LA100 EQUITY STRATEGIES

EXECUTIVE SUMMARY

LADWP NREL Transforming ENERGY UCLA

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LA100 Equity Strategies

Executive Summary

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A Letter From the Board

The City of Los Angeles (LA) set an ambitious goal to achieve 100% carbon-free energy by 2035. The Los Angeles Department of Water and Power (LADWP) is the nation's largest municipal water and power utility. LADWP was established more than 100 years ago to deliver reliable, safe water and electricity to LA and currently serves more than four million residents. To understand the pathways LA can take to achieve its 100% clean energy future—and how those pathways benefit Angelenos—LADWP partnered with the National Renewable Energy Laboratory (NREL) on the **Los Angeles 100% Renewable Energy Study** (LA100), which found that LA can achieve reliable, 100% renewable power as early as 2035. LA100 revealed that all communities in LA will share in benefits of the clean energy transition, including but not limited to health benefits from improved air quality, new jobs, and resilience to climate change. LADWP plans to lead the way to a decarbonized future by 2035. LADWP further commits that as it works to achieve its clean energy future, it will leave no community behind—from affluent enclaves to working-class neighborhoods.

LA100 Equity Strategies is the natural extension of the research findings in LA100. LA's clean energy future must be one where everyone benefits from cleaner air, good jobs, economic opportunity, wellbeing, and—equally important—an equitable household and small business energy cost structure. LADWP's objectives are to make its clean energy transition happen in a reliable, resilient, accessible, and affordable way for everyone. We know equity does not happen on its own, and actions must be proposed, adopted, and implemented. Addressing historical inequities requires intentional strategies and a long-term commitment to fairness that includes comprehending past actions and redressing them as well as any current actions that have perpetuated injustices, and meeting inequity with bold action. Said another way, it means ensuring that those Angelenos who have borne a disproportionate burden of the city's carbon past must benefit equally from its transition to a carbon-free future and should not bear a disproportionate burden of the costs associated with this historic transformation of the city's energy supply. In short, LADWP's clean energy future must be "Powered by Equity."

An equitable transition to 100% clean energy has many challenges. There are many proposed solutions identified in this study. LADWP, NREL, and the University of California Los Angeles (UCLA) partnered on the LA100 Equity Strategies project to develop effective strategies for engaging communities, funding equitable technology and infrastructure investments, expanding existing clean energy and energy assistance programs, and designing new proposed programs and policies to improve and enhance equity by incorporating what community leaders and neighborhood members themselves know is needed—and firmly stated would be needed—to achieve a more equitable energy future. This innovative community-informed approach integrated robust social science research techniques with rigorous data analysis and modeling to identify potential pathways to improving energy equity in LA's energy systems.

This groundbreaking two-year study placed the interests of our city's communities first and foremost. The community-based organizations that comprised our Equity Strategies Steering Committee and the individual community members who actively participated in listening sessions represented underserved and low-income communities throughout LA. Our community contributors guided the study's work by bringing their love of their city, passion for their communities, and shared vision for a just and equitable clean energy future to the forefront of the research activities, providing analysts with continuous feedback on the research approaches, data, and outcomes. The Equity Strategies Advisory Committee brought together subject matter experts from the Office of the Mayor, city departments, City Council offices, labor unions, and environmental organizations. The year 2035 is fast approaching. We all will need to continue to work together, as we did during our study—collaborating with our residents and customers—to make our 100% carbon-free future possible and "Powered by Equity."

We strongly believe and we firmly know that "Leading with Equity" is our only true, beneficial path to our city's decarbonized tomorrow.

Cynthia McClain-Hill

President, Los Angeles Board of Water and Power Commissioners

ABOUT THIS REPORT

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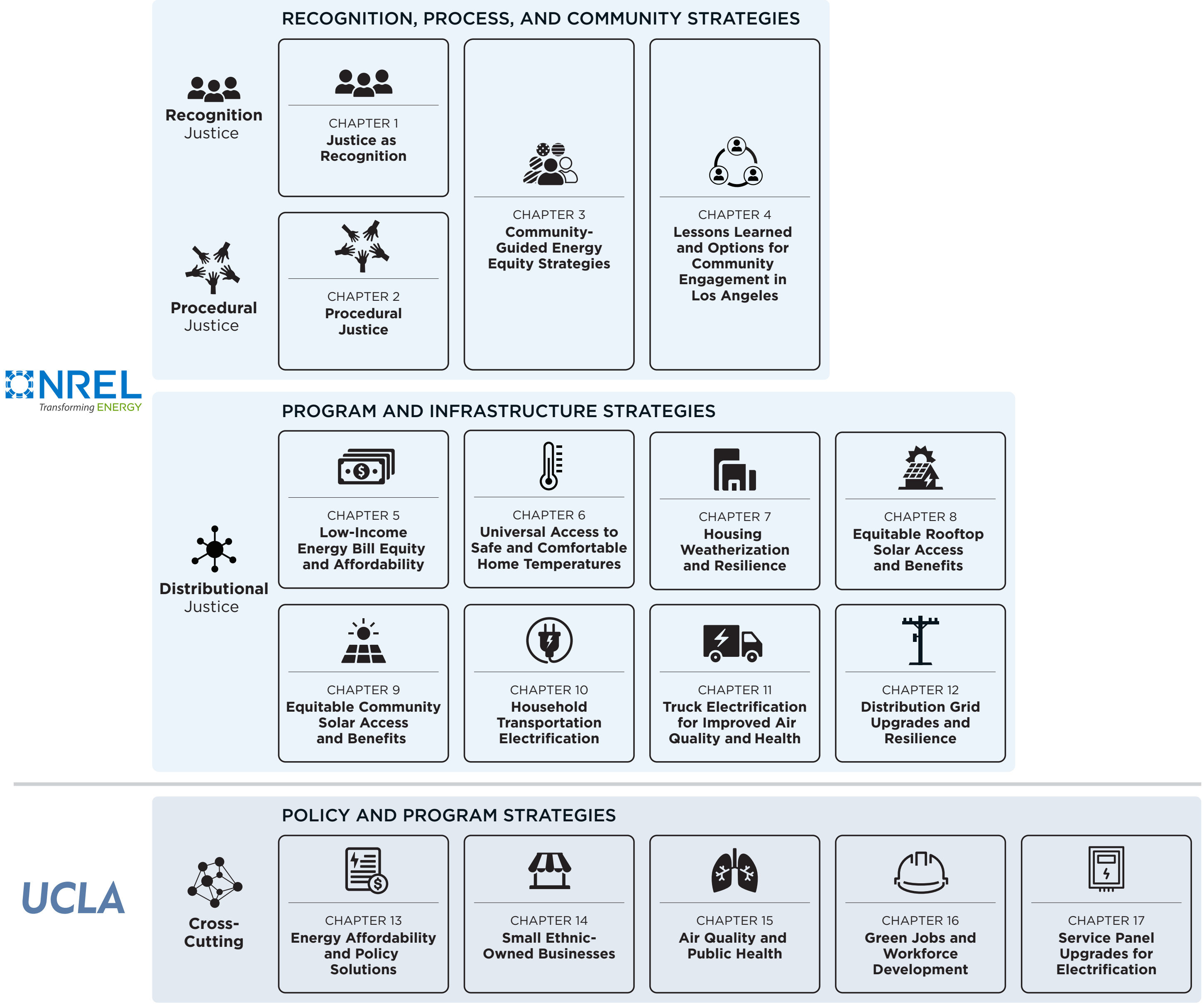
LA100 Equity Strategies is a collaborative effort between LADWP, NREL, UCLA, and Kearns & West that employs an interdisciplinary approach utilizing distinct—but connected—research efforts informed and guided by the project Steering Committee, which met monthly through the duration of the project. Chapters 1 through 4 address recognition and procedural justice through recognition, process, and community strategies, while Chapters 5 through 12 address distributional justice through program and infrastructure strategies. Chapters 13 through 17 provide policy and program strategies. Each chapter provides data, methods, tools, insights, and strategies to help LADWP make data-driven, community-informed decisions for equitable investments and program development.

This document explores the high-level conclusions from UCLA and NREL's extensive modeling, research, and stakeholder engagement through the LA100 Equity Strategies project. Links to download each chapter and a glossary of terms can be found on the study website at: **maps.nrel.gov/la100/equity-strategies**

While the study is focused on LA's energy transition, the methodology and many of the strategies developed can be adapted to other cities undertaking a just energy transition.



NREL Transforming ENERGY

RECOGNITION, PROCESS, AND COMMUNITY STRATEGIES

Recognition Justice

Procedural Justice

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CHAPTER 2 **Procedural Justice**

CHAPTER 3 **Community-Guided Energy Equity Strategies**

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UCLA

POLICY AND PROGRAM STRATEGIES

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EQUITY STRATEGIES

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Why Equity Matters

A 100% clean energy transition requires bringing everyone along, including those who can least afford it. A successful transition requires both energy system changes—by LADWP and the City—as well as household changes like shifting to electrified transportation and homes, which many people cannot afford. The City of Los Angeles—where more than a half million people live in poverty and most households are renters—faces a particular challenge in reaching 100% clean energy if it cannot provide affordable and accessible solutions for all residents.

To date in Los Angeles, clean energy rebates, incentives, and grid upgrades have disproportionately benefited higher income, home-owning, non-disadvantaged, mostly White, mostly non-Hispanic communities.

Improving equity requires intentionally designed strategies and actions. The strategies developed through community guidance and robust modeling and analysis in this project provide options to support Los Angeles in achieving 100% clean energy while improving energy equity for *all* its residents.

Key Findings

Community-guided modeling and analysis identified that:

- **The current energy system is inequitable.** Underserved communities experience more burdens (e.g., high energy burdens, unsafe temperatures, electricity outages, and poor air quality) and fewer benefits, especially in access to grid upgrades, clean energy incentives, and savings. Of the LADWP residential incentives analyzed, only 23% of electric vehicles (EVs), 38% of solar, and 46% of efficiency incentives went to disadvantaged communities.
- **Lack of ability to pay energy-related costs and lack of financial capital limits communities' access** to EVs, efficiency options, jobs, training, and entrepreneurship. Limited eligibility for existing energy-related incentives, subsidies, and other aid programs further reduces access and affordability.

Energy equity or **energy justice** "refers to the goal of achieving equity in both the social and economic participation in the energy system, while also remediating social,economic, and health burdens on those historically harmed by the energy system."[1]

- **Without changes in rates and solar compensation, energy inequity will increase over time.** Lower income households will pay disproportionately more for the energy system and experience fewer benefits—compared to households that can afford clean energy technologies and benefit from the savings they provide. Under existing rate and solar compensation approaches, modeled average electricity bills increase 79% for all households and 131% for low-income households by 2035 (in 2021 dollars).
- **California laws constrain rate affordability and prevent LADWP from providing robust low-income rate and bill assistance.** Current laws prevent LA from supporting low-income households with funds from higher income ratepayers, but they do not prevent low-income customers from in-effect subsidizing often higher income solar, EV, and building technology adopters. If laws are changed, rate and bill assistance reforms could triple the number of households receiving bill assistance and reduce low-income electricity bills between $14/month and $100/month depending on rate design.

LADWP RESIDENTIAL INVESTMENTS	TOTAL AMOUNT INVESTED	ALLOCATED TO DISADVANTAGED COMMUNITIES
SOLAR INSTALLATION (1999–2022)	$340M	38%
ENERGY EFFICIENCY (2013–2021)	$143M	46%
ELECTRIC VEHICLES (2013–2021)	$5M	23%
CUSTOMER DISCOUNTS (2006–2021)	$487M	68%

LADWP residential program investments (1999-2022)

- **Truck electrification substantially improves air quality and health, particularly in traffic-impacted disadvantaged communities.** Heavy-duty trucks generated 51% of LA on-road transportation nitrogen oxides and 32% of particulate matter pollution in 2022, though they made up only 5% of registered vehicles. Electrification of heavy-duty trucks, particularly the heaviest trucks like fire trucks, dump trucks, fuel trucks, and long haul tractors, would improve air quality and health more than closing in-basin LADWP fossil fuel power plants.
- **As the climate changes, universal access to home cooling will save lives.** Two hundred thirty thousand low-income households are projected to experience more than two months of exposure to dangerous indoor air temperatures annually by 2035. Multifamily building residents—who comprise 56% of the Los Angeles population and 95% of low-income renters—have the highest exposure to dangerous indoor temperatures. Adding cooling nearly eliminates dangerous temperature exposure in multifamily households, while cooling combined with efficiency is most effective in single-family homes.
- **Expanding Shared Solar can cost-effectively deliver solar bill savings to low-income households and renters.** LADWP solar net metering programs disproportionately benefit wealthier homeowners. Developing Shared Solar projects among the more than 1,800 economically viable 30 kilowatts (kW) or larger sites—totaling over 1,000 megawatts (MW) of potential—and establishing a 20% low-income discount rate will save low-income subscribers an average of $480/year. Compared to net-metered residential solar, LADWP can support five times more local solar capacity through Shared Solar for the same investment, while delivering bill savings to renters, multifamily building residents, and low-income households.
- **Distribution grid upgrades are needed to enable equitable participation in the clean energy transformation**. Although electrification of homes, universal home cooling, and electric vehicles will require distribution grid upgrades throughout the city, the traditionally smaller existing service connections and grid of low- and moderate-income customers will need proportionately larger upgrades to enable equitable access.
- **Energy equity requires continuous engagement between the utility and the community.** Community leadership in decision-making, program and policy design, and implementation will lead to more equitable outcomes and participation. Community members suggested a promotora-type approach to employ community members to deliver tailored training and education that informs ratepayers about options and benefits of programs and technologies, and to support program implementation.

What Are Equity Strategies and How Do You Use Them?

Equity strategies are options for LADWP, the City, and community members to consider for implementation and evaluation. Moving from strategy options to action will require significant work from LADWP and the City—in collaboration with community members—to assess tradeoffs, set priorities, identify lead- and partner-organizations, and allocate resources for implementation and evaluation. This project provides community-guided, data-driven strategy options as a starting point, but there is much more work to be done.

Achieving 100% clean energy will require long-term utility-community partnerships, program coordination across sectors, LADWP, and City departments, and inclusive policy making—beyond this project.

Photo from Chris Yarzab, Flickr

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[1] Initiative for Energy Justice. "The Energy Justice Workbook." https://iejusa.org/wp-content/uploads/2019/12/The-Energy-Justice-Workbook-2019.pdf.

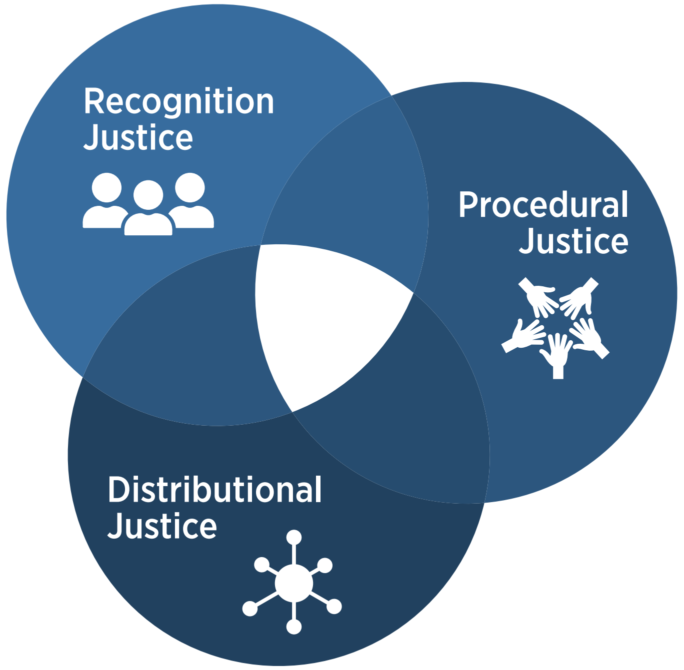
Framework

LA100 Equity Strategies is groundbreaking in its methodology that centers equity throughout the project. The project integrated community engagement and guidance with robust modeling and analysis organized around three tenets of justice:

Recognition justice: Seeks to understand and address past and current energy inequities within LA.

Procedural justice: Ensures Angelenos are actively engaged partners throughout the project, co-design the analysis, and shape the resulting equity strategies.

Distributional justice: Ensures a just and equitable distribution of benefits and burdens of the clean energy transition.



The three tenets of justice

Community Stakeholder-Driven Approach

The teams started by identifying and engaging with leaders of community-based organizations, and then with community members, to understand their aspirations and challenges and identify solutions to meet the energy needs of their communities.

- A Steering Committee, composed of leaders from 14 community-based organizations who are active in energy and environmental justice, met monthly throughout the duration of the project to provide guidance to the analysis teams. They also collaborated in the design of listening sessions with their community members to elicit community knowledge.
- An Advisory Committee, including representatives from City of Los Angeles departments, the Mayor's office, City Council Members' offices, unions, and local organizations, met bi-monthly. Their purpose was to share program and policy knowledge and to facilitate cross-sector interagency coordination.
- NREL conducted 15 community listening sessions to gather and analyze information on the challenges Angelenos face with regards to the energy transition and their visions and aspirations for their families and communities.[2]

Data-Informed Strategies

- Modeled hourly electricity and gas usage for 50,000 households representing the diversity of 1.57 million LADWP customers across 100 household and building characteristics
- Input from 100+ community members, 14 community-based organizations, and 32 city agencies
- 50 TB of data across many temporal and spatial dimensions.

LADWP's Strategic Long-Term Resource Plan (SLTRP) is an energy roadmap that estimates the quantity and type of resources needed to meet 100% carbon-free electricity by 2035. The 2022 SLTRP projected system costs were used to model strategies for a more affordable and equitable transition.

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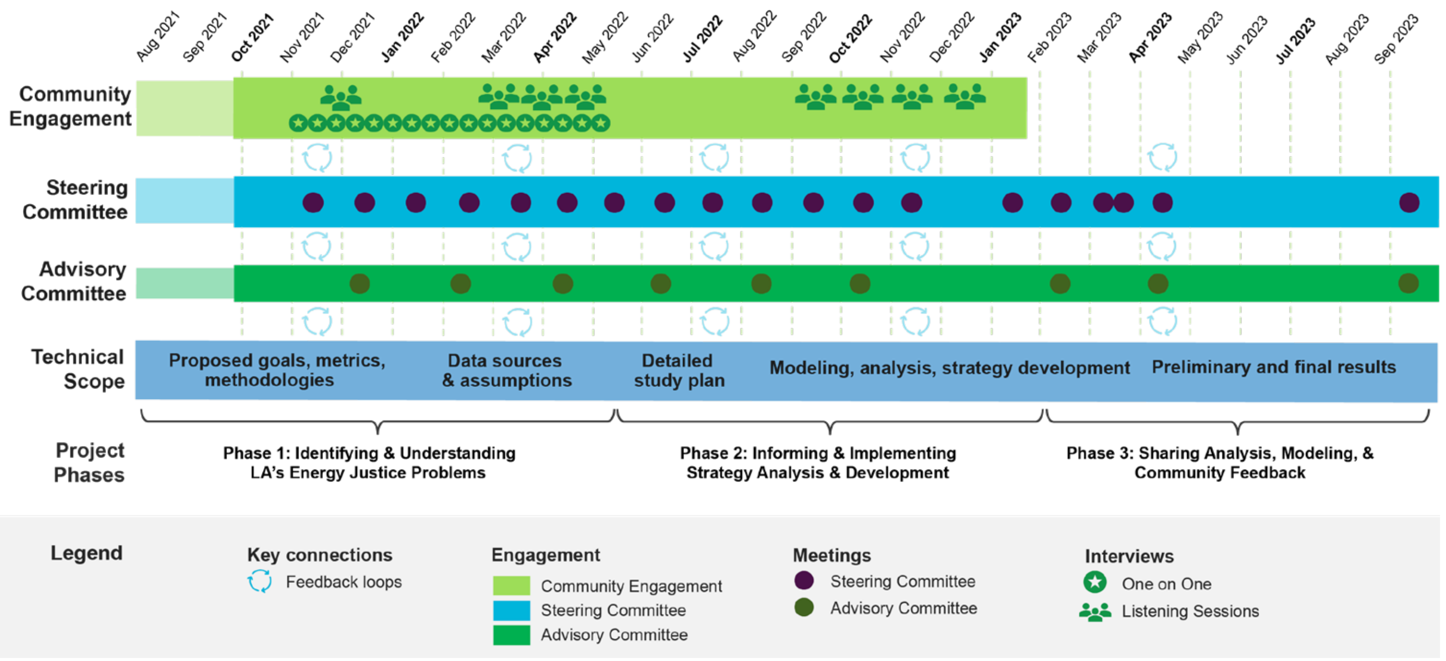
[2] Participating organizations for the Steering Committee and Advisory Committee are acknowledged at the end of this report with information on the neighborhood-specific community listening sessions.



Timeline and framework for LA100 Equity Strategies

Steering Committee members identified five priorities for equitable energy transitions. Each equity strategy option addresses one or more of these community-identified priorities:

Inclusive community involvement

Affordability and burdens

Access to and use of energy technologies, programs, and infrastructure

Health, safety, and community resilience

Jobs and workforce development

Engaging Communities in the LA100 Equity Strategies Project

- 19 Steering Committee meetings
- 9 Advisory Committee meetings
- 15 neighborhood-specific community listening sessions (Spanish and English)

Based on community engagement and the LA100 analysis, NREL identified potential focus areas for strategy development, from which Steering Committee members—with LADWP input—prioritized the following:

- Low-income energy bill affordability
- Housing weatherization, resilience, and access to safe home temperatures
- Community and rooftop solar and storage
- Equitable household transportation electrification
- Truck electrification for improved air quality and health outcomes
- Distribution grid upgrades for resilience and access.

NREL conducted modeling and analysis to identify potential strategies for more equitable distribution of the benefits and burdens of the clean energy transition and quantify the potential costs and benefits of each strategy.

Key Strategies

NREL developed a range of strategy options for improving equity in LA's transition to 100% clean energy. The full list of strategies can be found in the chapters on **maps.nrel.gov/la100/equity-strategies**.

Here we highlight key strategies in recognition and procedural justice and in distributional justice. We categorize the strategies into three types:

- **Foundational strategies:** Prerequisites for successful implementation of other strategies.
- **High-impact strategies:** Could have substantial impact on achieving a more equitable clean energy transition.
- **Low-hanging fruit strategies:** May be easier to implement because they meet four criteria.
  - › **No legal change required:** These strategies likely fall within the bounds of existing regulations.
  - › **LADWP controls implementation:** LADWP (rather than another city agency, the private sector, or the state) holds decision-making authority over these strategies.
  - › **Builds on existing LADWP programs:** These strategies adjust or expand existing LADWP programs, rather than starting new programs.
  - › **Low cost:** These strategies are expected to have minimal expense.

Recognition and Procedural Justice	**Founda-tional**	**High-Impact**	**Low-Hanging Fruit**
Implement a collaborative platform for continuous engagement. (1) Formalize LA100 Equity Strategies' partnerships into long-term agreements to maintain a continuous feedback loop with community partners, and (2) allocate dedicated personnel and resources to co-design, implement, and evaluate energy equity programs.	●	●	●
Co-develop programs and services and improve transparency and continuity. Rely on dedicated personnel and the collaborative platform to engage residents in ongoing, consistent, transparent, and community-adapted outreach and communication that builds trust, buy-in, and a continuous feedback loop for decision-making.	●	●	●
Provide tailored outreach and education through local trusted messengers. Build on Community Partnership Grants and Science Bowl to (1) inform ratepayers about programs and technologies and (2) incorporate energy-related resources into community science and the community health workers (promotoras) educational methods.	●	●	●
Provide debt relief and prevent the accumulation of debt through utility bill management procedures and debt relief programs to address a primary barrier to energy affordability.		●	
Expand workforce development programs that provide equitable access to tailored training and high-road jobs (i.e., jobs that provide family-sustaining living wages, comprehensive benefits, and opportunities for career advancement). These are crucial in the cross-cutting priority area of jobs and workforce development.	●	●	●

Distributional Justice	**Founda-tional**	**High-Impact**	**Low-Hanging Fruit**
Affordable and Equitable Rates			
Implement simplified tiered or time-of-use rates and replace solar net metering with net billing.* Under current rate and solar compensation approaches, average electricity bills increase more for low-income households than average households by 2035. Rate reforms reduce low-income electricity bills $15/month by 2035, even when low-income bill assistance programs are eliminated. Switching to net billing reduces the cost shift from solar adopter (typically higher income) to non-adopter (typically lower income) that occurs with net metering.	●	●	
Implement robust low-income bill assistance programs. Implementing low-income assistance programs that meet state standards for other utilities reduces LA's low-income household monthly bills by 22% compared to continuing current approaches.		●	
Explore income-based fixed charges. This rate approach reduces low-income electricity bills by more than $110/month and eliminates high electricity burdens for all customers by 2035.		●	
Implement low-income customer on-bill tariffs for energy efficiency. Leveraging Inflation Reduction Act (IRA) funds and on-bill tariff financing to install heat pump water heaters or enhanced insulation can reduce energy bills without upfront costs, credit checks, or homeownership for 150,000 and 72,000 low- and moderate-income customers respectively.			●
Housing Weatherization and Safe Home Temperatures			
Provide heat pump incentives in the Cool LA Program and auto-enroll low-income incentive recipients in bill assistance programs to mitigate energy burdens. More than 30% of extremely low-income households in Los Angeles lack access to cooling. Heat pumps have high capital costs but provide up to 29% more energy-efficient cooling compared to window-unit air conditioners. Providing low- and moderate-income** households incentives can support equitable access to cooling. Bill assistance can help offset increased energy bills for households adding cooling.			●
Expand direct installation of cooling in low-income households without cooling, prioritizing multifamily buildings. An estimated 230,000 low-income households in LA lack access to cooling and are projected to experience over two months of exposure to dangerous indoor temperatures by 2035. Multifamily renters have the most dangerous heat exposure in LA, particularly in utility outages. Access to cooling is the most effective intervention to reduce exposure for low-income multifamily residents.		●	●
Partner with the Housing Authority to provide cooling and weatherization in public housing and implement mechanisms to mitigate rent increases and displacement associated with LADWP-supported upgrades elsewhere. Renter protections, "right to return" if renovations temporarily displace renters, and mechanisms to prevent short-term rent increases for multifamily rental properties receiving utility-supported upgrades could avert rent increases and displacement for non-public housing receiving low-income-qualified cooling and weatherization interventions.		●	●

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* The current practice of net metering credits customers for excess solar generation exported to the grid at higher retail rates and allows excess generation credit to apply at other times of the month or sometimes year. Net billing compensation is set at the avoided cost of energy at the time it is delivered to the grid.

** Households with income levels lower than 80% of the Area Median Income (AMI). https://www.huduser.gov/portal/datasets/il.html

Distributional Justice	Founda-tional	High-Impact	Low-Hanging Fruit
Local Solar and Storage			
Establish a low- and moderate-income (LMI) Shared Solar subscription rate. Enrollment in the Shared Solar Program currently requires a premium payment to achieve long-term savings. Implementing a reduced subscription rate for LMI customers and increasing the monthly subscription cap can reduce energy bills for LMI customers by an annual average of $480 per household.		●	●
Substantially expand Shared Solar capacity at identified economically viable ≥30 kW public and multifamily sites and allocate 50% of new capacity to LMI subscribers. LADWP solar net energy metering programs disproportionately benefit wealthier homeowners. Expansion of Shared Solar capacity with a discounted LMI rate would enable LMI, renter, and multifamily building households to access bill savings from solar energy and take this benefit with them if they move within the city.		●	
Develop Shared Solar on economically viable ≥30 kW multifamily sites in low-income tracts eligible for 50% investment tax credit (ITC). NREL identified 607 economically viable sites totaling 255 MW of potential capacity that could expand equitable access to solar bill savings.		●	
Household Transportation Electrification			
Expand at- and near-home EV charging access for low-income multifamily building residents and include low-voltage charging outlets. By 2035, approximately 20% of EV owners in LA are predicted to lack at-home charging access, 80% of which will be multifamily building residents. Adding 50,000 charging ports in identified areas without sufficient charging infrastructure would enable more equitable access to EVs. Including e-bike charging options, sidewalk improvements, and lighting improve community-prioritized safety and accessibility.	●	●	
Provide vouchers or charging subscriptions for public EV charging for low-income households through partnerships with charging network providers or free access to LADWP-owned charging infrastructure. Adopting EVs decreases vehicle fuel cost burdens, yet public charging can cost an average of $300/year more for households without home charging access. Lower-income households are especially sensitive to price differences.			●
Establish EV car-share, e-bike, and e-scooter programs in transportation disadvantaged communities to realize cost savings of 7% and reductions in travel time of up to 30% for households who do not own vehicles. Expanding infrastructure to support e-bike programs and use—particularly in the Panorama City, North Hills, Reseda, Winnetka, and Boyle Heights neighborhoods with low vehicle ownership rates and low transit access—would improve safety.		●	●
Increase LADWP used EV low-income incentive from $2,500 to $4,000, add a purchase price cap of $25,000 for all rebates, shift to point-of-sale discounts, and establish e-bike and e-scooter rebates. LADWP's investments in residential vehicle electrification and charging were the most inequitable of the programs analyzed, with 77% of residential rebates going to non-disadvantaged communities. Owning a standard model used EV can reduce median income LA household costs by about 3%. Increasing the low-income used EV incentive could increase used EV adoption among LMI households by 50,000 vehicles by 2035.		●	

Distributional Justice	Founda-tional	High-Impact	Low-Hanging Fruit
Truck Electrification for Air Quality and Health			
Establish goals, a timeline, and a budget for electrification of LADWP's heavy-duty truck fleet, with a heavy-heavy-duty truck carve-out. Heavy-duty trucks in LA generate 51% of on-road transportation emissions of nitrogen oxides and 32% of particulate matter, which contribute to premature death and disease, particularly among disadvantaged communities. Heavy-heavy-duty trucks like fire trucks and dump trucks generate more than five times the near-road pollutant concentrations of other heavy-duty trucks. Traffic-impacted disadvantaged communities benefit 25% more from truck electrification than non-disadvantaged communities.			●
Establish a citywide 2035 heavy-duty truck electrification target, a City-owned fleet truck electrification target, and purchase incentives. A goal of approximately 28,000 electrified Class 3-8 trucks in LA by 2035 aligns with state policies. More ambitious heavy-duty truck electrification would contribute proportionally to cleaner air and improved health outcomes.		●	●
Establish citywide charging infrastructure targets aligned with truck electrification goals. Collaborate with city and regional agencies like Southern California Area Governments to optimally locate charging infrastructure. Charging infrastructure needs to meet truck electrification targets: • 1,900–3,300 truck chargers by 2025 • 5,400–9,600 truck chargers by 2030 • 14,000–24,000 truck chargers by 2035.	●		●
Distribution Grid Upgrades and Resilience			
Incorporate equity as a metric in prioritizing grid infrastructure investments. Load growth and technology uptake has been more prevalent in wealthier neighborhoods, resulting in inequitable grid investments. Incorporating equity metrics into upgrade prioritization—by using metrics such as grid stress, level of anticipated distributed energy resource (DER) adoption, and demographic data—is crucial to overcoming the inequities seen in current and projected grid stress and corresponding reliability.	●		●
Upsize transformer capacity by two to three times when replacing service transformers to accommodate electrification and DERs, particularly those serving customers with low capacity (<125A) service. Equitable access to vehicle electrification, home cooling, rooftop solar, and storage can require increased customer power needs that could be stymied by distribution service transformer limitations. Transformers are being replaced and upsized by factors of 1.6–2x. Load and DER changes may require 2–3+x increases.	●		●
Implement community-specific, equitable resilience strategies. Disadvantaged communities have historically lower grid resilience during disaster events, although this varies by neighborhood. Backup generation (such as photovoltaics + storage) and microgrids—supporting critical infrastructure such as hospitals, shelters, grocery stores, convenience stores, and banking—can increase resilience in neighborhoods where NREL analysis identified low resilience scores.		●	●

A DEEPER DIVE: RECOGNITION AND PROCEDURAL JUSTICE

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LA community members repeatedly stressed that equity is about making—and following through with—a commitment to prioritize historically underserved and overburdened communities in decision-making for LA's energy transition. To achieve this, the strategies in this section address historic inequities (i.e., recognition justice), and foster inclusive community involvement in the decision-making process (i.e., procedural justice). Recognition and procedural justice principles are interconnected and form the foundation for ensuring more equitable distribution of benefits and burdens (i.e., distributional justice).

Recognition Justice

NREL examined historical inequities in LA, along with the corresponding causal factors, to understand how inequities have become embedded in policies, processes, and community members' experiences. NREL worked with communities to analyze broader structural factors and to co-design strategies for redressing past inequities.

The Challenges

- Poor quality and maintenance of infrastructure and housing due to decades of disinvestment and neglect
- A lack of affordable housing for renters and owners
- Barriers to making energy decisions for themselves and their communities (i.e., self-determination)
- A lack of access to financial capital for energy access, affordability, and decision-making
- Mistrust and grievances related to government agencies and policies
- A lack of accessible and useful information about resources and programs.

Key Findings

- The benefits of LADWP's programs—such as solar installation benefits, non-low-income-targeted energy efficiency programs, and EV incentives—are not equitably distributed across communities.
- Underserved Angelenos—such as low-income families, renters, and people of color—face higher energy and transportation burdens, unsafe temperatures, higher impact from extreme heat events, and other negative impacts of historical legacies that are still present in current policies and practices. Underserved communities are mostly located in South LA, East LA, San Fernando Valley, and the Harbor area. At the same time, those who benefit from LADWP investments are disproportionately higher-income, homeowner, and White populations.

NREL analyzed address-level data on beneficiaries of 16 LADWP energy efficiency, solar, and EV incentive programs, and customer discount programs to understand if socioeconomic or demographic differentiation exists in access to LADWP program and infrastructure investments. Program recipient data was aggregated by census tract to determine the number of households receiving benefits and the total dollar amount invested by LADWP for each census tract. These data were merged with CalEnviroScreen disadvantaged communities[3] and the following census tract-level socioeconomic and demographic information from the American Community Survey: race, ethnicity, income, and homeownership. This integrated data allowed NREL to determine if certain communities disproportionately received incentives and benefits provided by LADWP.

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[3] Defined here as census tracts designated as disadvantaged by California Senate Bill 535 (SB535).

LADWP RESIDENTIAL INVESTMENTS 1999–2022		NUMBER OF YEARS	TOTAL AMOUNT SPENT	AVERAGE AMOUNT PER CUSTOMER DAC/Non-DAC	% OF INCENTIVES Normalized by number of customers DAC/ Non-DAC	WHICH COMMUNITIES DISPROPORTIONATELY BENEFITED FROM PROGRAMS?				
						DAC /Non-DAC	Mostly Non-White /White	Mostly Hispanic /Non-Hispanic	Mostly Renters /Owners	Below /Above Median Income
SOLAR INSTALLATION (1999–2022)	Net Energy Metering Programs	22	$340,604,541	0.25 kW 0.41 kW	38% 62%	Non-DAC	White	Non-Hispanic	Owners	Above
ENERGY EFFICIENCY (2013–2021)	Home Energy Improvement Program	3	$3,378,869	$3 $2	61% 39%	DAC		Hispanic	Owners	
	Refrigerator Turn-In and Recycle Program	5	$2,667,307	0.010 refrigerators 0.014 refrigerators	42% 58%	Non-DAC	White	Non-Hispanic	Owners	Above
	Consumer Rebate Program	6	$93,248,144	$64 $74	46% 54%	Non-DAC	White	Non-Hispanic	Owners	Above
	Other Non-Low-Income-Targeted Programs	15	$36,343,548	$178 $196	35% 65%	Non-DAC	White	Non-Hispanic	Owners	Above
	Energy Savings Assistance Program*	5	$7,897,260	$11 $1	92% 8%	DAC	Non-White	Hispanic	Renters	Below
ELECTRIC VEHICLES (2013–2021)	Incentive Programs	8	$5,361,426	$41 $64	23% 77%	Non-DAC	White	Non-Hispanic	Owners	Above
CUSTOMER DISCOUNTS (2006–2021)	Low-Income Program*	15	$173,633,204	$195 $64	73% 27%	DAC	Non-White	Hispanic	Renters	Below
	Lifeline Program*	15	$313,424,782	$302 $164	65% 35%	DAC	Non-White	Hispanic	Renters	Below

* Low-Income Targeted

Statistical analysis of equity in LADWP residential program investments (1999-2022)

> Watts, LA resident:
>
> **"In my humble opinion, we should be considered. I don't ask for free giveaways, I ask for a good job with a good salary for [the people of] the city of Watts. Because companies come and bring workers. And they don't benefit the residents [living] there. They should give jobs to every community where they work. They should give jobs to the people of the community there with good pay. And that, in my opinion, would [be the help I need]."**

Procedural Justice

Procedural justice prioritizes fair, equitable, and inclusive participation in the decision-making process. Its application focuses on who is invited and able to participate, whose voices are considered as decisions are made, the co-development of procedures to inform this deliberative process, and who has access to formal measures of regulation and accountability. As community engagement is a principal method for applying procedural justice measures, the LA100 Equity Strategies project included 15 neighborhood-specific listening sessions (in English and Spanish), 19 Steering Committee meetings, and 9 Advisory Committee meetings.

The Challenges

- Underserved Angelenos have historically not been invited and able to participate, and their knowledge and expertise have not been considered as decisions are made.
- Attempts to develop more equitable energy outcomes can be constrained by a misunderstanding of what equity means to the people most negatively affected by LA's current energy system.

Key Findings

- Residents referred to the unaffordability of current electricity bills, particularly given other monthly expenses, and noted that they did not have the ability to lower these high costs.
- Factors limiting participants' ability to determine their own EV access include a lack of accessible guidance to make informed decisions, limited financial capital to purchase a used car (let alone an EV), and insufficient local EV charging infrastructure in their communities.
- Barriers to accessing programs for low-income participants include language limitations, citizenship status, housing tenure, and information gaps. Moderate-income participants emphasized the shortcomings of current eligibility criteria that effectively exclude their participation in existing programs due to an incomplete understanding of their economic status and financial burdens.
- Residents who live in non-rent-controlled housing where property owners implement upgrades—even subsidized LADWP upgrades and benefits—will most likely experience an increase in rent to cover the cost. For those living in rent-controlled housing, homeowners will most likely refrain from investing in upgrades given their inability to utilize rent to cover costs.
- While there are existing LADWP programs designed to increase energy affordability for ratepayers, there is a "missing middle"—a subset of ratepayers who cannot afford the more efficient renewable energy technologies and yet are not included in the program design for subsidized benefits given their relatively higher incomes.

Find additional information about this topic in **Chapters 1, 2, 3, and 4** on the LA100 Equity Strategies website (**http://maps.nrel.gov/la100/equity-strategies**).

Equity Strategies

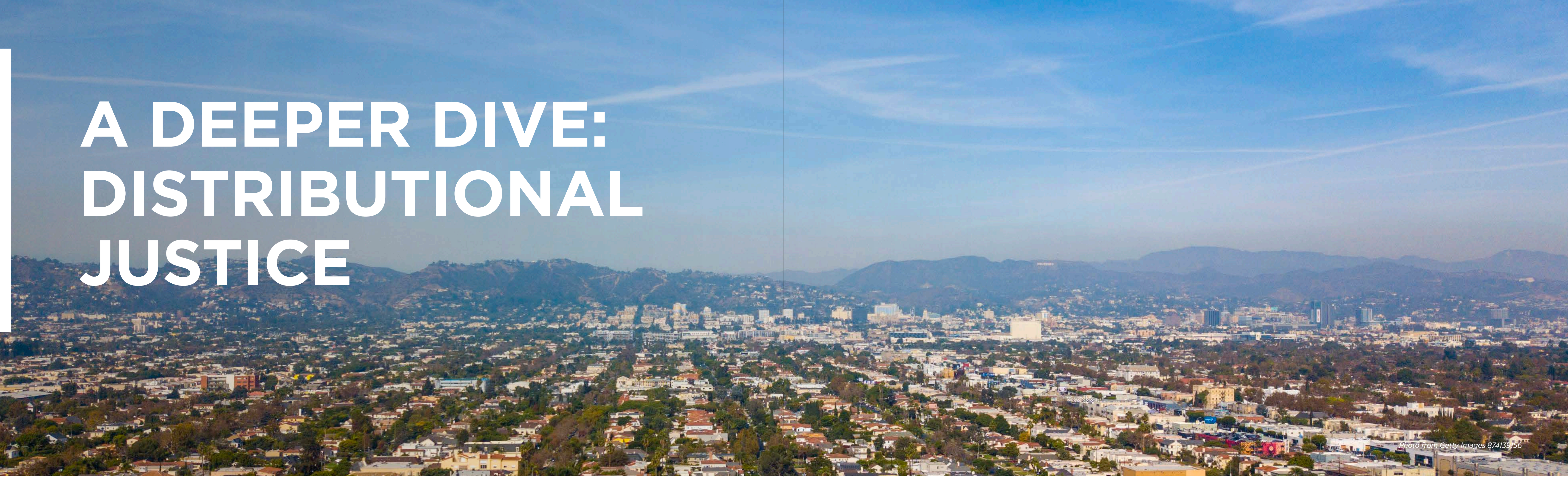
This section presents community-guided strategies seeking to improve access to affordable, safe, and resilient energy services, technologies, and programs. These improvements range from the reduction of negative impacts on health and quality of life to creating opportunities for workforce development in the green economy. These strategies focus on procedural justice: the procedures, practices, and decision makers involved in designing, implementing, and evaluating benefits such as LADWP programs. Some strategies also operationalize recognition justice by redressing the structural legacies of energy inequity.

Procedural and Recognition Justice Equity Strategies

Equity Strategy	Implementation Entity	Existing Programs	Assessment Metrics
Engage residents in developing programs and services targeting community priorities. Listening session participants suggested fostering intentional energy strategies—procedures, partnerships, and practices—that engage residents from underserved communities in developing programs and services that meet their needs and priorities.	LADWP, HACLA, Metro	LIHEIP, RETIRE, REP, ESAP, Community Grants	% of enrollment, % of households eligible, number of programs and services
Provide tailored outreach and education through local trusted messengers. Build on Community Partnership Grants and Science Bowl to (1) inform ratepayers about the options and benefits of programs, services, and technologies, and (2) incorporate energy-related resources into the community science and the community health workers (promotoras) educational methods.	LADWP	HEIP, RETIRE, REP, ESAP, Adopt a School, Community Grants	% of ratepayers aware of programs, programs using trusted messengers
Expand workforce development programs that provide equitable access to tailored training and high-road jobs (i.e., jobs that provide family-sustaining living wages, comprehensive benefits, and opportunities for career advancement). These are crucial in the cross-cutting priority area of jobs and workforce development.	LADWP, LATTC	UPCT, Lineman	% of enrollment, % of enrolled Angelenos with LADWP jobs
Tailor strategies for providing debt relief and preventing the accumulation of debt. The accumulation of debt was a primary barrier to energy affordability for many listening session participants. Mechanisms for guaranteeing energy access and use include utility bill management procedures and debt relief options. Such mechanisms could be employed via programs that incorporate community suggestions into debt relief and prevention strategies.	LADWP	EZ-SAVE Program, Level Pay, LIDP	% of enrollment, % of households eligible, shutoff protections
Invest in programs that foster community health, resilience, and well-being. Investing in programs that foster community resilience supports local capacities to identify and navigate health risks and maintain well-being among community members. For example, listening session participants mentioned supporting community science by offering home air quality monitors.	LADWP, LAUSD	LADWP Science Bowl, Neighborhood Scientists	Number of programs, quality of programs
Co-develop programs and services and improve transparency and continuity. Rely on dedicated personnel and resources and the suggested collaborative platform to engage residents in ongoing, more consistent, transparent, and community-adapted outreach and communication that builds trust, buy-in, and a continuous feedback loop for decision-making.	LADWP, HACLA, Metro	HEIP, RETIRE, REP, ESAP	% of enrollment, improvement in transparent reporting
Provide affordable programs to safely upgrade housing and infrastructure. Expand programs like the Home Energy Improvement Program and Comprehensive Affordable Multifamily Retrofits Program and collaborate with the LA Metro transit agency and Housing Authority of Los Angeles to provide affordable energy and home upgrades fostering affordable access to solar, storage, electric vehicles, and other technologies.	LADWP, HACLA, Metro	EE, EVs, LIHEIP, Weatherization Shared Solar, Cool LA	% of structural energy upgrades per type, e.g., solar panels benefiting underserved communities
Prioritize disadvantaged Angelenos in energy transition programs and investments. The ongoing need for affordable and safe upgrades in LA reveals the significance of infrastructural and systemic barriers to energy equity. For example, without upgrading home service panels, residents cannot install the infrastructure needed to support solar and storage and EV-charging in underserved neighborhoods.	LADWP, HACLA, Metro, LAUSD	EE, EVs, Solar, HEIP, RESAP, Cool LA, CAMR	% of sectoral investments and programs per type, e.g., solar panels benefiting underserved communities
Invest in programs to foster energy and housing security and safety. There is a systemic need for targeting energy and housing security, including homeowner-renter split incentives, affordability issues, and monitoring of housing safety and upgrade needs. This strategy targets homeowner and renter issues, and supports monitoring to ensure that ratepayer homes are safely up to code.	LADWP, HACLA, Metro City of Los Angeles	LADWP Customer Service, City of Los Angeles online services, Stay Housed LA	% of underserved ratepayers benefiting from: (1) Eviction protections, and (2) monitoring and enforcing programs
Build on existing networks of trusted messengers. During the listening sessions, promotoras de salud (also known as promotoras) were raised as a method to improve communications and build trust. Promotoras are community health workers who utilize their knowledge of local sociocultural norms to become trusted messengers, providing their neighbors and residents in their Latino communities access to relevant health and social resources.	LADWP, LA Care Churches	LADWP Science Bowl, Health Promoters	Number and quality of programs using trusted messengers
Improve City regulation, accountability, and enforcement for safe and efficient infrastructure. Improvements include inspection and monitoring to support housing maintenance and upgrades, and regulations and information to prevent unsafe built environments and predatory practices among service and technology providers.	City of Los Angeles, LADWP	HEIP, Solar, EVs, EE	Monitoring and enforcement of (1) upgrade and safety programs, and (2) service and technology providers
Implement a collaborative platform for continuous engagement. (1) Formalize the current LA100 Equity Strategies and other partnerships and collaborations into long-term agreements to maintain a continuous feedback loop with community partners, trusted messengers, and residents, and (2) allocate dedicated personnel and resources to co-design, implement, and evaluate the multiple energy equity projects, technologies, and programs involved in LA's just energy transition.	LADWP	All programs	Number and quality of collaborative programs

CAMR = Comprehensive Affordable Multifamily Retrofits
ESAP = Energy Savings Assistance Program
EZ-SAVE Program = Low-Income Discount Program
HACLA = Housing Authority of the City of Los Angeles
HEIP = Home Energy Improvement Program
LATTC = Los Angeles Trade-Technical College
LDP = Lifeline Discount Program
LAUSD = Los Angeles Unified School District
REP = Refrigerator Exchange Program
RETIRE = Refrigerator Turn-In and Recycle
UPCT = Utility Pre-Craft Trainee Program

A DEEPER DIVE: DISTRIBUTIONAL JUSTICE



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Distributional justice equity strategies address inequities in infrastructure investments, technology access, and negative impacts from energy systems. Strategy development began with identifying current energy equity metrics and establishing a baseline for where LA is today. Community guidance on barriers and solutions informed modeling and analysis of key scenarios and helped to ground truth findings. The baseline, community guidance, and key findings were synthesized in community-informed equity strategies for six focus areas:

1. Low-income energy bill affordability
2. Housing weatherization, resilience, and access to safe home temperatures
3. Community and rooftop solar and storage
4. Household transportation electrification
5. Truck electrification for improved air quality and health outcomes
6. Distribution grid upgrades and resilience.

Important Caveats

- Strategies are based on scenarios modeled through 2035 using data inputs and assumptions. Scenarios are not projections or predictions; they are merely modeled changes that may or may not occur. Scenarios help test different actions to identify which strategies lead to more equitable and affordable outcomes.
- LA100 Equity Strategies did not model clean energy transition costs. NREL used costs from LADWP developed through the 2022 SLTRP process. Strategies provide options and pathways to allocate costs more equitably and make the transition more affordable for low-income customers. Future costs are highly uncertain and the SLTRP process will revise cost projections annually. Rate modeling indicates the directionality of changes under various scenarios, not specific future rates.
- To analyze access to safe and comfortable home temperatures, NREL modeled home temperatures under whole-home system cooling approaches and costs for whole-home cooling and one-room cooling. Scope and modeling limitations prevent NREL from determining if one-room cooling options maintain the cooling set point for the room in which they are located.

Distributional Justice Analysis Framework

Low-Income Energy Bill Affordability

Steering Committee members identified energy affordability as their highest priority. Continuing LADWP's existing rates and low-income assistance approach will decrease affordability for low-income customers on all metrics examined. Rate and program reforms can improve affordability and equity for LADWP's low-income households in the clean energy transition.

The Challenges

Continuing LADWP's existing rate structure and bill assistance program approach would result in the lowest-income households experiencing disproportionately higher bill increases.

- Los Angeles County has a higher concentration of low-income population (30%) than any other California county, underscoring the need for effective low-income assistance.
- LADWP has low enrollment (7% of residential class in 2019) and low bill discounts ($8/month in 2019) compared to enrollment and discounts in low-income assistance programs offered by investor-owned utilities in California.
- LADWP's ability to revise rate design is inhibited by California Propositions 218 and 26, which treat municipal utility rates as taxes,[4] limit rate increases, and prohibit supporting low-income assistance programs through funds recovered from non-low-income customers (League of California Cities 2021).

Electricity bill affordability metrics modeled for 2035 include:

- Electricity and energy burdens, or the percentage of income spent on energy bills
- Monthly electricity bills by income level
- Hours worked at minimum wage required to pay for electricity bills.

Find additional information on this topic on the LA100 website (http://maps.nrel.gov/la100/equity-strategies) and in Chapter 5 (https://www.nrel.gov/docs/fy24osti/85952.pdf) of the full report.

Listening session participant from Boyle Heights:

> **"I worked for [an organization] where we help low-income families with their utility bills. I don't earn that much, but yet I'm not qualified to get help with my electricity or gas. I helped a lot of people who make more than I do, but they get the help and that was a little concerning to me, that people like me who work have to pay bills, but that they are not qualified for assistance. It's always the low income. And I just don't know what to do. I live check by check ... and it's really hard to get help from someone to raise up the low-income guidelines a little to help people like me who doesn't earn that much; you know, they think we do, but we actually don't."**

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[4] Investor-Owned Utilities (IOUs) and non-municipal cooperatives are not subject to CA Propositions 218 and 26.

Key Findings

- Converting from LADWP's current complex, multi-period rate structure to a California Public Utility Commission (CPUC)-recommended simplified tiered or time-of-use (TOU) rate design, and replacing solar net metering with net billing reduces low-income average monthly bills by $15/month even in the absence of the EZ SAVE or Lifeline low-income assistance programs. Switching to net billing reduces the cost shift from solar adopter (typically higher income) to non-adopter (typically lower income) customers that occurs with net metering.
- Continuing LADWP's rate design and solar compensation practices, but replacing the existing EZ-SAVE and Lifeline low income assistance programs with more robust assistance programs modeled after the CPUC's California Alternate Rates for Energy (CARE) and Family Electric Rate Assistance (FERA) programs yields a 22% ($42/month) reduction in average monthly electricity bills for lowest-income customers in 2035. If robust low-income assistance is combined with improved rate design (i.e., simplified tiers or TOU) and net billing for solar compensation, average monthly bills are decreased by 28% ($55/per month) and the solar adopter to non-adopter cost spread is further reduced to $29-39/month.
- Income-based fixed charges (IBFC), where certain utility costs are assigned to customers scaled to their income, achieve the greatest affordability for low-income customers and reduce energy burdens below the 6% affordable threshold for all customers.[5] IBFC design tends to increase solar adopter average monthly bills because solar adopters tend to have higher incomes (thus higher fixed charges, driving up the average). Solar adopters in all income bins continue to see lower bills than non-adopters under IBFC. IBFC are currently being investigated for implementation in California by the CPUC.
- Leveraging federal funding through the IRA, an on-bill tariff program (e.g., Pay-As-You-Save) for heat pump water heaters or enhanced insulation has the technical potential to provide energy bill (gas and electricity) savings to 154,000 or 72,000 low-income customers, respectively.

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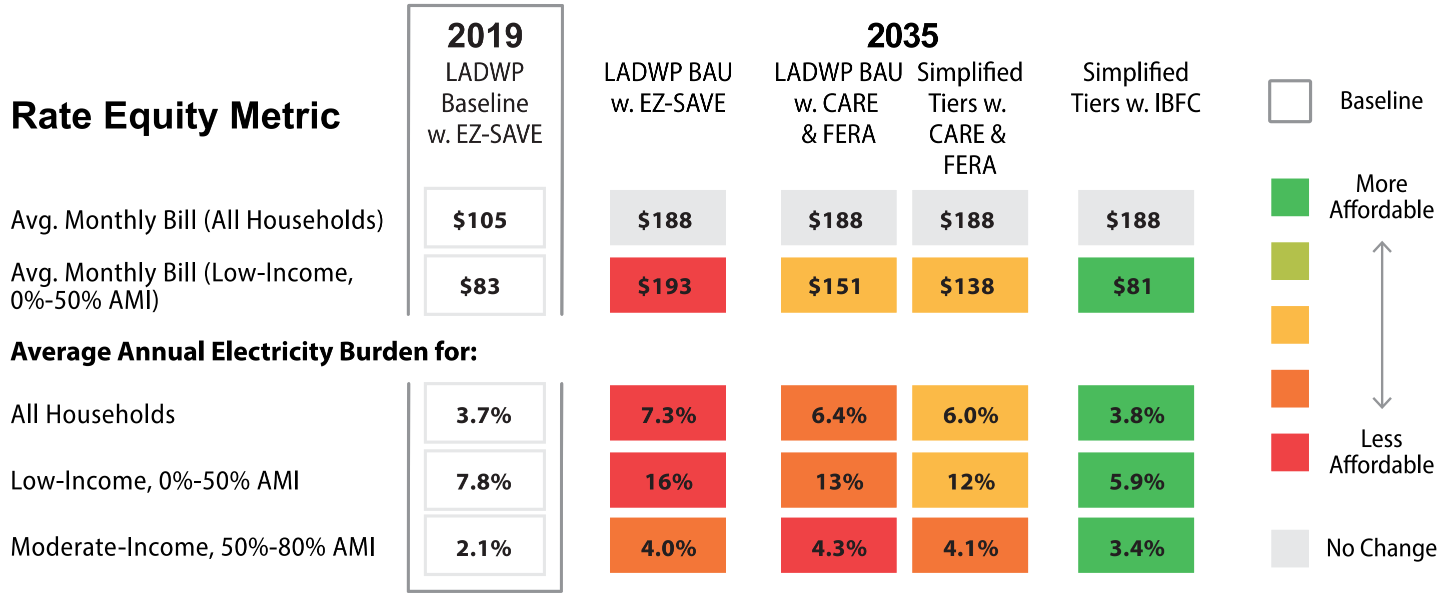
[5] Six percent is a common affordability threshold for total energy burden. Here we use the 6% affordability threshold with the electricity burden, which slightly overstates affordability for these warm-weather climate households.



Rate Equity Metric	2019 LADWP Baseline w. EZ-SAVE	2035 LADWP BAU w. EZ-SAVE	2035 LADWP BAU w. CARE & FERA	2035 Simplified Tiers w. CARE & FERA	2035 Simplified Tiers w. IBFC
Avg. Monthly Bill (All Households)	☐ $105	$188	$188	$188	$188
Avg. Monthly Bill (Low-Income, 0%-50% AMI)	☐ $83	🟥 $193	🟨 $151	🟨 $138	🟩 $81
Average Annual Electricity Burden for:					
All Households	☐ 3.7%	🟥 7.3%	🟧 6.4%	🟨 6.0%	🟩 3.8%
Low-Income, 0%-50% AMI	☐ 7.8%	🟥 16%	🟧 13%	🟨 12%	🟩 5.9%
Moderate-Income, 50%-80% AMI	☐ 2.1%	🟧 4.0%	🟥 4.3%	🟧 4.1%	🟩 3.4%

Equity Outcomes Under Various LADWP Rate Structure and Bill Assistance Program Options. Based on LADWP 2022 SLTRP Case 1 projected revenue requirements

Equity Strategies for Low-Income Energy Bill Affordability*

EQUITY STRATEGY: Implement a simplified tiered or time-of-use rate structure, switch solar compensation from net metering to net billing, and moderately boost low-income solar adoption. Even without a low-income assistance program (i.e., EZ-SAVE and Lifeline), this strategy improves affordability and equity outcomes. This strategy requires legal changes.

Benefit/Impact	**Cost****	**Metric**
• Low-income electricity bills would decrease by $14 to $15/month. • Reduced average monthly bill disparity between solar adopter (typically high-income) and non-solar adopter (typically lower-income) from $169 to $55-$65. • 3,500–3,300 fewer customers with >100% energy burdens compared to business-as-usual.	• All strategies are modeled to cover LADWP projected 2035 revenue requirements. • Improved price signals could promote cost savings if customers respond by avoiding consumption in higher-priced periods.	• Average monthly electricity bill savings. • Reduced intra-class cross-subsidization for solar compensation. • Reduced number of customers over 100% energy burden. • Customer satisfaction and customer understanding surveys before and after rate design changes.

EQUITY STRATEGY: Implement robust low-income assistance programs modeled after the CPUC CARE and FERA programs to increase electricity bill affordability for the lowest-income customers. This strategy requires ballot action or legal changes as Propositions 26 and 218 currently prohibit supporting low-income assistance programs through funds recovered from non-low-income customers.

Benefit/Impact	**Cost****	**Metric**
• 22% ($42/month) lower electricity bills for low-income customers. • 2035 monthly assistance increases from $5.78/month under EZ-SAVE to $54/month under CARE and about $37/month under FERA. Increase in assistance recipients from 150,000 under EZ-SAVE to 436,000 under CARE and FERA.	• Larger cross-subsidy from non-participating to participating customers. • $307-$335 million per year (in 2035) of reallocated funds from non-participating to participating customers.	• 30%–35% discount on electric bills for CARE enrollees. • 89% and 15% eligible enrollment rate for CARE and FERA, respectively.

EQUITY STRATEGY: Explore income-based fixed charges (IBFC).

Benefit/Impact	**Cost****	**Metric**
• 58% ($112/month) lower average monthly electricity bills compared to current rate structures business-as-usual for low-income customers. • IBFC reduces average electricity burdens below the 6% affordability threshold.	• No direct low-income program budget required. • Costs for income verification. • Higher fixed costs and bills for higher-income customers. • Potential for weaker price signals that reduce incentive to conserve; may incentivize electrification.	• Change in electricity burden by different income bins.

EQUITY STRATEGY: Implement an on-bill tariff program leveraging IRA funds, to support heat pump water heater or enhanced insulation installation for low-income customers.

Benefit/Impact	**Cost****	**Metric**
• Technical potential for nearly 154,000 and 74,000 LMI customers to save on energy bills through on-bill financed heat pump water heaters and enhanced insulation, respectively.	• Leverages Inflation Reduction Act funds. • Only participating customers are assessed monthly bill riders.	• Income-eligible customers who qualify for the program will see energy (gas and electricity) bill savings 25% higher than the program bill rider. • Number of participating households.

* All dollar values in this chart are in 2021 dollars. **Strategies that change LADWP's current rate structure require ballot action and will also likely result in cessation of the approximately $220 million annual transfer from LADWP to the City of Los Angeles. Eliminating this transfer would reduce customer rates.

Photo from Getty Images 82136780

Housing Weatherization, Resilience, and Access to Safe Home Temperatures

An estimated 230,000 low-income households in LA lack access to cooling and are projected to experience the equivalent of more than two months of exposure to dangerous indoor temperatures by 2035. Multifamily building residents are at much higher risk of dangerous heat exposure. This analysis identified strategies to increase access to safe and comfortable home temperatures through housing weatherization and cooling technologies. NREL identified building envelope upgrades and cooling strategies that could save lives and maintain safe home temperatures for low-income households during heat waves.

The Challenges

- Fewer than half of low-income households use cooling, even if they have access to cooling. More than 30% of extremely low-income households, and more than 26% of renters and households in disadvantaged communities, lack access to cooling.
- More than half of low-income households will experience dangerous indoor air temperatures of 95°F at least once a year by 2035. In the event of a power outage during a heat wave, 85% of LA housing stock reaches the dangerous temperature threshold (86°F) in the first 24 hours of an outage. Thirty-seven percent of low-income households will start a power outage during a heat wave at unsafe indoor temperatures.
- Although roughly half the population lives in disadvantaged communities, less than half of LADWP spending on residential energy efficiency programs between 2013 and 2021 benefited households in these communities.
- Communities are seeking affordable options with fewer upfront costs, programs that reach moderate-income households and renters, and upgrades that will not raise rents and cause displacement.

Housing energy equity metrics include:

- Level and duration of exposure to unsafe (>86°F) home temperatures by income, housing type, and renter or owner occupancy
- Upgrade costs and utility bill impacts by income, housing type, and renter or owner occupancy
- Access to cooling by income, housing type, and renter or owner occupancy.

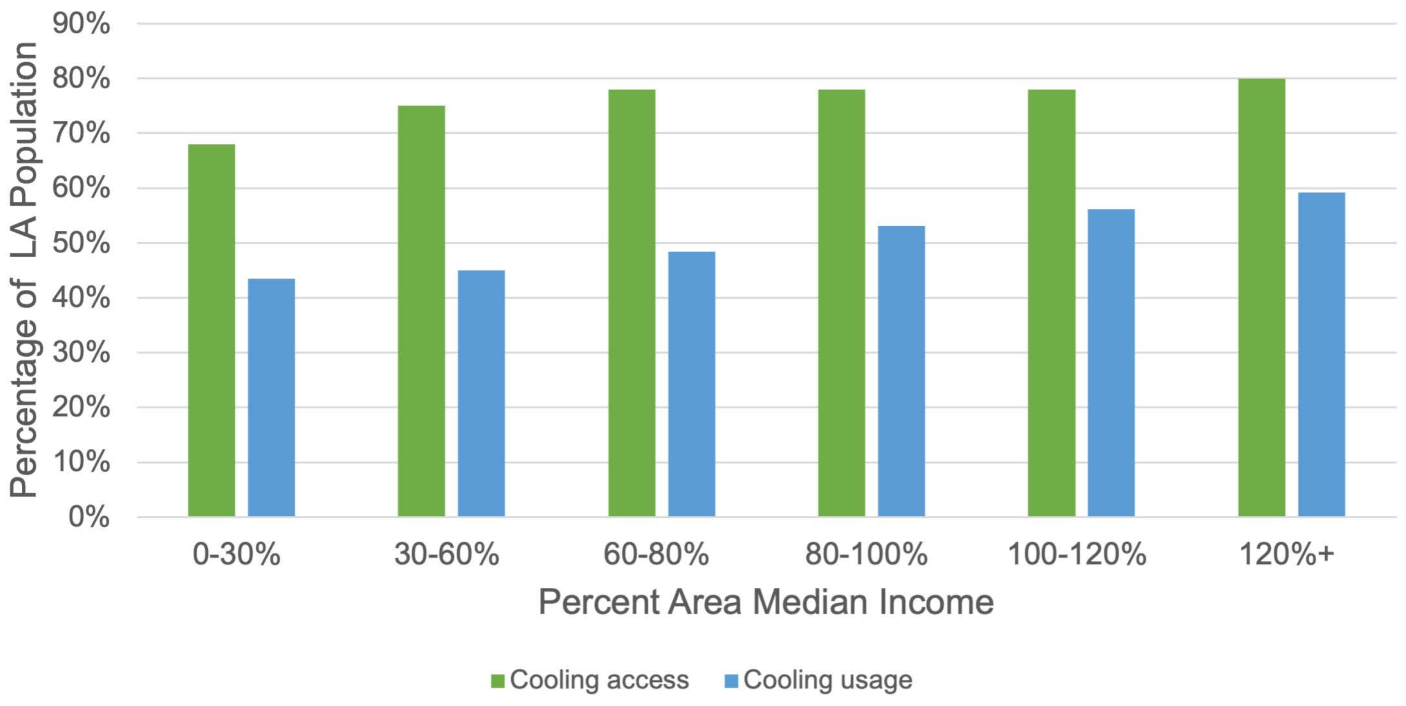
Find additional information on this topic on the LA100 website (**http://maps.nrel.gov/la100/equity-strategies**) and in **Chapters 6** (**https://www.nrel.gov/docs/fy24osti/85953.pdf**) and **7** (**https://www.nrel.gov/docs/fy24osti/85954.pdf**) of the full report.

Equity Strategies Steering Committee member on how they handled a recent heat wave:

> **"I have a window [AC] unit and it's in a different room than what I spend most of my time in. It was quite difficult. I would just go sit in my car for relief."**

Key Findings

- Multifamily building residents, who comprise 56% of the Los Angeles population and 95% of low-income renters, have the highest exposure to dangerous indoor temperatures. Exposure increases as the number of units increase due to the increased thermal mass of the buildings, limited natural ventilation, and insulated, shared walls.
- Dangerous heat exposure can be reduced at lower cost in multifamily buildings than single-family buildings. Installation costs are lower in multifamily dwellings than single-family dwellings because these dwellings are generally smaller and better insulated, resulting in smaller cooling system sizes and costs.
- Providing cooling through heat pumps dramatically improves access to safe and comfortable whole-home temperatures. Heat pumps nearly eliminate dangerous temperature exposures (above 86°F) for low-income, multifamily households.
- Installing and using cooling systems in households with no prior access to cooling would increase utility bills between $140 and $180 annually for cooling one room, and between $120 and $270 for whole-home cooling.
- IRA rebates, when available, reduce or eliminate the cost of upgrades for LMI households. With IRA Section 50122 rebates, LADWP could install cooling with mini-split heat pumps in low-income (0%–80% AMI) households without households incurring any debt or subscribing to payment plans by using a direct install program. However, IRA program budgets are limited, and current funds would likely cover upgrades in less than 1% of 0%–150% AMI households in LA.
- Whole-home heat pumps provide the most energy efficient cooling but have high initial costs of $5,700–$9,000 for minimum efficiency systems in low-income households. In some cases, the costs can be mitigated by IRA funds. Adding minimum efficiency cooling for a single room has costs of $530 to $800 for low-income homes.



Cooling access and usage based on area median income

Equity Strategies for Safe Home Temperatures

EQUITY STRATEGY: Expand direct installation of cooling in extremely low-income households without cooling, prioritizing multifamily buildings.

Benefit/Impact	Cost	Metric
• An estimated 230,000 low-income households in Los Angeles lack access to cooling and are projected to experience nearly two months of exposure to dangerous indoor temperatures by 2035.	• Whole home cooling system upgrade costs range from $5,700-$9,000 for minimum efficiency systems in low-income households. One-room minimum efficiency upgrades for low-income households are $530-$800 per home. Providing one-room minimum efficiency cooling for all extremely low-income households lacking cooling would cost approximately $79 million.	• Number of systems deployed in LMI households. • Percentage of LMI households with cooling.

EQUITY STRATEGY: Provide heat pump incentives in the Cool LA Program and auto-enroll low-income incentive recipients in bill assistance programs to mitigate energy burdens.

Benefit/Impact	Cost	Metric
• Heat pumps provide up to 29% more energy-efficient cooling for equivalent total lifecycle costs to window-unit air conditioning (ACs). • Adding one-room cooling increases annual average utility costs between $140 and $180.	• Cool LA provides up to $225 on new cooling units and a $25 rebate to dispose of an old AC system. • If the City of LA provided the maximum Cool LA incentive for the purchase of a heat pump and the removal of an old system ($250) for every extremely low-income household without cooling, it would cost $58 million.	• Number of households with heat pump incentives. • Percentage of eligible households enrolled in program. • Average bill assistance enrollment time of less than 10 minutes on a smart phone.

EQUITY STRATEGY: Combine IRA or Weatherization Assistance Program funding with LADWP incentives to augment LADWP's HEIP, Cool LA, and other programs to lower heat pump and envelope efficiency upgrade costs for low-income households. Expand LADWP's HEIP to include funding for electrical upgrades needed to install heat pumps.

Benefit/Impact	Cost	Metric
• The Weatherization Assistance Program covered an average of $8,250 per dwelling in low-income households for energy efficiency upgrades. • IRA Section 50122 covers up to $8,000 for heat pumps in low-income households. • IRA Section 50122 provides rebates up to $2,500 for electrical wiring and $4,000 for electrical panel upgrades.	• A total of 1,500 low-income (0%–80% AMI) households could be covered by federal funding available through IRA Section 50122. • Providing the $250/dwelling incentive would reduce upfront cost for low-income households by 3.7%. • Electric panel upgrades required to install heat pumps are estimated to cost $1,300 to $5,000 (NV5 2022).	• Number of households with upgrades as a result of incentives.

EQUITY STRATEGY: Partner with the Housing Authority to provide cooling and weatherization in public housing and implement mechanisms to mitigate rent increases associated with LADWP-supported upgrades elsewhere. Renter protections, "right to return" provisions if renovations temporarily displace renters, and mechanisms to prevent short-term rent increases for multifamily rental properties receiving utility-supported upgrades could avert rent increases and displacement for non-public housing that receives low-income-qualified cooling and weatherization interventions.

Benefit/Impact	Cost	Metric
• More than 95% of low-income LA households living in multifamily buildings are renters. • Improve health and resilience without increased rent.	• Potentially limited to administrative costs or implementing rent increase restrictions post-upgrade.	• Number of public housing units with LADWP-supported upgrades. • Number of LADWP-supported upgrades with rent increase mitigation measures.

Photo from Getty images 1311966604

Community and Rooftop Solar and Storage

Rooftop solar has had limited reach in disadvantaged communities because of barriers such as homeownership, financing challenges, costs to upgrade electrical panels or replace roofs, and split incentives (where a building owner would pay for solar, but renters would save on electricity bills).

Wilmington, LA Harbor resident:

> **“I’m a homeowner. And I have a duplex, so I rent out … And we’re trying to get solar from the Department of Water and Power, it’s difficult. Yes, you have subsidies and stuff. But you gotta put up almost twenty grand just to get the solar power. Who’s going to take on all that with my tenants?”**

Community solar can broaden access to solar energy benefits such as bill savings for low-income and disadvantaged community customers.

Steering Committee Member:

> **“Find ways to financially incentivize community solar participation. We hear folks want to participate, but there is not enough incentive.”**

Challenges:

- Analysis of LADWP residential net energy metering programs indicates that 62% of incentives went to households in non-disadvantaged communities. The $340 million in LADWP solar net energy metering incentives analyzed (1999-2021) disproportionately benefited predominantly White, non-Hispanic, home-owning, and wealthier communities. Disadvantaged communities, particularly in South LA and the Harbor Region, did not receive solar incentives proportional to their populations.
- Analysis of the 2,116 LADWP Shared Solar Program participants (as of December 31, 2021) indicates higher participation and subscribed capacity among non-disadvantaged, non-Hispanic, and above-median-income communities. While only multifamily building residents are eligible to participate, there was no statistically significant difference in program participation between mostly owner and mostly renter communities.

Local solar equity metrics include:

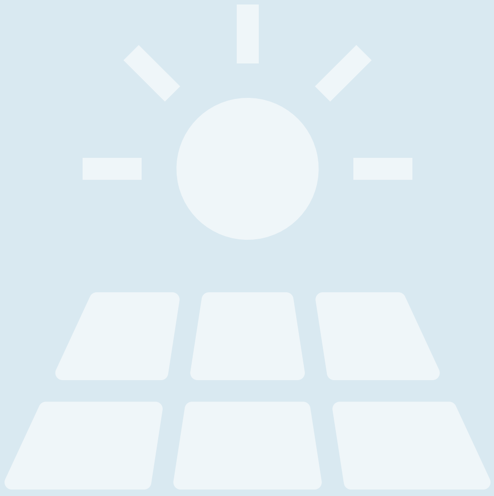
- Annual electricity bill savings by income, housing type, and low-income community status
- Change in electricity burden by income, housing type, and low-income community status.

Find additional information on this topic on the LA100 website (http://maps.nrel.gov/la100/equity-strategies) and in Chapters 8 (https://www.nrel.gov/docs/fy24osti/85955.pdf) and 9 (https://www.nrel.gov/docs/fy24osti/85956.pdf) of the full report.

Key Findings

Community Solar

- The maximum savings available to customers who subscribe to the LADWP Shared Solar Program under our model assumptions are approximately $68/year over 10 years. Increasing the maximum subscription amount to 500 kWh, establishing a 20% lower subscription rate for low-income customers, and allocating 50% of new capacity to these customers can provide average savings of $480/year for low-income subscribers.
- More than 800 MW on approximately 1,300 sites could be economically viable as 30 kW or larger projects under this modified Shared Solar approach on government-owned land, recreation centers, educational institutions, hospitals, and multifamily parcels. There are 610 economically viable potential community solar sites on multifamily properties in low-income census tracts.
- Sites in low-income census tracts that serve low-income subscribers are more economically attractive because the IRA provides incentives for projects in which at least 50% of the financial benefits are provided to low-income households via an additional 20% ITC.



Rooftop Solar

- 1.4 gigawatts (GW) of cumulative rooftop solar adoption are projected by 2035 in LA. Approximately 70% of that adoption is projected to come from single-family, owner-occupied, non-LMI households under current trends and compensation structures.
- Rooftop PV adoption among LMI customers could increase by 85% (up to 530 MW of solar and 520 MW of storage) under a direct install program for LMI customers funded by LADWP, if combined with strategies to convey solar savings to renters and resolve the split incentive challenge. A direct install approach would provide LMI households with average annual electricity bill savings of $420, or 16%–18%. Program costs of $2.2 billion over 16 years for 160,000 additional LMI household PV installations mean full implementation of this approach is cost-prohibitive and risks increasing rates for non-solar adopters.
- LMI rooftop PV adoption could increase by 40% (up to 280 MW of solar with no added storage) under a net metering program, where LMI customers are paid for any excess solar energy generated at retail rate, combined with strategies to convey solar savings to renters. Net metering would provide LMI households with average annual electricity bill savings of $460 or 30%–34%. Program costs of $2.7 billion over 16 years for 52,000 LMI households mean full implementation of a net metering approach has the highest costs of modeled scenarios and risks increasing rates for non-solar adopters.

Equity Strategies for Rooftop and Community Solar

EQUITY STRATEGY: Establish an LMI Shared Solar subscription rate. Deliver solar bill savings to LMI, renter, and multifamily building resident customers by lowering the subscription rate by 20% for low-income customers and increasing the maximum subscription to 500 kWh per month.

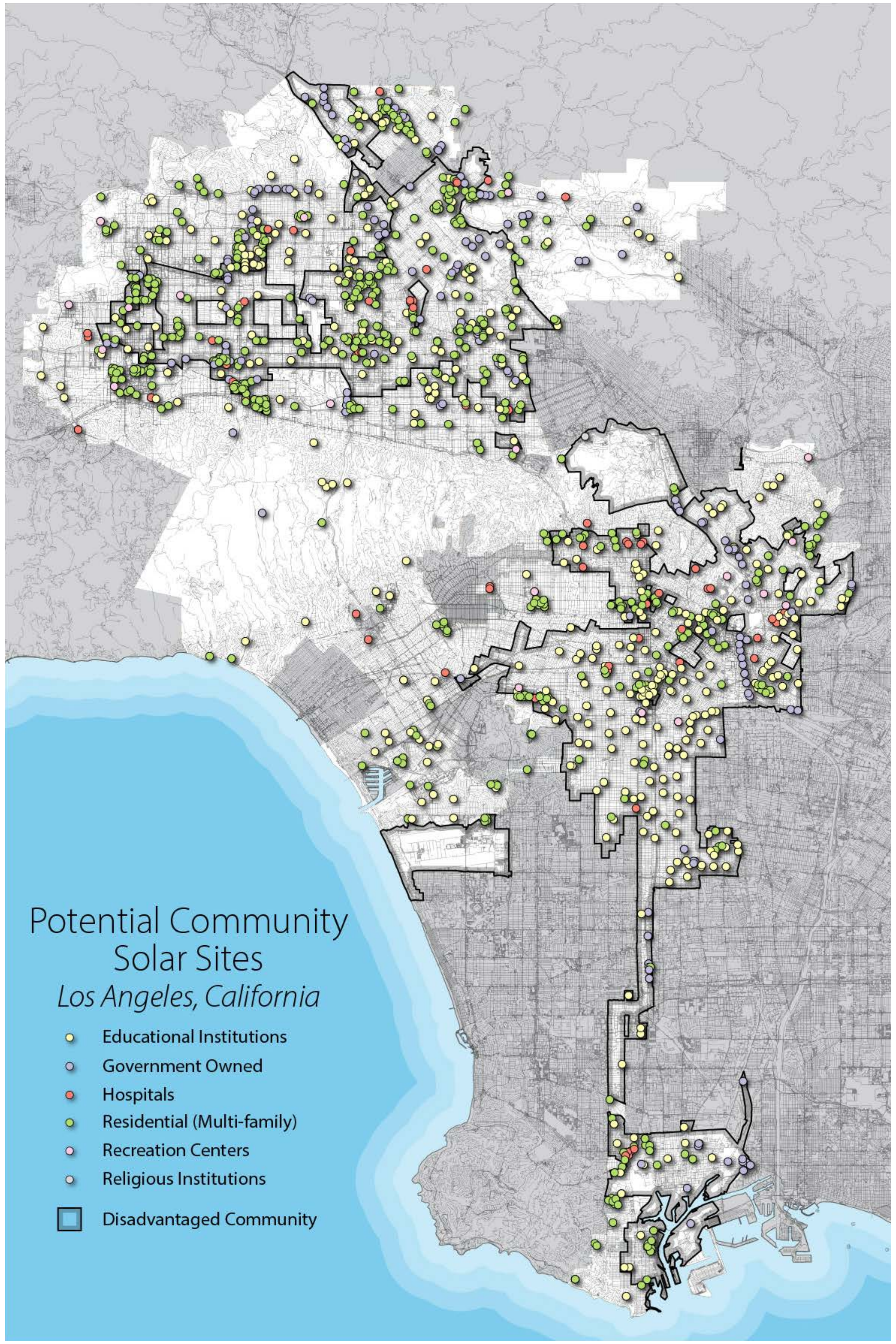
Benefit/Impact	Cost	Metric
• Maximum subscriber savings increase from a $68/year average over 10 years to $480/year for LMI customers. • Potential sites have a 41% higher net present value (NPV) under community solar compared to a feed-in-tariff power purchase agreement financial model.	• Decreases average NPV by 20%, but positive NPV still modeled at more than 4,000 potential sites with ≥30 kW capacity totaling more than 3.2 GW.	• 50% of all new Shared Solar subscribers and capacity delivered to LMI subscribers under discount rate makes projects eligible for 50% ITC.

EQUITY STRATEGY: Develop Shared Solar on economically viable ≥30 kW multifamily potential sites in low-income tracts eligible for 50% ITC to deliver solar bill savings to LMI, multifamily building renters.

Benefit/Impact	Cost	Metric
• Prioritize affordable public housing to mitigate rent increases from improvements. • Integrate Shared Solar deployment with CAMR. Six hundred economically viable, ≥30 kW suitable multifamily shared solar sites identified in low-income census tracts totaling 250 MW.	• All identified sites have a positive NPV. • LADWP costs would be primarily administrative.	• Number of the potential multifamily sites developed for Shared Solar by 2030 and 2035, e.g., 15% economically viable multifamily sites in low-income tracts developed by 2030 (38 MW), 40% by 2035 (100 MW). • Number of LMI renters enrolled by 2030 and 2035.

EQUITY STRATEGY: Substantially expand Shared Solar capacity at economically viable ≥30 kW sites and allocate 50% of new capacity to LMI subscribers. Partner with developers, contractors, and property owners to dramatically expand Shared Solar capacity on the 1,900 economically viable ≥30 kW potential community solar sites on government-owned land, recreation centers, educational institutions, hospitals, and multifamily buildings.

Benefit/Impact	Cost	Metric
• Economically viable, ≥30 kW potential sites identified at 150 government, 21 recreation center, 75 hospital, and 370 educational institution sites.	• All identified sites have positive NPV.	• Meet in-basin solar goals more affordably and equitably through Shared Solar development on economically viable public-benefit sites, e.g., 15% economic capacity developed by 2030 (125 MW), 40% by 2035 (334 MW), 80% by 2050 (668 MW).



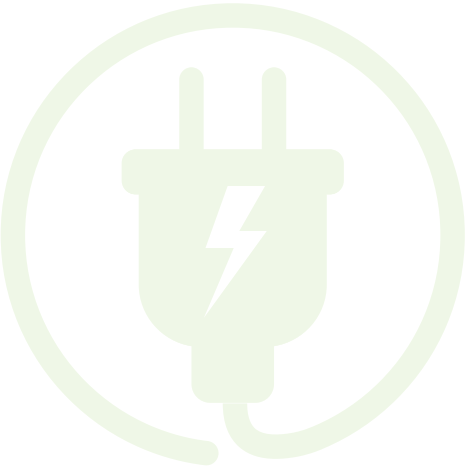
Potential community solar sites on government-owned land, recreation centers, educational institutions, hospitals, and multifamily parcels that have a positive NPV under the Equity scenario for a community solar-based financial model

Household Transportation Electrification

The most significant inequities in the distribution of LADWP residential incentives were identified in residential EV and EV charging infrastructure investments. NREL modeled scenarios that increase equity in household light-duty EV adoption and EV charging infrastructure distribution and extend access to electric transportation to households who do not own vehicles.

Challenges:

- Between 2013 and 2021, 67% of LADWP incentives for used light-duty EVs and 82% of incentives for residential charging infrastructure went to households in non-disadvantaged communities. The $5.4 million in LADWP incentives analyzed disproportionately benefited predominantly White, non-Hispanic, home-owning, and wealthier neighborhoods.
- Communities are seeking affordable and accessible transportation options to enhance mobility and reduce pollution.
- More than 11% of LA households do not currently own a vehicle (American Community Survey [ACS] 2015–2019), including 16% of households in disadvantaged communities.



Household transportation electrification equity metrics include:

- Used EV affordability as a percentage of household expenses
- Access to home and public charging
- Household vehicle ownership rates, public transit access, time and cost of shared EV, e-bike, and transit options
- Proximity to bike lanes
- Income and disadvantaged community status.

Find additional information on this topic on the LA100 website (**http://maps.nrel.gov/la100/equity-strategies**) and in Chapter 10 (**https://www.nrel.gov/docs/fy24osti/85957.pdf**) of the full report.

