approach is required for such a local analysis, with attention to a different set of pollutants and health effects.

The one potential negative effect of LA100 scenarios with regard to local community exposure to air emissions is if exhaust stacks are shorter than today's. While such a change would reduce local visual nuisance, it also reduces the dilution of air emissions before they reach the height at which people are breathing. When a power plant is operating with combustion emissions, exposure concentrations could be higher with a lower stack than with a taller one. Yet, recall from Table 9 that overall emissions are significantly lower, and thus health effects from the remaining combustion are expected to be lower than under today's conditions. This qualitative and suggestive conclusion could be tested with air quality modeling to confirm.

Air pollutant emission reductions are also expected to reduce visual nuisance of the smokestacks. When not operating, smokestacks will not produce any visible plume. One thing residents might notice from the plants that burn hydrogen fuel is a somewhat more frequent white vapor emission coming from the exhaust stack when they are operating, compared to current plants. That is because the primary emissions product from these plants is water vapor (steam), compared to natural gas plants that mainly produce a mix of water vapor and invisible carbon dioxide with a small amount of particulates.

Finally, there is a potential effect on the heat island. A heat island refers to how urban areas have higher temperatures than immediately surrounding rural areas. This is mainly due to heat retention in the built environment – impervious surfaces, roofs, concrete infrastructure, etc. There could be some reduction in the LA heat island from LA100 scenarios resulting from vehicle electrification (reducing tailpipe waste heat), but it is likely not large. There could be some local reduction of heat generated from LADWP in-basin power plants, but again this is likely to be quite small. Modeling could be performed to investigate this if deemed important.

A summary of the qualitatively assessed issues described above is provided in Table 10 below.

Table 10. Qualitative Assessment of Direction of Change Related to Local Air Quality and Health from Today's LADWP Thermal Generating Plants Burning Natural Gas to Changes Associated with LA100 Scenarios Where Minimal Natural Gas Is Burned (SB100) or Only Hydrogen Is Burned (Early & No Biofuels)

(Two arrows indicate greater magnitude of change relative to one arrow. NG = natural gas)

Issue	Direction of Change Compared to Today's LADWP Thermal Generating Plants Burning NG		Notes
	Hydrogen	Natural Gas	
LADWP thermal generating sites size	Same		
Exhaust stacks on site	Y		
Stack height (compared to steam unit)	↓		Converting steam units to combustion turbines
Types of pollutants emitted (vs. NG)	↓	Same	
Combustion frequency (hrs/yr)	↓	↓	Frequency of combustion decreases significantly in all LA100 scenarios
Total stack emissions (tons/yr)	↓	↓	e.g., -72% to -97% in NOx emissions (see Chapter 9)
Concentration of emitted pollutants in adjacent neighborhoods	↔	↑	Same when operating if stack is same height; higher concentrations would result if the stack were shorter
Emissions from other on-site sources	↓		e.g., maintenance vehicles, to the extent electrified
Noise	↓	↓	Especially if site operations are electrified
Odor	↓	Same	
Heat island effect	~		Heat island is mostly from infrastructure heat retention, not exhaust heat

6.2 Issues Related to Changes to Other LA100-Affected Sectors: Transportation, Ports, and Buildings

Communities living near major roads in LA should experience significant reductions in near-road air pollutant emissions by 2045 based on the light-duty vehicle electrification rates in LA100 scenarios. Along the lines of the discussion above about air quality benefits of the LA100 scenarios for communities living near the in-basin power plants, there are overlapping and also different pollutants of concern in terms of near-road exposures as compared to those relevant to the formation of ozone and $PM_{2.5}$ in the atmosphere. Thus, a different modeling approach is required to quantify these benefits. There should also be tangible changes in noise and odor owing to the electrification of the light-duty vehicle fleet.

The Ports of Los Angeles and Long Beach both have substantial electrification in the LA100 scenarios, where major sources owned by the Ports or under their jurisdiction are 80%–100% electrified (see Table 4 of Chapter 9). These are two major facilities in terms of air pollution in Los Angeles, and the electrification planned at these facilities should significantly reduce exposure by local communities to air emissions of NO_2, air toxics (hazardous air pollutants), PM and other pollutants. Similar to the in-basin power plants, a different modeling approach is required to quantify these changes to air quality and local community public health. And as mentioned above for the in-basin power plants as well as major roadways, noise and odor should also be reduced as a result of the electrification of sources.

Finally, there are also improvements to note for those buildings receiving energy efficiency and electrification upgrades in the LA100 scenarios. Foremost perhaps is the reduction in several important combustion sources in buildings: water and space heating in commercial buildings (including multifamily residential buildings), and those two plus clothes drying and cooking appliances in residential buildings. (See Table 3 in Chapter 9 for a summary of these electrification rates, which vary by load projection and end use from 50% to 100% by 2045.) Most people spend the vast majority of their time indoors on a given day. Air quality is often worse indoors than outside. Important sources of emissions of air pollutants indoors include combustion sources. These sources emit the same set of pollutants they would in the outdoor environment except that indoor combustion appliances often do not have emission controls like large facility smokestacks would and often do not operate in ideal combustion conditions, both of which lead to higher emissions per unit of fuel burned. Thus, electrifying indoor sources can have a greater effect on reducing health effects from air pollution than the equivalent reduction for a source emitting outdoors. Modeling of indoor air quality impacts from electrifying sources electrified in LA100 is complex, with results depending on many factors about home design, occupancy, ventilation, other sources, etc., and was outside the scope of the LA100 study. Yet, we know that electrifying these sources will lead to reduced air pollutant exposure if all else is held equal, and thus provide for health improvements to building occupants.

A summary of the qualitatively assessed issues described above is provided in Table 11.

Table 11. Qualitative Assessment of Direction of Environmental Justice-Related Changes Resulting from Changes to Non-Power Sectors Under LA100 Scenarios

Issue	Direction of Change Compared to Today's Sectors	Notes
Near-road		From LDV electrification
Pollutant emissions		Proportional to electrification projection (Mod, High)
Odor		
Noise		
Ports		From electrification of Port operations
Pollutant emissions		
Odor		
Noise		
Buildings		From electrification of building appliances
Indoor combustion emissions		Ensure energy efficiency doesn't reduce indoor air quality (e.g., adequate ventilation provided)

7 Actions that Could Prioritize Benefits to Disadvantaged Communities

Disadvantaged communities could expect to see many benefits in a clean energy transition, including reduced local and regional air pollution, improved indoor air quality from electrification, reduced vulnerability to climate change and improve health outcomes. Ensuring prioritization of disadvantaged communities, however, is not an inevitable result of the power-system transition. A just, equitable clean-energy future would require intentionally designed decision-making processes and policies/programs that prioritize these communities.

Example actions to support prioritization of environmental justice could include:

- **Participation in Decision-Making**: Identifying barriers to procedural justice can inform improvements to who is included in decision-making, how decisions get made, and what resources are needed to enable parity of participation.
- **Energy infrastructure**: LA100 shows strong potential for electrification, efficiency, demand response, and rooftop solar in disadvantaged communities—but the modeling does not capture real-world experiences and barriers to adoption. Actions to prioritize environmental justice include:
    - Improved data collection and modeling on characteristics that could inform the design and evaluation of electrification, efficiency, demand response, and solar programs (e.g., differences in household size, appliance age, mobility options, access to smart energy devices)
    - More comprehensive representation of benefits (e.g., indoor air quality, improved resilience to extreme weather events with energy efficiency upgrades)
    - Policy designs that target barriers to these programs and related concerns (e.g., the potential for prioritization of benefits to lead to gentrification; impact of stranded costs on low-income customers who do not electrify or adopt rooftop solar; barriers specific to renters)
    - Metrics for success and process for course-correction established in collaboration with stakeholders. One gap in environmental justice metrics is a method to align forward-looking modeling with retrospective-based tools such as CalEnviroScreen. While CalEnviroScreen scores are useful as benchmarks, there is a need to evaluate options for their potential future effects prior to implementation. Aligning forward-looking models with CalEnviroScreen metrics can enable flagging of potential deficiencies and the creation of optimal solutions toward improvement within the recognized CalEnviroScreen framework, as well as tracking of progress with granularity and frequency not now available through CalEnviroScreen.
- **Jobs**: While not reviewed in this chapter, identifying workforce needs for each energy technology identified in the study has important implications for potential future hiring and training needs. The city could facilitate programs for in-demand occupations that may be hard to fill and other high-quality jobs. The city could also include in clean energy program design some of the workforce objectives sought by the community. For example, some in the public requested solar installations within disadvantaged communities as a way to support clean energy jobs that do not require long commutes.
- **Health benefits**: Electrification of transportation, building end uses, and the Ports of Los Angeles and Long Beach provide significant air quality and related public health benefits. Hence, a prioritization of disadvantaged communities as first immediate beneficiaries of localized air quality improvements

would include a focus on electrification. But electrification can be hindered by increasing electricity rates. Toward the end of the 100% renewable energy transition, the cost of decarbonizing the power sector, if reflected in increased rates, could lead to public pressure to reduce the pace of electrification. Further analysis could consider options that maintain decarbonization and improved health as a goal, but with a better understanding of the interaction among the costs of power system decarbonization, pace of electrification, and rate design.

- In addition, quantifying neighborhood-level impacts could be an important component of an evaluation of LA100 with regard to achieving outcomes beneficial to disadvantaged communities. For example, the design and evaluation of any electric vehicle incentives could be coupled with analysis of local air quality benefits, especially in neighborhoods along roadways that suffer high local pollution. As another example, LA100 results suggest value to reliability in building new, state-of-the-art combustion turbines at current thermal generating stations sites fueled by renewable electricity-derived fuels (such as hydrogen) and operated less frequently compared to natural gas today. One step that LADWP and the City can consider to prepare for this change is to establish expectations of anticipated neighborhood environmental impacts, monitor these impacts, and revise operating protocols as needed.