East LA resident:

> **“I’m envisioning…a future of carbon free…and I was thinking about like, will it be cheap to buy solar panels for charging my car? Or like, as of right now, gas prices are so expensive, so…I’m choosing to not…go to certain places, like sometimes even skip work because I work so far away like a cost-benefit is [not going to work], it’s really impacting my financial decisions. Right? Will it be affordable for everybody?”**

Key Findings

- Increasing LADWP’s used light-duty EV rebates for low-income households from the current $2,500 to $4,000 could result in an increase in used EV adoption among low-income households in LA of approximately 50,000 vehicles by 2035.
- Households in LA that make $75,000 or less annually and adopt used EVs would reduce their average total household expenditures by 3%, scaled by income, compared to the case adopting new EVs.
- Around 20% of EV owners in LA in 2035 are estimated to lack at-home charging access, of which about 80% are those living in multifamily homes. The lack of home charging access would cost an additional approximately $300/year for LMI households, compared to households with home charging access. Neighborhood chargers can compensate for the lack of home charging access and enable increased low-income EV access and affordability. Neighborhoods including Little Tokyo, Crenshaw, Leimert Park, Central City, and Hollywood are projected to have high EV adoption potential with low home charging access.
- Providing shared EV programs, shared e-bike programs, and improved transit service could reduce trip travel time up to 12%, save up to 18% in transportation costs, and increase access to destinations by up to 3% in neighborhoods with very low car ownership.
- Fewer than 50% of LA households eligible for California Air Resources Board e-bike incentives (i.e., household incomes up to 300% of the Federal Poverty Level) are within 1,000 feet of existing bike infrastructure.
- Widespread access to e-bikes could reduce vehicle miles traveled in LA by an estimated 4.7%, saving 316,000 tons of carbon dioxide equivalent annually relative to gasoline-powered cars and avoiding 187 gigawatt-hours (GWh) of electricity demand, relative to those miles being traveled in light-duty EVs.

🚲 Shared e-bike access 🚗 Shared EV access 🚌 Improved transit

Transportation Analysis Zone ID & Neighborhood	Most affordable	Most time efficient	Access to most opportunities	Transportation Analysis Zone ID & Neighborhood	Most affordable	Most time efficient	Access to most opportunities
3718 – Panorama City	🚲	🚲	🚌	4111 – Boyle Heights	🚲	🚲	🚗
3731 – Panorama City	🚲	🚲	🚌	4114 – Boyle Heights	🚲	🚗	🚗
3734 – North Hills	🚲	🚲	🚌	4115 – Boyle Heights	🚗	🚗	🚗
3737 – Panorama City	🚲	🚲	🚌	4150 – Boyle Heights	🚲	🚗	🚗
3864 – Reseda	🚲	🚲	🚌	4335 – East Hollywood	🚗	🚲	🚗
3866 – Canoga Park	🚗	🚲	🚗	4611 – Wilmington	🚗	🚲	🚗
3872 – Winnetka	🚲	🚲	🚌	4612 – Wilmington	🚗	🚲	🚗
3877 – Van Nuys	🚗	🚲	🚗	4614 – San Pedro	🚗	🚲	🚗
4067 – Boyle Heights	🚗	🚗	🚗	4630 – Wilmington	🚗	🚲	🚗
4105 – Boyle Heights	🚲	🚗	🚗	*Calculated for low-vehicle ownership, low transit access, disadvantaged communities*			

Optimized, neighborhood-specific multimodal strategies for affordability, time efficiency, and access to opportunities (by transportation analysis zone and associated neighborhoods)

Equity Strategies for Household Transportation Electrification

EQUITY STRATEGY: Increase the low-income used EV incentive from $2,500 to $4,000 and establish a purchase price cap of $25,000 for incentive eligibility.

Benefit/Impact	Cost	Metric
• Increasing low-income used EV rebates could result in 50,000 more vehicles adopted among low-income households by 2035.	• $6.2 million/year. May be offset by $25,000 purchase price cap.	• Incentive uptake of 4,200 low-income households per year for 12 years.

EQUITY STRATEGY: Shift from delayed rebates to a point-of-sale discount.

Benefit/Impact	Cost	Metric
• A point-of-sale price discount will shift some administrative burden off the customer and lower credit and loan qualification barriers.	• Neutral	• Number of participating dealerships in the city. • Incentive uptake of 4,200 low-income households per year for 12 years.

EQUITY STRATEGY: Expand at- and near-home EV charging access for low-income multifamily building residents to enable more equitable access to and use of EVs, targeting neighborhoods identified with high EV adoption potential and low charging access.

Benefit/Impact	Cost	Metric
• Apply the $5,000 maximum rebate for Level 2 chargers in disadvantaged communities and other incentives to achieve 50,000 chargers by 2035.	• $22 million/year from 2024 to 2035. • $260 million total potentially offset by state and federal funding.	• 50,000 chargers by 2035, 4,200 chargers/year in predicted low-income EV adopter areas with low charging access. • 70% Level 2 in disadvantaged communities; 20% Level 2 non-disadvantaged communities; 10% Direct current fast charging.

EQUITY STRATEGY: Provide vouchers or charging subscriptions for public EV charging for low-income households without home charging access, in partnership with charging network providers.

Benefit/Impact	Cost	Metric
• Public charging costs approximately $300/year more than home charging for LMI households in Los Angeles.	• $1.7 million/year through 2035.	• Provide each low-income used EV incentive recipient with $300/year electric vehicle supply equipment (EVSE) voucher.

EQUITY STRATEGY: Establish community-guided EV car-share, e-bike, and e-scooter programs in transportation disadvantaged communities, including Boyle Heights, Wilmington, and Panorama City.

Benefit/Impact	Cost	Metric
• Grants for program establishment and e-bike, e-scooter, and potentially low-speed EV purchase. Support with existing EVSE rebates of $5,000 for Level 2 chargers in disadvantaged communities.	• See universal basic mobility pilot in South LA (Los Angeles Department of Transportation) costs .	• Apply the existing disadvantaged community EVSE rebate for each installed charger for the program.

EQUITY STRATEGY: Collaborate to pair e-bike incentives and programs with the expansion of safe and accessible bike infrastructure and charging options.

Benefit/Impact	Cost	Metric
• LADWP e-bike incentives can be stackable with state and potential future federal incentives. • Collaborate on charging and bike lane infrastructure planning; provide financial support for program development. • Fewer than 50% of LA households eligible for California Air Resources Board e-bike incentives are within 1,000 feet of existing bike lanes.	• California Air Resources Board $13 million 2023 budget will fund 4,000–7,000 state rebates.	• Number of e-bike incentive recipients; vehicle miles traveled and emission reduction. • E-bike incentive recipients within 1,000 feet of bike lanes.

Photo from Getty Images 1164647702

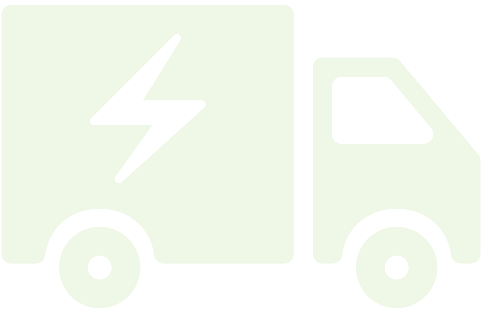
Truck Electrification for Improved Air Quality and Health Outcomes

Air pollution from heavy-duty trucks disproportionately impacts residents living in disadvantaged communities, which are more likely to be located near freeways and experience poorer air quality. Although heavy-duty trucks account for only 5% of registered vehicles in LA, they account for 51% of emissions of nitrogen oxides (NO_X) from on-road transportation. Electrification of heavy-duty trucks could yield significant health benefits, including reduction in premature deaths and reduction in asthma incidences in children. Pursuing electrification of heavy-duty trucks (>8,500 lbs.), and within that, heavy-heavy-duty trucks (>33,000 lbs.) like fire trucks, dump trucks, fuel trucks, and long haul tractors could achieve the highest and most equitable air quality and health improvements.

Truck electrification equity metrics include:

- Exposure to poor air quality from traffic by disadvantaged community status
- Premature deaths and asthma-related health impacts from exposure to heavy-duty truck emissions, by disadvantaged community status.

Find additional information on this topic on the LA100 website (**http://maps.nrel.gov/la100/equity-strategies**) and in Chapter 11 (**https://www.nrel.gov/docs/fy24osti/85958.pdf**) of the full report.



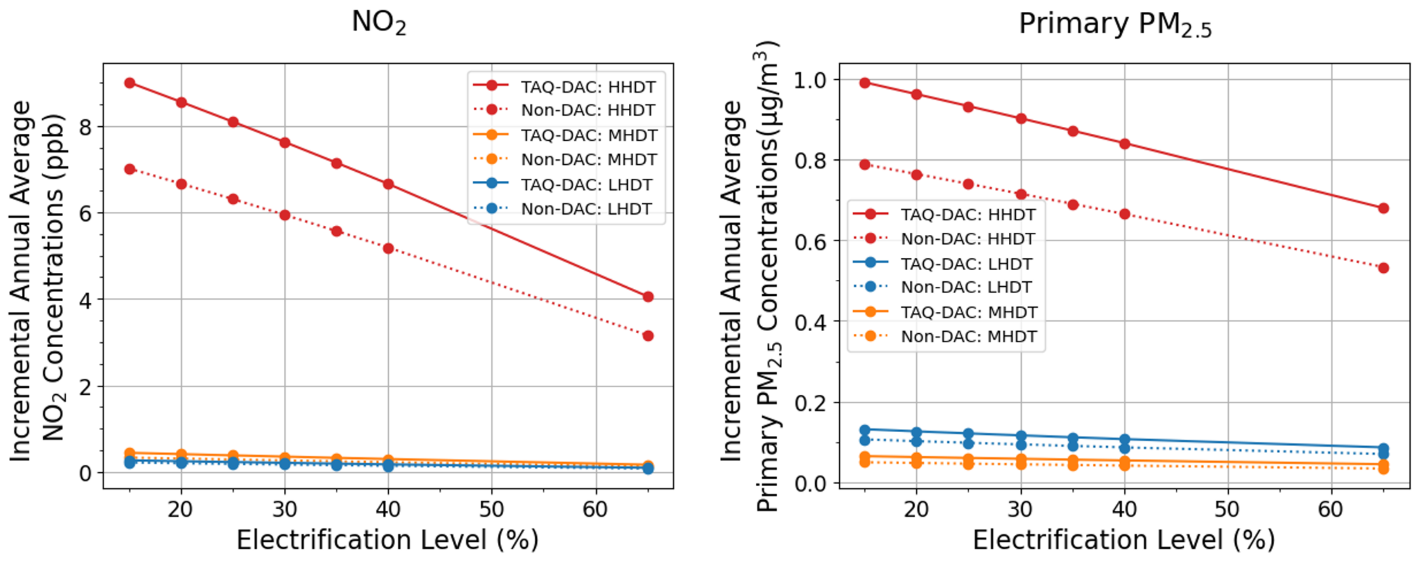
Challenges:

- Disadvantaged communities are disproportionately affected by traffic; 58% of disadvantaged communities have percentile scores >75 for either traffic impacts, measured by the number of vehicles on roads in the area, or diesel particulate matter exposure, and 32% of disadvantaged communities have both. NREL identified traffic air quality disadvantaged communities where neighborhoods face both high traffic impacts and diesel particulate matter exposure.
- LADWP's Charge Up LA! electric vehicle charging incentive program has had minimal participation in medium- and heavy-duty charger rebates. Communities are seeking reduced pollution from truck traffic, starting with investments in areas that have had the most pollution burden.

> Wilmington, LA Harbor resident:
>
> **"Since I have been here, three generations, half of my family has died from cancer. As young as 34 years old. From breast cancer, lung cancer, liver cancer, kidney cancer. With people that don't even drink or smoke…I know that the refineries have an issue. The contaminants from the trucks and the containers, from the brakes. They have a black soot in our community. And in that black soot, who knows what that's giving us? …And you wake up in the morning, your car is full of that stuff. You wipe your car down and your rag is black. Or it's inside your house."**

Key Findings

- Heavy-duty trucks currently contribute 51% of emissions of NO_x and 32% of particulate matter ($PM_{2.5}$) emissions from on-road transportation sources.
- By 2035, heavy-heavy-duty trucks (such as fire trucks, dump trucks, fuel trucks and long haul tractors) are expected to generate more than 90% of truck-related NO_2 and 80% of $PM_{2.5}$ incremental near-road pollutant concentrations (five times the other heavy-duty truck categories).
- The air quality benefits that can be achieved by electrifying heavy-duty trucks vary by where such trucks are more prevalent on LA roadways. The largest pollutant concentration reductions from heavy-duty truck electrification occur in census tracts located closest to freeways, including Interstate Highways 5, 10, 110, and 405, and U.S. Highway 101.
- Truck electrification can benefit traffic-impacted disadvantaged communities approximately 25% more than comparable non-disadvantaged communities. This is because disadvantaged communities, and especially traffic air quality disadvantaged communities, are more likely to be near major roadways in Los Angeles than non-disadvantaged communities and thus would see greater benefit from emission reductions on these roadways.
- Electrifying heavy-duty trucks could provide major health benefits, especially for disadvantaged communities near high traffic areas. These include avoided premature deaths, avoided hospital visits for cardiovascular and respiratory illnesses, and fewer asthma cases and heart attacks. Disadvantaged communities see more benefits than non-disadvantaged ones for each increase in truck electrification. For example, disadvantaged areas accrue about 55% of the benefits in avoided deaths and 60%-65% of the benefits in avoided childhood asthma incidences associated with higher electrification levels.



Incremental annual-average truck-related NO_2 concentrations (ppb, left panel) and primary $PM_{2.5}$ (μg/m³, right panel) at tested electrification levels for the three categories of heavy-duty trucks registered in LA. Evident from these results is the outsized role heavy-heavy-duty trucks play in air pollution near roadways and the greater benefits from electrification of this heavy-duty truck category. *(TAQ-DAC = traffic air quality disadvantaged community; LHDT = light-heavy-duty truck; MHDT = medium-heavy-duty truck; HHDT = heavy-heavy-duty truck).*

Equity Strategies for Truck Electrification for Improved Air Quality

EQUITY STRATEGY: Establish goals, a timeline, and a budget for electrification of LADWP's heavy-duty truck fleet (Class 2b-8), with a heavy-heavy-duty truck carve-out. Consider adding a contractual provision requiring electrification of heavy-duty vehicle fleets over time by companies contracting with LADWP.

Benefit/Impact	Cost	Metric
• Health and air quality benefits increase proportional to the fraction of LADWP fleet electrified. • Electrification of heavy-heavy-duty trucks reduces air pollution emissions five times more than electrification of other truck types, which leads to proportionally greater improvements in health outcomes.	• Dependent on fleet goal, purchase price, and operation and maintenance cost differentials.	• 6% of LADWP heavy-duty truck fleet electrified by 2025 is 240 Class 2b–8 trucks. • 18% of LADWP heavy-duty truck fleet electrified by 2030 is 710 Class 2b–8 trucks. • 40% of LADWP heavy-duty truck fleet electrified by 2035 is 1,580 Class 2b–8 trucks and aligns with Advanced Clean Fleets target.

EQUITY STRATEGY: Establish a citywide 2035 Charge Up LA! heavy-duty truck electrification target, with a heavy-heavy-duty truck carve-out; Collaborate with city agencies to establish a city-owned fleet truck electrification target; Establish heavy-duty electric truck purchase incentives.

Benefit/Impact	Cost	Metric
• 38% and 23% reduction in incremental near-road NO$_2$ and primary PM$_{2.5}$ concentrations respectively from heavy-duty trucks in traffic-impacted disadvantaged communities.	• Cost as low as $0 by leveraging federal and state funds or augmented by LADWP funding.	• 28,000 electric heavy-duty trucks in LA in 2035 (40% of heavy-duty trucks) aligns with Advanced Clean Fleets target.

EQUITY STRATEGY: Locate incentivized charging infrastructure by working with city and regional agencies (e.g., Los Angeles Department of Transportation and Southern California Area Governments) to understand where heavy-duty trucks would ideally be charged.

Benefit/Impact	Cost	Metric
• 400–1,700 GWh demand increase/year.	• $10,000– $125,000 per Class 3–8 truck charger rebate. • $12 to $250 million/year.	• 1,900–3,300 truck chargers by 2025. • 5,400–9,600 truck chargers by 2030. • 14,000–24,000 truck chargers by 2035.

Photo from Getty images 678817331

Distribution Grid Upgrades for Resilience and Access

The transition toward a clean energy future can put additional stress on the distribution system from DERs and electrification—especially EVs and increased use of electricity for heating, cooling, cooking, and hot water. As LA transitions toward clean energy, existing and aging distribution grid infrastructure will need to be updated and expanded to support routine operations, enable interconnection of DERs and electrified loads, and provide access to energy-related services during disaster events. Ensuring a resilient and reliable distribution grid for all communities within LA in a changing climate will require distribution system upgrades that enable equitable access to, and adoption of, clean energy technologies and equitable, resilient access to electricity-related services during disaster events.

South LA resident:

> **"I need to find someone with an upgrade of electric because...we have blockage [outages] all the time when somebody hits a [utility] post and the electricity go off and it cause problem in my home now that I cannot wash [clothes] and watch a TV at the same time. My electric goes off... they have these accidents, these people hit these posts [utility poles], then your electric's out for two hours or so, and it messes up your appliance...your appliance be off and...it's a mess."**

Find additional information on this topic on the LA100 website (**http://maps.nrel.gov/la100/equity-strategies**) and in **Chapter 12** (**https://www.nrel.gov/docs/fy24osti/85959.pdf**) of the full report.

Challenges:

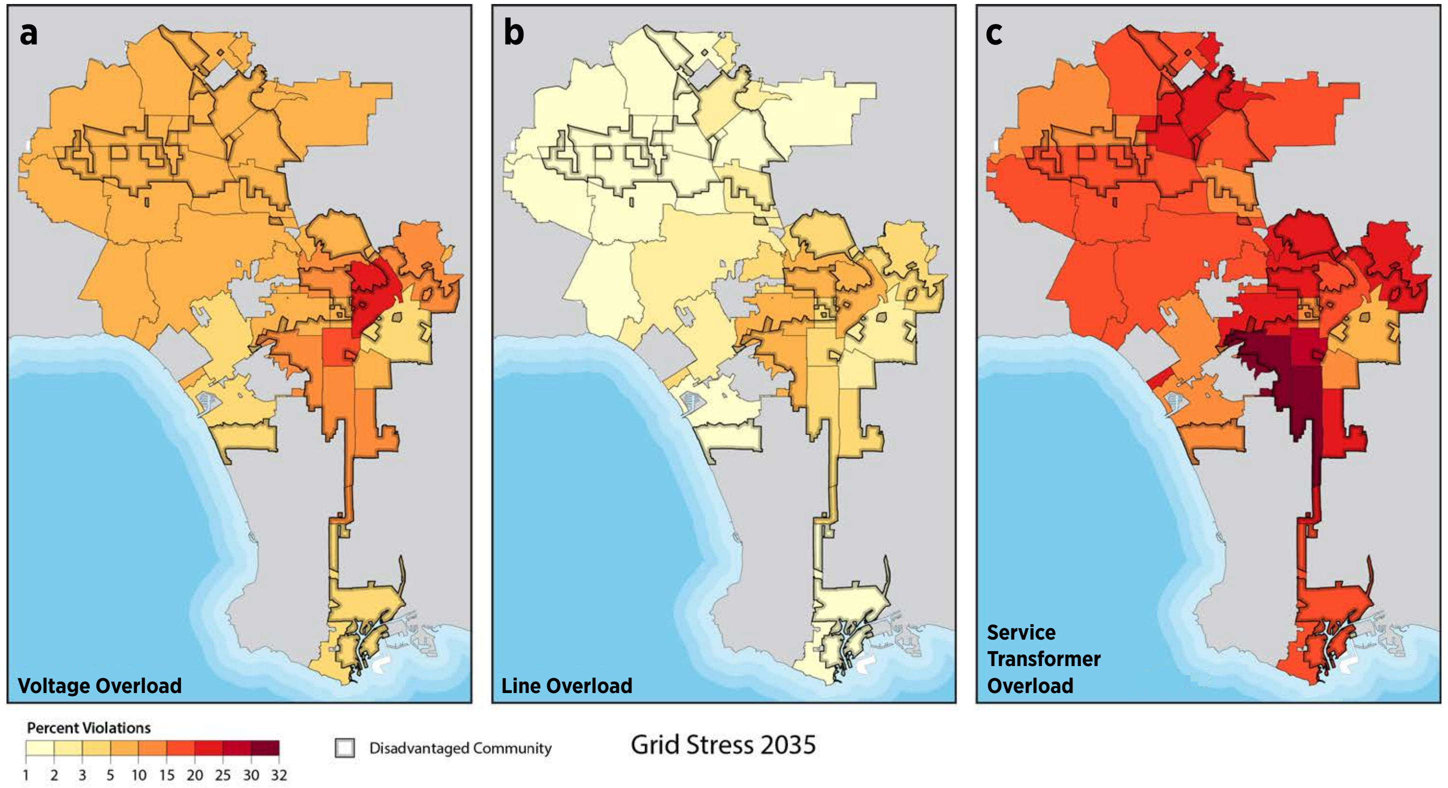
- A significant quantity of deferred maintenance has resulted in grid stress throughout LA, creating reliability challenges. These effects already cause inequitable impacts, with disadvantaged communities and mostly Hispanic communities experiencing more frequent power interruptions than non-disadvantaged, mostly non-Hispanic communities. Without intervention, these trends are likely to become worse with future load growth, particularly in areas with historically small electric usage that could see substantially higher loads with electrification.
- Underground lines offer reliability, aesthetic, and other benefits, yet disadvantaged communities are less than one-half as likely to have underground distribution lines compared to non-disadvantaged community areas (13% versus 27% of lines undergrounded).
- During disasters, the distribution system can be damaged, knocking out power to both customers and critical services. With weather-related disasters likely to become more common with climate change and the potential for significantly higher impacts of electricity outages as more services become electrified—notably transportation—distribution grid resilience becomes critical.

Distribution grid equity metrics include:

- Risk of power outages and grid stress by disadvantaged community status and neighborhood
- Ability for LMI customers to install electrified appliances, EVs, solar, storage, and other technologies without grid or service transformer limitations
- Access to critical services during disasters by disadvantaged community status and neighborhood.

Key Findings

- Grid reliability challenges are unequally distributed and disproportionally impact disadvantaged communities. Modeled levels of grid stress—overloads and voltage challenges that provide a forward-looking proxy for lower reliability—are an average of 14% higher in regions of the city with significant disadvantaged community fractions. This is expected to worsen to 25% by 2035.
- Grid stress represents a key challenge to supporting significantly higher loads from electrification and widespread integration of distributed solar and storage. By 2035, to overcome these challenges, significant increases in distribution capacity are needed.
- Grid limitations may hinder clean energy equity programs. Upgrade costs borne by customers can deter adoption, especially for lower-income customers. Required grid upgrades, if delayed, could also delay programs promoting electrification, solar, and storage.
- Access to critical services—grocery stores, hospitals, emergency shelters, convenience stores, and banking—and residential electricity varies considerably across neighborhoods, even without disaster events. Although disadvantaged communities have generally lower access to services such as groceries, hospital, and convenience stores, they generally have higher access to emergency shelters and banking. These trends continue during disasters bringing some neighborhoods into very low service access particularly for residential electricity.
- Implementing resilience strategies such as microgrids and adding backup power such as solar plus storage to 50% of critical infrastructure can improve service access during disasters. If targeted for communities with initially lower resilience, such approaches could help provide more equitable service access during disaster events.



Grid stress level estimates for 2035-Equity case showing (a) over/under voltages, (b) line overloads, and (c) service transformer overloads

Equity Strategies for Distribution Grid Upgrades for Resilience and Access

EQUITY STRATEGY: Incorporate equity as a metric in prioritizing grid infrastructure investments. Load growth and technology uptake has historically been more prevalent in wealthier neighborhoods, resulting in inequitable grid investments. Incorporating equity metrics into upgrade prioritization—such as grid stress, level of anticipated DER adoption, and demographic data—is crucial to overcoming the inequities seen in access to clean energy technologies, current and future grid stress, and reliability.

Benefit/Impact	**Cost**	**Metric**
• Reduce grid stress, increase reliability, and prevent the grid from presenting a barrier to clean energy adoption in disadvantaged communities.	• Neutral.	• Grid stress (undervoltages, overvoltages, service transformer overloads and line overload) and reliability (e.g., system average interruption duration index and system average interruption frequency index) in disadvantaged communities versus non-disadvantaged communities.

EQUITY STRATEGY: Upsize transformer capacity by a factor of 2–3+ when replacing service transformers to cover load increases and high-capacity services needed with electrification and technology adoption. This is especially important for customers with existing 60-100A service projected to need to grow to 150-200A.

Benefit/Impact	**Cost**	**Metric**
• Reduce grid barriers to clean energy adoption and avoid a need for further upgrades if new transformers have to be upgraded within a few years to accommodate higher growth.	• Medium now; cost reduction in long run.	• Number of transformers upsized systemwide, in disadvantaged community versus non-disadvantaged community, and for clusters of LMI customers outside disadvantaged communities.

EQUITY STRATEGY: Coordinate grid upgrade programs with other programs—such as those aimed at increasing equity in cooling, EVs, home electrification, and electric panel upgrades—so that the grid does not create a barrier for electrification and upgrade deployment. For example, this could include programs that cover any service transformer upgrade costs for LMI customers.

Benefit/Impact	**Cost**	**Metric**
• Prevent grid limitations from being a barrier to electrification, efficiency, and other programs.	• Neutral: potential moderate increase in program cost offset by increased ability for programs to achieve goals.	• Percent of equity-oriented programs that impact customer loads that have a correlated equity-oriented grid upgrade program.

EQUITY STRATEGY: Consider increased investment in underground distribution lines in non-flood-prone portions of disadvantaged communities.

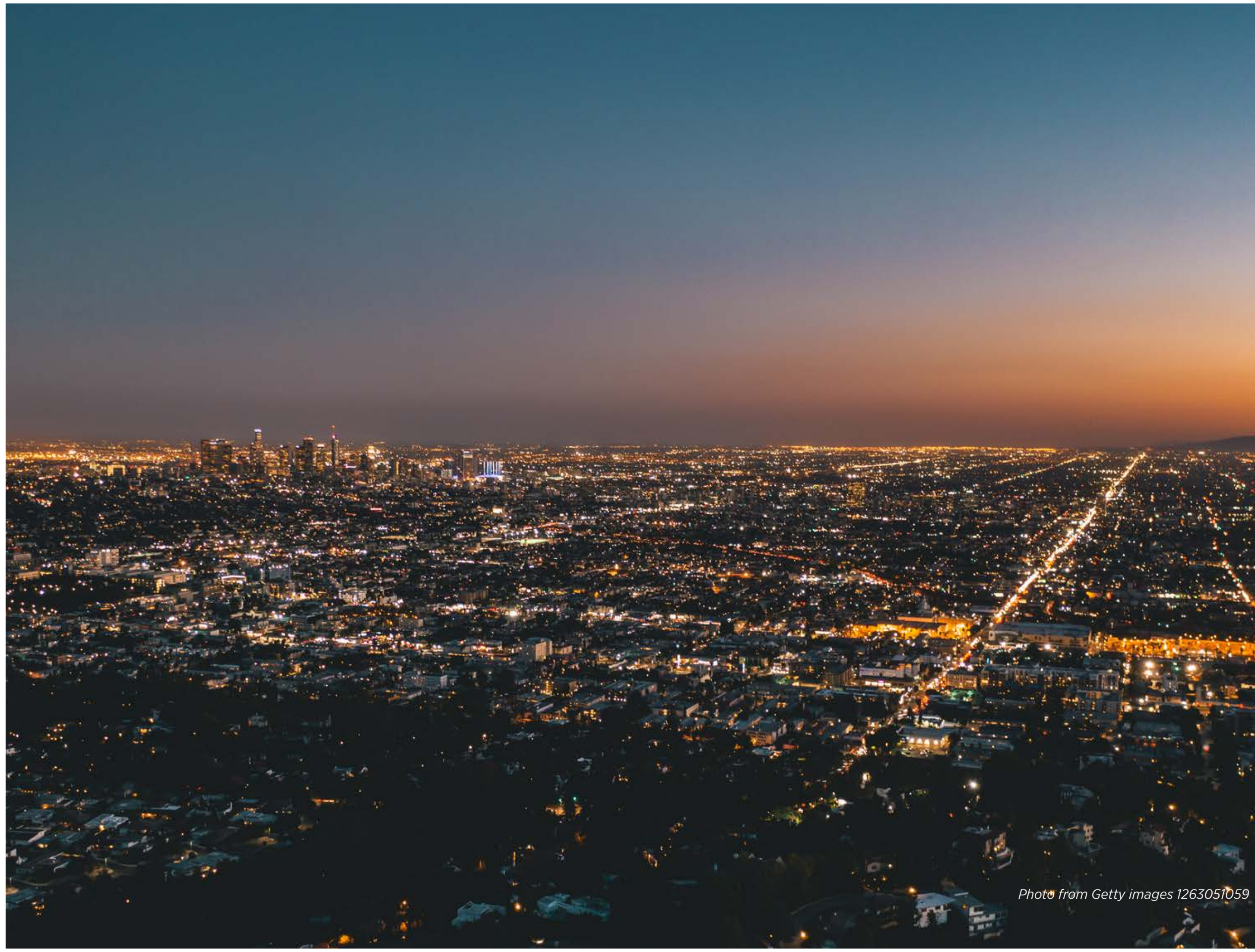
Benefit/Impact	**Cost**	**Metric**
• Increased reliability, improved aesthetics, and higher resilience to most disaster events.	• High.	• Non-disadvantaged communities have 27% of distribution lines underground. Achieving disadvantaged community parity (27%) would require 980 underground miles of the total 3,700 miles of distribution lines in disadvantaged communities, an increase of 520 miles or 43 miles/year through 2035.

EQUITY STRATEGY: Implement community-specific resilience strategies for equitable service access during disasters. This includes targeted programs to prioritize resilient electricity upgrades for critical emergency services in neighborhoods with low non-disaster service access.

Benefit/Impact	**Cost**	**Metric**
• Increased equity in access to critical services.	• Medium to high.	• Number of critical services that can be accessed during disaster events in disadvantaged communities versus non-disadvantaged communities.

EQUITY STRATEGY: Collaborate with community-based organizations for preparedness education and support programs.

Benefit/Impact	**Cost**	**Metric**
• Increased preparedness in disadvantaged communities.	• Low.	• Number of promotoras trained. • Number of community members reached.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COMMUNITY-INFORMED AND DATA-DRIVEN POLICY AND PROGRAM STRATEGIES

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UCLA

Introduction, Framework, and Approach

The University of California Los Angeles (UCLA) recognizes the landmark opportunities and challenges that the Los Angeles Department of Water and Power (LADWP) faces as a result of the Los Angeles City Council's commitment to achieving 100% carbon-free energy by 2035, and from the call for community-driven pathways stemming from the scenarios developed through the LA100 project. As a customer, partner and stakeholder, UCLA has committed to applying its research, relationships and expertise to support a vision of what our public utility and the communities it serves will need to thrive, both financially and otherwise, during this time of immense transition. UCLA's contribution demonstrates the variety of methods and disciplinary perspectives that we integrate to support LADWP and the broader city community in preparing for the challenges that lie ahead.

The UCLA portfolio of work described here reflects UCLA's capacity, commitment and contributions to ground-truth LA100 Equity Strategies rooted in the local context by providing community-informed and data-driven strategies reflecting the policy landscape to provide direct recommendations to LADWP that will help the utility deliver renewable energy at affordable prices, in a manner that is equitable and responsive to the ways in which the unfolding climate crisis is already harming our communities. UCLA's approach is justice centered, promoting mixed methods of community engagement to ensure that priorities are co-developed and responsive to the needs of residents and stakeholders within the region.

The contributing UCLA researchers believe that the LA100 Equity Strategies analyses should go beyond a technology and economics focus, and incorporate broader local context, behavioral, social and political insights to ensure a more just transition. Overlooking these influences, both past and present, fails to represent the co-evolving nature of society and technology, which are critical factors of influence in a large-scale socio-technical transition like what LADWP is faced with. UCLA is especially poised for this work, and to speak to the landscape of related societal and institutional elements, both on individual and organizational levels.

Below, are the main equity dimensions of the transition that UCLA either led or co-led within the LA100 Equity Strategies effort.

Affordability and Policy Solutions Analysis. LADWP must continue to explore and increasingly implement at scale novel and innovative metrics and policies to support customer affordability. This entails adapting its core business model, while also acknowledging current regulatory limitations in terms of revenue collection. UCLA's work considers the paradigm shift inherent with the increased adoption of Distributed Energy Resources (DERs), while also providing a menu and specific recommendations for actionable strategies to improve energy and broader customer affordability across LADWP's service territory beyond the status quo. Additionally, UCLA has considered the affordability impacts on ethnic-owned businesses and assessed financial and other barriers to energy access.

Air Quality and Public Health. While LADWP is not the lead agency for the implementation of ZEV and alternative electrified modes, it plays a crucial role in ensuring that there is sufficient electricity to power these ZEVs and other modes. Therefore, it is essential for LADWP to develop the necessary infrastructure, especially in disadvantaged communities, to support the transition to ZEVs. UCLA's research examines the potential benefits of transitioning from conventional vehicles to ZEVs in LA, emphasizing equity strategies for a just transition. The study provides valuable insights for LADWP to achieve this goal and underscores the agency's unique position to contribute to the improvement of the region's air quality and public health.

Jobs and Workforce Development. A major transformational impact of LA100 will be on jobs, workforce, technology and business development within the energy, infrastructure and broader green jobs sectors in the city. This is a multi-faceted concern, and UCLA developed a multiscale data analysis and modeling platform to project changing occupational and industry needs for green jobs employment throughout the city, including all race/gender demographics groups and disadvantaged communities.

In parallel to this multiscale data platform, the research team conducted an in-depth community case study in Wilmington, CA which has drawn on local knowledge and established relationships in the region with community members, unions and decision-makers to inform the development of workforce development pathways and technology solutions for communities that will be impacted most severely. This work can guide LADWP's strategy at multiple scales and locations, in multiple dimensions, using mixed methods that together could yield a comprehensive perspective to inform this transition strategy.

Housing and Buildings. As the transportation fleet and domestic appliances transition from being powered by fossil fuels to renewable, electrical energy, buildings will become a central conduit of energy flows. These declines in fossil fuel consumption will result in corresponding, but not necessarily proportional, increases in building electricity demand. Due to the criticality of these end-uses for health, safety, and economic activity, the reliability of the power system must improve in a commensurate manner. Via the Energy Atlas, UCLA has enriched historical account level energy usage, expenditures, and arrears data with additional relevant context. This is done by aggregating account level usage to the parcel level and linking these records to building attributes from County Assessors' office, building construction permits data from the city, and sociodemographic information from the Census. Additionally, we are also able to aggregate and visualize these data at the community level, relative to measures environmental pollution burden and community disadvantage from CalEnviroScreen, among others. This work provides a technical foundation from which LADWP can build on in the future to better assess other related equity issues within the energy system such as (1) if there is inequitable exposure to grid disruptions, (2) estimate the economic impact of power outage incidents, (3) support evidence-based prioritization of grid upgrades and if the 100% renewable future will mitigate this situation.

Energy Affordability and Policy Solutions Analysis

Gregory Pierce, Rachel Sheinberg, Daniel Coffee, et al.

UCLA Luskin Center for Innovation, Institute of the Environment and Sustainability and School of Law

I. Introduction

Background and Motivation

Affordability refers to utility customers' ability to pay their bill. The considerable but necessary costs of the transition to 100% renewable electricity by 2035, coupled with the folding in of current heating and transport expenditures into future electric bills, are a key equity concern to LADWP, LA residents and small businesses as they directly influence energy burden, and, indirectly, affect broader affordability considerations for LADWP customers.

Generally, costs incurred by public utilities such as LADWP, including those to transition to renewable energy, must be recovered directly by the utility through revenue increases. This first means increased rates and fees assessed on customers. Since many low- and moderate-income LA residents already struggle with the burden of their LADWP bills and general cost of living, cost and revenue increases at the utility scale have equity- and economic justice-related ramifications that must be directly addressed by policy. It is thus a delicate balancing act to complete the transition to 100% renewable energy without further increasing the financial burdens of already disadvantaged Angelenos, while also making sure that the broader benefits of the transition are equitably distributed. There also remains considerable uncertainty on the exact level and timing of costs associated with the utility's 100% renewable investments.

To that end, the UCLA Luskin Center for Innovation (LCI) and School of Law were commissioned to conduct an Energy Affordability and Policy Solutions analysis as part of the broader LA100 Equity Strategies (ES) effort. This work builds on LCI's past and present engagement on utility affordability and broader equity issues in both LA and California. Our work on affordability in LA100 Equity Strategies was undertaken in complement to and in partnership with NREL's affordability focused-rate structure and on-bill financing modeling. Consequently, our research goes beyond rate (re)design to focus on the landscape of and specific options for, implementable, robust, and long-term structural solutions. Specifically, this entails data, analyses, and strategy architecture that will comprehensively address affordability, building on ongoing efforts. This work is also complementary to the UCLA Center for Neighborhood Knowledge's analysis of ethnic small business energy equity issues, including affordability.

II. Approach

Data and Methods

To undertake this work, we synthesized data from five major types of sources using a mix of quantitative and qualitative methods. We decided to use this approach, rather than using a single one-off original survey design, in part to facilitate replication and refinement of a sustainable strategy architecture by LADWP in the future.

Our main data source categories are:

- Existing primary quantitative, representative, or census-type household and customer data, including LADWP customer-level data shared through the UCLA California Center for Sustainable Communities' Energy Atlas, as well as recurring external survey sources such as the Loyola Marymount University's Los Angeles Public Opinion Survey and the California Energy Commission's Residential Appliance Saturation Study.
- Published reports by LADWP and LA city offices including the Office of Public Accountability and City Controller.
- Stakeholder input, including from LA100 ES Steering and Advisory Committees.
- Academic and peer utility literature review.
- LADWP administrative staff interviews.

Using these data sources, we produced four distinct, but interrelated analyses detailed in brief with key highlights below:

- Describing current and historical legal constraints to addressing affordability.
- Creating a profile of the baseline energy affordability status quo in LA.
- Producing a landscape analysis as well as detailed consideration of and recommendations on implementation for long-term energy affordability metrics.
- Producing a landscape analysis as well as detailed consideration of and recommendations on implementation for long-term energy affordability policy solutions.

III. Findings

Legal Constraints on Affordability Support

We include an analysis of regulatory and legal constraints on LADWP's ratemaking, as careful consideration and understanding of these constraints is crucial in the implementation of any major rate or policy changes. This work included a review of the various agencies and governing documents that determine how LADWP sets electricity rates, which exist at the municipal, state, and, to a lesser extent, federal levels. Regulations reviewed include but are not limited to: California's Constitution and Propositions 13, 218, and 26; California's Public Utilities Code and California Energy Commission regulations; and the Los Angeles City Charter, Municipal and Administrative Codes, City Council Ordinances, and Executive Directives.

First among these constraints, especially in the context of ratemaking for affordability, is Proposition 26's restriction on municipal imposition of new special taxes, fees, and cross-subsidies unless approved by two-thirds in a city-wide vote. Therefore, discussion of structural changes to LADWP's electricity rate structure or discount programs will have to consider working within the bounds of Proposition 26 or pushing for a ballot initiative for approval of more fundamental changes.

Baseline Affordability Profile

In order to map a path forward it is critical to understand the energy affordability status quo facing LADWP ratepayers, especially vulnerable populations. Our Baseline Affordability Analysis provides a wide-ranging overview of electricity affordability considerations for households in LA. This analysis addresses the effects of bureaucratic processes and structures, effects of rates and costs, utility policy actions, and consumption trends as they relate to the planned renewables and electrification transitions. With respect to each of these areas, the prevailing focus is on the experience of in-need households.

We characterize, broadly, the status quo facing in-need LA households with respect to energy affordability and energy burden to answer key questions, including:

- How will the LA100 transition impact affordability for in-need households?
- How do rates and billing affect affordability?
- What is the profile of in-need households with respect to knowledge of cost-saving programs and technologies, use of energy-saving technologies, and other factors?
- What are other potential barriers that might influence the transition to renewables?

A few high-level takeaways from this work are that:

- The whole LADWP bill – that includes four services (power, water, sewer, and trash) in 15 possible combinations – matters for affordability. Power charges must be understood in the context of broader affordability and energy insecurity dynamics.
- Inequitable customer utility debt burden persists across LA city, despite pandemic-era and post-pandemic shut-off moratoria and crisis relief policies. Debt is concentrated in communities of color and stratified by income and housing status.
- Bills from customers on discounted rates represent a small portion of LADWP's residential and total power system revenue, and discount program offerings are under-enrolled and have smaller, less flexible benefits than similar programs in other service areas. Expansion of enrollment and benefits is needed and will have muted negative revenue impacts.
- Electricity affordability burdens constrain energy use among in-need households, and this constraint manifests in potentially health-harming under-consumption of air conditioning, and thus insufficient thermal comfort in extreme heat events.
- Affordability and broader just transition support programs continue to grow at LADWP, but as is true across many utilities, survey data suggests program offerings are hard to navigate for many households, leaving major programs under-enrolled and not benefitting all households in need.

Energy Affordability Metrics

As the LA100 transition moves forward, LADWP will need to commit to tracking and transparently reporting on specific, quantitative affordability outcomes for the city's in-need households to assess whether equity and affordability goals are being realized. Capturing data that accurately reflects real-world outcomes calls for a multifaceted approach that is in keeping with the breadth of ways in which energy costs influence day-to-day life. At the same time, metrics must also be feasible to implement, which requires reliable data collection options.

We conducted a first-stage analysis consisting of background review of pros and cons for each of eight core metric categories to reduce energy burden. Based on the results of this background analysis and input from the LA100 Steering Committee and other stakeholders, our second-stage, detailed analysis focused on four potential metric areas: Discount Programs, Crisis Relief, Thermal Comfort and Energy Insecurity. Two of these metrics, discount programs and crisis relief, relate to specific policies, whereas thermal comfort and energy insecurity can be supported by a wider range of policy strategies. See Figure 1 for our core recommendations for adoption and tracking in these metric areas.

Energy Affordability Policy Strategies

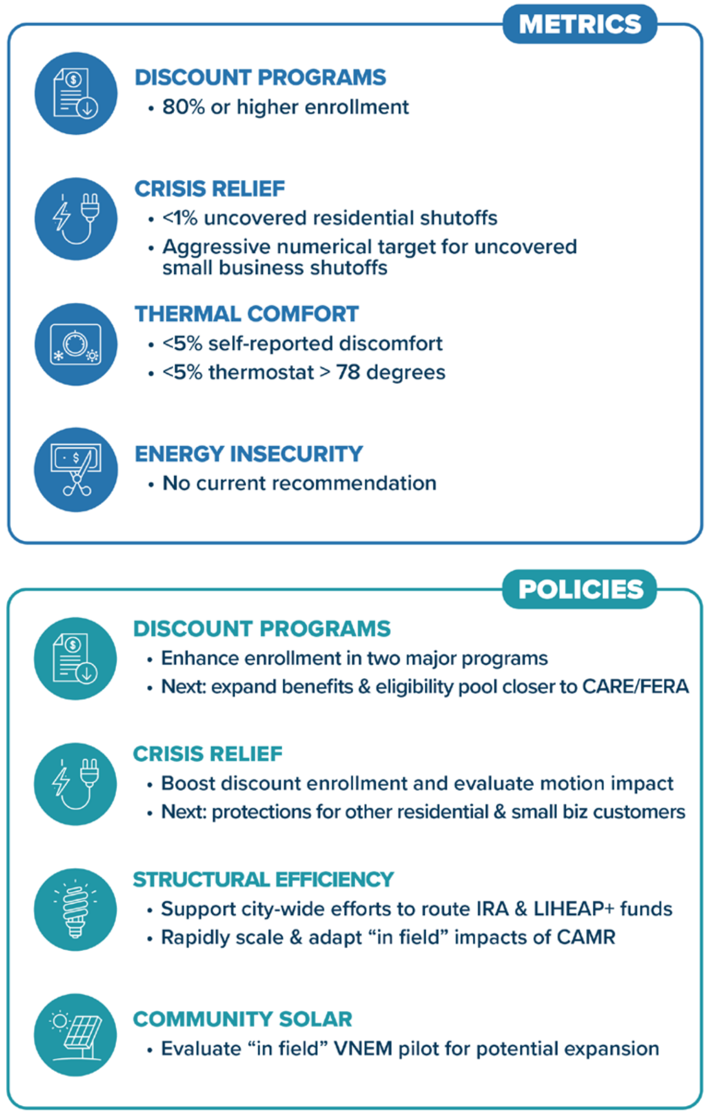
The adoption of robust affordability metrics alone will do little to actually ensure affordability for customers. LADWP will need to take further, short- and long-term policy action to lower energy bills for low-income households and equitably distribute other LA100 benefits. We conducted a first-stage background review of eight core policy strategy categories to reduce energy burden. Based on the results of this background analysis and input from the LA100 Steering Committee, our second-stage, detailed analysis focuses on four potential policy areas: Discount Programs, Crisis Relief, Structural Energy Efficiency, and Community Solar. This analysis serves to complement NREL's focus on Rate Structure and On-Bill Financing.

Two of these policies, discount programs and crisis relief, are affordability specific, whereas structural efficiency and community solar relate to broader energy equity and supply goals.

In each of these areas, LADWP also undertook action during the course of our study. Accordingly, our analysis addresses both how best to evaluate the benefits of these actions and potential pathways to evolve programs further in the long-term.

IV. Recommendations and Next Steps

See the figure below for our core recommendations for adoption of and tracking in these policy areas. Generally, we recommend focusing on data collection and evaluation of novel programs in the near-term, while scaling up and expanding program activities and benefits in the long-term.



METRICS

DISCOUNT PROGRAMS
- 80% or higher enrollment

CRISIS RELIEF
- <1% uncovered residential shutoffs
- Aggressive numerical target for uncovered small business shutoffs

THERMAL COMFORT
- <5% self-reported discomfort
- <5% thermostat > 78 degrees

ENERGY INSECURITY
- No current recommendation

POLICIES

DISCOUNT PROGRAMS
- Enhance enrollment in two major programs
- Next: expand benefits & eligibility pool closer to CARE/FERA

CRISIS RELIEF
- Boost discount enrollment and evaluate motion impact
- Next: protections for other residential & small biz customers

STRUCTURAL EFFICIENCY
- Support city-wide efforts to route IRA & LIHEAP+ funds
- Rapidly scale & adapt "in field" impacts of CAMR

COMMUNITY SOLAR
- Evaluate "in field" VNEM pilot for potential expansion

Small Ethnic-Owned Businesses Study

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[1] UCLA Center for Neighborhood Knowledge
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I. Introduction

Small Ethnic Owned Businesses (EOBs) are a vibrant part of the economy, our culture, and a critical pathway for wealth building in ethnic economies. In the City of Los Angeles alone, there are over 400,000 entrepreneurs, 3 in 5 are people of color, and 1 in 3 are ethnic-owned enterprises. Despite EOBs making up a majority of the business sector in the City of Los Angeles, little research has been conducted to understand the structural barriers EOBs' will face in adapting to climate change and transitioning to renewable energy as well as the opportunities for EOBs to contribute to the transition to cleaner energy. Developing evidence-based policies, programs, and practices to assist EOBs is critical because they employ a significant number of workers and are crucial to the economic growth of disadvantaged communities.

II. Approach

The UCLA Center for Neighborhood Knowledge (CNK) and the UCLA Latino Policy and Politics Institute (LPPI) embarked on a one-year community informed research project to identify and assess financial and other barriers to energy access and affordability for small EOBs and entrepreneurs in the Los Angeles region as LADWP commits to 100% renewable energy.

In the Ethnic Small Business Technical Chapter, we present findings from a survey of small ethnic-owned businesses (EOB) in the Los Angeles area and pilot workshops to better understand their attitudes towards sustainability, energy burden, anticipated climate change impacts, and needs to transition to 100% renewable energy. We conducted this study using a community partnership model where the following organizations informed and provided feedback for the research: Asian Business Association - Los Angeles, Asian Pacific Islander Small Business Program, Dine Black Los Angeles, the Greater Los Angeles African American Chamber of Commerce, Inclusive Action for the City, Los Angeles Legal Assistant, and New Economics for Women. We employed an online survey to draw quantitative findings to inform the Los Angeles Department of Water and Power's transition to 100% renewable energy. The community/business partners, LADWP staff, and prototype workshops provided qualitative insights.

III. Findings

Our analysis of the survey yielded six key takeaways:

- Nearly three-fourths of small ethnic-owned businesses (EOBs) experienced negative COVID impacts and faced numerous barriers to accessing government programs and assistance.
- Almost a third of small EOBs are energy burdened and struggle to pay their utility bills.
- Over half of EOBs reported that they have already been hurt by climate change, and nearly half expect negative impacts for their future.
- Only a tenth of EOBs businesses in the City of Los Angeles are aware of and understand the consequences of LADWP's transition to 100% renewable energy.
- Less than a quarter of EOBs in the Los Angeles region have a sustainability plan in place.
- The priority needs for small EOBs to transition to 100% renewable energy are payment programs to fund upgrades to existing equipment, educational materials, available in multiple languages, to understand how their business can transition and new energy efficiency equipment.

The analysis also finds significant differences in small EOBs by race/ethnicity, industrial clusters, and type of business (home-based vs. storefront).

- African American/Black and home-based businesses face more challenges in paying their utility bills than other racial/ethnic groups and storefront businesses.
- Businesses in low-wage industries feel that climate change will have a negative impact on their businesses and storefront businesses are more likely to anticipate both positive and negative impacts due to climate change.
- Storefront businesses were more likely to select educational materials to understand how their business can transition, and training for existing staff as their top needs to adapt to 100% renewable energy.

In addition to the survey findings, the prototype workshops and qualitative input from stakeholders yielded three additional findings:

- LADWP does not currently have a unified strategy to analyze business data to better understand their small business customers in terms of energy consumption and program participation.
- Direct outreach to small ethnic-owned businesses, small ethnic business serving organizations, and in-language accessibility is necessary to reach entrepreneurs who are typically excluded from traditional business studies.
- Outreach events should include opportunities for two-way interaction -- LADWP providing critical information on small-business programs to EOBs, and EOBs providing recommendations to LADWP on EOB priorities and needs.

IV. Recommendations and Next Steps

Based on the empirical findings from the survey, the prototype workshops and qualitative input from stakeholders, we offer five main recommendations for LADWP:

- Evaluate recent and current small-business energy efficiency programs to identify which have been effective in engaging small EOBs to effectively reduce energy consumption and costs.
- Develop more targeted policies, programs, and practices to assist small businesses and eliminate the participation barriers that EOBs face.
- Partner with business-serving community-based organizations and other trusted agencies to provide technical assistance and better engage their small business customers, particularly EOBs.
- Collect and generate more robust and precise data on energy usage, energy burden and location of their small business customers to prioritize LADWP's outreach to the most disadvantaged businesses and neighborhoods.

Examine the legal mechanism that would enable LADWP to provide monetary assistance to small businesses and EOBs to reduce participation barriers to energy efficiency equipment upgrades which are typically cost prohibitive.

LADWP has taken some important initial steps to achieve equity for small businesses and EOBs, but much more is required. Implementation of new equity policies, programs and practices will not be easy. It will also require joint efforts with governmental energy agencies and utilities. As daunting as this may sound, these entities share a common goal of a just transition to 100% renewable energy. While the study focuses on LADWP, many of the findings and recommendations are applicable to the other entities. Many of the potential solutions are also relevant beyond LADWP.

Air Quality and Public Health

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I. Introduction

We explore the potential environmental and public health benefits of replacing conventional vehicles with zero-emission vehicles (ZEVs) in LA, especially in disadvantaged communities as the city transitions to 100% renewable electricity by 2035.

Los Angeles faces persistent challenges related to air pollution, which disproportionately affects disadvantaged communities. These communities often experience higher levels of traffic-related air pollution due to their proximity to roadways, leading to increased health risks. By examining the potential benefits of ZEV adoption, this study addresses existing knowledge gaps regarding the equitable distribution of air quality and health benefits during the clean vehicle transition.

The findings from this research have practical applications for policymakers, stakeholders, and communities working together to develop a more sustainable and equitable future for LA. By assessing the environmental, health, and economic impacts of increased ZEV adoption, this study can help inform decision-making and ensure that the benefits of cleaner transportation are shared by all residents, including those in historically underserved areas.

II. Approach

We developed three future scenarios in 2035 to assess how ZEV adoption affects various communities, particularly disadvantaged ones. These scenarios are Disparity (varying light-duty ZEV ownership rates), Equity (uniform 50% light-duty ZEV ownership rate), and Equity_MSS (focus on medium- and heavy-duty vehicles and off-road equipment with emission reductions aligned with CARB's Mobile Source Strategy).

We estimated ZEV ownership in each census tract within Los Angeles County for 2035. We also developed an integrated transportation system model to predict traffic volume distribution. Furthermore, we collected emission data for different sources and adjusted them based on ZEV adoption scenarios. Finally, we used a meteorology-chemistry model, to simulate air quality and a health benefits analysis tool, to estimate the health impacts of changes in air pollution levels.

Our approach provides a comprehensive understanding of the potential consequences of different ZEV adoption scenarios on air quality and public health in disadvantaged communities. By comparing these scenarios, we can inform decision-making processes and recommend strategies for cleaner air and healthier communities.

III. Findings

Air Quality:

- Light-duty ZEV adoption leads to relatively even improvements in regional air quality across LA, as the benefits are spread out due to travel between communities.
- Hotspots with high fine particulate matter ($PM_{2.5}$) concentrations are found in city center areas and the southern part of the city.

- As reported in the original LA100 study, the reduction of NO_x emissions led to an increase in ozone (O_3) levels.
- Implementing the Equity_MSS scenario, which involves a higher adoption of zero-emission medium- and heavy-duty vehicles and off-road equipment, leads to the most significant reduction in $PM_{2.5}$ concentrations.

Impact on disadvantaged communities:

- Disadvantaged communities have higher $PM_{2.5}$ concentrations and lower O_3 concentrations compared to non-disadvantaged communities.
- The Equity_MSS scenario provides the most substantial health benefits, particularly for the Hispanic population, highlighting the importance of considering racial and ethnic-specific factors in health impact assessments.

Health benefits and economic gains:

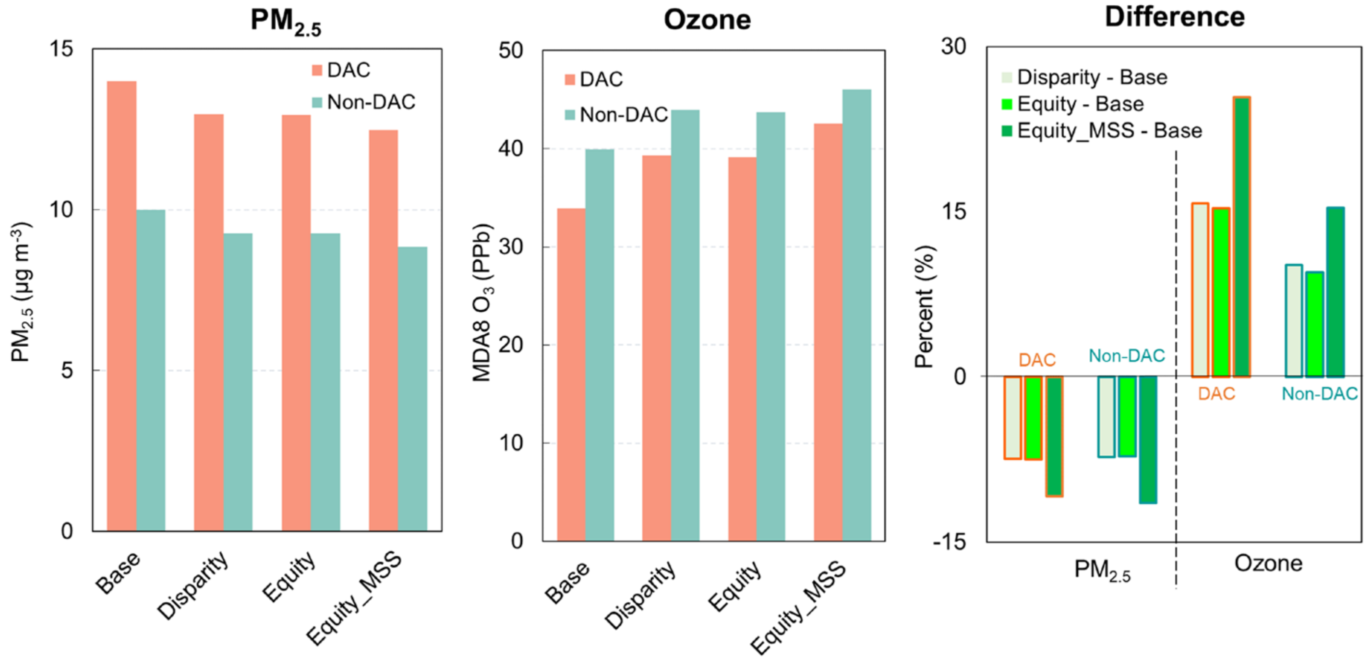
- Transitioning to zero-emission light-duty vehicles could result in $2 billion in health benefits, with $1.3 billion directed toward disadvantaged communities.
- By implementing the Equity_MSS scenario, an additional $900 million in health benefits can be achieved, with $500 million specifically benefiting disadvantaged communities.

IV. Recommendations and Next Steps

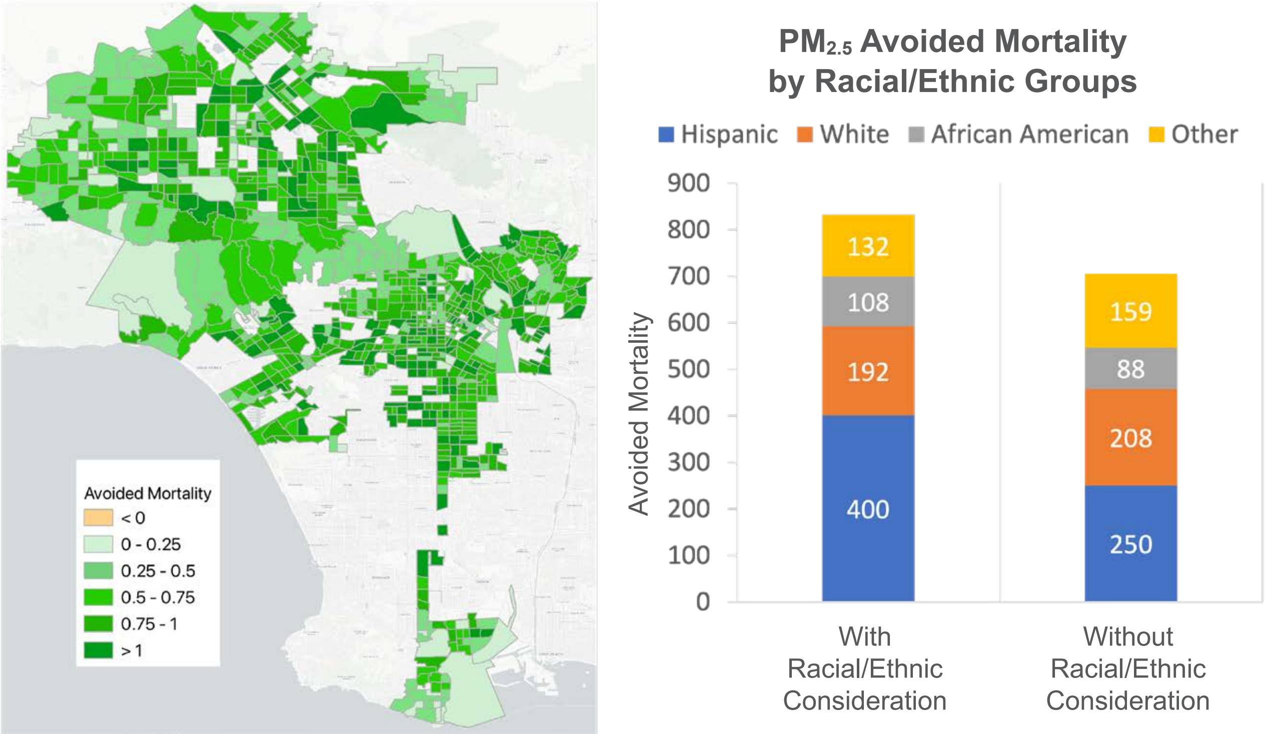
Based on our results, we recommend that LADWP collaborate with other responsible parties, focusing on the following next steps:

- Encourage vehicle electrification to reduce $PM_{2.5}$ levels to provide significant public health and economic benefits.
- Focus on electrifying medium- and heavy-duty trucks, as this will bring extra health benefits, especially for disadvantaged communities.
- Employ ethnic- and race-specific dose-response parameters in health benefits analysis to enable more equitable evaluations of the health benefits from air quality improvement strategies.
- Continue reducing both NO_x and VOC to lower O_3 levels and create a more complete strategy for managing air quality in LA.

In conclusion, our study highlights the need for comprehensive air quality control strategies that consider the complex relationships between pollutants and focus on fair treatment for all communities. By understanding these complexities and targeting the right strategies, decision-makers can improve public health and ensure a just transition toward a cleaner future.



$PM_{2.5}$ (left) and ozone (middle) concentrations averaged over disadvantaged community and non-disadvantaged communities in Los Angeles City for 2017 Base, and 2035 Disparity, Equity and Equity_MSS scenarios, as well as the relative differences between the Disparity, Equity, and Equity_MSS scenarios compared to the base scenario (right).



$PM_{2.5}$-related avoided mortality in Los Angeles City, comparing 2035 Equity_MSS and 2017 Base scenarios. Spatial distribution (left). Differences contrasting the use of a uniform beta (i.e., change function) with racial/ethnic-specific beta (right). This visualization emphasizes the disparities in health outcomes when incorporating race and ethnicity in the analysis. "Other" includes Asian American, Pacific Islander, and Native American populations.

Green Jobs and Workforce Development

Raul Hinojosa, Abel Valenzuela, Leticia Bustamante, Marcelo Pleitez, Magali Sanchez-Hall, Saul Ruddick-Schulman

I. Introduction

This research focuses on creating an equitable workforce development strategy as an integral element of a "Just Transition" to 100% renewable energy generation by LADWP in the context of the emerging green jobs economy for LA City and LA County. We developed a LA100 Public Access Data Calculator that allows for multiple community stakeholders (including ratepayers) to engage in environmental and energy justice planning. We also conducted a Community Case Study of Wilmington and created a Community Engagement Approach to identify multiple pathways for meaningful community engagement and planning for energy, ecological, and environmentally- just transition with a primary focus on jobs and workforce development connected to LADWP investments, policies, and existing programs.

II. Approach

The LA100 Public Access Data Calculator was created to allow stakeholders to explore multiple policy questions with respect to historical employment equity of LADWP and Green Jobs, as well as potential future scenarios for greater employment equity for LADWP and Green Jobs in Los Angeles (both at LADWP and outside of LADWP). The Calculator was based on well established modeling techniques such as Input-Output techniques and Social Accounting Matrices, and was customized and expanded as a unique tool designed to address a series of questions specific to the Equity Strategies project and LADWP (see Findings below).

Wilmington Case Study and Community Engagement

Wilmington, CA is known as an example of ground zero for pollution exposure locally and nationally. To complement our LA100 Public Access Data Calculator, we conducted a case study in Wilmington, CA to gather direct input from typically excluded community members that have often been excluded historically. This engagement involved monthly meetings over a period of six months, with two main goals in mind: (1) educating the community about green jobs and LADWP, and (2) understanding the obstacles in accessing such jobs. The feedback from this engagement is invaluable in informing the development of an effective LADWP and green jobs workforce development plan that includes building a green job pipeline to meet LADWP transition demands and addresses the specific needs and challenges faced by the community. Our approach was based on leading disadvantaged community indicators that revealed the environmental racism inflicted on a population that is approximately 90% Latinx and was subjected to high levels of emissions from the oil industry and Port of Los Angeles. In our community engagement meetings we developed a survey to measure before and after levels of knowledge of residents on environmental racism, green jobs, workforce development and LADWP.

III. Findings

What was the historical growth of green and non-green jobs in LA City and County between 2011 and 2019, as well as the "direct" and "indirect" employment impact of green job creation on green and non-green jobs?

- Our findings show that total green jobs grew more rapidly compared to total non-green jobs in LA City from 2011 to 2019. Green jobs grew 8.2% while non-green jobs grew 4.6%. We also found that direct green jobs are growing at a rapid pace, and are influencing the growth of non-green jobs due to green job linkages with other sectors that are not considered "green." This is creating a multiplier growth in non-green jobs.

What is the equity composition of employment by race and gender (Latinx, African American, White, Asian and other workers) for all Green Jobs in terms of Zip Codes and Disadvantaged Communities?

- Latinx represent nearly 48% of the workers holding Green Jobs, while whites hold 32% of the Green Jobs positions in the City of LA. The most underrepresented race in Green Jobs are American Indian or Alaska Native people, with 0.1% of total Green Jobs.

What is the race and gender of LADWP workers by industry and occupation, inside and outside of the LA Basin, by work location and residency as well as by Zip Codes and disadvantaged communities?

- Most LADWP workers, who are relatively well paid, do not live in disadvantaged communities. However, Latinx and African American workers make up the largest share of LADWP employees living in disadvantaged communities and earn the lowest wages of LADWP workers living in both disadvantaged communities and Non-disadvantaged communities. This is because Latinx and African American workers are more concentrated in lower wage occupations and activities, but do earn comparable wages to workers of other races in both higher and lower paid occupations.

What are the likely future scenarios for Green jobs in LA City and Country (direct, indirect and induced), taking into account future ethnic demographic projections to identify "gaps" needed to be filled in order to achieve future equity in Green employment?

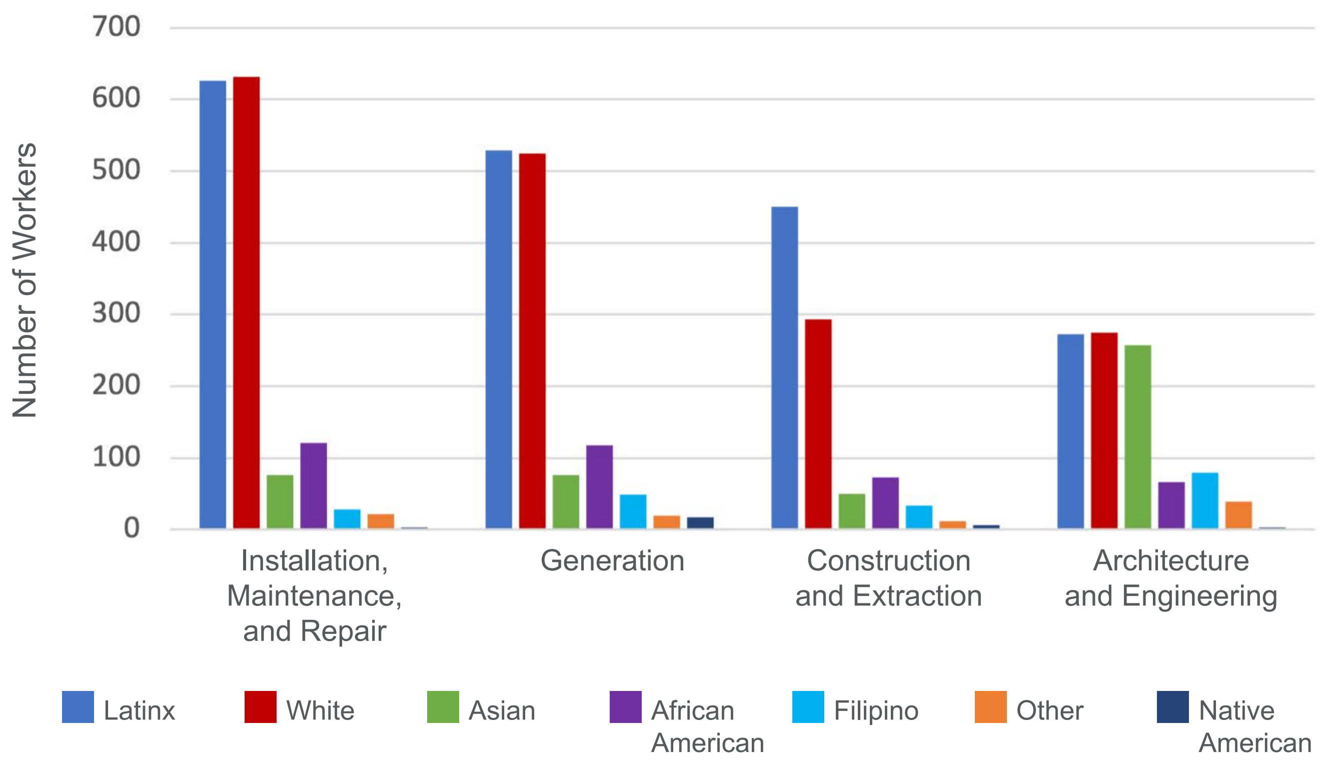
- Total green jobs in LA County are expected to grow 20% from 2019 to 2035, while non-green jobs are expected to grow 30%. The "gap" analysis shows that the number of Latinx green job workers will have to grow faster to keep up with higher demographic growth.

What are the potential future employment scenarios for LADWP by industry and occupations based on LA100 modeling of alternative technology investment options, including employment "gap" projections by race and gender category and geography?

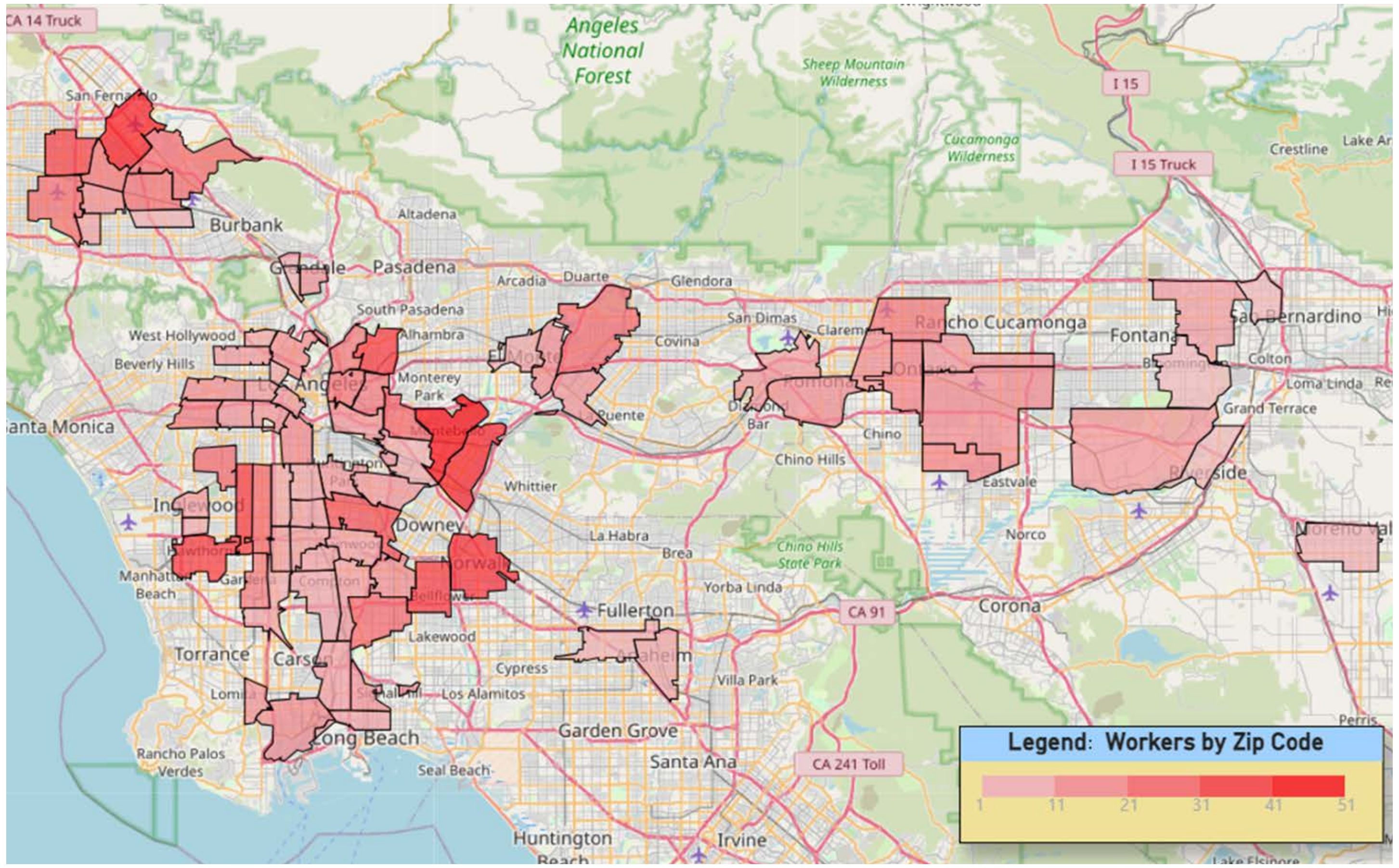
- Future LADWP employment scenarios indicate important growth in large LADWP industry sub-sectors and occupations, which will require more rapid recruitment and targeted training of Latinx and African American workers

Based on estimates for Green jobs and LADWP scenarios for workforce development training needs by industry and occupations, what are the best future equitable employment transition strategies that could be implemented?

- LADWP will need to manageably invest in and implement new Green Jobs Workforce Development pilot projects designed to expand training in particular projected occupations and to specifically recruit workers from growing race and gender groups in disadvantaged communities.



LADWP total workers in power sector by occupation and ethnicity.



LADWP workers living in zip codes with high concentration of DACs.

To assess the participants' familiarity with green jobs and workforce development for the Wilmington Case Study through the community engagement meetings, we created a survey that was administered before the community engagement sessions. The purpose of this survey was to inform the development of the curriculum. Additionally, the same survey was administered after the completion of all community sessions to track the increase in understanding and confidence in the material. The survey was completed anonymously by the same 20 participants on both occasions. Based on our analysis, the main findings are:

- The level of understanding about green jobs increased greatly, with 85% of participants indicating an above average or very high understanding compared to only 15% in the first survey.
- The level of understanding about the purpose of LADWP increased greatly, with 70% of participants indicating a higher than average or very high understanding in the second survey, compared to only 55% in the first survey.
- While participants feel better informed about job opportunities in their communities, some still feel like they could use more guidance. The number of participants who felt very empowered or extremely empowered more than doubled between the first and second survey. However, 60% of participants still felt either slightly or moderately informed.
- Participants feel more comfortable about training others, with 75% of participants indicating they feel either very empowered or extremely empowered to train other community members on green jobs and workforce development, compared to only 50% in the initial survey. Furthermore, only 1 participant indicated feeling slightly empowered, compared to 7 people in the initial survey.
- All participants maintained their interest in having a green job, with 80% indicating their desire for a green job in the second survey, compared to 75% in the initial survey.
- There was a slight increase in participation in workforce development programs, with 2 more participants indicating participation in a workforce development program in the second survey, and four others unsure if they had been part of a program. In the initial survey, 90% of participants indicated they had never been a part of a workforce development program, with only one participant stating they participated in a program.
- Interest in certification and training slightly increased, with 75% of participants indicating a very high interest in receiving certification or training from LADWP in the second survey, compared to 55% in the first survey. In both surveys, all participants had indicated an interest in receiving certification or training from LADWP.

IV. Recommendations and Next Steps

This report shows that the City of Los Angeles can achieve a just transition to renewable energy and a green jobs future, but requires community engagement and workforce development for green and LADWP jobs to close the inequality gaps in gender and race employment.

Expanding and maintaining stakeholder access to a Green Jobs Calculator can help direct investments in green jobs workforce development centers in communities that are usually marginalized, such as Wilmington, CA. A just transition for LADWP and green jobs will require a skilled and prepared workforce, and a higher paying workforce development pipeline that can cost-effectively be directed to disadvantaged communities in order to create a fair distribution of jobs in the new green economy. Our Wilmington Case Study and Community Engagement approach shows that the community is ready to participate in developing the new training pipeline for green jobs and workforce development pilot projects. More projects like this could be created by accessing Justice40 funds that require partnerships with community based organizations to invest in more disadvantaged communities Green Jobs LADWP Workforce Development.

Service Panel Upgrade Needs for Future Residential Electrification

Eric Daniel Fournier, Ph.D. and Stephanie Pincetl, Ph.D.

California Center for Sustainable Cities, Institute of the Environment & Sustainability, University of California Los Angeles

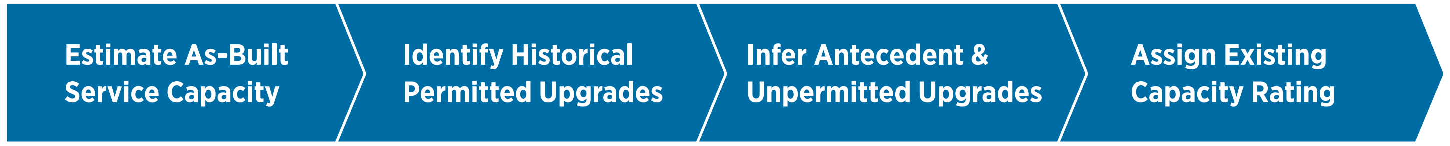


Figure 1. Methodology overview diagram.

I. Introduction

The goal of the electrical panel analysis was to understand the landscape of existing customer-owned electric service panels (a.k.a. load centers) within the city of LA. Utilities typically do not record information about hardware components that are installed on the customer side of the meter. Rather, they tend to only track the status of the utility-owned distribution system hardware that resides on the utility side of the meter. This analysis of customer owned service panels is explicitly focused on the equity implications associated with expected future growth in the electrification of the light-duty transportation vehicle fleet and domestic end-use appliances. Understanding the implications for customer owned infrastructure is important as all of the different transition pathways that were previously analyzed as part of the original LA100 analysis assumed significant increases in these types of electrification. The degree to which the existing capacity of customer's service panels might be a barrier to the adoption of these new technologies, particularly within disadvantaged communities, has so far been poorly understood.

The results of this work include detailed estimates of the as-built and existing service capacities of the load center hardware installed at all of the single and multi-family properties throughout LADWP's service territory. We also provide estimates of the total number of properties that will likely require panel upgrades to support full electrification going forward. Detailed analyses of these findings focus on the differences in the scope of the challenges in this area for the city's disadvantaged versus non-disadvantaged communities. Cost estimates associated with these upgrade requirements were only able to be generated for the single-family context due to high levels of uncertainty within the multi-family sector. The analyses concluded with a set of summary findings and recommendations for strategies that could better promote equitable electrification going forward. As part of this discussion, we point to new technologies and approaches to panel sizing requirements that could potentially reduce the need for service capacity upgrades, and their associated costs.

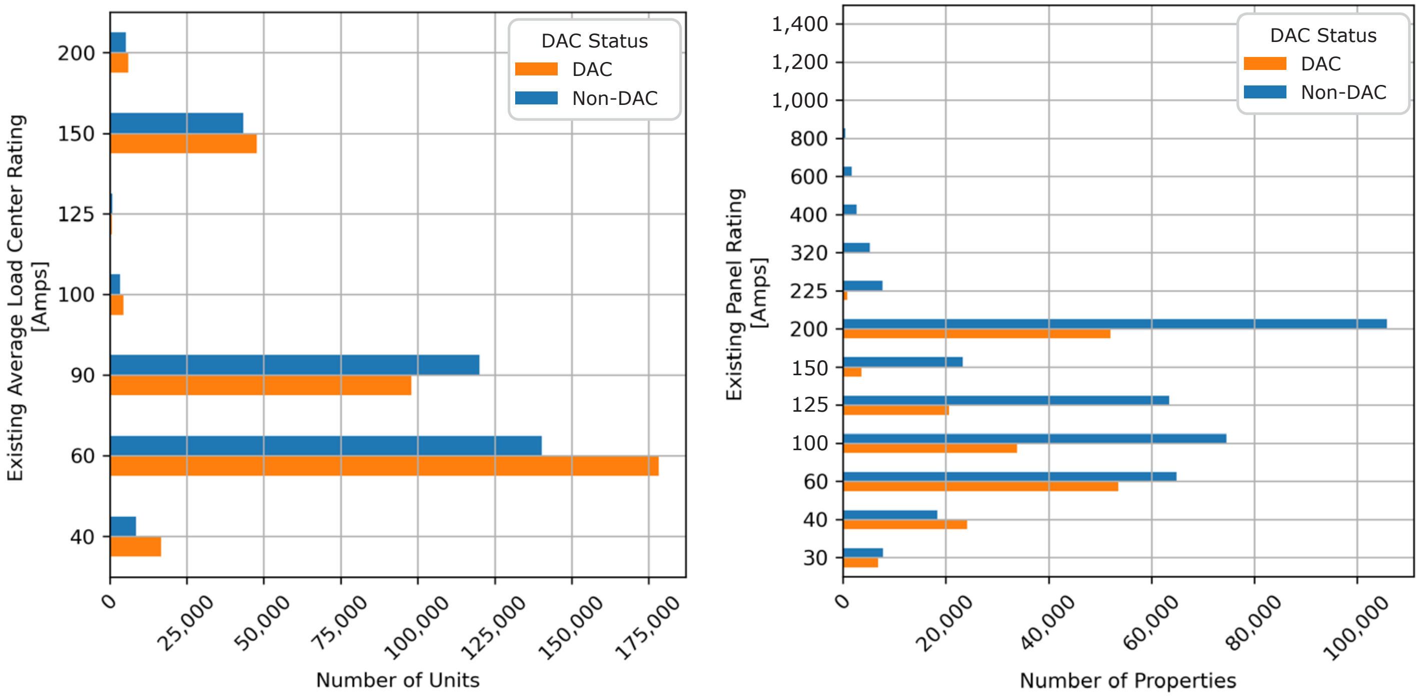
II. Approach

In order to estimate the capacity of existing customer owned load center hardware, and the potential need for hardware upgrades to support future electrification, we developed a quantitative methodology that draws upon a combination of data from historical electrical code requirements, literature analyses, local parcel level building attributes, and historical building construction permit applications throughout the city. A high-level overview of this methodology is provided in Figure 1.

III. Findings

We first estimated as-built panel sizes for each parcel in the city based upon code recommended panel sizing guidelines at the time of each building's construction. From an equity standpoint, it is important to note that both the age and size of single-family homes are strongly correlated with the disadvantaged community status of the census tracts in which they are located. For example, the average disadvantaged community single-family home is 1,427 ft2 and was constructed in 1948 while the average non-disadvantaged community home is 2,094 ft2 and was built in 1960. This means that the non-disadvantaged community homes are 46% larger and 12 years newer, on average, than their disadvantaged community counterparts. As we shall discuss, these differences manifest important equity implications in terms of the likely need for panel upgrades to support future decarbonization of the residential sector.

In analyzing the building permit data, and specifically, permitted panel upgrades, we found that there has been a roughly ~2x faster rate of turnover of panel upgrades for single family dwellings within the non-disadvantaged community census tracts, and the rate at which the number of annual upgrades is occurring has been steadily increasing over time. The average annual total permitted panel upgrades over this period (1996-2022) were 2,189 per year for disadvantaged community census tracts and 4,234 per year for non-disadvantaged community households. However, in the multi-family sector, this panel turn-over was significantly slower with only around ~200 properties being upgraded each year, in recent years. Overall, the distribution of cumulative permitted panel upgrades shows the highest concentration of permitted upgrades in single family homes has occurred within the city's more affluent coastal, hills, and inland valley neighborhoods.



Overview of the estimated existing load center rating capacities for the city's single-family (left) and multi-family (right) housing stock disaggregated by disadvantaged community status.

By combining these panel upgrade permit data with a novel simulation approach, we were also able to assess the likelihood of upgrades having occurred before the time period of permit data availability as well as in the case of upgrades that were otherwise unpermitted. By combining these approaches, we developed final estimates for the number of existing panels of different sizes throughout the city.

Future Upgrade Requirements

Generally, ≥200 Amps is considered sufficient panel capacity for the typical single-family home to support full electrification of all existing fossil fuel end-uses as well as the addition of a single EV fast charger. It is possible for similarly sized homes with panel sizes ranging between 100-200 Amps to fully electrify without panel upgrades. However, doing so will be more challenging, and likely require the selection of lower power appliances, the use of load splitting hardware and/or dynamic load management systems. Homes whose existing panels have rated capacities <100 Amps, are considered very likely to require an upgrade in order to fully electrify. For tenant sub-panels within multi-family properties, these thresholds are different, mostly due to the assumption that they will not be the interconnection point for EV-charging infrastructure. In the multi-family case, the thresholds for likely, potentially, or unlikely upgrades shift to <90 Amps, ≥90-150 Amps, and ≥150 Amps, respectively. Table 1 below provides the percentage of properties that fall into these different categories for each property class based upon our estimates of their existing panel capacity ratings.

Moving beyond these simple threshold based methods, using information about the size distribution of service panels at properties where permitted upgrades have occurred, we estimate that a total of 67% of the single-family homes in the non-disadvantaged community cohort and 71% of the homes in the disadvantaged community cohort have existing panel ratings that are deficient with respect to the capacity of the hardware that would most likely be installed if an upgrade were to be performed today. These figures are based upon the individual size characteristics of each property and assume that the same recommended panel sizing calculation methods that have been historically used would remain unchanged, though this may not be the case going forward given new technologies and standards. For the multi-family context, the proportion of properties that will very likely need to be upgraded to support full electrification is 67% in disadvantaged communities versus 56% in non-disadvantaged communities.

We estimate that the total cumulative costs of upgrading all of the single-family properties with deficient capacity service panel hardware to be between $279–$629 Million within disadvantaged community census tracts and in $502–$1,129 Million in the non-disadvantaged communities. These are non-trivial figures and represent a significant potential barrier for property owners, particularly within disadvantaged community communities with less financial resources. It is possible that many of these panel upgrades can be avoided, or at least deferred, if intelligent electrification strategies are pursued and code mandated panel sizing calculations can be updated to accommodate the capabilities of new technologies and more realistic load assumptions. We did not estimate costs for multi-family upgrades due to the heterogeneity of the load center hardware and communal/unitary load configurations involved.

IV. Recommendations and Next Steps

- Support efforts to retrofit the capacity of the load centers at existing residential buildings to 200 Amps for single-family homes and 150 Amps for multi-family units.
- Prioritize alternative approaches to enlarging capacity, as further capacity increases will likely require significant investments in upstream transmission and distribution systems.
- Leverage different sources of external funding support for panel upgrades that are currently being made available at both the state and federal levels, especially those offered through CA's TECH program and the Federal Inflation Reduction Act (IRA).
- ncentivize the installation of 120-Volt electric appliances and/or circuit splitting hardware when pursuing electrification retrofits.
- Incentivize the adoption of new smart-panel and smart breaker software-controlled load center hardware.
- Support the revision of code required methods for calculating the capacity of load center hardware to take into account more realistic assumptions about concurrent loads and the new load management capabilities of smart panel/breaker systems.
- Begin tracking both the capacity and command/control capabilities of customer installed load center hardware.
- Advocate for new City, State, and Federal programs that provide more direct funding support for multi-family property load center upgrades with detailed prescriptions for how costs/incentives will be split between tenants and property owners.

Summary overview of the proportions of single and multi-family properties that will likely require panel upgrades to support full electrification based upon commonly used panel rating classification thresholds

Property Class	Panel Rating Classification	Upgrade Required for Future Full Electrification?	Disadvantaged Community Properties	Non-Disadvantaged Community Properties
Single-Family	<100 Amps	Likely	45.8%	25.9%
	≥100 & <200 Amps	Potentially	30.6%	45.1%
	≥200 Amps	Unlikely	23.6%	29.0%
Multi-Family	<90 Amps	Likely	66.9%	56.3%
	≥90 & <150 Amps	Potentially	19.2%	30.0%
	≥150 Amps	Unlikely	13.9%	13.7%

Conclusions and UCLA's Vision for LA100 Equity Strategies Beyond this Report

UCLA is committed to working collaboratively with LADWP staff on continued knowledge transfer, advising on metrics and developing evaluation architecture that can be implemented and iterated over time. UCLA has been committed to a fulsome and productive collaboration with the National Renewable Energy Laboratory (NREL) for the life of this project, and, importantly, an ongoing partnership with LADWP to see the findings of this study implemented.

Ensuring greater equity for the residents of Los Angeles, the constituents and partners in our public utility, is a process that takes time. The legacy of redlining and the current inequalities in the city, including exposures to environmental contamination, poverty, unaffordable housing, and more, are a result of many decades of history. LADWP has an important role to play to ensure that everyone has equal access to energy sufficiency at affordable costs, while maintaining the fiscal integrity of the utility.

One of the important tasks going forward includes assessing the technical recommendations of NREL's 100 percent renewable analysis, and their implications for the region and for equity. This deep dive and unpacking needs to be done with communities across Los Angeles such that there is deep engagement and dialogue about the choices before us. UCLA can work to develop the assessments and materials that can frame these discussions and help organize them.

NREL's report has important equity implications for LADWP, both internally and externally, and its novelty requires new thinking about metrics to evaluate equity over time. UCLA can help co-develop tools with LADWP (such as using the Energy Atlas for a database that is spatially enabled) in conjunction with the Luskin Center's equity analysis to propose different strategies for measurement and tracking as the Department determines priorities with communities and its internal needs. UCLA can bring best practices that may help in this development.

Included in the endeavor of developing energy metrics is more work on energy burden. This may include both the financial burden on households and businesses in the region, particularly small businesses, but also the burden that very large scale consumers of electricity create, for example very large luxury homes. This is not analysis that has been commonly done, anywhere and is important for LADWP such that it can meet 100% renewable generation in a manner that minimizes harm. Through a deep look at rates and the inequalities in consumption alongside the power division's capacities for distributing energy across the region, through to increased need for generation to meet the increasing consumption of electricity with electrification, a better understanding of the requirements for the transition will be possible. This can include such things as materials necessary (metals and minerals), land and transmission impacts and more. Such cost factors are an important part of equity analysis and the impacts of 100% renewable. UCLA is well placed to provide this analysis for the agency to consider.

NEXT STEPS

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LA100 Equity Strategies is just the beginning of our journey to a more equitable clean energy future. The strategy options presented in this report will serve as guidance for our city's transition. We have a bold goal, and we have the knowledge and strategies needed to reach that goal. Now it is up to us, the city of Los Angeles, to make it happen.

The city of Los Angeles is its people and the unique, diverse communities that they form. LADWP has a mission to serve the people of LA with reliable, resilient, affordable energy. We know that past injustices have resulted in an inequitable distribution of the costs and benefits of our energy system. We know that improving equity requires intentionally designed strategies and actions. The guidance provided by the community-based organizations represented on the Steering Committee helped us to better understand and appreciate the priorities and challenges of some of the city's most vulnerable communities. The clean energy transition requires a new way of thinking about how we share in both the benefits and costs of our energy systems: Available does not mean it is accessible to everyone. Lowest-cost energy is not affordable to many of our residents. Life-saving technology such as air conditioning may be commonplace to some, but out of reach for others. And equal is not the same as equitable.

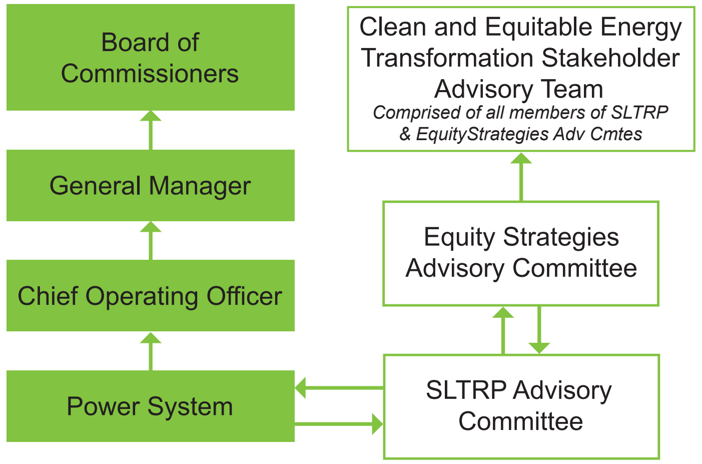
Our commitment is to make future decisions by leading with equity. This means:

- Carefully considering and implementing a subset of the strategies developed through this work
- Engaging communities in the decision-making process and co-designing our energy future together
- Measuring our progress along the way to provide transparency and accountability.

Building on LA100 Equity Strategies, LADWP will update the SLTRP, LADWP's roadmap for decarbonization and modernization. Changes that will be part of the 2024 SLTRP include:

- **Energy Burden and Affordability.** In addition to evaluating alternatives based on reliability and decarbonization, scenarios will also include comparisons of energy burden and relative affordability.
- **Local Air Quality.** Future plans will also include relative comparisons of improvements to local air quality, driven primarily by transportation and building electrification.
- **Community Outreach.** Expanding on LADWP's industry-leading public engagement, LADWP will also include a broader campaign to increase awareness of decarbonization plans and program offerings.
- **The Equity Strategies Advisory Committee.** Continuing the model established through LA100 Equity Strategies, a newly-formed Equity Strategies Advisory Committee will have an active role throughout the SLTRP process.

- **Equity Strategies Program Development.** The Equity Strategies Advisory Committee will provide important contributions on a full range of strategic options, evaluations and design of existing and new programs, planning for equitable infrastructure investments, green jobs workforce initiatives, data analytics, and metrics development.
- **The Clean & Equitable Energy Transformation Stakeholder Advisory Team.** Collectively, the Equity Strategies Advisory Committee and the SLTRP Advisory Committee will form the Clean & Equitable Energy Transformation Stakeholder Advisory Team as illustrated in the figure.



The Clean & Equitable Energy Transformation Stakeholder Advisory Team

LADWP cannot do this alone. The partnerships that are required to move into a carbon-free future are tremendous. We have already seen the passion and determination of the communities and people who participated in this work, but more engagement is needed. City and county agencies must work closely on policies, programs, and strategic initiatives in order to create more energy efficient housing, access to cooling and EV charging, truck electrification, and to develop cleaner transportation options for Angelenos. More importantly, our community leaders, elected officials, industry leaders, and private organizations must engage to ensure no one is left behind in this transition. It will require difficult conversations about money, priorities, and a hard look at our current regulations so that the city can evolve to better serve its people. All of its people.

Together, we'll change the future of our city. We'll change the future of our nation. We'll build an equitable clean energy future for all.

Acknowledgements

LADWP, NREL, and UCLA would like to thank the following organizations for guiding our team throughout the duration of this project:

Steering Committee

Climate Emergency Mobilization Office (CEMO)
Climate Resolve
Community Build
DWP MOU Advisory Committee
Enterprise Community Partners
Esperanza Community Housing
Los Angeles Alliance for a New Economy (LAANE)
Move LA
PACE
Pacoima Beautiful
RePower
SLATE-Z
South LA Alliance of NCs
Strategic Concepts in Organizing and Policy Education (SCOPE)

Advisory Committee

Center for Energy Efficiency and Renewable Technologies (CEERT)
Chief Legislative Analyst (CLA)
Civil & Human Rights and Equity Department
Council District 01 - CM Eunisses Hernandez
Council District 02 - CM Paul Krekorian
Council District 03 - CM Bob Blumenfield
Council District 04 - CM Nithya Raman
Council District 05 - CM Katy Yaroslavsky
Council District 06 - CM Imelda Padilla
Council District 07 - CM Monica Rodriguez
Council District 08 - CM Marqueece Harris-Dawson
Council District 09 - CM Curren Price
Council District 10 - CM Heather Hutt
Council District 11 - CM Traci Park
Council District 12 - CM John Lee
Council District 13 - CM Hugo Soto-Martinez
Council District 14 - CM Kevin de Leon
Council District 15 - CM Tim McOsker
Housing Authority of the City of Los Angeles
International Brotherhood of Electrical Workers (IBEW)
LA Cleantech Incubator
Los Angeles City Planning Department (LACP)
Los Angeles Department of Transportation
Los Angeles World Airport (LAWA)
Natural Resources Defense Council
NC Sustainability Alliance
Office of Public Accountability (Rate Payer Advocate)
Office of the Mayor
Port of Los Angeles (POLA)
Sierra Club
Southern California Association of Non-Profit Housing
USC Equity Research Institute

A special thanks to the residents of the following communities who provided their expertise, insights, and ideas through participation in the community listening sessions:

South LA*	March 29, 2022 @ 6 p.m.
SF Valley*	March 29, 2022 @ Noon
East LA*	March 30, 2022 @ 6 p.m.
Harbor*	March 31, 2022@ 6 p.m.
South LA*	April 27, 2022 @ 6 p.m.
SF Valley	September 21, 2022 @ 1 p.m.
South LA 2	October 25, 2022 @ 10 a.m.
Wilmington 1	October 25, 2022 @ 6 p.m.
Wilmington 2	October 26, 2022 @ 6 p.m.
Watts	November 9, 2022 @ 6 p.m.
South LA 2	November 10, 2022 @ 5:30 p.m.
South LA 1	December 6, 2022 @ 6 p.m.
East LA	December 7, 2022 @ 5:30 p.m.
East LA	December 8, 2022 @ 6 p.m.

**Meeting held virtually.*

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LA100 EQUITY STRATEGIES

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
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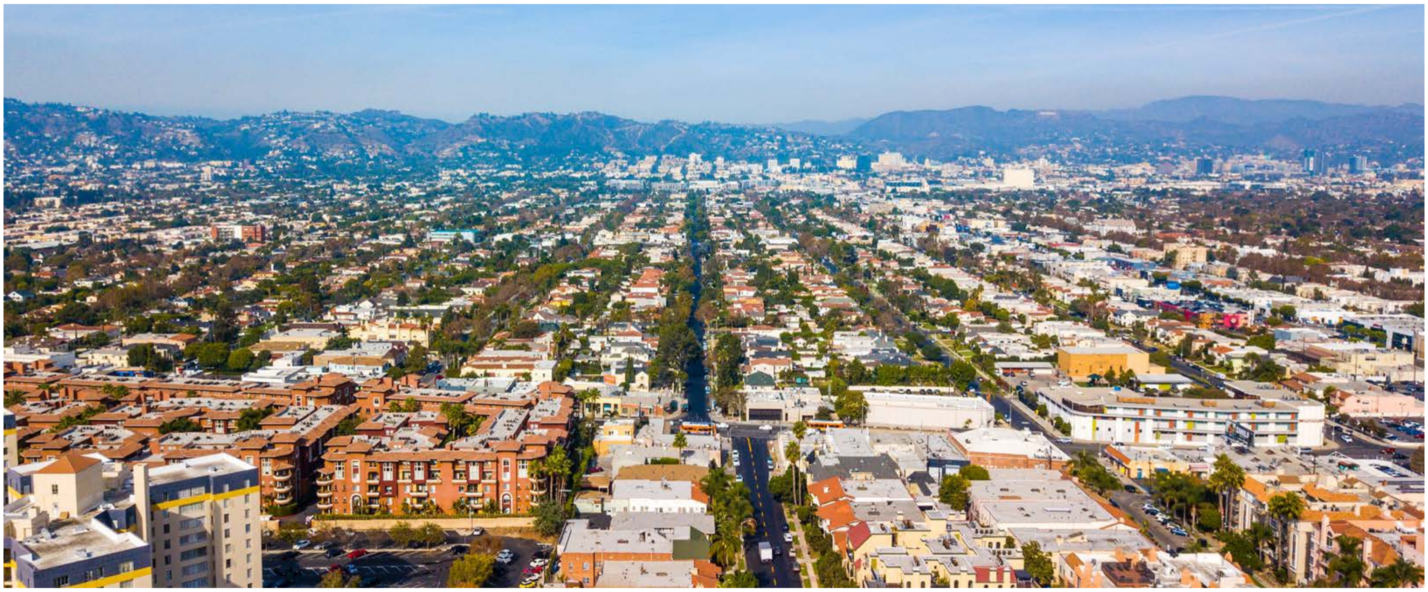

Chapter 1: Justice as Recognition

FINAL REPORT: LA100 Equity Strategies

Patricia Romero-Lankao, Nicole Rosner, Jane Lockshin, Daniel Zimny-Schmitt, and Lis Blanco

LA100 EQUITY STRATEGIES

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Authors

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Suggested Citation—Entire Report

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November 2023

LA DWP

NREL Transforming ENERGY

LA100 EQUITY STRATEGIES

Produced under direction of the Los Angeles Department of Water and Power by the National Renewable Energy Laboratory (NREL) under Work for Others Agreement number ACT-18-00039.

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LA DWP

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Preface

The Los Angeles 100% Renewable Energy Study, or LA100, revealed that although all communities in Los Angeles will share in the air quality and public health benefits of the clean energy transition, increasing equity in participation and outcomes will require intentionally designed policies and programs. The LA100 Equity Strategies project was specifically designed to help Los Angeles identify pathways to such policies and programs in the form of equity strategies. The project aimed to do this by incorporating research and analysis to chart a course toward specific, community-prioritized, and equitable outcomes from the clean energy transition outlined in the LA100 study.

The Project Partners

The Los Angeles Department of Water and Power (LADWP), the National Renewable Energy Laboratory (NREL), and the University of California Los Angeles (UCLA) partnered on the LA100 Equity Strategies project to develop strategies for engaging communities, funding equitable technology and infrastructure investments, expanding existing programs, and designing new programs and policies to improve equity by incorporating what community members themselves know is needed to achieve a more equitable energy future.

The Project Approach

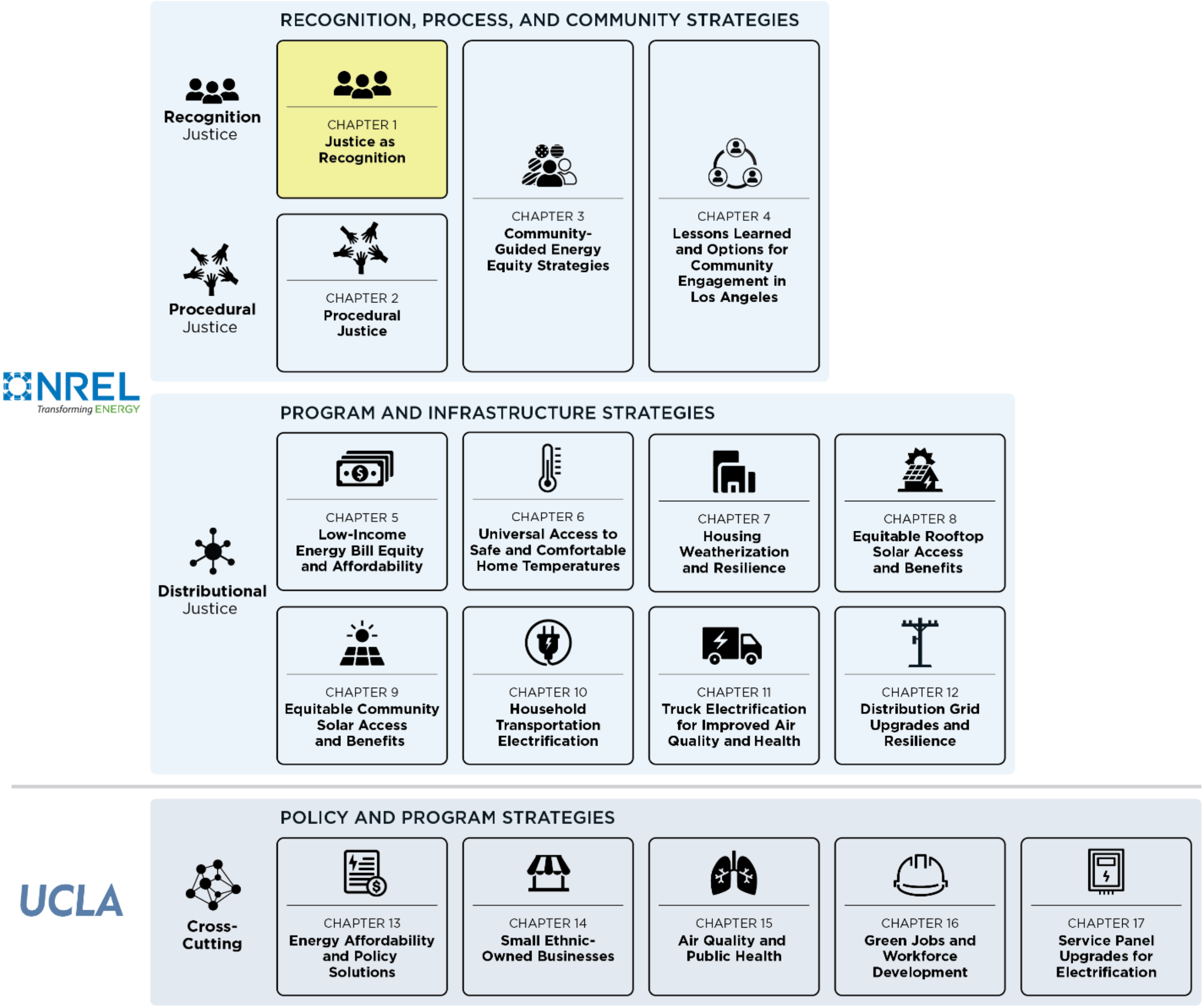
LA100 Equity Strategies employs a unique mixed-methodological approach utilizing three distinct—but connected—research efforts. Through these efforts, NREL and UCLA developed a range of strategy options for increasing equity in LA's transition to 100% clean energy.

A Project Summary

To get a high-level overview of the project, you can dive into the executive summary, interactive data visualizations, and more on the LA100 Equity Strategies website at maps.nrel.gov/la100/equity-strategies.

The Full Report

NREL's final full report for the LA100 Equity Strategies project encompasses seventeen chapters. The first twelve chapters, authored by NREL, are organized around the three tenets of justice. Chapters 1–4 address recognition and procedural justice, while Chapters 5–12 address distributional justice. The final five chapters, authored by UCLA, provide crosscutting policy and program strategies. Each chapter provides data, methods, insights, and strategies to help LADWP make data-driven, community-informed decisions for equitable investments and program development.



NREL Chapters

Chapter 1: Justice as Recognition

Chapter 2: Procedural Justice

Chapter 3: Community-Guided Energy Equity Strategies

Chapter 4: Lessons Learned and Options for Community Engagement in Los Angeles

Chapter 5: Low-Income Energy Bill Equity and Affordability

Chapter 6: Universal Access to Safe and Comfortable Home Temperatures

Chapter 7: Housing Weatherization and Resilience

Chapter 8: Equitable Rooftop Solar Access and Benefits

Chapter 9: Equitable Community Solar Access and Benefits

Chapter 10: Household Transportation Electrification

Chapter 11: Truck Electrification for Improved Air Quality and Health

Chapter 12: Distribution Grid Upgrades for Equitable Resilience and Solar, Storage, and Electric Vehicle Access

UCLA Chapters

Chapter 13: Energy Affordability and Policy Solutions Analysis

Chapter 14: Small Ethnic-Owned Businesses Study

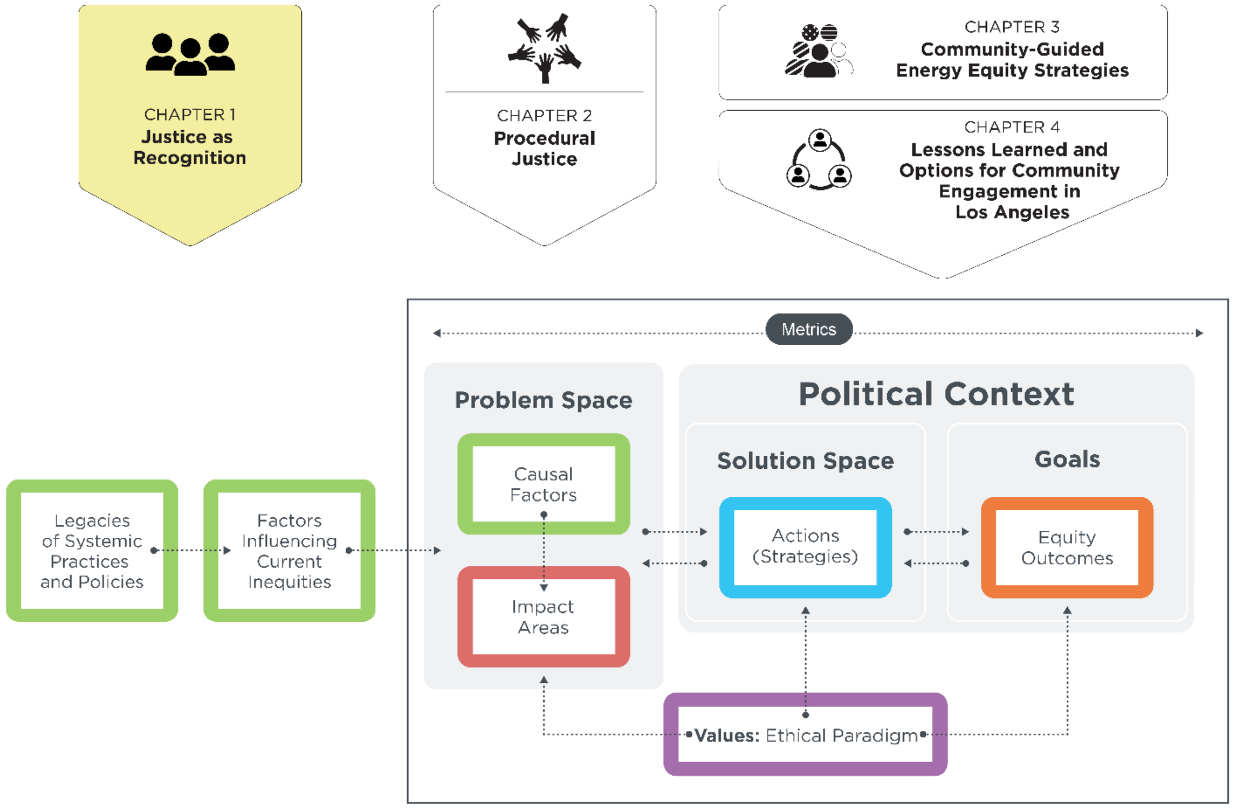
Chapter 15: Air Quality and Public Health

Chapter 16: Green Jobs Workforce Development

Chapter 17: Service Panel Upgrade Needs for Future Residential Electrification

About Chapters 1–4

In Chapters 1–4, NREL presents community-grounded research and analysis results on recognition justice and procedural justice, community-guided equity strategies and future options for community engagement by LADWP. Across these chapters, a mixed-methodological approach is applied, including a systematic literature review, statistical analysis of access to LADWP programs, and qualitative research with communities and community-based organizations to examine understandings of energy transition needs, barriers, and priorities. This work informs modeling and development of equity strategies by analyzing (1) the distribution of benefits of LADWP programs and strategies in the city and (2) historical and current factors contributing to this distribution and other energy inequities in the city.



List of Abbreviations and Acronyms

CalEPA	California Environmental Protection Agency
CBO	community-based organization
DAC	disadvantaged community
DER	distributed energy resources
ESAP	Energy Savings Assistance Program
EV	electric vehicle
FPL	federal poverty level
GHG	greenhouse gas
HECA	High Efficiency Cabin Air
HEIP	Home Energy Improvement Program
HOLC	Home Owners' Loan Corporation
HVAC	heating, ventilation, and air conditioning
LADWP	Los Angeles Department of Water and Power
NEM	net energy metering
NIMBY	not in my back yard
NREL	National Renewable Energy Laboratory
OEHHA	Office of Environmental Health Hazard Assessment
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
UPCT	Utility Pre-Craft Training

Executive Summary

The Challenge

The LA100 Equity Strategies project synthesizes community guidance with robust research, modeling, and analysis to identify strategy options that can increase equitable outcomes in Los Angeles' clean energy transition. Grounded in the analysis of past and ongoing energy inequities and engagement with underserved communities, the project presents community-guided and community-tailored strategies that aim to operationalize recognition and procedural justice. This chapter focuses on recognition justice, identifying and analyzing past and present social, cultural, and institutional barriers to affordable and clean energy for LA communities, as well as disparities in the distribution of energy system burdens and benefits. Acknowledging historical and structural factors behind current energy inequities is a first step in developing energy equity strategies for the Los Angeles Department of Water and Power (LADWP) to achieve distributional justice—the just and equitable distribution of energy benefits and burdens in LA's energy transition. Recognition, procedural, and distributional justice are the three tenets of energy justice around which the LA100 Equity Strategies project is organized (see the Glossary).

In the United States, theory and practice around justice have historically focused on unequal distribution of environmental benefits and burdens. The historical siting of hazardous infrastructure such as power plants and transportation corridors in communities of color and low-income communities has disproportionately concentrated negative environmental impacts in their neighborhoods. Those inequities are reproduced via programs, policies, and other efforts (e.g., zoning and regulations, rebates and incentives, lending, investment, and financing) that directly affect people's lives and livelihoods. In recent decades, energy justice scholars and activists broadened their analysis to examine how environmental inequities intersect with other forms of social difference in the distribution of energy benefits and burdens. This approach investigates how differences in class, race, gender, age, and abilities, among others, intersect to understand the social, cultural, and institutional processes that create and perpetuate energy inequities.

The LA100 Equity Strategies project embraces this approach to developing a more just clean energy future for LA. Because recognizing and understanding past and existing inequities is vital to addressing them in ways that ensure an equitable energy transition for all Angelenos, this chapter focuses on identifying and analyzing the challenges and inequities of LA's past and existing energy system, including LADWP programs.

Goal and Approach

Chapter 1 uses energy justice as a conceptual tool to identify and analyze past and existing inequities as barriers to recognition justice. NREL social scientists closely examined historical inequities in Los Angeles, along with the corresponding causal factors, to understand how these inequities became embedded in policies, processes, and finally, in community members' experiences and livelihoods. NREL social scientists worked with communities that have been historically underserved and overburdened by the energy system in Los Angeles to analyze the broader structural factors determining energy inequities and to co-design a solution space for more equitable policy action.

As shown in Figure ES-1, we analyzed the legacies of systemic practices and policies as underlying factors influencing current inequities that we organized into four prioritized areas:

1. Affordability and burdens
2. Access and use
3. Health, safety, and resilience
4. Jobs and workforce development.

This analysis led to the identification of building blocks for community-guided equity strategies that LADWP could use on the pathway to equitable outcomes in the clean energy transition (Chapters 3 and 4). The goal is to utilize a recognition justice approach to draw insights for the development of strategies (Chapter 3) and procedures (Chapter 4) that more equitably distribute the benefits and burdens of the 100% clean energy transition.

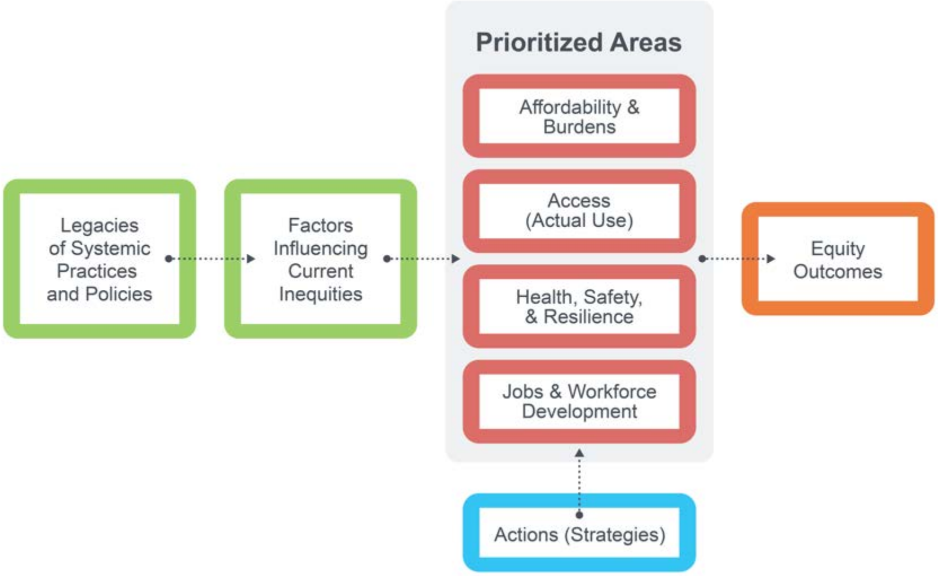


Figure ES-1. Analytic approach to recognition justice

Grounding Community Engagement

Listening to, learning from, and partnering with communities and community-based organizations (CBOs) in Los Angeles formed the foundation of our research, analysis, and engagement process. The historical and statistical analysis of energy inequities in Los Angeles presented in this chapter forms the baseline conditions for LA100 Equity Strategies' community engagement. Complementing this baseline understanding, engagement with community members in listening sessions, CBOs on the Steering Committee, and institutional actors on the Advisory Committee informed our analysis and identification of priority areas (Chapter 2) and helped to illuminate the steps LADWP can take to improve equity outcomes for their ratepayers.

Key Findings: Past and Current Energy Inequities

Here we provide the results of a qualitative and quantitative overview of critical processes determining inequities in education, employment, income, housing, and transportation relevant to the current energy transition. We focus on the causal factors affecting current inequities in priority areas such as (1) energy affordability, (2) energy access, (3) health, and (4) jobs (Figure ES-1), finding that:

- LADWP's programs such as solar installation benefit, non-low-income-targeted energy efficiency programs, and electric vehicle incentives are not equitably distributed across communities. Higher-income mostly homeowner and White populations benefit more.
- Underserved communities such as low-income families, renters, and people of color face higher energy and transportation burdens, unsafe temperatures, and higher impact from extreme heat events, and other negative impacts of historical legacies that are still present in current policies and practices. Our analysis concentrated on underserved communities located in South LA, East LA, San Fernando Valley, and the Harbor area (i.e., Wilmington and San Pedro).

These inequities are evidenced in the everyday experiences of underserved community members, who reported:

- Poor quality and maintenance of infrastructure and housing due to decades of disinvestment and neglect
- A lack of affordable housing for renters and owners
- Barriers to making energy decisions for themselves and their communities (that we term *self-determination*)
- A lack of access to financial capital for energy access, affordability, and decision-making
- Mistrust and grievances related to the government agencies and policies, and
- A lack of accessible and useful information about resources and programs.

Factors Influencing Energy Inequity in Health, Safety and Community Resilience

With a focus on health, safety, and community resilience one of the prioritized areas, Table ES-1 presents a series of structural and intersecting factors that influence energy inequities. Table 4 (page 20) through Table 7 (page 27) discuss how these factors can impact inequities in affordability and access in the other prioritized areas analyzed and modeled in Chapters 2–12. As can be seen in Table ES-1, communities and CBOs referred to built-environment factors, such as "addressing habitability with energy retrofits" (Steering Committee Members 2022a) and associated "space concerns with electrification technologies" (Steering Committee Members 2022a). In Los Angeles, the "biggest health danger [is] from transportation" (Steering Committee Members 2022a) rather than peaker plants; thus, "electrifying transportation will reduce GHGs" and result in public health benefits in their communities (Steering Committee Members 2022a). Yet, there is still a "need to address pollutants produced by peaker plants" (Steering Committee Members 2022a). A recurrent socioeconomic concern relates to the fracturing and displacement of low-income communities of color, and how to "avoid eviction and affordable housing loss" (Steering Committee Members 2022a). Such forms of displacement relate to affordability, but also to community resilience, as a loss of community members—whether due to utility disconnection, infrastructure-related displacement, eviction, and/or loss of affordable housing options—fractures social safety nets and professional networks that are key determinants of a household's capacity to deal with burdens and stressors.

Table ES-1. Examples of Factors that Can Impact Inequalities in Health, Safety, and Community Resilience in Relation to Home Temperatures and Housing Weatherization

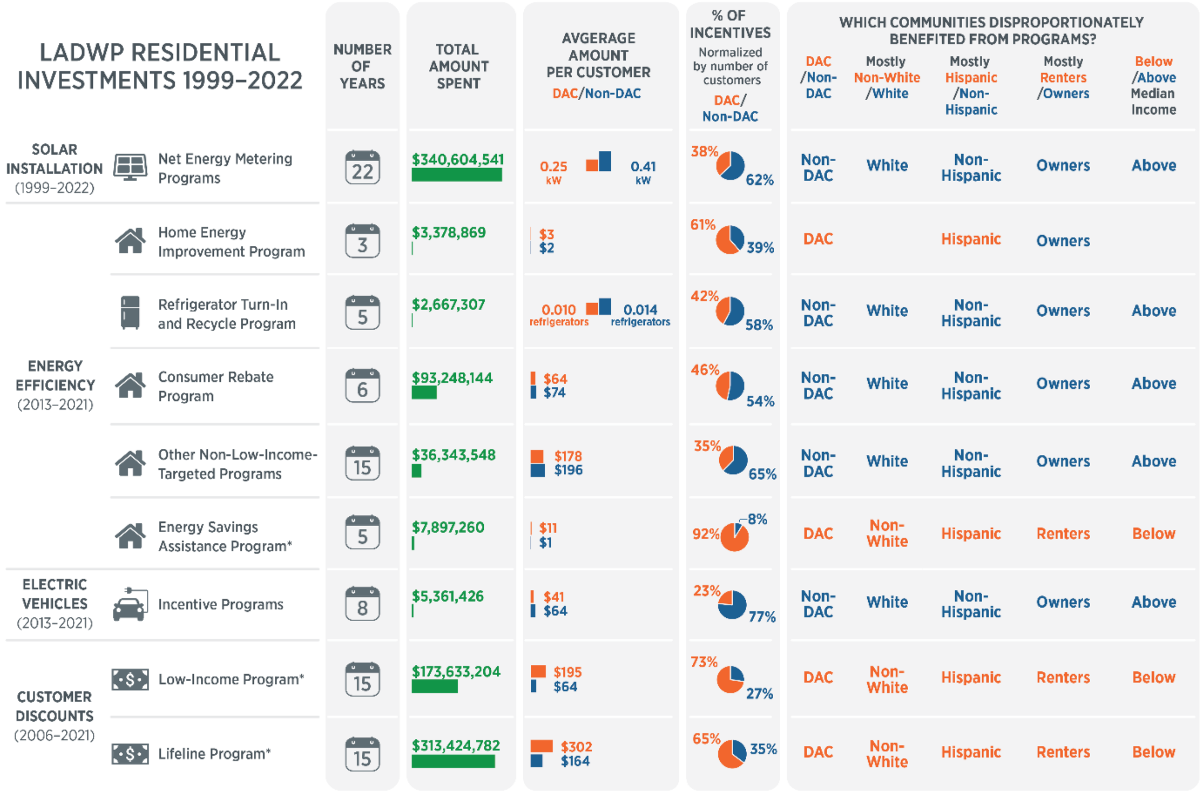
Dimension	Structural Factors
Built environment	Appliances lighting: efficiency of dishwashers Building age and envelope: maintenance and insulation Heating and cooling system: system type, fuel type, and fuel cost
Economic dimension	Sudden or chronic economic hardship due to unstable or persistent low income Difficulty affording up-front costs of energy investments and technologies
Policy and political context	Building codes Inadequate policies, programs, and investments
Sociocultural and behavioral dimension	Awareness of time-of-use rate, changes to net metering policies

Participants also considered how to redress inequities through cultural and behavioral change in the way government entities engage with communities and procedural justice. Part of community resilience includes defining what engagement and accountability look like after the LA100 Equity Strategies project and recognizing the importance of including "often-marginalized equity communities in the decision process for LA100 policies and timeline." Finally, participants pointed to a need for "more direct install programs" (Steering Committee Members 2022a) as well as LADWP programs designed with "incentives rather than rebates" to support resilience in their communities.

Envisioning Equitable LADWP Programs

In this chapter, we analyze critical processes that have historically determined inequities in education, employment, income, housing, and transportation in Los Angeles. This historical groundwork orients proposed building blocks for LADWP to operationalize recognition justice, as Chapters 3 and 4 demonstrate. Across this report, we use our findings to develop strategies that will more equitably distribute the benefits and burdens of the LA clean energy transition.

Linking our analysis of LADWP customer-facing programs to the experiences LA community members shared, our research findings revealed that the benefits of LADWP programs are not equitably distributed across communities (Figure ES-2). NREL analyzed address-level data on LADWP program beneficiaries, including the amount of benefit received. Customer discount programs benefit disadvantaged communities, but programs subsidizing electric vehicles and solar installations disproportionately benefited non-disadvantaged, mostly White, mostly non-Hispanic, mostly home owning, and above median income communities (Figure ES-2).



LADWP RESIDENTIAL INVESTMENTS 1999–2022		NUMBER OF YEARS	TOTAL AMOUNT SPENT	AVGERAGE AMOUNT PER CUSTOMER DAC/Non-DAC	% OF INCENTIVES Normalized by number of customers DAC/Non-DAC	WHICH COMMUNITIES DISPROPORTIONATELY BENEFITED FROM PROGRAMS? DAC/Non-DAC	Mostly Non-White/White	Mostly Hispanic/Non-Hispanic	Mostly Renters/Owners	Below/Above Median Income
SOLAR INSTALLATION (1999–2022)	Net Energy Metering Programs	22	$340,604,541	0.25 kW 0.41 kW	38% 62%	Non-DAC	White	Non-Hispanic	Owners	Above
ENERGY EFFICIENCY (2013–2021)	Home Energy Improvement Program	3	$3,378,869	$3 $2	61% 39%	DAC		Hispanic	Owners	
	Refrigerator Turn-In and Recycle Program	5	$2,667,307	0.010 refrigerators 0.014 refrigerators	42% 58%	Non-DAC	White	Non-Hispanic	Owners	Above
	Consumer Rebate Program	6	$93,248,144	$64 $74	46% 54%	Non-DAC	White	Non-Hispanic	Owners	Above
	Other Non-Low-Income-Targeted Programs	15	$36,343,548	$178 $196	35% 65%	Non-DAC	White	Non-Hispanic	Owners	Above
	Energy Savings Assistance Program*	5	$7,897,260	$11 $1	92% 8%	DAC	Non-White	Hispanic	Renters	Below
ELECTRIC VEHICLES (2013–2021)	Incentive Programs	8	$5,361,426	$41 $64	23% 77%	Non-DAC	White	Non-Hispanic	Owners	Above
CUSTOMER DISCOUNTS (2006–2021)	Low-Income Program*	15	$173,633,204	$195 $64	73% 27%	DAC	Non-White	Hispanic	Renters	Below
	Lifeline Program*	15	$313,424,782	$302 $164	65% 35%	DAC	Non-White	Hispanic	Renters	Below

* Low-Income Targeted

Figure ES-2. Statistical analysis of access to the benefits of LADWP programs and investments

Chapter 1 maps how unequal access to LADWP programs relates to the legacy of trends and practices in education, jobs, housing, transportation, and energy infrastructure. While energy assistance policies and programs are widely considered best practices in the clean energy transition, inequities have become entrenched in these programs across energy utilities in the United States (analyzed in Chapter 4). We present actionable solutions and strategies in Chapters 3 and 4 that LADWP can use to ensure that going forward, their programs will be more accessible and equitable for LA communities.

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1 Introduction

From its inception, environmental justice theory and practice in the United States have focused on the unequal distribution of benefits and burdens. Understanding the historical development of these inequities through programs, policies, infrastructure, and other efforts has also been a part of this theory and practice (Morello-Frosch and Jesdale 2006; Morello-Frosch et al. 2011; Cushing et al. 2015). Early environmental justice research and advocacy included documenting how the location of hazardous sites has disproportionately affected communities of color and low-income communities. This approach also examined how transportation corridors have disproportionately affected communities of color and low-income communities, and the ways in which environmental impacts have become entrenched in these neighborhoods where community members live their day-to-day lives (Section 3.1).

In the last two decades, however, scholarly and environmental approaches to environmental justice were broadened to examine how environmental inequities intersect with other forms of social difference—e.g., class, race, gender, age, and abilities—to understand the social, cultural, and institutional processes of exclusion through which these inequities are (re)produced (Bulkeley et al. 2013; Agyeman et al. 2016; Schlosberg and Collins 2014; Walker 2009a). These processes, policies, and practices of structural exclusion include infrastructure siting and investment, zoning and regulations, rebates and incentives, lending, and financing (i.e., redlining), and other strategies and practices through which inequalities arise in the distribution of benefits and costs. Benefits include energy access, affordability, and reliable public health and safety. Regarding costs, the negative social and environmental impacts disproportionately affect predominantly underserved groups.

Over the past decade, energy justice has become a conceptual, analytical, and decision-making tool for unifying diverse justice considerations (Sovacool and Dworkin 2015). The LA100 Equity Strategies report employs three energy justice tools developed by Sovacool and Dworkin (2015) to inform context, engagement processes, and overall findings. This chapter uses energy justice as a *conceptual tool* to analyze how the legacy of past and ongoing policies and practices impact current energy inequities in Los Angeles. These findings inform Chapter 2, which focuses on procedural justice. Chapter 2 employs energy justice as an *analytical tool* to examine how values and decision-making shape energy inequities. Chapters 3–12 use energy justice as a *decision-making tool* to support the Los Angeles Department of Water and Power (LADWP), city officials, ratepayers, and community-based organizations (CBOs) in developing more informed and grounded energy equity strategies. Chapters 5–12 specifically address distributional justice, focused on the distribution of energy-related benefits (e.g., energy access, affordability, and reliability), as well as the distribution of negative consequences (e.g., public health, safety, jobs, and financial burdens).

LA100 Equity Strategies follows forward-looking and groundbreaking scholarship (Walker 2009b; Schlosberg and Collins 2014; McCauley and Heffron 2018) and practice (e.g., Initiative for Energy Justice) by moving beyond an examination of only the distributional aspects of benefits, burdens, and disadvantages (i.e., distributional justice) to analyze three critical tenets of energy justice: recognition, procedural, and distributional justice (see the Glossary). The goal of this first chapter is to present an analytic approach to recognition justice, aiming to understand and address past and current energy inequities (Figure 1, page 3) and to examine the legacies and causal factors influencing energy inequities in Los Angeles (Walker 2009b; Carley and Konisky 2020; Carley, Engle, and Konisky 2021; Schlosberg and Collins 2014; McCauley and Heffron 2018). The results of this analysis are the baseline for the following chapters, which present the analysis and findings from a collaborative community engagement process led by the National Renewable Energy Laboratory (NREL), LADWP, and CBO partners. Through this engagement process, we worked with communities that have been historically underserved and negatively affected by the current energy system to identify energy problems and co-design a solution space for more equitable decision-making and effective policy action. The engagement process, as a critical component of procedural justice, entails forming partnerships with community members and local institutions to co-identify barriers and opportunities for designing and implementing more equitable energy outcomes. Thus, the focus on procedural justice in Chapter 2 grounds the historical findings from this chapter in the lived experience of local Angelenos.

In the following sections, we define key terms and develop an analytic approach to the just transition to clean energy in Los Angeles that guides Chapters 2–4 (Section 2.1). We present the mixed methods used to understand the barriers to justice as recognition, including a literature review, community engagement process, and statistical analysis of LADWP programs (Section 2.2). We then examine the processes influencing energy inequalities in education, employment, income, housing, and transportation (Section 3.1). We also analyze the causal factors affecting current inequities in four areas: energy affordability, energy access, health, and jobs (Section 4). These findings inform energy equity strategies and options for community engagement to address those causal factors (Chapters 3 and 4).

Analytic Approach

Our conceptual approach to energy justice emphasizes the legacy of historical policies and practices (e.g., mortgage lending) on ongoing causal factors of energy inequities in Los Angeles (Figure 1). In this framework, the *causal factors* refer to historical and current structural processes, policies, and practices that have led to current inequities in the energy system (Agyeman et al. 2016; Álvarez and Coolsaet 2020). Causal factors directly and indirectly affect the energy system and the energy transition in Los Angeles. Equity strategies seek to address these effects or *impact areas* to engender more equitable *energy outcomes*. An impact area can include an energy sub-sector, such as housing, or a crosscutting prioritized area, such as energy affordability and health.

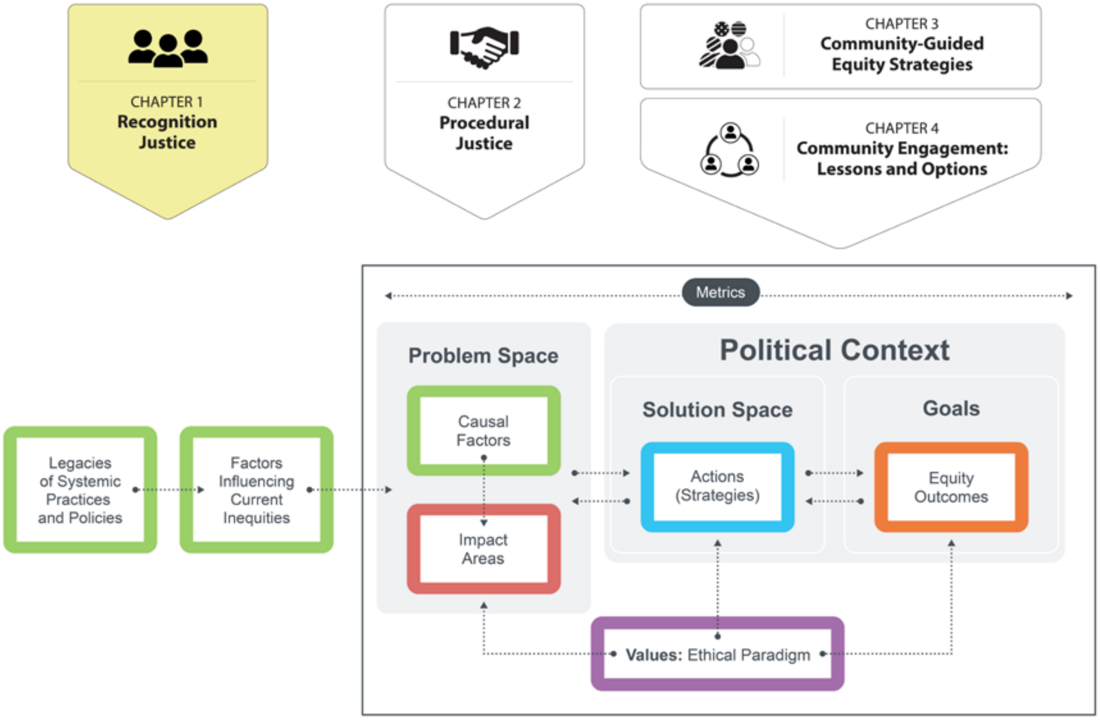

Figure 1. Overarching framework of LA100 Equity Strategies Chapters 1–4

An energy transition entails changes in sociotechnical energy systems and systems of policy action or strategy (*solution space*, see Figure 1), including regulations, subsidies, and investments and how they are designed, implemented, and evaluated. In turn, these strategies are the means to achieve more equitable energy outcomes as the City of LA transitions to clean energy (Arent et al. 2017; McCauley and Heffron 2018; Carley and Konisky 2020). The *political context* includes any institutional element (e.g., LADWP internal organizational structure or City of Los Angeles regulations) that might impact how LADWP and other city officials can approach a problem and the strategies to target that problem. We analyze the political context in Chapters 3 and 4.

Underlying this framework is the *value system*, or the ethical paradigm that structures the sociocultural norms, beliefs, and practices guiding how a group of people prioritize and relate to the current energy transition (see definition in the Glossary, page 37). Our framework assumes that just energy transitions can be more effectively and inclusively achieved by a systematic effort to explicitly understand and address community and stakeholder values.

The analysis in this chapter emphasizes the legacy of historical policies and practices (e.g., mortgage lending) on ongoing causal factors of energy inequities in Los Angeles (Figure 2). Causal factors include the processes, policies, and practices influencing current inequities in participation, protection from burdens, and fair treatment in access to benefits, in four crosscutting priority areas. These areas were *prioritized* by Steering Committee members in 1:1

meetings, supported by an energy justice literature review presented at the National Academies (Romero-Lankao 2022), and aligned with U.S. policymaking (e.g., Justice40[1]):

- Affordability and burdens
- Access to energy technologies, infrastructure, and LADWP programs
- Public health, safety, and community resilience
- Jobs and workforce development (Figure 2 and Chapter 2).

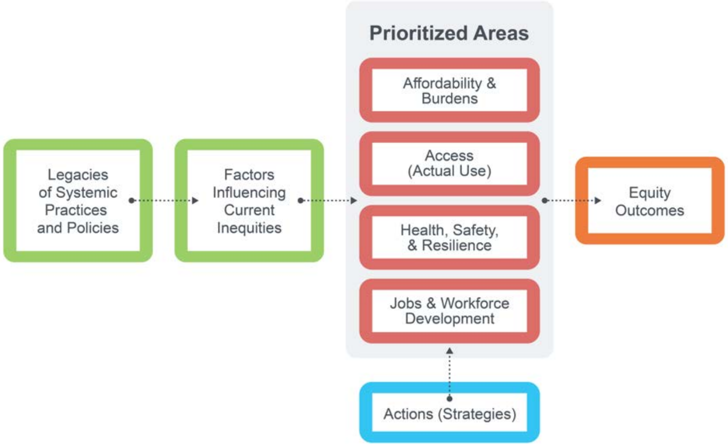

Figure 2. Analytic approach to recognition justice

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[1] www.whitehouse.gov/environmentaljustice/justice40

2 Methods

To identify and examine the most relevant causal factors impacting equity in Los Angeles' energy transition, we employ both quantitative and qualitative methods. Our mixed methodological approach includes a literature review, statistical and qualitative analysis, and a tiered community engagement process, as shown in and described in detail in Chapter 2. Causal factors and impacts were identified through a review of academic literature, government reports, LA City Council policy documents, and direct stakeholder engagement. Thus, the analysis and findings below also reflect causal factors as perceived, understood, and experienced by LA residents and energy system actors. This analysis has informed technical strategy development in the LA100 Equity Strategies study moving forward.

Figure 3 depicts the overall approach and timeline for each of the primary research and engagement efforts we used to develop a community-guided approach to (a) agree on goals, metrics, methods, and data sources, and (b) refine a detailed plan for modeling, analysis, and evaluation of implementation-ready strategies for Los Angeles' just energy transition. The team created a continuous feedback loop through engagement efforts, such as neighborhood-specific community listening sessions, Steering Committee meetings, and Advisory Committee meetings (for details, see Chapter 2).

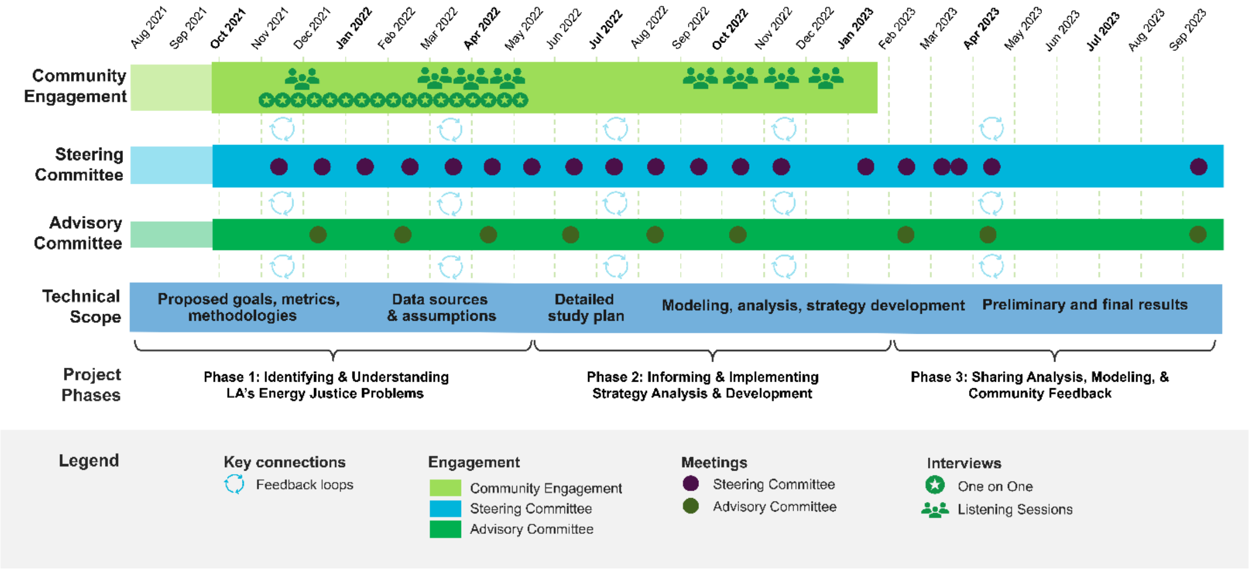

Figure 3. LA100 Equity Strategies framework and timeline

2.1 Literature Review

We conducted a systematic literature review to ground LA100 Equity Strategies analysis and engagement efforts in prior research (Romero-Lankao, Qin, and Dickinson 2012). This literature review relies on the analysis of secondary data, such as academic scholarship, research reports, policy documents, newspaper articles, local CBO publications, and press releases. We conducted a literature search of available academic databases (e.g., Web of Science, BioOne, and Google

Scholar), official documents, policy databases, and additional references selected from these sources. Given that just energy transitions are a relatively new area in energy research and practice (Carley and Konisky 2020), we focused our review on studies published over the past 22 years (2000–2022). The following search terms were selected to help guide our literature search:

- Procedural justice terms included procedural justice, community driven, energy solutions, and inclusive urban energy strategies.
- Recognition justice terms included recognition justice, policy, built environment, political, and cultural determinants of energy equity.
- Distributional justice terms included distributional justice, attributes and socio-spatial distribution of energy affordability, access, security, poverty, and disadvantage.

As a result, more than 130 sources were reviewed and analyzed for Chapters 1–4. Additionally, we reviewed policies, reports, public comments, and community impact statements associated with more than 20 separate Los Angeles City Council motions relevant to energy, equity, and environmental issues affecting the LADWP service territory to (1) inform understandings of causal factors contributing to existing inequities, and (2) anticipate potential barriers to energy equity strategies (Chapter 3). These council files were primarily identified through an advanced search of the Los Angeles City Clerk Council File Management System[2], references made by LA100 Equity Strategies Steering Committee and Advisory Committee members from 2021–2023, and a thorough review of LA100 Advisory Group meeting summaries from 2017–2021. Finally, we reviewed notes, summaries, presentations, and other relevant documents from all LA100 Steering and Advisory Group meetings held during the duration of this project (Chapter 2).

2.2 Statistical Methods

We conducted a mapping of socioeconomic and demographic differentiation in access to LADWP program and infrastructure investments and electricity reliability (LADWP 2021). A statistical analysis was performed to measure how LADWP incentives and benefits have been distributed across sociodemographic groups and identify any disproportionate outcomes. Using address-level customer data provided by LADWP, we analyzed 16 programs. Of these, six programs provide energy incentives, six provide electric vehicle (EV) incentives, and two programs provide customer discounts (Table 1, page 7; details are provided in Table A-1 in Appendix A).

Customer data from each program were geocoded by address and aggregated by census tract to determine the total number of households receiving benefits as well as the total dollar value of the investment from LADWP for each census tract within Los Angeles. These data were then merged with information from CalEnviroScreen (August et al. 2021) to identify tracts that are in disadvantaged communities (DACs).[3] Using American Community Survey data (U.S. Census

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[2] cityclerk.lacity.org/lacityclerkconnect

[3] In this chapter and in chapters 2-4, we use the terms "disadvantaged communities" to refer to statistical analysis that utilizes census data and CalEnviroScreen data. The qualitative analysis uses the term "underserved communities". Both terms are defined in the Glossary.

Bureau 2019), we integrated census tract-level data on sociodemographic indicators of race, ethnicity, income, and homeownership (see an in-depth explanation in Appendix B).

Causal factors and impacts were identified through a review of academic literature, government reports, LA City Council policy documents, and direct stakeholder engagement. Therefore, the analysis and findings below also reflect causal factors as perceived, understood, and experienced by LA residents and energy system actors. This analysis has informed technical strategy development in the LA100 Equity Strategies study.

Table 1. LADWP Programs and Services for which Statistical Analysis was Conducted (1999–2022)

Program Type	Program Name
Energy efficiency incentive programs	Commercial Direct Install (CDI)
	Home Energy Improvement Program (HEIP)
	Refrigerator Turn In and Recycle Program (RETIRE)
	Consumer Rebate Program (CRP)
	Other non-low-income-targeted programs
	Energy Savings Assistance Program (ESAP) (low-income-targeted)
Solar installation programs	Net Energy Metering (NEM)
	Solar Incentive Program (SIP)
EV incentive programs	Feed-in Tariff (FiT)
	Solar Rooftops Lease Agreement (SRP)
	New Commercial/Residential Chargers/Sub-Meters
	Used Residential Vehicles
	Direct Current Fast Charging (DCFC)
	Medium-Duty and Heavy-Duty (MDHD)
Customer discount programs	Low-Income Program
	Lifeline Program
Power infrastructure reliability metrics	System Average Interruption Duration Index (SAIDI)
	System Average Interruption Frequency Index (SAIFI)
Other programs	Tree Canopy Program (CITY – “City Plants”)

Next, we calculated the total amount of dollars spent per program, year, and community. We compared the number of benefits (adjusted by population) from each program to determine if communities receive benefits proportional to their population (see Appendix B). Lastly, we mapped program information by tract to determine which areas receive the most and least number of incentives proportional to their population.

3 Analysis of Historical Factors Influencing Current Inequities

This section provides a qualitative and quantitative overview of critical processes determining inequalities in education, employment, income, housing, and transportation. The section also targets the causal factors affecting current inequities in four areas: energy affordability, energy access, health, and jobs. The goal is twofold: (1) to utilize a recognition justice approach that allows us to (2) draw insights that can be used to develop strategies that more equitably distribute the benefits and burdens of the 100% clean energy transition.

3.1 Determinants of Historical Urban Inequities

This subsection focuses on the historical context that led to present-day energy inequities in five key sectors of urban development: education, workforce development, housing, transportation, and energy infrastructure. Particular attention is paid to the legacy of historical mortgage lending practices in the United States and their ongoing influence in Los Angeles today. This lending legacy is not only visible in the housing sector and related energy burdens, but also correlates with the siting of energy system and transportation infrastructure and related environmental impacts.

3.1.1 Education and Workforce Development

Access to education and educational attainment are crucial factors influencing Angelenos' employment, income, and poverty status. Over the past 40 years, existing educational and socioeconomic inequities have been exacerbated by the changing structure of the city's economy, producing important impacts on access to jobs and career opportunities. During the 1980s–1990s, Los Angeles witnessed a de- and reindustrialization process that resulted in the decline of postwar manufacturing jobs, affecting new-immigrant neighborhoods where the garment industry had been a major employer. Although gains were made in aerospace and light manufacturing, underserved communities were only able to access a limited spectrum of service sector jobs in restaurants, hotels, offices, theme parks, and private homes (Davis 2006).

As a result of these trends, the relative prevalence of jobs in different sectors in Los Angeles County has changed significantly in the past two decades (Figure 4). Using the Longitudinal Employer-Household Dynamics data set, which links employment records to employees, trends in the 10-largest employment sectors can be observed. Manufacturing has seen the largest decline in employment, with wholesale and retail trades also declining. Health care and social assistance have seen the largest growth in employment, followed closely by information, professional and scientific services, and accommodation and food services. Transportation and warehousing, educational services, and administrative and support services have fluctuated some but have remained relatively constant (Figure 4; for details, see Chapter 16).

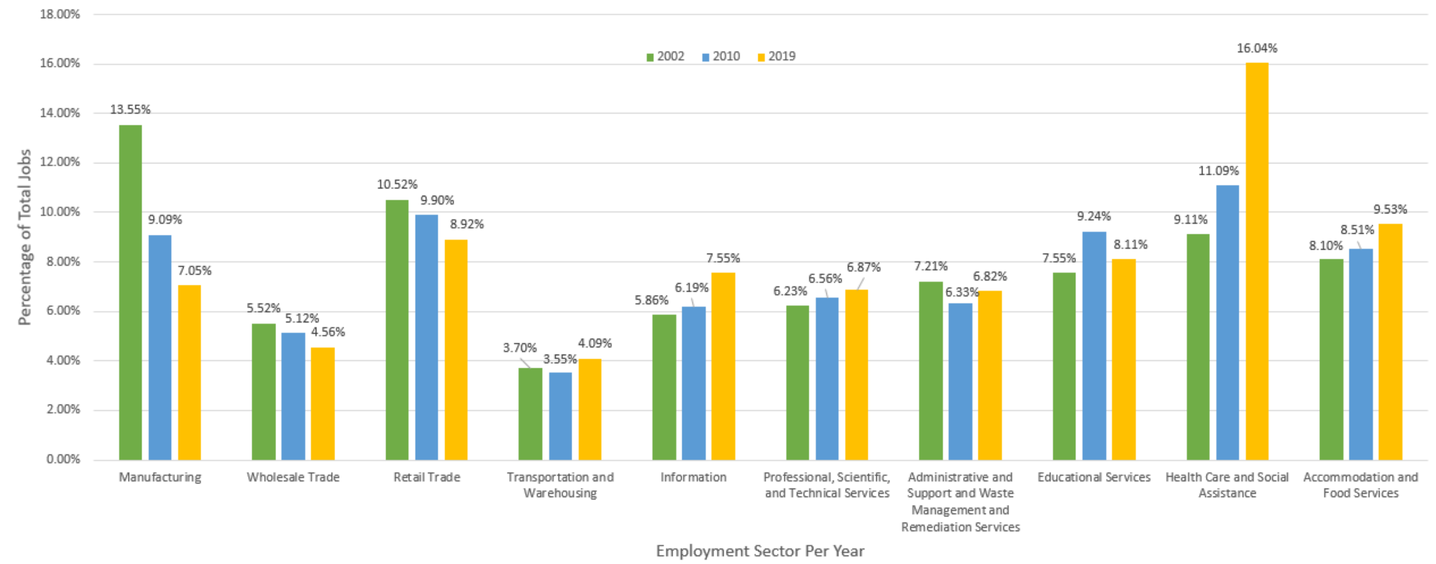

Figure 4. Percentage of total jobs in Los Angeles County by employment sector (North American Industry Classification System sectors)

Source: Longitudinal Employer-Household Dynamics Residence Area Characteristics data set ("Longitudinal Employer-Household Dynamics," U.S. Census Bureau, https://lehd.ces.census.gov/data/)

For many Angelenos who do not own a home, earnings from employment represent the most significant—and frequently the only—portion of all income. Over the last three decades, the median wage earned per hour of work has differed substantially between racial and ethnic groups in Los Angeles. As shown in Figure 5, earnings by White Angelenos have increased slightly and are roughly double earnings by Latino Angelenos. Black and Asian Angelenos have earned a median wage roughly halfway between wages of Whites and Latinos, although over the past two decades, wages earned by Asians have increased and wages earned by Black people have decreased.

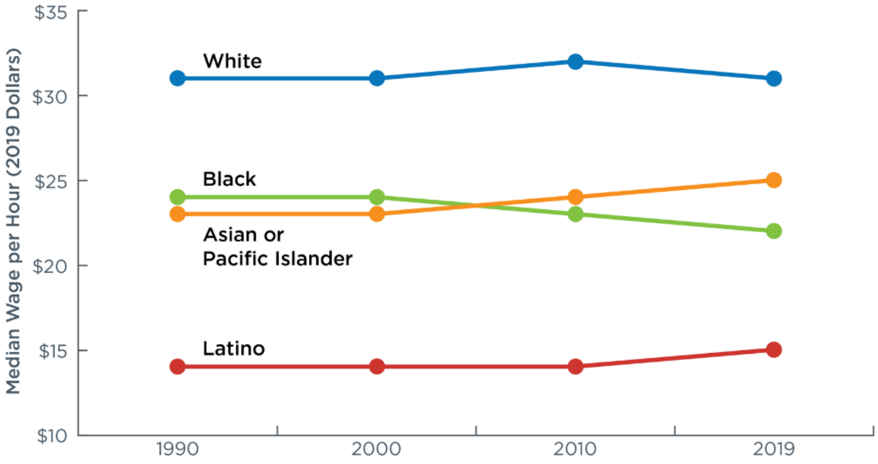

Figure 5. Median wage earned per hour by race/ethnicity in Los Angeles (2019 dollars)

Source: National Equity Atlas

Increase of low-wage work is a key structural contributor to economic inequality in Los Angeles. Wages have not kept up with home prices; 64.1% of Angelenos are renters, and 55% of renters are rent burdened (Rosen et al. 2020). This growing economic inequity leads to growing energy inequity by impacting households' abilities to pay energy bills, live in energy efficient housing, and afford transportation. As shown in Table 2, energy burdens for low-income multifamily households are higher than the national average. However, for all other groups, energy burdens in Los Angeles are lower than the national average.

Table 2. Median Energy Burdens in Metropolitan Areas for All Households and Highly Impacted Groups[a]

Metro Areas	All Households	Low-Income (≤200 FPL[b])	Black	Hispanic	Older Adults (65+)	Renters	Low-Income Multifamily[c]	Built Before 1980
National	3.1%	8.1%	4.2%	3.5%	4.2%	3.4%	3.1%	3.4%
LA	2.2%	6.0%	3.6%	2.6%	3.2%	2.4%	4.8%	2.3%
Phoenix	3.0%	7.0%	3.2%	3.6%	4.0%	2.8%	4.6%	3.6%
San Jose	1.5%	6.5%	1.8%	1.9%	2.4%	1.5%	4.7%	1.6%
San Francisco	1.4%	6.1%	2.4%	1.2%	2.4%	1.4%	4.9%	1.4%

Source: Drehobl, Ross, and Ayala (2020)

[a] Highly Impacted Groups include low-income, Black, Hispanic, older adult (65+), renters, low-income multifamily residents, and those residing in buildings built before 1980.

[b] FPL refers to the federal poverty level.

[c] Low-income multifamily households are below 200% FPL and in a building with five or more units.

3.1.2 Housing and Development

Historical and ongoing mechanisms of institutionalized exclusion and discrimination in the housing sector have direct and indirect impacts on current energy inequalities.[4] These mechanisms include:

- Restrictive covenants[5]
- Zoning ordinances[6]
- Real estate and lending practices, such as redlining[7]
- Federal Housing Administration lending policies[8]
- Rental practices, such as price gouging, volatile rents, and illegal landlord actions (e.g., "cash for keys" and absentee landlords)[9]
- Legislation (i.e., Article 34 and Proposition 14).[10]

Using redlining as an example, we analyze how these mechanisms have interacted to create energy inequity impacts such as residential segregation;[11] poor construction quality, unsafe and inefficient housing stock (related to the need for constant maintenance and general noncompliance with required code upgrades);[12] displacement, disinvestment, and neglect[13, 14].

The practice of discriminatory mortgage lending is one example of the historical mechanisms that continue to entrench structural inequity in present-day urban development. Discriminatory lending practices—such as redlining—limited investment in certain areas of the city, affecting residents living in those areas by creating or supporting residential segregation. Such practices resulted in communities of color living in neighborhoods that have poor-quality construction and unsafe and inefficient housing stock. These policies limited residents' access to credit to improve those conditions, resulting in increased maintenance costs, high energy bills given inefficiencies, and against-code upgrades. Without access to structurally sound housing stock related to conditions like asbestos, lead, mold, and/or legal upgrading options, these households also become ineligible for available energy efficiency programs, such as publicly accessible solar installation programs.

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[4] Ong, Comandon, and González 2019; Covington et al. 2019; Tijerina 2019; Kun and Pulido 2014; Massey and Denton 1993; Jackson 1985; 1980; Hillier 2003; Katznelson 2005; Rothstein 2017; Redford 2017; Stephens and Pastor 2020; Pulido, Sidawi, and Vos 1996; Pulido 2010; Michney and Winling 2019

[5] Ong, Comandon, and González 2019; Massey and Denton 1993; Jackson 1985; Katznelson 2005; Rothstein 2017; Redford 2017

[6] Massey and Denton 1993; Jackson 1985; Katznelson 2005; Rothstein 2017; Redford 2017

[7] Tijerina 2019; Massey and Denton 1993; Jackson 1985; Hillier 2003; Katznelson 2005; Rothstein 2017; Redford 2017; Jackson 1980; Michney and Winling 2019

[8] Massey and Denton 1993; Jackson 1985; Hillier 2003; Katznelson 2005; Rothstein 2017; Redford 2017

[9] Tijerina 2019; Kun and Pulido 2014; Massey and Denton 1993; Jackson 1985; Rothstein 2017

[10] Ong, Comandon, and González 2019; Tijerina 2019; Rothstein 2017

[11] Ong, Comandon, and González 2019; Covington et al. 2019; Tijerina 2019; Kun and Pulido 2014; Massey and Denton 1993; Jackson 1985; 1980; Hillier 2003; Katznelson 2005; Rothstein 2017; Redford 2017; Stephens and Pastor 2020; Pulido, Sidawi, and Vos 1996; Pulido 2010; Michney and Winling 2019

[12] Covington et al. 2019; Kun and Pulido 2014; Jackson 1985

[13] Covington et al. 2019; Kun and Pulido 2014; Massey and Denton 1993; Jackson 1985; Rothstein 2017; Redford 2017; Stephens and Pastor 2020

[14] Kun and Pulido 2014; Massey and Denton 1993; Pulido, Sidawi, and Vos 1996; Pulido 2010

3.1.2.1 Redlining: The History

Redlining “refers to lending (or insurance) discrimination that bases credit decisions on the location of a property to the exclusion of characteristics of the borrower or property. Usually, it means that lenders will not make loans to areas with African Americans or other perceived risks to real estate investments” (Hillier 2003). In the 1930s, the federal government’s new Home Owners’ Loan Corporation (HOLC) began developing “Residential Security Maps” of U.S. cities to calculate perceived mortgage lending risk (Jackson 1985). The rating system evaluated neighborhoods based on racial/ethnic composition, occupation, income, physical quality and age of housing stock, and economic demand, using the A, B, C, and D color-coded system illustrated in Table 3 (Jackson 1985). The fourth ranked category—Category D—was color-coded red, generating the name redlining. These maps effectively endorsed and institutionalized existing discriminatory practices of lenders and bankers.

While redlining was a practice of lending discrimination against an *area,* not individuals, it impacted individual lives when their homes and communities were marked as lending risks and systemically refused access to credit, loans, and the opportunities associated with those benefits. Benefits that were denied to certain individuals and communities include equal access to opportunities to buy, maintain, and repair their homes as well as equal ability to leverage the wealth from homeownership (Massey and Denton 1993; Jackson 1985). The HOLC, designed to support borrowers in homeownership, compounded a racial wealth gap by restricting loan access to Black borrowers, most frequently living in “D” coded areas (Michney and Winling 2019).

Understanding how this source of systemic inequity functioned in the past will help LADWP and the City of Los Angeles redress present inequities for the future as they design more equitable energy strategies.

Table 3. HOLC "Residential Security Maps" Lending Risk Categories

	"Grade"	Description
Low ↑	**A** **"Best"**	"The First and best grade, i.e., green, areas were described as new, homogenous, and 'in demand as residential locations in good times or bad.' Homogeneous meant 'Americans of the better class,' and not Jewish, Black, or immigrant sections" (Jackson 1980, 431–432).
Mortgage Lending Risk	**B** **"Still Desirable"**	"The Second security grade (blue) went to 'still desirable' areas that had 'reached their peak,' but were expected to remain stable for many years" (Jackson 1980, 431–432).
	C **"Definitely Declining"**	"The Third grade (yellow) or 'C' neighborhoods were 'definitely declining' because of age, obsolescence, or change of style. 'Having seen their better days,' such yellow-colored sections were 'within such a low price or rent range as to attract an undesirable element'" (Jackson 1980, 431–432).
↓ High	**D** **"Hazardous"**	"The Fourth grade (red) or 'hazardous' areas were those 'in which the things taking place in C areas have already happened.' Black neighborhoods were invariably rated 'D' as were any areas characterized by poor maintenance, poverty, or vandalism" (Jackson 1980, 431–432).

3.1.2.2 Redlining: The Legacy

A robust body of scholarship has found that the housing and lending practices of the past influence the present-day distribution of DACs' income and capacity to buy, maintain, repair, and leverage wealth from private property (i.e., home ownership) in Los Angeles. These forms of discrimination directly and indirectly affect the ongoing wealth gap and the socio-spatial distribution of energy inequity in the city.[15] As Table 3 and the map in Figure 6 show, 92.25% of tracts with HOLC Grades C and D are currently in DAC tracts. The median income of households currently in tracts graded by HOLC in 1935 as A is *229.4% higher* than households currently in tracts graded as D[16].

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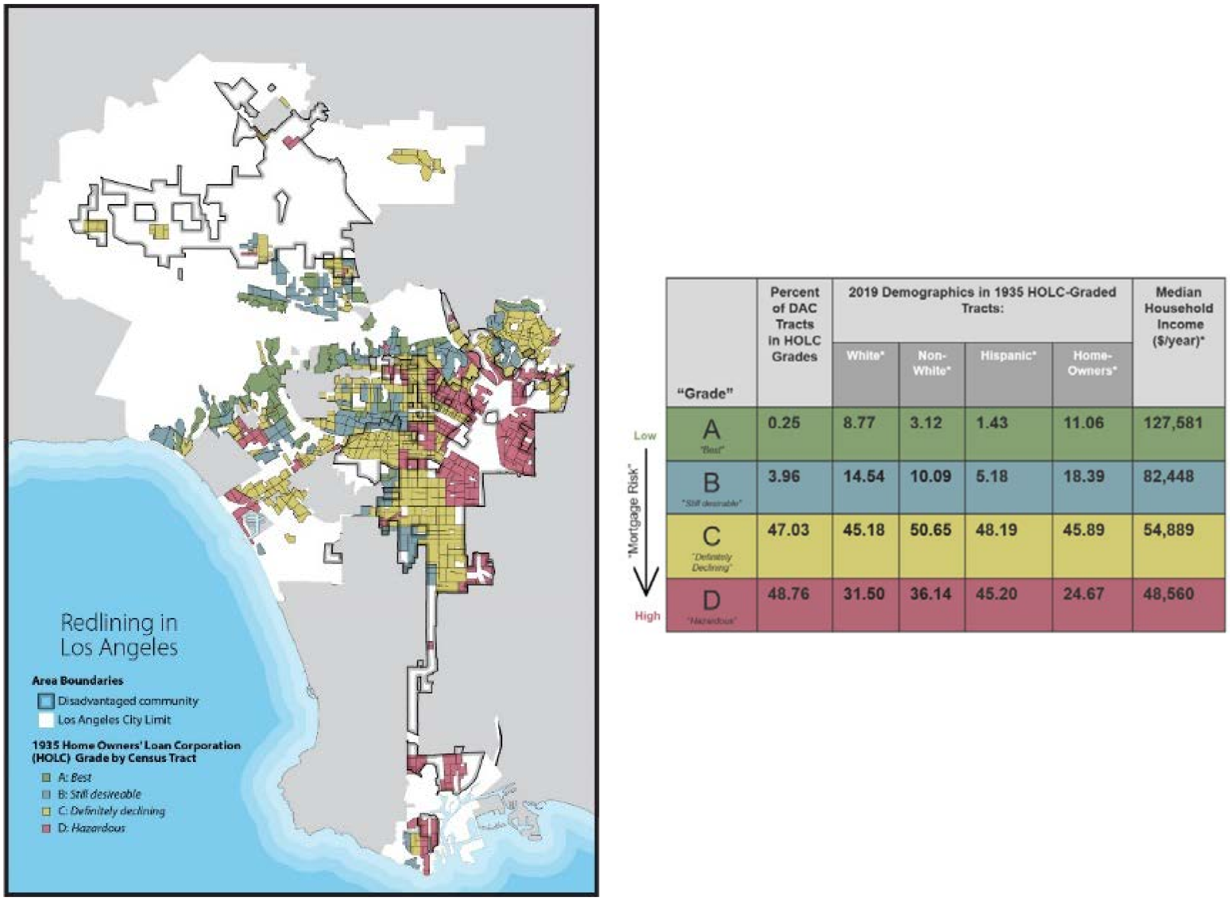
[15] Tijerina 2019; Massey and Denton 1993; Jackson 1985; Hillier 2003; Katznelson 2005; Rothstein 2017; Redford 2017; Jackson 1980; Michney and Winling 2019; Hoffman, Shandas, and Pendleton 2020.

[16] It is also important to note here that the income data is **capped** at $250,000, thus likely underreporting what the actual income gap is.



"Grade"	Percent of DAC Tracts in HOLC Grades	2019 Demographics in 1935 HOLC-Graded Tracts:				Median Household Income ($/year)*
		White*	Non-White*	Hispanic*	Home-Owners*	
A "Best"	0.25	8.77	3.12	1.43	11.06	127,581
B "Still desirable"	3.96	14.54	10.09	5.18	18.39	82,448
C "Definitely Declining"	47.03	45.18	50.65	48.19	45.89	54,889
D "Hazardous"	48.76	31.50	36.14	45.20	24.67	48,560

Figure 6. Redlining and current demographics in Los Angeles

The legacy of redlining can also be seen in the siting of major freeway construction in Los Angeles in the decades following the 1930s (Figure 7, page 16). Most major freeway construction was sited in low-income communities of color living in neighborhoods formerly graded D and C by the HOLC. Such projects have significant impacts on these communities—resulting in displaced residents, fractured social and professional networks, and increased pollution as a result of freeway traffic. For example, the 1993 Century Freeway (Interstate 105) alone displaced 25,000 residents over a 15-year period. Interstate 105 plans predominantly affected African American and low-income neighborhoods, which had been mapped as Grades C and D (Hughes 2021), and have faced higher health impacts (see Figure 8).