8 References

Grell, Georg A., Steven E. Peckham, Rainer Schmitz, Stuart A. McKeen, Gregory Frost, William C. Skamarock, and Brian Eder. 2005. "Fully Coupled "Online" Chemistry within the WRF Model," *Atmospheric Environment* 39 (37): 6957–6975. https://doi.org/10.1016/j.atmosenv.2005.04.027.

Kim, T. K. 2015. "T Test as a Parametric Statistic." *Korean Journal of Anesthesiology* 68 (6): 540–546. https://doi.org/10.4097/kjae.2015.68.6.540.

Powers, Jordan G., Joseph B. Klemp, William C. Skamarock, Christopher A. Davis, Jim Dudhia, David O. Gill, et al. 2017. "The Weather Research and Forecasting Model: Overview, System Efforts, and Future Directions," *Bulletin of the American Meteorological Society* 98 (8): 1717–1737. https://doi.org/10.1175/BAMS-D-15-00308.1.

Sacks, Jason D., Jennifer M. Lloyd, Yun Zhu, Jim Anderton, Carey J. Jang, Bryan Hubbell, and Neal Fann. 2018. "The Environmental Benefits Mapping and Analysis Program: Community Edition (BenMAP–CE): A Tool to Estimate the Health and Economic Benefits of Reducing Air Pollution," *Environmental Modelling and Software* 104: 118–129. https://doi.org/10.1016/j.envsoft.2018.02.009.

Wong, David W., Lester Yuan, and Susan A Perlin. 2004 "Comparison of Spatial Interpolation Methods for the Estimation of Air Quality Data," *Journal of Exposure Science and Environmental Epidemiology* 14 (5): 404–415. https://doi.org/10.1038/sj.jea.7500338.

Appendix A. Additional Analysis of Distributional Justice Aspects of Customer Rooftop Solar

The LA100 customer solar adoption model incorporates several estimates of rooftop solar. Technical potential incorporates attributes of the physical building structure, roof, and insolation to estimate potential generation capacity. Economic potential downscales technical potential in accordance with energy rates, incentives, system capital costs, and cost of financing.

Realized economic potential measures the overall penetration of a given technology relative to modeled economic potential. A gap in “realized economic potential” among communities likely arises from conditions apart from sheer cost effectiveness from a customer perspective. To compute the realized economic potential by tract, we sum estimates for adopted customer solar by scenario, sector, tract, and year, and divide them by the corresponding economic potential (Figure 20). As noted in Section 4.1, economic potential measured in this study does not include impact of low-income electricity rates or differences in access to financing, among other factors, that could impact economic potential.

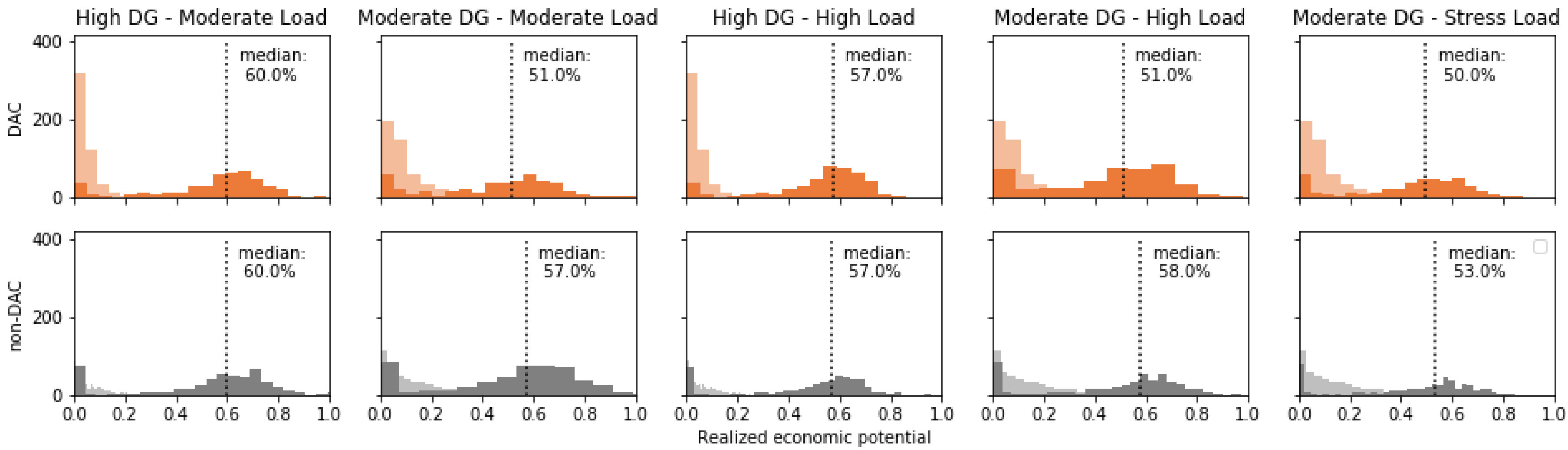

Figure 20. Realized economic potential, by tract, 2020 vs. 2045

The histograms show in light and saturated colors the count of tracts at different amounts of realized economic potential in 2020 (light) and 2045 (saturated), inside and outside disadvantaged communities. As the distribution of tracts shifts rightward (2020 to 2045), more tracts see higher rates of distributed generation uptake relative to economic potential.

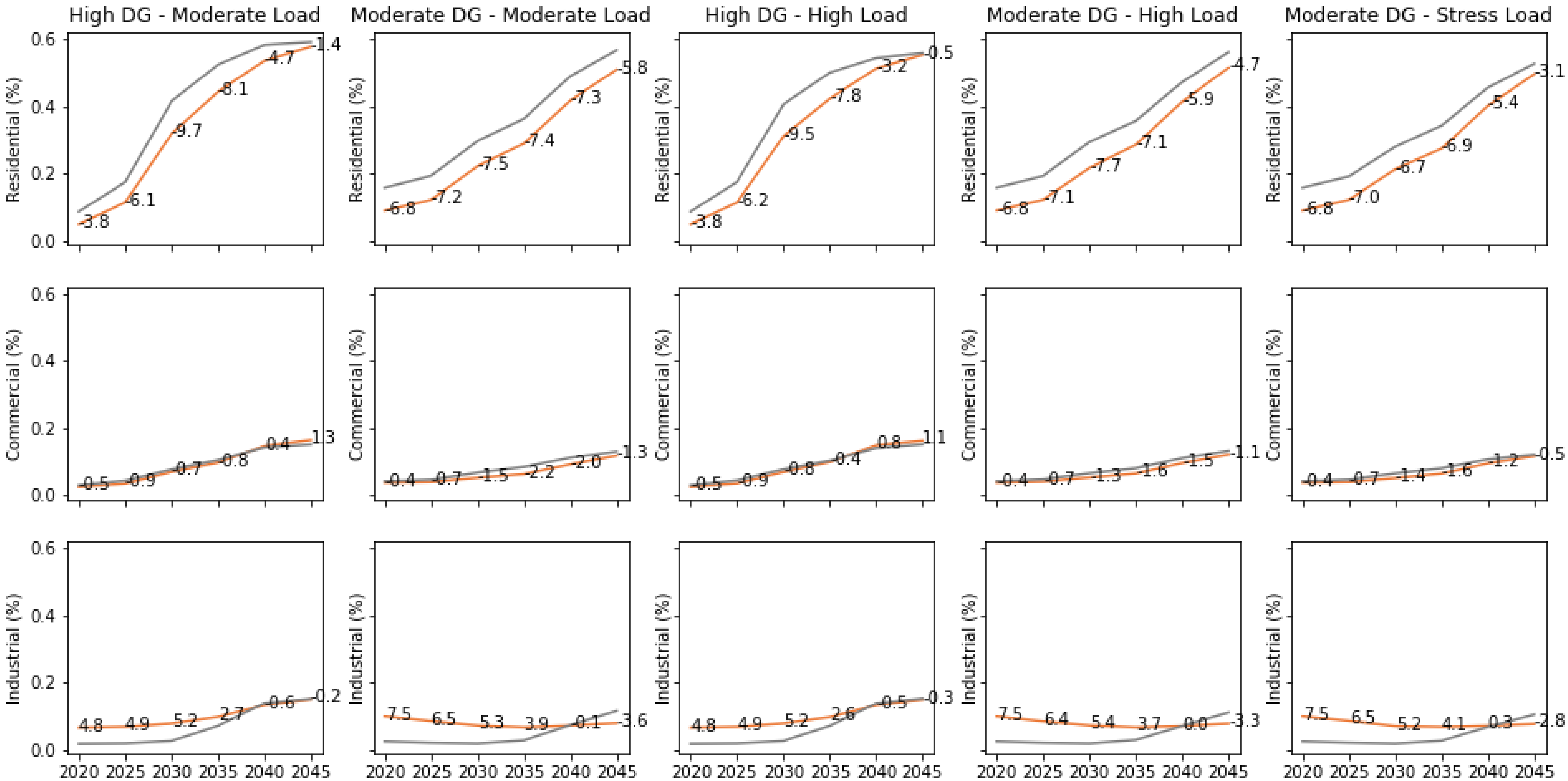

Figure 21. Realized potential is the capacity of new solar deployment (MW) divided by the economic potential (MW) within a given geography

here, disadvantaged communities are shown in orange and non-disadvantaged communities in grey.