Finally, recent research demonstrates that the effects of climate change, such as extreme heat, can be felt more acutely in formerly redlined neighborhoods, leading to increased health risks and higher energy costs. This can lead to higher mortality risk during heat waves and higher cooling loads. On the date (i.e., 2017) measured by Hoffman, Shandas, and Pendleton (2020), redlined neighborhoods (Grade D) in Los Angeles were, on average, 4.2°C (7.6°F) hotter than those neighborhoods deemed "Best" (Grade A) by the HOLC in the 1930s (Figure 8). These trends are partly attributable to urban disinvestment practices and land use patterns that result in a lower relative amount of tree canopy and greenspace (cools and reflects heat) as compared to asphalt (absorbs heat) in "D" neighborhoods (Hoffman, Shandas, and Pendleton 2020). Other causal factors, such as inefficient and poorly maintained air conditioning and poorly insulated homes, may compound these differences.[17]

1939 HOLC "Residential Security Map"

Map of Perceived Mortgage Lending Risk in

LA Neighborhoods

Color-Coded Categories:

Category 1: **"Best"** = Grade A

Category 2: "**Still Desirable**" = Grade B

Category 3: "**Definitely Declining**" = Grade C

Category 4: "**Hazardous**" = Grade D

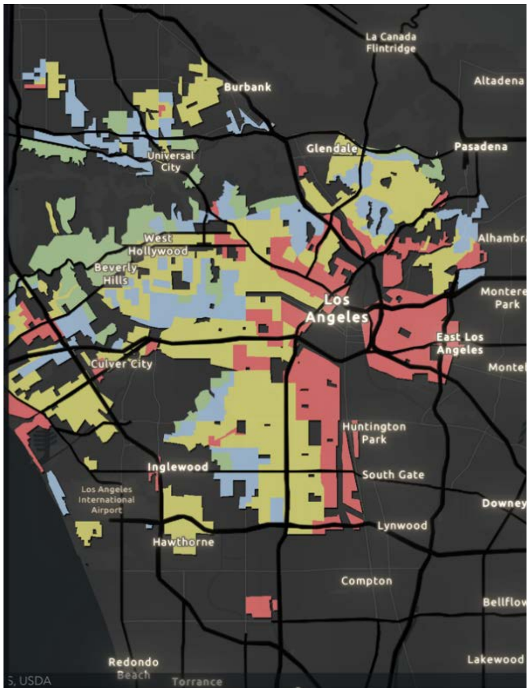


Figure 7. The correlation between the legacy of redlining and major freeway projects in Los Angeles, where thick black lines represent freeways

Source: Hughes 2021

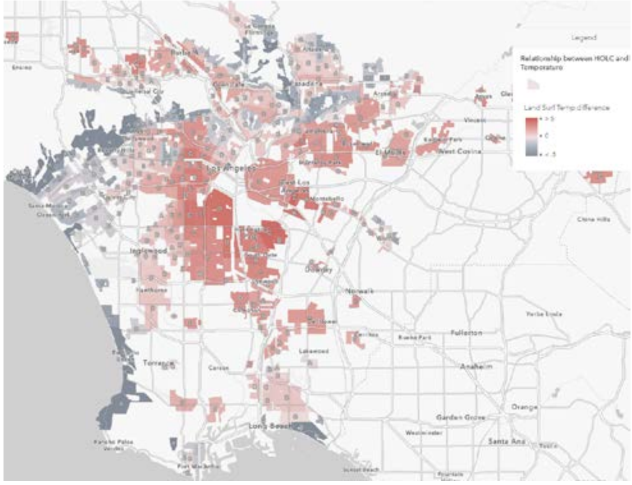


Figure 8. Effects of historical housing policies on resident exposure to intra-urban heat in LA

Source: Hoffman, Shandas, and Pendleton (2020)

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[17] Note that zoning in Los Angeles (https://zimas.lacity.org/) loosely follows DAC boundaries. In other words, renters likely residing in DACs are the very same segment that are most vulnerable to heat, air pollution, and other hazards (Romero-Lankao, Qin, and Dickinson 2012; Romero-Lankao, Wilhelmi, and Chester 2018; Harlan et al. 2013a).

3.1.3 Transportation Development

As shown in Figure 7 and discussed above, a web of freeways was built through Los Angeles since the 1950s, particularly in East LA and South LA. The construction of this infrastructure required demolition of thousands of homes and businesses (Meares 2020), disproportionately displacing residents of historically redlined or racially diverse neighborhoods (Fleischer 2020). This fractured communities and exacerbated segregation (Stermon and Lukinbeal 2021), the wealth gap, and the health gap (Nardone, Chiang, and Corburn 2020), because neighborhoods in close proximity to freeways are exposed to higher levels of pollution (including air pollution and noise pollution). This pollution has a long-term impact of suppressing property values for homeowners (Li and Saphores 2012; Cervero and Duncan 2002). At the same time, an additional inequitable impact is created that keeps the cost of housing relatively lower—and therefore more accessible to lower-income households—due to the hazards of pollution.

This pattern of development also embedded a dependency on the automobile, with its associated public health impacts, its connection to economic opportunities and inherent costs, and greenhouse gas emissions. For individuals and households without access to an automobile, economic opportunity is typically harder to access; and, even when controlling for many other influential variables (e.g., levels of education, race, age, gender, employment status, and household size), incomes of carless households in Los Angeles are significantly lower than those of car-owning households (King, Smart, and Manville 2019). At the same time, the cost of owning and maintaining a personal vehicle is proportionately higher as a share of a household's budget, the lower a household's income.

In terms of accessing employment, Angelenos commute 8.8 miles on average each way to work (Kneebone and Holmes 2015). Since 2000, the proximity to employment for residents living in neighborhoods with high poverty rates and/or majority-minority populations has notably decreased, leading these residents to travel further for livable-wage jobs. Thus, disadvantaged populations are suffering longer commutes (Kneebone and Holmes 2015; Tijerina 2019), which effectively lowers the value of their labor per hour as the time and cost of travel to work increases.[18] Although many factors are intervening, this distance can contribute to increased emissions and health and quality of life impacts.

These issues disproportionately negatively impact low-income residents, people of color, and immigrants. Negative impacts, such as increases in the cost of transportation and the distance from livable-wage jobs and other services, are exacerbated by limited transportation options. These residents contend with limited access to reliable and frequent public transportation options, while access to private transportation—a norm in Los Angeles given the city's auto-centric geography—is limited by economic barriers. Furthermore, the transportation options available to these residents place them at a higher risk of incidents and crashes that compromise traffic safety. This has translated to more than 250 traffic fatalities per year in recent years, with almost one-half of those being pedestrians or bicyclists (Fonseca 2022). These victims are disproportionately residents of underserved communities, with Black residents especially impacted (Brozen and Yahata Ekman 2020).

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[18] LA100 Equity Strategies Listening Sessions, 2022

3.1.4 Energy System Infrastructure

Analysis in this section does not include aging distribution, which may potentially impact underserved communities as illustrated by the recent death due to downed powerlines[19]. LADWP's 8 GW of electrical generating capacity comes from power plants in five different states using seven different energy sources: coal, geothermal, hydropower, natural gas, nuclear, solar, and wind (Furnaro and Kay 2021). Of these power plants, the Harbor Generating Station and the Valley Generating Station are located within the LA city limits. Both are natural gas-fired power plants located in two disadvantaged areas: the Harbor Generating Station in LA's Wilmington neighborhood and the Valley Generating Station in the Sun Valley neighborhood of LA's San Fernando Valley. The communities around these power plants bear a larger burden of the air pollution they generate (Ramirez 2020). An example concerning the siting and systems surrounding existing fossil fuel infrastructure in Los Angeles is instructive here. Jill Johnston, Assistant Professor of Preventive Medicine at the University of Southern California, notes:

> "In working class communities of color in South Los Angeles, for instance, oil and gas operations occur within close proximity of where people live or go to school, but few policy protections are enforced to limit the migration of various chemicals from oil well sites in these communities. In contrast, when you look at sort of White and wealthier parts of the county, like near Beverly Hills, you do see those oil facilities tend to be completely enclosed. There tends to be noise barriers and a lot more systems in place to try to prevent the release of chemicals or other harmful effects upon the nearby communities." (Ramirez 2020)

Aware of this situation, an LA100 Equity Strategies listening session participant also noted that:

> "[W]hile I appreciate raising the concern about addressing current infrastructure, shoring up that infrastructure, I also wonder if there is a plan to remediate some of the infrastructure that currently exists in South LA that is problematic, in terms of known adverse health outcomes. So, I think one thing is capacity. Does our infrastructure have the capacity to deal with these things. But I also think, just in terms of—from what I understand from the community—there is a sense of neglect. In terms of the outdated infrastructure that needs remediation…"

In 2020, regulators voted to allow four Southern California natural gas plants to remain online potentially till 2026,[20] indicating that the state does not yet have sufficient clean energy resources or storage and reliability provisions to close fossil fuel plants. In the meantime, Angelenos living close to these generating facilities will continue to breathe the accompanying hazardous air pollutants (Roth 2020).

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[19] For details, see Chapter 12 and the following sources: "LADWP Launches Website to Share Locations and Daily Progress of Priority Pole Replacement Work," LADWP, May 4, 2023, https://www.ladwpnews.com/ladwp-launches-website-to-share-locations-and-daily-progress-of-priority-pole-replacement-work/ and "L.A. to Pay $38 Million Over Downed Power Line that Electrocuted Father and Daughter," David Zahniser and Dakota Smith, *Los Angeles Times*, April 24, 2023, https://www.latimes.com/california/story/2023-04-24/dwp-will-settle-downed-power-line-lawsuit-for-38-million.

[20] See "California just can't kick its coastal gas plant addiction," Sammy Roth, *Los Angeles Times*, June 22, 2023, https://www.latimes.com/environment/newsletter/2023-06-22/california-just-cant-kick-its-coastal-gas-plant-addiction-boiling-point.

3.2 Causal Factors of Current Energy Inequities in Crosscutting Prioritized Areas

In this section, we analyze the legacies and causal factors influencing energy inequalities in four crosscutting prioritized areas identified through a literature review and one-on-one meetings with CBOs that were in LA100 Equity Strategies Steering Committee (Figure 1, page 3):

1. Energy affordability and burdens (Chapter 5)
2. Access to and use of energy technologies, infrastructure, and LADWP programs
3. Jobs and workforce development
4. Public health, safety, and community resilience.

Table 4 (page 20), Table 5 (page 22), Table 6 (page 25), and Table 7 (page 27)—which correspond to the prioritized areas of energy affordability and burdens; access and use; jobs and workforce development; and public health, safety, and community resilience respectively—illustrate causal factors that have contributed to present-day inequities in the following areas modeled in this report:[21]

- Safe home temperatures and housing weatherization (Chapters 6 and 7)
- Transportation electrification and truck electrification for air quality (Chapters 10 and 11)
- Rooftop solar and storage, and community solar (Chapters 8 and 9)
- Grid upgrades (Chapter 12).

3.2.1 Affordability and Burdens

Although the LA100 study (Cochran and Denholm 2021) found that the goal of achieving 100% renewable energy by 2035 is feasible and essential, there must be a concentrated effort to remediate existing and future inequities in energy affordability and burdens. This includes the potential future burden of higher electricity rates that become unaffordable for low- and moderate-income ratepayers in Los Angeles (Brown et al. 2020a and Chapter 5). To achieve equity goals in the clean energy transition and remediate past inequities in Los Angeles, Chapter 5 examines strategies that could address energy burdens, particularly for underserved Angelenos. Currently, Los Angeles has energy incentive programs that often disproportionately benefit wealthier populations (see Section 4), rather than enhancing energy affordability or reducing burdens that can lead to achieving energy justice. Energy burden is "the percent of a household's income spent on utilities for heating, cooling, and other energy services" (Brown et al. 2020b; Drehobl, Ross, and Ayala 2020; Hernández and Bird 2010). However, calculating the energy burden, while important for understanding inequities, is not enough. Many other burdens (e.g., rent, health care, childcare) lower the funds available to individuals and families, and utility bills must be paid.

Energy justice scholars and practitioners are increasingly calling for a more holistic approach to energy burdens that (a) considers energy inequalities embedded in housing, transportation, infrastructural investments, and program development, and (b) examines tradeoffs households

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[21] For further information on how these causal factors relate to present-day energy equity impacts, see Appendix C.

may make to pay for rent, mobility, and other needs while avoiding disconnection, displacement, and other disruptions (Hernández and Bird 2010; Gonzalez et al. 2021). The ultimate purpose is to develop strategies that more effectively foster affordability. As already described in Section 3.1.1 and Table 2 (page 11), high energy burdens—set in the United States at more than 6% of a household's income (Drehobl, Ross, and Ayala 2020)—result from a series of intersecting factors, barriers, and challenges that Angelenos face. By analyzing the qualitative findings from engagement with community members and CBOs, as well as our ongoing literature review, we identified examples of these factors in Table 4.

In Steering Committee meetings, affordability and energy burdens have been a primary area of concern for member CBOs. Comments have ranged from built-environment concerns, such as how "new building standards may affect housing affordability" (Steering Committee Members 2022a), to socioeconomic concerns, such as "funding assistance for low-income folks" (Steering Committee Members 2022a) and the "need for fully funded technical assistance" (Steering Committee Members 2022a) in low-income homes to redress costly energy inefficiencies. Members have also considered how to redress inequities through cultural and behavioral change, such as providing "better real-time information about peak energy use rates to nudge behavior and save money on energy bills" (Steering Committee Members 2022b). Finally, members have pointed to programmatic- and policy-related opportunities, such as developing a pathway to initiate "automatic enrollment in low-income rate subsidy programs" (Steering Committee Members 2022b).

After qualitatively coding CBO data into priority areas, we created subcategories to map the types of causal factors and energy impact areas to each form of feedback and literature review referred to in Chapter 2, and in Section 2 of this chapter. Table 4 integrates this qualitative coding. For a more detailed illustration, please see Table C-1 in Appendix C.

Table 4. Examples of Factors That Can Impact Energy Affordability and Burdens

Modeled Areas	Dimension	Causal Factors
Safe Home Temperatures, Housing Weatherization	Built Environment	Cost of upgrading and energy retrofits
		Cost of introducing heat pumps in single-family, multifamily, commercial, manufactured, municipal buildings
		Cost of local infrastructure (e.g., physical accessibility, maintenance, accessibility for people with mobility challenges)
	Policy / Political context	LADWP conservation and efficiency-promoting programs to reduce home / community energy bills (e.g., accessibility of information)
		Incentives vs. rebates for building energy upgrades (e.g., impact of up-front investment requirements) and reducing energy bills
	Sociocultural / Behavioral	Awareness of time-of-use rates, changes to net metering policies (e.g., information access for informed decision-making)
		Cultural / language barriers to understanding tariffs

Modeled Areas	Dimension	Causal Factors
		Time poverty (e.g., ability to participate in appliance programs)
Rooftop Solar and Storage, Community Solar,	Built Environment	Cost of overcoming barriers to solar installation (building and roof upgrades)
		Constraints on *where* and *when* distributed generation and local solar is deemed economically feasible
		Cost of installing solar on public facilities
	Policy / Political Context	Cost of communication of plans and studies with appropriate language, materials, transparency in assumptions and process, etc.
	Sociocultural / Behavioral	Cost of introducing discount programs
		Cost of introducing neighborhood-level pilots and neighbor or peer effects shaping community uptake of solar and storage
Transportation and Truck Electrification	Built Environment	Cost of introducing workplace / public EV charging
	Policy / Political Context	Cost of developing community outreach and engagement activities
	Sociocultural / Behavioral	Cost of communicating technical plans and studies to communities
Grid Upgrades	Built Environment	Cost and technical feasibility of upgrading distribution infrastructure (e.g., distributed generation and rooftop solar)
	Policy / Political Context	Technical and financial resources to improve existing LADWP policies and develop new ones
	Sociocultural / Behavioral	Cost of communication of plans and studies with appropriate language, materials, transparency in assumptions and process, etc.

3.2.2 Access to Energy Technologies, Infrastructure, and Programs

LA100 Equity Strategies involves co-developing energy equity strategies that achieve a more equitable and just energy transition. A key means to achieving this goal is to holistically examine how different communities can access or use energy transition technologies and services such as energy efficient air conditioners, heat pumps, solar, and electric mobility to fulfill their everyday needs of heating, cooking, power, transportation, and telecommunications. No single definition is used to define energy access (IEA 2020), but access typically refers to a household's *actual use* of: (a) a minimum level of reliable electricity; (b) safer and more sustainable energy for cooking, AC, and heating and stoves; (c) a grid that enables productive economic activity and public services; and (d) heat pumps, AC, electric mobility, rooftop solar, and other transition technologies, devices, and services.

Energy access can be constrained by a suite of intersecting factors, barriers, and challenges that communities face. Beyond physical access, energy access includes the means to take advantage of utilizing existing technologies—whether constraints be economic (i.e., budget), knowledge-based (i.e., information, training), or sociocultural (i.e., behavioral norms). As with affordability, qualitative methods employed during community engagement and a literature review have been used to identify examples of these factors (see Table 5). For a more detailed illustration of how these causal factors relate to energy equity impacts related to access, see Table C-2 in Appendix C.

In Steering Committee meetings, member CBOs have consistently called attention to the question of access—e.g., to energy technologies, infrastructure, and programs—as a critical equity-opportunity space. Comments have ranged from built-environment concerns, such as how to "incentivize upgrades in older rental properties" (Steering Committee Members 2022a), to socioeconomic concerns, such as access to information that can "help small businesses understand affordable options" and developing "new financing models to ameliorate [their] up-front cost concerns" (Steering Committee Members 2022a). Members have also considered how providing access to "real-time information on energy sources to lower-income households" (Steering Committee Members 2022a) can bolster cultural and behavioral change for both LADWP and their customers, emphasizing the need to "keep cost increases transparent and clear before introducing a technology" (Steering Committee Members 2022b). As LADWP increases transparency with their customers, Angelenos are given the tools to calculate how their everyday actions directly relate to changes in the environment and utility costs (Steering Committee Members 2022a; 2022b). Finally, members have pointed to the need for more program and policy actions to increase all Angelenos' access to career-advancing opportunities, such as developing "paid apprenticeship training programs and intentional gender inclusivity," providing educational "training in key communities," and opening job training access to underserved populations such as "non-college bound high schoolers" and the "prison population" (Steering Committee Members 2022a; 2022b).

After qualitatively coding CBO data into primary areas of concern regarding access, we created subcategories to map out the types of causal factors and energy impact areas to which each form of feedback referred. Table 5 integrates this qualitative coding system into our ongoing literature review to provide a more robust analysis of the factors limiting access to energy equity.

Table 5. Examples of Causal Factors That Can Impact Access and Use

Modeled Areas	Dimension	Causal Factors
Safe Home Temperatures, Housing Weatherization	Built Environment	Building age (e.g., technical barriers to electrification and energy retrofits)
		Building type (e.g., feasibility of technologies in single-family, multifamily buildings)
		Local infrastructure (e.g., physical accessibility, maintenance, accessibility for people with mobility challenges)
	Policy / Political context	DWP conservation and efficiency-promoting programs to reduce home and community energy demand (e.g., accessibility of information)

Modeled Areas	**Dimension**	**Causal Factors**
		Incentives vs. subsidies or rebates for building energy upgrades (e.g., impact of up-front investment requirements)
	Sociocultural / Behavioral	Awareness of time-of-use rates, changes to net metering policies (e.g., information access for informed decision-making)
		Cultural and language barriers to information (e.g., accessibility of information related to existing assistance programs or technical guidance)
		Time poverty (e.g., ability to participate in community engagement activities and/or education and outreach programs)
Rooftop Solar and Storage, Community Solar	Built Environment	Building and roof age (e.g., technical barriers to solar installation)
		Constraints on distributed generation and rooftop solar technical feasibility (e.g., *where* and *when* distributed generation and local solar is deemed economically and technically feasible)
		Land use patterns and development density (e.g., density impacts on solar potential and feasibility)
		Solar on public facilities (e.g., access to resilient energy and educational co-benefits of visible solar)
	Sociocultural / Behavioral	Ability of partners to communicate technical plans and studies to their communities with appropriate language, materials, transparency in assumptions and process, etc.
		Barriers to participation in community outreach and engagement activities
		Neighborhood-level uptake of solar and storage (e.g., peer effects help solar adoption feel accessible)
Transportation and Truck Electrification	Built Environment	Availability of workplace / public EV charging
	Sociocultural / Behavioral	Ability of partners to communicate technical plans and studies to their communities with appropriate language, materials, transparency in assumptions and process, etc.
		Barriers to participation in community outreach and engagement activities
		Mode-shifting policies and trends affecting social and cultural acceptability and perceived accessibility and safety of alternative transportation options
		Time poverty (e.g., ability to shift transportation behaviors or modes, ability to take advantage of off-peak hours EV charging incentives)
Grid Upgrades	Built Environment	Age of existing distribution infrastructure (and timeline for future upgrades) constraining technical feasibility of distributed generation and rooftop solar
	Policy / Political Context	LADWP policies prioritizing energy efficiency vs. new generation (e.g., access to energy efficiency programs, technical and financial resources)

Modeled Areas	Dimension	Causal Factors
	Sociocultural / Behavioral	Ability of partners to communicate technical plans and studies to their communities with appropriate language, materials, transparency in assumptions and process, etc.
		Barriers to participation in community outreach and engagement activities

3.2.3 Jobs and Workforce Development Opportunities

LA100 showed the potential for a 100% renewable energy target by 2035 to require an average of more than 10,000 jobs annually to build and operate power generation-related infrastructure (Cochran et al., n.d., 100). Existing scholarship has found that as they expand, clean energy industries can create more job opportunities than fossil fuel industries (Cameron and Van Der Zwaan 2015; Pollin and Callaci 2019). However, underserved communities, who are often already excluded from equitable workforce participation, are particularly likely to face challenges from labor disruptions associated with the energy transition, even if a low-carbon economy creates more job opportunities than fossil fuel industries (Carley and Konisky 2020; Furnaro and Kay 2021). A series of causal factors and best practices could be considered to avoid detrimental job impacts and foster workforce development opportunities during the transition away from fossil fuels in Los Angeles. To identify these factors and practices, qualitative methods employed during community engagement and an ongoing literature review have been used (see Table 6, page 25). For a detailed illustration of how these causal factors relate to energy equity impacts related to jobs and workforce development, please see Table C-3 in Appendix C.

In Steering Committee meetings, providing career-advancing jobs and workforce development opportunities has been a crosscutting issue for member CBOs. Comments have ranged from geographic and built-environment concerns, such as how to develop “targeted job training for communities near LADWP properties” (Steering Committee Members 2022a), to socioeconomic concerns, such as identifying “who will finance an equitable workforce transition” (Steering Committee Members 2022a). Members have also considered how to redress inequities through cultural and behavioral change on the employer side, suggesting LADWP “support funders [employers] with strong labor standards & practices” (Steering Committee Members 2022a). Finally, members emphasized a need to develop a “Jobs Plan for LA100” (Steering Committee Members 2022b) that includes expanding successful existing LADWP programs that increase career-advancing jobs for underserved populations, such as the Utility Pre-Craft Training (UPCT) program (Steering Committee Members 2022a; 2022b; 2021).

After qualitatively coding CBO data into primary areas of concern related to jobs and workforce development, we created subcategories to map the types of causal factors and energy impact areas to which each form of feedback referred. Table 6 integrates this qualitative coding system into our ongoing literature review to provide a more robust analysis of the factors influencing energy-related jobs and workforce development in Los Angeles today.

Table 6. Examples of Causal Factors That Can Impact Jobs and Workforce Development Opportunities

Modeled Areas	Dimension	Causal Factors
Safe Home Temperatures, Housing Weatherization	Policy / Political Context	Building codes (e.g., impact of new building codes on quantity, quality of construction jobs)
		City contracting standards (e.g., impact of hiring and labor standards on ensuring quality jobs for local residents)
		Collective bargaining agreements and workforce development and training in relation to the energy transition
		LADWP conservation and efficiency-promoting programs to reduce home and community energy demand (e.g., impact of programs on employment and training for clean energy trades in local communities)
Rooftop Solar and Storage, Community Solar	Built Environment	Interrelated dependencies of transmission upgrades, distributed generation, and small-scale residential solar (e.g., long-term job potential and security in these different sectors)
	Policy / Political Context	City contracting standards (e.g., impact of bid requirements on ability for small local businesses to bid for and win City contracts)
		Hiring practices for construction, operation, and maintenance of solar and related infrastructure
		Workforce training programs and opportunities for construction, operation, and maintenance of solar technology and infrastructure
Transportation and Truck Electrification	Policy / Political Context	City contracting standards (e.g., impact of hiring and labor standards on ensuring quality jobs for local residents)
		Hiring practices for construction, operation, and maintenance of transportation systems and infrastructure
		Workforce training programs and opportunities for construction, operation, and maintenance of panels and charging infrastructure
Grid Upgrades	Built Environment	Existing natural gas units and associated infrastructure (e.g., economic dependence on fossil-fired generation for jobs and tax revenue)
	Economic	Rate structures (e.g., impacts on ability for small businesses to hire and raise wages)
		Revenue losses from closure of fossil-fired generation (e.g., impacts on long-term household- and community-level economic stability)
	Policy / Political Context	City contracting standards (e.g., impact of hiring and labor standards on ensuring quality jobs for local residents)

3.2.4 Public Health, Safety, and Community Resilience

LA100 found that DACs located near LADWP in-basin power plants, the Ports of Los Angeles and Long Beach, and major roadways, as well as those living or working in buildings with space-heating or other appliances, could expect different types of benefits from the transition to a 100% renewable future. The benefits include improved public health from reduced use of indoor combustion equipment replaced with electric appliances, as well as reductions in air pollution and in concentrations of more local pollutants (Hettinger et al. 2021).

Energy justice scholars emphasize that the effect of indoor and outdoor air pollution, extreme heat, and other climatic and environmental impacts on communities is determined by socioeconomic and spatial inequalities, driven by the already referred to socio-institutional dynamics shaping urban development. Scholars emphasize that in many cities, a series of factors springing from social inequality result from legacies of past practices and policies (Section 1.4.1). These factors prevent DACs from reaping the rewards of local environmental amenities such as tree shade, open space, good-quality housing and building envelopes, and cleaner air (Morello-Frosch et al. 2011; Lucas 2012; Church, Frost, and Sullivan 2000). These factors relate to higher exposure and lower community resilience, defined as the capacity to draw on income, education, and other resources to adapt to the health impacts of pollution, heat, energy outages, and other disruptions and stressors (Harlan et al. 2013b; Romero-Lankao, Qin, and Dickinson 2012; Qin et al. 2015; Hayden, Brenkert-Smith, and Wilhelmi 2011).

In this section, we summarize preliminary results from qualitative methods employed during community engagement and a literature review to identify examples of these factors (see Table 7). For a detailed illustration of how these causal factors relate to energy equity impacts related to public health, safety, and community resilience, please see Table C-4 in Appendix C.

In Steering Committee meetings, public health, safety, and community resilience have surfaced as primary areas of concern for member CBOs. Comments include built-environment concerns, such as “addressing habitability with energy retrofits” (Steering Committee Members 2022a) and associated “space concerns with electrification technologies” (Steering Committee Members 2022a). Members have also emphasized that in Los Angeles, the “biggest health danger [is] from transportation” (Steering Committee Members 2022a) rather than peaker plants; thus, “electrifying transportation will reduce GHGs” (Steering Committee Members 2022a) and significantly contribute to public health benefits in their communities. Yet, there is still a “need to address pollutants produced by peaker plants” (Steering Committee Members 2022a). A recurrent socioeconomic concern is related to the fracturing and displacement of low-income communities of color, and how to “avoid eviction and affordable housing loss” (Steering Committee Members 2022a). Such forms of displacement relate to affordability, but also to community resilience, as a loss of community members—whether a result of utility disconnection, infrastructure-related displacement, eviction, and/or loss of affordable housing options—fractures social safety nets and professional networks that are key determinants of a household’s capacity to deal with burdens. Members have also considered how to redress inequities through cultural and behavioral change in the way government entities engage in community engagement and procedural justice. Community resilience includes defining what engagement and accountability look like after the LA100 Equity Strategies project and recognizing the importance of including “often-marginalized equity communities in the decision process for LA100 policies and timeline” (Steering Committee Members 2022b). Finally, members have pointed to a need for “more direct install programs” (Steering Committee Members 2022a; 2021) as well as LADWP programs designed with “incentives rather than rebates” (Steering Committee Members 2022a; 2021) to support resilience in their communities.

After qualitatively coding CBO data into primary areas of concern, we created subcategories to map out the types of causal factors and energy impact areas each form of feedback referred to. Table 7 integrates this qualitative coding system into our ongoing literature review to provide a more robust analysis of the factors influencing public health, safety, and community resilience in Los Angeles today.

Table 7. Examples of Causal Factors That Can Impact Public Health, Safety, and Community Resilience

Modeled Areas	Dimension	Causal Factors
Safe Home Temperatures, Housing Weatherization	Built Environment	Indoor air pollution and emissions from building systems and appliances (e.g., refrigerants, air toxins, methane)
		Building age (e.g., affecting structural stability and health risks)
		Building exposure to climate hazards / adaptability to climate extremes
		Local microclimatic and infrastructural characteristics associated with ability to maintain thermal comfort, exposure to energy infrastructure-related hazards, etc.
	Economic	Sudden or chronic economic hardship due to persistent low (or unstable) income affecting ability to maintain safe and healthy home or work environment (e.g., thermal comfort, routine maintenance, addressing sources of indoor air pollution)
		Rent burden affects ability to maintain safe and healthy housing
	Sociocultural / Behavioral	Baseline vulnerability of building occupants to indoor air pollution, extreme heat, and health multiplier problems affecting resilience to acute health threats (e.g., heat waves and respiratory viruses)
	Policy / Political Context	City contracting standards (e.g., impacts of pollution related to contractors hired for City building projects)
		Zoning ordinances to fund HVAC upgrades for homes, schools, and community facilities in polluted areas
Community Solar, Rooftop Solar and Storage	Built Environment	Backup for remote and local resources (e.g., affecting energy reliability during outages)
		Life cycle costs and emissions of distributed energy technology and infrastructure (e.g., related health impacts across geographic and temporal/intergenerational scales)
		Solar on public facilities providing access to resilient energy
	Economic	Land acquisition costs for solar farms (e.g., siting decisions and associated environmental impacts)

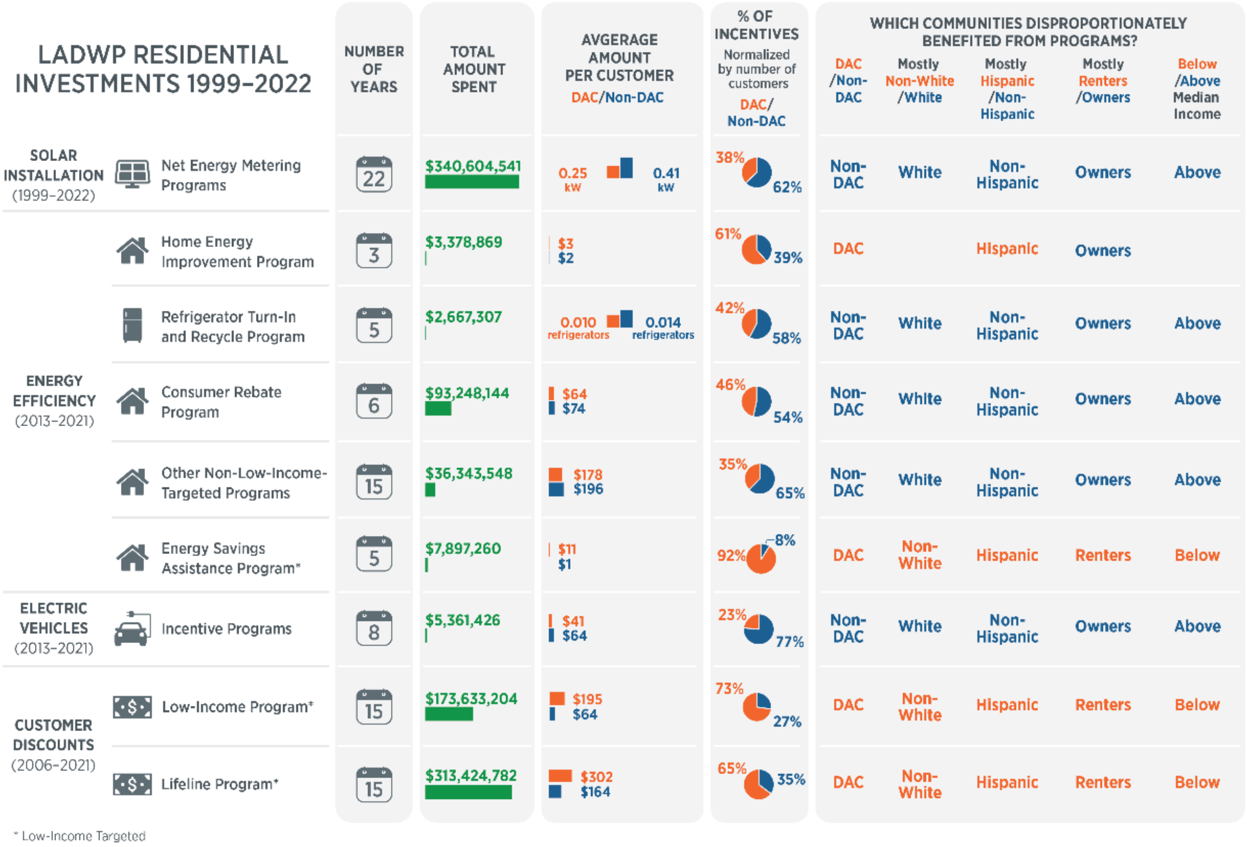
Modeled Areas	Dimension	Causal Factors
		Long-term funding for infrastructure maintenance and intergenerational impacts of allowing energy generation infrastructure to fall into disrepair or fail
	Policy / Political Context	City contracting standards for distributed energy installation and infrastructure projects influencing life cycle impacts of City activities, including pollution related to work performed by contractors
		Tax credits for solar and storage enabling broad adoption of resilient energy systems
	Sociocultural / Behavioral	Baseline individual vulnerability to air pollution from power generation creating individual- and community-level disparities in health benefits (and burdens) associated with distributed energy systems
		Not in my back yard (NIMBY) -ism (e.g., siting polluting or undesirable infrastructure in disadvantaged areas)
		Failure to prioritize health and resilience of outlying communities when analyzing impacts of clean energy facilities and infrastructure
Transportation and Truck Electrification	Built Environment	Infrastructure enabling electrification of trains, heavy-duty transport beyond buses (including freight) affecting feasibility of reducing emissions near warehouses, port, other heavy transportation corridors
		Electrification of private medium-duty vehicles, delivery truck fleets to reduce health impacts of air pollution
	Economic	Electricity rates relative to cost of gasoline affecting speed of electrification and mitigation tradeoffs between emissions from transportation and emissions from power generation
	Policy / Political Context	City contracting standards (e.g., pollution related to contractors hired for transportation infrastructure projects)
		Fossil fuel subsidies affecting speed of transition to clean energy and resulting health benefits
		Reduction policies and trends for vehicle miles traveled (e.g., changes in *sources* and *distribution* of emissions and air quality impacts over time)
		Rollback of Corporate Average Fuel Economy standards and resulting emissions and health impacts
	Sociocultural / Behavioral	Baseline vulnerability to transportation-related air pollution, health multiplier problems
		Behavior changes in response to COVID-19 (e.g., ability to shift to new transportation modes and resulting emissions and health impacts)
		Mode-shifting (e.g., from transit to private vehicles and resulting emissions and health impacts)

Modeled Areas	Dimension	Causal Factors
Grid upgrades	Built Environment	Age of existing 4.8 kV distribution infrastructure affecting current operating performance of existing feeders and impacts on customer energy reliability and resilience
		Exposure to pollution from existing natural gas units and associated infrastructure
		Increasing frequency / severity of extreme weather, wildfires due to climate change
		Life cycle costs and emissions of distributed energy technology and infrastructure affecting the timing and distribution of different types of emissions and impacts
		Siting of current and planned transmission infrastructure enabling or constraining transition to clean energy systems in communities economically dependent on (and exploited by) extractive fossil energy systems
	Economic	Revenue losses from closure of fossil-fired generation affecting long-term household- and community-level economic stability, tax base, and ability to maintain critical public services
	Policy / Political Context	City contracting standards (e.g., pollution related to contractors hired for City building projects)
		Fossil fuel subsidies affecting speed of transition to clean energy and resulting health benefits
	Sociocultural / Behavioral	Adoption of demand response and load flexibility programs and behaviors affecting system-wide resilience
		Baseline individual vulnerability to air pollution from power generation
		Customer adoption of distributed energy systems affecting system-wide resilience
		Social and political acceptability of generation fuels, battery storage facilities for resilience

4 Access to the Benefits of LADWP Programs

Our recognition justice efforts included mapping current access to the benefits of LADWP programs (“LADWP Investments” in 30), to identify and measure inequities. Here, we compare the *number of benefits* distributed as well as the *total dollars* spent per program across communities (Figure 11, page 32).

We described in Section 2.2 the Statistical Methods used to analyze each program. We calculated the total amount of dollars spent (in the column “Total Amount Spent”) as well as the total amount spent per customer in DAC and non-DAC communities (in the column “Avg. Amount per Customer”) in Figure 9. Likewise, we adjusted the number of benefits received according to population to compare the percentage of benefits distributed across communities (represented in the column titled “% of Incentives” in Figure 9). Additionally, we performed a statistical analysis to determine if these percentages are statistically significant; in other words, the communities identified in the column titled “Which Communities Disproportionately Benefited from Programs?” in Figure 9 determine the communities that received a disproportionate amount of program benefits. Lastly, we identified if certain communities experienced more and/or longer power interruptions according to the System Average Interruption Duration and Frequency Indices (SAIDI and SAIFI; Figure 10). These analyses of utility-offered programs, services, and power infrastructure reliability contribute to recognition justice by identifying the communities that have historically benefited from programs and services in which LADWP has invested.



LADWP RESIDENTIAL INVESTMENTS 1999–2022		NUMBER OF YEARS	TOTAL AMOUNT SPENT	AVGERAGE AMOUNT PER CUSTOMER DAC/Non-DAC	% OF INCENTIVES Normalized by number of customers DAC/ Non-DAC	WHICH COMMUNITIES DISPROPORTIONATELY BENEFITED FROM PROGRAMS?				
						DAC /Non-DAC	Mostly Non-White /White	Mostly Hispanic /Non-Hispanic	Mostly Renters /Owners	Below /Above Median Income
SOLAR INSTALLATION (1999–2022)	Net Energy Metering Programs	22	$340,604,541	0.25 kW 0.41 kW	38% 62%	Non-DAC	White	Non-Hispanic	Owners	Above
ENERGY EFFICIENCY (2013–2021)	Home Energy Improvement Program	3	$3,378,869	$3 $2	61% 39%	DAC		Hispanic	Owners	
	Refrigerator Turn-In and Recycle Program	5	$2,667,307	0.010 refrigerators 0.014 refrigerators	42% 58%	Non-DAC	White	Non-Hispanic	Owners	Above
	Consumer Rebate Program	6	$93,248,144	$64 $74	46% 54%	Non-DAC	White	Non-Hispanic	Owners	Above
	Other Non-Low-Income-Targeted Programs	15	$36,343,548	$178 $196	35% 65%	Non-DAC	White	Non-Hispanic	Owners	Above
	Energy Savings Assistance Program*	5	$7,897,260	$11 $1	92% 8%	DAC	Non-White	Hispanic	Renters	Below
ELECTRIC VEHICLES (2013–2021)	Incentive Programs	8	$5,361,426	$41 $64	23% 77%	Non-DAC	White	Non-Hispanic	Owners	Above
CUSTOMER DISCOUNTS (2006–2021)	Low-Income Program*	15	$173,633,204	$195 $64	73% 27%	DAC	Non-White	Hispanic	Renters	Below
	Lifeline Program*	15	$313,424,782	$302 $164	65% 35%	DAC	Non-White	Hispanic	Renters	Below

* Low-Income Targeted

Figure 9. Analysis of LADWP investments in programs and services

Figure 10. Analysis of the benefits of LADWP programs and investments

Overall, the key findings (by program type) reveal that:

- The net energy metering (NEM) *solar installation programs* disproportionately served more installed solar capacity (kW) in non-disadvantaged, mostly White, mostly non-Hispanic, owner-occupied, and affluent tracts (Figure 9). Given the financial capital required for customers to be able to install rooftop solar and participate in these NEM programs, these findings are consistent with the trends of customer-adopted solar explored throughout the nation (Sigrin and Mooney 2018).
- *Energy efficiency incentive programs* (except the low-income-targeted program, otherwise known as the Energy Savings Assistance Program) disproportionately benefited households in non-disadvantaged communities as well as communities with mostly White, mostly non-Hispanic, owner-occupied, and affluent households (Figure 9).
- LADWP *EV incentive programs* disproportionately benefited non-disadvantaged communities and communities with mostly White, mostly non-Hispanic, owner-occupied, affluent households. However, there is no statistical difference between disadvantaged communities and non-disadvantaged communities in the distribution of *all* EV charging stations that are available to the public (Chapter 10), although our findings indicate that communities with mostly non-Hispanic households have more EV charging stations than communities with mostly Hispanic households.
- The Low-Income and Lifeline *customer discount programs* benefited disadvantaged communities as designed.
- Disadvantaged and mostly Hispanic communities have, on average, marginally more *power interruptions* per year than non-disadvantaged communities (0.93 in disadvantaged communities compared to 0.78 in non-disadvantaged communities; Figure 9*)*. However, there was no statistical significance between communities regarding the *duration* of the experienced power interruptions.

Lastly, we mapped program information to spatially identify census tracts that receive incentives proportional to their population. Our results indicate that most tracts that received disproportionate amounts of non-low-income-targeted residential energy efficiency incentives are located outside of DAC boundaries and conversely, residential energy efficiency programs that targeted low-income customers *appropriately* served households in DACs (Figure 12). Likewise, NEM solar installation programs (Figure 13) and residential EV incentives (Figure 9) disproportionately served census tracts located outside of DACs.

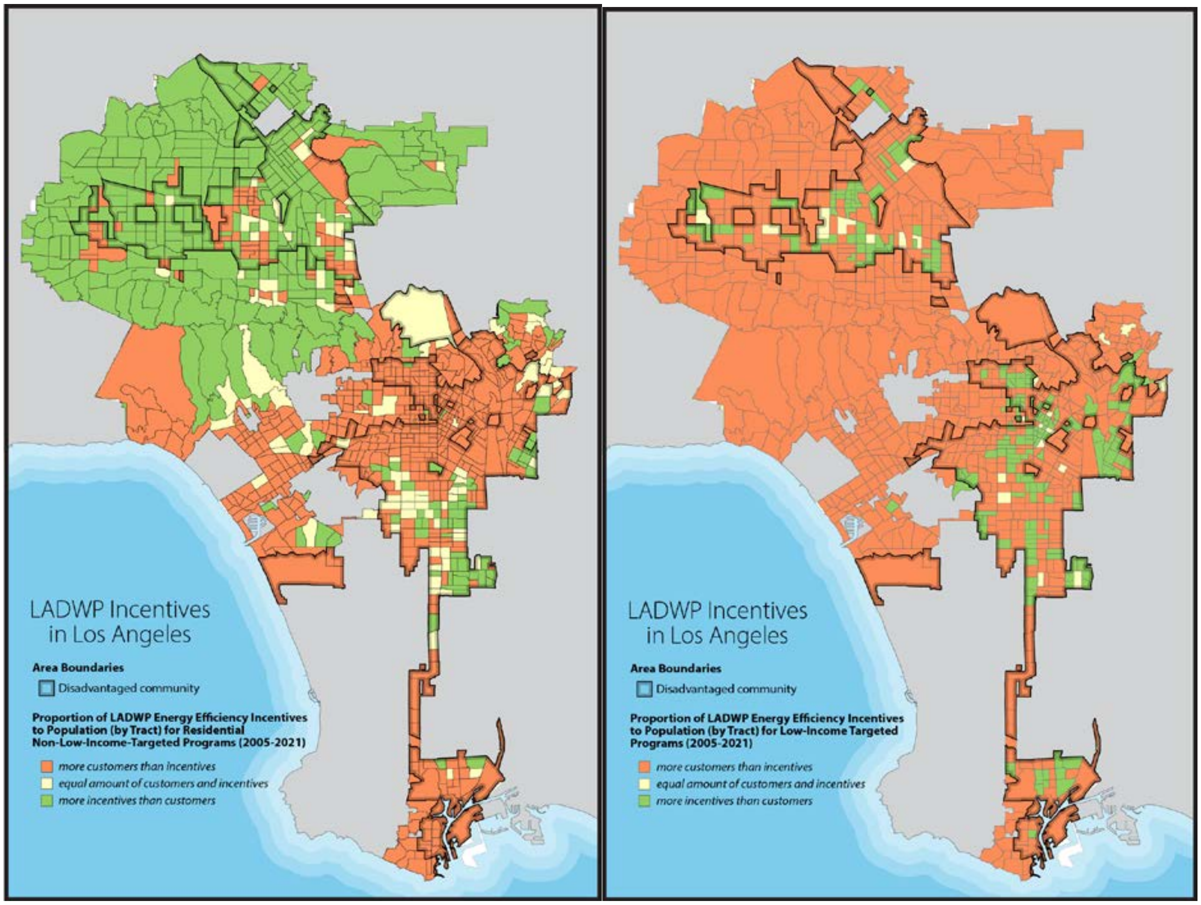


Figure 11. Proportion of residential energy efficiency incentives to population by census tract for programs *not* targeting low-income households (left) and programs targeting low-income households (right)

Orange tracts indicate the percentage of households in each tract is greater than the percentage of benefits received, green tracts indicate the percentage of incentives received is greater than the percentage of households in each tract, and yellow tracts represent areas where the percentage of incentives is proportional to the *population*.

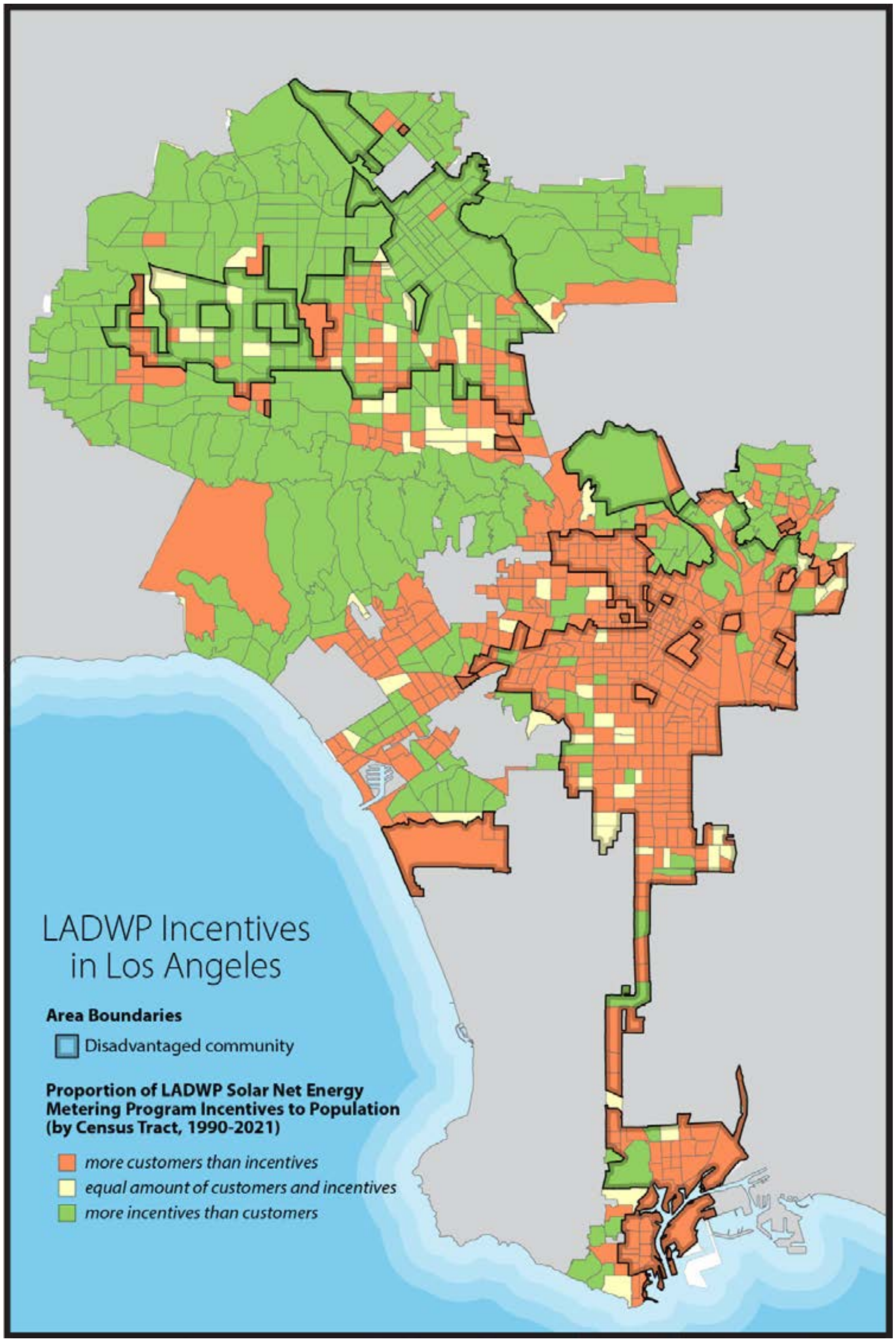


Figure 12. Proportion of residential incentives to population by census tract for solar NEM programs

Orange tracts indicate the percentage of households in each tract is greater than the percentage of benefits received, green tracts indicate the percentage of incentives received is greater than the percentage of households in each tract, and yellow tracts represent areas where the percentage of incentives is proportional to the *population*.

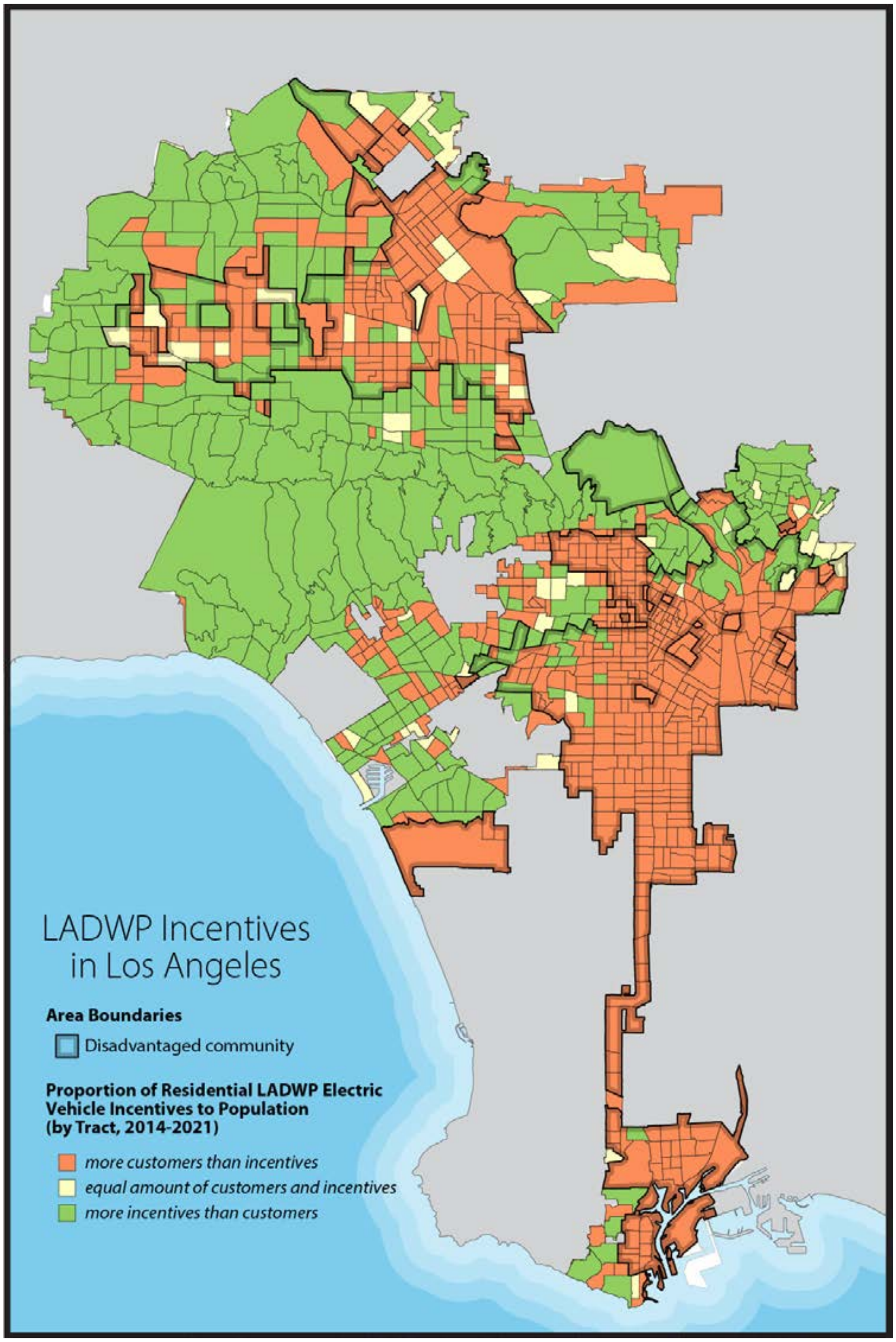


Figure 13. Proportion of residential EV incentives to population by census tract

Orange tracts indicate the percentage of households in each tract is greater than the percentage of benefits received, green tracts indicate the percentage of incentives received is greater than the percentage of households in each tract, and yellow tracts represent areas where the percentage of incentives is proportional to the *population*.

5 Conclusion

In this chapter, we presented results of analysis on *recognition justice.* We used a mixed methodological approach, including a systematic literature review and statistical analysis of LADWP programs and investments. Our aim was to inform modeling and development of equity strategies by analyzing (a) the distribution of benefits of LADWP programs and investments in the city and (b) historical and current factors contributing to this distribution and other energy inequities in the city. We provided the results of a qualitative and quantitative overview of critical processes determining inequities in education, employment, income, housing, and transportation relevant to the current energy transition. We focused on the causal factors affecting current inequities in four areas: (1) energy affordability, (2) energy access, (3) health, and (4) jobs (Figure ES-1), finding that:

- The benefits of LADWP's programs such as solar installation benefits, non-low-income-targeted energy efficiency programs, and EV incentives are not equitably distributed across communities.
- Underserved communities such as low-income families, renters, people of color face higher energy and transportation burdens, unsafe temperatures, and higher impact from extreme heat events, and other negative impacts of historical legacies that are still present in current policies and practices. At the same time, those who benefit include higher-income families, White Angelenos, and homeowners.

Redlining and infrastructure investment and siting belong to a set of historical and ongoing processes of institutionalized exclusion that have direct and indirect implications on current energy inequities in Los Angeles. For instance, the legacies of redlining negatively affect populations living in poor-quality buildings and unsafe and inefficient housing stock; they also constrain people's access to credit to improve those conditions, and force families to pay high energy bills. These inequities are evidenced in the everyday experiences of underserved community members, who reported:

- Poor quality and maintenance of infrastructure and housing due to decades of disinvestment and neglect
- A lack of affordable housing for renters and owners
- Barriers to making energy decisions for themselves and their communities (that we term *self-determination*)
- A lack of access to financial capital for energy access, affordability, and decision-making
- Mistrust and grievances related to the government agencies and policies
- A lack of accessible and useful information about resources and programs.

Without access to structurally sound housing stock or to legal upgrading options, these households also become ineligible for available energy efficiency programs, such as publicly accessible solar installation programs.

We identified a series of structural, intersecting factors currently influencing energy inequalities. For example, chronic economic hardship due to persistent low income intersects with factors such an inefficient housing stock to impact households' ability to afford electricity. Building type and age intersect with ownership status to influence a household's capacity to benefit from solar incentive, Feed-in Tariff, and Feed-in Tariff Plus programs. Analysis of these factors informs the modeling and strategy development described in subsequent chapters that effectively redresses current inequities for the future as LADWP and their partners design just transition strategies.

We mapped how unequal access to LADWP programs relates to the legacy of trends and practices in education, jobs, housing, transportation, and energy infrastructure. While energy assistance policies and programs are widely considered best practices in the clean energy transition, inequities have become entrenched in these programs across energy utilities in the United States (analyzed in Chapter 4). We present actionable solutions and strategies in Chapters 3 and 4 that LADWP can use to ensure that going forward, their programs will be more accessible and equitable for LA communities.

6 Glossary

Actions/Strategies: the means used to solve identified problems in an impact area; actions and strategies involve programs such as bills, regulations, rates, subsidies, and investments and how they are designed, implemented, and evaluated (Dubash et al. 2022)

Causal Factors: "Events, incidents, happenings that lead to the occurrence or development of a phenomenon" (Buckley and Waring 2013, 156).

Climate Justice: the remediation of the impacts of climate change on poor people and people of color, and compensation for harms suffered by such communities due to climate change (Burkett 2008)

Co-Creation: "a process through which two or more public and private actors attempt to solve a shared problem, challenge, or task through a constructive exchange of different kinds of knowledge, resources, competences, and ideas that enhance the production of public value in terms of visions, plans, policies, strategies, regulatory frameworks, or services, either through a continuous improvement of outputs or outcomes or through innovative step-changes that transform the understanding of the problem or task at hand and lead to new ways of solving it" (Torfing et al. 2019, 802)

Community Engagement: Often entails public participation through an ongoing, two-way or multidirectional process, ideally with an emphasis on relationships and trust-building rather than instrumental decisions. The latter are processes where engagement becomes the instrument to achieve social acceptance (Stober et al. 2021).

Disadvantaged Community: "Disadvantaged communities refers to the areas which most suffer from a combination of economic, health, and environmental burdens. These burdens include poverty, high unemployment, air and water pollution, presence of hazardous wastes as well as high incidence of asthma and heart disease. One way that the state identifies these areas is by collecting and analyzing information from communities all over the state. CalEnviroScreen, an analytical tool created by the California Environmental Protection Agency (CalEPA), combines different types of census tract-specific information into a score to determine which communities are the most burdened or "disadvantaged"" (California Public Utilities Commission 2023).

Energy Equity: the equitable distribution of social, economic, and health benefits and burdens of energy across all segments of society (Jenkins 2017)

Energy Justice: the provision of safe, affordable, and sustainable energy to all individuals, across all areas (Jenkins 2017); this is done with a framework informed by justice movements, including attention to three core tenets:

- *Distributional justice* seeks to ensure a just and equitable distribution of benefits and negative impacts of the clean energy transition.
- *Justice as recognition* seeks to understand and address past and current energy inequities by analyzing structural causes of exclusion and vulnerability and specific needs associated with energy services among social groups.

- *Procedural justice* aims to actively engage partners and communities throughout the project, to co-design the analysis and shape the resulting equity strategies (Energy Equity Project 2022).

Energy Transition: a large-scale or deep societal change in the production, distribution, and use of energy; this transition can entail transformations in social-technical systems and systems of policy and governance intended to substantially improve the outcomes out of unsustainable pathways, such as fossil fuel use (Carley and Konisky 2020)

Environmental Justice: the distribution of environmental hazards and access to all natural resources; it includes equal protection from burdens, meaningful involvement in decisions, and fair treatment in access to benefits (U.S. EPA 2023)

Equity Outputs: immediate, easily measurable effects of an action aimed at achieving equity (Dubash et al. 2022).

Equity Outcomes: ultimate changes that a policy will yield (Dubash et al. 2022).

Equity: a measurement of fairness and justice. Unlike equality, which refers to the provision of the same to all, equity aims to recognize the historical and ongoing differences in experiences and outcomes between people, groups, and communities to redress those imbalances.

Frontline Community: a community, frequently a low-income community of color, that experiences the first and worst consequences of environmental and climate change including floods, heat waves, and other climate extremes as well as the impacts of facilities that are used to extract, produce, process, and transport energy resources.

Impact Areas: particular sectors and subsectors of the energy system impacted by causal factors

Just Energy Transition: a deep societal change in the energy system that fulfills at minimum three of the tenets of justice: recognition justice, procedural justice, and distributional justice (McCauley and Heffron 2018)

Justice: involves removing barriers that prevent equity through energy actions (strategies) that offer individuals and communities equal access to energy resources and options to self-determine their energy goals (Romero-Lankao and Nobler 2021).

Participation: relates to the involvement of the public in infrastructure siting and other clean energy decisions and policies (Stober et al. 2021). Participation is an umbrella concept that includes processes of community engagement and public decision-making (Stober et al. 2021). Participatory decision-making denotes inclusion of actors such as underserved communities in an energy project as a decision-maker. Direct participation refers to the level of economic and/or political involvement of a local community or municipality in an energy project.

Underserved Community: a community, frequently a low-income community of color, that (a) does not benefit from energy programs, investments, and technologies, and (b) is not recognized, considered, or able to participate in energy decision-making (Klinsky et al. 2017)

Values: the ethical paradigm that structures the sociocultural norms, beliefs, and practices guiding how a group of people prioritize and relate to the current energy transition (Jenkins 2017)

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Appendix A. Detailed Classification of LADWP Investment Programs and Services

Table A-1. Detailed Classification of LADWP Investment Programs and Services

Program	Years	Unique Locations	Number of Records	Total Dollars	Description
System Average Interruption Duration Index (SAIDI)	2015–2020	158 (DS-level)	872	no data	Average number of minutes a customer's power is out in a year for the system
System Average Interruption Frequency Index (SAIFI)	2015–2020	158 (DS-level)	872	no data	Average number of interruptions per year for the system
Tree Canopy Program (CITY)	2014–2021	12,450	17,594	$13,782,835	"City Plants": Tree planting to address the low tree canopy cover in LA
Commercial Direct Install Program (CDI)	2013–2021	17,187	41,151	$220,352,003	Energy- and water-saving equipment is installed at the business at no cost to the owner for qualifying businesses.
Home Energy Improvement Program (HEIP)	2017–2020	5,844	7,038	$3,378,869	The direct install whole-house program offers LADWP residential customers free lighting and water efficiency upgrades to improve the home's envelope and core systems.
Refrigerator Turn In and Recycle (RETIRE)	2016–2021	12,230	16,057	$2,667,307	A free service to pick up and recycle refrigerators
Consumer Rebate Program (CRP)	2015–2021	30,846	84,580	$93,248,144	Educate and encourage LADWP residential customers to purchase and install qualifying energy efficient products in their home
EV Incentives	2013–2021	6,910	987	$63,647,945	Commercial New Charger

Program	Years	Unique Locations	Number of Records	Total Dollars	Description
			339	no data	Commercial New Sub-Meter
			6	$430,000	Medium-Duty Heavy-Duty (MDHD)
			14	$1,800,000	Direct Current Fast Charge (DCFC)
			5,678	$3,017,576	Residential New Charger
			374	$92,500	Residential New Sub-Meter
			1,967	$2,251,350	Residential Used Vehicle
Solar Incentive Programs	2013–2021	100	137	$90,096,630	Feed-in Tariff Interconnection Agreement (FiT)
	1999–2021	21,344	34,551	$340,604,541	NEM (up to 1 MW) (SIP)
	2016–2021	16,068	24,763		Net Energy Metering (up to 1 MW) (NEM)
	2017–2020	32	32	$28,920	Solar Rooftops Program Lease Agreement (SRP)
Energy Efficiency Incentive Programs	2018–2019	74	74	$145,574	Energy Upgrade California (EUCA)
	2013–2017	60	60	$5,206,681	California Advanced Home Program (CAHP)
	2018–2021	17,939	30,651	$2,220,823	Efficient Product Marketplace (EPM)
	2017–2021	13,998	39,766	$22,561,827	HVAC Optimization Program (ACOPT)
	2007–2021	1,089	1,948	$85,361,268	Custom Performance-Based Efficiency Program (CPP)
	2005–2021	5,721	10,252	$116,752,703	Commercial Lighting Incentive Program / Commercial Lighting Efficiency (CLIP)
	no data	199	207	$229,455	Food Service Program (FSP)

Program	Years	Unique Locations	Number of Records	Total Dollars	Description
	2016–2021	924	2,327	$21,500,939	Upstream HVAC (UHVAC)
	2020–2021	6	6	no data	Multifamily Whole Building (MFWB)
	2007–2016	35	35	$1,442,410	New Construction (NC)
	2010–2012	39	64	$4,213,033	Chiller Efficiency Program (CEP)
	2012	46	51	$751,682	Nonprofit Program (NP)
	2006–2016	1,186	1,541	$1,995,610	Refrigeration (REF)
	no data	1,624	6,318	$7,897,259	Energy Savings Assistance Program (ESAP) (*Low-Income Targeted*)
	no data	no data	25	$3,611,156	Savings By Design / Zero By Design (SBD)
Low Income Discount Program (now EZ-SAVE)	2006–2021	43,561	598,542	$173,633,204	Customers may qualify to have a discount applied to their electric and/or water bills based on their income and household size.
Lifeline Discount Program	2006–2021	40,854	308,824	$313,424,782	Customers 62 years of age or older or permanently disabled may qualify, based on their income, to have a discount applied to their electric and/or water bills.

Appendix B. T-Tests: Methodology and Results

We evaluated the distribution of incentives by sociodemographic group using statistical analysis (t-tests) to identify areas of uneven distribution. Using this tract-level data as input, unequal variance independent t-tests were performed. These tests assume that data from two groups of the population both follow a normal distribution (i.e., data near the mean are more frequent than data far from the mean). However, unequal variance independent t-tests do not assume that data from two groups of the population have the same mean or variance (Welsh 1947). This means that the average values from two data sets (each representing a group of the population), as well as the dispersion of data points to their average value from each data set, are not assumed to be the same.

T-tests produce inferential statistics that evaluate hypotheses regarding differences between two groups of the population. In this analysis, we hypothesize that incentives *are not* evenly distributed among different households. T-tests provide two outputs: t-values and p-values. The significance of the t-values is determined by *p-values*, or the probability of an observed outcome when we assume the null hypothesis is true. A null hypothesis claims that there is no difference in data represented by two groups of the population. In this case, our null hypothesis is that incentives *are* evenly distributed among different households. If a *p-value* is smaller than a *pre-defined alpha*, the results of the *t-test* are statistically significant. In this analysis, we used an alpha of 0.025, which is the standard for two-tailed tests (Welsh 1947). Therefore, p-values smaller than 0.025 are interpreted in our results as: given our input data, the probability of receiving data points that are distributed evenly among all households is so low that we must reject our null hypothesis. Therefore, we can claim that incentives are unevenly distributed to one group of households compared to another.

The following tables identify communities according to sociodemographic indicators that disproportionately benefited from programs (blank entries indicate that no statistical significances between households and incentives existed) as well as the corresponding p- and t-values according to the number of benefits distributed and the total dollar amount spent for each program for the following types of investments: (1) energy efficiency programs, (2), solar installation programs, (3) EV incentive programs, (4) customer discount programs, and (5) power infrastructure reliability metrics.

B.1 Energy Efficiency Programs

Table B-1. Number of Households Receiving Benefits from Residential Energy Efficiency Investments

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
California Advanced Home Program (CAHP)	no statistically significant difference				
Chiller Efficiency Program (CEP)	no statistically significant difference				
Consumer Rebate Program (CRP)	Non-DAC	Mostly White	Mostly Non-Hispanic	Mostly Owners	Above Median Income
Efficient Product Marketplace (EPM)	Non-DAC	Mostly White	Mostly Non-Hispanic	Mostly Owners	Above Median Income
Energy Savings Assistance Program (ESAP)[a]	DAC	Mostly Non-White	Mostly Hispanic	Mostly Renters	Below Median Income
Energy Upgrade California (EUCA)	no statistically significant difference				
Home Energy Improvement Program (HEIP)	DAC		Mostly Hispanic	Mostly Owners	
HVAC Optimization Program (ACOPT)	Non-DAC	Mostly White	Mostly Non-Hispanic	Mostly Owners	Above Median Income
Refrigeration Program (REF)	Non-DAC	Mostly White	Mostly Non-Hispanic		Above Median Income
Refrigerator Turn In and Recycle Program (RETIRE)	Non-DAC	Mostly White	Mostly Non-Hispanic	Mostly Owners	Above Median Income

[a] Low-Income Targeted

Table B-2. Number of Households Receiving Benefits from Residential Energy Efficiency Investments (p-value)

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
California Advanced Home Program (CAHP)	0.264	0.836	0.247	0.062	0.202
Chiller Efficiency Program (CEP)	0.113	0.647	0.107	0.543	0.938
Consumer Rebate Program (CRP)	<0.001	<0.001	0.003	<0.001	<0.001
Efficient Product Marketplace (EPM)	<0.001	<0.001	<0.001	<0.001	<0.001
Energy Savings Assistance Program (ESAP)[a]	<0.001	0.001	<0.001	<0.001	<0.001
Energy Upgrade California (EUCA)	0.048	0.080	0.178	0.051	0.102
Home Energy Improvement Program (HEIP)	<0.001	0.141	0.005	<0.001	0.906
HVAC Optimization Program (ACOPT)	<0.001	<0.001	<0.001	<0.001	<0.001
Refrigeration Program (REF)	<0.001	0.001	<0.001	0.079	<0.001
Refrigerator Turn In and Recycle Program (RETIRE)	<0.001	<0.001	<0.001	<0.001	<0.001

[a] Low-Income Targeted

Table B-3. Number of Households Receiving Benefits from Residential Energy Efficiency Investments (t-value)

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
California Advanced Home Program (CAHP)	1.131	0.209	1.180	-1.936	1.328
Chiller Efficiency Program (CEP)	1.608	0.463	1.772	-0.624	0.079
Consumer Rebate Program (CRP)	6.596	7.984	2.950	13.246	8.877
Efficient Product Marketplace (EPM)	33.693	14.659	20.939	14.000	23.393
Energy Savings Assistance Program (ESAP)[a]	-8.781	-3.236	-5.763	-5.951	-6.986
Energy Upgrade California (EUCA)	1.994	1.783	1.362	1.999	1.659
Home Energy Improvement Program (HEIP)	-8.143	-1.473	-2.832	7.497	0.118
HVAC Optimization Program (ACOPT)	10.121	6.594	6.933	5.510	7.645
Refrigeration Program (REF)	1.131	0.209	1.180	-1.936	1.328
Refrigerator Turn In and Recycle Program (RETIRE)	1.608	0.463	1.772	-0.624	0.079

[a] Low-Income Targeted

Table B-4. Amount of Investment Dollars Spent on Residential Energy Efficiency Investments

Program	**Non-DAC/ DAC**	**Mostly White/ Mostly Non-White**	**Mostly Non-Hispanic/ Mostly Hispanic**	**Mostly Owners/ Mostly Renters**	**Mostly Above Median Income/ Mostly Below Median Income**
California Advanced Home Program (CAHP)	Mostly Non-Hispanic				
Chiller Efficiency Program (CEP)	no statistically significant difference				
Consumer Rebate Program (CRP)	Non-DAC	Mostly White	Mostly Non-Hispanic	Mostly Owners	Above Median Income
Efficient Product Marketplace (EPM)	Non-DAC	Mostly White	Mostly Non-Hispanic	Mostly Owners	Above Median Income
Energy Savings Assistance Program (ESAP)[a]	DAC		Mostly Hispanic	Mostly Renters	Below Median Income
Energy Upgrade California (EUCA)	Non-DAC				
Home Energy Improvement Program (HEIP)	DAC			Mostly Owners	
HVAC Optimization Program (ACOPT)	Non-DAC	Mostly White	Mostly Non-Hispanic	Mostly Owners	Above Median Income
Refrigeration Program (REF)	Non-DAC		Mostly Non-Hispanic	Mostly Owners	Above Median Income
Refrigerator Turn In and Recycle Program (RETIRE)	no data				

[a] Low-Income Targeted

Table B-5. Amount of Investment Dollars Spent on Residential Energy Efficiency Investments (p-value)

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
California Advanced Home Program (CAHP)	0.229	0.770	0.024	0.058	0.133
Chiller Efficiency Program (CEP)	0.346	0.725	0.174	0.648	0.584
Consumer Rebate Program (CRP)	<0.001	<0.001	<0.001	<0.001	<0.001
Efficient Product Marketplace (EPM)	<0.001	<0.001	<0.001	<0.001	<0.001
Energy Savings Assistance Program (ESAP)[a]	<0.001	0.033	<0.001	<0.001	<0.001
Energy Upgrade California (EUCA)	0.002	0.080	0.288	0.305	0.461
Home Energy Improvement Program (HEIP)	<0.001	0.124	0.765	<0.001	0.187
HVAC Optimization Program (ACOPT)	<0.001	<0.001	<0.001	<0.001	<0.001
Refrigeration Program (REF)	<0.001	0.318	0.001	0.021	0.001
Refrigerator Turn In and Recycle Program (RETIRE)	no data				

[a] Low-Income Targeted

Table B-6. Amount of Investment Dollars Spent on Residential Energy Efficiency Investments (t-value)

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
California Advanced Home Program (CAHP)	1.220	0.295	2.390	-1.948	1.576
Chiller Efficiency Program (CEP)	0.950	0.355	1.442	0.472	0.555
Consumer Rebate Program (CRP)	6.593	7.628	3.998	14.796	9.548
Efficient Product Marketplace (EPM)	33.613	14.598	20.657	13.756	23.014
Energy Savings Assistance Program (ESAP)[a]	-4.245	-2.139	-3.675	-4.479	-6.152
Energy Upgrade California (EUCA)	3.182	1.804	1.075	1.035	0.742
Home Energy Improvement Program (HEIP)	-5.652	-1.541	0.298	7.368	1.322
HVAC Optimization Program (ACOPT)	12.138	8.229	8.356	7.399	9.340
Refrigeration Program (REF)	4.860	0.999	3.363	2.327	3.306
Refrigerator Turn In and Recycle Program (RETIRE)	no data				

[a] Low-Income Targeted

Table B-7. Number of Entities Receiving Benefits from Commercial Energy Efficiency Investments

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
Commercial Direct Install (CDI)	DAC			Mostly Renters	Below Median Income
Commercial Lighting Incentive Program (CLIP)	DAC			Mostly Renters	
Custom Performance-Based Efficiency Program (CPP)	Non-DAC		Mostly Non-Hispanic		
Food Service Program (FSP)	Non-DAC				
New Construction Program (NC)	no statistically significant difference				
Nonprofit Program (NP)	no statistically significant difference				

Table B-8. Number of Entities Receiving Benefits from Commercial Energy Efficiency Investments (p-value)

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
Commercial Direct Install (CDI)	<0.001	0.076	0.312	<0.001	0.007
Commercial Lighting Incentive Program (CLIP)	0.005	0.027	0.080	<0.001	0.585
Custom Performance-Based Efficiency Program (CPP)	0.002	0.205	0.001	0.089	0.063
Food Service Program (FSP)	0.003	0.364	0.071	0.812	0.053
New Construction Program (NC)	0.693	0.947	0.385	0.043	0.739
Nonprofit Program (NP)	0.259	0.975	0.453	0.223	0.425

Table B-9. Number of Entities Receiving Benefits from Commercial Energy Efficiency Investments (t-value)

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
Commercial Direct Install (CDI)	-7.469	-1.776	-1.012	-3.495	-2.693
Commercial Lighting Incentive Program (CLIP)	-2.833	-2.222	1.756	-3.802	-0.547
Custom Performance-Based Efficiency Program (CPP)	3.131	-1.272	3.504	-1.705	1.865
Food Service Program (FSP)	3.040	0.910	1.819	-0.238	1.955
New Construction Program (NC)	0.397	0.067	0.882	-2.152	-0.338
Nonprofit Program (NP)	1.155	-0.032	-0.759	1.246	-0.817

Table B-10. Amount of Investment Dollars Spent on Commercial Energy Efficiency Investments

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
Commercial Direct Install (CDI)	DAC				
Commercial Lighting Incentive Program (CLIP)			Mostly Non-Hispanic		
Custom Performance-Based Efficiency Program (CPP)	no statistically significant difference				
Food Service Program (FSP)	no statistically significant difference				
New Construction Program (NC)	no statistically significant difference				
Nonprofit Program (NP)	no statistically significant difference				

Table B-11. Amount of Investment Dollars Spent on Commercial Energy Efficiency Investments (p-value)

Program	**Non-DAC/ DAC**	**Mostly White/ Mostly Non-White**	**Mostly Non-Hispanic/ Mostly Hispanic**	**Mostly Owners/ Mostly Renters**	**Mostly Above Median Income/ Mostly Below Median Income**
Commercial Direct Install (CDI)	<0.001	0.220	0.977	0.472	0.782
Commercial Lighting Incentive Program (CLIP)	0.730	0.268	0.001	0.038	0.301
Custom Performance-Based Efficiency Program (CPP)	0.058	0.063	0.060	0.150	0.080
Food Service Program (FSP)	0.143	0.708	0.071	0.160	0.327
New Construction Program (NC)	0.534	0.692	0.339	0.194	0.359
Nonprofit Program (NP)	0.315	0.169	0.059	0.043	0.426

Table B-12. Amount of Investment Dollars Spent on Commercial Energy Efficiency Investments (t-value)

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
Commercial Direct Install (CDI)	-6.394	-1.228	-0.029	-0.720	-0.277
Commercial Lighting Incentive Program (CLIP)	0.345	-1.108	3.340	-2.082	1.036
Custom Performance-Based Efficiency Program (CPP)	1.899	-1.872	1.886	-1.442	1.762
Food Service Program (FSP)	-1.471	0.376	1.822	1.423	0.983
New Construction Program (NC)	0.629	0.403	0.983	-1.329	0.964
Nonprofit Program (NP)	1.022	1.406	1.969	2.104	0.809

B.2 Solar Installation Programs

Table B-13. Number of Households Receiving Benefits from Solar Installation Programs

Program	**Non-DAC/DAC**	**Mostly White/ Mostly Non-White**	**Mostly Non-Hispanic/ Mostly Hispanic**	**Mostly Owners/ Mostly Renters**	**Mostly Above Median Income/ Mostly Below Median Income**
Feed-In Tariff Program (FiT)	no statistically significant difference				
Net Metering Programs (NEM and SIP)	Non-DAC	Mostly White	Mostly Non-Hispanic	Mostly Owners	Above Median Income

Table B-14. Number of Households Receiving Benefits from Solar Installation Programs (p-value)

Program	**Non-DAC/ DAC**	**Mostly White/ Mostly Non-White**	**Mostly Non-Hispanic/ Mostly Hispanic**	**Mostly Owners/ Mostly Renters**	**Mostly Above Median Income/ Mostly Below Median Income**
Feed-In Tariff Program (FiT)	0.258	0.776	0.200	0.339	0.341
Net Metering Programs (NEM and SIP)	<0.001	<0.001	<0.001	<0.001	<0.001

Table B-15. Number of Households Receiving Benefits from Solar Installation Programs (t-value)

Program	**Non-DAC/** **DAC**	**Mostly White/** **Mostly Non-White**	**Mostly Non-Hispanic/** **Mostly Hispanic**	**Mostly Owners/** **Mostly Renters**	**Mostly Above Median Income/** **Mostly Below Median Income**
Feed-In Tariff Program (FiT)	-1.131	-0.284	-1.283	-0.956	-0.953
Net Metering Programs (NEM and SIP)	15.809	10.879	7.547	16.311	14.203

Table B-16. Amount of Installed Capacity from Solar Installation Programs

Program	**Non-DAC/** **DAC**	**Mostly White/** **Mostly Non-White**	**Mostly Non-Hispanic/** **Mostly Hispanic**	**Mostly Owners/** **Mostly Renters**	**Mostly Above Median Income/** **Mostly Below Median Income**
Feed-In Tariff Program (FiT)	no statistically significant difference				
Net Metering Programs (NEM and SIP)	Non-DAC	Mostly White	Mostly Non-Hispanic	Mostly Owners	Above Median Income

Table B-17. Amount of Installed Capacity from Solar Installation Programs (p-value)

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
Feed-In Tariff Program (FiT)	0.163	0.846	0.791	0.685	0.737
Net Metering Programs (NEM and SIP)	<0.001	<0.001	<0.001	<0.001	<0.001

Table B-18. Amount of Installed Capacity from Solar Installation Programs (t-value)

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
Feed-In Tariff Program (FiT)	-1.406	-0.195	-0.267	-0.408	-0.338
Net Metering Programs (NEM and SIP)	16.565	9.429	9.840	13.804	13.748

B.3 EV Incentive Programs

Table B-19. Number of Households Receiving Benefits from Residential EV Investment Programs

Program	**Non-DAC/ DAC**	**Mostly White/ Mostly Non-White**	**Mostly Non-Hispanic/ Mostly Hispanic**	**Mostly Owners/ Mostly Renters**	**Mostly Above Median Income/ Mostly Below Median Income**
New Charger	Non-DAC	Mostly White	Mostly Non-Hispanic	Mostly Owners	Above Median Income
New Sub-Meter	Non-DAC	Mostly White	Mostly Non-Hispanic	Mostly Owners	Above Median Income
Used Vehicle	Non-DAC	Mostly White	Mostly Non-Hispanic	Mostly Owners	Above Median Income

Table B-20. Number of Households Receiving Benefits from Residential EV Investment Programs (p-value)

Program	**Non-DAC/ DAC**	**Mostly White/ Mostly Non-White**	**Mostly Non-Hispanic/ Mostly Hispanic**	**Mostly Owners/ Mostly Renters**	**Mostly Above Median Income/ Mostly Below Median Income**
New Charger	<0.001	<0.001	<0.001	<0.001	<0.001
New Sub-Meter	<0.001	<0.001	<0.001	<0.001	<0.001
Used Vehicle	<0.001	<0.001	<0.001	<0.001	<0.001

Table B-21. Number of Households Receiving Benefits from Residential EV Investment Programs (t-value)

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
New Charger	25.978	8.968	15.102	11.068	16.199
New Sub-Meter	6.773	7.650	3.964	3.857	5.590
Used Vehicle	14.446	5.909	11.376	7.943	10.275

Table B-22. Amount of Investment Dollars Spent on Residential EV Investment Programs

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
New Charger	Non-DAC	Mostly White	Mostly Non-Hispanic	Mostly Owners	Above Median Income
New Sub-Meter	Non-DAC	Mostly White	Mostly Non-Hispanic	Mostly Owners	Above Median Income
Used Vehicle	Non-DAC	Mostly White	Mostly Non-Hispanic	Mostly Owners	Above Median Income

Table B-23. Amount of Investment Dollars Spent on Residential EV Investment Programs (p-value)

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
New Charger	<0.001	<0.001	<0.001	<0.001	<0.001
New Sub-Meter	<0.001	<0.001	<0.001	<0.001	<0.001
Used Vehicle	<0.001	<0.001	<0.001	<0.001	<0.001

Table B-24. Amount of Investment Dollars Spent on Residential EV Investment Programs (t-value)

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
New Charger	26.019	9.067	15.096	11.039	16.249
New Sub-Meter	6.709	7.573	3.944	3.762	5.579
Used Vehicle	11.345	4.201	10.045	6.554	8.330

Table B-25. Number of Entities Receiving Benefits from Commercial EV Investment Programs

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
New Charger	Non-DAC		Mostly Non-Hispanic	Mostly Renters	Above Median Income
New Sub-Meter			Mostly Non-Hispanic		

Table B-26. Number of Entities Receiving Benefits from Commercial EV Investment Programs (p-value)

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
New Charger	<0.001	0.170	<0.001	0.024	0.011
New Sub-Meter	0.546	1.000	<0.001	0.979	0.222

Table B-27. Number of Entities Receiving Benefits from Commercial EV Investment Programs (t-value)

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
New Charger	3.827	1.377	8.103	-2.281	2.561
New Sub-Meter	0.604	-0.001	4.108	0.026	1.228

Table B-28. Amount of Investment Dollars Spent on Commercial EV Investment Programs

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
New Charger	Non-DAC		Mostly Non-Hispanic	Mostly Renters	Above Median Income
New Sub-Meter	no data				

Table B-29. Amount of Investment Dollars Spent on Commercial EV Investment Programs (p-value)

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
New Charger	<0.001	0.709	<0.001	0.016	0.024
New Sub-Meter	no data				

Table B-30. Amount of Investment Dollars Spent on Commercial EV Investment Programs (t-value)

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
New Charger	3.595	0.374	7.147	-2.429	2.272
New Sub-Meter	no data				

B.4 Customer Discount Programs

Table B-31. Number of Households Receiving Benefits from Customer Discount Programs

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
EZ-SAVE[a]	DAC	Mostly Non-White	Mostly Hispanic	Mostly Renters	Below Median Income
Lifeline[a]	DAC	Mostly Non-White	Mostly Hispanic	Mostly Renters	Below Median Income

[a] Low-Income Targeted

Table B-32. Number of Households Receiving Benefits from Customer Discount Programs (p-value)

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
EZ-SAVE[a]	<0.001	<0.001	<0.001	<0.001	<0.001
Lifeline[a]	<0.001	<0.001	0.006	<0.001	<0.001

[a] Low-Income Targeted

Table B-33. Number of Households Receiving Benefits from Customer Discount Programs (t-value)

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
EZ-SAVE[a]	-30.547	-9.795	-14.590	-14.319	-20.062
Lifeline[a]	-14.924	-4.925	-2.731	-5.735	-9.663

[a] Low-Income Targeted

Table B-34. Amount of Customer Savings from Customer Discount Programs

Program	Non-DAC/ DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/ Mostly Hispanic	Mostly Owners/ Mostly Renters	Mostly Above Median Income/ Mostly Below Median Income
EZ-SAVE[a]	DAC	Mostly Non-White	Mostly Hispanic	Mostly Renters	Below Median Income
Lifeline[a]	DAC	Mostly Non-White			Below Median Income

[a] Low-Income Targeted

Table B-35. Amount of Customer Savings from Customer Discount Programs (p-value)

Program	**Non-DAC/ DAC**	**Mostly White/ Mostly Non-White**	**Mostly Non-Hispanic/ Mostly Hispanic**	**Mostly Owners/ Mostly Renters**	**Mostly Above Median Income/ Mostly Below Median Income**
EZ-SAVE[a]	<0.001	<0.001	<0.001	<0.001	<0.001
Lifeline[a]	<0.001	<0.001	0.434	0.051	<0.001

[a] Low-Income Targeted

Table B-36. Amount of Customer Savings from Customer Discount Programs (t-value)

Program	**Non-DAC/ DAC**	**Mostly White/ Mostly Non-White**	**Mostly Non-Hispanic/ Mostly Hispanic**	**Mostly Owners/ Mostly Renters**	**Mostly Above Median Income/ Mostly Below Median Income**
EZ-SAVE[a]	-37.227	-10.243	-19.145	-9.852	-21.251
Lifeline[a]	-13.834	-3.828	-0.783	-1.956	-7.380

[a] Low-Income Targeted

B.5 Power Infrastructure Reliability

Table B-37. Average Indexes from Power Reliability Metrics

Program	**Non-DAC/ DAC**	**Mostly White/ Mostly Non-White**	**Mostly Non-Hispanic/ Mostly Hispanic**	**Mostly Owners/ Mostly Renters**	**Mostly Above Median Income/ Mostly Below Median Income**
Frequency of Power Interruptions (SAIFI)	DAC		Mostly Hispanic		
Duration of Power Interruptions (SAIDI)	no statistically significant difference				

Table B-38. Average Indexes from Power Reliability Metrics (p-value)

Program	**Non-DAC/ DAC**	**Mostly White/ Mostly Non-White**	**Mostly Non-Hispanic/ Mostly Hispanic**	**Mostly Owners/ Mostly Renters**	**Mostly Above Median Income/ Mostly Below Median Income**
Frequency of Power Interruptions (SAIFI)	<0.001	0.834	0.015	0.231	0.606
Duration of Power Interruptions (SAIDI)	0.195	0.979	0.181	0.302	0.883

Table B-39. Average Indexes from Power Reliability Metrics (t-value)

Program	**Non-DAC/DAC**	**Mostly White/ Mostly Non-White**	**Mostly Non-Hispanic/ Mostly Hispanic**	**Mostly Owners/ Mostly Renters**	**Mostly Above Median Income/ Mostly Below Median Income**
Frequency of Power Interruptions (SAIFI)	-4.248	-0.210	-2.470	1.207	-0.517
Duration of Power Interruptions (SAIDI)	-1.298	-0.026	-1.347	1.038	0.147

Appendix C. Structural Factors and Present-Day Equity Impacts in Los Angeles

Table C-1. Examples of Factors That Can Impact Energy Affordability and Burdens in Buildings, Transportation, Distributed Energy Resources, and Utility-Scale Infrastructure

Sector	Dimension	Structural Factors	Present-Day Equity Impacts
Buildings	Built Environment	Appliances and lighting (type, efficiency)	Energy burden due to wasted energy / inefficiency (Steering Committee Members 2021)
		Building age	Technical feasibility of (barriers to) electrification / energy retrofits to reduce energy burden (Steering Committee Members 2022a; Advisory Group Members 2018c; Harris-Dawson et al. 2022)
			Effort / investment / time required to upgrade / decarbonize (Harris-Dawson et al. 2022)
		Building efficiency (envelope, HVAC)	Energy burden due to wasted energy / inefficiency (Steering Committee Members 2021)
		Exposure to climate change-related hazards / adaptability to climate extremes	Financial burden of evacuation, displacement, repairs
			Energy burden associated with coping measures (e.g., air conditioning) (Advisory Group Members 2019a; 2019c; 2021)
			Water cost burden associated with drought (Rodriguez 2021)
		Local microclimatic / infrastructural characteristics	Energy burden associated with cooling to mitigate urban heat island effects (Steering Committee Members 2021)
			Technical feasibility of onsite energy generation: construction density, shading, rooftop space, etc. (Steering Committee Members 2022a)
	Economic	Building occupancy / ownership status (owner-occupied vs. renter-occupied)	Split incentives for building energy upgrades (renters' ability to invest in cost-saving energy upgrades vs. owners' ability to recover costs of investment) (Steering Committee Members 2022b)
			Ability to participate in solar incentive, Feed-in Tariff, and Feed-in Tariff Plus programs (Krekorian and O'Farrell 2021b)
		Sudden or chronic economic hardship due to unstable / persistent low income	Chronic high energy burden
			Affordability of building repairs / maintenance (Advisory Group Members 2021; Steering Committee Members 2022a)

Sector	Dimension	Structural Factors	Present-Day Equity Impacts
		Rent burden	(Lack of) Discretionary income to invest in building repairs / maintenance (Harris-Dawson et al. 2022)
		Up-front EE/RE technology costs	Affordability of transition to weatherization / electrification technologies (Advisory Group Members 2019c; 2021)
		Use of public funding vs. private funding for technology and infrastructure upgrades	Distribution of costs related to the transition among different customer types (Advisory Group Members 2021)
	Policy / Institutional	Building codes	Impact of enhanced building codes on housing affordability, minimum building efficiency (Steering Committee Members 2022a; Harris-Dawson et al. 2022)
		Policies / programs / investments for energy efficiency vs. new generation	Ability for customers to control energy use and costs (existence of programs and customer knowledge / trust of programs and benefits) (Advisory Group Members 2017a; 2019b; 2020d; 2021)
		Incentives vs. rebates for building energy upgrades	Up-front costs and magnitude of financial burden on building owners / renters (Steering Committee Members 2022a; 2022b; Advisory Group Members 2021)
	Sociocultural / Behavioral	Awareness of time-of-use rates, changes to net metering policies	Ability to apply knowledge to control bill costs / make informed energy decisions (Residents of Los Angeles 2022a; Advisory Group Members 2017b; 2020c)
		Changing electricity use patterns in response to behavior changes driven by COVID-19	Impact of rate increases on total energy bills for different sectors / building types
			Redistribution of energy costs / burden among commercial and residential sectors (Advisory Group Members 2017a; 2020b; Lou et al. 2021)
		Household energy demands related to occupant characteristics	Disparities in how, when, and how much energy is needed by different households / building occupants (Advisory Group Members 2020b; 2021)
			Impact of transition on total energy bills for median and lifeline customers, neighborhood-level disparities in energy bill impacts (Advisory Group Members 2020b; 2020c; 2021)
		Time poverty	Ability to implement and participate in load shifting / demand response programs and behavior changes (Advisory Group Members 2020b)

Sector	Dimension	Structural Factors	Present-Day Equity Impacts
Distributed Energy Resources	Built Environment	Interrelated dependencies of transmission upgrades, distributed generation, and rooftop solar	Distribution of cost of new transmission / distribution infrastructure, and who pays costs of new transmission (Advisory Group Members 2018a; 2018b; 2018c; 2018d; 2019b; 2019c; 2020a; 2020c; 2020d)
		Need to transition land use patterns with higher densities	Higher adoption rates for rooftop solar photovoltaics in lower-density residential areas (Advisory Group Members 2018d; 2020a)
	Economic	Economic impacts of COVID-19 pandemic (income loss, rising costs)	Affordability of customer-owned DERs (Advisory Group Members 2019c; 2020a)
		Housing market fluctuations	Financial tools (e.g., mortgage refinance) available to afford customer-owned DERs
			Ability to repay debts incurred to purchase DERs (Advisory Group Members 2019a)
		Up-front cost of customer-owned DERs	Affordability of DERs (Advisory Group Members 2020b)
			Opportunity to realize long-term savings from reduced power bills / energy burden (Advisory Group Members 2019c)
	Policy / Institutional	Design of incentives, credits, subsidies for rooftop solar (magnitude, change over time)	Economic feasibility, ROI for customer-owned DERs (Advisory Group Members 2019a; 2019b; 2019c; 2020a; 2020b; 2020c; Lou et al. 2021)
			Magnitude of financial benefits to early adopters vs. late adopters (Advisory Group Members 2020a; O'Shaughnessy 2022)
		Feed-in tariffs, net billing, net metering policies and rates	Distribution of costs and economic benefits for excess customer generation (Advisory Group Members 2019b; 2019c; 2020a; 2020b; Krekorian and O'Farrell 2021b)
		LADWP programs to support ratepayer adoption of DERs	Efforts to lower economic barriers to DER adoption for low-income customers (Advisory Group Members 2018d)
Mobility / Transportation	Built Environment	Availability of workplace / public EV charging	Access to free and public EV charging, energy burden for businesses vs. drivers (Advisory Group Members 2019a)

Sector	Dimension	Structural Factors	Present-Day Equity Impacts
Mobility / Transportation	Economic	Electricity rates vs. cost of gasoline	Affordability, feasibility, and speed of transition to electric vehicles (Advisory Group Members 2018b; 2018d; 2019c; 2020b)
		Funding mechanisms for installation and maintenance of EV supply equipment	Distribution of installation costs for fast-charging stations
			Who pays / collects fees for use of fast charging
		Up-front vehicle costs	Affordability of personal gasoline / electric vehicles (Advisory Group Members 2019c)
	Sociocultural / Behavioral	Behavior changes in response to COVID-19 pandemic	Changing mobility / commuting needs, ability to shift transportation mode to reduce risk / transportation energy burden (Advisory Group Members 2020a; Williams, Blair-Loy, and Berdahl 2013; Kossek, Lautsch, and Eaton 2006)
		Consumer sensitivity to electricity rates	Acceptability / willingness to transition to new technologies to reduce transportation energy burden (Advisory Group Members 2018b; 2020b)
		Time poverty	Ability to take advantage of incentives for charging personal EVs during off-peak hours to reduce transportation energy burden (Advisory Group Members 2020b; Williams, Blair-Loy, and Berdahl 2013; Kossek, Lautsch, and Eaton 2006; Lambert 2008; Hyde, Greene, and Darmstadt 2020)
Utility-Scale Infrastructure	Built Environment	Age of existing 4.8 kV distribution infrastructure	Geographic disparities in technical feasibility of distributed generation (Advisory Group Members 2019c)
		Increasing frequency / severity of extreme weather, wildfires due to climate change	(Distribution of) Costs for system hardening, undergrounding lines (Advisory Group Members 2019a; 2019b; 2019c; 2020b; 2020c)
		Seasonal environmental variation / drought	Higher water costs for households and small businesses with limited financial / technical ability to adopt conservation measures (Advisory Group Members 2018c; 2019c; Koretz and O'Farrell 2021; Rodriguez 2021)
	Economic	Cost-benefit optimization models for analyzing decentralization strategies and storage investments	Mechanisms to value / prioritize investments with multiple / indirect benefits for decision-making, including social cost of carbon, methods for assigning monetary value to human health and well-being (Advisory Group Members 2018d; 2019a; 2019b)

Sector	Dimension	Structural Factors	Present-Day Equity Impacts
		Rate structures	Impact of rates on other sectors of the economy (Advisory Group Members 2019b)
			Energy burden (Advisory Group Members 2019b)
			Greater impact of rate increases on household and community health / well-being for low-income households (Advisory Group Members 2020b)
	Policy / Institutional	Prioritization of energy efficiency vs. new generation	Availability of energy efficiency programs and incentives
			Magnitude of financial and technical assistance, incentives (Advisory Group Members 2019b)
		Real-time pricing, time-of-use rates	Burden on customers with limited ability to reduce or shift consumption (Advisory Group Members 2018b; 2020a)
	Sociocultural / Behavioral	Adoption of demand response and load flexibility programs and behaviors	Opportunity to realize long-term savings from reduced power bills (Advisory Group Members 2019b)
		Customer adoption of DERs	Impacts on system reliability, need for infrastructure upgrades / expansion (Advisory Group Members 2020a)

Table C-2. Examples of Factors That Can Limit Access in Buildings, Transportation, Distributed Energy Resources, and Utility-Scale Infrastructure

Sector	Dimension	Structural Factors	Present-Day Equity Impacts
Buildings	Built Environment	Building age	Technical feasibility of (barriers to) electrification / energy retrofits (Steering Committee Members 2022a; Advisory Group Members 2018c; Harris-Dawson et al. 2022)
		Building type (e.g., single-family, multifamily, commercial, manufactured, municipal)	Technical feasibility of onsite energy systems for single-family vs. multifamily vs. manufactured homes (Krekorian and O'Farrell 2021b)
		Local infrastructure (maintenance, ADA accessibility, etc.)	Physical accessibility of buildings and facilities (and the services they provide) (Llewellyn 2019)
	Policy / Institutional	DWP conservation and efficiency-promoting programs to reduce home	Accessibility of information through targeted outreach (Advisory Group Members 2017a; 2020d; 2021)

Sector	Dimension	Structural Factors	Present-Day Equity Impacts
		/ community energy demand	Contracting opportunities for local grassroots organizations to assist in dissemination of information (Advisory Group Members 2017a; 2021)
		Incentives vs. rebates for building energy upgrades	Ability to take advantage of economic assistance policies that require up-front investment (Steering Committee Members 2022a; 2022b)
	Sociocultural / Behavioral	Awareness of time-of-use rates, changes to net metering policies	Ability to provide comment /input on proposed policy changes (Residents of Los Angeles 2022a; Advisory Group Members 2017b; 2020c)
			Access to information to make informed energy decision (Residents of Los Angeles 2022a)
		Cultural / language barriers to information	Access to information on bill assistance, energy efficiency, energy conservation, and demand response programs (Residents of Los Angeles 2022a; 2022b; Advisory Group Members 2020c)
			Accessibility of technical information for non-technical audiences (Residents of Los Angeles 2022b; Advisory Group Members 2018c; 2020b; 2020d)
		Time poverty	Ability to participate in education / outreach programs (Residents of Los Angeles 2022a; 2022b)
			Ability to provide comment, attend public hearings, and/or participate in community engagement activities related to zoning, building codes, homeowner / neighborhood associations, etc.
			Ability to implement and participate in load shifting / demand response programs and behavior changes
Distributed Energy Resources	Built Environment	Building and roof age	Technical feasibility of customer-owned / community solar (Advisory Group Members 2019b)
		Interrelated dependencies of transmission upgrades, distributed generation, and small-scale residential solar	Where and when distributed generation and local solar are deemed economically and technically feasible (Advisory Group Members 2018a; 2018b; 2018c; 2018d; 2019b; 2019c; 2020b; 2020d)
		Land use patterns and development density	Impact of construction density on solar technical potential and feasibility (Advisory Group Members 2018d; 2019b)

Sector	Dimension	Structural Factors	Present-Day Equity Impacts
		Solar on public facilities	Access to resilient energy (Advisory Group Members 2019b)
			Access to educational co-benefits of visible renewable energy (Advisory Group Members 2019b)
		Transmission-related bottlenecks in deployment of solar and storage	Technical feasibility / access to distributed energy (Advisory Group Members 2020b)
	Sociocultural / Behavioral	Ability of partners to communicate technical plans and studies to their communities with appropriate language, materials, transparency in assumptions and process, etc.	Accessibility of information necessary to participate (Residents of Los Angeles 2022b; Advisory Group Members 2019c; 2020b; 2020c)
		Barriers to participation in community outreach and engagement activities	Ability to participate (Advisory Group Members 2020c)
		Neighborhood-level uptake of solar and storage	Peer effects on solar adoption (Advisory Group Members 2020a)
Transportation	Built Environment	Availability of workplace / public EV charging	Access to free and public EV charging (Advisory Group Members 2019a)
	Sociocultural / Behavioral	Ability of partners to communicate technical plans and studies to their communities with appropriate language, materials, transparency in assumptions and process, etc.	Accessibility of information necessary to participate (Advisory Group Members 2019c; 2020b; 2020c)
		Barriers to participation in community outreach and engagement activities	Ability to participate (Advisory Group Members 2020c)
		Mode-shifting policies and trends	Perceived accessibility / acceptability of different mobility options (Williams, Blair-Loy, and Berdahl 2013; Kossek, Lautsch, and Eaton 2006)
		Time poverty	Ability to shift transportation behaviors / modes

Sector	Dimension	Structural Factors	Present-Day Equity Impacts
			Ability to participate in planning / outreach / education activities and programs (Williams, Blair-Loy, and Berdahl 2013; Kossek, Lautsch, and Eaton 2006; Lambert 2008; Hyde, Greene, and Darmstadt 2020)
			Ability to take advantage of incentives for charging personal EVs during off-peak hours
Utility-Scale Infrastructure	Built Environment	Age of existing 4.8 kV distribution infrastructure	Upgrade timeline enabling / constraining technical feasibility of distributed generation, larger system changes (Advisory Group Members 2019c; 2020b)
		DWP regional stormwater capture projects in the North Valley	Accessibility of LADWP nature-based projects designed to improve water quality and supply, other community benefits (Krekorian, Martinez, and Rodriguez 2021b)
	Policy / Institutional	Prioritization of energy efficiency vs. new generation	Availability of / access to energy efficiency programs and incentives, financial and technical assistance (Advisory Group Members 2019b)
	Sociocultural / Behavioral	Ability of partners to communicate technical plans and studies to their communities with appropriate language, materials, transparency in assumptions and process, etc.	Accessibility of information necessary to participate (Advisory Group Members 2019c; 2020b; 2020c)
		Barriers to participation in community outreach and engagement activities	Ability to participate (Advisory Group Members 2020c)

Table C-3. Examples of Factors that Can Limit Access to Jobs and Workforce Development Opportunities in Housing, Transportation, Distributed Energy Resources, and Utility-Scale Infrastructure

Sector	Dimension	Structural Factors	Present-Day Equity Impacts
Buildings	Policy / Institutional	Building codes	Impact of new building codes on quantity, quality of construction jobs (Harris-Dawson et al. 2022)
		City contracting standards	Impact of hiring and labor standards on ensuring quality jobs for residents (Koretz and Krekorian 2021; Krekorian and O’Farrell 2021a)

Sector	Dimension	Structural Factors	Present-Day Equity Impacts
			Impact of bid requirements on ability for some small and local businesses to bid for / win City contracts (Koretz and Krekorian 2021; Krekorian and O'Farrell 2021a)
		Collective bargaining agreements and workforce development / training in relation to the renewable energy transition	Empowerment of organized labor to participate and take ownership of the transition (Advisory Group Members 2019b)
		DWP conservation and efficiency-promoting programs to reduce home / community energy demand	Contracting opportunities for local grassroots organizations to assist in dissemination of information (Advisory Group Members 2017a; 2021)
			Impact of conservation and weatherization programs on employment and training for clean energy trades in local communities (Residents of Los Angeles 2022a; Advisory Group Members 2017a; 2020b)
Distributed Energy Resources Distributed Energy Resources	Built Environment	Interrelated dependencies of transmission upgrades, distributed generation, and small-scale residential solar	Long-term job potential / job security in different energy generation sectors and infrastructure construction (Advisory Group Members 2020b; 2021)
	Policy / Institutional	City contracting standards	Impact of hiring and labor standards on ensuring quality jobs for local residents (Koretz and Krekorian 2021; Krekorian and O'Farrell 2021a)
			Impact of bid requirements on ability for some small and local businesses to bid for / win City contracts (Koretz and Krekorian 2021; Krekorian and O'Farrell 2021a)
		Hiring practices for construction, operation, and maintenance of DER systems and related infrastructure	Impact of past / current transitions on quantity, quality, and distribution of jobs (Advisory Group Members 2019b; 2020b)
		Workforce training programs / opportunities for construction, operation, and maintenance of technology and infrastructure	Access to knowledge / skills / opportunities to transition professionally (Advisory Group Members 2019b; 2020b)
			Economic mobility through past energy technology expansions / transitions

Sector	Dimension	Structural Factors	Present-Day Equity Impacts
Mobility / Transportation	Policy / Institutional	City contracting standards	Impact of hiring and labor standards on ensuring quality jobs for local residents (Koretz and Krekorian 2021; Krekorian and O'Farrell 2021a)
			Impact of bid requirements on ability for some small and local businesses to bid for / win City contracts (Koretz and Krekorian 2021; Krekorian and O'Farrell 2021a)
		Hiring practices for construction, operation, and maintenance of transportation systems and infrastructure	Impact of electrification on quantity, quality, and distribution of jobs (Advisory Group Members 2019b; 2020b)
		Workforce training programs / opportunities for construction, operation, and maintenance of infrastructure	Access to knowledge / skills / opportunities to transition professionally (Advisory Group Members 2019b; 2020b)
			Economic mobility through past transportation system expansions / transitions (Advisory Group Members 2019b; 2020b)
Utility-Scale Infrastructure	Built Environment	Existing natural gas units and associated infrastructure	Economic dependence on fossil-fired generation for jobs, tax revenue, community budget (Navajo Nation) (O'Farrell 2020)
	Economic	Rate structures	Impact of rates on other sectors of the economy (e.g., small business' ability to hire / raise wages) (Advisory Group Members 2019b)
		Revenue losses from closure of fossil-fired generation	Long-term community-level economic stability (O'Farrell 2020)
	Policy / Institutional	City contracting standards	Impact of hiring and labor standards on ensuring quality jobs for residents (Koretz and Krekorian 2021; Krekorian and O'Farrell 2021a)
			Impact of bid requirements on ability for some small and local businesses to bid for / win City contracts (Koretz and Krekorian 2021; Krekorian and O'Farrell 2021a)

Table C-4. Examples of Factors Contributing to Inequities in Public Health, Safety, and Community Resilience

Sector	Dimension	Structural Factors	Present-Day Equity Impacts
Buildings	Built Environment	Building / appliance efficiency, type	Other energy-related emissions (besides carbon dioxide, e.g., methane, refrigerants, air toxics) (Advisory Group Members 2018c; 2021; 2020c; 2020b)
			Indoor air quality, thermal comfort, occupant health (Steering Committee Members 2022a; 2022b; Advisory Group Members 2021; Harris-Dawson et al. 2022)
		Building age	Structural stability / safety risks (e.g., earthquakes) (Harris-Dawson et al. 2022)
		Exposure to climate hazards / adaptability to climate extremes	Occupant health / habitability, morbidity and mortality, climate resilience (Advisory Group Members 2019c; 2020b)
		Local microclimatic / infrastructural characteristics	Neighborhood-level disparities in exposure to energy infrastructure-related hazards (Advisory Group Members 2020b; 2020c; 2020d)
	Economic	Sudden or chronic economic hardship due to persistent low (or unstable) income	Lack of resources to maintain safe and healthy home / work environment (e.g., thermal comfort, addressing sources of mold / leaks, routine maintenance) (Steering Committee Members 2022a; Lou et al. 2021; Drehobl and Ross 2016)
		Rent burden	Unstable access to safe, healthy, and affordable housing (Steering Committee Members 2022a; Harris-Dawson et al. 2022)
			Loss of community services (grocery stores, pharmacies, etc.) due to eviction / displacement of small businesses
	Sociocultural / Behavioral	Baseline vulnerability to indoor air pollution, health multiplier problems	Occupant health / resilience to acute health threats (e.g., COVID-19, heat waves) (Advisory Group Members 2020b)
	Policy / Institutional	City contracting standards	Life cycle impacts of City activities, including pollution related to contractors hired for building projects (Koretz and Krekorian 2021)

Sector	Dimension	Structural Factors	Present-Day Equity Impacts
		DWP conservation and efficiency-promoting programs to reduce home / community energy demand	Reduced demand /need for construction of additional generation and infrastructure (and associated impacts) (Advisory Group Members 2017a)
		Zoning: Ordinances to fund HVAC upgrades for homes, schools, and community facilities in polluted areas	Access to resources to ameliorate health impacts of power generation and pollution (Krekorian, Martinez, and Rodriguez 2021b)
Distributed Energy Resources	Built Environment	Backup for remote and local resources	Customer energy reliability during outages (Advisory Group Members 2018d)
		Life cycle costs and emissions of distributed energy technology and infrastructure	Displaced timing and location of different types of emissions and impacts across geographic and intergenerational scales (Advisory Group Members 2020c)
		Solar on public facilities	Access to resilient energy (Advisory Group Members 2019b)
	Economic	Land acquisition costs for solar farms	Siting decisions for large solar projects (and associated environmental impacts) (Advisory Group Members 2019b)
			Conflicting / competing land uses serving other community needs (Advisory Group Members 2019b)
		Long-term funding for infrastructure maintenance	Intergenerational impacts of allowing energy generation infrastructure to fall into disrepair / fail (Advisory Group Members 2017b)
	Policy / Institutional	City contracting standards	Life cycle impacts of City activities, including pollution related to contractors hired for DER installation / infrastructure projects (Koretz and Krekorian 2021)
		Tax credits for solar and storage	System-wide reliability / resilience benefits of customer DERs, reduction in peak demand and distribution stress (Advisory Group Members 2020a)
	Sociocultural / Behavioral	Baseline vulnerability to air pollution from power generation	Distribution of health benefits from customer adoption of clean and distributed energy (Advisory Group Members 2020b)
		NIMBY-ism	Siting polluting / undesirable infrastructure and facilities (including batteries, large solar farms) in / near communities with less social / political capital to mount political opposition (Advisory Group Members 2018b; 2019b; 2020a)

Sector	Dimension	Structural Factors	Present-Day Equity Impacts
		Treatment of outlying communities in analysis of renewable energy development impacts	Prioritization of urban / interior communities vs. rural / outlying communities (Advisory Group Members 2019a)
Mobility / Transportation	Built Environment	Infrastructure for electrification of trains, heavy-duty transport beyond buses (including freight)	Feasibility of reducing criteria emissions associated with transportation, especially near warehouses, ports, other heavy transportation corridors (Steering Committee Members 2022a; 2022b; Advisory Group Members 2019c)
	Economic	Electricity rates vs. cost of gasoline	Tradeoffs between emissions reductions in power and transportation sectors (Advisory Group Members 2018b; 2018d; 2019c; 2020b)
	Policy / Institutional	City contracting standards	Life cycle impacts of City activities, including pollution related to contractors hired for transportation infrastructure projects (Koretz and Krekorian 2021)
		Fossil fuel subsidies	Investment in fossil fuel-dependent technology and infrastructure (Advisory Group Members 2019c)
		Childhood exposure to diesel pollution while riding in school buses	Loss of funding for schools with high absence rates (Advisory Group Members 2019c; Muñoz et al. 2019; Lee, Fung, and Zhu 2015)
			Impacts to learning from chronic / repeated school absences due to asthma (Advisory Group Members 2019c; Muñoz et al. 2019; Lee, Fung, and Zhu 2015)
		Rollback of Corporate Average Fuel Economy standards	Delayed realization of health benefits from implementation of emission-reducing technologies (Advisory Group Members 2019b)
	Sociocultural / Behavioral	Baseline vulnerability to transportation-related air pollution, health multiplier problems	Health impacts of exposure / vulnerability to transportation-related air pollution (Advisory Group Members 2020b)
		Behavior changes in response to COVID-19	Changing mobility needs / ability to shift to new transportation modes (i.e., ability to stay at home or use personal vehicle to avoid exposure) (Advisory Group Members 2020a; Williams, Blair-Loy, and Berdahl 2013; Kossek, Lautsch, and Eaton 2006)

Sector	Dimension	Structural Factors	Present-Day Equity Impacts
		Electrification of private medium-duty vehicles, delivery truck fleets	Significant impact on air quality and public health, exposure to tailpipe emissions (especially among children) (Advisory Group Members 2019b; Muñoz et al. 2019; Lee, Fung, and Zhu 2015)
		Mode-shifting policies and trends	Reductions in total number of vehicles on the road (and traffic, collisions, etc.) (Advisory Group Members 2019c)
		VMT reduction policies and trends	Changes in sources and distribution of emissions and air quality impacts over time (Advisory Group Members 2019b; 2019c)
Utility-Scale Infrastructure	Built Environment	Age of existing 4.8 kV distribution infrastructure	Current operating performance of existing feeders, impact on customer energy reliability and resilience (Advisory Group Members 2019c)
		DWP regional stormwater capture projects in the North Valley	Spatial distribution of LADWP nature-based projects designed to improve water quality and supply, and accessibility of community and environmental benefits (Krekorian, Martinez, and Rodriguez 2021b)
		Existing natural gas units and associated infrastructure	Local exposure to pollution associated with combustion (Advisory Group Members 2020a; 2020c)
			Economic dependence on fossil-fired generation for jobs, community budgets and services (Navajo Nation) (Steering Committee Members 2022b; O’Farrell 2020)
		Increasing frequency / severity of extreme weather, wildfires due to climate change	Health impacts of public safety power shutoffs (Advisory Group Members 2019a)
		Life cycle costs and emissions of distributed energy technology and infrastructure	Timing and location of different types of emissions and impacts (Advisory Group Members 2020c)
		Seasonal environmental variation / drought	Increasing need for / reliance on different seasonal storage technologies to maintain system reliability (Advisory Group Members 2018c; 2019c; Koretz and O’Farrell 2021)
		Siting of current and planned transmission infrastructure	Reliability of current transmission infrastructure / frequency of extended transmission outages (Advisory Group Members 2019c; 2020b; 2020c)

Sector	Dimension	Structural Factors	Present-Day Equity Impacts
			Legacy infrastructure from extractive fossil energy systems (Advisory Group Members 2018b; 2019a; 2020a; 2020b; Krekorian, Martinez, and Rodriguez 2021a)
	Economic	Revenue losses from closure of fossil-fired generation	Long-term community-level economic stability, tax base, and ability to maintain public services (Navajo Nation) (O’Farrell 2020)
	Policy / Institutional	City contracting standards	Life cycle impacts of City activities, including pollution related to contractors hired for building projects (Koretz and Krekorian 2021)
		Colorado River Compact	Governance of water allocation across states, Native Tribes, and jurisdictions in the Southwest (Koretz and O’Farrell 2021)
		Fossil fuel subsidies	Investment in fossil fuel-dependent technology and infrastructure, externalizing social cost of carbon (Advisory Group Members 2019c)
	Sociocultural / Behavioral	Adoption of demand response and load flexibility programs and behaviors	Overall system demand, reliability, resilience (Advisory Group Members 2019b)
			(Avoided) emissions from fossil-fired peaker plants
		Baseline vulnerability to air pollution from power generation	Health impacts of exposure to air pollution from power generation (Advisory Group Members 2020b)
		Customer adoption of DERs	Impacts on system reliability, need for infrastructure upgrades / expansion and associated environmental impacts (Advisory Group Members 2020a)
		Social / political acceptability of generation fuels, battery storage facilities	Which technologies, risks, impacts have been / will be allowed (Advisory Group Members 2019b; 2019c; 2020a; 2020b)

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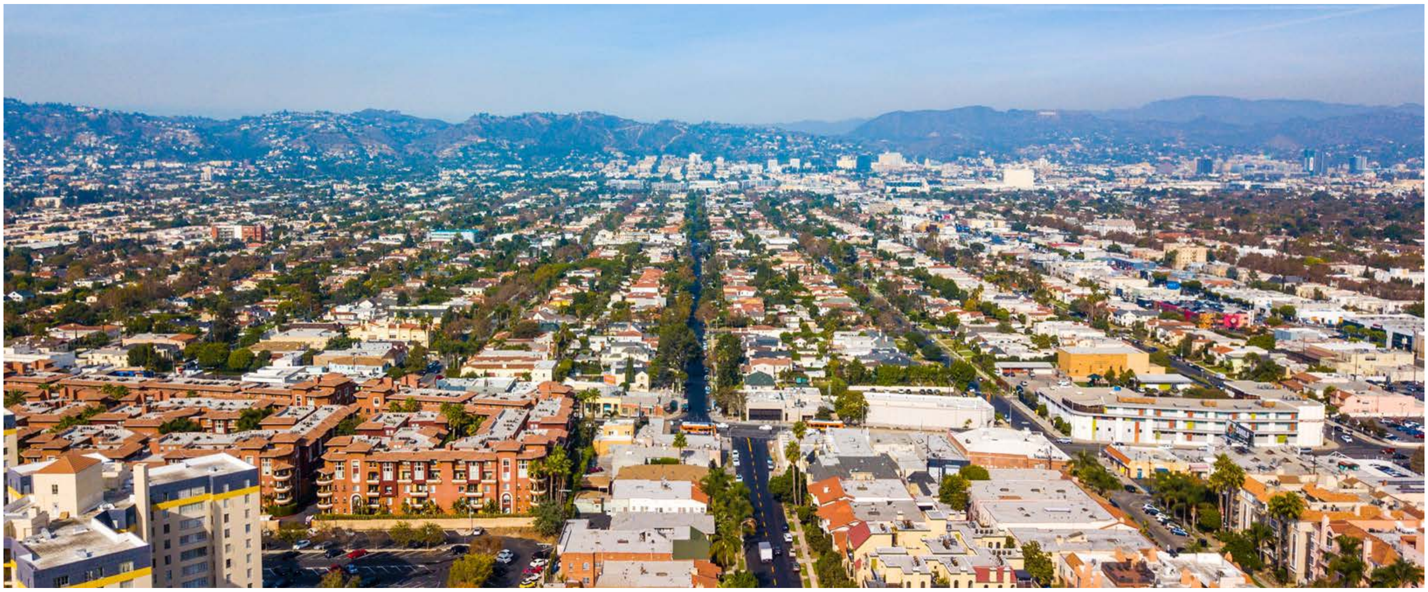

Chapter 2: Procedural Justice

FINAL REPORT: LA100 Equity Strategies

Nicole Rosner, Lis Blanco, Patricia Romero-Lankao, and
Daniel Zimny-Schmitt

LA100 EQUITY STRATEGIES

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Preface

The Los Angeles 100% Renewable Energy Study, or LA100, revealed that although all communities in Los Angeles will share in the air quality and public health benefits of the clean energy transition, increasing equity in participation and outcomes will require intentionally designed policies and programs. The LA100 Equity Strategies project was specifically designed to help Los Angeles identify pathways to such policies and programs in the form of equity strategies. The project aimed to do this by incorporating research and analysis to chart a course toward specific, community-prioritized, and equitable outcomes from the clean energy transition outlined in the LA100 study.

The Project Partners

The Los Angeles Department of Water and Power (LADWP), the National Renewable Energy Laboratory (NREL), and the University of California Los Angeles (UCLA) partnered on the LA100 Equity Strategies project to develop strategies for engaging communities, funding equitable technology and infrastructure investments, expanding existing programs, and designing new programs and policies to improve equity by incorporating what community members themselves know is needed to achieve a more equitable energy future.

The Project Approach

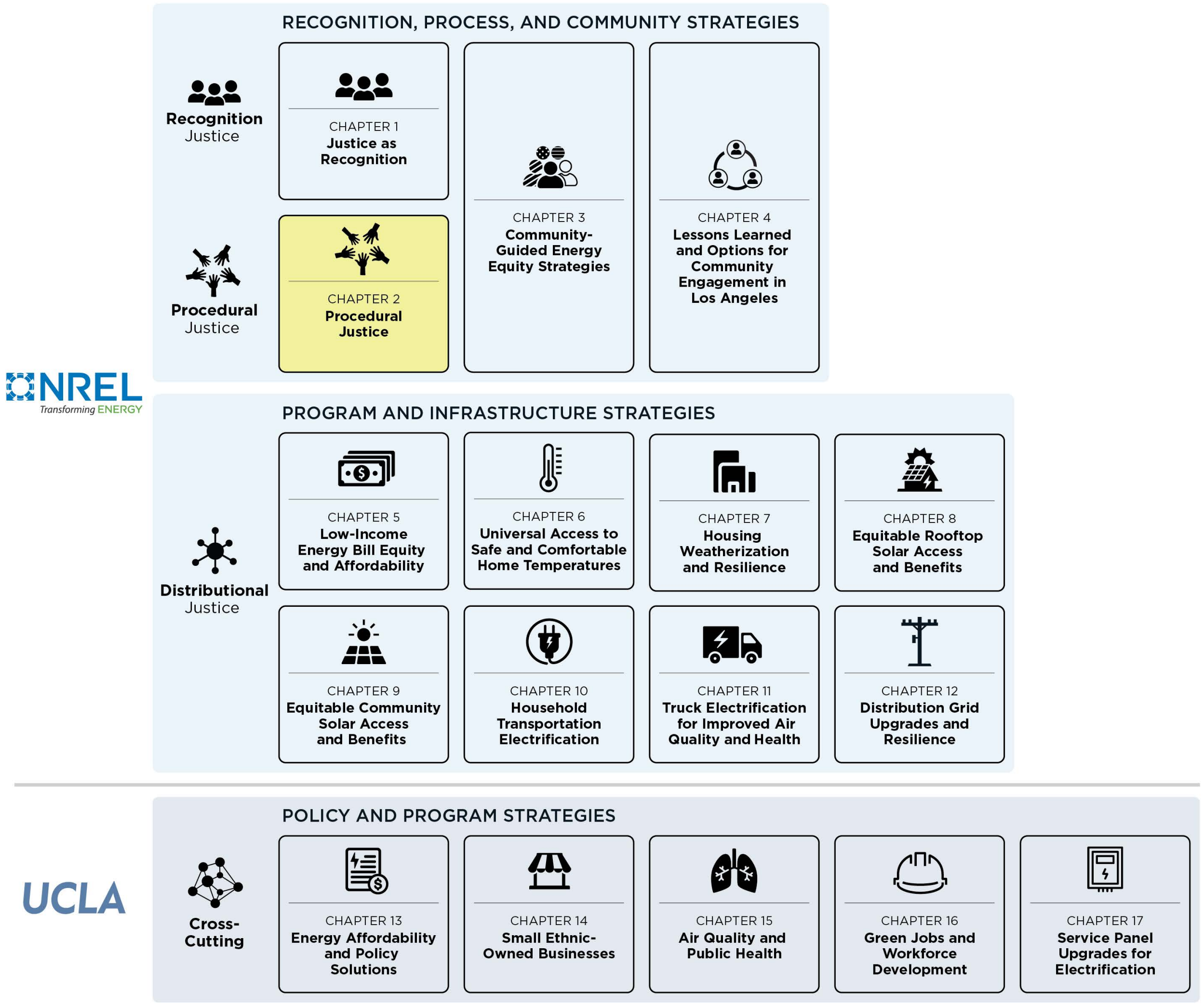
LA100 Equity Strategies employs a unique mixed-methodological approach utilizing three distinct—but connected—research efforts. Through these efforts, NREL and UCLA developed a range of strategy options for increasing equity in LA's transition to 100% clean energy.

A Project Summary

To get a high-level overview of the project, you can dive into the executive summary, interactive data visualizations, and more on the LA100 Equity Strategies website at maps.nrel.gov/la100/equity-strategies.

The Full Report

NREL's final full report for the LA100 Equity Strategies project encompasses seventeen chapters. The first twelve chapters, authored by NREL, are organized around the three tenets of justice. Chapters 1–4 address recognition and procedural justice, while Chapters 5–12 address distributional justice. The final five chapters, authored by UCLA, provide crosscutting policy and program strategies. Each chapter provides data, methods, insights, and strategies to help LADWP make data-driven, community-informed decisions for equitable investments and program development.



NREL Chapters

Chapter 1: Justice as Recognition

Chapter 2: Procedural Justice

Chapter 3: Community-Guided Energy Equity Strategies

Chapter 4: Lessons Learned and Options for Community Engagement in Los Angeles

Chapter 5: Low-Income Energy Bill Equity and Affordability

Chapter 6: Universal Access to Safe and Comfortable Home Temperatures

Chapter 7: Housing Weatherization and Resilience

Chapter 8: Equitable Rooftop Solar Access and Benefits

Chapter 9: Equitable Community Solar Access and Benefits

Chapter 10: Household Transportation Electrification

Chapter 11: Truck Electrification for Improved Air Quality and Health

Chapter 12: Distribution Grid Upgrades for Equitable Resilience and Solar, Storage, and Electric Vehicle Access

UCLA Chapters

Chapter 13: Energy Affordability and Policy Solutions Analysis

Chapter 14: Small Ethnic-Owned Businesses Study

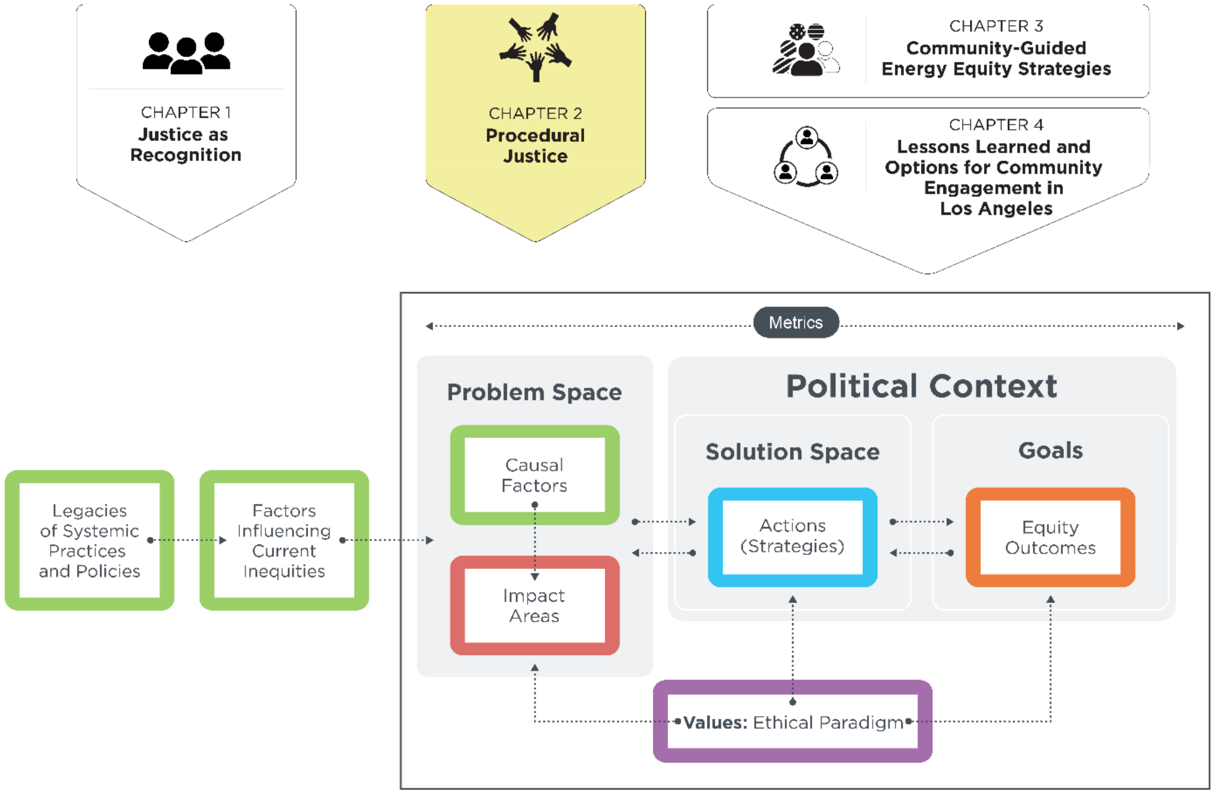
Chapter 15: Air Quality and Public Health

Chapter 16: Green Jobs Workforce Development

Chapter 17: Service Panel Upgrade Needs for Future Residential Electrification

About Chapters 1–4

In Chapters 1–4, NREL presents community-grounded research and analysis results on recognition justice and procedural justice, community-guided equity strategies, and future options for community engagement by LADWP. Across these chapters, a mixed-methodological approach is applied, including a systematic literature review, statistical analysis of access to LADWP programs, and qualitative research with communities and community-based organizations to examine understandings of energy transition needs, barriers, and priorities. This work informs modeling and development of equity strategies by analyzing (1) the distribution of benefits of LADWP programs and strategies in the city and (2) historical and current factors contributing to this distribution and other energy inequities in the city.



List of Abbreviations and Acronyms

CBO	community-based organization
EV	electric vehicle
LADWP	Los Angeles Department of Water and Power
NREL	National Renewable Energy Laboratory
UCLA	University of California Los Angeles
ZEV	zero-emission vehicles

Executive Summary

The Challenge

The LA100 Equity Strategies project synthesizes community guidance with robust research, modeling, and analysis to identify strategy options that can increase equitable outcomes in Los Angeles' clean energy transition. Grounded in the analysis of past and ongoing energy inequities and engagement with underserved communities, the project presents community-guided and community-tailored strategies that aim to operationalize recognition and procedural justice. This chapter focuses on procedural justice, examining priorities identified during the community engagement portion of the LA100 Equity Strategies project. This process, and our approach to partnering with community-based organizations (CBOs) and the communities they serve, was developed from the baseline analysis in Chapter 1, which centers on recognition justice, examining past and current inequities in LA. Recognition, procedural, and distributional justice are the three tenets of energy justice around which the LA100 Equity Strategies project is organized (see the Glossary).

Procedural justice prioritizes fair, equitable, and inclusive participation in the decision-making process. This tenet's practical application entails who is invited and able to participate, whose voices are considered as decisions are made, the co-development of procedures to inform this deliberative process, and who has access to formal measures of regulation and accountability (Walker 2009; Carley and Konisky 2020; Upham, Sovacool, and Ghosh 2022). Engaging with Angelenos to examine the causes of inequities and identify impact areas and priorities that center community experiences, values, and goals represents a first step in developing energy equity strategies for the Los Angeles Department of Water and Power (LADWP) to achieve distributional justice—the just and equitable distribution of energy benefits and burdens in LA's energy transition. Equity, as community members insisted, is about making—and following through with—a commitment to prioritize historically underserved and overburdened communities. Community engagement is a principal method for operationalizing this commitment, guiding our analytic approach and potential equity strategies.

Using procedural justice as an analytical tool, this chapter presents the LA100 Equity Strategies approach to community engagement from 2021 to 2023 and the results of this process in relation to community-identified barriers and burdens impacting procedural justice outcomes. We analyze the procedural elements of reaching the equity goals Angelenos set to inform future LADWP decision-making and program development.

Goal and Approach

With a focus on procedural justice, the analysis in this chapter identifies critical procedural barriers to achieving equity in the LA energy transition. We reveal how community-identified values and underlying factors of energy-relevant inequities inform the co-development of equity strategies presented in Chapter 3. Our analytic approach emerged from an iterative process that recognizes the reciprocal relationship between community engagement and equity outcomes analyzed in Chapter 4. We listened to how CBOs and their community members framed energy problems, articulated aspirations for LA's energy future, and centered our analysis around those priorities.

Community engagement for the LA100 Equity Strategies project included one-on-one meetings with CBOs, neighborhood-specific listening sessions, Advisory Committee meetings, and Steering Committee meetings. While we collected data from various sources, this chapter presents results from the listening sessions as an engagement methodology that examined different forms of community guidance. By sharing preliminary findings from the listening sessions in Steering Committee and Advisory Committee meetings, the listening session results connected community members' stated aspirations, barriers, and concerns with guidance from Committee members. Steering Committee partners helped interpret and amplify session priorities, and Advisory Committee members provided institutional guidance. We used crosscutting priority areas and the three tenets of energy justice (recognition, procedural, and distributional) to (1) structure the engagement efforts for LA100 Equity Strategies, and (2) connect those priorities and tenets to the analysis of the data gathered during community engagement activities.

Through qualitative coding, we identified categories and concepts in the data and linked passages of CBO one-on-one meeting notes and 15 listening session transcriptions to themes that became labeled with a particular "code" (e.g., barriers to program participation and support). Our key findings emerged as we used the frequency of overlapping codes—two themes that were identified in the same passage—to analyze key relationships between causes (i.e., causal factors) and effects (i.e., impact areas), thus grounding our theoretical understandings of the energy transition in local realities.

Key Findings

A thorough review of the overlapping codes with the highest frequency across community discussions revealed three relevant categories (primary codes) of procedural justice: (1) self-determination, (2) barriers to program participation and support, and (3) energy affordability and burden. High frequency refers to the number of times these three primary codes overlapped with community-identified causal factors and impact areas. While the frequency of overlaps is an indicator of value, our focus here is not on statistical relevance, but rather on the recurrent significance of these categories to impact procedural justice in Los Angeles. We present these categories—their presence or lack thereof—as the primary barriers to procedural justice in the clean energy transition identified by community members during engagement. Below we include three tables with two examples of community-identified overlapping issues per category.

Self-Determination: For community participants, self-determination is the ability and power to make decisions for themselves in relation to the energy system. A key goal of the LA100 Equity Strategies project is developing a lasting methodology that centers community members in the energy decision-making process. Community participants discussed how causal factors (e.g., energy affordability and burden, access to financial capital) limit their energy-related decision-making and their ability to self-determine their own access to the benefits of the clean energy transition (e.g., electric vehicles [EVs]; jobs, training, and entrepreneurship). The power to determine one's own energy future in Los Angeles is not only about offering lower-income Angelenos subsidized opportunities and benefits. Access to high-road and well-paid jobs, training, and entrepreneurship in their communities also has direct impacts on self-determination. We performed a content analysis of the overlapping issues related to self-determination, which revealed procedural challenges participants experienced or predicted related to accessing clean, efficient, and affordable energy and technologies, as well as the jobs needed to facilitate that access.

Table ES-1. Codes Overlapping with Self-Determination

Primary Code	Overlapping Codes	Key Findings
Self-Determination	Energy Affordability and Burden	Residents referred to the unaffordability of current electricity bills, particularly given other monthly expenses, and noted that they did not have the ability or power to lower these high costs. What they did have the power to change was their own everyday routines in their homes, which did not necessarily impact their electricity bills.
	Electric Vehicles (EVs)	Factors limiting participants' ability to determine their own EV access include a lack of accessible guidance to make informed decisions, limited financial capital to purchase a used fuel car let alone an EV, and insufficient local EV charging infrastructure in their communities. For low- to moderate-income Angelenos, these factors become limitations on their power to choose an EV as their preferred mode of transportation.

Barriers to Program Participation and Support: This category refers to a series of causal factors limiting communities' ability to participate in, or become eligible to access and/or use, existing energy-related incentives, subsidies, and other aid programs. These barriers are embedded in eligibility criteria, predatory practices among service and credit providers, lack of accessible information, and renter and homeowner issues. Content analysis of the overlapping issues related to barriers to program participation and support showed a historical lack of procedural justice in LA's lower- and moderate-income communities, specifically in how government programs and benefits are designed and implemented today. This section of the chapter reveals LA's historical disinvestment, disenfranchisement, and lack of self-determination in particular neighborhoods. Our analysis reveals that in practice, programs that are designed to redress inequities in these areas can inadvertently reproduce inequities during implementation.

Table ES-2. Codes Overlapping with Barriers to Program Participation and Support

Primary Code	Overlapping Codes	Key Findings
Barriers to Program Participation and Support	Moderate to Low Income	Participants referred to the financial difficulties in accessing clean and efficient energy technologies via existing programs. Low-income participants emphasized barriers to accessing programs due to structural factors such as language limitations, citizenship status, housing tenure, and information gaps. Moderate-income participants emphasized the shortcomings of current eligibility criteria that effectively exclude their participation in existing programs due to an incomplete understanding of their economic status and financial burdens.
	Renter and Homeowner Issues	According to participants, residents who live in non-rent-controlled housing where homeowners implement upgrades—even subsidized LADWP upgrades and benefits—will most likely experience an increase in rent to cover the cost. For those living in rent-controlled housing, homeowners will most likely refrain from investing in upgrades given their inability to utilize rent to cover costs, and therefore place the burden of safety and efficiency upgrades on renters who are ineligible for LADWP benefits. For low-to-moderate-income homeowners, purchasing a home creates new and long-term financial burdens that limit their capacity to invest in subsidized energy efficiency improvements.

Energy Affordability and Burden: Community members' abilities to pay energy-related costs—from transportation and housing to work, food, and recreation—describes *energy affordability and burden* in the context of their everyday lives. Energy burdens are often understood as "the percent of a household's income spent on utilities for heating, cooling, and other energy services" (Drehobl and Ayala 2020). However, participants consider energy burden to include the trade-offs households must make to pay their energy bills alongside other monthly financial burdens (e.g., cost of health care, childcare, rent)—which aligns with scholarship that expands the above established understanding of the term. The *energy affordability and burden* code overlapped with many of the previous codes; therefore, we only highlight two overlapping codes—*barriers to program participation and support* and *responsibility, accountability, and transparency*—that illuminate the procedural changes needed to increase Angelenos' access to affordable energy. Our content analysis of *energy affordability and burden* revealed procedural issues impacting access to specific clean energy technologies and services.

Table ES-3. Codes Overlapping with Energy Affordability and Burden

Primary Code	Overlapping Codes	Key Findings
Energy Affordability and Burden	Barriers to Program Participation and Support	While there are existing LADWP programs designed to increase energy affordability for ratepayers, listening session participants emphasized the barriers to accessing those benefits that maintain ongoing energy burdens. One such barrier is the "missing middle": a subset of ratepayers who cannot afford the more efficient clean energy technologies and yet are not included in the program design for subsidized benefits given their relatively higher incomes. This lack of access thus increases the energy inequities among ratepayers: as energy technologies become more efficient yet also more expensive, moderate-income Angelenos receive disproportionately fewer of the benefits while becoming more financially burdened.
	Responsibility, Accountability, Transparency	In listening sessions, participants described both the presence and absence of institutional responsibility, accountability, and transparency. Participants explained the direct impacts that their absence has on financial and other burdens produced by the current energy system. Participants understand themselves as part of the energy system as ratepayers, and therefore demand transparency and accountability.

The three categories above—self-determination, barriers to program participation and support, and energy affordability and burden—reveal causal factors that must be redressed to achieve procedural justice. This intersectional relationship shows the importance of developing and maintaining transparency and accountability to ensure an equitable distribution of energy services, resources, and technologies for all Angelenos. Chapters 1–4 of this report center and operationalize recognition and procedural justice to co-identify and analyze energy equity strategies with underserved communities and their organizations, and Chapters 5–12 present a series of strategies to improve distributional justice.

Envisioning Equitable LADWP Programs

This chapter analyzes a crucial component of procedural justice—LADWP's engagement with historically underserved communities and CBOs—to define where and when to prioritize more equitable goals and strategies in Los Angeles. Employing a mixed-methodological approach, we identify procedural barriers and challenges to ground our understanding of energy-relevant inequities in areas of impact prioritized by Steering Committee members and listening session participants. Our analysis and key findings are critical to ensuring fair, equitable, and inclusive participation in the decision-making process for LA's energy transition. The findings can serve to guide and inform LADWP in future planning and program development toward a more equitable LA energy transition.

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1 Introduction

Energy, climate, and environmental justice initiatives in the United States are embedded in processes that involve social movements, research, and policy development. These initiatives address the environmental impacts faced by underserved and frontline communities (Walker 2009; Hettinger et al. 2021). One of the first legal actions to include environmental justice principles in federal regulatory practice was President Clinton's 1994 Executive Order 12898. This order required the U.S. Environmental Protection Agency and other federal agencies to implement environmental justice strategies that address the disproportionate negative effects of federal programs and policies on low-income and communities of color. In September 2019, the State of California further ratified environmental justice principles into law when the California Assembly Bill 1628 called for "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" (Rivas 2019). The Biden Administration's commitment to environmental justice opens up new opportunities and programs, such as the Inflation Reduction Act and the Justice40 Initiative, to develop and foster a more equitable energy system. These processes at the federal and state levels guide environmental justice decisions. Procedural justice then focuses on the equitable inclusion of people in the decision-making process, which ultimately defines the local effects of federal and state policies.

The concept of *justice* has interrelated threads that run through the fields of social, energy, climate, and environmental sciences (McCauley and Heffron 2018; Jenkins 2018; Carley and Konisky 2020). As already indicated in Chapter 1, our emphasis in Chapters 1–4 is on energy justice, following the three functions developed by Sovacool and Dworkin (2015): energy justice as a conceptual, analytical, and decision-making tool. We use energy justice as a *conceptual tool,* to analyze the legacy of past and ongoing policies and practices on current energy inequities in Los Angeles (Chapter 1). As an *analytical tool,* it guides analyses of how social norms and ethical paradigms are reproduced through energy systems and of how structural, causal factors impact energy outcomes. As a *decision-making tool*, it supports energy planners, ratepayers, and community-based organizations (CBOs) in developing more informed and grounded energy strategies and actions. In these three functions, energy justice integrates social and engineering science tools and methods through feedback loops with local communities, trusted institutions, and diverse research disciplines. This chapter focuses on energy justice as an *analytical tool* for understanding how social norms, ethical paradigms, and causal factors impact the current energy process in Los Angeles.

LA100 Equity Strategies moves beyond a singular focus on the distributional aspects of benefits, burden, and disadvantage (i.e., distributional justice) to analyze three tenets of energy justice: procedural, recognition, and distributional justice (Chapter 1). The goal of this chapter is to present the results of the social analysis of community engagement data collected from 2021 to 2023 in relation to the causal factors, impact areas, and values affecting procedural justice outcomes. Chapter 3 then operationalizes those community-identified mechanisms related to *procedural justice* and *justice as recognition* to inform a more inclusive and equitable engagement process guiding the energy transition in Los Angeles (Chapter 4).

In the following sections, we define key terms and the analytic approach to the just transition to clean energy in Los Angeles (Section 2 and the Glossary, page 29). We then present the methods used to center procedural justice, including an ongoing community engagement process (Section 2.3) that identifies critical procedural barriers and challenges to achieving more equitable energy outcomes. This analysis creates a lens for understanding energy-relevant inequities crosscutting areas prioritized by Steering Committee members and listening session participants (Section 2.4). The concluding remarks map the analytic trajectory from the problem space (Section 2.5) toward the solution space (Chapter 3 and 4). Chapter 3 and Chapter 4 operationalize the key findings of our recognition and procedural justice analysis related to equity in the energy decision-making process to co-develop strategies with communities that impact their prioritized areas (Chapter 3).

2 Analytic Approach

Any attempt to develop more equitable energy outcomes in Los Angeles must first involve understanding what energy equity means to the people most negatively affected by the current energy system. The Los Angeles Department of Water and Power (LADWP) is committed to that effort, and this chapter presents steps to address this challenge through a procedural justice approach.

Actively engaging underserved communities and CBOs in defining where and when to prioritize more equitable goals and strategies has become a best practice (Romero-Lankao and Nobler 2021). This process of community engagement is critical to procedural justice (Williams, Blair-Loy, and Berdahl 2013; Walker 2009). Procedural justice is concerned with ensuring fair, equitable, and inclusive participation in the decision-making process. This tenet entails who is invited and able to participate, whose voices are considered as decisions are made, the co-development of procedures to inform this deliberative process, and who has access to formal measures of regulation and accountability (Walker 2012; Carley and Konisky 2020; Upham et al. 2021).

Recognizing the reciprocal relationship between community engagement and equity outcomes, our analytic approach to Chapters 1–4 emerged from an iterative process that connected the systems of thought, concepts, and ways of framing problems (Burawoy 1998) shared with us by community members to the three tenets of energy justice: procedural, recognition, and distributional (Chapter 1 and the Glossary). Utilizing an adaptation of grounded theory concepts (Charmaz 2006; Buckley and Waring 2013), we used existing (deductive) crosscutting priorities and justice tenets to (1) structure the engagement efforts for LA100 Equity Strategies (Section 3.3.1) and (2) connect those priorities and tenets (deductive) to the bottom-up (inductive) analysis of the data gathered during community engagement activities (Section 4).

This approach framed our empirical data around a problem space made up of community-identified causal factors and impact areas, a solution space made up of community-identified actions and strategies, and the underlying values that orient community understandings, actions, and future visions. Structured by this framework, our approach enables community member and stakeholder understandings to ground the operationalization of energy justice. Here grounding entails the identification of local strategies to achieve more equitable energy outcomes. These efforts inform the analysis in Chapters 3–12 of actions aimed at addressing recognition and procedural injustices and fostering equity in the distribution of benefits and burdens in the LA energy transition (*distributional justice*).

In this framework, the *causal factors* refer to historical and ongoing structural processes, policies, and practices that have led to current inequities in the energy system. In this chapter, they refer to the root causes of inequitable participation in decision-making. In turn, a lack of decision-making power becomes a causal factor in itself, creating inequities in both decision-making and fair treatment in access to benefits in crosscutting prioritized areas, such as energy access and affordability, jobs, and health (Agyeman et al. 2016; Álvarez and Coolsaet 2020).

These causal factors have direct and indirect effects on the energy system and current transition. We define the areas in which these energy-related effects land as *impact areas*, the areas that must be addressed to engender more equitable energy outcomes. An impact area could refer to an energy subsector, such as transportation, or a crosscutting prioritized area, such as affordability and access.

An energy transition entails changes in sociotechnical energy systems and systems of policy action (depicted in “Solution Space” in Figure 1). *Actions* involve programs such as regulations, subsidies, and investments and how they are designed, implemented, and evaluated. In turn, these actions can become a means to achieving more equitable energy transition outcomes, or the ultimate changes that a policy or program will yield (Arndt et al. 2017; McCauley and Heffron 2018; Carley and Konisky 2020).

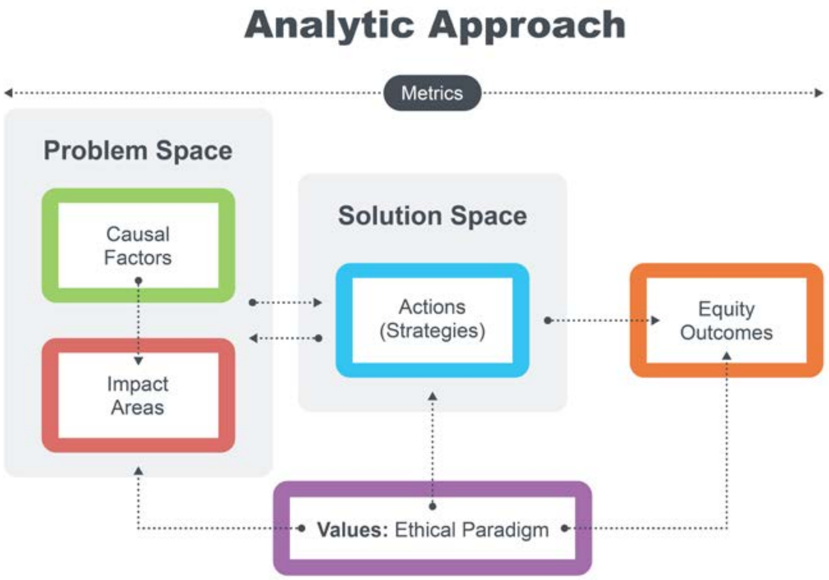

Figure 1. Analytic approach to procedural justice

Underlying this framework is the *ethical paradigm* or *value* system that structures the sociocultural norms, beliefs, and practices guiding how a group of people prioritize and relate to the current energy transition (see the Glossary, page 29). Our framework builds on the assumption that just energy transitions can be more effectively and inclusively achieved by a systematic effort to understand and consider community and stakeholder value systems in the engagement process.

Through engagement with underserved communities and project stakeholders in Los Angeles, this analytic approach can help: (a) determine if strategies are equitable in their design, development, impacts, and outcomes; and (b) establish the process to monitor and revise program design and implementation. This engagement process—substantively integrating historically underserved communities into the decision-making process—is a critical component of procedural justice.

3 Methods and Data

This chapter builds upon the literature review and statistical analysis described in Chapter 1 by using a mixed-methodological approach to identify community barriers, impact areas, and underlying factors affecting equity in the energy system. Chapter 3 uses these findings to produce community-guided equity strategies. Community engagement involved three stages developed through combined engagement with communities and stakeholders, including both the Steering Committee and the Advisory Committee (see Figure 2, page 6). The stages are:

1. Envisioning what a just energy future means for communities and CBOs, identifying and understanding Los Angeles' energy justice problems and analyzing determinants of energy inequities.
2. Informing strategy analysis and development.
3. Sharing analysis, models, and community feedback.

Figure 2 lays out the timeline for each of the primary research and engagement efforts used to develop a community-informed approach to producing implementation-ready strategies for Los Angeles' just energy transition. These efforts include:

- Steering Committee meetings
- Advisory Committee meetings
- Neighborhood-specific community listening sessions.

Ongoing community engagement is critical to all phases of LA100 Equity Strategies. However, it plays a particularly important role in its first phase by setting the stage—recognizing local histories of energy inequities and identifying their ongoing impacts on the present context—and building critical community relationships to co-design just energy strategies for LA's future. In this chapter, we present results from our community engagement, which included one-on-one meetings with CBOs on the Steering Committee, neighborhood-specific listening sessions, Advisory Committee meetings, and Steering Committee meetings (Figure 2). We describe each of these in the next sections.

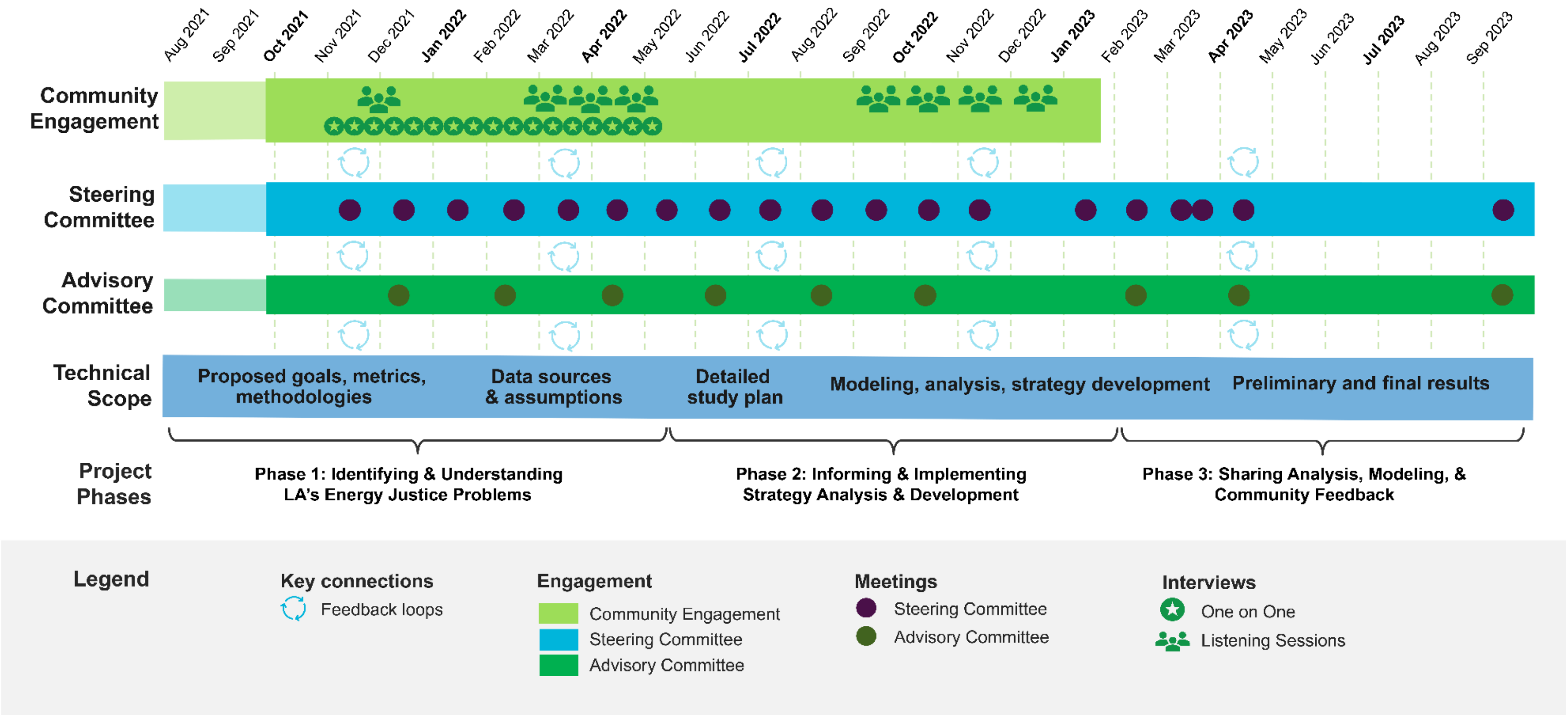

Figure 2. LA100 Equity Strategies timeline and procedural framework

3.1 Steering Committee Meetings

Comprised of LA-based environmental justice organizations representing a range of interests and energy justice communities, the Steering Committee plays a central role in the study by providing strategic and technical direction to LA100 Equity Strategies through the identification of prioritized energy equity outcomes (see Appendix A, *Steering Committee Charge and Protocols*). In the first phase of LA100 Equity Strategies, five monthly Steering Committee meetings were held between November 2021 and March 2022. In the second phase, eight monthly Steering Committee meetings were held between April and November 2022. In the third phase, seven monthly Steering Committee meetings were held between January and May 2023 to present preliminary results.

3.2 Advisory Committee Meetings

Comprised primarily of representatives for the offices of elected officials and key city department partners and stakeholders, the Advisory Committee provides input and feedback on the feasibility of strategies and approaches identified by the Steering Committee (see Appendix A, *Steering Committee Charge and Protocols*). The Advisory Committee identifies LA100 Equity Strategies priorities that intersect with other City of Los Angeles department programs and/or have potential for multi-benefit programs and partnerships with other city departments. In the first phase of LA100 Equity Strategies, two bimonthly Advisory Committee meetings were held in December 2021 and February 2022. In the second phase, four bimonthly Advisory Committee meetings were held in April, June, August, and October 2022 and two meetings were held in February and April 2023.

3.3 Neighborhood-Specific Community Listening Sessions

One-on-one meetings with 10 Steering Committee CBOs in November 2021 helped shape the initial thematic focus and geographic siting of 15 neighborhood-specific community listening sessions held throughout 2022 in five energy justice communities in Los Angeles: two regions of South LA, East LA, San Fernando Valley, and the Harbor Region. Community listening sessions are a form of focus group that centers on community members' lived experiences and energy equity concerns.

Working with CBO partners from the Steering Committee throughout 2022, we adapted the listening sessions to each local context to understand the energy priorities and needs of 8–10 participating community members per session.[1] LADWP compensated all participants for their time and expertise. Listening sessions were co-designed and co-hosted with CBO partners from the Steering Committee, and preliminary results were shared and discussed with both Steering Committee and Advisory Committee members.

While we collected data from various sources identified in Figure 2, this chapter presents results from the listening sessions as a collaborative engagement methodology that linked different forms of community guidance (Sauermann et al. 2020; Chapter 3). By sharing preliminary findings from the listening sessions in Steering Committee and Advisory Committee meetings, the listening session results connected community members' stated needs, aspirations, and concerns with guidance from

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[1] There was a total of 139 participants in all listening sessions, with 36 individuals participating in the first round of virtual sessions and 103 individuals participating in the second round of in-person sessions.

Steering Committee members. Steering Committee partners helped interpret and amplify session priorities, and Advisory Committee members provided institutional guidance.

3.3.1 Methodological Design

Methodologically, the listening sessions were divided into two phases, aligning with the first two "feedback phases" in Figure 2. These two phases consisted of listening sessions conducted in two rounds over the course of 2022. In this first phase, the National Renewable Energy Laboratory (NREL), LADWP, and the Steering Committee partner CBOs co-designed five listening sessions adapted to the five energy justice communities in Los Angeles described above. Working closely with CBOs, the sessions were designed to ground understandings of context-specific (in)equities in crosscutting prioritized areas, such as affordability and burdens; access to City of Los Angeles and LADWP infrastructure, services, and programs; public health, safety, and community resilience; and jobs and workforce development. These crosscutting areas of priority are described in more detail in the following section (Section 3.3.2.1). This first round of five listening sessions was conducted virtually in March and April 2022 and focused on identifying energy justice problems—barriers and needs—in participants' communities. We used the following topics and questions to facilitate these discussions:

- **Envisioning Just Energy Futures:** What are your community's or organization's energy justice goals in Los Angeles? What do just energy transitions and outcomes look like in sectors such as housing, transportation, solar and storage, and workforce development?
- **Identifying Factors and Barriers:** What barriers to achieving these goals have you already identified?
- **Identifying Just Energy Strategies:** What strategies exist to address these barriers? How do you think these strategies could be improved?

Content analysis of the first round of listening sessions revealed a set of causal factors, energy-related impact areas, and underlying values that helped focus and refine questions for the second round of listening sessions, which was aimed at identifying actions and strategies to redress stated problems. In the second phase, NREL shared Round 1 preliminary findings on community-identified energy justice problems with CBOs and listening session participants to assess and ground these understandings. This feedback loop served as part of the process toward identifying community-guided solutions. The second round consisted of 10 listening sessions conducted from September to December 2022. These sessions were held in person, co-hosted with CBO partners located in the five prioritized energy justice communities, and focused on community-identified solutions described in Chapter 3 to inform the design and development of LA100 Equity Strategies.

Each of these community engagement activities was transcribed, translated when needed,[2] anonymized to protect participants' personal information, coded to identify key themes and concerns, and utilized to inform NREL technical models for future energy justice strategies. Section 2.4 analyzes this initial community feedback to identify and map key causal factors and impact areas for use in designing just transition strategies.

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[2] Many of the quotes utilized in this chapter were originally in Spanish and translated into English by the authors.

3.3.2 Crosscutting Priority Areas: Informing Listening Session Design

Operationalizing energy justice in the transition to clean energy is a complex challenge, which necessitates grounding intersectional theoretical concepts in lived local realities. In general, energy justice entails providing universal access to energy that is affordable, available, safe, resilient, and able to provide opportunities for workforce development. Everybody should have access to quality information about issues such as energy equity, financing, and the environment, as well as fair, transparent, and accountable forms of energy decision-making (Sovacool et al. 2017). However, if equity is not prioritized, some aspects of the energy transition can exacerbate, rather than redress, energy injustices (Carley and Konisky 2020; Romero-Lankao, Wilson, and Zimny-Schmitt 2022; Sovacool et al. 2022). Therefore, LA100 Equity Strategies began by organizing community engagement activities around four *crosscutting areas prioritized* by Steering Committee members in one-on-one meetings and supported by an energy justice literature review presented at the National Academies (Romero-Lankao 2022). These crosscutting priority areas also emerge as critical areas in academic literature on energy justice and in U.S. policymaking (e.g., Justice40):

- **Affordability and Burdens:** The costs of an energy transition are not equally felt. Energy burdens often impact low-income and communities of color more than others, at least in the short term, as consumers pay the costs for smart meters, power lines, battery storage technologies, and carbon-free grids (Carley and Konisky 2020; Drehobl and Ayala 2020; Romero-Lankao, Wilson, and Zimny-Schmitt 2022). We go beyond the conventional approach to measuring energy burdens as "the percent of a household's income spent on utilities for heating, cooling, and other energy services" (Drehobl and Ayala 2020) and use an approach to energy burdens that includes energy inequities embedded in transportation, housing, and community infrastructural investments (Hernández and Bird 2010).
- **Access or Actual Use:** Underserved communities are often economically excluded from or limited in their opportunities to transition to clean energy technologies. Electrification to meet LA's clean energy goals will entail converting from fossil fuel-based to electrical energy-powered technologies (e.g., heat pumps). Because of factors such as lack of familiarity, mistrust, risk aversion, trade-offs, and cost, these technologies may prove inaccessible for lower-income Angelenos. Therefore, transitioning to these cleaner technologies will either be unattainable without support or continue as a low priority given ongoing structural constraints and concerns. We examine how different communities navigate these constraints and articulate strategies to access the technologies that meet their everyday needs.
- **Public Health, Safety, and Community Resilience:** If not properly planned, transitions to clean energy technologies can exacerbate or create new health and safety inequities. In many underserved communities, there is a history of negative impacts and burdens from existing infrastructural interventions with harmful effects on local health and quality of life (Chapter 1). Therefore, we worked with underserved communities to identify and examine the causal factors affecting (1) their health and quality of life, (2) potential benefits and risks of clean energy innovations, and (3) gentrification, displacement, and other negative impacts on community resilience. By community resilience, we are referring to the resources, safety nets, and options community members can draw on to adapt to stressors and pursue their lives with dignity (Romero-Lankao et al. 2016). Acknowledging and mapping these barriers led to the identification of community-guided strategies.
- **Jobs and Workforce Development:** As the green economy expands, clean(er) energy innovations offer the potential to create more job opportunities than fossil fuel industries (Carley and Konisky 2020; Crowe and Li 2020; Carley, Engle, and Konisky 2021). However, they can also disrupt existing employment for populations and economies currently dependent on coal, fracking, and other fossil fuel industries (Lobao et

al. 2016; Crowe and Li 2020; Carley, Evans, and Konisky 2018). In Chapter 1, we examined a series of factors and actions (such as targeted job training and career development opportunities) that can help to avoid detrimental job impacts and foster workforce development opportunities in green infrastructures and industries.

These crosscutting prioritized areas were then utilized to design the listening sessions. In the first round of listening sessions, questions were designed to elicit community feedback on these four thematic prioritized areas. Early findings from Round 1 corroborated the significance of these thematic areas as priorities in local communities. In the second round of listening sessions, questions were more formally organized around each theme to structure and focus the sessions. Thus, these four crosscutting priority areas were deductively structured into the engagement methodology from 2021 to 2023.

3.3.2.1 Data Analysis

All 15 listening sessions were recorded, transcribed, anonymized, and uploaded into the qualitative data analysis software MAXQDA for coding. Coding is the process by which categories and concepts are identified in the data and passages of the transcription are linked to themes that become labeled with a particular code (Charmaz 2006; Buckley and Waring 2013). Beginning inductively (bottom-up) in the first round of analysis, each listening session was analyzed by assigning open descriptive and thematic codes, related to energy justice in Los Angeles and the city's transition to clean energy, to segments of the data. After the first five sessions were coded, an analytic coding was applied to organize, refine, and map these inductive categories to the adapted grounded theory concepts developed deductively (top-down), as described above (causal factors, impact areas, actions/strategies, values, and equity outcomes).

The Round 1 coding system was used to analyze the second round of 10 listening sessions, where codes were refined and relations between codes were analyzed (see Appendix C for details). Through this comparative analysis, the relations between key codes began to attain saturation—the point when gathering more data reveals no new insights, issues, or categories related to this research (Glaser, Strauss, and Strutzel 1968). Concurrently, a codebook was developed to define the inductive codes utilizing a grounded theory approach and connect them to energy equity and just energy transition categories, iteratively refining these codes and relations over the course of the analysis process (see Appendix B: Codebook).

An overlapping code occurs when two themes are identified in the same passage. The codes that frequently overlapped in participants' understandings of energy inequities become key data points for analysis. We analyzed these overlaps because they reveal how participants understand relationships between different themes. The MAXQDA software has tools to identify passages with multiple themes. As the overlapping codes attained saturation over the course of 15 listening sessions, they revealed critical causal factors and actions to address in LADWP's pursuit of procedural energy justice in Los Angeles. We organized these high-frequency overlapping codes according to the three tenets of justice: procedural, recognition, and distributional. We analyzed the overlapping passages of the 111 codes related to procedural justice.

In this chapter, we present the analysis of a set of overlapping codes in the *problem space*, addressing key relationships between causal factors, impact areas, and values related to *procedural justice* in underserved LA communities. This analysis informs Chapter 3 and 4, where the tenets of *recognition* and *procedural justice* are operationalized in community-guided strategies and options for community engagement presented as part of the *solution space* for energy justice in these same LA communities. To organize those key strategies, we group the coding results according to the crosscutting priority areas used to design the listening sessions and described above (Section 3.3.2).

In the following section, we present the results of a thorough review of the highest frequency overlapping codes, revealing three codes as the most analytically relevant categories for impacting the problem space of *procedural justice*. Each of these codes overlapped with a series of causal factors, values, and impact areas to reveal community priorities in relation to the existing energy system and engagement process. While we include the frequency of overlaps as an indicator of value, our focus here is not on statistical relevance, but rather on the recurrent significance of these overlapping codes to procedural justice. Thus, while certain intersectional contributions may have been provided only 10 times, those contributions from community members still contain valuable feedback with actionable guidance for developing more equitable procedures in the LA energy transition. Understanding that equity, as one of our participants described, depends on how this process is proceeding, we are highlighting here the procedures and practices that community members identified as problematic and/or in need of closer attention.

4 Results

In this section, we examine procedural justice by (a) analyzing procedural causal factors of inequities in energy affordability, access and actual use, health and safety, and workforce development; and (b) identifying and interpreting the qualitative data from community engagement that will inform the quantitative models technically guiding the energy transition. We focus on the causal factors, needs, and actions that community members identify as impacting everyday decision-making and energy-related procedures in their experience. This lens reveals *how* these community members understand the failures of the past and existing energy systems and begins to chart the co-creation[3] of a process that improves equity outcomes as LADWP moves forward. It is the basis for the co-development of a deliberative process to impact Los Angeles' energy transition and ensure accountability in program design, implementation, and evaluation (Chapter 3). This process is central to realizing the promise of more equitable outcomes in Los Angeles' future.