Across scenarios, we can observe a gap in realized economic potential for residential distributed solar between disadvantaged and non-disadvantaged tracts (as observed by comparing the annotations of the realized potential curves in the topmost row of Figure 21 showing the difference in share of realized potential inside and outside DACs). This gap is greatest in mid-scenario years (2030–2035) and lessens across scenarios in later years. The customer solar chapter (Chapter 4) shows how economic potential is greatest in the High DG – High Load scenario, followed by the Moderate DG – Stress Load scenario. End-use electrification and customer solar rate design will jointly impact whether it will be economic to adopt solar. As electricity becomes more expensive and electricity consumption grows, solar will become more economically efficient to adopt, even if customer-sited generation is compensated below retail energy rates.

The gap between residential realized economic potential in disadvantaged and non-disadvantaged communities is smallest in the High DG – High Load scenarios (corresponding with the scenario with the highest overall economic potential). However, we observe the next smallest gap in realized economic potential in the High DG – Moderate Load scenarios, followed by Moderate DG – Stress Load (the second highest overall economic potential), Moderate DG – High Load, and Moderate DG – Moderate Load.

We see that in general, non-DAC tracts have a slightly higher rate of realized economic potential than DAC tracts, in particular for residential solar; distributed solar is nearly equal (DAC vs. non-DAC) with commercial agents and for Industrial agents the relative adoption switches from initially higher for DAC to higher for non-DAC in later scenario years. High load scenarios see a smaller gap in distributed solar uptake (<1%), while moderate load scenarios see a larger gap in average realized technical potential. Still, solar uptake in general increases dramatically by 2045: by a roughly seven to ten-fold increase outside disadvantaged communities, and 9- to 12-fold increase inside disadvantaged communities.

A.1 Inequality Curves

To provide a simplified, synthetic view of distributional equality in solar adoption by CalEnviroScreen score, we plot Lorenz curves to show how the population-wide share of socioeconomic disadvantage and pollution burden compare to the share of realized economic potential (Figure 22). Lorenz curves are traditionally used to illustrate income or wealth inequality in a population, but they have occasionally been applied in the context of energy equity studies.[61] A straight diagonal line would correspond to perfect equality – social and environmental disadvantage and realized solar potential being distributed uniformly across all tracts. The further a curve is from the straight 1:1 line, the less equal its distribution. A corresponding Gini coefficient is calculated for each Lorenz curve, which measures the area between that curve and perfect equality. Gini coefficients closer to zero correspond to more equal distributions, and ones closer to one less equal distributions. The High DG – High Load projection has the lowest Gini coefficient (0.26), followed by High DG – Moderate Load (0.267),

[61] Arne Jacobson, Anita D. Milman, and Daniel M. Kammen, "Letting the (Energy) Gini Out of the Bottle: Lorenz Curves of Cumulative Electricity Consumption and Gini Coefficients as Metrics of Energy Distribution and Equity," *Energy Policy* 33 (14): 1825–1832 (September 2005). https://doi.org/10.1016/j.enpol.2004.02.017.

Moderate DG – High Load (0.313), Moderate DG – Stress Load (0.327), and Moderate DG – Moderate Load (0.33). The 2020 baseline Gini coefficient is 0.534.

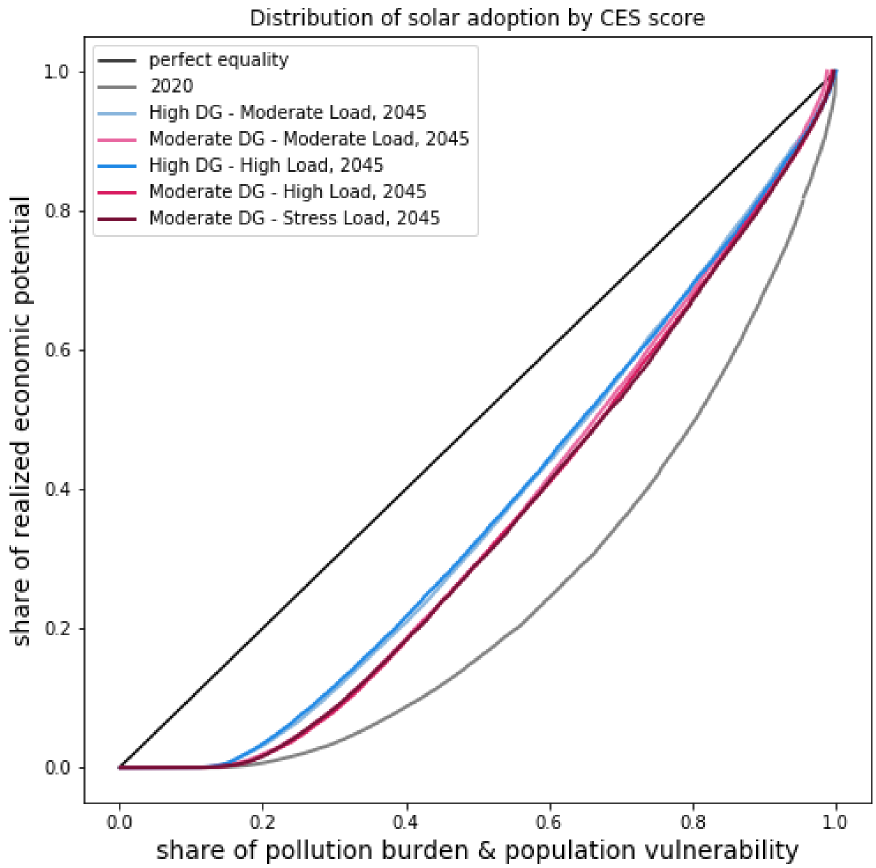

Figure 22. Lorenz equality curves for share of customer solar adoption and socioeconomic/environmental burdens

A.2 Distributed Solar Adoption by Income

Historically, residential solar has been adopted by higher-income households who are more likely to own their homes and afford the upfront expense of a solar system purchase. Previous studies have highlighted the potential of adverse distributional impacts if higher-income households disproportionately benefit from clean energy incentives.[62] We use the median income for each tract to group residential PV systems by income bin (Figure 23). In 2018, the median household income in Los Angeles for a family of four is $69,300.[63] We assign each tract to an area median income range based on that tract's median income relative to $69,300.

[62] Severin Borenstein and Lucas W. Davis, "The Distributional Effects of U. S. Clean Energy Tax Credits," *Tax Policy and the Economy* 30 (1): 191–234 (2016).
[63] "State Income Limits for 2018," California Department of Housing and Community Development (April 26, 2018 memo), https://www.hcd.ca.gov/grants-funding/income-limits/state-and-federal-income-limits/docs/inc2k18.pdf.

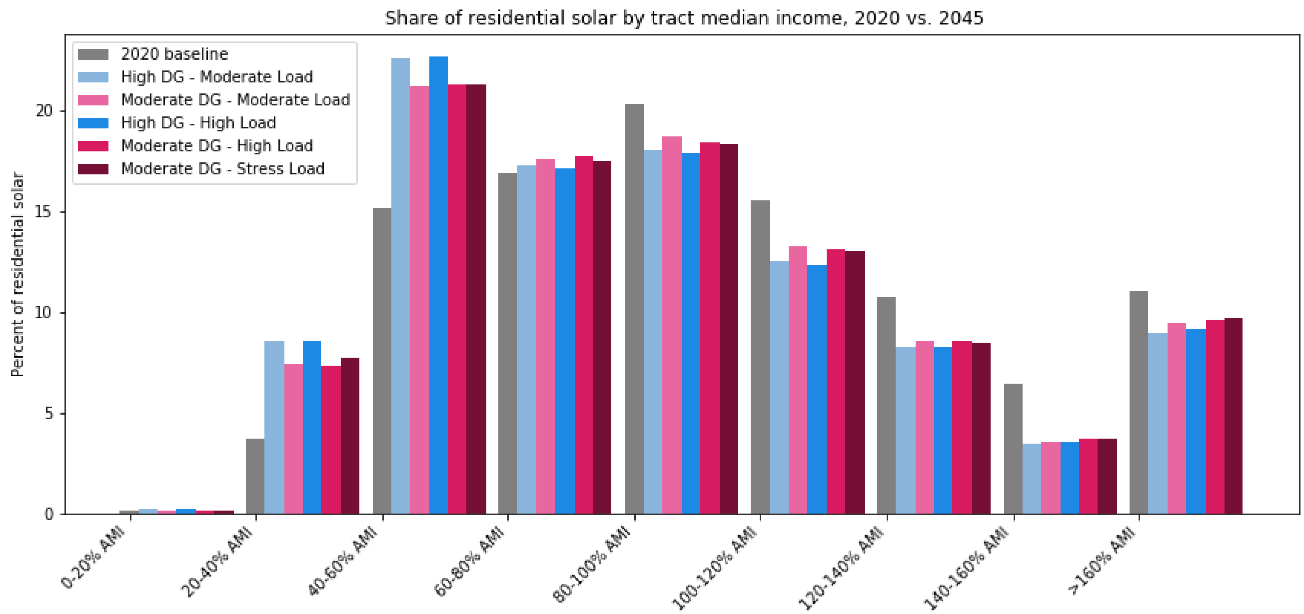

Figure 23. Residential solar adoption share, by tract median income as percentage of area median income and scenario, for census tracts in the city of LA

Appendix B. Technologies Not Analyzed for Distributional Equality

While the LA100 study projected a range of customer demand projections that could have impacts on ratepayers' capital and bill expenses, these projections were not calibrated to census tract boundaries or income groups within Los Angeles. Thus, we are unable to conduct a formal distributional analysis for energy efficiency and electrification of buildings' loads nor electric vehicle adoptions and their charging infrastructure. This appendix describes each modeling approach and its spatial limitations, and it includes recommendations for further research.