Procedural justice therefore requires reassessing the legislation, policies, programs, and procedures informing the development of pathways toward a more just future. The need for this iterative process with community members is clearly defined in a recurrent guiding value stated in the listening sessions:

> The very definition of equity, which we spent a lot of time talking about. And even now those of us who have been disadvantaged are sometimes uncomfortable with. Means it's not about how much. It means that we've all made a commitment that, until we catch up, nobody else gets anything. So more and more of it becomes ours. Because we have been inequitably treated. But what we want to know is, how is it proceeding.

Understanding *how* and *why* most energy transition actions and procedures fail to address inequity is not only necessary but embedded in the core principles of procedural justice. Addressing procedural justice is not only about final outcomes but also about the process necessary to achieve more equitable outcomes. To focus on how "*it is proceeding*" is a way of redressing the factors underlying Los Angeles' structural and current inequities and grounding them in community-based knowledge to co-design future actions and strategies.

Key findings emerged as we used the frequency of overlapping codes to connect those causal factors identified by communities to other causal factors, impact areas, underlying values, and potential actions (see Section 3.3.1). While many of the inductive (bottom-up) coded categories—termed "codes"—come from the project's structure (i.e., electric vehicles, housing, solar energy), analyzing key relationships between causes (i.e., causal factors) and effects (i.e., impact areas) grounds theoretical understandings of the energy transition in local realities. This process and its main findings, as detailed below, enable community understandings to inform the conditions of possibility for more equitable energy outcomes in the LA energy transition. Again, while we collected data from the

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[3] Here we understand co-creation as "a process through which two or more public and private actors attempt to solve a shared problem, challenge, or task through a constructive exchange of different kinds of knowledge, resources, competences, and ideas that enhance the production of public value in terms of visions, plans, policies, strategies, regulatory frameworks, or services, either through a continuous improvement of outputs or outcomes or through innovative step-changes that transform the understanding of the problem or task at hand and lead to new ways of solving it." (Torfing et al. 2019, 802)

various sources identified in Figure 2 and Section 3.3.1, this chapter only presents results from the listening sessions.

In a thorough review of the highest frequency overlapping codes, three codes emerged as the most analytically relevant categories for impacting procedural justice. Each of these codes overlapped with a series of causal factors, values, and impact areas to reveal community priorities in relation to the existing energy system and engagement process. Understanding that equity, as one of our participants described, depends on how this process is proceeding, we are highlighting here the procedures and practices that community members identified as problematic and/or in need of closer attention.

The three overlapping codes for impacting procedural justice are defined in Table 1.

Table 1. Definitions of Three Primary Overlapping Codes

Number	Code Name	Code Definition
1	Self-Determination	Passages that relate to community members' abilities, resources, and power to make decisions for themselves in relation to the energy system.
2	Barriers to Program Participation and Support	Passages that relate to obstacles, barriers, and challenges that community members face that limit their ability to participate in, access, and/or utilize existing energy-related incentives, subsidies, and other aid programs. This includes but is not limited to the barriers embedded in eligibility criteria.
3	Energy Affordability and Burden	Passages that relate to people and their communities' ability to pay energy-related costs embedded in their everyday lives—from transportation and housing to work, food, and recreation. Energy burdens are often understood as "the percent of a household's income spent on utilities for heating, cooling, and other energy services" (Drehobl and Ayala 2020). This code expands that definition to consider the trade-offs people and families must make to pay all their energy bills alongside other monthly financial burdens (e.g., cost of health care, childcare, rent).

Each of these three codes overlaps 10 or more times with a series of other causal factors, impact areas, and values. Those intersections take the form of quotes from listening session participants. In this section, we trace the principle *overlapping codes* that elucidate how energy inequities manifest in the practices and procedures shaping these community members' everyday lives. By tracing these intersectional relationships and analyzing specific quotes as representative content, these results aim to expose key causal factors and point to the procedures that could lead to more equitable outcomes. The following subsections analyze specific quotes that represent a recurrent challenge to achieving energy justice present in the highlighted overlapping codes.

4.1 Code 1: Self-Determination

Defining “Self-Determination” as a conceptual “value” of energy justice, it refers to community members’ ability and power to make decisions for themselves within the current energy transition (Table 2). Self-determination overlapped with three causal factor codes and two impact area codes, revealing root causes of inequity underlying the procedures that affect energy outcomes (Table 3).

Table 2. Frequency of Overlapping Codes with Self-Determination

Primary Code	Overlapping Codes	Frequency of Overlaps
Self-Determination	*Causal Factors*	
	Energy Affordability and Burden	25
	Access to Financial Capital	11
	Barriers to Program Support	23
	Impact Areas	
	Electric Vehicles (EVs)	10
	Jobs, Training, and Entrepreneurship	10

4.1.1 Self-Determination and Energy Affordability and Burden

“Self-Determination” and “Energy Affordability and Burden” overlapped 25 times across all listening sessions. “Energy Affordability and Burden” was utilized when a participant referred to the cost of energy as a challenge, including as a financial, emotional, or health burden in the everyday lives of themselves, their families, or their communities. Many residents referred to the unaffordability of current electricity bills, particularly given other monthly expenses, and noted that they did not have the ability or power to lower these high costs. They substantiated this claim by explaining what they *did* have the power to change: their own everyday routines in their homes, which did not necessarily impact their electricity bills.

Their statements shed light on a contradiction between ratepayer theory and practice. While utility companies commonly request that ratepayers modify their individual behavior to reduce daily electricity use and therefore lower electricity bills, the lived experience of ratepayers in the listening sessions revealed that behavior modification that reduces electricity usage in a home does not always lower their electricity bills; electricity usage is also influenced by other intersecting causal factors—e.g., building age and urban heat islands (see Section 3.2 in Chapter 1). It is a request for self-determination, rather than a lack thereof, that exposes the need to address this contradiction in practice. As one resident clarified:

> It’s not that we are asking for anything. We are just being told to provide solutions. I believe that each person can provide solutions in their own home. From saving water, from saving 15 to 10 minutes in the shower. We are doing it, and a lot. We are saving water; we are not using coolers in hot weather. We are learning to use only one light at night. We move to the kitchen, turn off the living room [light]. We move to the living room, turn off the kitchen [light]. We move to the bedroom; we turn off all the lights.

> We’re doing a lot. The ones who are not doing much is the company [LADWP], which is not doing anything. We see that we save, we turn off all the lights and the bill does not go down. On the contrary, it keeps going up. I think that the ones who have to do something are the electricity company. We are doing a lot, I think. So, it is a very big dissatisfaction because, I am talking about my house, my business, which is so small. It is unfair that the bill arrives more expensive than the rent I pay for the premises, for my premises, which are so small. So, if I am running my business... my business is just food to take to my house. It is my job. Not to get rich, just to take food to my house. And it’s unfair that it’s so exorbitantly expensive. The electricity bill exceeds all my business’s bills. That’s what...we are doing. The company is not doing anything.

Here, the resident frames the problem as one of self-determination and accountability rather than purely financial or behavioral. On the one hand, she highlights the actions taken by ratepayers—both residential and commercial—to change their everyday behaviors and reduce energy usage by implementing strategies such as turning off lights when they leave a room and lowering the usage of high-energy-consumption appliances. On the other hand, she argues that despite these acts of self-determination, ratepayers are still not able to lower their electricity bills, and she holds the utility company accountable for resolving that problem. From her perspective, it is the behavior of the utility company, rather than the individual ratepayer, that needs to change to make energy more affordable and less of a daily burden for Angelenos.

It is also important to highlight that the concept of energy burden is understood as interwoven in other aspects of energy and economic security, which expands the common use in scholarly literature (Drehobl and Ayala 2020) and policy. As the resident points out, the ability to afford or to manage the “energy burden” is connected to her livelihood, to the possibilities of “tak[ing] food to [her] house.” This means that in most cases, energy burdens impact—and are also impacted by—other important sectors related to one’s ability to secure the basic necessities to live with dignity.

4.1.2 Self-Determination and Access to Financial Capital

One structural strategy aiming to increase self-determination among low-income ratepayers is the government-subsidized opportunities (i.e., rebates, incentives, and programs) designed to increase the affordability of access to efficient energy and clean energy technologies. That is, community members connected “self-determination” to “access to financial capital.” However, participants pointed to the limitations of that strategy in practice. The value “Self-Determination” and the causal factor “Access to Financial Capital” overlapped 11 times across all listening sessions. “Access to Financial Capital” was used when a participant referred to a need for and/or lack of access to financial capital, particularly as a necessary means to transitioning to clean energy technologies and achieving energy efficiency. As such, these participants experienced a lack of financial capital as a notable barrier impeding their ability to self-determine their own access to the benefits of Los Angeles’ energy transition.

The limitations of a lack of access to financial capital can manifest even in situations specifically designed to attend to the needs of low-income populations by providing them with decision-making power. One participant shared her lived experience with an EV rebate program that, while designed to give her more agency and access to purchase an affordable EV, in practice revealed underlying barriers to EV affordability. She told us:

> Look, I already carry this experience with me. I already had it [with] the electric car. They won't forget me because one day I have to qualify. I won't lose hope. What they put there does sound very nice, everything. Then one says "Yes, I will qualify." Because they ask for your papers, you have no idea... And my X [the CBO employee who helped her], thanks to [X]. She filled everything in with me and I brought her everything—"Here it is [X]"—... "Look, I'm missing this!"—Here it's [X], okay. But [then], when I went to the dealership, they sent me the letter [saying] that [I had qualified] for seven thousand five hundred. … It is a gift, they said to me [in the letter]. The guy in the [dealership] took us for a ride in the car. The car was worth twenty thousand, [it was] electric. And I was crazy excited going around in that car. And the man [told me] –"Drive around again, drive around again"—I felt like this car was mine. That I was riding in a car, never in my life have I had a car like that. One day I will have it thanks to you who will be flexible…
>
> When it was time to fill out the paperwork, the [contract] said that they were going to give me no more than seven thousand dollars, [and an interest rate of seven percent]... And the bank [wanted to give me the remaining balance at] a twelve percent interest rate. Ah no, and they said, "I can't give you the car. Here it says seven percent down." And the bank was giving [the remaining balance] to me at twelve percent, and they said [it is this] or no [car]. No, well yes, tears came to my eyes, I got [so] frustrated. Because I [had] felt that this car was already mine.
>
> So, imagine, having seven percent is having…good credit. So, no, I didn't qualify. I went to sell my car for three hundred dollars because I [thought I was] qualified for the program. That is very sad. And since it's a program for us, we can't afford to buy a car ... I have not had it, the joy of having such a car. But when people have high salaries, they don't enter those programs either. [Having more flexible qualification criteria] to have a car. ... It's what I [suggest].

This resident's narrative highlights not only the failure of this program to benefit the very population it was designed for—Angelenos unable to afford a market-priced EV—but also the increased burdens the program produced as hope and pride led to disillusionment and grief. Poor credit and, in turn, a higher interest rate disqualified this resident from utilizing or accessing the rebate she was technically eligible for. The eligibility criteria for the rebate program did not include a credit check, and therefore, she qualified for the rebate, began shopping for vehicles, and "already felt like this car was [hers]" before discovering that no bank would offer her affordable interest rates for the remaining balance. Thus, for this resident, the EV rebate program became a sign of procedural injustice rather than justice, as it revealed the remaining procedural barriers that must be overcome before people like herself are truly able to self-determine their purchase of an EV. Yet, equally important are the emotional scars this experience left, eroding the trust she has in the government institutions that are purportedly investing in strategies that produce more equitable energy outcomes.

4.1.3 Self-Determination and Barriers to Program Participation and Support

Government-subsidized programs are often designed to increase the user's ability to make their own decisions in relation to the targeted benefits, from affordable EVs to rooftop solar. However, as the last narrative revealed, in practice, not all residents in need of this support are able to fully benefit from these programs. For those residents, barriers limiting access to program participation and support expose restrictions on their abilities to self-determine their own energy outcomes.

The value “Self-Determination” and the causal factor “Barriers to Program Participation and Support” overlapped 23 times across all 15 listening sessions. The code “Barriers to Program Participation and Support” was used when a participant referred to challenges in their access and actual use of government programs and other support mechanisms, such as subsidies and rebates. This intersection reveals eligibility criteria are often a limiting factor restricting residents’ access to program participation and support, and therefore further hindering self-determination. One resident suggests a primary barrier to equitable eligibility criteria is income limits:

> But I think that something that can help is to [increase] the [eligibility] limits. I mean, make it not $38,000. Make it $52,000. Because then you know, you limit me. Because then, when I do my taxes I say, I better not have taken this last job, because I’m going to exceed my limit. And then, the next year, it’s going to be even more expensive for me to pay. Because look, out of $40,000, out of almost $50,000 you have to pay about $3,000 in taxes a year. So, no. And I have a son. But if I didn’t have this child, what you have to pay goes up. And if we don’t have social security, it’s even more expensive. And so, that’s why a lot of people don’t do taxes, because it implies a very high cost. So, it’s very important to lower the limit, because if I do taxes obviously, I can have credit. I do taxes, I can access health care and probably we can access many things that we don’t know. But it is the access to the resource, inequity is present in all services, in the *use* of services.”

Here, the participant is pointing to broader structural inequities in the U.S. system of governance that incentivize residents to consider difficult trade-offs to maintain economic stability, a key determinant of energy affordability. These trade-offs include either restricting their income to access more subsidized resources and services or hiding their income to avoid paying taxes and fees, which disqualifies them from accessing government resources and services. In both cases, the resident determines their own path; yet this path is structurally limited, and they are unable to fully access the benefits of both their own income and available government resources and services. Expanding the income limit is one strategy this participant identified to redress these procedural inequities. However, their final message—“inequity is present in all services”—points to an important procedural distinction between *theoretical* access and *actual* use of a resource of service. To design resources for equitable access and use, we must both examine how people devise strategies to utilize services when presented with barriers to access, as well as understand the limitations that prevent access and actual use.

4.1.4 Self-Determination and Barriers to Accessing Electric Vehicles

Electric vehicles are an important example of a government-subsidized technology that remains inaccessible to many Angelenos. As listening session participants discussed the barriers that prevent their access to EVs, one key determinant their narratives identified was a lack of self-determination. The value “Self-Determination” and the causal factor barriers to accessing “Electric Vehicles [EVs]” overlapped 10 times across all 15 listening sessions. The code barriers to “Electric Vehicles [EVs]” was used when a participant referred to EVs. Here, we focus on the procedural challenges participants experienced or predicted in relation to accessing an EV.

A series of causal factors limit these participants in access to and use of EVs. Community-identified factors include: a lack of accessible guidance to make informed decisions, limited financial capital to purchase a used fuel car let alone an EV, and insufficient local EV charging infrastructure in their communities. These factors become limitations on their power to choose an EV as their mode of transit. However, they also point to how current structural inequities in transportation create the perception that EVs are simply inaccessible for lower- and middle-income Angelenos. As one participant stated: "Electric cars, to me, they're for people with a lot of money. I don't have that. So, I do want to make that change. But how am I going to do it?" In this participant's understanding, while she has the will to transition to an EV, her ability to choose an EV is determined not by her will but by her (lack of) financial capital.

The causal factors that effectively limit participants' potential for accessing EVs also relate to their ability to use these vehicles efficiently and economically in their everyday lives. One participant's experience with EVs led her to articulate key challenges thwarting her ability to fully utilize EVs:

> I have … a friend, she told me. And I was talking to her because I want to buy a car. But there were no trucks, I was waiting ... And then I was ready to buy a car … a friend scares me. She tells me, look, I left my gas car. And I [bought] an electric car. And what happens, it discharges very quickly. And more if I use AC, the battery goes out quickly. And I searched like crazy, and I went all the way to San Diego … It is very difficult to find charging [stations] where you can charge. So, they are trying to put the cars in, but they are not putting the main thing, charging [stations]. There's not enough [charging infrastructure]. So, I went to Target and there is another and another [charging station]. No wait, I'll get in, but people are fighting [to charge]. They are causing people to fight with each other [to charge their EV]. It would be better to first design a strategy and put [charging infrastructure in place] ... So, I want to buy [an EV]. First, make it more affordable [for people] like me … [or] at least like my friend. For the middle- or low-income class …
>
> But make it more affordable for the community. Because it seems to me that the cars are there and we have to make the change … Those who want their luxury cars, over there, they [can buy] them. But we who buy something more affordable. It needs to fit my budget, so to speak. And then I'll be able to get something more affordable for us. And [have the infrastructure] to recharge them. Let the [officials] make their strategy [like with] a gas station. To recharge [because right now] not even one works.

Her comments point to the ways in which policies aiming to promote the transition to clean energy can unintentionally increase inequities, particularly for lower- and moderate-income Angelenos. Referencing the recent plan "requiring 100 percent of new car sales in California to be zero-emission vehicles (ZEVs) by 2035" (Newsom 2022), this participant points to the increased burdens that a decrease in transportation choices will create if the current EV status quo is upheld. In her understanding, EVs are simply unaffordable for moderate- and lower-income Angelenos. Yet, even if they were affordable, she points to other factors that impede her access: the lack of available charging infrastructure in her community and mistrust in EV reliability given her friend's experience with low battery range. Therefore, her message to make EVs "more affordable for our communities" must also be connected to a strategy to develop both the physical infrastructure necessary for equitable EV use in their communities as well as access to educational opportunities and materials that allow community members to make informed transportation choices.

4.1.5 Self-Determination and Jobs, Training, and Entrepreneurship

The power to determine one's own energy future in Los Angeles is not only about offering lower-income Angelenos subsidized opportunities and benefits. Access to high-road and well-paid jobs, career training, and entrepreneurship in their communities has direct impacts on self-determination. Our findings indicate that investing in those opportunities and capabilities is another way to invest in Angelenos' access to making energy decisions for themselves. The value "Self-Determination" overlapped with the impact area of "Jobs, Training, and Entrepreneurship" 10 times across all listening sessions. One participant reacted to a discussion of LADWP program benefits by stating:

> In my humble opinion, we should be considered. I don't ask for free giveaways, I ask for a good job with a good salary for [the people of] the city of Watts. Because companies come and bring workers. And they don't benefit the residents [living] there. They should give jobs to every community where they work. They should give jobs to the people of the community there with good pay. And that, in my opinion, would be help [the help I need].

This participant is not only emphasizing the need for local well-paid jobs that give residents of the South LA neighborhood Watts the freedom to make their own energy choices, but he is also pointing to the extractive practices of many local energy-related companies. As other listening session participants noted from the five energy justice communities, contaminating industries, such as local refineries and battery manufacturers, often utilize their neighborhoods' land and natural resources, leaving pollution behind. Yet, they do not offer local residents sustainable benefits such as decent jobs. Jobs become the sustainable long-term lifeline that creates the conditions for community energy decision-making when subsidies, programs, and other temporary opportunities have run their course.

4.2 Code 2: Barriers to Program Participation and Support

"Barriers to Program Participation and Support," as a causal factor, refers to obstacles, barriers, and challenges that community members face that limit or prevent participation in, access to, and/or utilization of existing energy-related incentives, subsidies, and other aid programs. This includes but is not limited to the barriers embedded in eligibility criteria. The "Barriers to Program Participation and Support" code overlapped with four causal factors and one impact area (Table 3), revealing inequities underlying the design and implementation of programs aimed at more equitably distributing energy-related benefits.

Table 3. Frequency of Overlapping Codes with Barriers to Program Participation and Support

Primary Code	Overlapping Codes	Frequency of Overlaps
Barriers to Program Participation and Support (Causal Factor)	*Impact Areas*	
	Moderate to Low Income	39
	Causal Factors	
	Predatory Practices	10

Primary Code	Overlapping Codes	Frequency of Overlaps
	Lack of Accessible Information	24
	Renter Issues	45
	Homeownership	22

> It's not that people just want action; they want specific action in the community. Because historically, our communities, especially lower- to moderate-income people. What happens is, we get left behind. Whatever the goal is, it's like, this is what we are going to do, and then it just happens.
>
> South LA Participant

The above epigraph emphasizes the historical lack of procedural justice in Los Angeles' lower- and moderate-income communities in the way government programs and benefits are designed and implemented today. This section highlights how Los Angeles' history of disinvestment, disenfranchisement, and lack of self-determination in particular neighborhoods is revealed through the ways in which programs aiming to redress inequities can also reproduce these inequities in practice. Factors including unregulated predatory practices, lack of accessible information, and ineligibility of renters and homeowners to access specific programs, impact moderate- and lower-income communities' abilities to access benefits.

4.2.1 Barriers to Program Participation and Support, and Moderate and Low Income

Listening session participants discussed the barriers that prevent their access to "Program Participation and Support." Their narratives consistently identified income limitations as a key determinant of inequity. The causal factor "Barriers to Program Participation and Support" and the impact area "Moderate and Low Income" overlapped 39 times across all 15 listening sessions. The code "Moderate and Low Income" was utilized when a participant referred to their economic status. In this section, we focus on how narratives connect economic status to the procedural challenges of accessing and utilizing existing government program support. This intersection reveals a series of impact areas and causal factors that delimit these participants' inclusion into the process of building an equitable energy transition.

Numerous participants referred to the financial difficulties in accessing clean and efficient energy technologies via existing programs. Lower-income participants emphasized barriers to accessing programs due to structural factors such as language limitations, citizenship status, housing tenure, and information gaps. Moderate-income participants emphasized the shortcomings of current eligibility criteria that effectively exclude their participation in existing programs due to an incomplete understanding of their economic status. These participants highlighted the daily struggles they face to make ends meet, often taking on multiple jobs, occupying shared and/or multigenerational households, and developing strategies to lower expenses. Those actions that theoretically increase their disposable income do not provide them with sufficient funds to purchase clean, energy efficient technologies. Because of those very actions toward building a more dignified life for themselves and their families, these moderate-income residents become ineligible for program benefits.

One participant shared her own experience to clarify this contradiction in program eligibility criteria:

> I live in Boyle Heights, and I worked for [Organization Name], I don't know if you guys are familiar with that agency, where they/we help low-income families with their utility bills. Such as electrical and gas, and the thing is, I work for that company and I don't earn that much, but yet I'm not qualified to get help with my electricity or gas. I helped a lot of people who make more than I do, but they get the help and that was a little concerning to me, that people like me who work have to pay bills, but that they are not qualified for assistance. It's always the low income. And I just don't know what to do. I live check by check … and it's really hard to get help from someone to raise up the low-income guidelines a little to help people like me who doesn't earn that much; you know, they think we do, but we actually don't.

The contradiction this participant points to is layered. Not only is she ineligible to qualify for energy benefits that she cannot access without assistance, but the very reason that she is ineligible is the salary she earns by helping others access this assistance. Her experience teaches us that eligibility criteria should not be limited to formal annual income; rather, it could include an understanding of the multiple expenses Angelenos have to pay to pursue their lives with dignity, and the related burdens they experience daily. Furthermore, as she and other participants noted, the cost of living and what it means to be low- or moderate-income in Los Angeles changes depending on where you live in the city.

4.2.2 Barriers to Program Participation and Support, and Predatory Practices

One challenge undermining equitable access to the benefits of existing energy-related programs is the predatory practices of service providers. The causal factor "Barriers to Program Participation and Support" and the causal factor "Predatory Practices" overlapped 10 times across all listening sessions. The code "Predatory Practices" was used when a participant referred to service or resource providers who take advantage of local communities. We examine the processes by which identified practices create mistrust in energy technology programs due to the increased burdens produced by those providers.

Two types of predatory practices were identified consistently throughout the listening sessions. The first relates to the appliance providers that LADWP subcontracts in their customer-facing energy efficiency programs. The second relates to solar energy providers who are not LADWP subcontractors, yet residents connect their mistrust in those providers with mistrust in the safe benefits of energy program opportunities. One participant described his frustration with LADWP subcontracted service providers:

> I was going to comment on the appliance assistance program for refrigerators and such. And what they are offering is garbage. At least they should offer something good, but they give them, when they least say they pay a dollar a month or a year, whatever, but they need to help, they need to offer good appliances, not crap. Personally, I applied to have my house fixed, they were going to insulate the windows and replace the glass, it was a complete scam, and supposedly they were sent by [LADWP]. When I saw that they were doing things wrong—no! [LADWP] also ordered me to put in... so that the kitchen wouldn't leak... it was [garbage] what they sent me to put in. So what good are they? They don't check if the contractor is doing his job correctly or not. So why do we want this kind of help?

This resident is emphasizing the need for accountability with subcontracted service providers to ensure quality products and service. The absence of accountability results in community mistrust that dissuades residents from seeking these available benefits, given that their application becomes more of a problem than a solution. Beyond the specific programs, this mistrust sows the seeds for questioning the benefits of clean and efficient energy technologies and services in general. Furthermore, this resident interprets the poor quality of this service as a lack of respect for the ratepayer, asking LADWP: If these energy efficient appliances and upgrades don't function, "why do we want this kind of help?"

The reservations residents feel regarding the benefits of energy efficient appliances and upgrades are confounded by their experiences with other clean energy technologies and their providers. Participants called particular attention to the predatory practices of solar energy developers in their communities. One resident shared her ongoing struggle with one solar developer:

> I have a very big problem. And it is with [company x]…because they said they were from [company x]. Before it was not [company x], it was another company and [company x] bought it. They made me sign a 20-year contract when it started ... And that contract, I still pay $48 a month, apart from my electricity bill. And I would like to know why they made me sign that contract, for 20 years … It was the other company and [company x] bought it … I'd like to know if [company x] can delete it ... before the company was called [company y], but [company x] bought it. So, this is my question to you. If they [LADWP] can help us to delete that [contract]? For about $48 a month apart from the other electricity bill. And it's a 20-year contract, with another company, but [company x] bought it … [And now] it's the same with [company x]. We continue to pay the $48. And we continue to pay for electricity.

This participant is struggling with the lack of information related to her rights and benefits regarding the solar panels installed on her rooftop, and a lack of support from those who have the power to help her navigate her current problem. In her understanding, in practice, she receives no benefits from the solar panels on her rooftop yet pays monthly energy bills to both the company and LADWP. Thus, while the company is profiting from her real estate and owns the panels, she believes she is paying more energy expenses than she would have without solar panels. Although her request for help from LADWP is beyond the purview of their authority, the request itself reveals how ratepayers connect energy technology providers and their actions with LADWP. That connection fosters a lack of confidence in the utility company's ability to care for their most vulnerable ratepayers. The emotional burdens produced by these traumatic experiences become a barrier deterring participation in existing energy programs.

4.2.3 Barriers to Program Participation and Support, and Lack of Accessible Information

Related to the disorientation produced by predatory practices, participants also emphasized the negative impacts produced by a lack of accessible information to assess existing energy-related programs. The causal factor "Barriers to Program Participation and Support" and the causal factor "Lack of Accessible Information" overlapped 30 times across all 15 listening sessions. The code "Lack of Accessible Information" was employed when participants described situations in which they were unable to make informed decisions. We examine the processes by which informational barriers in decision-making were produced, limiting participants' knowledge of important benefits, rights, and burdens.

Participants' experiences revealed the ways in which a lack of knowledge or misunderstanding of existing benefits can reproduce energy inequities. More specifically, they pointed to the absence of sufficient accessible information related to not only the existence of programs and policy protections, but to the procedures needed to access those benefits and protections. In fact, the close relationship between information access and energy access is revealed in our listening session analysis. We found participants connected "Lack of Accessible Information" to "Energy Affordability and Burden" 24 times. One resident shared a collective experience with the burdens produced by the lack of accessible information in her community:

> Because I had an experience in 2020, when it was said that LADWP was going to give away $500. But people got confused. They didn't apply for that, but I had to help several parents make an account so they could apply there. So, a lot of people lost that [opportunity] and got into a lot of debt.

This narrative reveals *how* knowledge of the potential benefits that LADWP could provide the participant's community was not enough to guarantee their access to those benefits. In fact, misunderstanding the procedures needed to access one specific program creates more financial burdens for members of the participant's community, increasing their long-term economic instability.

While misunderstandings and partial knowledge can reproduce inequities, a lack of knowledge revokes Angelenos' power to determine their own energy futures. At times, the significance of that lack of knowledge is hidden within indirect relationships to the energy sector, emerging in the form of other impact areas, such as housing or transportation. One participant related their struggles with housing tenure to energy insecurity by tracing their experience of disempowerment:

> Now with COVID, many were inviting people [to stay with them] to be able to pay their rent. So, the owners were evicting them. Why? Because they were going to pay them more. I always go around in workshops and wherever I go, in videos, I say: they say, they can't evict us. If before they couldn't be evicted, now with the pandemic they can even less. You are allowed to bring as many people as you want into [your household] and they cannot be kicked out. Because there is a lot of tenant protection. There's a lot. There is rent control. And throughout the Los Angeles community there is rent control. Something that many communities do not know. So, that's what we are informed about. Empowering the community … How are we going to empower ourselves? Knowing our rights. And it doesn't matter our legal status. It doesn't matter how we are. Knowledge is power.

Focusing first on a lack of community knowledge related to existing housing protections—including California's COVID-19 eviction moratorium and Los Angeles' rent control policies—this participant reveals how programs designed to aid vulnerable residents in specific impact areas fail to fulfill their goals due to the inability to reach prioritized constituents. In her analysis, part of that failure has to do with the structural inequities that prevent these communities from knowing their rights, even when they understand the power of knowledge.

4.2.4 Barriers to Program Participation and Support, and Renter Issues

The last narrative highlights the importance of understanding how the relationship between renters and homeowners unevenly distributes the benefits and burdens of energy programs. While our coding methods separated “Renter Issues” from “Homeownership” to maintain analytic clarity, the nature of their relation to causal factors impacting housing and energy security is deeply intertwined. Therefore, this section combines our analysis of these causal factors to argue that their energy-related problems must be understood by considering both experiences.

The causal factor “Barriers to Program Participation and Support” overlapped 45 times with the causal factor “Renter Issues” and 22 times with the causal factor “Homeownership” across all listening sessions. The codes “Renter Issues” and “Homeownership” were used when participants described problems with housing tenure. We analyze the interrelated challenges that both renters and landlords face related to eligibility and implementation of energy program benefits. One participant who lives in a rent-controlled apartment described the potential dangers of benefiting from LADWP program updates. She explained how a positive benefit—upgrades to housing energy infrastructure—can in fact become an additional burden on renters:

> … if he [the landlord] fixes your property, if he comes in your ... I live in a 1932 house, you can forget about it. He ain’t doing it. I basically did the repairs myself because I just got sick of them: ok, I’ll do it, don’t worry. He doesn’t bother me, I don’t bother him, I pay him the rent. However, everybody’s not lucky like that because when you live in an old building and they upgrade the electric and they upgrade the floors and all this stuff it’s gonna affect people’s rent because they’re not in a rent-controlled ... I’m in a rent-controlled, City of Los Angeles is rent-controlled, nobody else, everybody else’s rent can go up in September, it’s gonna be sad. Because a lot of people won’t be able to stay where they’re at. So, they’re asking to add some more onto that with the car and electric and all that, make sure you can afford it ... you’re not getting better, you’re gonna get worse if you can’t afford it.

This narrative exposes a series of potential risks that both renters and homeowners must consider when implementing upgrades to their home energy systems and efficiency. According to listening session participants, for residents who live in non-rent-controlled housing, homeowners who implement upgrades—even subsidized LADWP upgrades and benefits—will most likely increase rent to cover the production cost. For those living in rent-controlled housing, homeowners will most likely refrain from investing in upgrades given their inability to utilize rent to cover costs, and therefore place the burden of safety and efficiency upgrades on renters, who are ineligible for LADWP benefits. As a consequence of this dynamic, ratepayers are reluctant to apply for these benefits and upgrades that directly affect their lives and livelihoods. Ultimately, that leaves renters in the precarious position of either displacement or having to live in unsafe and inefficient homes, impacting energy affordability, access to more efficient energy appliances, and related burdens, including health. Given the history of existing risks related to LADWP energy efficiency programs, participants warn that those existing burdens could be exacerbated as Los Angeles moves into the clean energy transition.

Another recurrent concern among participants was the vulnerability of residents living in informal housing arrangements. Participants referred to “houses in the back” that are detached from the principal residence, yet not formalized in Los Angeles as accessory dwelling units. Renters of those homes must pay all their utility and service bills through the landlord and therefore remain ineligible for many government benefits and programs. They also lack decision-making power to upgrade their own homes. Their ineligibility to access home energy programs increases their vulnerability to related financial and health burdens.

The burdens renters experience are deeply intertwined in the challenges of homeownership for low- and moderate-income Angelenos. While homeownership remains extremely inaccessible for most lower-income Angelenos, those who are able to purchase a home continue to struggle to maintain and improve it. As one participant explained:

> I'm a homeowner. And I have a duplex, so I rent out. Me and [my wife] rent out. And we're trying to get solar from the Department of Water and Power, it's difficult. Yes, you have subsidies and stuff. But you gotta put up almost twenty grand just to get the solar power. Who's going to take on all that with my tenants. So, if I have a tenant there, I would think that they'd have to help pay to get this solar there. Or there should be a subsidy from the Department of Water and Power, and the money that's coming down to reimburse the communities of low income. So, we can help them and we can help ourselves at the same time, without having that extra burden. I just bought the house. And buying the house I had to pay $900, just for a deposit of water. And my tenants don't pay for water. Where am I going to get that at? With the burden that's going on right now. So right now, I got a final notice coming, because I'm short $300 on the $900. So there has to be some kind of alleviation. And it has to look at both sides, on the renters and the owners. And there should be stronger subsidies for the homeowners who have renters.

While this participant clearly understands and values the benefits of LADWP and other government agency clean energy programs, he is effectively excluded from those programs in practice. For lower- and moderate-income Angelenos, purchasing a home creates new and long-term financial burdens that limit the capacity of owners such as himself to invest in subsidized solar energy and other energy efficiency improvements. If they were to invest in those upgrades, he states that the cost would have to be transferred to the renters. One of the reasons for this intersecting burden is the absence of energy efficiency programs and subsidies designed for renters and programs tailored for local homeowners with rental properties. The implications of the absence of such co-benefits are felt in low- and moderate-income renters' and homeowners' household budgets as they struggle to pay monthly utility bills.

4.3 Code 3: Energy Affordability and Burden

Understanding "Energy Affordability and Burden" as a causal factor, this coded category of energy justice refers to passages of the listening sessions that call attention to people and their communities' ability to pay energy-related costs embedded in their everyday lives—from transportation and housing to work, food, and recreation. Energy burdens are often understood as "the percent of a household's income spent on utilities for heating, cooling, and other energy services" (Drehobl and Ayala 2020). This code expands that definition to consider the trade-offs people and families must make to pay all their energy bills alongside other monthly financial burdens, such as the cost of health care, childcare, and rent. The "Energy Affordability and Burden" code overlapped with many of the above codes; therefore, we are highlighting two relevant codes—one factor and one value, as shown in Table 4—

that help us understand the procedural changes needed to increase Angelenos' access to affordable energy.

Table 4. Frequency of Overlapping Codes with Energy Affordability and Burden

Primary Code	Overlapping Codes	Frequency of Overlaps
Energy Affordability and Burden (Causal Factor)	*Causal Factor*	
	Barriers to Program Participation and Support	74
	Values	
	Responsibility, Accountability, Transparency	16

4.3.1 Energy Affordability and Burden and Barriers to Program Participation and Support

Two codes with a notably high frequency of overlaps in our analysis were "Barriers to Program Participation and Support" and "Energy Affordability and Burden." Over the course of the 15 listening sessions, we identified 74 times when these concepts overlapped in the same statement. Their consistent relationship in participants' narratives exposes a common experience: while there are existing LADWP programs designed to increase energy affordability for ratepayers, participants in these sessions emphasized the barriers to accessing those benefits that maintain ongoing energy burdens. Although this intersection was already analyzed in the sections above, here, we intend to highlight the procedural mechanisms that impact access to specific clean energy technologies and services.

One participant wove these concerns into a comment related to EVs as a priority impact area for her community. She tied the inaccessibility of EVs to ongoing energy affordability problems related to transportation and the barriers many low- and moderate-income residents face in benefiting from existing EV incentive programs. She explained:

> I think that some of the barriers that we actually have seen is that, with larger corporations and government at the higher levels, they are not on the ground to actually see the average taxpayer or person that lives everywhere. And the struggles that we actually have. So, for example, everybody wants to buy a Tesla car, but it isn't necessarily affordable. Therefore, the missing middle, as well as other people who are not able to afford that type of a car, are completely left out. And then for businesses who are actually focusing, not on the Teslas, that are focusing on low-speed neighborhood electric vehicles. They are also being subject to the burdens of not fitting into the category of those charging stations. So, the charging stations are these huge cables that you plug into your car. When for example, the low-speed neighborhood electric vehicle is actually just a three-prong outlet that is required. That would be much more feasible to have at your local department store or a mall, for example. I think those are some of the barriers that we have, that they are not considering all of us. It's always at a certain financial status that they are actually thinking of the people who are going to be traveling to Vegas every weekend. But not the people that are actually traveling to work or the elders, or the missing middle.

By pointing to the “missing middle,” this participant is exposing a subset of ratepayers who cannot afford the more efficient clean energy technologies, such as EVs, and yet are not included in the program design for subsidized benefits given their relatively higher incomes. This lack of access thus increases the energy inequities among ratepayers: as energy technologies become more efficient yet also more expensive, moderate-income Angelenos receive disproportionately fewer of the benefits while becoming more financially burdened. Furthermore, she highlights the need to consider other disadvantaged groups, such as commuters and seniors, who are often left out of program design considerations. Access and use of these technologies—whether via direct purchase or program benefits—become exclusionary procedural mechanisms for those left unconsidered. However, it is important to consider who is and should be responsible and accountable for developing more equitable distributions of energy resources and services.

4.3.2 Energy Affordability and Burden, and Responsibility, Accountability, and Transparency

The question of who is responsible for developing a transparent energy transition and accountable for its outcomes was posed during the listening sessions. The answers participants gave us manifested in the intersection of the causal factor “Energy Affordability and Burden” and the value “Responsibility, Accountability, and Transparency” that overlapped in the same statement 16 times across the 15 listening sessions. We coded comments with “Responsibility, Accountability, and Transparency” when participants described either their presence or a lack thereof. Here, we examine the direct impacts that their absence has on financial and other burdens that the current energy system produces. Participants understand themselves as part of the energy system as ratepayers, and therefore demand transparency and accountability. As one participant explained:

> If the office is here, it has to give access to the community. All that they are offering, supposedly you are saying that there is a lot of help, they have to [inform] the community. Because they are benefiting from the community, because they are taking our money every month. So we have the right to know what they are offering us. Now for the pandemic, supposedly that office had a lot of money that the government had given to help the community. And I never saw that money, I wanted to know where was that money. Because if I am low-income, I also have the right to collect a little. Because I am a ratepayer, I have been here for 24 years paying a bill. So, I feel that I also have the right to see if I could qualify for help even with a dollar. And I’m sorry they didn’t give it. So [the benefits] need more scope, we need more information. Inform the community, I feel. Sorry. My respects, my respects.

This participant teaches us why procedural justice is not charity: benefits to ratepayers regardless of their income are not handouts but rather the responsibility of a company to its customers. Therefore, following the logic of listening session participants, customers, like shareholders, are entitled to transparent access to information regarding their investments in Los Angeles’ energy system and transition. They are also entitled to mechanisms of accountability that ensure the equitable distribution of their funds. Procedural justice is about being part of the process as a decision-maker—sharing the burdens, but also and mainly the benefits, of this transition. Equity is about knowing how this process “is proceeding” and being able to inform and decide your community’s energy future.

5 Conclusion

This chapter has laid the groundwork for operationalizing a crucial component of procedural justice—LADWP's engagement with historically underserved communities and CBOs—to define where and when to prioritize more equitable goals and strategies in Los Angeles. This analysis and its main findings are critical to ensuring fair, equitable, and inclusive participation in the decision-making process for Los Angeles' energy transition. Employing a mixed-methodological approach, we identified critical procedural barriers and challenges to structure our lens for understanding energy-relevant inequities in areas of impact prioritized by Steering Committee members and listening session participants.

Here, we employ energy justice as an *analytical tool* to guide our analysis of how values are integrated into the LA energy system and of the causal factors that impact the city's energy outcomes. These findings informed Chapter 1 on justice as recognition, where energy justice is employed as a *conceptual tool* to connect the tenets of distributional, procedural, and recognition justice. In Chapter 3, the analysis of energy equity strategies on procedural and recognition justice will support energy planners, ratepayers, and CBOs to develop community-grounded energy strategies and actions as a *decision-making tool* for guiding the energy transition.

The three primary codes highlighted in this chapter—(1) self-determination, (2) barriers to program participation and support, and (3) energy affordability and burdens—and their intersections with critical categories of inequity reveal mechanisms and measures that must be redressed to achieve procedural justice. Listening session participants emphasized the need for self-determination as decision-makers in the LA energy transition, reminding us that a deliberative process is fundamental to justice.

Residents identified barriers in existing government energy support programs that limit their capacity to make their own energy-related decisions. In turn, those barriers augment the burdens ratepayers experience and limit their access to the benefits of this transition. One of the key findings that this intersectional relationship revealed is the importance of developing and maintaining mechanisms of transparency and accountability that ensure the equitable distribution of energy services, resources, and technologies. *Equity, as our participants insisted, is about making and following through with a commitment to prioritize historically underserved and overburdened communities in LA's energy transition*. Chapters 3-17 operationalize strategies committed to that goal.

6 Glossary

Actions/Strategies: the means used to solve identified problems in an impact area; actions and strategies involve programs such as bills, regulations, rates, subsidies, and investments and how they are designed, implemented, and evaluated (Dubash et al. 2022)

Causal Factors: "Events, incidents, happenings that lead to the occurrence or development of a phenomenon" (Buckley and Waring 2013, 156).

Climate Justice: the remediation of the impacts of climate change on poor people and people of color, and compensation for harms suffered by such communities due to climate change (Burkett 2008)

Co-Creation: "a process through which two or more public and private actors attempt to solve a shared problem, challenge, or task through a constructive exchange of different kinds of knowledge, resources, competences, and ideas that enhance the production of public value in terms of visions, plans, policies, strategies, regulatory frameworks, or services, either through a continuous improvement of outputs or outcomes or through innovative step-changes that transform the understanding of the problem or task at hand and lead to new ways of solving it" (Torfing et al. 2019, 802)

Community Engagement: Community engagement often entails public participation through an ongoing, two-way or multidirectional process, ideally with an emphasis on relationships and trust-building rather than instrumental decisions. The latter are processes where engagement becomes the instrument to achieve social acceptance (Stober et al. 2021).

Disadvantaged Community: "Disadvantaged communities refers to the areas which most suffer from a combination of economic, health, and environmental burdens. These burdens include poverty, high unemployment, air and water pollution, presence of hazardous wastes as well as high incidence of asthma and heart disease. One way that the state identifies these areas is by collecting and analyzing information from communities all over the state. CalEnviroScreen, an analytical tool created by the California Environmental Protection Agency (CalEPA), combines different types of census tract-specific information into a score to determine which communities are the most burdened or "disadvantaged"" (California Public Utilities Commission 2023).

Energy Equity: the equitable distribution of social, economic, and health benefits and burdens of energy across all segments of society (Jenkins 2017)

Energy Justice: the provision of safe, affordable, and sustainable energy to all individuals, across all areas, (Jenkins 2017); this is done with a framework informed by justice movements, including attention to three core tenets:

- *Distributional justice* seeks to ensure a just and equitable distribution of benefits and negative impacts of the clean energy transition.
- *Justice as recognition* seeks to understand and address past and current energy inequities by analyzing structural causes of exclusion and vulnerability and specific needs associated with energy services among social groups.
- *Procedural justice* aims to actively engage partners and communities throughout the project, to co-design the analysis, and shape the resulting equity strategies (Energy Equity Project 2022).

Energy Transition: a large-scale or deep societal change in the production, distribution, and use of energy; this transition can entail transformations in social-technical systems and systems of policy and governance intended to substantially improve the outcomes out of unsustainable pathways, such as fossil fuel use (Carley and Konisky 2020)

Environmental Justice: the distribution of environmental hazards and access to all natural resources; it includes equal protection from burdens, meaningful involvement in decisions, and fair treatment in access to benefits (U.S. EPA 2023)

Equity Outputs: Equity outputs are the immediate, easily measurable effects of an action aimed at achieving equity (Dubash et al. 2022).

Equity Outcomes: Equity outcomes are the ultimate changes that a policy will yield (Dubash et al. 2022).

Equity: Equity refers to a measurement of fairness and justice. Unlike equality, which refers to the provision of the same to all, equity aims to recognize the historical and ongoing differences in experiences and outcomes between people, groups, and communities to redress those imbalances.

Frontline Community: a community, frequently a low-income community of color, that experiences the first and worst consequences of environmental and climate change including floods, heatwaves, and other climate extremes as well as the impacts of facilities that are used to extract, produce, process, and transport energy resources.

Impact Areas: particular sectors and subsectors of the energy system impacted by causal factors

Just Energy Transition: a deep societal change in the energy system that fulfills at minimum three of the tenets of justice: recognition justice, procedural justice, and distributional justice (McCauley and Heffron 2018)

Justice involves removing barriers that prevent equity through energy actions (strategies) that offer individuals and communities equal access to energy resources and options to self-determine their energy goals (Romero-Lankao and Nobler 2021).

Participation relates to the involvement of the public in infrastructure siting and other clean energy decisions and policies (Stober et al. 2021). Participation is an umbrella concept that includes processes of community engagement and public decision-making (Stober et al. 2021). Participatory decision-making denotes inclusion of actors such as underserved communities in an energy project as a decision-maker. Direct participation refers to the level of economic and/or political involvement of a local community or municipality in an energy project.

Underserved Community: a community, frequently a low-income community of color, that (a) does not benefit from energy programs, investments, and technologies, (b) is not recognized, considered, or able to participate in energy decision-making (Klinsky et al. 2017)

Values: the ethical paradigm that structures the sociocultural norms, beliefs, and practices guiding how a group of people prioritize and relate to the current energy transition (Jenkins 2017)

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Appendix A. Steering Committee Charge and Protocols

The City of Los Angeles has set ambitious goals to transform its energy supply—so LADWP partnered with the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) on the Los Angeles 100% Renewable Energy Study (LA100), a first-of-its-kind objective, highly detailed, rigorous, and science-based study to analyze potential pathways to achieve a 100% clean energy future.

Released in March 2021, the LA100 study found that Los Angeles can achieve reliable, 100% renewable power by 2035. But while LA100 identified infrastructural changes to achieve clean energy transitions across power, buildings, and transportation sectors, more work is needed to analyze strategies that achieve a just and equitable clean energy transition.

On September 1, 2021, the LA City Council voted unanimously to direct LADWP to achieve 100% carbon-free energy by 2035 "in a way that is equitable and has minimal adverse impact on ratepayers," specifically prioritizing equity for environmental justice communities, while "shifting energy benefits to renters at equitable rates."

To develop implementation-ready strategies to answer this call, the LADWP Board of Water and Power Commissioners authorized NREL to lead the LA100 Equity Strategies project in partnership with the University of California Los Angeles (UCLA).

Ensuring all Angelenos will share in the benefits of the clean energy transition is a fundamental priority for the City of Los Angeles.

LA100 identified the infrastructural changes Los Angeles can implement to achieve deep decarbonization, and now LA100 Equity Strategies will identify ways to ensure those changes are made equitably.

A.1 Approach

LA100 Equity Strategies picks up where LA100 left off by applying cutting-edge modeling and analysis to answer the question: How can Los Angeles ensure its transition to 100% clean energy will improve energy justice as measured by metrics including reduced energy burdens, increased access to energy services like cooling and electric mobility, and improved quality of life?

LA100 Equity Strategies will provide answers by bringing together energy and environmental justice communities and other key Los Angeles stakeholders to identify prioritized equity outcomes in this clean energy transition—particularly for those in disadvantaged communities.

To inform these outcomes objectively and credibly, *NREL will model sector-specific strategies under different scenarios across sociodemographic, geographic, and building characteristics to achieve prioritized outcomes*. Community members will be active participants in the study through an ongoing feedback loop that includes structuring the goals, iterating, and evaluating the results of the analysis.

The results will provide LADWP, the City of Los Angeles, and community leaders with extensive information for decision support at a detailed, implementation-ready level. The suite of options to meet community needs and goals for energy justice will include the metrics and methodology needed to monitor LA's progress toward reaching these goals.

A.2 Steering Committee Role and Goals

The LA100 Equity Strategies Steering Committee will be responsible for providing strategic direction and play a critical role in helping to guide the LA100 Equity Strategies work by identifying prioritized energy equity outcomes and providing input, ideas, comments, and feedback throughout the project. The Committee will meet once a month from October 2021 through project culmination on May 5, 2023.

LADWP will consider Steering Committee input when developing finalized equity strategies and policies for LA's transition to clean energy, along with input from the broader community and stakeholder engagement process, technical and regulatory requirements, and other city needs and goals. Adoption authority for LA100 Equity Strategies is held by LADWP, based on modeling and analysis from LA100 Equity Strategies and the Strategic Long-Term Resource Plan (SLTPR).

A.3 Compensation

LADWP will compensate underrepresented voices and organizations who need resources to participate in the Steering Committee.

A.4 Composition

To represent the diverse communities and stakeholders in Los Angeles who have long been affected by the city's energy inequities yet lacked the power to shape energy decisions, the Steering Committee will primarily be composed of representatives from energy and environmental justice advocacy groups, CBOs, and community leaders from disadvantaged communities.

Steering Committee members were identified through an empirical process that started with the identification of more than 150 stakeholders and potential local non-profits and community leaders. This list was then refined to ensure geographic coverage, particularly of disadvantaged communities within Los Angeles, and to prioritize coalitions, alliances, and partnerships that could represent diverse voices on the Committee.

A.5 Participation and Collaboration Principles

Steering Committee Principles

The preferred deliberation process is a collaborative process whereby Steering Committee members choose to cooperate to achieve shared and/or overlapping objectives, in support of the Department of Power and Water's direction for a more just and equitable transition to clean energy in Los Angeles. By agreeing to serve on the Steering Committee, members commit to the following principles:

- Participate in an active and focused manner – commit to success of the process.
- Interact respectfully with all other members, valuing all perspectives.
- Communicate interests.
- In meetings, be brief and concise in communications, and be prepared.
- Help involve all members.
- Seek solutions for all – help to integrate each other's interests into creative solutions that address diverse needs.
- Commit to a good faith effort.

- Share relevant information.
- Attend all meetings, start on time.
- Participate effectively, using open, frank communications within the Steering Committee, and when sharing reports of Steering Committee discussions, do not attribute discussions to any individual member.
- Keep cell phones in silent mode and, when meeting in person, minimize screen time during meetings.

Deliberation Process

The preferred deliberation process includes:

- A consensus model to promote collaboration and avoid contentious voting
- Shared leadership rather than elected positions to foster collaboration and avoid competition
- Working groups, which will function as a space for more focused deliberation among smaller groups
- An understanding that once equity strategies are identified, LADWP will decide on the implementation plan.

Facilitator Principles

Meetings will be conducted using a facilitator, who will:

- Maintain a neutral position during Steering Committee discussions.
- Work to ensure that all Steering Committee members have the opportunity to participate equally.
- Guide meeting discussions per the agenda and manage time.
- Provide dialogue activities as needed for productive outcomes.
- Enforce the Steering Committee collaboration principles stated above.
- Ask “why” to clarify interests.
- Track actions, next steps, and deadlines.
- Participate in agenda preparation as part of meeting the above responsibilities and integrating the Steering Committee in the planning process.

We also will:

- Notify the public about Steering Committee membership after holding the first community engagement meeting.
- Keep the public informed on Steering Committee and LA100 Equity Strategies developments as the study moves forward, whether in person, on their website, or on social media.
- Include the public in public (e.g., community engagement) meetings, but not in all Steering Committee meetings. It may be difficult to accomplish much if all Steering Committee meetings are public, and it may also constrain some of the advice we are getting from the Steering Committee group if they are performing for a public audience.

A.6 Primary Members and Alternates

The protocol for primary members and alternates is guided by goals for consistent involvement, which will benefit the Steering Committee process and contribute to the success of the LA100 Equity Strategies project. *Primary members* refer to the members who were initially invited. Each primary member can identify an *alternate representative* or a proxy who can substitute for the primary if she, he, or they are unavailable for a meeting. Alternates are highly encouraged to attend the meetings as observers. In the event of an alternate is asked to step in for a primary member, it is the primary’s responsibility to ensure that the alternate is briefed on the process to date before activity participating.

A.7 Working Groups

Working Groups are integrated into the community engagement process. Working Groups will generally meet one week following the Steering Committee meetings for more extensive discussion of the topics discussed in the Steering Committee meetings as related to their energy justice areas of focus. The specific energy justice focus of each Working Group will be decided via consensus by the Steering Committee. However, NREL will present a suggestion of eight possible focus categories developed from our analysis of the energy justice issues in Los Angeles. They will be the following:

1. Clean renewables
2. Energy burdens
3. Policy and strategy
4. Housing and buildings
5. Jobs
6. Health
7. Pollutants (e.g., air and other toxins)
8. Transportation

Depending on the focus of individual Working Groups, they may decide to focus on a subset of the Steering Committee topics. The Steering Committee's initial input, questions, ideas, and concerns should help to guide the Working Group meeting discussions. Working Group reports will be provided at the Steering Committee meetings.

The Working Groups will be comprised of Steering Committee members as well as other identified community stakeholders. Working Groups will be composed of moderate sizes (~10-15 members) to contribute to productive and inclusive discussions.

A.8 Meeting Agenda and Frequency

The Steering Committee will meet at least once a month. Working Groups will be established by the Steering Committee once it is convened. Working Groups will generally meet monthly or at their discretion. Meeting will be approximately 2 hours, held virtually at least through 2021.

A.9 Meeting Logistics and Communications

Steering Committee members may want to share information and documents with other members during the duration of LA100 Equity Strategies. To ensure that all members have the same information available to them, all documents are to be distributed through the established LADWP point of contact, who is listed at the end of this document.

A.10 Email Communication

The Steering Committee is intended to be a collaborative experience, in which members work through issues and dialogue in a group setting to gain mutual understanding. So, Steering Committee members agree to avoid engaging in email “dialogue” with other Steering Committee members, and instead commit to using Steering Committee meetings for dialogue and discussion purposes. Email exchanges often do not constitute constructive dialogue and at times can result in unproductive exchanges that can cause unraveling of mutual understanding and collaboration.

A.11 Media Interaction

Given the high interest in the LA100 Equity Strategies project, there will likely be coverage of the study in local media, blogs, and other forms of communications. Steering Committee members agree to respect the open, frank discussions that occur within the meetings and not attribute specific conversations to other Steering Committee members in interactions with the media and other external communication channels. Furthermore, Steering Committee members agree not to make statements about Steering Committee meeting discussions and deliberations. The overriding consideration in all communications among Steering Committee members is to honor and sustain the constructive, collaborative process. While Steering Committee members are free to speak with the media from their perspectives as individuals or representing their respective organization, members are not to serve as a spokesperson on behalf of the Steering Committee.

A.12 More Information

The main points of contact for the LA100 Equity Strategies project and Steering Committee are:

- Dawn Cotterell, LADWP Senior Public Relations Specialist dawn.cotterell@ladwp.com (Main logistics contact)
- Vanessa Gonzalez, LADWP Resource Planning, Development & Programs vanessa.gonzalez@ladwp.com (Main content contact)
- Paty Romero-Lankao, NREL Distinguished Senior Researcher Paty.RomeroLankao@nrel.gov

Appendix B. Codebook Names and Definitions

Table B-1. Code Names and Definitions

Code Name	Definition to Guide Coding
Structural Phenomena	
(Dis)Investment and Development	
Economic Development and Land Use	Existing land use and how it relates to opportunity and economic growth; preferred land use; general economic development.
Economic Development and Energy	Economic growth and development related to energy and/or energy business.
Gentrification and Displacement	Housing, job, economic displacement, homelessness, geographic segregation; feeling the push to leave community but not wanting to; rent/landlord caused displacement because of upgrades to home.
Socioeconomic Marginalization	Historic disinvestment in communities, equity vs equality, being left behind; those with and without means get different things (and have different experiences in their communities).
Neighborhood Disinvestment	Physical manifestation of socioeconomic marginalization. Mention of lack of upkeep, excess litter, poor infrastructure; community empowerment/pride in ownership.
Resilience	
Grid Resilience	Threats to electrical grid resilience and practices that support resilience; instances (or insinuations) or examples of resilience or the lack of resilience in the grid; how technologies may help or threaten the resilience.
Community Resilience	Programs or strategies that support a community's energy resilience; could also be related to health; economic resilience; examples of a community being able to withstand hardships.
Public Health and Safety	
Emotional Burden	References to emotions like hurt, sadness, pain, etc. Sometimes related to physical environment; and references to systems to support emotional burdens.
Heat Wave	Mention of heat wave, lack of AC, dealing with the heat.
Shade	Shade or lack thereof (i.e., (un)covered bus stops); lack of trees or presence of trees.
Pollution	
Dumping	Environmental pollution via dumping; physical contamination of certain areas and how it impacts those living there (trash as well); what people are doing to clean up or prevent dumping; targeted; trash and other pollution.

Code Name	Definition to Guide Coding
Mobility and Pollution	Clean4 transportation, negative effects of transportation/mobility on surrounding communities, or the desire for clean transportation.
Pollution (other)	General pollution or contamination; noise, odor, other contaminants.
Air Pollution	Comments about air pollution, bad air, and causes and effects of it; specific pollutants in the air.
Air Quality	Comparison of air quality in different places; includes all comments related to air pollution too.
Public Health (or Community Health)	Anything related to public/community health. Or individual health, often as it relates to the environment. Encompasses a lot of the more general statements but also many of the ones in the pollution section above.
Safety	Safety as it relates to health, transportation, and housing; safety of people and goods (cars, houses); accessibility to health facilities.
Crime	General mentions of crime.
Criminal Justice Reform	Mention of criminal justice reform concepts, including reentry programs.
Historical Conditions	Mention of something that happened in the past that affects conditions of the community today.
Cultural Barriers	Barriers to clean energy access and use related to sociocultural norms and traditions.
Public Services	Water, electric, trash services provided by city; commentary on them and supply/ bills.
Infrastructure Phenomena	
Water	
Water Affordability and Burden	Water use, cost, supply; how cost seems inflated.
Water Quality	Drinkability of water, health concerns with water, general water quality.
Public Spaces	
Community Spaces	Schools, churches, places where community members gather or attend gatherings; open to the public; also, community spaces that were lost; general public spaces, or spaces that do not really “belong” to anyone.
Green Space	Lack of green space, or condition of the existing green space; parks.
Cooling Spaces and Heat Island	Places to go when there is a heat wave, effects of heat in city; how you can change (or cannot change) home to have more efficient cooling.
Public Lighting	Street lighting, darkness in public places.

Code Name	Definition to Guide Coding
Maintenance and Upgrades	
Housing Maintenance and Upgrades	Mention of old housing stock, housing conditions related to maintenance and upgrades; energy efficiency of houses (and buildings).
Infrastructure Maintenance and Upgrades	City-wide infrastructure related maintenance and upgrades.
Energy Security	Issues related to infrastructure/LADWP capacity to deliver quality electrical connection to residents.
Mobility and Transportation	
Public Transportation	Anything related to public transportation, its condition and use.
Walking	Mention of walking in relation to mobility impact area.
Biking	Mention of biking in relation to mobility impact area.
E-Scooters	Mention of e-scooters in relation to mobility impact area.
Electric Vehicles (EVs)	Mention of electric vehicle technology in relation to mobility impact area.
Electric Fleets (Heavy Duty)	Mention of Electric Fleets in relation to mobility impact area.
Autonomous Vehicles (AVs)	Mention of autonomous vehicle technology in relation to mobility impact area.
Mobility and Job Access	Driving, public transport and anything that relates to mobility and its relationship to job access.
Mobility and Services	Driving, public transport and anything that relates to mobility and its relationship to services.
Ride-Hailing	Mention of ride-hailing in relation to mobility impact area, such as Uber, Lyft, or some service that you pay for.
Private Vehicle	Mention of using personal vehicles; or lack of one.
Car Share	Mention of car share programs/ and carpooling.
Car Dealer	Mention of car dealer, or dealerships, car salesperson.
Parking	Mention of parking.
Energy Efficient Mobility	Any mention of energy efficiency in transportation, electric, other; also includes some mentions of public transportation.
Housing and Residential Infrastructure	
Appliances	Mention of appliances e.g., outdated, energy inefficient, lack of access to efficient appliances, etc.
Electrical Capacity	Effects of old electrical system in a home, the capacity at a home to charge vehicles, or run appliances; mentions of the failure of electrical capacity in older homes.
Outages	Mentions of utilities turning off, due to electrical capacity within the home, rolling or planned outages, or community wide electrical/water capacity.

Code Name	Definition to Guide Coding
Homeownership	Issues that affect homeowners specifically; barriers to resources because not a homeowner; benefits and burdens of being a homeowner.
Renter Issues	Issues related to renters' experience such as landlord reticence, lack of control over property, cost and safety concerns.
Quality of building (Home)	Issues related to quality of residence's fuse box, rooftops, internal wiring; energy efficiency of a home; not specific to home either, could be community building.
Solar and Storage	Mentions of solar: installation, affordability.
Economic Phenomena	
Affordability and Stability	
Shutoffs (Barriers)	Energy or water (utilities) service shut off due to missed payments.
Economic Stability/Security	Related to broader picture of job stability, or housing stability and housing prices; prioritizing other expenses over energy bills; cost of housing maintenance and how that relates to stability; prioritizing what you choose to pay more for (or what you have to pay more for).
Debt	Mentions of debt or having bills that have stacked up (i.e., ratepayer has not been able to pay off each month).
Energy Affordability and Burden	Passages that relate to people and their communities' ability to pay energy-related costs embedded in their everyday lives—from transportation and housing to work, food, and recreation. Energy burdens are often understood as "the percent of a household's income spent on utilities for heating, cooling, and other energy services." This code expands that definition to consider the trade-offs people and families must make to pay all their energy bills alongside other monthly financial burdens (e.g., cost of health care, childcare, rent).
Learning and Workforce Development	
Jobs, Training, and Entrepreneurship	Mention of jobs/work in general, businesses that people own; lack of jobs; jobs in energy; also mentions of trainings, workshops, continuing education with career focus; what prevents people from working (i.e., physical constraints).
Local Jobs and Production	Manufacturing locally, local jobs and training to enable local employment.
Education	Mentions of education, how it should be directed/dispersed; education related to electric energy and solar for consumers and careers, as well as other topics.
Youth Career Development	Educating youth to encourage careers in energy or other sectors; teaching skills to further career development for youth; need for training.

Code Name	Definition to Guide Coding
Accessibility Phenomena	
Access and Use	
Access (Actual Use)	Mentions of access to services, resources, and technologies that do not fit within other access categories; this includes how people actually use those services, resources, and technologies and if not, why.
Access to Financial Capital	Access to initial funding for energy-related capital improvements such as rooftop solar, purchase of EV and related EV supply equipment installations; community wide funding and individual funding.
Waiting and Delays	Waiting and delays, specifically with transportation, implementing projects (promises made or hopes for projects).
Monitor Program Application and Reach	Accountability for program implementation and monitoring, generally how was the program implemented, who did it benefit, and who was involved in the implementation; elements to include in order for program to reach the right people and how many people it is reaching.
Eligibility	Specifically, who qualifies for programs, or what causes someone who needs the benefits to not qualify for them.
Predatory Practices	Mentions of contracts not being upheld, paying more than anticipated and not receiving what was promised (from both private and public programs); poor work from contractors.
Electrical Preventive Maintenance	Mentions of unsafe conditions because of overdue electrical preventive maintenance; old electric systems at homes; landlords not doing the work needed.
Technological Barriers	Mentions of barriers to new technology (like EVs, energy efficient appliances, etc.). Mentions of electrical supply (capacity, infrastructure) barriers in the home and community.
Energy efficient technologies	Technology that minimizes energy usage; also mentions of working in energy efficient technology realm; mentions of investment in energy efficient technologies.
Programs and Support	
Urgent Need for Support	Mention of imbalance between need for support now versus plans and policies or programs that have long waiting lists or take years to see change; also mentions of debt and needing to focus on urgent needs versus longer term concepts like the energy transition.
Misunderstanding	Miscommunication, including different interpretations between communities and those implementing policy/government.
Community Study	Recommendations for community wide studies; or comments about previous/current community studies.

Code Name	Definition to Guide Coding
Food Banks	Mention of food banks.
Subsidies and Incentives	Mentions of subsidies (or monetary incentives), how they could help and what they currently do not cover; general incentives geared toward a specific group that encourage and facilitate energy efficiency, workforce development and helping communities reach their energy goals.
Grants/ Scholarships/ Internships	Mention of internships or grants geared toward workforce development or school.
Utility Debt Relief	Mentions of extremely high bills that ratepayers cannot pay off and therefore require relief; many related to the covid moratorium that built up; full relief or payment plans that provide debt relief; also, general mentions for need for debt relief.
Consistent Ratepayer Support	Mentions of support to clients by the utility services (customer service). This includes comments related community members' experiences with utility employees who provide direct support to clients; also, requests for forms of support that recognize people who have been consistent customers for years and now cannot pay bills.
Barriers to Program Participation and Support	Passages that relate to obstacles, barriers, and challenges that community members face that limit their ability to participate in, access, and/or utilize existing energy-related incentives, subsidies, and other aid programs. This includes but is not limited to the barriers embedded in eligibility criteria.
Future Programs/Support/Policies	Mentions of future programs/ policies that communities would like to see; and how community members are involved in them, including in their co-creation.
Successful Past or Existing Programs/Policies	Mentions of programs related to energy efficiency, that are either offered, or people are partaking in that have been successful.
Knowledge/access/use of existing programs/services	Mentions of what happens when communities do not have access to knowledge of programs; knowledge that programs are not working; how to spread awareness/ access to the services, resources, and programs coded in the Programs and Support subcategories above.
Participation, Outreach and Communications	
Building Trust and Confidence	Mentions of commitment, strategies to build trust; lack of trust; not following through on promises.
Continuity	Mentions of that lack of consistency in outreach, communications and therefore participation. This includes outreach that sends different people to have conversations each time communities are engaged. Relates to a lack of accountability due to a lack of continuity.

Code Name	Definition to Guide Coding
Circular Conversations/ Stakeholder Fatigue	Mentions of repetitive conversations with no actual output; mentions of being asked for opinions and then asked again.
Lack of information	Mentions of lacking information about plans from government, about how public money is spent, how programs will operate, and how decisions are being made. Being left behind or out of conversations because of lack of access to information, specifically with an energy focus.
Bilingual Communication and Engagement	Outreach/meetings in both Spanish and English; mentions of presence or lack of this.
Customer Communications and Problem Resolution	Utility companies, communication, and customer service; how they respond when people bring up problems; general availability and responsiveness.
Face-to-Face/Door-to-Door	Mentions of canvassing, going to the people, or having face-to-face interaction.
Social Media and Texting	Mentions of social media and texting as ways to communicate information widely.
Mailer	Using flyers etc. to communicate and conduct outreach.
Community Committee and Mobilization	Mentions of building internal community knowledge (mobilization) or committees/councils to represent and provide continuous local insight; also mentions of community coming together to resist interventions and/or build coalitions.
Promotoras Method	Mentions of the Promotoras de Salud (also known as promotoras) method. The promotoras are community health workers, seen as trusted messengers, who guide local residents in their Latino communities through the complex health care system. They use their knowledge of local sociocultural norms to provide their neighbors access to relevant health and social resources.
Participant Motivation and Means	The burden of participation, and what alleviates that burden or makes it worth it; why people are participating in programs or meetings.
Participant Compensation	Mentions of compensating (or needing to) for participation in engagement, outreach, meetings etc.
Workshops	Commentary on workshops that are offered or desire for workshops or that type of continuing education.
Intergenerational Engagement	Mentions of youth and adults both being engaged, a focus on education, or generally a focus on outreach (or a need for this).
Previous Engagement/Input	Mentions of previous engagement that government or other entities have done, ways they have (or have not) gotten community input.

Code Name	Definition to Guide Coding
Participant Observations and Reflections	
Alternative Energy Technologies	Call-out any mention of any alternative energy technology.
Solar and Storage	Mention of rooftop solar (not community solar).
Green Hydrogen	Mention of green hydrogen.
Electric Vehicles (EVs)	Mention of electric vehicle technology.
Electric Fleets (Heavy Duty)	Mention of heavy duty EVs.
Autonomous Vehicles (AVs)	Mention of autonomous vehicle technology.
Energy efficient cooling technologies	Strategies used or technology used to have more energy efficient households, to keep buildings cool.
Socio-demographics of Participants	
Parent/ Individual with dependents	Self-identifying the people who are talking, if they mention these categories.
Disability	Self-identifying the people who are talking, if they mention these categories.
Age and Longevity	Self-identifying the people who are talking, if they mention these categories.
Location	Self-identifying the people who are talking, if they mention these categories.
Large Household (multifamily, intergenerational)	Self-identifying the people who are talking, if they mention these categories.
Ethical Paradigm	
Ethnical Entailments	
Quality of Life	When people define what they think of as a high quality of life or a need for this.
Responsibility, Accountability, Transparency	Participants' mention of their personal value of responsibility, accountability, and transparency across the board (between service providers and ratepayers, elected officials, project team, etc.).
Carbon Emission Reduction/Efficiency/Environmentally Friendly	Participants' mention of their personal value of environmentally friendly policies and actions (related to climate change, drought, etc.).
Reliable Transportation	The importance of reliability in transportation and its personal value.
Self-Determination	Passages that relate to community members' abilities and power to make decisions for themselves in relation to the energy system.

Code Name	Definition to Guide Coding
Dignity	Participants' mention of the right to live with respect and the power to make decisions for themselves.
(In)Equity and Inclusion	
Priority Social Groups	Groups that need special focus/priority in the energy transition.
People with Disabilities	Groups that need special focus/priority in the energy transition: individuals with disabilities.
Gender	Groups that need special focus/priority in the energy transition: mentions of gender inequities.
Race	Groups that need special focus/priority in the energy transition: mentions of racial/ethnic groups.
Youth	Groups that need special focus/priority in the energy transition: mentions of youth/children.
Seniors and Retirees	Groups that need special focus/priority in the energy transition: mentions of elderly, seniors, and retirees.
Moderate and low income	Groups that need special focus/priority in the energy transition: mentions of people with low and moderate incomes.
Sociospatial Difference	Mentions of the physical differences in locations or physical disparities that align with sociodemographic differences.
Undocumented and Limited Immigration Status	Mentions of not having valid immigration documents or limited immigration status and its impact on access to programs.
Power Dynamics	Control, power plays in communities, between various actors including companies, organizations, groups of people.
Racism	Specific mention of race and/or ethnicity as a factor influencing participant's experience with energy inequity and injustice.

Appendix C. Methodological Process

Table C-1. Methodological Process

[a] These recognition justice codes were also analyzed as factors and impact areas necessary for procedural justice.

Grounded Theory Subcategories	Grounded Theory Codes	Grounded Theory Concepts	Review of Literature: Energy Justice Theory Concepts
Structural Phenomena			
(Dis)Investment and Development	Economic Development and Land Use	Causal Factors	Recognition Justice
	Economic Development and Energy		
	Neighborhood Disinvestment		
	Gentrification and Displacement		
	Socioeconomic Marginalization		
Resilience	Grid Resilience	Actions/Strategies	Procedural Justice
	Community Resilience		
Public Health and Safety	Emotional Burden	Values	Recognition Justice
	Heat Wave	Causal Factors	Procedural Justice
	Shade		
	Dumping[a]	Impact Area	Recognition Justice
	Mobility and Pollution[a]		
	Pollution (Other)[a]		
	Air Pollution[a]		
	Air Quality[a]		
	Public Health (Community Health)[a]		
	Safety[a]		
	Crime[a]		
Historical Conditions	Historical Conditions	Causal Factors	
Cultural Barriers	Cultural Barriers		
Public Services	Public Services		Procedural Justice
Infrastructure Phenomena			
Water	Water Affordability and Burden[a]	Causal Factors	Recognition Justice
	Water Quality[a]		

Grounded Theory Subcategories	Grounded Theory Codes	Grounded Theory Concepts	Review of Literature: Energy Justice Theory Concepts
Public Spaces	Community Spaces[a]		
	Green Space[a]		
	Cooling Spaces and Heat Island[a]		
	Public Lighting[a]		
Maintenance and Upgrades	Housing Maintenance and Upgrades[a]		
	Infrastructure Maintenance and Upgrades[a]		
	Energy Security[a]		
Mobility and Transportation	Public Transportation[a]	Impact Area	
	Walking[a]		
	Biking[a]		
	E-Scooters[a]		
	Electric Vehicles (EVs)[a]		
	Electric Fleets (Heavy Duty)[a]		
	Autonomous Vehicles (AVs)[a]		
	Mobility and Job Access[a]		
	Mobility and Services[a]		
	Ride-Hailing[a]		
	Private Vehicle[a]		
	Car Share[a]		
	Car Dealer[a]		
	Parking[a]		
	Energy Efficient Mobility[a]		
Housing and Residential Infrastructure	Appliances[a]	Causal Factors	
	Electrical Capacity[a]		
	Outages[a]		
	Homeownership[a]		
	Renter Issues[a]		
	Quality of Building (Home)[a]		
	Solar and Storage[a]		

Grounded Theory Subcategories	Grounded Theory Codes	Grounded Theory Concepts	Review of Literature: Energy Justice Theory Concepts
Economic Phenomena			
Affordability and Stability	Shutoffs (Barriers)[a]	Impact Area	Recognition Justice
	Economic Stability/Security[a]		
	Debt[a]		
	Energy Affordability and Burden[a]		
Learning and Workforce Development	Jobs, Training, and Entrepreneurship		Procedural Justice
	Local Jobs and Production		
	Education		
	Youth Career Development		
Accessibility Phenomena			
Access and Use	Access (Actual Use)[a]	Impact Area	Recognition Justice
	Access to Financial Capital[a]		
	Waiting and Delays		Procedural Justice
	Monitor Program Application and Reach		
	Eligibility		
	Predatory Practices		
	Electrical Preventive Maintenance[a]		Recognition Justice
	Technological Barriers	Causal Factors	
	Energy Efficient Technologies[a]		
Programs and Support	Urgent Need for Support	Actions/Strategies	Procedural Justice
	Misunderstanding		
	Community Study		
	Food Banks		
	Subsidies and Incentives		
	Grants/ Scholarships/ Internships		
	Utility Debt Relief		
	Consistent Ratepayer Support		
	Barriers to Program Participation and Support		

Grounded Theory Subcategories	Grounded Theory Codes	Grounded Theory Concepts	Review of Literature: Energy Justice Theory Concepts
	Future Programs/Support/Policies		
	Successful Past or Existing Programs/Policies		
	Knowledge/access/use of existing programs/services		
Participation, Outreach and Communications	Building Trust and Confidence	Actions/Strategies	Procedural Justice
	Continuity		
	Circular Conversations/ Stakeholder Fatigue		
	Lack of information		
	Bilingual Communication and Engagement		
	Customer Communications and Problem Resolution		
	Face-to-Face/Door-to-Door		
	Social Media and Texting		
	Mailer		
	Community Committee and Mobilization		
	Promotoras Method		
	Participant Motivation and Means		
	Participant Compensation		
	Workshops		
	Intergenerational Engagement		
	Previous Engagement/Input		
Participant Observations and Reflections			
Alternative Energy Technologies	Solar and Storage	Causal Factors	Procedural Justice
	Green Hydrogen		
	Electric Vehicles (EVs)		
	Electric Fleets (Heavy Duty)		
	Autonomous Vehicles (AVs)		

Grounded Theory Subcategories	Grounded Theory Codes	Grounded Theory Concepts	Review of Literature: Energy Justice Theory Concepts
	Energy Efficient Cooling Technologies		
Socio-demographics of Participants	Parent/ Individual with dependents		Recognition Justice
	Disability		
	Age and Longevity		
	Location		
	Large Household (multifamily, intergenerational)		
Ethical Paradigm			
Ethical Entailments	Quality of Life	Values	Procedural Justice
	Responsibility, Accountability, Transparency		
	Carbon Emission Reduction/Efficiency/Environmentally Friendly		
	Reliable Transportation		
	Self-Determination		
	Dignity		
(In)Equity and Inclusion	Priority Social Groups[a]		Recognition Justice
	People with Disabilities[a]		
	Gender[a]		
	Race[a]		
	Youth[a]		
	Seniors and Retirees[a]		
	Moderate and Low Income[a]		
	Sociospatial Difference[a]		
	Undocumented and Limited Immigration Status[a]		
	Power Dynamics[a]		
	Racism[a]		

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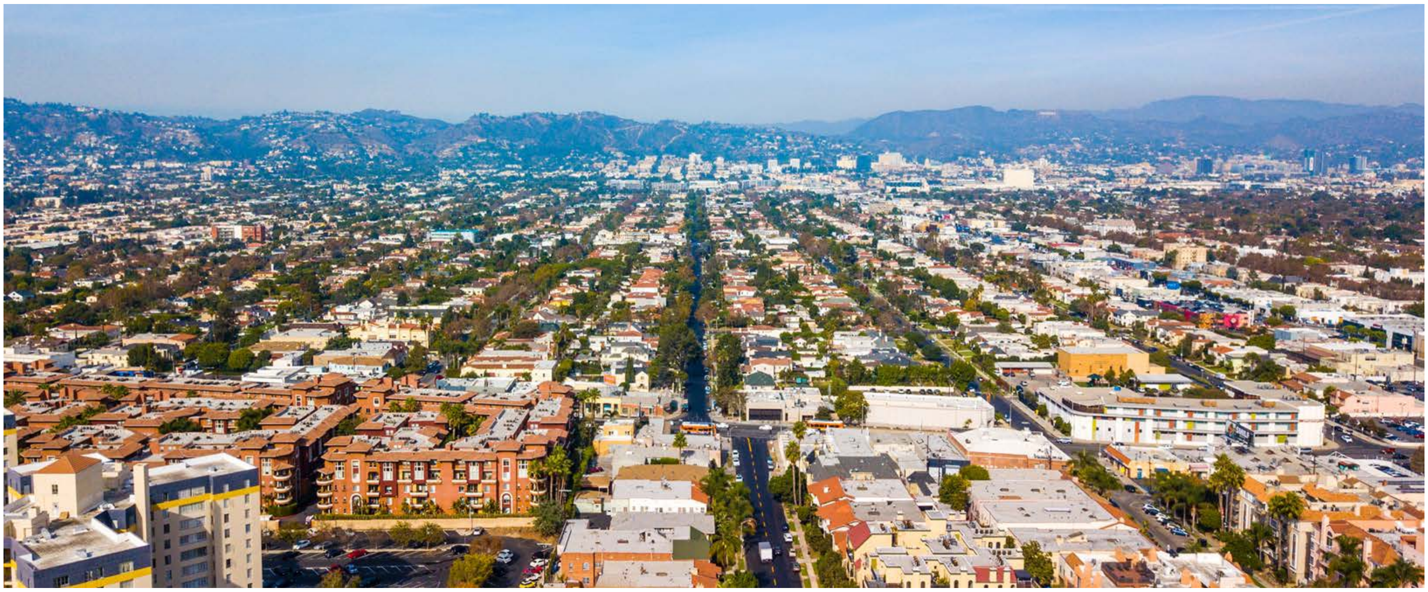
Strategic Partnership Project Report
NREL/TP-5400-85949
November 2023

LA100 EQUITY STRATEGIES



Chapter 3: Community-Guided Energy Equity Strategies

FINAL REPORT: LA100 Equity Strategies

Patricia Romero-Lankao, Lis Blanco, and Nicole Rosner

LA100 EQUITY STRATEGIES

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November 2023

LA DWP

NREL Transforming ENERGY

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Preface

The Los Angeles 100% Renewable Energy Study, or LA100, revealed that although all communities in Los Angeles will share in the air quality and public health benefits of the clean energy transition, increasing equity in participation and outcomes will require intentionally designed policies and programs. The LA100 Equity Strategies project was specifically designed to help Los Angeles identify pathways to such policies and programs in the form of equity strategies. The project aimed to do this by incorporating research and analysis to chart a course toward specific, community-prioritized, and equitable outcomes from the clean energy transition outlined in the LA100 study.

The Project Partners

The Los Angeles Department of Water and Power (LADWP), the National Renewable Energy Laboratory (NREL), and the University of California Los Angeles (UCLA) partnered on the LA100 Equity Strategies project to develop strategies for engaging communities, funding equitable technology and infrastructure investments, expanding existing programs, and designing new programs and policies to improve equity by incorporating what community members themselves know is needed to achieve a more equitable energy future.

The Project Approach

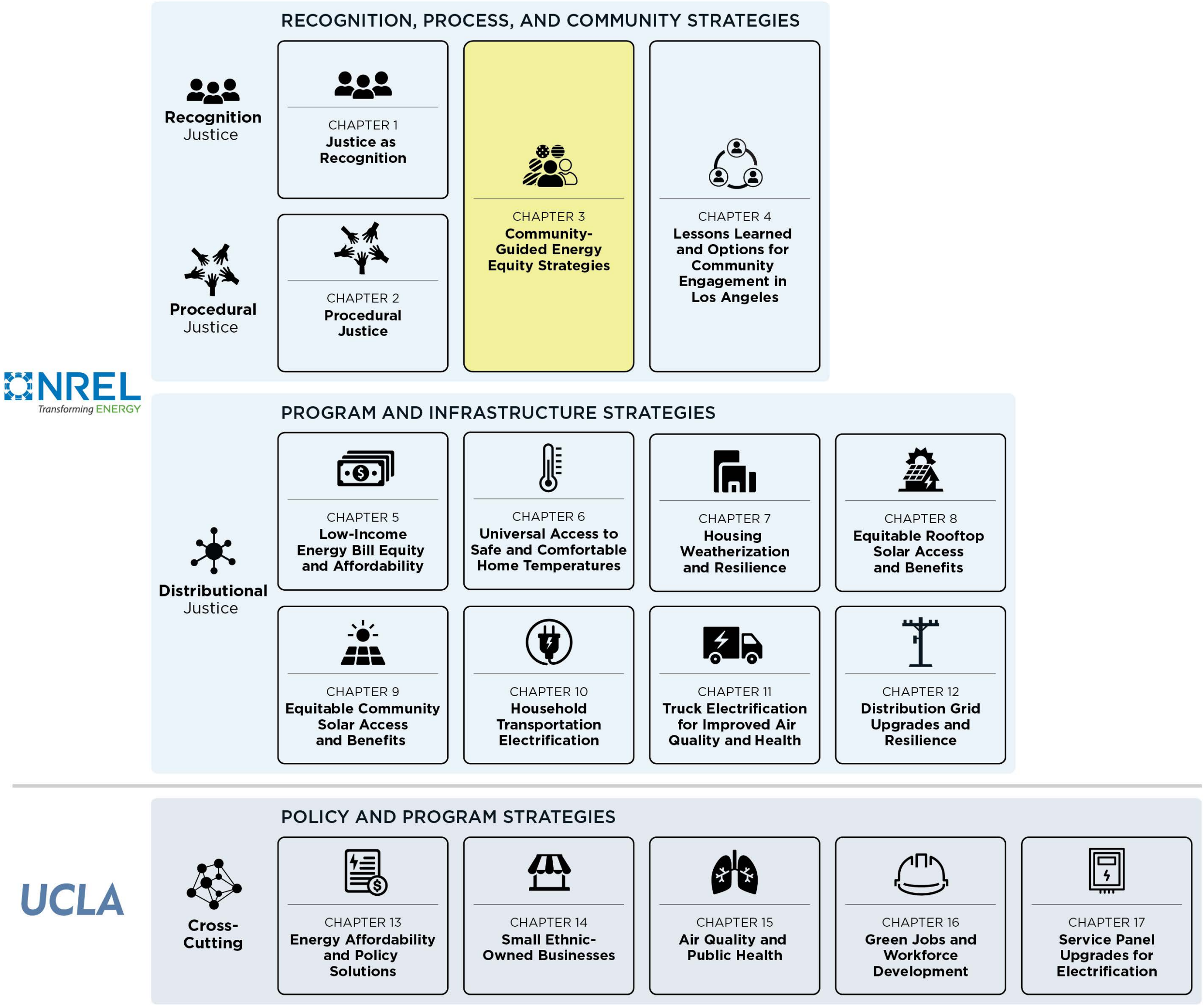
LA100 Equity Strategies employs a unique mixed-methodological approach utilizing three distinct—but connected—research efforts. Through these efforts, NREL and UCLA developed a range of strategy options for increasing equity in LA's transition to 100% clean energy.

A Project Summary

To get a high-level overview of the project, you can dive into the executive summary, interactive data visualizations, and more on the LA100 Equity Strategies website at maps.nrel.gov/la100/equity-strategies.

The Full Report

NREL's final full report for the LA100 Equity Strategies project encompasses seventeen chapters. The first twelve chapters, authored by NREL, are organized around the three tenets of justice. Chapters 1–4 address recognition and procedural justice, while Chapters 5–12 address distributional justice. The final five chapters, authored by UCLA, provide crosscutting policy and program strategies. Each chapter provides data, methods, insights, and strategies to help LADWP make data-driven, community-informed decisions for equitable investments and program development.



NREL Chapters

Chapter 1: Justice as Recognition

Chapter 2: Procedural Justice

Chapter 3: Community-Guided Energy Equity Strategies

Chapter 4: Lessons Learned and Options for Community Engagement in Los Angeles

Chapter 5: Low-Income Energy Bill Equity and Affordability

Chapter 6: Universal Access to Safe and Comfortable Home Temperatures

Chapter 7: Housing Weatherization and Resilience

Chapter 8: Equitable Rooftop Solar Access and Benefits

Chapter 9: Equitable Community Solar Access and Benefits

Chapter 10: Household Transportation Electrification

Chapter 11: Truck Electrification for Improved Air Quality and Health

Chapter 12: Distribution Grid Upgrades for Equitable Resilience and Solar, Storage, and Electric Vehicle Access

UCLA Chapters

Chapter 13: Energy Affordability and Policy Solutions Analysis

Chapter 14: Small Ethnic-Owned Businesses Study

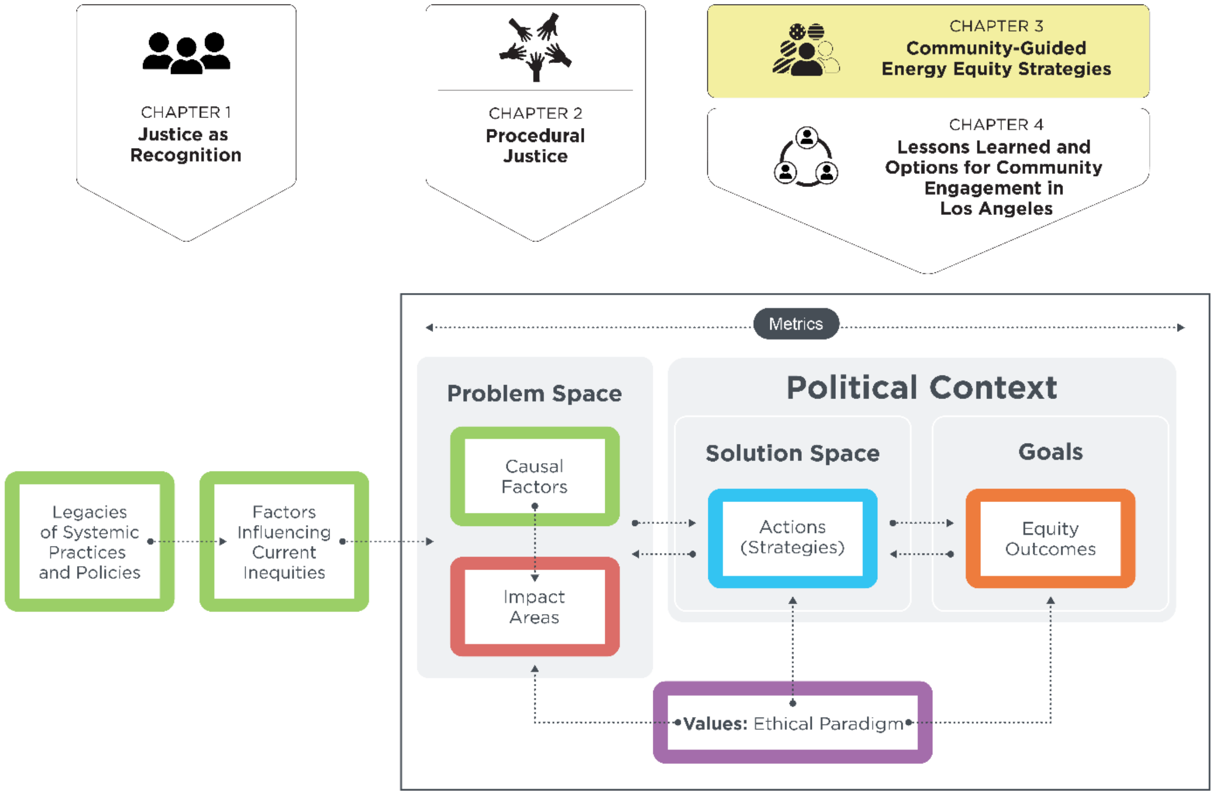
Chapter 15: Air Quality and Public Health

Chapter 16: Green Jobs Workforce Development

Chapter 17: Service Panel Upgrade Needs for Future Residential Electrification

About Chapters 1–4

In Chapters 1–4, NREL presents community-grounded research and analysis results on recognition justice and procedural justice, community-guided equity strategies and future options for community engagement by LADWP. Across these chapters, a mixed-methodological approach is applied, including a systematic literature review, statistical analysis of access to LADWP programs, and qualitative research with communities and community-based organizations to examine understandings of energy transition needs, barriers, and priorities. This work informs modeling and development of equity strategies by analyzing (1) the distribution of benefits of LADWP programs and strategies in the city and (2) historical and current factors contributing to this distribution and other energy inequities in the city.



List of Abbreviations and Acronyms

CAMR	Comprehensive Affordable Multifamily Retrofits
DEI	diversity, equity, and inclusion
ESAP	Energy Savings Assistance Program
EV	electric vehicle
HACLA	Housing Authority of the City of Los Angeles
HEIP	Home Energy Improvement Program
LADWP	Los Angeles Department of Water and Power
LATTC	Los Angeles Trade-Technical College
LIHEAP	Low Income Home Energy Assistance Program
LIHWAP	Low-Income Household Water Assistance Program
STEM	science, technology, engineering, and math
UPCT	Utility Pre-Craft Trainee

Executive Summary

Rising to the Challenge

The LA100 Equity Strategies project synthesizes community guidance with robust research, modeling, and analysis to identify strategy options that can increase equitable outcomes in Los Angeles' clean energy transition. Grounded in the analysis of past and ongoing energy inequities and engagement with underserved communities, the project presents community-guided strategies that aim to operationalize recognition and procedural justice. Chapters 1 and 2 target the problem space—the causal factors, impact areas, and values affecting LA's energy justice landscape. This chapter threads those themes through to begin focusing on the solution space. We examine community-identified problems and solutions through the lens of recognition and procedural justice, presenting analysis and strategies that form the basis for more equitable outcomes in LA's energy transition.

In our listening sessions, underserved Angelenos highlighted the need to transition away from the status quo one participant described as "transactional extraction of information to check the box. To say yes, we engaged." She asked the LA Department of Water and Power (LADWP) to approach her community with respect and transparency, stating, "We consider you all to be experts in your community, and we'd like to authentically engage with you in the decision-making process. So, I do think there needs to be some intentional actions for that rapport building and that trust building." The community-informed analysis and strategies described in this chapter, which are foundational to the LA100 Equity Strategies project, rise to the challenge of engaging authentically to build rapport, establish relationships of respect, and meaningfully involve Angelenos in the decision-making process.

LADWP is already making concerted efforts to redress a disproportionate distribution of investments in physical infrastructure and energy efficient technologies in Los Angeles. This chapter concentrates on the challenge to further rectify past and ongoing inequities in the social, cultural, and institutional scaffolding of Los Angeles. We examine community-guided strategies to tackle this challenge, informed by community input on how all Angelenos can equitably access green jobs and affordable, safe, and resilient energy services, technologies, and programs. These actionable strategies can help move energy equity programs from plans to applied practices, supporting LADWP in launching a just and equitable clean energy transition.

Goal and Approach

In this chapter, we present 11 community-guided equity strategies aiming to operationalize procedural and recognition justice by grounding our analysis in the needs, priorities, and aspirations of LA's communities. We draw on a body of energy justice scholarship and empirical research, using quantitative and qualitative methods to examine and present implementation and evaluation options for 11 energy equity strategies. Our approach centers the knowledge, expertise, and lived experiences of underserved communities and community-based organizations in Los Angeles.

Key Findings

The analysis in this chapter provides foundational building blocks for community-guided equity strategies that LADWP and city agencies could use to achieve more equitable outcomes in the energy transition. This process includes co-developing solutions that redress barriers to energy equity identified by the local community members most negatively affected by the past and existing energy system. Two key overarching findings merit special attention:

- Participants referred more often to "deep infrastructures" (i.e., the social, cultural, and institutional scaffolding that moves energy equity programs from theoretical plans into feasible applied practices) as their primary barriers and challenges, rather than to technological issues. Examples of strategies for addressing deep infrastructure challenges and barriers include tailored training, education, professional development, or guidelines on resources to upgrade electrical panels and retrofit buildings.
- The presentation of 11 community-guided energy equity strategies demonstrates how LADWP could co-design more equitable transition processes to address crosscutting priority areas and achieve energy equity goals (identified on the right columns of Figures ES-1 and ES-2 and discussed in Chapter 4).

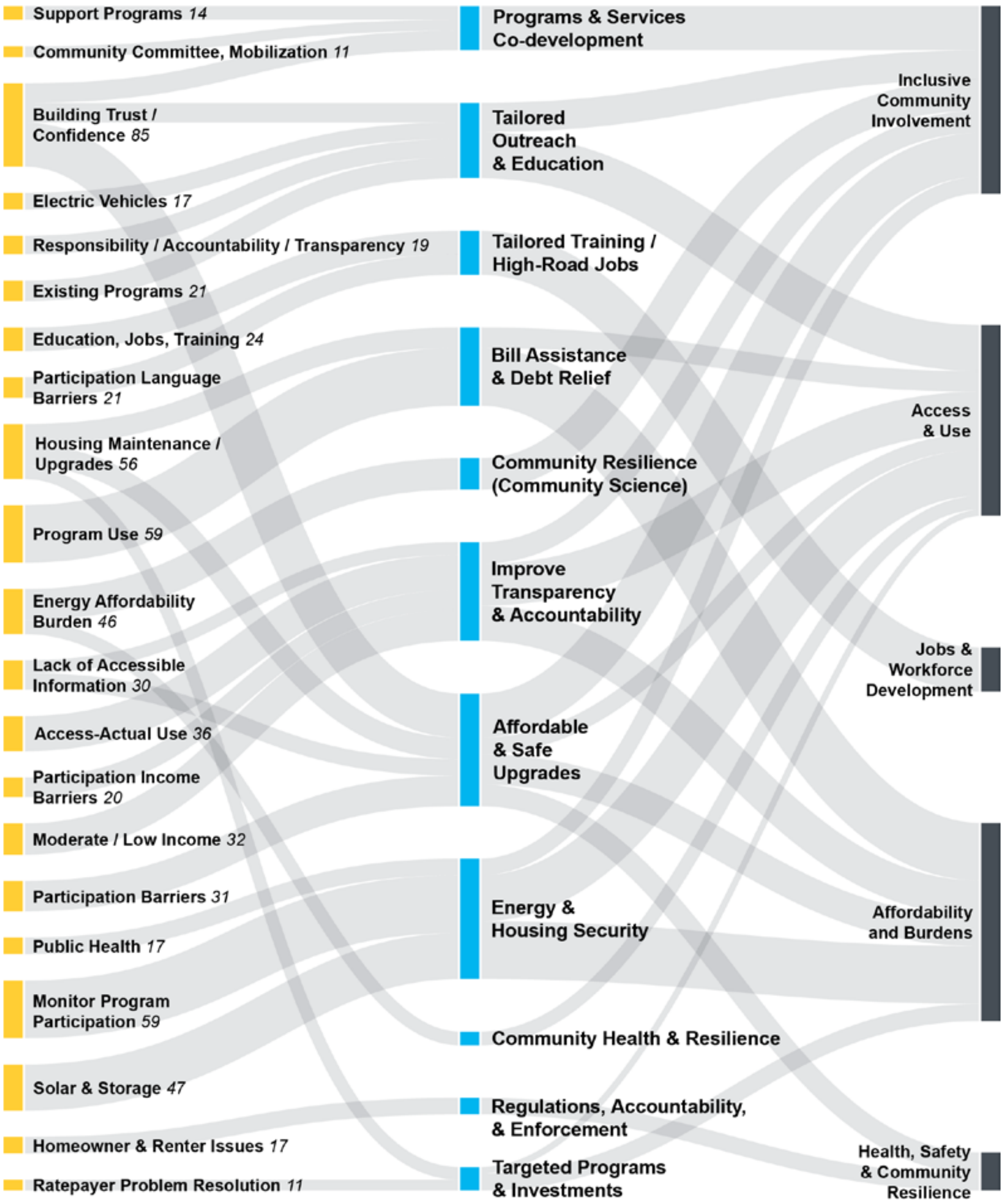


Figure ES-1. Strategy development analysis: Problem space (left), equity strategies (middle), and priority areas (right)

The numbers on the left in this figure represent the number of times community members made intersecting comments related to the problems on the left and suggestions for solutions to future LADWP programs. We quantified this number of intersections as overlapping codes. Overlapping codes occur when two themes (codes) are identified in the same passage of a listening session transcript. Our analysis of these overlaps developed a series of community-guided equity strategies that are listed in the center of the diagram. The right column reveals how these equity strategies relate with five crosscutting priority areas: affordability and burdens; access and use; health, safety, and community resilience; jobs and workforce development; and inclusive community involvement. (For details on how these were identified, see Section 2.2, page 3.)

Envisioning Equitable LADWP Programs

Our first overarching finding—which focuses on social, cultural, and institutional "deep infrastructures"—relates to access and use of energy transition programs, investments, and technologies, but does not singularly focus on technological barriers. In line with this finding, we developed strategies that aim to redress inequities related to access and use of energy rebates, programs, investments, and technologies. The goals of these strategies are:

- Lowering socio-institutional barriers to parity in access and use of energy transition services, technologies, and programs (right column of Figure ES-2).
- Reducing energy burdens by providing affordable options for underserved Angelenos to benefit from the clean energy transition.
- Investing in educational and professional development (increasing energy democracy).
- Supporting community health, safety, and resilience and lowering environmental burdens.
- Including local communities in the design and implementation of the energy transition services, technologies, programs, and policies that affect their lives.

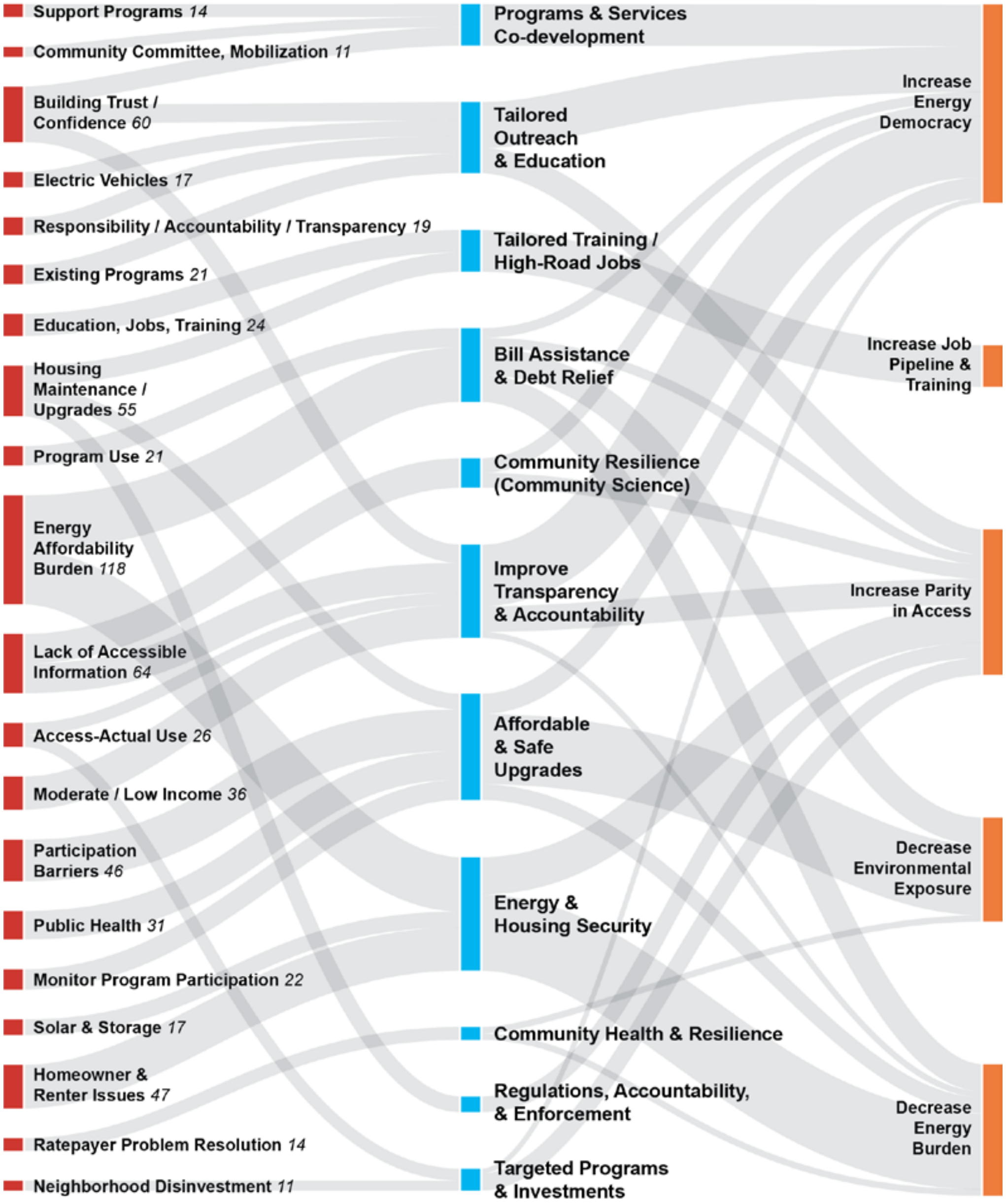


Figure ES-2. Strategy development analysis: problem space (left), equity strategies (middle), and energy equity goals (right)

The numbers on the left represent the number of times community members made intersecting comments related to the problems on the left and suggestions for solutions to future LADWP programs. Our analysis of these overlaps developed a series of community-guided equity strategies that are listed in the center of the diagram. The right column reveals how the outcomes of these equity strategies align with key policy priorities identified through a literature review. (For details on how these were identified, see Section 2.2, page 3)

Envisioning Equitable LADWP Programs

Our second overarching finding demonstrates how LADWP could co-design more equitable transition processes to address crosscutting priority areas and achieve energy equity goals. The 11 community-guided energy equity strategies presented here point to building blocks and options in crucial priority areas and energy equity goals depicted in the right column of Figures ES-1 and ES-2. Because the equity strategies build on and expand existing programs, LADWP could navigate regulatory and other constraints imposed by the political context (solution space in Figure ES-3). LADWP could use criteria such as relevant implementation entities, success metrics, and regulatory constraints to stage the strategies as follows (see Figure ES-3 and Table ES-1):

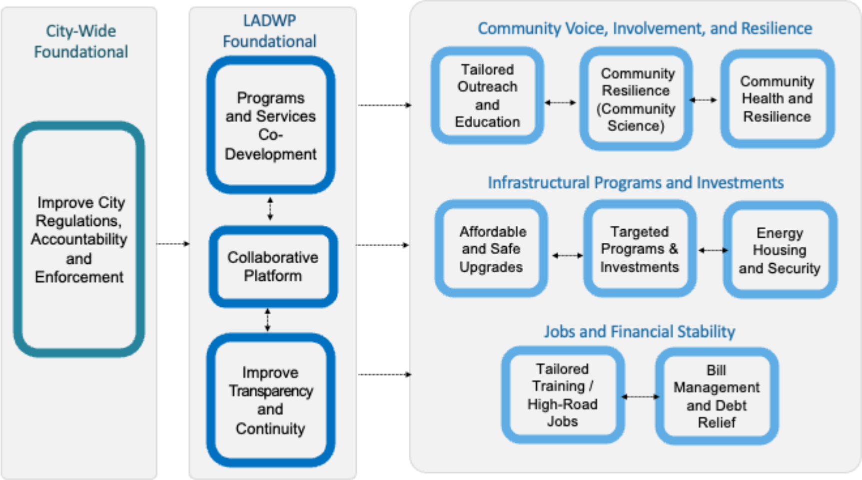


Figure ES-3. Mapping of energy equity strategies

- **City-Wide Foundational (Figure ES-3 and Table ES-1): Improve regulation, accountability, and enforcement for safe, affordable, and efficient infrastructure and housing.** Improvements in regulation, accountability, and enforcement include inspection and monitoring to support housing maintenance and upgrades, regulations, and informational support to prevent unsafe built-environments, and predatory practices among service and technology providers. These strategies and services are beyond the purview of LADWP's authority, yet they are foundational, high-impact backbones for LADWP's success in its energy transition programs, technologies, and policies.
- **LADWP Foundational (Figure ES-3 and Table ES-1): Co-develop programs and services with communities and community-based organizations and improve transparency and continuity.** Effectiveness of LADWP programs can be limited by lack of community involvement in priority setting and decision-making. LADWP can rely on its dedicated personnel and resources and a collaborative platform discussed in Chapter 4 to engage residents in developing programs and services that meet their needs and priorities. Engaging residents in ongoing, more consistent, transparent, and community-adapted outreach and communication builds trust, buy-in, and a continuous feedback loop for decision-making.
- **Develop a collaborative platform** to provide an effective organizational means for an ongoing engagement. LADWP's Corporate Strategy Communications Division; the Diversity, Equity, and Inclusion Office; and the Customer Service Operations could (1) formalize the current LA100 Equity Strategies' Steering and Advisory Committees and other partnerships and collaborations into long-term agreements to maintain a continuous feedback loop with community partners, trusted messengers, and residents, and (2) allocate dedicated personnel and resources to co-design, implement, and evaluate the multiple energy equity projects, technologies, and programs involved in LA's just energy transition. A continuous feedback loop would allow all participants to benefit from and contribute to LADWP's success (for details, see Chapter 4).

- **Community Voice, Involvement, and Resilience (Figure ES-3 and Table ES-1) can be achieved by co-developing programs and services and improving transparency and continuity.** Effectiveness of LADWP programs can be limited by lack of community involvement in priority setting and decision-making. LADWP can rely on its dedicated personnel and resources and the suggested collaborative platform to engage residents in developing programs and services that meet their needs and priorities. Engaging residents in ongoing, more consistent, transparent, and community-adapted outreach and communication builds trust, buy-in, and a continuous feedback loop for decision-making.
  Also important is to provide **tailored outreach and education** through local trusted messengers to build awareness of energy programs, train communities on how use resources related to upgrading electrical panels and retrofitting buildings, and foster community health and resilience. A lack of trust in government agencies and misunderstanding of how community members access outreach information can limit access to LADWP programs. LADWP could build on its Community Partnership Grants and Science Bowl to (a) inform ratepayers about the options and benefits of programs, services, and technologies and (b) incorporate energy-related resources into the community science and the promotora (health promoter) educational methods. These strategies are impactful means to foster parity in access to energy programs, increase community health and resilience, and build trust and buy-in with local communities.
- **Infrastructural Programs, Technologies, and Investments (Figure ES-3 and Table ES-1).** Without upgrading outdated housing and equipment like home service panels, residents cannot install the infrastructure needed to support clean energy technologies. Three strategies address these challenges: *(1) affordable and safe upgrades of infrastructure, buildings, and electric panels, (2) programs and investments targeting* solar and storage, EVs, and grid upgrades in underserved communities, and *(3) programs fostering clean energy and housing security*, for instance, by avoiding affordable housing loss and eviction, and monitoring housing safety needs. LADWP could expand programs like the Home Energy Improvement Program (HEIP), the Comprehensive Affordable Multifamily Retrofits (CAMR), and rely on other city initiatives (e.g., Stay Housed LA, Table ES-1) to develop these recognition strategies. They could collaborate with the Metro and Housing Authority of the City of Los Angeles to provide affordable energy and home upgrades fostering affordable access to solar, storage, EVs, and other technologies.
- **Jobs and Financial Stability (Figure ES-3 and Table ES-1) includes tailored job training, and bill management and debt relief.** These strategies seek to foster Angelenos power to determine their own energy future by enhancing access to well-paid jobs, training, and entrepreneurship in underserved communities. Such strategies could include expansion of LADWP programs like the Utility Pre-Craft Trainee Program, the Low-Income Discount Program, and the Lifeline Discount Program. These programs provide LADWP with opportunities to address structural inequities by supporting residents of frontline and underserved communities – particularly the youth – with pathways for more sustainable livelihoods and options to decrease their energy burdens.

In summary, this chapter presents community-guided strategies for LADWP and related government agencies to begin redressing barriers to energy equity. The strategies developed through community engagement and accompanying analysis can lead the way to more accessible and equitable programs and technologies in the LA clean energy transition.

Table ES-1. Equity Strategies for Procedural and Recognition Justice in Los Angeles

Equity Strategy	Implementation Entity	Existing Programs	Assessment Metrics
1: Programs and Services Co-Development	LADWP, HACLA, Metro	LIHEIP, RETIRE, REP, ESAP, Community Grants	% of enrollment, % of households eligible, Number of programs and services
2: Tailored Outreach and Education	LADWP	HEIP, RETIRE, REP, ESAP, Adopt a School, Community Grants	% of ratepayers aware of programs, Programs using trusted messengers
3: Tailored Training / High-Road Jobs	LADWP, LATTC	UPCT, Lineman	% of enrollment, % of enrolled Angelenos with LADWP jobs
4: Bill Management and Debt Relief	LADWP	EZ-SAVE Program, Level Pay, LIDP	% of enrollment, % of households eligible, Shutoff protections
5: Community Resilience (Community Science)	LADWP, LAUSD	LADWP Science Bowl, Neighborhood Scientists	Number of programs, Quality of programs
6: Improve Transparency and Continuity	LADWP, HACLA, Metro	HEIP, RETIRE, REP, ESAP	% of enrollment, Improvement in transparent reporting
7: Affordable and Safe Upgrades	LADWP, HACLA, Metro	EE, EVs, LIHEIP, Weatherization Shared Solar, Cool LA	% of structural energy upgrades per type – e.g., solar, panels – benefiting underserved communities
8: Targeted Programs and Investments	LADWP, HACLA, Metro, LAUSD	EE, EVs, Solar, HEIP, RESAP, Cool LA, CAMR	% of sectoral investments and programs per type – e.g., solar panels – benefiting underserved communities
9: Energy and Housing Security	LADWP, HACLA, Metro City of Los Angeles	LADWP Customer Service, City of Los Angeles online services, Stay Housed LA	% of underserved ratepayers benefiting from: (a) Eviction protections, (b) Monitoring and enforcing programs
10: Community Health and Resilience	LADWP, LA Care Churches	LADWP Science Bowl, Health Promoters	Number and quality of programs using trusted messengers
11: Improve City Regulations, Accountability, and Enforcement	City of Los Angeles,	HEIP, Solar, EVs, EE	Monitoring and enforcement of (a) upgrade and safety programs (b) and service and technology providers
12: Collaborative Platform (see Chapter 4)	LADWP	All programs	Number and quality of collaborative programs

CAMR = Comprehensive Affordable Multifamily RetrofitsESAP = Energy Savings Assistance Program

EZ-SAVE Program = Low-Income Discount Program

HACLA = Housing Authority of the City of Los Angeles

HEIP = Home Energy Improvement Program

LATTC = Los Angeles Trade-Technical College

LAUSD = Los Angeles Unified School District

LDP = Lifeline Discount Program

REP = Refrigerator Exchange Program

RETIRE = Refrigerator Turn-In and Recycle

UPCT = Utility Pre-Craft Trainee Program

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1 Introduction

Los Angeles' transition to equitable and zero-carbon energy in sectors such as housing, transportation, and electricity will not merely involve technical and infrastructural changes. This transition will also require seismic shifts in investments, community safety nets, resources, and integrative policy strategies to successfully achieve more equitable outcomes (Dubash et al. 2022; Romero-Lankao et al. 2018a). Strategies that target sociocultural and institutional factors are as crucial as those targeting techno-infrastructural factors (Cherp et al. 2018).

Concerted efforts are currently being made to redress the disproportionate distribution of investments in physical infrastructure and energy efficient technologies across Los Angeles. While important, these efforts alone cannot rectify Los Angeles' past and ongoing energy inequities. First, there must be an understanding of *why* past investments were inequitably distributed (Chapter 1), *what* impact they had on local communities (Chapters 1 and 2), and *how* to develop procedures that center Los Angeles' historically underserved communities in the energy transition decision-making process (Chapter 2). This chapter concentrates on operationalizing the recognition and procedural justice aims outlined in Chapters 1 and 2 by presenting a series of community-guided equity strategies for the LA energy transition and examining *how* to design more equitable processes to develop these strategies (also see Chapter 4).

Various actors will need to participate in the LA energy transition, from transportation and housing officials to commercial firms, community members, and community-based organizations (Avelino 2021). Furthermore, all Angelenos play crucial roles as ratepayers, users of technological solutions, adopters of more efficient energy practices, and voters who influence regulators and policymakers (Sauerman et al. 2020). Incorporating the lived experiences, aspirations, and voices of historically underserved communities in the decision-making process for Los Angeles' energy transition is critical to ensuring more equitable outcomes in the city's future (McCauley et al. 2019; Devine-Wright 2005).

2 Equity Strategies and Just Energy Transitions

2.1 Involving Communities in Equity Strategy Development

The technical and societal elements of energy transition problems and solutions are determined by multiple causal factors that cut across areas such as housing, transportation, the energy system, urban planning, health, and economic development (Rutherford and Coutard 2014; Castán Broto et al. 2020). Problems and solutions involve governmental, private, and civil society sectors and are approached differently across disciplines, from engineering and economics to the social sciences (Sauermann et al. 2020; Romero-Lankao et al. 2018b). Community members have often been excluded from the energy decision-making process (Nowotny 2003; Sauermann et al. 2020; Smith, Stirling, and Berkhout 2005). However, community involvement in strategy development has been found to be essential to addressing the inherent complexity of problems and solutions, improving energy equity outcomes, and achieving "democratically legitimate consent" (Burke and Stephens 2017; Sauermann et al. 2020; Nowotny 2003; Smith et al. 2005).

Two crucial reasons underlie the importance of involving underserved Angelenos in equity strategy development in the LA energy transition. First, avoiding the reproduction of past energy inequities necessitates understanding *why* the current energy system produced disproportionately inequitable impacts across LA communities, what strategies can improve energy equity outcomes, and *how* to design more equitable processes to develop these strategies. Therefore, this chapter follows a just energy transition approach, whereby ordinary Angelenos—particularly in the communities that have been most adversely impacted by the current energy system—have guided our analysis, grounding the identification of a set of priorities and understandings to inform the Los Angeles Department of Water and Power's (LADWP's) energy equity strategies.

Second, a solid body of scholarship (Sauermann et al. 2020; Heaslip and Fahy 2018) has found that energy transition solutions, such as community solar and electric vehicle (EV) infrastructure charging, often prompt not only support but also opposition—particularly if their promoters use top-down, one-way engagement approaches (for details, see Chapter 4). These approaches can contribute to public indifference, and even opposition, because of community and ratepayer uncertainties and concerns about potential safety, health, and energy affordability impacts (Boudet 2019; Devine-Wright 2005; Devine-Wright and Devine-Wright 2009).

Those problems often arise when there is a lack of community involvement and co-ownership in strategy development (Hall et al. 2020). Moving away from top-down engagement approaches, developing co-ownership of knowledge production with local communities can ground institutional understandings of the problem space in residents' lived experiences. Furthermore, incorporating community experiences into research development improves the effectiveness of the analytic models that inform energy strategies and solutions (Sauermann et al. 2020). Particularly for government entities, involving residents in the decision-making process—a key element of procedural justice—fosters community trust in those institutions.

Through equitable community involvement, Angelenos learn about potential benefits, options, and trade-offs while actively participating in decisions about key energy problems and solutions (Sauermann et al. 2020). This inclusive method creates precedents and capacities for long-term, meaningful involvement in energy system decision-making (Burke and Stephens 2017). By centering local understandings and regulating the influence of powerful decision-makers, government entities are able to expand both the effectiveness of and the equity in energy transition outcomes.

2.2 Analytic Approach

In Chapters 1 and 2, we focused on the LA energy transition's problem space—community-identified causal factors and impact areas and the underlying values that condition local understandings of the current energy system and future transition. In this chapter, we move from the problem space to the solution space by presenting a series of community-guided equity strategies. Aligning local community and city concerns with federal priorities[1] (U.S. Department of Energy 2021), we identify those that decrease energy burdens, increase parity in access to transition programs and technologies, increase access to low-cost capital, decrease environmental exposure, improve the clean energy job pipeline and training, and enhance energy democracy. This process of priority alignment and identification of energy equity strategies requires examining options that connect stated priorities to potential avenues for practical application in Los Angeles. Here, we focus on the solution space of our analytic approach laid out in Chapters 1 and 2.

Within the solution space, the *political context* (Figure 1) entails any institutional element that might impact how LADWP, as well as other city officials, approaches a problem and the strategies (actions) to target that problem. In Los Angeles' current political context, LADWP and other city officials can benefit from institutional opportunities (Section 3, page 7)—such as those offered by the federal Inflation Reduction Act of 2022 and the Bipartisan Infrastructure Law—to prioritize equity strategies. Beyond federal incentives, the political context consists of other potential influences, including regulations (e.g., California Propositions 26 and 218), local and state elections and changes to executive or legislative offices, and consensus and coalition building (Sabatier 2007; Bjerkan and Seter 2021).

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[1] Justice40 Policy Priorities: www.energy.gov/diversity/justice40-initiative.

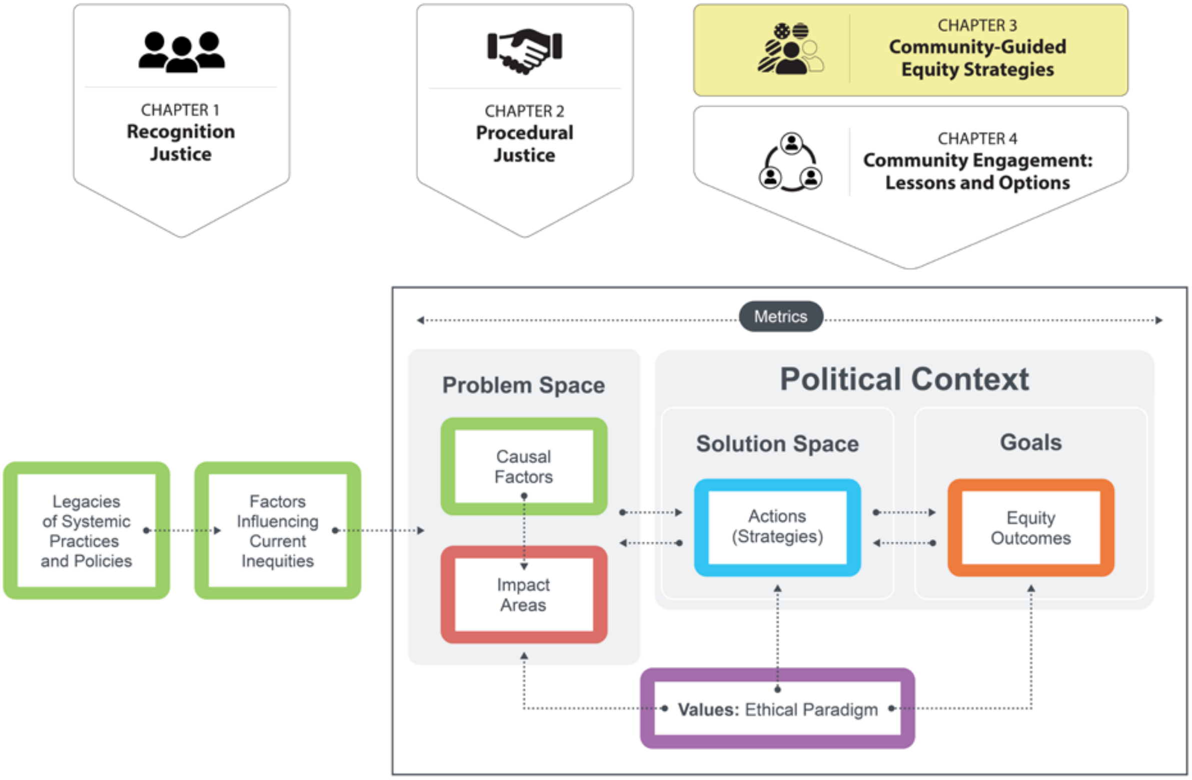

Figure 1. Analytic approach for equity strategy analysis

Equity strategies entail the design, implementation, and evaluation of instruments and programs, which are the means to achieving more equitable energy goals, termed here *equity outcomes* (Figure 1) (Arndt et al. 2017; McCauley and Heffron 2018; Carley and Konisky 2020). Equity strategies include the "what"—the instruments to achieve energy equity outcomes—and "how" those instruments are developed. Implementation refers to any city entity, including LADWP, with remit over equity instruments and the financial and human resources allocated for energy equity program execution, such as LADWP's Refrigerator Exchange Program and their Low-Income Discount Program analyzed in Chapter 1.

However, program implementation is not enough. Policy evaluation is an essential phase of equity strategy development (Dubash et al. 2022). As a critical method of implementing energy justice, this evaluation often focuses on tools and measures to increase a program's environmental effectiveness, economic efficiency, and affordability, and/or lower institutional barriers to implementation (Section 3; Chapters 4–11).

Equity *metrics* are essential to operationalizing and evaluating energy equity strategies and are aimed at creating concrete measures that serve multiple objectives. These aims include categorizing and quantifying forms of disadvantage, assessing the performance of policy design and implementation, or assessing energy equity outcomes for underserved communities in the short and long term (Barlow, Tapio, and Tarekegne 2022; Romero-Lankao and Nobler 2021). Following this understanding, metrics are not inherently targets or indicators of success or failure. To inform or refine solutions, we utilize qualitative methods to develop an evaluation process that evinces why and how such metrics could inform a more transparent and accountable energy transition. Here, we orient our analysis toward the Justice40 policy priorities to ground this energy equity evaluation process in federal justice standards for achieving and assessing energy outcomes (see Section 3).

2.3 Methods

Building on the methodological approach used in Chapters 1 and 2, this chapter analyzes the LA100 Equity Strategies engagement data developed with local communities, stakeholders, and both the Steering Committee and the Advisory Committee to co-design a series of community-guided energy equity strategies. Developing equity strategies to operationalize energy justice in the transition to clean energy is a complex endeavor, which requires a two-step approach:

1. Grounding strategy analysis in lived local realities. This entails assessing community-informed strategies that improve access to energy services and technologies that are affordable, accessible, safe, resilient, reduce negative impacts on health and quality of life, and provide opportunities for workforce development. Therefore, we organized community engagement around four *crosscutting areas prioritized* by Steering Committee members, as well as academic literature on energy justice and in U.S. policymaking (e.g., Justice40). This chapter adds *inclusive community involvement* as an additional (fifth) crosscutting area (see Section 3).
2. Evaluating energy strategies based on a series of criteria (e.g., responsible entity, benefits) and metrics that can assist LADWP in identifying the most effective strategies for improving equity in the Los Angeles energy transition (Section 3). Not all criteria are applicable to all strategies or in all circumstances, and the relative importance of diverse criteria depends on the strategy objectives (see Konidari and Mavrakis 2007 and Cohen et al. 2019 in (Dubash et al. 2022)).

The listening sessions (Chapter 2), which center community voices in the development of LADWP's equity strategies, were divided into two phases. First, the National Renewable Energy Laboratory, LADWP, and the partnering community-based organizations from the Steering Committee co-designed five listening sessions adapted to the realities of five LA regions: two regions of South LA, East LA, San Fernando Valley, and the Harbor Region. To design the sessions, we grounded them in a mutual understanding of context-specific (in)equities in the following crosscutting priority areas:

1. Affordability and burdens
2. Access to City of Los Angeles and LADWP infrastructure, services, and programs
3. Public health, safety, and community resilience
4. Jobs and workforce development

Coding and content analysis of the first round of listening sessions conducted in March and April 2022 revealed a set of causal factors, impact areas, and underlying values that helped focus and refine questions for the remaining 10 listening sessions conducted from September to December 2022.

Chapter 2 laid out in detail how the National Renewable Energy Laboratory developed the methodological and analytic approach to community engagement, utilizing ground theory and both deductive and inductive analysis. (See also Annex and Azungah 2018). We began by organizing community engagement activities around the four prioritized crosscutting areas described above. We then utilized these prioritized areas deductively (top-down) to design all listening sessions. We utilized qualitative coding to identify categories and concepts in the data and link passages of 15 listening session transcriptions to themes that became labeled with a particular "code." When two themes were identified in the same passage, we labeled that intersection "overlapping codes." Key findings emerged as we used the frequency of overlapping codes to analyze key relationships between energy equity issues and solutions.

In this chapter, we add *inclusive community involvement* as an additional (fifth) crosscutting area. We present solutions to energy justice problems proposed by community members over the course of the listening sessions. These solutions formed the basis for the assessment of community-guided strategies. These strategies relate to how LADWP and other government entities can redress ongoing causes of inequity across energy-related sectors through the design, implementation, and evaluation of programs for underserved Angelenos. Thus, the following subsections examine information—segments of listening session text—shared by members of those communities that we coded as related to "future programs, support, and policies." These segments also overlap with causal factors and/or impact areas, connecting the problem space identified by community members with their suggested solutions for redressing past and existing inequities.

3 Energy Equity Strategies

This section presents 11 community-guided strategies seeking to improve access to affordable, safe, and resilient energy services, technologies, and programs. These improvements range from the reduction of negative impacts on health and quality of life to creating opportunities for workforce development in the green economy. Many strategies also include a focus on procedural justice: the procedures, practices, and decision-makers involved in designing, implementing, and evaluating benefits such as LADWP programs. Some strategies also operationalize recognition justice by examining energy strategies that redress the structural legacies of energy inequity. Yet other strategies focus on both procedural and recognition justice.

Below we describe how each strategy addresses community-identified issues related to procedural justice and/or recognition justice. While community members and community-based organization shared a rich set of strategies, this chapter focuses on the recurrence (saturation) of solutions provided, the quality of the proposed strategies (i.e., their ability to address community-identified needs and barriers), and their viability for implementation.

Below, we examine quotes from listening session participants organized in the following 11 energy equity strategies, connecting them to the problem space and five crosscutting priority areas (see also right column of Figure 2, page 9):

- **Equity Strategy 1:** Engage Residents in Developing Programs and Services Targeting Community Priorities (Programs and Services Co-Development)[2]
- **Equity Strategy 2:** Co-Design Community Outreach with Local, Trusted Messengers (Tailored Outreach and Education)
- **Equity Strategy 3:** Expand Job Programs that Provide Equitable Access to Training Opportunities and High-Road Jobs (Tailored Training / High-Road Jobs)
- **Equity Strategy 4:** Tailor Strategies for Providing Debt Relief and Preventing the Accumulation of Debt (Bill Management and Debt Relief)
- **Equity Strategy 5:** Support Community Science Through Programs that Foster Community Health, Resilience, and Well-Being (Community Resilience (Community Science))
- **Equity Strategy 6:** Improve Continuity, Transparency, and Accountability in Program Participation (Improve Transparency and Continuity)
- **Equity Strategy 7:** Affordable Programs to Safely Upgrade and Remediate Existing Housing and Infrastructure (Affordable and Safe Upgrades)
- **Equity Strategy 8:** Prioritize Disadvantaged Angelenos in Energy Transition Programs and Investments (Targeted Programs and Investments)
- **Equity Strategy 9:** Programs to Foster Energy and Housing Security and Safety (Energy and Housing Security)

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[2] The text within parentheses represents the short title of each strategy, which is used in the Sankey diagrams and Table 1 (page 11) in this chapter.

- **Equity Strategy 10:** Invest in Programs that Build Community Resilience (Community Health and Resilience)
- **Equity Strategy 11:** Improve City Regulations, Accountability, and Enforcement (Regulations, Accountability, and Enforcement).

The codes on the left in Figure 2 (page 9) represent the number of times community members made comments related to problems, such as those related to past and current LADWP programs and suggestions for solutions to future LADWP programs. We quantified this number of intersections as overlapping codes. Based on the analysis of these overlaps, we developed the 11 community-guided equity strategies that are listed in the center of the diagram (also see Table 1, page 11). The right column in Figure 2 connects these solutions to the five crosscutting priority areas:

1. Affordability and burdens
2. Access and use
3. Health, safety, and community resilience
4. Jobs and workforce development
5. Inclusive community involvement

Figure 2 depicts how the equity strategies (middle) connect with the crosscutting priority areas. Figure 3 (page 10) shows how the outcomes (right) of these equity strategies align with key policy priorities. Table 1 summarizes a series of actionable building blocks for LADWP to design, implement, and evaluate the 11 strategies, including:

- Relevant LADWP or governmental entity (implementation entity)
- Existing programs LADWP can build on in the near term
- Specific assessment metrics for success.

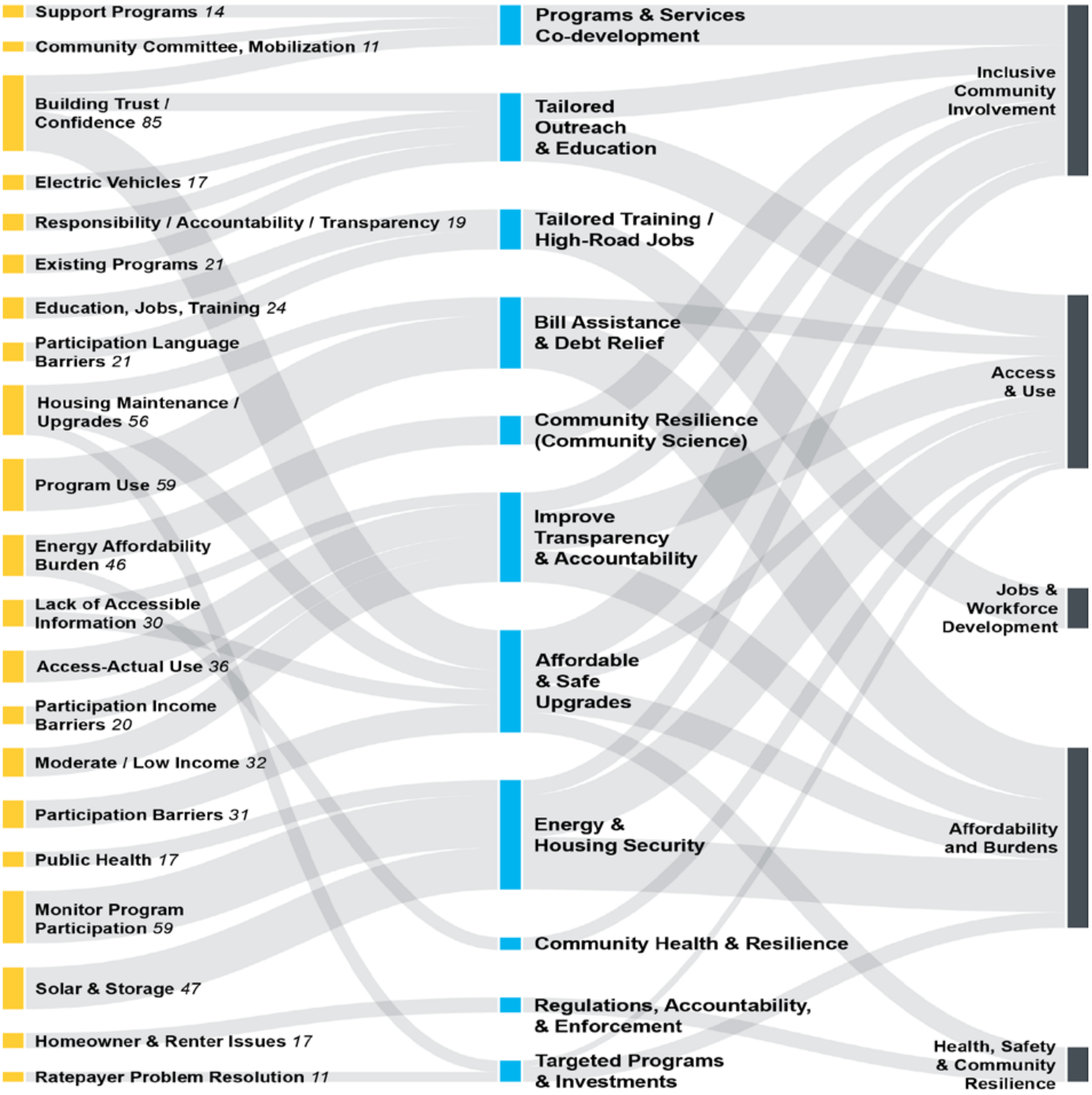

Figure 2. Strategy development analysis: Problem space (left), equity strategies (middle), and priority areas (right)

The numbers on the left in this figure represent the number of times community members made intersecting comments related to the problems on the left and suggestions for solutions to future LADWP programs. We quantified this number of intersections as overlapping codes. Our analysis of these overlaps developed a series of community-guided equity strategies that are listed in the center of the diagram. The right column reveals how these equity strategies relate with five crosscutting priority areas: affordability and burdens; access and use; health, safety, and community resilience; jobs and workforce development; and inclusive decision-making. (For details on how these were identified, see Section 2.2, page 3.)

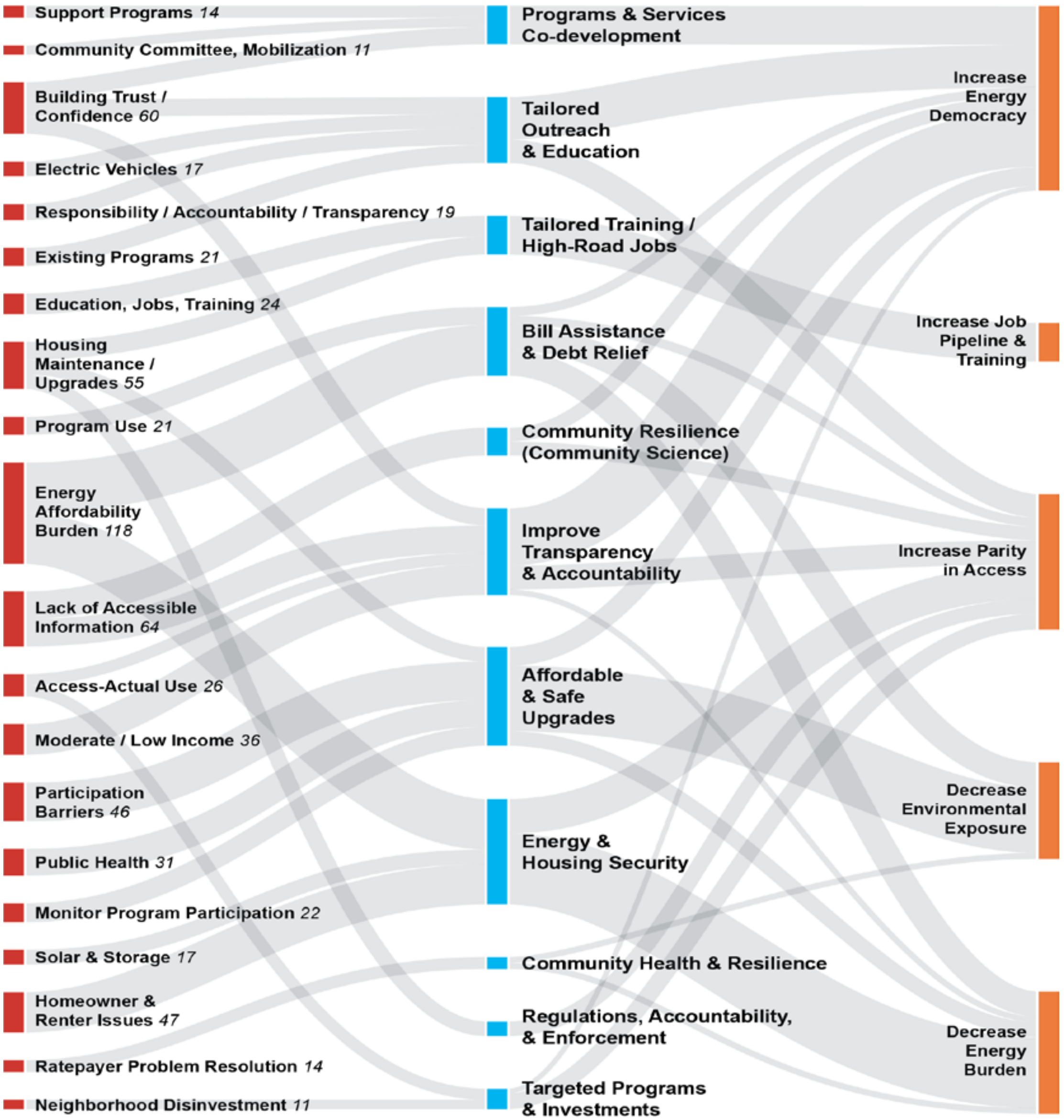

Figure 3. Strategy development analysis: Problem space (left), equity strategies (middle), and energy equity outcomes (right)

The numbers on the left represent the number of times community members made intersecting comments related to the problems on the left and suggestions for solutions to future LADWP programs. Our analysis of these overlaps developed a series of community-guided equity strategies that are listed in the center of the diagram. The right column reveals the outcomes of these equity strategies align with key policy priorities identified through a literature review. (For details on how these were identified, see Section 2.2, page 3.)

Table 1. Equity Strategies for Procedural and Recognition Justice in Los Angeles

Equity Strategy	Implementation Entity	Existing Programs	Assessment Metrics
1: Programs and Services Co-Development	LADWP, HACLA, Metro	LIHEIP, RETIRE, REP, ESAP, Community Grants	% of enrollment, % of households eligible, Number of programs and services
2: Tailored Outreach and Education	LADWP	HEIP, RETIRE, REP, ESAP, Adopt a School, Community Grants	% of ratepayers aware of programs, Programs using trusted messengers
3: Tailored Training / High-Road Jobs	LADWP, LATTC	UPCT, Lineman	% of enrollment, % of enrolled Angelenos with LADWP jobs
4: Bill Management and Debt Relief	LADWP	EZ-SAVE Program, Level Pay, LIDP	% of enrollment, % of households eligible, Shutoff protections
5: Community Resilience (Community Science)	LADWP, LAUSD	LADWP Science Bowl, Neighborhood Scientists	Number of programs, Quality of programs
6: Improve Transparency and Continuity	LADWP, HACLA, Metro	HEIP, RETIRE, REP, ESAP	% of enrollment, Improvement in transparent reporting
7: Affordable and Safe Upgrades	LADWP, HACLA, Metro	EE, EVs, LIHEIP, Weatherization Shared Solar, Cool LA	% of structural energy upgrades per type – e.g., solar, panels – benefiting underserved communities
8: Targeted Programs and Investments	LADWP, HACLA, Metro, LAUSD	EE, EVs, Solar, HEIP, RESAP, Cool LA, CAMR	% of sectoral investments and programs per type – e.g., solar panels – benefiting underserved communities
9: Energy and Housing Security	LADWP, HACLA, Metro City of Los Angeles	LADWP Customer Service, City of Los Angeles online services, Stay Housed LA	% of underserved ratepayers benefiting from: (a) Eviction protections, (b) Monitoring and enforcing programs
10: Community Health and Resilience	LADWP, LA Care Churches	LADWP Science Bowl, Health Promoters	Number and quality of programs using trusted messengers

Equity Strategy	Implementation Entity	Existing Programs	Assessment Metrics
11: Improve City Regulations, Accountability, and Enforcement	City of Los Angeles, LADWP	HEIP, Solar, EVs, EE	Monitoring and enforcement of (a) upgrade and safety programs (b) and service and technology providers
12: Collaborative Platform (see Chapter 4)	LADWP	All programs	Number and quality of collaborative programs

CAMR = Comprehensive Affordable Multifamily Retrofits

ESAP = Energy Savings Assistance Program

EZ-SAVE Program = Low-Income Discount Program

HACLA = Housing Authority of the City of Los Angeles

HEIP = Home Energy Improvement Program

LATTC = Los Angeles Trade-Technical College

LAUSD = Los Angeles Unified School District

LDP = Lifeline Discount Program

REP = Refrigerator Exchange Program

RETIRE = Refrigerator Turn-In and Recycle

UPCT = Utility Pre-Craft Trainee Program

Strategy 1: Engage Residents in Developing Programs and Services Targeting Community Priorities

Program and service co-development implements both recognition and procedural justice and contributes to inclusive decision-making (Figure 2). Listening session participants suggested fostering intentional energy strategies—procedures, partnerships, and practices—that engage residents from underserved communities in developing programs and services that meet their needs and priorities. They highlighted the need for transitioning away from, as one participant explained, the status quo “transactional extraction of information to check the box. To say yes, we engaged.” Instead, she asked LADWP to approach her community with respect and transparency, stating:

> We consider you all to be experts in your community, and we'd like to authentically engage with you in the decision-making process. And here are the decisions and the entry points in order to do that. And again, I think this is predicated on a general distrust among the community from the [LA]DWP. So, I do think there needs to be some intentional actions for that rapport building and that trust building.

Rather than an extractive process, “authentic” LADWP engagement that incorporates Angelenos into the decision-making process requires the time to repair mistrust and build rapport with relationships of respect.

The mistrust this participant refers to comes from a history of injustice that still marks community members’ everyday lives. The ongoing legacy of redlining—the practice of discriminatory mortgage lending examined in Chapter 1—became a point of departure for redressing inequities by identifying where to center engagement and investment in Los Angeles. As one request explained:

> …this is where the technology comes in. For centuries we have been marked by redlining, they know which communities are most in need. And this is where [using] technology to our advantage comes. [To know where] to start, what places [need to] have access, obviously, [to pay for] the cost of a better life. And this [redlining] map was much earlier than technology. Because it is a current map, where they marked us [and decided] they are not going to make more loans here, because there are more brown people, there are more people of other races that they will not have to pay. But there they are…if LADWP wants to start something, they can start there [in the redlined areas].

Beyond grounding LADWP's direction to focus engagement efforts and technology investments in communities that continue to live with the consequences of legacies of institutionalized injustice, it is still vital to consider how that relationship between LADWP and these communities will be rebuilt. Remediating the ongoing negative effects of structural inequities requires fostering their relationship with overburdened communities to understand how these inequities are experienced and manifested in their everyday lives.

One resident highlighted that this type of community engagement is not a siloed effort. It is only possible if LADWP listens to community needs as they design Los Angeles' clean energy future, particularly with regard to developing services that redress existing risks and burdens, such as health and safety. She told us that:

> Our community has a lot of pollution and a lot of problems, and I know that DWP is making plans to change the energy we receive. Not just solar, not just wind, not just oil, but they're also considering things like green hydrogen and all that. And I just hope that they are listening very well to what people are telling them: that they are tired of the pollution, they deserve more and want better services [from] DWP.

This participant asks LADWP to prioritize redressing the problem of local pollution as one negative effect of the current energy system that disproportionately impacts their community. However, her request moves beyond a singular focus on the problem of pollution to highlight the problems of existing engagement processes that allow such negative effects to continue and, at times, proliferate. She emphasizes a need for LADWP to be active listeners, tailoring their services to remediate community-identified problems and allow these residents to live their lives with dignity. Yet, how will LADWP build this dedicated space for listening to community members and responding to their requests? One resident had a powerful suggestion; she proposed developing a community committee for energy-related decision-making:

> And I also think we need a committee from the community, for the community where we can make energy decisions. That LADWP make us part of decision-making, rather than us being part of LADWP, so that our community [has a voice]. Because many times there are no such committees, or at least if there are I am not aware of them. I have tried to investigate a lot of this, where we also take

> part in program decisions and our needs are considered. Because you have to be realistic. The owner of the restaurant is not the same as the person who is going to eat there, never. And vice versa. So, it's good to have both sides because if we don't have both sides, the organization [LADWP] just by coming and listening to us can't be aware of everything that's happening. Some will say, the problem was the dealer and others will say, no, the problem was DWP. Others will say who structured the program? But the problem really comes from when the project was established, and all these problems were not channeled. Who is going to take responsibility if the [EV car] dealer wants to impose [an interest] rate of 20 percent? Who is going to take care of this? There is no committee, there is no one to follow up on this. So, I think that if we want to [address] these problems, we have to create committees….

This proposal for a community committee recognizes the importance of understanding both LADWP and community needs, concerns, and priorities. She also argues that active listening on the part of LADWP is not enough to truly tailor programs and services to specific community priorities. From her perspective, understanding the roots—causal factors—of the program problems and following through with their resolution can only be successful if there is a dedicated group of community experts who have lived, on-the-ground experience with energy-related issues and can utilize that expertise to inform LADWP decision-making. The scope and timeline of this type of collaborative work between communities and government agencies was discussed by another participant, who shared her experience with a development project in East LA. Before finalizing the project scope, she explained:

> I went to Mariachi Plaza [in East LA]. What we were saying is, we gotta send you a plan with the developer. And the developer is going to convince the community how to work the plan. Community says, no, we want to be a part of the planning. We had to as a commission say, we will stop. We will do it right. The community will speak to us before there is a plan. Before there is a proposal. And it's taking almost eight years to get the project going. But now the entire process, by which decisions are made, means you start with the community. So DWP is never going to get the message, unless they stop, and start with the people who are the consumers…We now have to understand the people who come with, lived the experiences and issues and problems we are trying to solve. Probably have a better mouse trap than we have. And DWP needs to get that.

This participant is emphasizing not only the scoping requirement of "start[ing] with the community," integrating them into the planning process—a form of inclusive policymaking; she is also calling attention to how long this type of work takes. It took them "almost eight years" to "do it right" by the community. If LADWP wants to solve these problems, according to this participant, they need to restructure their project planning, beginning with impacted communities, and adjust their project timelines to co-design and implement programs, (re)build community trust, and attain buy-in.

Existing LADWP programs hold great potential for actualizing this energy equity strategy for centering community priorities. LADWP could build on existing programs, such as the Home Energy Improvement Program (HEIP) and Energy Savings Assistance Program (ESAP), to engage residents in program development and decision-making processes. Such engagement in program expansion is an opportunity to increase energy democracy, decrease energy burden, and increase parity in clean energy technology access and adoption in underserved communities (see right column of Figure 3, page 10). To monitor performance as well as maintain transparency and accountability, LADWP could also develop and employ assessment metrics, such as the percentage of underserved communities enrolled in LADWP programs out of total enrollment, the percentage of LA households eligible for specific program participation and services, and the number of programs and services benefiting underserved communities (see metrics suggested in Table 1, page 11).

Strategy 2: Co-Design Community Outreach with Local, Trusted Messengers

Tailored outreach and education programs can operationalize procedural justice by developing inclusive policymaking that fosters parity in access to services, programs, and technologies (Figure 3). Los Angeles' energy transition requires procedures and programs that build partnerships with local communities. Those actions become the methods used to ground transition goals and equity outcomes in the ideas, visions, and experiences of communities that have historically been excluded from the energy system decision-making process. However, two key barriers to building those partnerships are: (1) on the community side, a lack of trust in government agencies; and (2) on the institutional side, a misunderstanding of how community members access and process outreach information and activities. To redress the latter by co-designing outreach in inclusive policymaking with residents, LADWP could first develop a partnership with local trusted messengers. These trusted messengers not only help their neighbors navigate institutional landscapes and government mistrust, but they also understand their community's needs, aspirations, and modes of gathering and processing information. Thus, this equity strategy entails how to identify and partner with local trusted messengers to build community relationships, as well as how that partnership helps LADWP tailor outreach to local communities to provide accessible information and educational opportunities.

Listening session participants mentioned several trusted messengers. Two prominent types were *promotoras de salud* (community health workers) and local faith-based organizations and institutions. *Promotoras de salud* (also known as *promotoras*) are community health workers, seen as trusted messengers guiding local residents in their Latino communities through the complex health care system. They utilize their knowledge of local sociocultural norms to provide their neighbors access to relevant health and social resources. Several *promotoras* attended the listening sessions in South LA and East LA. A recurrent sentiment in those sessions was how energy education and outreach could benefit from incorporating *promotora* methods of community engagement. As one *promotora* participant noted:

> One strategy would also be—what we're doing right now—to provide educational opportunities for more people. To help them reflect on how to avoid destroying our planet. We are, because we are all in this world...Just like what we're doing right now, reaching more people. We are part of an environmental health committee, and we are promotoras. So, we go out onto the streets, we hand out flyers. We talk to people, helping them understand. And you know that the promotora model works well because the community knows us. So, they trust us. Here comes the lady who...let's see, tell us. They listen to us. They have the

> confidence to tell us “it's true, you're right,” I'm going through the same thing as you ... So, I think that spreading this information would be a very good idea. Doing awareness workshops and also providing information through promotoras … that walk through the community and the community knows us.

By incorporating energy education into a social network of trusted messengers—*promotoras*—that already exists in their communities, this participant is suggesting that both LADWP and residents will gain benefits. Educational content, from awareness workshops to general information, will be more accessible to local residents, given the *promotoras* knowledge of local learning norms, and LADWP will gain the trust needed to co-design outreach that builds a feedback loop with local communities.

Along these lines, residents also pointed to a need for including educational programs in trusted community spaces as part of the energy-related decision-making process. One resident suggested partnering with local leaders of faith-based organizations in his community to build trust and equity strategies that are embraced because they are grounded. He told us:

> I think education needs to be up front. And it has to be education directed to the lower-income people and also moderate-income people. Who, frankly, aren't convinced that electric is the way to go. Second, when it comes to churches. Churches have historically been the way that a lot of education is disseminated. A number of pastors in small churches, medium size churches, aren't on board yet. It's going to be difficult to push this forward without them … if you are talking electric vehicles, I would also like to see a partnership with the churches. And maybe these electrical stations, maybe they receive that. Education happens in front of the churches as a catalyst to bring people onboard.

Paying particular attention to the spaces of historical trust in his community, this participant explains that “partnership with the churches” is one method of developing educational opportunities in trusted community spaces. Emphasizing that his community of lower- and moderate-income Angelenos does not trust electric mobility as their most viable option for the future, he points to the pitfalls of prevailing methods—top-down methods of educating communities about the energy transition. By localizing education about new technologies in spaces of historical trust (i.e., workshops about EV chargers hosted by community institutions), he sees an opportunity for expanding local understanding of, trust in, access to, and use of new energy technologies, such as electric mobility.

Finally, this partnership with local trusted messengers would also help LADWP identify the various methods that could be used to connect with different groups of people across the city. As one resident explained:

> I think that another thing that could help our community a lot is to provide more information. And not only to the people who are registered on the bills. If not, to do radio campaigns, television campaigns. I never see them. We could invest in that. Make television campaigns, radio campaigns. So, I think the outreach for our community could be bilingual. There are a lot of people who are starting to understand English more now. And people who didn't speak Spanish are starting to speak Spanish. So, I think that's another way we can reach out to these people.

This participant points to different modes of communication to prioritize in her community that ensures information is accessible, including not only investing in social media, but also in radio and TV campaigns that are bilingual, in English and Spanish. She sees this type of communication and information strategy as moving beyond a singular focus on homeowners—"the people who are registered on the bills"—to reach the Angeleno renters who use the energy in their homes daily. These are the types of equity strategies that develop when government entities co-design community outreach campaigns with local trusted messengers who know their communities.

To redress community mistrust and lack of clear, accessible, and trusted information on program participation and services, LADWP could build on its existing Community Partnership Grants program and community-based events to co-design community outreach with residents. LADWP could utilize the *promotora* model (see Table 1, page 11) and develop partnerships with trusted community entities, such as faith-based organizations, to ground their outreach activities. This procedural justice equity strategy—from partnership with trusted messengers and localizing efforts in spaces of historical trust, to reaching out via familiar communication methods—aims to produce equity outcomes that prioritize the need to (1) increase energy democracy in underserved LA communities and (2) increase parity in clean energy technology access and adoption across Los Angeles (see right column of Figure 3, page 10). To monitor performance as well as program accessibility, LADWP could also develop and employ assessment metrics such as the percentage of ratepayers aware of LADWP programs and number of programs partnering with trusted messengers for outreach and/or application (see metrics suggested in Table 1).

Strategy 3: Expand Job Programs that Provide Equitable Access to Training Opportunities and High-Road Jobs

Workforce development programs that provide equitable access to tailored training and high-road jobs[3] are crucial to implement procedural and recognition justice in the crosscutting priority area of jobs and workforce development (Figure 2). Throughout the listening sessions, participants stressed that community members' abilities and power to make decisions concerning the current energy system and the future transition are deeply connected to guaranteeing equitable access to workforce training and well-paid jobs in their communities—called "high-road jobs" by Steering Committee members and some participants. As one resident in Watts put it:

> In my humble opinion, we should be considered. I don't ask for free giveaways, I ask for a good job with a good salary for [the people of] the city of Watts. Because companies come and bring workers. And they don't benefit the residents

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[3] The term "high-road jobs" was utilized repeatedly by community-based organizations in the Steering Committee over the course of LA100 Equity Strategies. Following the report "Putting California on the High Road: A Jobs and Climate Action Plan for 2030," we understand these jobs as part of the "high-road economy [which] supports businesses that compete on the basis of the quality of their products and services by investing in their workforces; these businesses pay the wages and benefits necessary to attract and retain skilled workers, who in turn perform high-quality work. Building the high road requires interventions on both the demand side and the supply side of the labor market. Supply indicates workers and the institutions that train them; demand refers to jobs and the firms or institutions that offer them" (Zabin 2020, 6).

> [living] there. They should give jobs to every community where they work. They should give jobs to the people of the community there with good pay. And that, in my opinion, would [be the help I need].

Other residents highlighted the importance of nurturing local energy-related entrepreneurship programs as a co-benefit of the energy transition, supporting community resilience and improved energy efficiency. As one participant stated:

> I know what I'm doing. I've already started it. Here through this space, because of the actual development with the Resiliency Hub and Climate Resolve and the work I do with … schools, we started the Mural Workforce Academy. So, we are starting small and building a workforce of young artists, to teach them how to use this [mineral] paint [that keeps building façades cooler].

Here, this participant clearly reveals how programs investing in the community skills and materials needed to increase energy efficiency has a significant co-benefit of addressing their entrepreneurship needs. Access to these types of skillsets and resources makes energy more affordable for residents as the façades they paint insulate their homes, decreasing the need for energy-intensive cooling technologies such as air conditioners.

While some participants called attention to directing large companies located in their communities to invest in local workforce development, other residents emphasized how to guarantee equitable access to well-paid career opportunities by investing in the expansion of job training and placing programs. As one participant explained:

> We human beings have many abilities. And sometimes … it [happens] that what perhaps she can do, I cannot do. So, sometimes there are barriers for some people, let's say in technology and all that. And sometimes it is very difficult for them to get a job here in Los Angeles. So, it would be good if there were some [mechanism], I don't know, some organization, that when these people need help, perhaps for their rent, they can be provided [with support to] find a job. And say, what skills, what can you do. So that [these people] can have a monthly livelihood, to be able to support themselves and their family. And I believe that this way we will be able to get out of the level of poverty in which we find ourselves.

As this quote highlights, affordability is not just about income but also about access to the resources, services, and opportunities that lead to sustainable livelihoods and to a vibrant economy. Guaranteeing affordability for all Angelenos to "support themselves and their family" requires guaranteeing equitable access to the workforce opportunities that sustain their "monthly livelihoods." This participant's observation points to a pathway for achieving sustainable livelihoods for residents of frontline and underserved communities by identifying local skillsets, guaranteeing training to bolster their capabilities, and finally, connecting that education to high-road jobs in the green economy.

To expand job programs that provide equitable access to training opportunities and high-road jobs, LADWP could expand their existing training programs by identifying, utilizing, and enhancing local skillsets. LADWP's Utility Pre-Craft Trainee (UPCT) program currently offers Angelenos from frontline and historically underserved communities an opportunity for entry-level jobs and training for work in the green economy, providing trainees with high-road career pathways (Scott and Zabin 2016). LADWP could expand its UPCT, Lineman, and Civil Servant programs to prioritize increasing clean energy jobs and access to the job pipeline, as well as job training for individuals from historically underserved communities (right column of Figure 2 on page 9 and Figure 3 on page 10). Considering training part of a larger educational investment, LADWP could coordinate with entities such as Los Angeles Trade-Technical College (LATTC) that provide institutional support and broaden access to future job opportunities. To monitor performance as well as support sustainable careers in the green economy, LADWP could also develop and employ assessment metrics such as the percentage of underserved communities enrolled in LADWP programs out of total enrollment and the percentage of underserved Angelenos enrolled in LADWP job training programs (see metrics suggested in Table 1, page 11). Scaling up and tailoring this earn-and-learn workforce training model can increase the job pipeline, an important procedural and recognition justice strategy as the city transitions to clean energy.

Strategy 4: Tailor Strategies for Providing Debt Relief and Preventing the Accumulation of Debt

Procedural justice strategies democratizing energy access entail ensuring the affordability of energy use for all Angelenos. Mechanisms for guaranteeing energy access and use include utility bill management procedures and debt relief options. Such mechanisms could be employed via programs that incorporate community suggestions into debt relief and prevention strategies.

The accumulation of debt was a primary barrier to energy affordability for many listening session participants. Once debt is accrued, paying a monthly electricity bill becomes increasingly more onerous. Yet, participants highlighted that payment methods exist to support ratepayers while maintaining their dignity. An action identified by communities was to design tailored procedural strategies for providing debt relief and preventing the accumulation of debt. One resident outlined a strategy for creating a billing structure for residents struggling with the accumulation of debt that allows them to pay off their debt over time. She told us the following:

> If the bill was split from … [the] starting of the pandemic, to where you said it's over. If that bill was split between what you owe presently and then you work out a payment plan for people, I think that it would be a win-win, and then these improvements can happen, the bills still get paid, Water and Power does get their money, the people are satisfied.

Recognizing that many of the programs LADWP and the City of Los Angeles will develop, such as those fostering clean energies and energy efficiency improvement, will be pushed forward regardless of affordability, this participant emphasizes the mutually beneficial strategy of developing debt relief payment plans. When ratepayers are not overwhelmed by an unaffordable monthly bill but are rather given the option of affordable payments over time, they are able to pay their bills with dignity and support the transition to clean energy in Los Angeles.

Tailoring strategies to prevent debt accumulation and provide debt relief requires understanding debt as a main barrier to energy affordability and use. This strategy also entails identifying and incorporating community suggestions into existing and future energy efficiency programs. LADWP's Low-Income and Lifeline customer discount programs currently provide benefits to underserved communities. LADWP could also collaborate with Los Angeles County Low Income Home Energy Assistance Program (LIHEAP) and Low-Income Household Water Assistance Program (LIHWAP) service providers to decrease energy burdens for underserved Angelenos while increasing energy democracy and community resiliency (see right column of Figure 3, page 10). In addition to low-income communities, moderate-income customers also experience these types of financial burdens. To increase their access and use of clean energy and energy efficiency programs to support affordability, LADWP could expand programs such as the Low-Income and Lifeline customer discounts to moderate-income customers (Table 1, page 11). To monitor energy access and use, LADWP could also develop and employ assessment metrics such as the percentage of low- and moderate-income ratepayers enrolled in LADWP programs out of total enrollment and the percentage of LA households eligible for specific program participation and services (see metrics suggested in Table 1).

Strategy 5: Invest in Programs that Foster Community Health, Resilience, and Well-Being

Investing in programs that foster community resilience supports local capacities to identify and navigate health risks and maintain well-being among community members. One procedural justice method identified by listening session participants was supporting community science by offering home air quality monitors. This is an example of community science (Sauermann et al. 2020; Cooper et al. 2021) critical to fostering community resilience, health, and well-being (Figure 2, page 9). Here, we refer to community science as a community-driven method of identifying both problems and solutions in residents' own neighborhoods. These Angelenos "can help address technical as well as social aspects of problems…[These] problems are not universal but reflect the interests and needs of particular groups" (Sauermann et al. 2020, 13, 5). Particularly in communities historically burdened by energy-related pollution, community science becomes a vital decision-making tool for local community resilience. It creates the conditions for Angelenos to shape energy priorities in their communities along with other stakeholders (Fernandes et al. 2019).

In this case, community science is a method of measuring and mitigating community health risks. In the absence of institutional and structural protections, this method allows residents to evaluate everyday risks and chart a course that prioritizes community well-being and resilience. Grounding his community-developed strategy in his lived experience with intergenerational-health burdens, one resident shared the community science project that he has developed to monitor and mitigate the long-term burdens of everyday pollution in his community of Wilmington:

> I run a non-profit in the community and we have a STEM program. We have shared […] a device that we could teach the kids, called the Air Pie. And it […] gives us data of what the air quality is. So, we [can have] the kids build it. Get the data to understand what's in the air. Benzine, carbon monoxide, whatever. And we are looking at a pilot program for three years, about maybe $2 million. And [...] put these devices in various locations [...] collect the data. Because of the situation of Wilmington. Since I have been here three generations, half of my family has died from cancer. As young as 34 years old. From breast cancer, lung cancer, liver cancer, kidney cancer. People that don't even drink or smoke. So, I know that the

> refineries have an issue. The contaminants from the trucks and the containers, from the breaks. They have a black soot in our community. … I would like [to put the device] in [our] houses with a signal […] saying mild, bad. Where it sets off an alarm and goes into the central air-cooling system that has filters that go into effect. And those filters will automatically tell you to shut your windows and your doors. [... It's] something to help the community members in their homes to at least have some kind of fresh air system.

In LA communities like Wilmington, pollution from the local refineries, freight traffic, and the Port of Los Angeles has tangible intergenerational and everyday health and quality of life effects on local families. According to these residents, over generations, these energy-related outputs have been compromising local residents' health and well-being. While the negative consequence of energy-related contamination is palpable to Wilmington residents, the specificity of those contaminants—the "data to understand what's in the air"—remains inaccessible. Without that data and understanding, residents are unable to adapt their actions and environments to mitigate those health risks. They are also unable to provide authorities with hard evidence of the environmental exposure and burdens they have been experiencing to instigate needed institutional change.

Breaking these kind of efforts down into actionable steps, Sauermann et al. (2020), who focus on citizen science, identify "three pathways through which such [resident participation] impacts can occur [across stages in the research process]: (1) Problem identification and agenda setting; (2) Resource mobilization; and (3) Facilitating socio-technical co-evolution." In the case of Wilmington, Step 1 has been partially taken by residents, as explained above. Step 2 could include LADWP or other city agencies supporting residents with existing resources for air pollution monitoring. One possible option is the existing local air quality monitoring in the Wilmington area, which was set up by the State of California's Community Air Protection Program (California Assembly Bill 617). The program focuses on "reducing exposure in communities most impacted by air pollution. Communities around the state [of California] are working together to develop and implement new strategies to measure air pollution and reduce health impacts" (California Air Resources Board 2022). Eight community air monitors are located in the Wilmington area (see South Coast AQMD 2023). LADWP could develop more transparent and accessible information for communities to utilize existing air quality data. This type of effort creates a framework that builds local capacity for residents to shape and co-design solutions to energy-related problems that are both social and technical.

Investing in programs that foster community resilience, such as community science initiatives, is a strategy that can decrease exposure to environmental hazards (see right column of Figure 3, page 10), and increase local capacities to identify and respond to disruptive energy incidents. Beyond the three steps listed above that support this strategy, LADWP could also build on their ongoing Science Bowl program and the Los Angeles Public Library Neighborhood Scientist program to invest in the development of applied local knowledge. Implementation of this LADWP strategy could involve collaborating with agencies such as the Los Angeles Unified School District. To monitor the performance of this strategy, LADWP could also develop and employ assessment metrics such as the number of LADWP programs available to underserved communities (see metrics suggested in Table 1, page 11).

Strategy 6: Improve Continuity, Transparency, and Accountability in Program Participation

Part of building a grounded community engagement process is developing a continuous and transparent feedback loop with local residents, leaders, and trusted actors and institutions (procedural justice). Listening session participants emphasized a need to guarantee *continuity, transparency, and accountability* in LADWP's decision-making process (Chapter 2). Equity Strategy 6 intends to enhance access and use of affordable energy programs, services, and technologies (Figure 2). Continuity becomes a mechanism and tool for communities to maintain transparency and accountability over time. As long as government agencies continue to develop transparent engagement with local communities, those residents can hold authorities accountable for the promises they make.

This accountability mechanism becomes a vital decision-making tool for local communities. As one community leader requested:

> For continuity's sake … when they [LADWP] come back again, they should at least keep somebody [an LADWP representative] on board [e.g., somebody from Public Affairs or Diversity, Equity, and Inclusion (DEI)], and bring the others involved in prior programs back [to our communities]. Because ... if you've already been involved, you've heard the message, you at least have a perspective, a context. And you have a lens by which to hear and see what's going on.

This type of experiential knowledge acquired by continuity and housed within government institutions as LADWP representatives with lasting local ties, such as the public affairs or diversity, equity, and inclusion office, is a catalyst of structural change. It creates a space for institutional actors to become part of the engagement process, maintain that connection over time, and build a lens to ground their understandings of energy-related impacts on these communities. Recognizing the power of utilizing institutional actors to house collective memory within government entities, these communities want to avoid the status quo of constantly "starting over the same" and develop a long-term method of community-guided decision-making.