B.1 Energy Efficiency and Building Electrification

Future electric loads in buildings, such as appliances and heating/cooling systems, are highly dependent on economic conditions, policy decisions, and incentives, which are challenging to predict. Rather than forecast these factors independently, the LA100 demand-side grid (dsgrid) model constructed load projections (Moderate, High, and Stress) that consider combinations of all individually modeled loads. These load projections take into account historical trends and the carbon neutrality goals described in the Los Angeles pLAn. The dsgrid appendix provides detail on how each end use's electrification rate was modeled, accounting for technical ease and consumer preference. Clothes drying is anticipated to electrify most rapidly, followed by water heating, cooking, and space heating. dsgrid combines building stock and appliance turnover models to estimate fuel share in LADWP. Building characteristics from the LA County Parcel Assessor's data were used to construct probability distributions to describe the residential and commercial building stock as a whole. Because demand-side models were calibrated to factors such as customer billing, load shape, and location relative to power system boundaries, and not to capturing factors critical to understanding distribution justice (e.g., number of families in a household, sensitivity of results to income status), a robust comparison of energy efficiency and electrification impacts inside and outside disadvantaged communities is not possible.

A review of existing incentive program performance and uptake rates could provide a more complete sense of how these load projection assumptions could plausibly be met by existing or new programs, particularly those focused on low-income and multifamily households. LADWP's Equity Metrics Data Initiative and efficiency program measurement and evaluation studies could shed light on how much of the existing electrification and energy efficiency gap might be met by existing program design, and where additional policy support could be necessary to encourage efficiency and building electrification in disadvantaged communities. Energy efficiency programs designed to address the needs of older, higher occupancy, multifamily, and renter-occupied buildings may ensure that disadvantaged communities are prioritized in buildings-sector decarbonization programs.[64]

[64] Eric Daniel Fournier, Robert Cudd, Felicia Federico, and Stephanie Pincetl, "On Energy Sufficiency and the Need for New Policies to Combat Growing Inequities in the Residential Energy Sector," *Elementa: Science of the Anthropocene* 8 (1): 24 (June 11, 2020), https://doi.org/10.1525/elementa.419.

B.2 Electric Buses, Vehicles, and Charging Stations

EV adoption modeling in dsgrid yields a bottom-up forecast of energy demand from electric vehicles in order to model power sector needs, yet it does not explicitly model vehicle adoption behavior. EVI-Pro models consumer electric vehicle adoption based on the current adoption rate of hybrid electric vehicles by ZIP code, assuming that purchasers of hybrid vehicles are more likely to purchase electric vehicles in the future. In general, high load projection scenarios in LA100 see electric vehicle adoption rates across Los Angeles surpass 80%.

Present-day traffic burdens in disadvantaged communities shows that while Los Angeles as a whole experiences high concentrations of traffic, disadvantaged tracts contain a larger share of the highest traffic-burdened areas than non-disadvantaged communities.

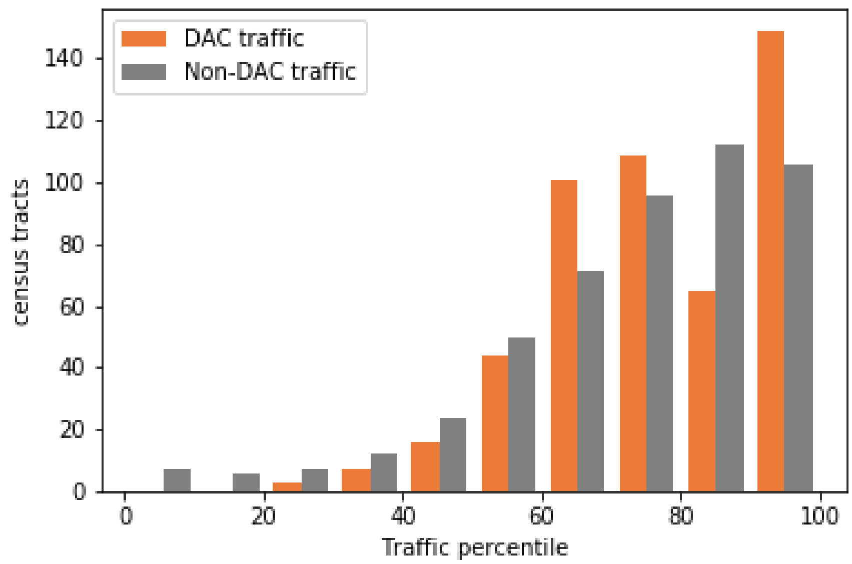

Figure 24. CalEnviroScreen traffic percentiles in the city of LA

https://oehha.ca.gov/media/downloads/calenviroscreen/report/ces3report.pdf

While not under the purview of LADWP decision-making authority, California has several clean vehicle rebate programs designed to incentivize electric vehicle adoptions. An analysis of historical rebate utilization data shows that the Clean Vehicle Rebate Project issues more rebates per household to geographies with higher income, education, and more white households.[65] Rebate designs that incorporate an income cap, tiered rebate amounts, or increased eligibility in disadvantaged communities can improve distributional equity in program participation (Ibid.).

In LA100, electric vehicle DCFC stations were assigned to commercial and industrial parking-lot agents that are within 0.3 miles of an existing 34.5 kV distribution line, with loads scaled by parking lot area. This procedure assumes that existing parking lots near the 34.5kV system are the best candidate locations for DCFC charging infrastructure investments. Charging loads were randomly assigned to candidate agents until all loads were allocated, and they did not take any specific charging demand assumptions into account. Similarly, L1 and L2 electric vehicle

[65] Yang Ju, Lara J. Cushing, and Rachel Morello-Frosch, "An Equity Analysis of Clean Vehicle Rebate Programs in California," *Climatic Change* 162 (4): 2087–2105 (2020), https://doi.org/10.1007/s10584-020-02836-w.

charging loads were allocated based on building type, with the EV loads allocated based on the building size and share of EVs in that building's ZIP code. Future analysis could evaluate where workplace and public charging station siting could enable electric vehicle adoption among households that do not own homes, live in buildings with off-street parking, or otherwise lack ready access to electric vehicle charging.

On average, households in Los Angeles spend 20% of their annual incomes on transportation-related expenses.[66] An analysis inclusive of public transit access would provide a more accurate picture of the environmental justice implications of transportation sector electrification than a simple spatial analysis of EV adoption inside and outside disadvantaged communities. Alongside electrification of existing transportation networks, future level of service will be an important indicator of future transportation affordability for low-income residents in LADWP.

[66] "H+T Fact Sheet: Municipality: Los Angeles, CA," H+T Index, https://htaindex.cnt.org/fact-sheets/?lat=34.0522342&lng=-118.2436849&focus=place&gid=1979#fs.

Appendix C. Additional Results Regarding Environmental Justice of Air Quality and Health Impacts

Table 12. Population-Weighted Concentrations of O_3 and $PM_{2.5}$ for the Five Modeled Scenarios (in 2045 Unless Otherwise Noted) and Corresponding Difference in the DAC versus Non-DAC Los Angeles Census Tracts

For reference, the national ambient air quality standard for O_3 is 0.070 parts per million (= 70 ppb), and for $PM_{2.5}$ is 12.0 µg/m^3.

Scenario	O_3 concentration (ppb)		O_3 difference (ppb)	$PM_{2.5}$ concentration (µg/m^3)		$PM_{2.5}$ difference (µg/m^3)
	DAC	Non-DAC	DAC - Non-DAC	DAC	Non-DAC	DAC - Non-DAC
Baseline (2012)	41	43	-2.4	12.7	10.7	2.0
Early & No Biofuels – High	46	47	-1.5	12.1	10.2	1.9
Early & No Biofuels – Moderate	46	47	-1.5	12.3	10.3	2.0
SB100 – High	46	47	-1.5	12.1	10.2	1.9
SB100 – Moderate	46	47	-1.5	12.3	10.3	2.0

Table 13. Population-Weighted Change in Concentrations of O_3 and $PM_{2.5}$ in DAC and non-DAC Los Angeles Tracts for the Four Modeled Scenarios in 2045 when Compared to the Baseline (2012)

Scenario	O_3 concentration or change from Baseline (2012) (ppb)		$PM_{2.5}$ concentration or change from Baseline (2012) (µg/m^3)	
	DAC	Non-DAC	DAC	Non-DAC
Baseline (2012) concentration	41	43	12.7	10.7
Early & No Biofuels – High - Baseline (2012) change	5.3	4.4	-0.61	-0.56
Early & No Biofuels – Moderate - Baseline (2012) change	5.1	4.2	-0.42	-0.39
SB100 – High - Baseline (2012) change	5.3	4.4	-0.61	-0.56
SB100 – Moderate - Baseline (2012) change	5.1	4.2	-0.42	-0.39

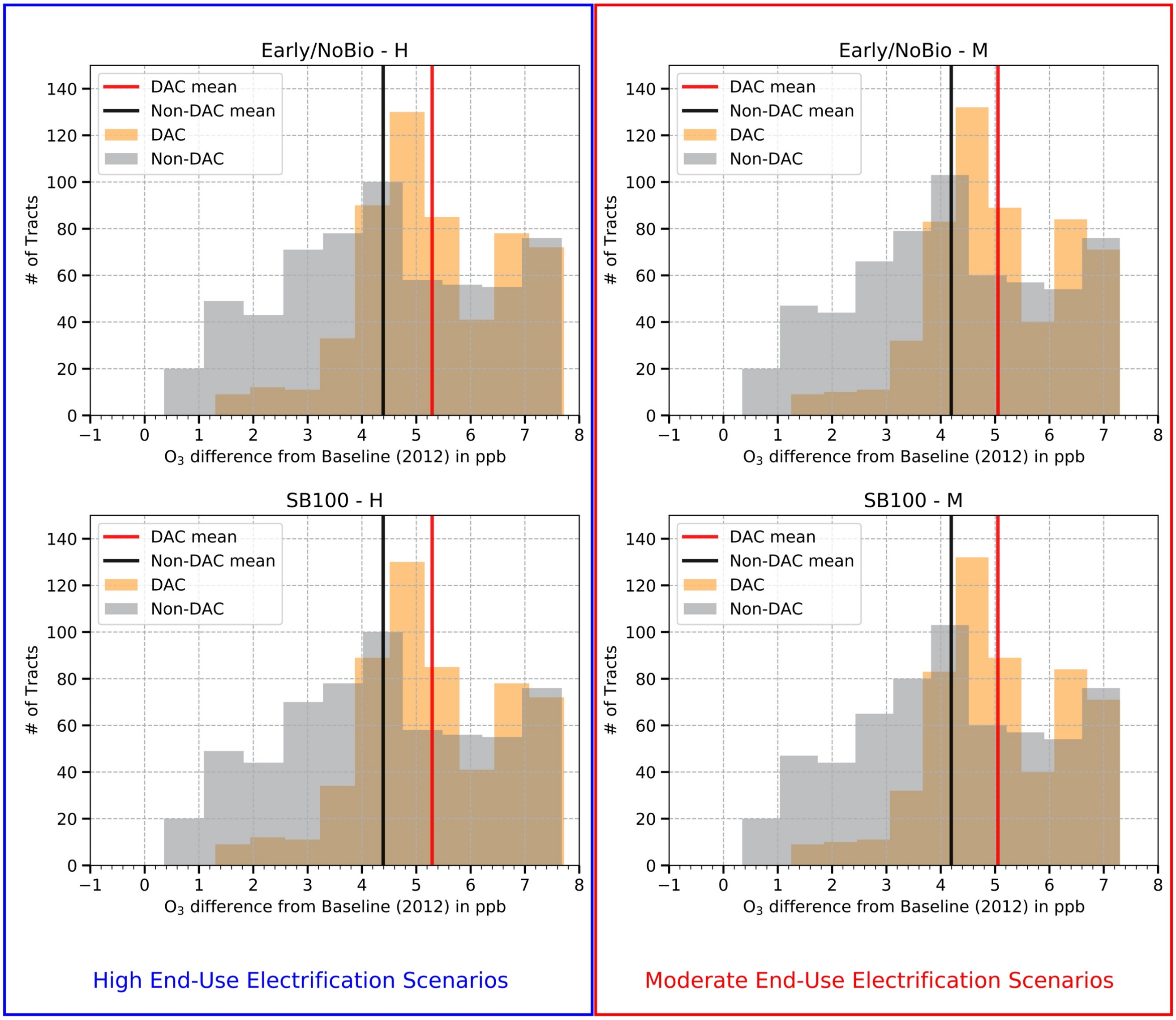

Figure 25. Histograms showing change in ozone concentration in DAC and non-DAC tracts in the city of LA in the two High electrification scenarios (left panel) and the two Moderate electrification scenarios (right panel) relative to Baseline (2012)

In all evaluated future scenarios, ozone concentration increases for DAC and non-DAC tracts, and the increase is larger by about 1 ppb in DAC tracts compared to the non-DAC tracts (Figure 13).

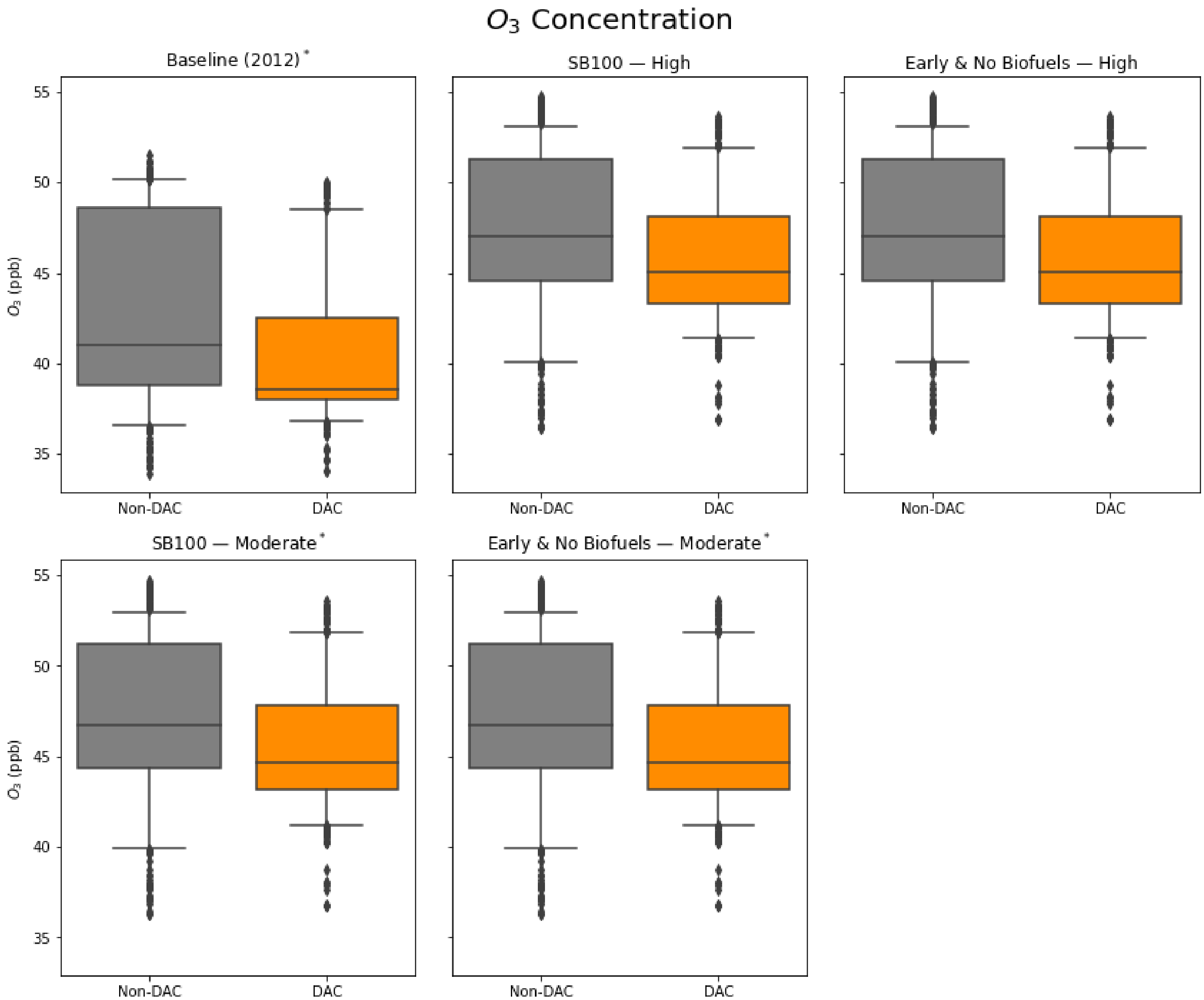

Figure 26. Population-weighted concentrations of O_3 (summertime average) in DAC and non-DAC Los Angeles census tracts in 2045 (except Baseline)

O_3 concentrations are similar in all scenarios for DACs, except the Baseline (2012); the same is true for non-DAC across scenarios. All four of the scenarios show increased concentrations compared to the Baseline. The relatively large range between the 25th and 75th percentile as well as the presence of outliers outside the 95th percentile indicate large variability among individual tract values. Only the Baseline (2012) and Early & No Biofuels – Moderate scenarios show significant differences between DAC and non-DAC tracts (at a 95% confidence level).

Definition of box plot markers: the box is bounded by the 75th percentile value (top of the box) and 25th percentile (bottom of the box) with the median (50th percentile) shown as a black line through the middle of the box. The whiskers represent the 5th (bottom whisker) and 95th (top) percentiles. Individual points above or below the whiskers (outliers) represent tract values outside those ranges and indicate extreme values. *Less than 5% chance differences in DAC and non-DAC are due to random sampling.

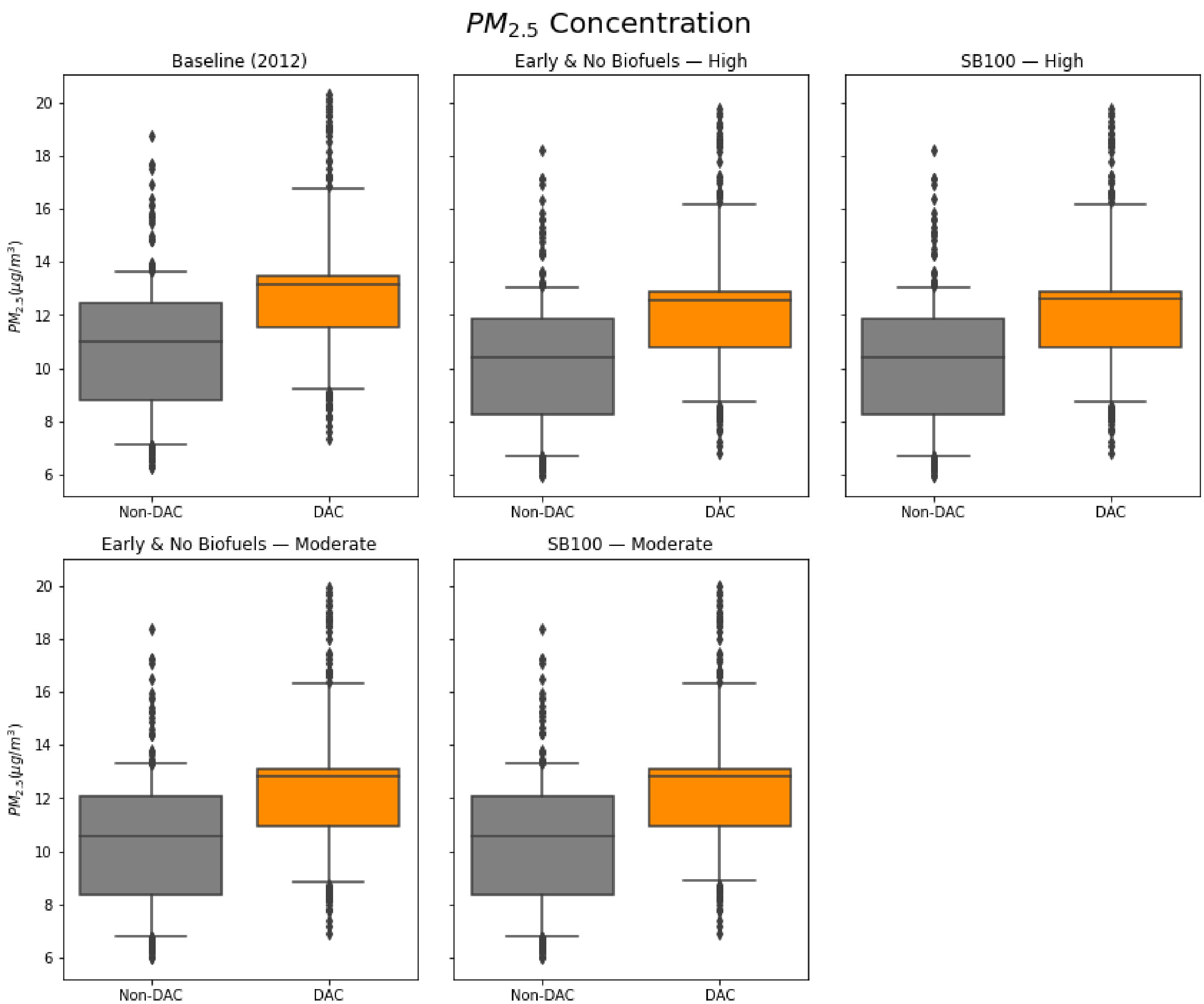

Figure 27. Comparison of distribution of population-weighted concentrations of $PM_{2.5}$ (annual average) in Los Angeles census tracts in 2045 (except Baseline)

DAC tracts show similar distributional characteristics for each scenario, as do non-DAC tracts. T-test results indicate statistically significant difference between DAC and non-DAC tracts for all scenario comparisons (at a 95% confidence level). DAC tracts are found to have, on average, higher concentrations of $PM_{2.5}$. All distributions show wide variability among individual tracts due to the presence of small and large outliers.

Definition of box plot markers: the box is bounded by the 75th percentile value (top of the box) and 25th percentile (bottom of the box) with the median (50th percentile) shown as a black line through the middle of the box. The whiskers represent the 5th (bottom whisker) and 95th (top) percentiles. Individual points above or below the whiskers represent tract values outside those ranges, which are deemed outliers.

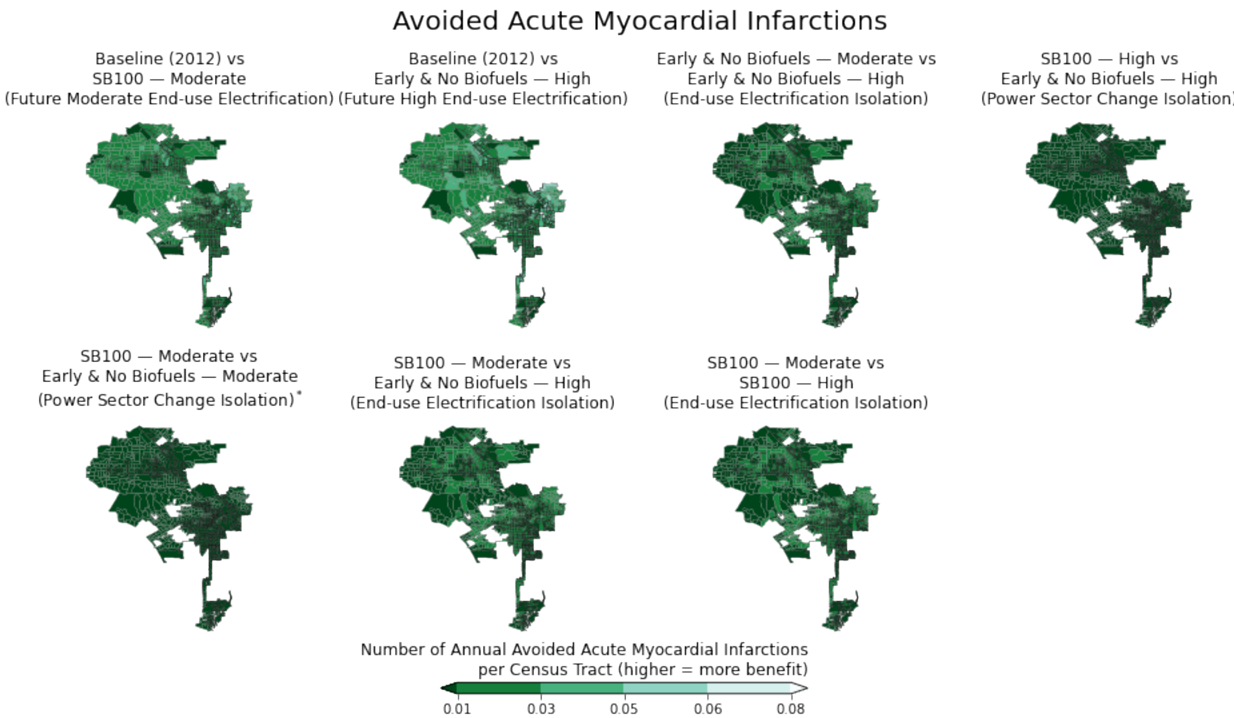

Figure 28. Population-weighted differences in annual number of avoided acute myocardial infarctions (heart attacks) in DAC and non-DAC Los Angeles census tracts in 2045

DAC tracts are outlined in black. Baseline (2012) versus SB100 – Moderate shows the greatest spatial variation and the largest decreases in acute myocardial infarctions from one scenario compared to the other among the scenario comparisons, however, the impacts are relatively evenly dispersed between DAC and Non-DAC tracts (not statistically significantly different) for all scenario comparisons except SB100 – Moderate versus Early & No Biofuels – Moderate. *Less than 5% chance differences in DAC and non-DAC are due to random sampling.

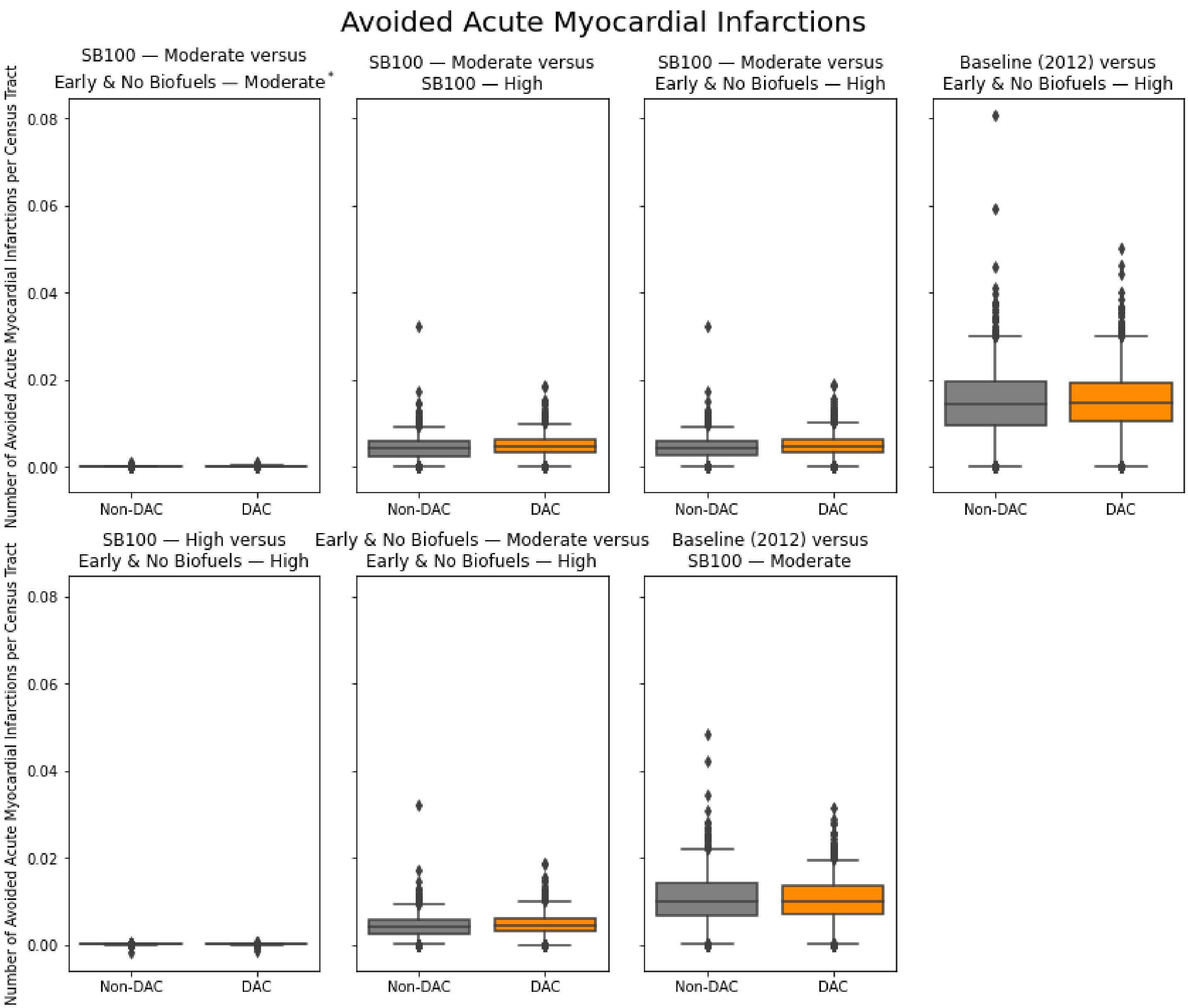

Figure 29. Population-weighted differences in annual number of avoided acute myocardial infarctions (heart attacks) in DAC and non-DAC Los Angeles census tracts in 2045

All scenarios show most tracts having decreased avoided acute myocardial infarctions. (SB100 – High versus Early & No Biofuels – High has some tracts with increases, but the absolute estimate is negligible.)

Definition of box plot markers: the box is bounded by the 75th percentile value (top of the box) and 25th percentile (bottom of the box) with the median (50th percentile) shown as a black line through the middle of the box. The whiskers represent the 5th (bottom whisker) and 95th (top) percentiles. Individual points above or below the whiskers (outliers) represent tract values outside those ranges and indicate extreme values. *Less than 5% chance differences in DAC and non-DAC are due to random sampling.

Table 14. Summary of the Statistical Analysis for Avoided Acute Myocardial Infarctions to Assess whether the Differences between DAC and Non-DAC Tracts in Annual Avoided incidence are Statistically Significant, based on Health Modeling Results for a Single Future Year (2045)

A positive number in the Mean columns indicate that the respective health endpoints decrease (i.e., are avoided) and a negative number indicates an increase (i.e., more incidences).

Compared Scenarios		Mean per Census Tract of Annual Avoided Incidence† (DAC)	Mean per Census Tract of Annual Avoided Incidence † (Non-DAC)	DAC Percentage Difference from non-DAC	t-Test Results (Median p-Value)
Baseline (2012)	SB100 – M	0.012	0.010	15%	0.26
Baseline (2012)	Early/NoBio – H	0.018	0.015	20%	0.16
Early/NoBio – M	Early/NoBio – H	0.0057	0.0044	29%	0.065
SB100 – H	Early/NoBio – H	0.000071	0.000046	56%	0.12
SB100 – M	Early/NoBio – H	0.0058	0.0045	30%	0.056
SB100 – M	Early/NoBio – M	0.00012	0.000062	96%	0.0015*
SB100 – M	SB100 – H	0.0057	0.0044	30%	0.060

Mean difference in nonfatal acute myocardial infarction concentrations by scenario comparisons for 561 DAC and 607 non-DAC Los Angeles tracts, with associated independent t-test p-values. Negative values indicate the compared scenario (column 2) results in a higher value than the source scenario (column 1), i.e., the acute myocardial infarction counts increase. AMI = nonfatal acute myocardial infarctions. †Area-weighted mean by tract. *Less than 5% chance results are due to chance. ‡Percent with respect to the total change.

Table 15. Summary of Citywide Acute Myocardial Infarctions for DAC and Non-DAC Tracts

Compared Scenarios		Citywide Total of Annual Avoided Incidence (DAC)	Citywide Total of Annual Avoided Incidence (Non-DAC)	DAC Percentage of City Total*
Baseline (2012)	SB100 – Moderate	6.7	6.3	52%
Baseline (2012)	Early & No Biofuels – High	10	9.0	53%
Early & No Biofuels – Moderate	Early & No Biofuels – High	3.2	2.7	54%
SB100 – High	Early & No Biofuels – High	0.040	0.028	59%
SB100 – Moderate	Early & No Biofuels – High	3.3	2.7	55%
SB100 – Moderate	Early & No Biofuels – Moderate	0.068	0.037	65%
SB100 – Moderate	SB100 – Moderate	3.2	2.7	55%

* Percentage with respect to the total change

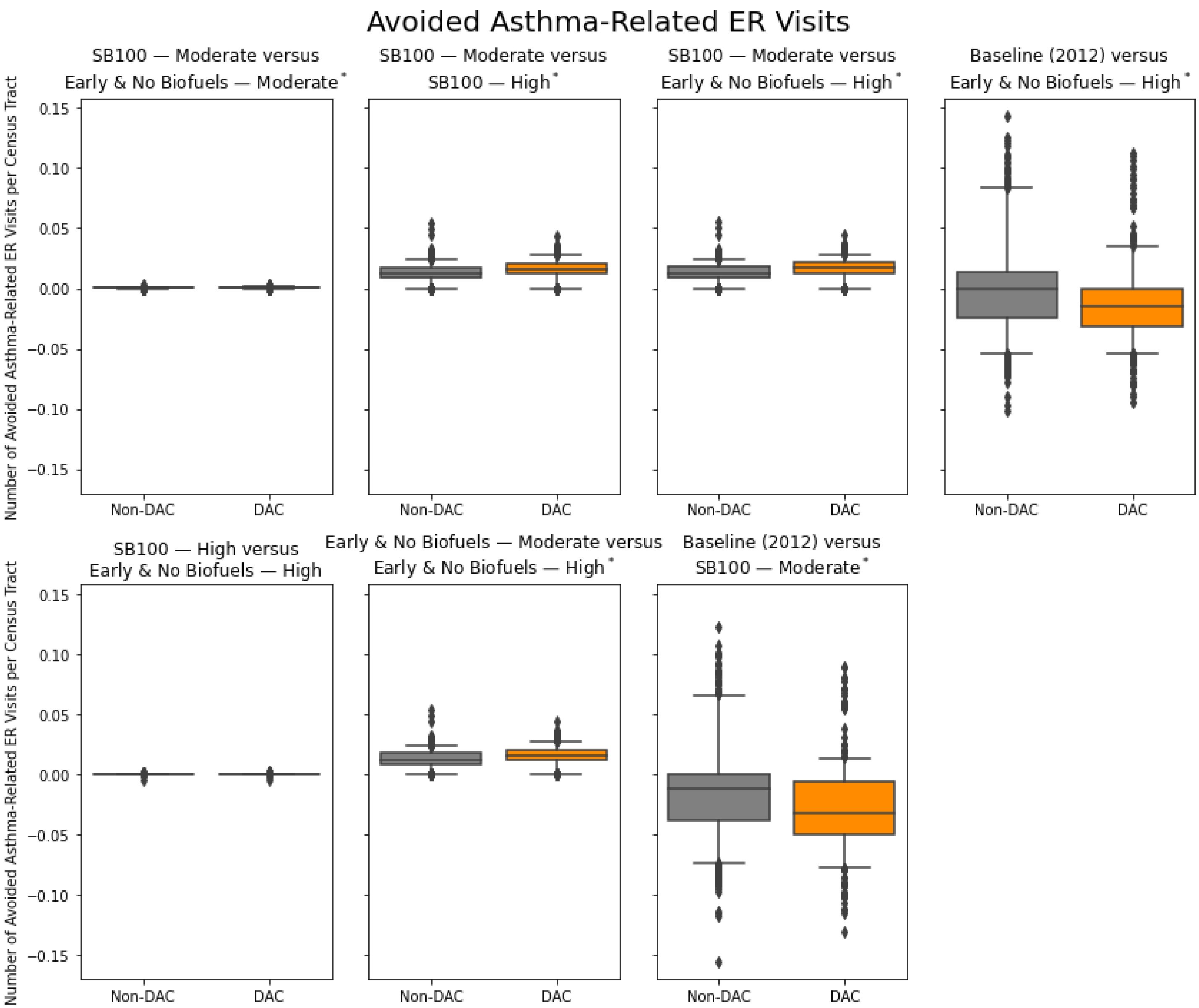

Figure 30. Population-weighted differences in annual number of avoided asthma-related emergency room (ER) visits in DAC and non-DAC Los Angeles census tracts in 2045

SB100 – Moderate versus SB100 High, SB100 Moderate versus Early & No Biofuels – High, and Early & No Biofuels – Moderate versus Early & No Biofuels – High show very similar distributions of DAC vs. non-DAC. As indicated by the negative values, only Baseline (2012) versus SB100 – Moderate shows most tracts with an increase in ER visits between compared scenarios; this is because the cause of asthma ER visits is ozone, whose concentration increases from Baseline (2012) to the future scenarios, including SB100 – Moderate and SB100 – High. Baseline (2012) versus SB100 – Moderate is also the only comparison to show a greater increase in ER visits in DAC tracts compared to non-DAC tracts. All scenario comparisons except SB100 – High versus Early & No Biofuels – High exhibit statistically significant differences between DAC and non-DAC tracts (SB100 – High versus Early & No Biofuels – High is nearly statistically significantly different, with a median p-value of 0.058).

Definition of box plot markers: the box is bounded by the 75th percentile value (top of the box) and 25th percentile (bottom of the box) with the median (50th percentile) shown as a black line through the middle of the box. The whiskers represent the 5th (bottom whisker) and 95th (top) percentiles. Individual points above or below the whiskers (outliers) represent tract values outside those ranges and indicate extreme values. *Less than 5% chance differences in DAC and non-DAC are due to random sampling.

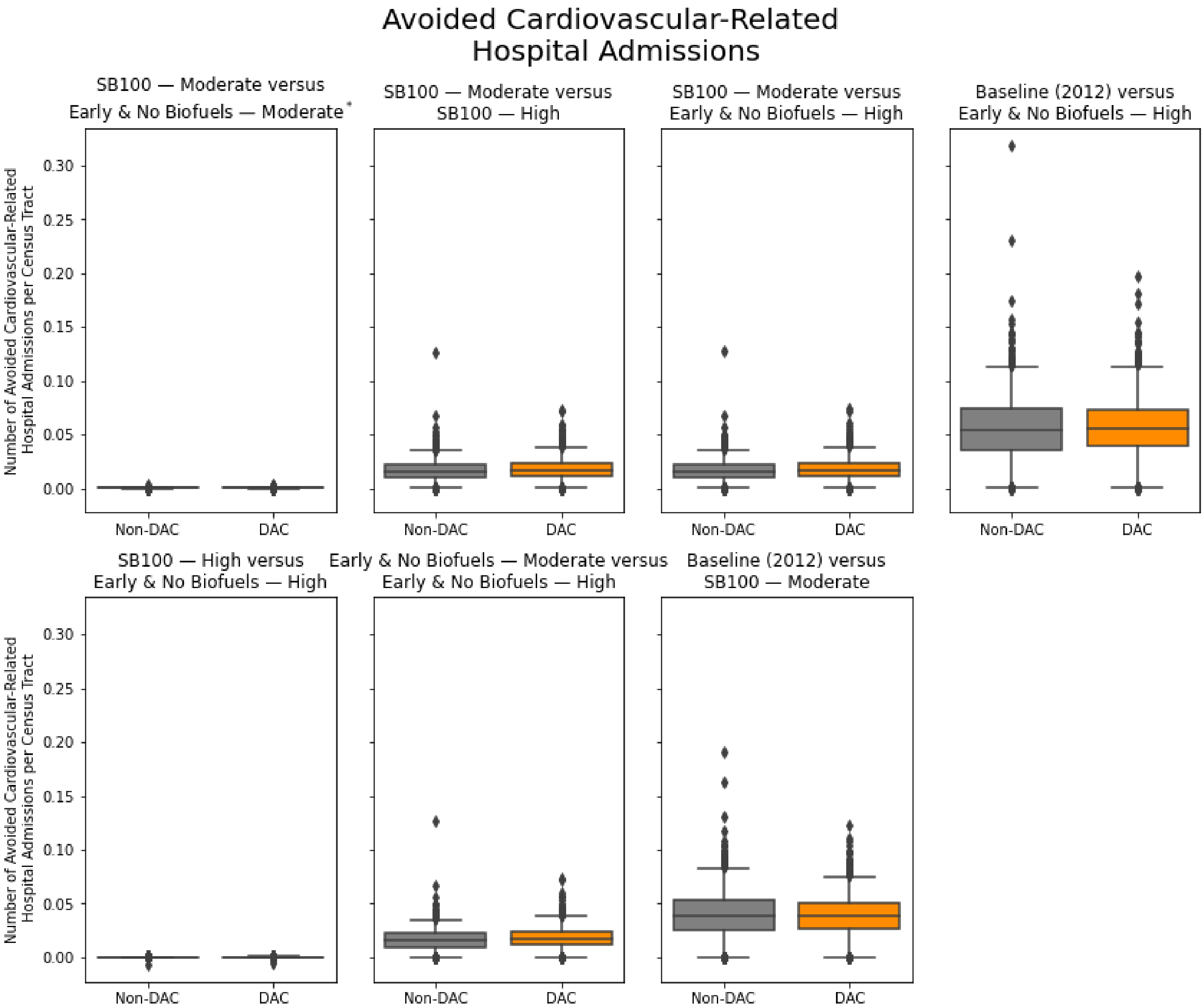

Figure 31. Population-weighted differences in annual avoided cardiovascular-related hospital admissions in DAC and non-DAC Los Angeles census tracts in 2045

All scenario comparisons show increases in hospital admissions, though sometimes negligibly (SB100 – Moderate vs. Early & No Biofuels – Moderate, SB100 – High vs. Early & No Biofuels – High) and otherwise small. Note that none of the differences between DAC and non-DAC tracts for scenario comparisons are statistically significantly different except SB100 – Moderate vs. Early & No Biofuels – Moderate, yet that difference is not meaningful in an absolute sense. The largest difference between DAC and non-DAC tracts (though not statistically significant) is seen between Baseline (2012) and SB100 – Moderate. When load levels are constant (i.e., the difference between scenarios is only with regard to power plant eligibility criteria), the absolute difference between scenarios is negligible.

Definition of box plot markers: the box is bounded by the 75th percentile value (top of the box) and 25th percentile (bottom of the box) with the median (50th percentile) shown as a black line through the middle of the box. The whiskers represent the 5th (bottom whisker) and 95th (top) percentiles. Individual points above or below the whiskers (outliers) represent tract values outside those ranges and indicate extreme values. *Less than 5% chance differences in DAC and non-DAC are due to random sampling.

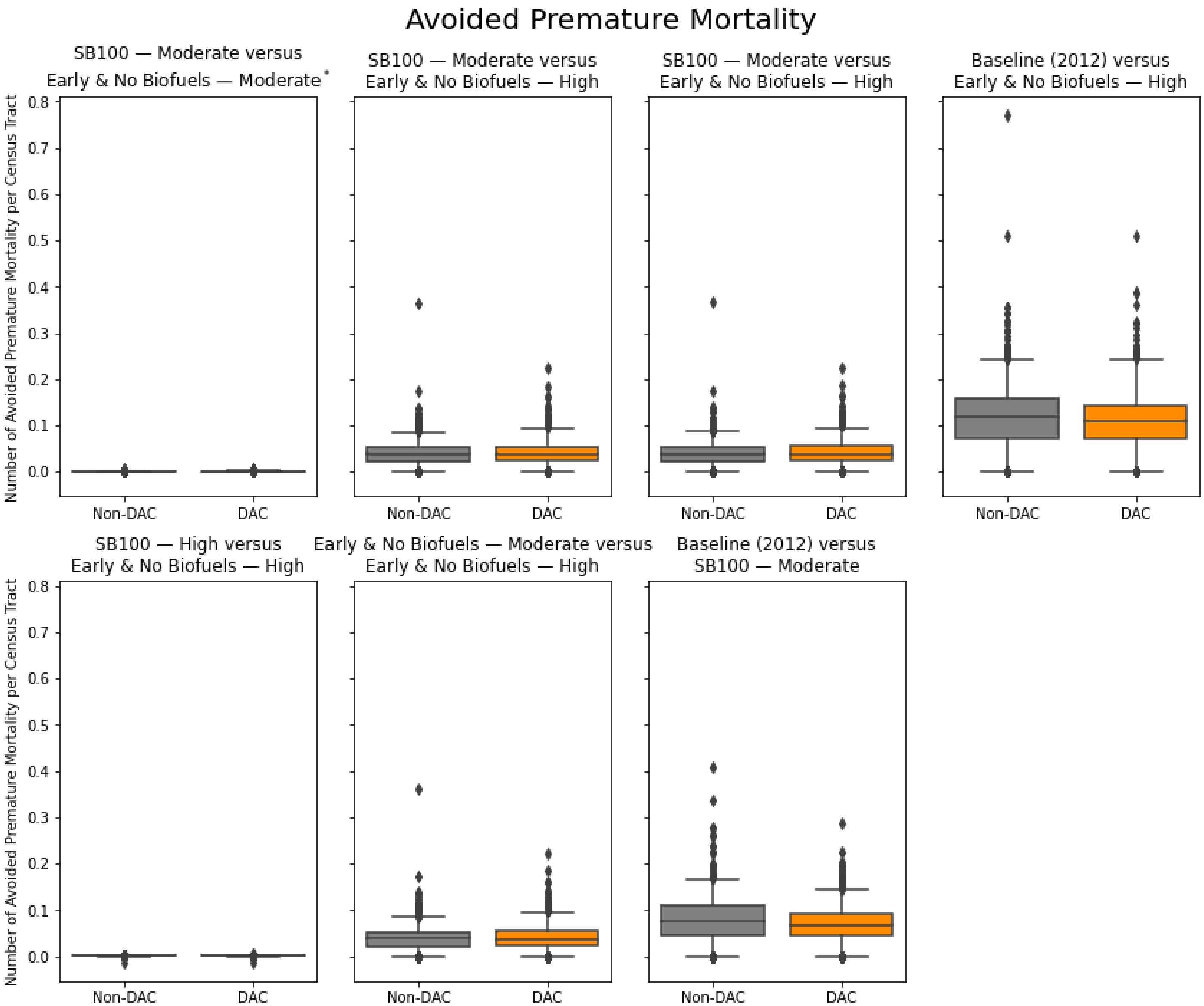

Figure 32. Population-weighted differences in annual number avoided premature mortality in DAC and non-DAC Los Angeles census tracts in 2045

All scenarios show most tracts having decreased mortalities. (SB100 – High versus Early & No Biofuels – High has some tracts with increases, but the absolute estimate is negligible.) SB100 – Moderate versus Early & No Biofuels – Moderate has the only statistically significantly difference between DAC and non-DAC tracts, yet again the absolute difference is negligible.

Definition of box plot markers: the box is bounded by the 75th percentile value (top of the box) and 25th percentile (bottom of the box) with the median (50th percentile) shown as a black line through the middle of the box. The whiskers represent the 5th (bottom whisker) and 95th (top) percentiles. Individual points above or below the whiskers (outliers) represent tract values outside those ranges and indicate extreme values. *Less than 5% chance differences in DAC and non-DAC are due to random sampling.

The Los Angeles 100% Renewable Energy Study

Strategic Partnership Project Report
NREL/TP-6A20-79444-10
March 2021

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Contract No. DE-AC36-08GO28308

Los Angeles Department of Water & Power

NREL Transforming ENERGY