Transparency and clarity are key to building and maintaining a trusted feedback loop between government agencies and local communities. Participants shared their struggles with the cost of current electricity bills as well as the barriers they experience to accessing the information provided by LADWP regarding their energy needs. One participant explained how these challenges impede their access to clean energy technologies and adoption:

> The truth is that I pay a lot for electricity. Too much … I really want [to have solar energy]. They should also be transparent [about this process], providing information as it should be. That there are no, as we say, hidden words. Little words. That they are direct. That they clearly say how much, so that one ... I'm sure that many people would benefit from those [solar] panels. But let them be honest and let them tell you ... let them tell you clearly how it is [and how much it is].

This request for transparency in energy information provision is also a request for access to clean energy technologies. Providing underserved communities with clear, comprehensive, and actionable materials to access and utilize clean energy efficient technologies (i.e., electric mobility, community solar and storage) will help make the benefits of the transition more accessible to all Angelenos.

By providing collective tools for making more informed and grounded decisions, continuity, transparency, and accountability become forms of self-determination, increasing energy democracy for underserved Angelenos (see Table 1 on page 11 and right column of Figure 3, page 10). To implement this strategy, LADWP could use existing tools such as its Equity Metrics Dashboard and its Board Meeting Environmental Impact Reports to provide continuity, transparency, and accountability. LADWP can use a collaborative platform (Chapter 4) and coordinate goals with the Housing Authority of the City of Los Angeles and other government agencies to enhance accountability and clarity. These actions are key to building and maintaining a trusted and transparent feedback loop between government agencies and local communities. To monitor procedural continuity, transparency, and accountability, LADWP could also develop and employ assessment metrics such as the percentage of enrollment change in LADWP programs from underserved communities over a set period of time and an assessment of improvement in transparent reporting (see metrics suggested in Table 1).

Strategy 7: Affordable Programs to Safely Upgrade and Remediate Existing Housing and Infrastructure

The ongoing need for affordable and safe upgrades in Los Angeles reveals the significance of infrastructural and systemic barriers to energy equity in the crosscutting priority areas (see Figure 2, page 9). Listening session participants emphasized the need to redress unsafe and inefficient infrastructure and housing in their communities (i.e., recognition justice). Recognizing that ongoing history of neglect, they suggested LADWP not only concentrate on making space for new infrastructure and technologies, but also redressing the old by developing programs that safely upgrade and remediate issues of disinvestment and neglect in the built environment of their neighborhood. Causal factors range from the systemic neglect of individual homes to the neighborhood infrastructure that collectively constrains residents' capacity to benefit from technologies and programs associated with the city's clean energy transition.

The causal factors identified included barriers to safely and efficiently upgrading homes, such as the lack of access to resources (i.e., LADWP programs) as well as the high cost of implementing weatherization, electricity panel, and roof upgrades. Participants framed the solution to their individual energy efficiency barriers as collective, benefiting the whole energy system. As one resident explained:

> They [LADWP] talk about the [energy] waste we have, well it's because we don't have the incentive programs of going ahead and getting insulation. What we don't have insulation on right now is underneath the home. So, it gets extremely cold. And I think that is another issue that we need to address and have our local representatives and the utility companies to go ahead and take the initiative to understand … Because they [LADWP] know that they will save the energy if we have these resources.

Highlighting a need for government resources to affordably and safely weatherize her home, this resident also argues that providing affordable energy efficiency upgrades to homes in her community would benefit the city as whole. Along similar lines, another participant emphasized the need for "some options of affordable ways to fix your house to take [use] your [energy efficient] product [i.e., appliances, electric vehicle chargers]. You understand? Work with them [resource providers] … [to implement] affordable [and safe] upgrades." Both commentaries recognize how a long history of disinvestment in these communities creates the need for developing equity strategies that provide *Affordable Programs to Safely Upgrade and Remediate Existing Housing and Infrastructure*.

Yet this community-identified strategy can be applied beyond the individual home, expanding to the neighborhood scale. Participants also emphasized the systemic neglect of neighborhood infrastructure as an important causal factor of energy inequity and the negative impact it has on community health and resilience. As one resident explained:

> [While] I appreciate raising the concern about addressing current infrastructure, [and shoring] up that infrastructure, I also wonder if there is a plan to remediate some of the infrastructure that currently exists in South LA that is problematic, in terms of known adverse health outcomes … one thing is capacity. Does our infrastructure have the capacity to deal with these things? But […] just in terms of—from what I understand from the community—there is a sense of neglect. In terms of the outdated infrastructure that needs remediation […] I'm hearing discussions about what we are going to do to fix, improve the infrastructure to make way for new. But how are we going to remediate the old? And I think that's also about building trust in the community. … Where is the plan to remediate some of the things that currently are causing damage and have been causing damage for quite some time now?

Here, the "sense of neglect" is localized not only in the space of the home. Rather—and importantly—it is localized in the lived experiences of bus stops, streetlights, electric cables, and other infrastructural elements of community spaces. Furthermore, it is localized in residents' collective memory of past and ongoing "damage" caused by this "outdated infrastructure." The negative effects of this neglect manifest in adverse quality of life, health, and safety outcomes across the community and across generations, consolidating as an intergenerational lack of institutional trust. Thus, redressing this history of inequity must begin with remediating and building not only infrastructure but also community trust by providing communities with *Affordable Programs to Safely Upgrade and Remediate Existing Housing and Infrastructure*.

Providing government resources that support affordable energy efficiency upgrades to existing residential housing and neighborhood infrastructure would offer underserved Angelenos needed safety and financial benefits. LADWP could implement equity strategies presented in Chapters 6, 7, 8, 9, and 12, and expand their existing programs supporting rooftop solar, energy efficiency, and weatherization, among others listed in Table 1 (page 11). This strategy could be developed in collaboration with agencies such as the Los Angeles County Metropolitan Transportation Authority (Metro) and the Housing Authority of the City of Los Angeles to produce equity outcomes that (1) decrease energy burden, (2) decrease environmental exposure and burdens, and (3) increase community resilience in historically underserved communities (see also Figure 3, page 10). To measure these equity outcomes, LADWP could also develop and employ assessment metrics such as the percentage of structural energy upgrades per type—e.g., solar, panels—benefiting underserved communities (see metrics suggested in Table 1).

Strategy 8: Prioritize Disadvantaged Angelenos in Energy Transition Programs and Investments

Without upgrading home service panels, residents cannot install the infrastructure needed to support solar and storage and EVs charging in underserved neighborhoods. Therefore, to enhance access to or actual use of technologies (e.g., solar and storage, EVs) locally, programs and investments operationalizing recognition justice in access to clean energy technologies need to prioritize underserved Angelenos (Figure 2, page 9). As one resident explained:

> The issue around charging stations was already put on the table. They are supposed to be put in neighborhoods that needed them the most. The state went ahead of everyone and offered cars to people without charging stations. So, it's almost as if we are being asked to participate in a circular communication […] But recognizing we have some real issues around what we say we want to do. Electrification, with the governor saying that all vehicles will be electrical, by what, 2030? Can't do that if you don't have the infrastructure. And you can't do that if you don't fix the homes to have the infrastructure.

To enhance access to or actual use of energy technologies (e.g., solar and storage, EVs) and related programs, LADWP could align their efforts with agencies such as the Housing Authority of the City of Los Angeles (HACLA), Metro, and the Los Angeles Unified School District (Table 1, page 11). LADWP could build on HEIP, RESAP, and other existing programs listed in Table 1. LADWP could also collaborate with these agencies to expand and develop programs and investments that (1) increase energy access and resilience in these historically underserved communities, (2) decrease their energy burden, (3) decrease exposure environmental to environmental hazards, and (4) increase job opportunities and training (see right column of Figure 3 on page 10 and evaluation metrics in Table 1). To measure these equity outcomes, LADWP could also develop and employ assessment metrics such as the percentage of sectoral investments and programs per type—e.g., EV charging infrastructure, solar panels—benefiting underserved communities (see metrics suggested in Table 1).

Strategy 9: Programs to Foster Energy and Housing Security and Safety

As the previous equity strategies elucidate, there is a systemic need for targeting energy and housing security, including homeowner-renter split incentives, affordability issues, and monitoring of housing safety and upgrade needs. This strategy operationalizes procedural and recognition justice in two ways. First, it targets homeowner and renter issues. Second, it focuses on institutionalizing a monitoring system that can ensure ratepayer homes are safely up to code, thus benefiting both renters and homeowners.

One renting participant proposed a solution to the homeowner-renter split incentive problem for energy efficiency and safety upgrades. She suggested:

> Like the owner should be like: ok, we're doing these upgrades but you cannot put this tenant out because you feel like you spent ... you know, make some kind of rule for them because it's not the tenant, it's the owners. And they feel like it's my property, I can do what I want […] I don't know who does these laws for this or who makes these kind of ... for at least five years you can't raise these tenants rent because they gotta [displace people]. Like if you benefited from a program there could be some kind of clause that says you can't raise the rent.

Renter and homeowner issues relate to avoiding affordable housing loss, eviction, and undermining community resilience. A loss of community members—through upgrade-related displacement—can fracture the safety nets and professional networks renting households rely on to deal with burdens (Chapter 1).

Second, by improving transparency and accountability through monitoring, this strategy targets participants' requests for affordable, accessible, and trusted services and resources that provide such monitoring capabilities (Figure 2, page 9). One resident noted the need for:

> […] an organization where you can monitor these types of complaints. Because if you go to, for example, housing equity, they will simply say 'you have electricity, you have water, these processes should have been arranged in a previous contract'. And they remove themselves from responsibility. Then the problem remains for both the tenant and the landlord because it is frustrating to be in a property dispute.

Providing all Angelenos with the security and consistency of institutionalized monitoring that ensures their homes are safely up to code can resolve issues for both renters and homeowners. Neither party gains from unsafe inefficient housing conditions. Designing programs that become responsible for monitoring housing safety and assessing the need for electrical upgrades can help make sure that home improvements are implemented correctly and evaluated for quality over time. Fostering energy and housing security and safety entails institutionalizing programs and services that monitor and guarantee the implementation of safe energy efficient home improvements.

To develop this strategy, LADWP could use its Customer Service Program and the LA Online Service to assess and evaluate the performance of their programs and service providers. It could also rely on the Stay Housed LA County Program connecting tenants with resources related to housing rights and legal assistance (Table 1, page 11). Providing all Angelenos with the security and consistency of monitoring efforts holds the potential to (1) increase energy resiliency in these historically underserved communities, (2) decrease their energy burden, and (3) decrease exposure to environmental hazards (see also Figure 3, page 10). To measure and track energy security, LADWP could also develop and employ assessment metrics such as the percentage of underserved communities benefiting from home energy efficiency programs that monitor use, reach, and participant outcomes (see metrics suggested in Table 1). These metrics could become assessment tools for Angelenos to monitors the safety and efficiency of their home environments over time.

Strategy 10: Invest in Programs that Build Community Health, Resilience and Well-Being

Part of equipping residents with the tools to hold service providers accountable is providing all Angelenos with the educational opportunities and environments that build community health, safety, and resilience (see Figure 2, page 9). One strategy entails building on existing networks of trusted messengers to improve LADWP's customer communication and problem resolution. The method that came up consistently during the listening sessions was the *promotoras de salud* (also known as *promotoras*)—the community health workers who become trusted messengers guiding local residents in their Latino communities through the complex health care system. They utilize their knowledge of local sociocultural norms to provide their neighbors access to relevant health and social resources.

Listening session participants suggested that incorporating energy resources into the existing *promotora* educational model could be a powerful strategy for improving community resilience. As one *promotora* who participated in our sessions explained:

> I really didn't know that so many organizations exist that can educate us, help us. It wasn't until I became a [health] promotora that I began to learn about a lot [of resources] that we are unaware of as a community. So, I would like the [promotoras] to talk about this too, to include it in schools. That [the promotoras] talk to students in schools, not only that there is a counselor, and they can come to him. [The promotoras] should also open [students'] eyes to the fact that there are organizations out there that they can approach. That there are so many resources that can educate students in other ways. Not just the education they receive at school. I would like them [government authorities] to include [promotoras in their education efforts].

Her proposal links the *promotora* community educational model to the institutional educational model of the school system. Here, she suggests government entities invest in not only adding energy resources to the traditionally health-based model of community education, but also incorporating that pedagogical method into Los Angeles's school system to begin educating Angelenos about their city's energy transition at a young age.

To invest in programs that build community health, resilience, and well-being entails not only incorporating community-grounded knowledge (community science) but also fostering and institutionalizing local educational and outreach methods. LADWP could build on its Community Partnership Grants and its Community Outreach Worker Pilot program to add energy-related resources to the traditionally health-based model of community education such as the *promotora* model. This method could also be incorporated into Los Angeles' school system to begin educating Angelenos about their city's energy transition at a young age (Table 1, page 11). This strategy has the potential to achieve at least three equity outcomes as programs are implemented and evaluated. These outcomes include: (1) increasing energy resilience in these historically underserved communities, (2) decreasing their energy burden, and (3) decreasing exposure to environmental hazards and health risks as Angelenos gain the tools and knowledge to assess the safety of their own environments and hold responsible parties accountable for upgrades (see Table 1 and right column of Figure 3, page 10). To measure these equity outcomes, LADWP could also develop and employ assessment metrics such as the number and quality of LADWP programs utilizing trusted messengers for outreach (see metrics suggested in Table 1).

Strategy 11: Improve City Regulations, Accountability, and Enforcement

One of the quotes in Strategy 7, the strategy for *Affordable Programs to Safely Upgrade and Remediate Existing Housing and Infrastructure*, poses an important question: "Where is the plan to remediate some of the things that currently are causing damage and have been causing damage for quite some time now?*"* This question points to the underlying structural need for recognition justice improvements in regulation, accountability, and enforcement across city agencies as key preventative measures needed to preclude the reproduction and proliferation of unsafe and inefficient infrastructure in their communities (Table 1, page 11). These types of regulations, which are beyond the purview of LADWP's authority, become fundamental backbones necessary for historically underserved Angelenos to fully benefit from LADWP programs and projects. However, given the institutional limitations of developing and implementing legal regulations, LADWP could focus on the short-term priority of providing ratepayers with trusted information on service providers to help guide their decision-making.

Without access to trusted resources that help Angelenos understand, assess, and navigate this transition in their own homes, there is no way for residents to hold service providers accountable for the quality of their work. As one resident put it:

> There's a lot of barriers, especially with old houses, and Boyle Heights has a ton of old houses. Or they have houses that are old that were flipped. Like a friend of mine just bought a house on Lorena, and the flipper just basically hid all the old stuff in there and when he found out that basically it was a fire hazard for him to have these old electrical wires. … The regulations just aren't there and there's no support for families who can't afford to fix these things. And it's not necessarily families' faults that this is happening, or homeowners' faults, or renters.

Creating regulations and informational support to prevent unsafe environments and predatory practices that have historically burdened these communities is an important action prioritized in the listening sessions. Throughout the sessions, participants identified a need for inspection and monitoring to support housing maintenance and upgrades, particularly in relation to old electrical wires and outdated panels. Without the economic means and informational support to navigate safety assessments and electrical system upgrades, these Angelenos must live with the daily risk of fire and other safety hazards. As another participant noted:

> That they inspect the house because we cannot know exactly what the problem is because we are not, well, in my case, I am not an electrician. I don't know where the problem is coming from. All I know is that I would have to turn the switch off and turn it back on to get it working again. But I think it would be good to have a professional inspection to tell us exactly what the problem is. Because you are in danger, the family is in danger. As I mentioned before, there could be a fire, or the gas could explode. First of all, it is important that it's at no cost. Or low cost.

Providing residents with affordable and accessible professional services and programs that assess home electrical systems and enforce safety regulations is a proactive action to keep those families out of danger. The limited electrical capacity of outdated systems also thwarts their transition to more energy efficient and clean technologies in their homes.

Recognition justice improvements in regulation, accountability, and enforcement across City of Los Angeles agencies could address unsafe and inefficient infrastructure in underserved communities. These types of regulations, which are beyond the purview of LADWP's authority, would support the success of LADWP energy transition programs and projects. Partnering with the City of Los Angeles, LADWP could use existing resources, such as the Housing Services or Rent Escrow Account Program, to develop this type of regulatory strategy. By fostering strategies that *Improve City Regulations, Accountability, and Enforcement*, government agencies can help reach equity outcomes that (1) increase energy resilience in these historically underserved communities, (2) decrease community members' energy burden, and (3) decrease their exposure to environmental hazards and related health risks (see also Figure 3, page 10). To measure and track regulatory practices, LADWP could also develop and employ assessment metrics such as the number and reach of programs and services that monitor home safety and energy efficiency (see metrics suggested in Table 1 on page 11).

4 Concluding Remarks

This chapter presents 11 energy equity strategies for LADWP and other government agencies to operationalize procedural and recognition justice, guided by members of the local communities most negatively affected by the past and existing energy system. Two key overarching findings merit special attention:

- First, our analysis revealed that participants referred more to social, cultural, and institutional factors (e.g., lack of meaningful representation and voice, and of tailored training and education) as their primary barriers and challenges to benefit from the energy transition programs, infrastructure, and technologies.
- Second, we present 11 community-guided energy equity strategies that demonstrate how LADWP could co-design more equitable transition processes to address crosscutting priority areas and achieve outcomes aligned to the policy priorities identified by the federal government, practitioners, and scholars (Figure 3). Table 1 (page 11) presents those options for LADWP to build on existing programs, collaborate with other entities, and consider metrics for assessing programs performance and reach (e.g., Equity Metrics Dashboard discussed in Chapter 4).

Our first overarching finding points to program and policy strategies that target inequities in "deep infrastructures"—the underlying social, cultural, and institutional factors that constrain underserved Angelenos' access to the benefits of energy transition programs and technologies. While they relate to energy transition technologies, these strategies are not singularly focused on technical barriers. Rather, these strategies adapt to different sociocultural and institutional contexts via community engagement approaches aimed at achieving the following goals depicted in Figure 3:

- Lowering socio-institutional barriers to access and use of programs, technologies, and infrastructure
- Providing affordable options for community members at all income levels to benefit from LA's energy transition
- Investing in the educational and professional development of underserved communities
- Supporting community health, safety, and resilience and lowering environmental burdens
- Including local communities in the design and implementation of the programs and policies affecting their lives.

Our second overarching finding demonstrates how LADWP could co-design more equitable transition processes to address identified crosscutting priority areas and achieve energy equity goals. We present short-term building blocks and options to improve outcomes aligned with policy goals, such as parity in access and improved affordability (right column of Figure 4), while expanding program benefits in the long term.

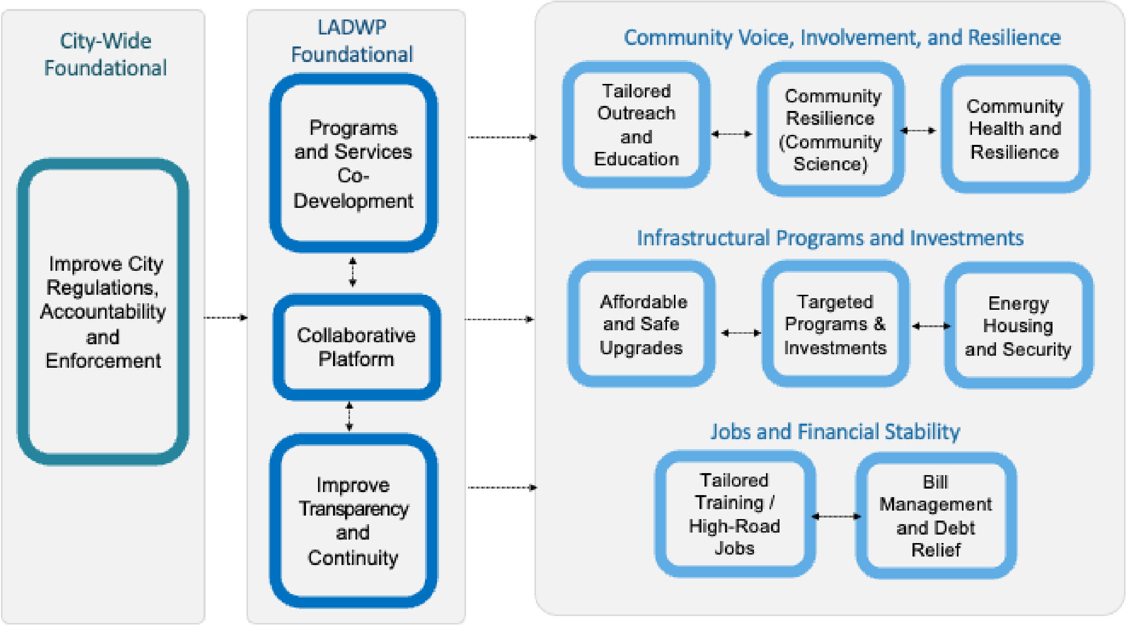

Figure 4. Mapping of energy equity strategies

The 11 equity strategies build on existing programs, thus avoiding elements of LA's political context such as Propositions 26 and 218 (Chapter 5) by seeking energy equity for all Angelenos. We use criteria such as relevant implementation entities, success metrics, and regulatory constraints to LADWP (among other elements of the political context) to suggest five groups of strategies (Figure 4 and Table 1):

- **City-Wide Foundational:** Improvements in regulation, accountability, and enforcement for safe, affordable, and efficient infrastructure and housing include (a) inspection and monitoring to support housing maintenance and upgrades as well as (b) regulations, and informational support to prevent unsafe built-environments, and predatory practices among service and technology providers. These strategies are beyond the purview of LADWP's authority, yet foundational, high-impact backbones for LADWP's success in its energy transition programs, technologies, and policies.
- **LADWP-Foundational: Co-develop programs and services with communities and community-based organizations and improve transparency and continuity.** Effectiveness of LADWP programs can be limited by lack of community involvement in priority setting and decision-making. LADWP can rely on its dedicated personnel and resources and a collaborative platform discussed in Chapter 4 to engage residents in developing programs and services that meet their needs and priorities. Engaging residents in ongoing, more consistent, transparent, and community-adapted outreach and communication builds trust, buy-in, and a continuous feedback loop for decision-making.
- **Community Voice, Involvement, and Resilience:** Tailored training and education, community health and resilience, and community science are procedural strategies aimed to foster social capacities, assets, and resources. Effectiveness of LADWP programs can be limited by lack of community involvement in priority setting and decision-making. LADWP can rely on its dedicated personnel and resources and the suggested collaborative platform to engage residents in developing programs and services that meet their needs and priorities. LADWP could build on its Community

Partnership Grants and Science Bowl to (a) inform ratepayers about the options and benefits of programs and technologies and (b) incorporate resources into the community science and the health promoter methods. These strategies are impactful means for communities to have a voice and be resilient, and for LADWP to build trust and buy-in.

- **Infrastructural Programs, Technologies, and Investments:** Without upgrading outdated housing and equipment like home service panels, residents cannot install the infrastructure needed to support clean energy technologies. Three strategies address these challenges: *(1) affordable and safe upgrades of infrastructure, buildings, and electric panels, (2) programs and investments targeting* solar and storage, EVs, and grid upgrades in underserved communities, and *(3) programs fostering clean energy and housing security*, for instance, by avoiding affordable housing loss and eviction, and monitoring housing safety needs. LADWP could expand programs like the Home Energy Improvement Program (HEIP) and the Comprehensive Affordable Multifamily Retrofits (CAMR) and rely on other City of Los Angeles initiatives (e.g., Stay Housed LA, Table 1) to develop these recognition strategies, which build infrastructural and built environment assets and resources. They could collaborate with Metro and HACLA to provide affordable energy and home upgrades, fostering affordable access to solar, storage, EVs, and other technologies.
- **Jobs and Financial Stability:** These strategies include tailored job training and bill management and debt relief. Increased access to both LADWP programs enhancing energy affordability and to well-paid jobs, training, and entrepreneurship has direct and positive impacts on community self-determination. LADWP could utilize two strategies— (1) tailored training for high-road jobs, and (2) bill management and debt relief—to foster employment in the green economy and financial stability. Such strategies could expand LADWP programs like the Utility Pre-Craft Training Program (UPCT), Low-Income Discount Program, and Lifeline Discount Program. These programs provide LADWP with opportunities to address structural inequities by supporting residents of frontline and underserved communities with pathways for more sustainable livelihoods and options to decrease their energy burdens.

By staging these community-guided energy equity strategies, LADWP could transform the energy transition into a long-term socioeconomic opportunity for historically underserved individuals and communities. Overall, the analysis presented in this chapter is a first and promising step to inform strategy design, implementation, and evaluation pathways that address the barriers we identified to accessing the benefits of existing programs, services, and transition technologies in Los Angeles.

5 Glossary

Actions/Strategies: the means used to solve identified problems in an impact area; actions and strategies involve programs such as bills, regulations, rates, subsidies, and investments and how they are designed, implemented, and evaluated (Dubash et al. 2022)

Causal Factors: "Events, incidents, happenings that lead to the occurrence or development of a phenomenon" (Buckley and Waring 2013, 156).

Climate Justice: the remediation of the impacts of climate change on poor people and people of color, and compensation for harms suffered by such communities due to climate change (Burkett 2008)

Co-Creation: "a process through which two or more public and private actors attempt to solve a shared problem, challenge, or task through a constructive exchange of different kinds of knowledge, resources, competences, and ideas that enhance the production of public value in terms of visions, plans, policies, strategies, regulatory frameworks, or services, either through a continuous improvement of outputs or outcomes or through innovative step-changes that transform the understanding of the problem or task at hand and lead to new ways of solving it" (Torfing et al. 2019, 802)

Community Engagement: Community engagement often entails public participation through an ongoing, two-way or multidirectional process, ideally with an emphasis on relationships and trust-building rather than instrumental decisions. The latter are processes where engagement becomes the instrument to achieve social acceptance (Stober et al. 2021).

Disadvantaged Community: "Disadvantaged communities refers to the areas which most suffer from a combination of economic, health, and environmental burdens. These burdens include poverty, high unemployment, air and water pollution, presence of hazardous wastes as well as high incidence of asthma and heart disease. One way that the state identifies these areas is by collecting and analyzing information from communities all over the state. CalEnviroScreen, an analytical tool created by the California Environmental Protection Agency (CalEPA), combines different types of census tract-specific information into a score to determine which communities are the most burdened or "disadvantaged"" (California Public Utilities Commission 2023).

Energy Equity: the equitable distribution of social, economic, and health benefits and burdens of energy across all segments of society (Jenkins 2017)

Energy Justice: the provision of safe, affordable, and sustainable energy to all individuals, across all areas, (Jenkins 2017); this is done with a framework informed by justice movements, including attention to three core tenets:

- *Distributional justice* seeks to ensure a just and equitable distribution of benefits and negative impacts of the clean energy transition.
- *Justice as recognition* seeks to understand and address past and current energy inequities by analyzing structural causes of exclusion and vulnerability and specific needs associated with energy services among social groups.

- *Procedural justice* aims to actively engage partners and communities throughout the project, to co-design the analysis, and shape the resulting equity strategies (Energy Equity Project 2022).

Energy Transition: a large-scale or deep societal change in the production, distribution, and use of energy; this transition can entail transformations in social-technical systems and systems of policy and governance intended to substantially improve the outcomes out of unsustainable pathways, such as fossil fuel use (Carley and Konisky 2020)

Environmental Justice: the distribution of environmental hazards and access to all natural resources; it includes equal protection from burdens, meaningful involvement in decisions, and fair treatment in access to benefits (U.S. EPA 2023)

Equity Outputs: Equity outputs are the immediate, easily measurable effects of an action aimed at achieving equity (Dubash et al. 2022).

Equity Outcomes: Equity outcomes are the ultimate changes that a policy will yield (Dubash et al. 2022).

Equity: Equity refers to a measurement of fairness and justice. Unlike equality, which refers to the provision of the same to all, equity aims to recognize the historical and ongoing differences in experiences and outcomes between people, groups, and communities to redress those imbalances.

Frontline Community: a community, frequently a low-income community of color, that experiences the first and worst consequences of environmental and climate change including floods, heatwaves, and other climate extremes as well as the impacts of facilities that are used to extract, produce, process, and transport energy resources.

Impact Areas: particular sectors and subsectors of the energy system impacted by causal factors

Just Energy Transition: a deep societal change in the energy system that fulfills at minimum three of the tenets of justice: recognition justice, procedural justice, and distributional justice (McCauley and Heffron 2018)

Justice involves removing barriers that prevent equity through energy actions (strategies) that offer individuals and communities equal access to energy resources and options to self-determine their energy goals (Romero-Lankao and Nobler 2021).

Participation relates to the involvement of the public in infrastructure siting and other clean energy decisions and policies (Stober et al. 2021). Participation is an umbrella concept that includes processes of community engagement and public decision-making (Stober et al. 2021). Participatory decision-making denotes inclusion of actors such as underserved communities in an energy project as a decision-maker. Direct participation refers to the level of economic and/or political involvement of a local community or municipality in an energy project.

Underserved Community: a community, frequently a low-income community of color, that (a) does not benefit from energy programs, investments, and technologies, (b) is not recognized, considered, or able to participate in energy decision-making (Klinsky et al. 2017)

Values: the ethical paradigm that structures the sociocultural norms, beliefs, and practices guiding how a group of people prioritize and relate to the current energy transition (Jenkins 2017)

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Appendix. Data Analysis

Appendix A, Chapter 2 describes the engagement process in more detail. As for the steps followed to analyze the qualitative data, all 15 listening sessions were recorded, transcribed, anonymized, translated when needed,[4] and uploaded into the qualitative data analysis software MAXQDA for coding. Coding is the process by which categories and concepts are identified in the data and passages of the transcription are linked to themes that become labeled with a particular code (Charmaz 2006; Buckley and Waring 2013). Beginning inductively (bottom-up) in the first round of analysis, each listening session was analyzed by assigning open descriptive and thematic codes, related to energy justice in Los Angeles and the city's transition to clean energy, to segments of the data. After the first five sessions were coded, an analytic coding was applied to organize, refine, and map these inductive categories to the adapted grounded theory concepts developed deductively (top-down), as described above (causal factors, impact areas, actions/strategies, values, and equity outcomes).

The Round 1 coding system was used to analyze the second round of 10 listening sessions, where codes were refined and relations between codes were analyzed (see the tables in Appendix B for details). Through this comparative analysis, the relations between key codes began to attain saturation—the point when gathering more data reveals no new insights, issues, or categories related to this research (Glaser, Strauss, and Strutzel 1968). Concurrently, a code book was developed to define the inductive codes utilizing a grounded theory approach and connect them to energy equity and just energy transition categories, iteratively refining these codes and relations over the course of the analysis process.

An overlapping code occurs when two themes are identified in the same passage. The codes that frequently overlapped in participants' understandings of energy inequities become key data points for analysis. We analyzed these overlaps because they reveal how participants understand relationships between different themes. The MAXQDA software has tools to identify passages with multiple themes. As the overlapping codes attained saturation over the course of 15 listening sessions, they revealed critical causal factors and actions to address in LADWP's pursuit of procedural energy justice in Los Angeles. We organized these high-frequency overlapping codes according to the three tenets of justice: procedural, recognition, and distributional. In what follows, we include the codebook.

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[4] Many of the quotes utilized in this chapter were originally in Spanish and translated into English by the authors.

Codebook

Table B-1. Code Names and Definitions

Code Name	Definition to Guide Coding
Structural Phenomena	
(Dis)Investment and Development	
Economic Development and Land Use	Existing land use and how it relates to opportunity and economic growth; preferred land use; general economic development.
Economic Development and Energy	Economic growth and development related to energy and/or energy business.
Gentrification and Displacement	Housing, job, economic displacement, homelessness, geographic segregation; feeling the push to leave community but not wanting to; rent/landlord caused displacement because of upgrades to home.
Socioeconomic Marginalization	Historic disinvestment in communities, equity vs equality, being left behind; those with and without means get different things (and have different experiences in their communities).
Neighborhood Disinvestment	Physical manifestation of socioeconomic marginalization. Mention of lack of upkeep, excess litter, poor infrastructure; community empowerment/pride in ownership.
Resilience	
Grid Resilience	Threats to electrical grid resilience and practices that support resilience; instances (or insinuations) or examples of resilience or the lack of resilience in the grid; how technologies may help or threaten the resilience.
Community Resilience	Programs or strategies that support a community's energy resilience; could also be related to health; economic resilience; examples of a community being able to withstand hardships.
Public Health and Safety	
Emotional Burden	References to emotions like hurt, sadness, pain, etc. Sometimes related to physical environment; and references to systems to support emotional burdens.
Heat Wave	Mention of heat wave, lack of AC, dealing with the heat.
Shade	Shade or lack thereof (i.e., (un)covered bus stops); lack of trees or presence of trees.
Pollution	
Dumping	Environmental pollution via dumping; physical contamination of certain areas and how it impacts those living there (trash as well); what people are doing to

Code Name	Definition to Guide Coding
	clean up or prevent dumping; targeted; trash and other pollution.
Mobility and Pollution	Clean4 transportation, negative effects of transportation/mobility on surrounding communities, or the desire for clean transportation.
Pollution (other)	General pollution or contamination; noise, odor, other contaminants.
Air Pollution	Comments about air pollution, bad air, and causes and effects of it; specific pollutants in the air.
Air Quality	Comparison of air quality in different places; includes all comments related to air pollution too.
Public Health (or Community Health)	Anything related to public/community health. Or individual health, often as it relates to the environment. Encompasses a lot of the more general statements but also many of the ones in the pollution section above.
Safety	Safety as it relates to health, transportation, and housing; safety of people and goods (cars, houses); accessibility to health facilities.
Crime	General mentions of crime.
Criminal Justice Reform	Mention of criminal justice reform concepts, including reentry programs.
Historical Conditions	Mention of something that happened in the past that affects conditions of the community today.
Cultural Barriers	Barriers to clean energy access and use related to sociocultural norms and traditions.
Public Services	Water, electric, trash services provided by city; commentary on them and supply/ bills.
Infrastructure Phenomena	
Water	
Water Affordability and Burden	Water use, cost, supply; how cost seems inflated.
Water Quality	Drinkability of water, health concerns with water, general water quality.
Public Spaces	
Community Spaces	Schools, churches, places where community members gather or attend gatherings; open to the public; also, community spaces that were lost; general public spaces, or spaces that do not really “belong” to anyone.
Green Space	Lack of green space, or condition of the existing green space; parks.
Cooling Spaces and Heat Island	Places to go when there is a heat wave, effects of heat in city; how you can change (or cannot change) home to have more efficient cooling.

Code Name	Definition to Guide Coding
Public Lighting	Street lighting, darkness in public places.
Maintenance and Upgrades	
Housing Maintenance and Upgrades	Mention of old housing stock, housing conditions related to maintenance and upgrades; energy efficiency of houses (and buildings).
Infrastructure Maintenance and Upgrades	City-wide infrastructure related maintenance and upgrades.
Energy Security	Issues related to infrastructure/LADWP capacity to deliver quality electrical connection to residents.
Mobility and Transportation	
Public Transportation	Anything related to public transportation, its condition and use.
Walking	Mention of walking in relation to mobility impact area.
Biking	Mention of biking in relation to mobility impact area.
E-Scooters	Mention of e-scooters in relation to mobility impact area.
Electric Vehicles (EVs)	Mention of electric vehicle technology in relation to mobility impact area.
Electric Fleets (Heavy Duty)	Mention of Electric Fleets in relation to mobility impact area.
Autonomous Vehicles (AVs)	Mention of autonomous vehicle technology in relation to mobility impact area.
Mobility and Job Access	Driving, public transport and anything that relates to mobility and its relationship to job access.
Mobility and Services	Driving, public transport and anything that relates to mobility and its relationship to services.
Ride-Hailing	Mention of ride-hailing in relation to mobility impact area, such as Uber, Lyft, or some service that you pay for.
Private Vehicle	Mention of using personal vehicles; or lack of one.
Car Share	Mention of car share programs/ and carpooling.
Car Dealer	Mention of car dealer, or dealerships, car salesperson.
Parking	Mention of parking.
Energy Efficient Mobility	Any mention of energy efficiency in transportation, electric, other; also includes some mentions of public transportation.
Housing and Residential Infrastructure	
Appliances	Mention of appliances e.g., outdated, energy inefficient, lack of access to efficient appliances, etc.
Electrical Capacity	Effects of old electrical system in a home, the capacity at a home to charge vehicles, or run appliances; mentions of the failure of electrical capacity in older homes.

Code Name	Definition to Guide Coding
Outages	Mentions of utilities turning off, due to electrical capacity within the home, rolling or planned outages, or community wide electrical/water capacity.
Homeownership	Issues that affect homeowners specifically; barriers to resources because not a homeowner; benefits and burdens of being a homeowner.
Renter Issues	Issues related to renters' experience such as landlord reticence, lack of control over property, cost and safety concerns.
Quality of building (Home)	Issues related to quality of residence's fuse box, rooftops, internal wiring; energy efficiency of a home; not specific to home either, could be community building.
Solar and Storage	Mentions of solar: installation, affordability.
Economic Phenomena	
Affordability and Stability	
Shutoffs (Barriers)	Energy or water (utilities) service shut off due to missed payments.
Economic Stability/Security	Related to broader picture of job stability, or housing stability and housing prices; prioritizing other expenses over energy bills; cost of housing maintenance and how that relates to stability; prioritizing what you choose to pay more for (or what you have to pay more for).
Debt	Mentions of debt or having bills that have stacked up (i.e., ratepayer has not been able to pay off each month).
Energy Affordability and Burden	Passages that relate to people and their communities' ability to pay energy-related costs embedded in their everyday lives—from transportation and housing to work, food, and recreation. Energy burdens are often understood as "the percent of a household's income spent on utilities for heating, cooling, and other energy services." This code expands that definition to consider the trade-offs people and families must make to pay all their energy bills alongside other monthly financial burdens (e.g., cost of health care, childcare, rent).
Learning and Workforce Development	
Jobs, Training, and Entrepreneurship	Mention of jobs/work in general, businesses that people own; lack of jobs; jobs in energy; also mentions of trainings, workshops, continuing education with career focus; what prevents people from working (i.e., physical constraints).
Local Jobs and Production	Manufacturing locally, local jobs and training to enable local employment.
Education	Mentions of education, how it should be directed/dispersed; education related to electric energy

Code Name	Definition to Guide Coding
	and solar for consumers and careers, as well as other topics.
Youth Career Development	Educating youth to encourage careers in energy or other sectors; teaching skills to further career development for youth; need for training.
Accessibility Phenomena	
Access and Use	
Access (Actual Use)	Mentions of access to services, resources, and technologies that do not fit within other access categories; this includes how people actually use those services, resources, and technologies and if not, why.
Access to Financial Capital	Access to initial funding for energy-related capital improvements such as rooftop solar, purchase of EV and related EV supply equipment installations; community wide funding and individual funding.
Waiting and Delays	Waiting and delays, specifically with transportation, implementing projects (promises made or hopes for projects).
Monitor Program Application and Reach	Accountability for program implementation and monitoring, generally how was the program implemented, who did it benefit, and who was involved in the implementation; elements to include in order for program to reach the right people and how many people it is reaching.
Eligibility	Specifically, who qualifies for programs, or what causes someone who needs the benefits to not qualify for them.
Predatory Practices	Mentions of contracts not being upheld, paying more than anticipated and not receiving what was promised (from both private and public programs); poor work from contractors.
Electrical Preventive Maintenance	Mentions of unsafe conditions because of overdue electrical preventive maintenance; old electric systems at homes; landlords not doing the work needed.
Technological Barriers	Mentions of barriers to new technology (like EVs, energy efficient appliances, etc.). Mentions of electrical supply (capacity, infrastructure) barriers in the home and community.
Energy efficient technologies	Technology that minimizes energy usage; also mentions of working in energy efficient technology realm; mentions of investment in energy efficient technologies.
Programs and Support	
Urgent Need for Support	Mention of imbalance between need for support now versus plans and policies or programs that have long waiting lists or take years to see change; also mentions

Code Name	Definition to Guide Coding
	of debt and needing to focus on urgent needs versus longer term concepts like the energy transition.
Misunderstanding	Miscommunication, including different interpretations between communities and those implementing policy/government.
Community Study	Recommendations for community wide studies; or comments about previous/current community studies.
Food Banks	Mention of food banks.
Subsidies and Incentives	Mentions of subsidies (or monetary incentives), how they could help and what they currently do not cover; general incentives geared toward a specific group that encourage and facilitate energy efficiency, workforce development and helping communities reach their energy goals.
Grants/ Scholarships/ Internships	Mention of internships or grants geared toward workforce development or school.
Utility Debt Relief	Mentions of extremely high bills that ratepayers cannot pay off and therefore require relief; many related to the covid moratorium that built up; full relief or payment plans that provide debt relief; also, general mentions for need for debt relief.
Consistent Ratepayer Support	Mentions of support to clients by the utility services (customer service). This includes comments related community members' experiences with utility employees who provide direct support to clients; also, requests for forms of support that recognize people who have been consistent customers for years and now cannot pay bills.
Barriers to Program Participation and Support	Passages that relate to obstacles, barriers, and challenges that community members face that limit their ability to participate in, access, and/or utilize existing energy-related incentives, subsidies, and other aid programs. This includes but is not limited to the barriers embedded in eligibility criteria.
Future Programs/Support/Policies	Mentions of future programs/ policies that communities would like to see; and how community members are involved in them, including in their co-creation.
Successful Past or Existing Programs/Policies	Mentions of programs related to energy efficiency, that are either offered, or people are partaking in that have been successful.
Knowledge/access/use of existing programs/services	Mentions of what happens when communities do not have access to knowledge of programs; knowledge that programs are not working; how to spread awareness/ access to the services, resources, and programs coded in the Programs and Support subcategories above.
Participation, Outreach and Communications	

Code Name	Definition to Guide Coding
Building Trust and Confidence	Mentions of commitment, strategies to build trust; lack of trust; not following through on promises.
Continuity	Mentions of that lack of consistency in outreach, communications and therefore participation. This includes outreach that sends different people to have conversations each time communities are engaged. Relates to a lack of accountability due to a lack of continuity.
Circular Conversations/ Stakeholder Fatigue	Mentions of repetitive conversations with no actual output; mentions of being asked for opinions and then asked again.
Lack of information	Mentions of lacking information about plans from government, about how public money is spent, how programs will operate, and how decisions are being made. Being left behind or out of conversations because of lack of access to information, specifically with an energy focus.
Bilingual Communication and Engagement	Outreach/meetings in both Spanish and English; mentions of presence or lack of this.
Customer Communications and Problem Resolution	Utility companies, communication, and customer service; how they respond when people bring up problems; general availability and responsiveness.
Face-to-Face/Door-to-Door	Mentions of canvassing, going to the people, or having face-to-face interaction.
Social Media and Texting	Mentions of social media and texting as ways to communicate information widely.
Mailer	Using flyers etc. to communicate and conduct outreach.
Community Committee and Mobilization	Mentions of building internal community knowledge (mobilization) or committees/councils to represent and provide continuous local insight; also mentions of community coming together to resist interventions and/or build coalitions.
Promotoras Method	Mentions of the Promotoras de Salud (also known as promotoras) method. The promotoras are community health workers, seen as trusted messengers, who guide local residents in their Latino communities through the complex health care system. They use their knowledge of local sociocultural norms to provide their neighbors access to relevant health and social resources.
Participant Motivation and Means	The burden of participation, and what alleviates that burden or makes it worth it; why people are participating in programs or meetings.
Participant Compensation	Mentions of compensating (or needing to) for participation in engagement, outreach, meetings etc.
Workshops	Commentary on workshops that are offered or desire for workshops or that type of continuing education.

Code Name	Definition to Guide Coding
Intergenerational Engagement	Mentions of youth and adults both being engaged, a focus on education, or generally a focus on outreach (or a need for this).
Previous Engagement/Input	Mentions of previous engagement that government or other entities have done, ways they have (or have not) gotten community input.
Participant Observations and Reflections	
Alternative Energy Technologies	Call-out any mention of any alternative energy technology.
Solar and Storage	Mention of rooftop solar (not community solar).
Green Hydrogen	Mention of green hydrogen.
Electric Vehicles (EVs)	Mention of electric vehicle technology.
Electric Fleets (Heavy Duty)	Mention of heavy duty EVs.
Autonomous Vehicles (AVs)	Mention of autonomous vehicle technology.
Energy efficient cooling technologies	Strategies used or technology used to have more energy efficient households, to keep buildings cool.
Socio-demographics of Participants	
Parent/ Individual with dependents	Self-identifying the people who are talking, if they mention these categories.
Disability	Self-identifying the people who are talking, if they mention these categories.
Age and Longevity	Self-identifying the people who are talking, if they mention these categories.
Location	Self-identifying the people who are talking, if they mention these categories.
Large Household (multifamily, intergenerational)	Self-identifying the people who are talking, if they mention these categories.
Ethical Paradigm	
Ethnical Entailments	
Quality of Life	When people define what they think of as a high quality of life or a need for this.
Responsibility, Accountability, Transparency	Participants' mention of their personal value of responsibility, accountability, and transparency across the board (between service providers and ratepayers, elected officials, project team, etc.).
Carbon Emission Reduction/Efficiency/Environmentally Friendly	Participants' mention of their personal value of environmentally friendly policies and actions (related to climate change, drought, etc.).

Code Name	Definition to Guide Coding
Reliable Transportation	The importance of reliability in transportation and its personal value.
Self-Determination	Passages that relate to community members’ abilities and power to make decisions for themselves in relation to the energy system.
Dignity	Participants’ mention of the right to live with respect and the power to make decisions for themselves.
(In)Equity and Inclusion	
Priority Social Groups	Groups that need special focus/priority in the energy transition.
People with Disabilities	Groups that need special focus/priority in the energy transition: individuals with disabilities.
Gender	Groups that need special focus/priority in the energy transition: mentions of gender inequities.
Race	Groups that need special focus/priority in the energy transition: mentions of racial/ethnic groups.
Youth	Groups that need special focus/priority in the energy transition: mentions of youth/children.
Seniors and Retirees	Groups that need special focus/priority in the energy transition: mentions of elderly, seniors, and retirees.
Moderate and low income	Groups that need special focus/priority in the energy transition: mentions of people with low and moderate incomes.
Sociospatial Difference	Mentions of the physical differences in locations or physical disparities that align with sociodemographic differences.
Undocumented and Limited Immigration Status	Mentions of not having valid immigration documents or limited immigration status and its impact on access to programs.
Power Dynamics	Control, power plays in communities, between various actors including companies, organizations, groups of people.
Racism	Specific mention of race and/or ethnicity as a factor influencing participant’s experience with energy inequity and injustice.

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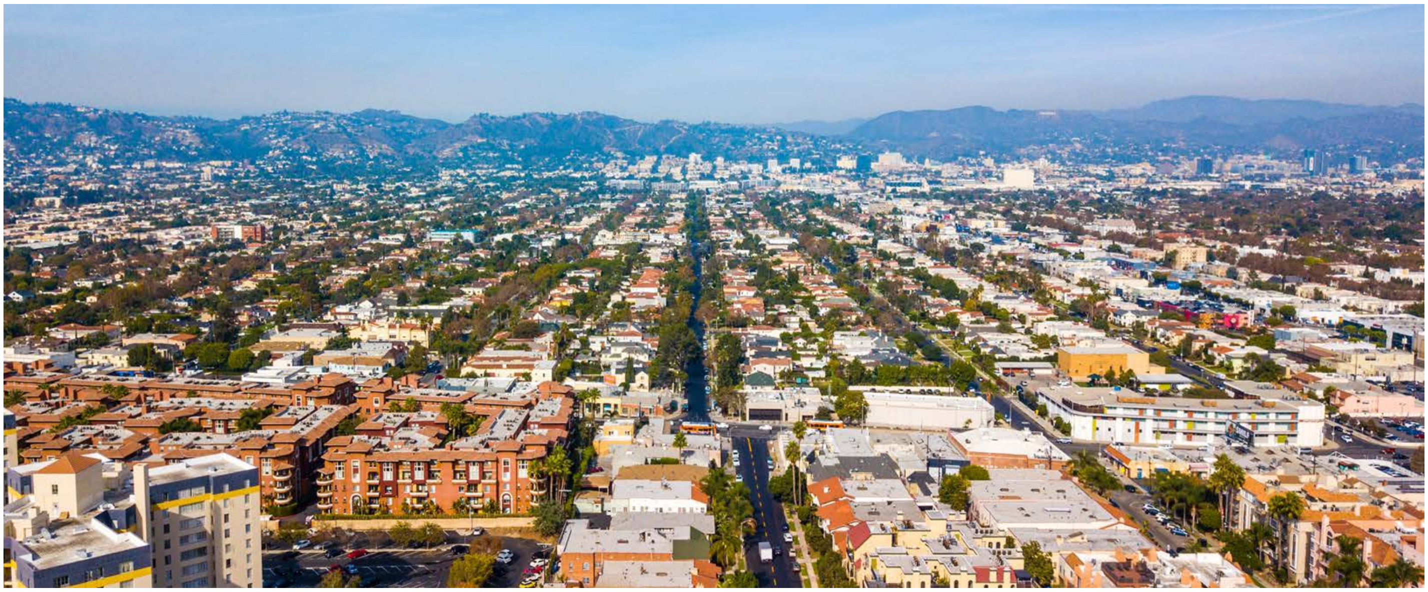
November 2023



Chapter 4: Lessons Learned and Options for Community Engagement in Los Angeles

FINAL REPORT: LA100 Equity Strategies

Patricia Romero-Lankao, Nicole Rosner, and Lis Blanco

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November 2023

LA100 EQUITY STRATEGIES

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Preface

The Los Angeles 100% Renewable Energy Study, or LA100, revealed that although all communities in Los Angeles will share in the air quality and public health benefits of the clean energy transition, increasing equity in participation and outcomes will require intentionally designed policies and programs. The LA100 Equity Strategies project was specifically designed to help Los Angeles identify pathways to such policies and programs in the form of equity strategies. The project aimed to do this by incorporating research and analysis to chart a course toward specific, community-prioritized, and equitable outcomes from the clean energy transition outlined in the LA100 study.

The Project Partners

The Los Angeles Department of Water and Power (LADWP), the National Renewable Energy Laboratory (NREL), and the University of California Los Angeles (UCLA) partnered on the LA100 Equity Strategies project to develop strategies for engaging communities, funding equitable technology and infrastructure investments, expanding existing programs, and designing new programs and policies to improve equity by incorporating what community members themselves know is needed to achieve a more equitable energy future.

The Project Approach

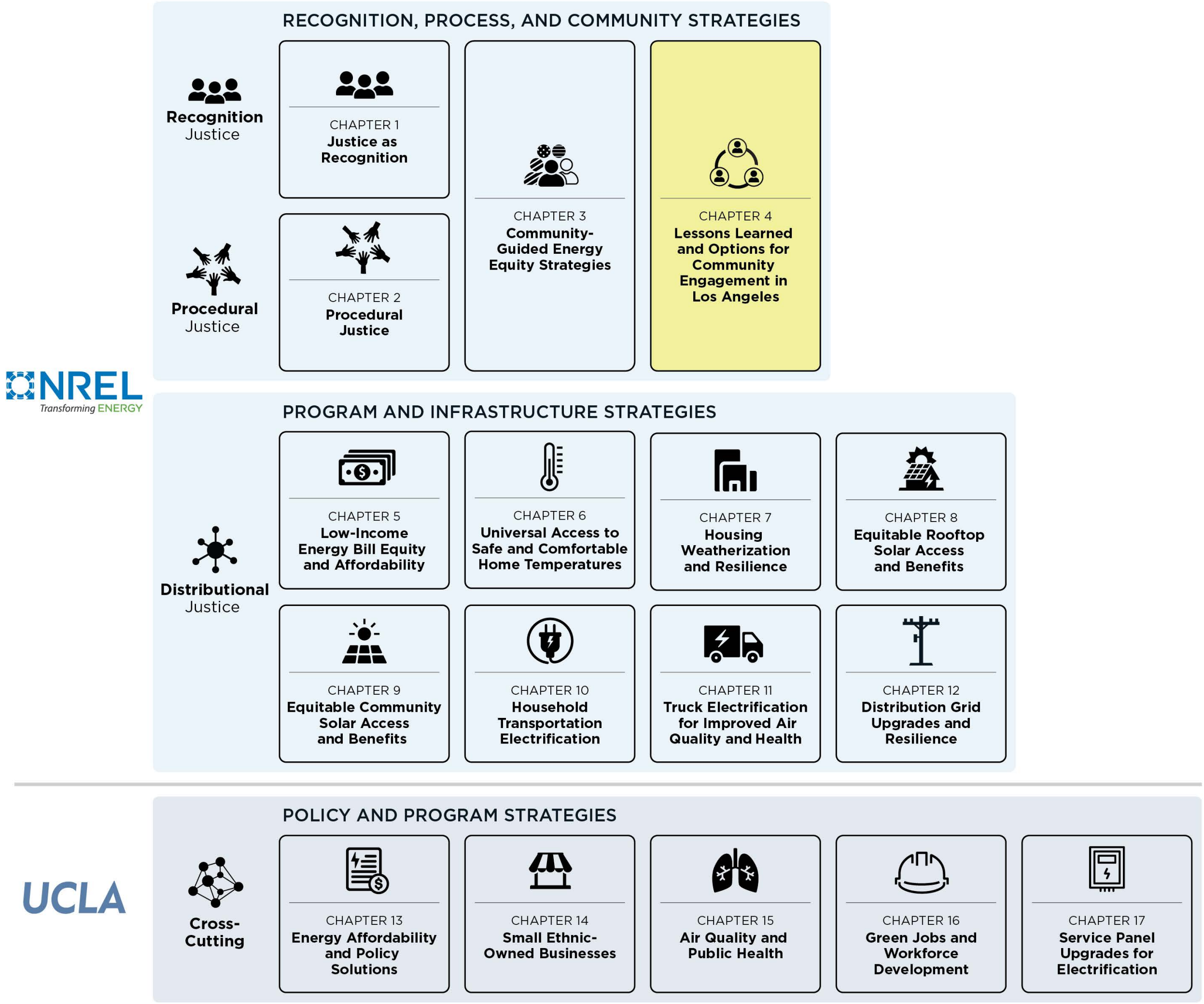
LA100 Equity Strategies employs a unique mixed-methodological approach utilizing three distinct—but connected—research efforts. Through these efforts, NREL and UCLA developed a range of strategy options for increasing equity in LA's transition to 100% clean energy.

A Project Summary

To get a high-level overview of the project, you can dive into the executive summary, interactive data visualizations, and more on the LA100 Equity Strategies website at maps.nrel.gov/la100/equity-strategies.

The Full Report

NREL's final full report for the LA100 Equity Strategies project encompasses seventeen chapters. The first twelve chapters, authored by NREL, are organized around the three tenets of justice. Chapters 1–4 address recognition and procedural justice, while Chapters 5–12 address distributional justice. The final five chapters, authored by UCLA, provide crosscutting policy and program strategies. Each chapter provides data, methods, insights, and strategies to help LADWP make data-driven, community-informed decisions for equitable investments and program development.



NREL
Transforming ENERGY

RECOGNITION, PROCESS, AND COMMUNITY STRATEGIES

Recognition Justice

Procedural Justice

CHAPTER 1 **Justice as Recognition**

CHAPTER 2 **Procedural Justice**

CHAPTER 3 **Community-Guided Energy Equity Strategies**

CHAPTER 4 **Lessons Learned and Options for Community Engagement in Los Angeles**

PROGRAM AND INFRASTRUCTURE STRATEGIES

Distributional Justice

CHAPTER 5 **Low-Income Energy Bill Equity and Affordability**

CHAPTER 6 **Universal Access to Safe and Comfortable Home Temperatures**

CHAPTER 7 **Housing Weatherization and Resilience**

CHAPTER 8 **Equitable Rooftop Solar Access and Benefits**

CHAPTER 9 **Equitable Community Solar Access and Benefits**

CHAPTER 10 **Household Transportation Electrification**

CHAPTER 11 **Truck Electrification for Improved Air Quality and Health**

CHAPTER 12 **Distribution Grid Upgrades and Resilience**

UCLA

POLICY AND PROGRAM STRATEGIES

Cross-Cutting

CHAPTER 13 **Energy Affordability and Policy Solutions**

CHAPTER 14 **Small Ethnic-Owned Businesses**

CHAPTER 15 **Air Quality and Public Health**

CHAPTER 16 **Green Jobs and Workforce Development**

CHAPTER 17 **Service Panel Upgrades for Electrification**

NREL Chapters

Chapter 1: Justice as Recognition

Chapter 2: Procedural Justice

Chapter 3: Community-Guided Energy Equity Strategies

Chapter 4: Lessons Learned and Options for Community Engagement in Los Angeles

Chapter 5: Low-Income Energy Bill Equity and Affordability

Chapter 6: Universal Access to Safe and Comfortable Home Temperatures

Chapter 7: Housing Weatherization and Resilience

Chapter 8: Equitable Rooftop Solar Access and Benefits

Chapter 9: Equitable Community Solar Access and Benefits

Chapter 10: Household Transportation Electrification

Chapter 11: Truck Electrification for Improved Air Quality and Health

Chapter 12: Distribution Grid Upgrades for Equitable Resilience and Solar, Storage, and Electric Vehicle Access

UCLA Chapters

Chapter 13: Energy Affordability and Policy Solutions Analysis

Chapter 14: Small Ethnic-Owned Businesses Study

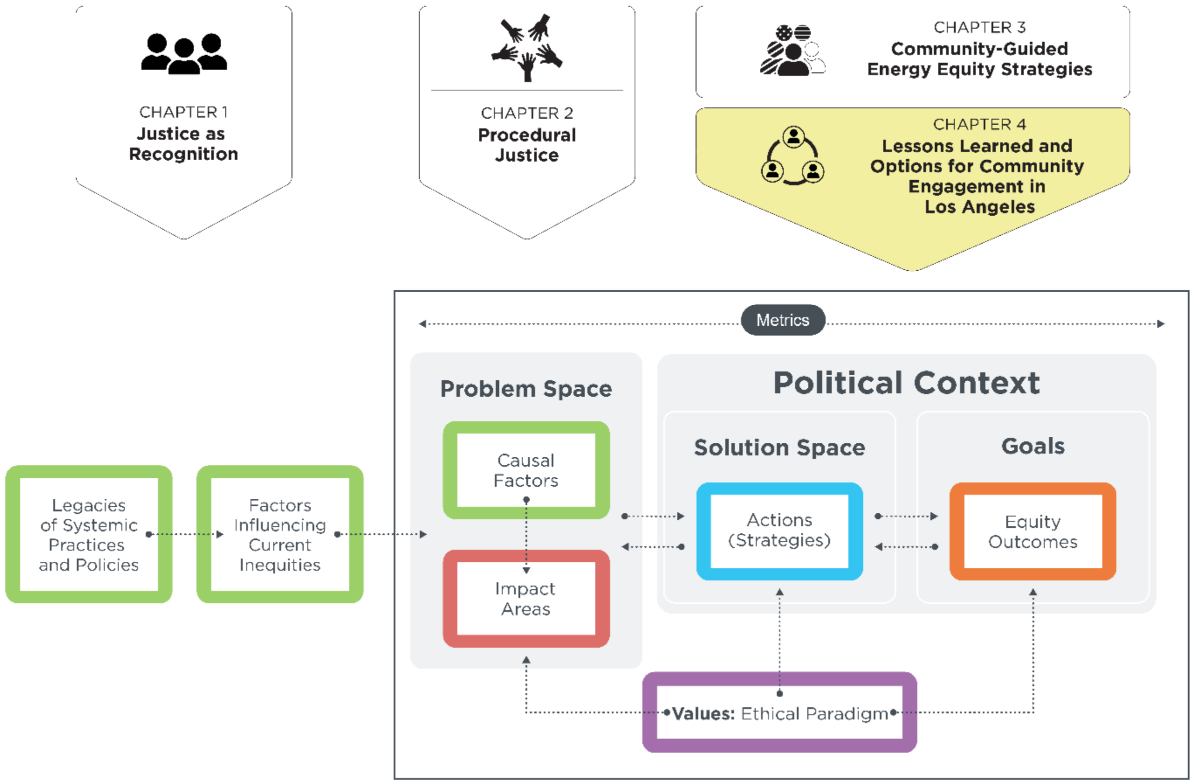
Chapter 15: Air Quality and Public Health

Chapter 16: Green Jobs Workforce Development

Chapter 17: Service Panel Upgrade Needs for Future Residential Electrification

About Chapters 1–4

In Chapters 1–4, NREL presents community-grounded research and analysis results on recognition justice and procedural justice, community-guided equity strategies and future options for community engagement by LADWP. Across these chapters, a mixed-methodological approach is applied, including a systematic literature review, statistical analysis of access to LADWP programs, and qualitative research with communities and community-based organizations to examine understandings of energy transition needs, barriers, and priorities. This work informs modeling and development of equity strategies by analyzing (1) the distribution of benefits of LADWP programs and strategies in the city and (2) historical and current factors contributing to this distribution and other energy inequities in the city.



List of Abbreviations and Acronyms

CBO	community-based organization
DER	distributed energy resource
DOE	U.S. Department of Energy
EMDI	Equity Metrics Data Initiative
EV	electric vehicle
G&T	generation and transmission
IAP2	International Association for Public Participation
LADWP	Los Angeles Department of Water and Power
LIHEAP	Low-Income Home Energy Assistance Program
NREL	National Renewable Energy Laboratory

Executive Summary

Rising to the Challenge

The LA100 Equity Strategies project synthesizes community guidance with robust research, modeling, and analysis to identify strategy options that can increase equitable outcomes in Los Angeles' clean energy transition. Grounded in the analysis of past and ongoing energy inequities and engagement with underserved communities, the project presents community-guided strategies that aim to operationalize recognition and procedural justice. Building on the community-identified problems and solutions, and the analysis of the 11 strategies described in Chapter 3, this chapter continues to focus on the solution space through the lens of recognition and procedural justice. It centers the role of community engagement in energy utility planning and project development with a specific focus on how the Los Angeles Department of Water and Power (LADWP) can engage and work equitably with Los Angeles communities to cocreate a clean and just energy future for LA.

LA100 Equity Strategies is rooted in the crucial role community engagement plays in restructuring the energy systems of cities, states, and nations. Scholarship on wind, solar, and other transitional energy technologies and projects has documented that such engagement is commonly used as a top-down mechanism for adapting social practices to fit new technological innovations (Devine-Wright 2005; Baxter et al. 2020; Boudet 2019). Yet, understanding how the clean energy transition—with related changes in technologies, infrastructures, practices, and costs—will fit equitably into the existing socio-political context is a challenge that requires substantive collaboration with local communities. Any form of community engagement opens up government officials and utilities to opposition from their public (Baxter et al. 2020). Meaningful engagement methods turn such dissent into a strength, embracing critical feedback—particularly from communities historically excluded from decision-making—as contributing to more grounded design and effective implementation. Leveraging this collaborative model to further rectify past and ongoing inequities in the social, cultural, and institutional scaffolding of LA, this chapter presents options and methods to support LADWP in launching a just and equitable clean energy transition. We approach community engagement as a critical process linking recognition, procedural, and distributional justice, outlining how LADWP could learn from past engagement, coordinate such knowledge organization-wide, and use engagement as a key tool for achieving energy justice and equity.

Goal and Approach

To support an equitable clean energy transition, we analyzed how past and ongoing LADWP engagement channels, actions, and findings can be harnessed to build stronger, more substantive relationships with underserved Angelenos. We conducted a systematic literature review of energy-related community engagement to inform and ground an exploratory analysis of 57 U.S. utility community engagement efforts from 52 utility companies. We utilized this exploratory analysis to understand how U.S. utilities currently connect community engagement with energy equity in their regions. We then analyzed data from listening sessions and co-identified constraints and options for embedding energy justice into LADWP organization. These findings allowed us to examine potential opportunities for LADWP engagement practices. Finally, we explored opportunities for LADWP to use community engagement as a catalyst for advancing energy justice in Los Angeles.

We consider *what* community engagement is, and what it can be. We also elaborate on what tools and activities community engagement entails (see also Chapter 3), as well as *how* LADWP can design, implement, and evaluate those tools and activities. Thus, by considering community engagement as a foundational process for co-defining distributional and recognition justice goals, this chapter sets the methodological stage for the distributional equity strategies that follow in Chapters 5–12.

Key Findings and Takeaways

With a focus on community engagement as a holistic approach to achieve energy equity in the clean energy transition in Los Angeles, we organize this chapter's main findings in three groups of options and potential next steps for LADWP moving forward.

Results from Exploratory Analysis of Community Engagement in U.S. Utility Programs

We used the Spectrum of Public Participation, developed by the International Association for Public Participation (IAP2), to assess 57 community engagement programs from 52 U.S. utilities according to the five levels of increasing community impact on decision-making: (1) inform, (2) consult, (3) involve, (4) collaborate, and (5) empower. We also analyzed *if* and *how* utilities target distributional, procedural, and recognition justice in their engagement.

We found that more than 50% of the analyzed programs do not mention any engagement with communities in their public-facing material (i.e., websites), and nearly 25% of the utilities mention informing and consulting communities for their energy projects (see Table ES-1). From our content analysis of information available on utility websites, we found that none of the 57 programs evaluated demonstrate the more collaborative and empowering levels of engagement on public-facing online material (see Table ES-1).

As for how utilities target the three justice tenets, 81% of utility programs that demonstrate engagement primarily target distributional justice, followed by procedural justice (45%); only 29.8% target recognition justice (Figure ES-1). Thus, there is a lack of demonstrated engagement addressing procedural and recognition justice.

Table ES-1. Community Engagement in Program or Initiative Development by U.S. Utilities

Level of Community Engagement	Number of Programs
Utility informed	2
Utility consulted	10
Utility involved	12
Utility collaborated	0
Utility empowered	0
Engagement is suggested	3
Utility did not engage	29
Unclear	1
Total	**57**

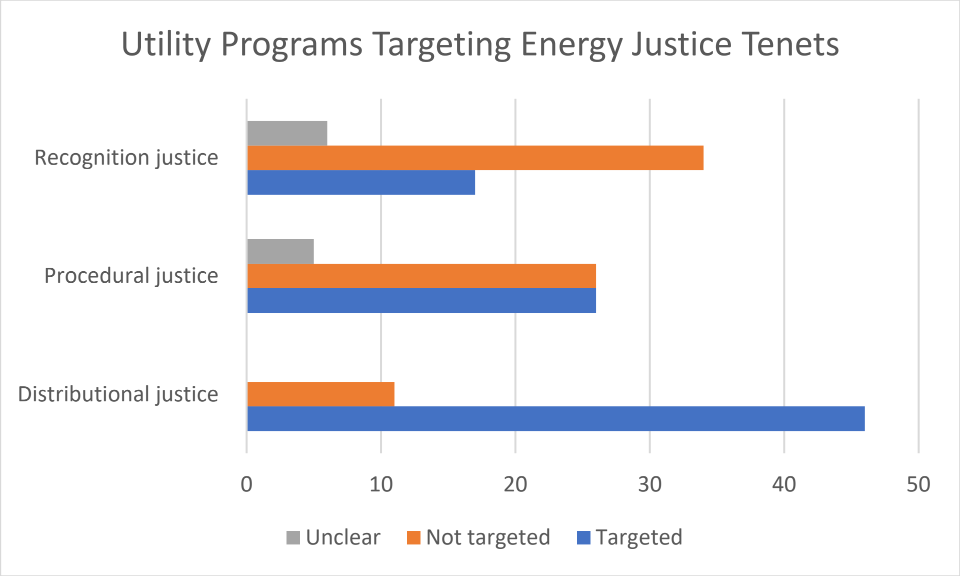


Figure ES-1. Utility programs and initiatives targeting energy justice tenets

A Literature Review to Guide LADWP's Community Engagement Staging

Moving beyond the Spectrum of Public Participation into co-creation via community engagement (see the Glossary, page 25), we connect LADWP's potential for fostering a collaborative engagement platform to lessons learned from energy engagement scholarship (Drakellis 2022; Waters 2015; First Solar n.d.; New York State Department of Environmental Conservation 2009; Lezberg, Dane, and Mullins 2010; Ross and Day 2022; Ziegler and Forbes 2010). These scholars suggest a series of phases to structure an effective engagement process:

- **Phase 1:** In the initial planning, LADWP would need to understand why it is engaging, with what goal (or whom) it plans to engage, and with what intended outcome or result—e.g., site infrastructure, create jobs, reduce health impacts.
- **Phase 2:** The next phase involves two components: a mapping of relevant actors created with residents, and understanding actors' aspirations, interests, and lived experiences. Equally

important is to understand their potential to contribute to the goals of the project, and the ways in which the project can benefit them (or avoid burdening them).

- **Phase 3:** Building relationships with local actors is the next phase, where LADWP needs to select the engagement techniques, the engagement points in the process, the message(s), and the approaches to solicit and include residents' input.
- **Phase 4:** The final phase involves maintaining relationships and evaluating and redefining LADWP's strategy. Because engagement is an iterative and dynamic process, updating and adapting the engagement approach using evaluation tools is crucial to understand: 1) if the engagement efforts are working; 2) how to report back to your actors with progress and updates; 3) how to manage expectations; and 4) how to reflect new information and changing circumstances.

Although these best practices offer options for community engagement in specific initiatives and programs, a collaborative platform could inform LADWP's long-term, multisectoral, and systemic energy transition programs, technologies, and policies. Furthermore, it could help LADWP integrate conflicting sectoral and local interests (e.g., market value versus equity) into citywide energy transition goals (Koontz and Johnson 2004; Scott, Thomas, and Magallanes 2019).

A Collaborative Platform

To involve communities equitably and effectively in the clean energy transition, LADWP could build on its existing entities and programs to develop a collaborative platform, or customized institutional approach, defined as a set of decision-making processes and organizational structures that:

- Engage community-based organizations (CBOs), trusted messengers, communities, and other relevant actors constructively and continuously.
- Are formal, consensus-oriented, and iterative, involving processes of co-producing goals, strategies, and the means to share responsibilities, capabilities, and resources.
- Foster a sense of shared purpose, belonging, and trust (Lee 2022; Patricia Romero-Lankao et al. 2023).

Our findings indicate that the collaborative platform could be an effective organizational means to realize a just and equitable transition to clean energy. Here we present four primary actionable options related to the collaborative platform as a methodological toolkit that could benefit LADWP community engagement in the short and long term. First, the Corporate Strategy Communications Division and the Diversity, Equity, and Inclusion Office, and the Customer Service Operations at LADWP could be responsible for this collaborative platform. These entities could allocate dedicated personnel and resources to co-design, implement, and evaluate the multiple energy equity projects, technologies, and programs involved in Los Angeles' just energy transition.

Second, functioning as a stable, flexible, and agile organizational structure, this platform could formalize the current LA100 Equity Strategies Steering and Advisory Committees and other partnerships and collaborations into long-term agreements to maintain a continuous feedback loop between LADWP, their community partners, and residents. This feedback loop would allow partner CBOs, trusted messengers, and communities to benefit from and contribute to LADWP's success. As trusted sources of knowledge and opportunities in their community, community committees, CBOs, and trusted messengers (e.g., health promoters [*promotoras de salud*]) could become critical platform nodes in LADWP's engagement network, connecting community challenges, needs, and priorities to institutional decision-making and policymaking. For instance, like the CBOs in LADWP's LA100 Equity Strategies Steering Committee, an LADWP Community Committee could gather a group of representative local community members from underserved communities across Los Angeles to collectively review the accessibility and suitability of LADWP programs and services and suggest community-tailored adaptations.

Third, the collaborative platform could move beyond ad-hoc, individual project engagement efforts by enhancing engagement practices and procedures that (1) disseminate accessible, community-tailored information about concerns, opportunities, and costs for residents to benefit from LADWP's energy equity strategies, and (2) create a consistent and agile feedback loop between LADWP and residents that impacts the course of Los Angeles' energy transition toward more just outcomes.

Fourth, as LADWP further expands its engagement efforts in LA communities, its current equity metrics could be refined to assess the design, evaluation, and implementation of its energy equity strategies. LADWP could utilize ongoing engagement efforts to develop community-grounded indicators; they could build a more robust equity measurement methodology to evaluate the outcomes of LA100 Equity Strategies implementation over time. This would include quantitative LADWP indicators, such as the number of power outages per census tract per month, and qualitative LADWP indicators, such as the level of customer satisfaction on customer service calls related to power outages (Chapter 3, Table ES-1). As these indicators come closer to measuring the concrete experiences of a community, they will offer better insights into the effects of the Los Angeles clean energy transition on the lived experiences and realities in these communities.

Besides guaranteeing distributional justice in the equitable distribution of resources, this coordinated equity approach would expand the potential for advancing procedural and recognition justice in current and future engagement processes. Section 5 maps how this toolkit of methods moves beyond the Spectrum of Public Participation into co-creation, connecting community engagement practices and procedures to lessons learned from energy engagement scholarship.

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1 Introduction

In the transition from fossil fuels to clean energy infrastructures in cities, states, and nations, technologies and social and institutional practices will change (Dubash et al. 2022). Community engagement is commonly used as a top-down mechanism for adapting social practices to fit new technological innovations (Devine-Wright 2005; Baxter et al. 2020; Boudet 2019). Furthermore, a growing body of energy justice literature finds community engagement does not necessarily result in more equitable energy outcomes or the perception thereof (Upham, Sovacool, and Ghosh 2022; Carley and Konisky 2020). Understanding how the existing context will be most *equitably* impacted by the clean energy transition—with its related changes in technologies, infrastructures, practices, and costs—is a challenge that requires substantive collaboration with local communities. Any form of community engagement opens up government officials and utilities to opposition from the public (Baxter et al. 2020).[1] Meaningful engagement methods turn such dissent into a strength, embracing critical feedback—particularly from communities historically excluded from the decision-making process—as contributing to more grounded design and effective implementation. From this collaborative approach, public critique is understood as a mechanism of accountability and an opportunity for adapting institutional actions to local needs, priorities, and aspirations, rather than a barrier to the energy transition (Sillak, Borch, and Sperling 2021).

This chapter presents a series of procedural and recognition justice findings, tools, and methods to support the Los Angeles Department of Water and Power (LADWP) as they develop a more equitable distribution of energy benefits and burdens in Los Angeles. We approach community engagement holistically, seeing it as a critical process linking recognition, procedural, and distributional justice. By working *with* Los Angeles' underserved communities and their community-based organizations and institutions, LADWP can: (1) identify past and ongoing historical inequities affecting historically underserved communities, (2) partner with these communities and their trusted institutions to redress identified problems and suggested solutions, and (3) operationalize those community-guided decisions in the more equitable distribution of clean energy benefits and burdens. Thus, by considering community engagement as a foundational process for co-defining distributional justice goals, this chapter lays the methodological groundwork for the distributional equity strategies that follow in Chapters 5–12.

Here, we outline how LADWP could learn from past engagement and centralize such knowledge across their organization. This effort aims to build a foundation for developing more accessible and transparent energy-related communication and engagement with underserved communities, committing to continuity, and providing tools for accountability. To do so, we move from lessons learned from other utility companies to those developed by LADWP. Thus, this chapter includes an analysis of how other utilities from across the United States connect community engagement with energy justice in their projects and programs, to inform LADWP's equity strategies via engagement methods. To support an equitable clean energy transition, we also consider how past and ongoing LADWP engagement channels, actions, and findings can be

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[1] For example, scholars have documented opposition to wind and smart grid projects because of concerns about security, privacy, noise, and uncertainty about potential health and socioeconomic impacts (Devine-Wright 2005; Baxter et al. 2020; Boudet 2019).

harnessed to build stronger, more substantive relationships with underserved communities in Los Angeles. We combine a literature review and an exploratory analysis of 57 utility programs and initiatives that can inform LADWP's engagement process (Section 3). We then analyze findings from listening sessions and the institutional constraints and options for embedding energy justice into the organization (Section 4). Finally, we offer closing remarks on opportunities for LADWP to use community engagement as a catalyst for advancing energy justice in Los Angeles (Section 5).

2 Community Engagement and Energy Justice

Community engagement and energy transition projects are already impacting communities globally in positive and negative ways (Carley and Konisky 2020). For instance, a study of transportation inequities within 36 U.S. cities found unequal access to health, livelihood, and economic benefits as well as unequal health and energy burdens (Patricia Romero-Lankao, Wilson, and Zimny-Schmitt 2022). Therefore, scholars are calling for examination of the meanings and uses of community engagement and energy equity. In this section, we examine the definitions of these concepts to understand the links between engagement and equity in LA energy transition projects.

2.1 Participation and Community Engagement

Internationally, community engagement has increasingly become a prominent method employed by local governments, organizations, and corporations to "incorporate representative community opinions into decision-making" (Johnston 2010). Community engagement has come to signify a series of steps or levels, often defined as a form of public participation. The Spectrum of Public Participation, developed by the International Association for Public Participation (IAP2), is one highly utilized model that operationalizes community engagement into five levels of increasing community impact on decision-making: (1) inform, (2) consult, (3) involve, (4) collaborate, and (5) empower.[2]

In the United States, the origins of the community engagement approach to public participation lie in the critique of centralized, top-down urban planning in the 1960s and 1970s (Jacobs 2016; Arnstein 1969). Scholars and activists promoted the development of participatory planning processes that fostered partnerships with residents to increase citizen control over their cities, including the infrastructures that shape their experience of everyday life (Jacobs 2016; Arnstein 1969). In the 1980s and into the 1990s, participatory governance was eclipsed by austerity measures and a focus on economic, rather than socioeconomic, development. However, by the end of the 1990s and into the 2000s, community participation in governance and development gained renewed force as social and environmental concerns returned to the political forefront in U.S. domestic and foreign policy (Aitken, Haggett, and Rudolph 2016).

In the 2010s, as clean energy became increasingly promoted as a form of environmental justice, energy researchers emphasized the need for community engagement in the clean energy transition (Aitken, Haggett, and Rudolph 2016). In 2022, the Biden Administration's environmental justice agenda institutionalized incentives to include local communities in an energy decision-making process that "ensures [the] equitable distribution of the benefits of many [existing government] programs" (White House 2022). Thus, community engagement has become a key method employed in government efforts to advance energy justice.

Community engagement in and of itself does not denote substantive and equitable inclusion in decision-making and policymaking processes. In the literature on community engagement in energy transition programs, a line of scholarship[3] connects participation and engagement with

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[2] For more detail on the IAP2 public participation model, see cdn.ymaws.com/www.iap2.org/resource/resmgr/pillars/Spectrum_8.5x11_Print.pdf.

[3] See Glossary of Terms for how participation and engagement are defined in the literature.

social acceptance of energy projects and policies (Boudet 2019; Segreto et al. 2020; Stadelmann-Steffen and Dermont 2021a). Following this school of thought, Boudet (2019) understands public ambivalence or disapproval of energy-related programs as one of the most substantial barriers to inclusively achieving clean energy targets. Scholars such as Segreto et al. (2020) Upham, Sovacool, and Ghosh (2022), and Hindmarsh (2010), however, see community engagement as an essential component of procedural justice and energy democracy, critical for building trust, buy-in, and advancing equity in the distribution of benefits and burdens. In our research, community engagement is a critical process for connecting recognition, procedural, and distributional justice.

2.2 Community Engagement and Just Energy Transitions

The transition to cleaner and more equitable energy systems requires the development and/or improvement of decision-making processes and the policies that structure them. Projects and programs created to achieve a just transition can prompt not only support but also opposition, even with the deployment of community engagement tools and strategies (Boudet 2019; Devine-Wright 2005; Devine-Wright and Devine-Wright 2009). Numerous examples are available of such public oppositions to nuclear energy, wind energy, and infrastructure siting, resulting from concerns about security, privacy, pollution (i.e., air, sound), and potential health and socioeconomic impacts (Boudet 2019; Devine-Wright 2005; Devine-Wright and Devine-Wright 2009). Therefore, energy justice scholars and advocates highlight the need to understand the challenges and opportunities of participation and engagement in decision-making and policymaking processes (Baxter et al. 2020; Kallis et al. 2021).

Over the past decade, a large and substantive body of scholarship (Carley and Konisky 2020; Electric Power Research Institute 2021; Sovacool et al. 2016; Heffron and McCauley 2017) has revealed how energy transition projects across the globe affect local communities, disproportionately impacting underserved social groups. This research includes analyzing how the lack of participation in the design and implementation of energy projects can increase inequities in community access to health, well-being, and economic benefits, further intensifying existing health and energy burdens (Romero-Lankao, Wilson, and Zimny-Schmitt 2022). Therefore, advocates for energy justice support a shift in the way underserved communities participate in the energy decision-making process, as well as the policies that shape those decisions.

This literature offers a perspective on how community engagement practices can be developed as a key tool for achieving more equitable energy outcomes. Therefore, to incorporate justice goals in the energy transition, clean energy projects should include: (1) *procedural justice* by substantively partnering with underserved communities to co-develop analysis of technology risk perception and guide the decision-making process throughout the design, implementation, and evaluation of energy projects and programs; (2) *distributional justice* concerns related to the equitable distribution of project benefits and negative impacts, as well as the effects of perceived technology risks on technology and infrastructure deployment (Boudet 2019); and (3) *recognition justice* commitments to redress historical inequities that are reproduced in the current distribution of investments, programs, health impacts, and other energy benefits and burdens. Research on energy-related community engagement practices highlights the positive correlation between procedurally just engagement and community trust in utility companies and other associated institutions (Segreto et al. 2020; Prosperi, Lombardi, and Spada 2019; Delicado, Figueiredo, and Silva 2016).

However, *how* engagement is designed and implemented determines the potential for equitable impact. This body of scholarship also emphasizes that engaging and developing participatory methods does not guarantee just outcomes. One reason participation alone is not sufficient is that dominant, institutionalized approaches tend to focus on transactional relationships that impose preconceived solutions disconnected from local realities. For example, one type of transactional engagement process consists of utilities that present large-scale energy projects to the public as necessary social costs for advancing technical innovation and progress, rather than events that can influence community members' energy burdens and day-to-day lives (Walker and Baxter 2017; Dunlap 2018; Mejía-Montero, Alonso-Serna, and Altamirano-Allende 2020).

Critical knowledge gained from evaluations of existing energy equity projects has shown the significance of actively engaging underserved communities and community-based organizations (CBOs) in defining more equitable priorities, goals, and strategies (Patricia Romero-Lankao and Nobler 2021). However, the below analysis of community engagement practices promoted by 52 U.S. utility companies (Section 3), as well as results from the LA100 Equity Strategies community engagement activities, reveals that while several energy utilities in the United States are incorporating public participation in energy project implementation, most of these efforts prioritize *distributional justice* without including *recognition* and *procedural justice*.

As Chapter 2 discusses in detail, the process of community engagement is critical to procedural justice "conceived in terms of the way decisions are made, who is involved and has influence, and access to the formal justice system" (Williams and Doyon 2019, 147). Procedural justice also requires reassessing the legislation, policies, programs, investments, and procedures that inform the development of pathways toward a more just future. This idea was recurrently stated by community members in LA100 Equity Strategies listening sessions. For these Angelenos, understanding *how* and *why* projects related to the energy transition fail to address inequities is a crucial part of achieving energy justice, in all its tenets. Understanding how community engagement strategies have been developed is a way of identifying the underlying factors that produce current inequities in Los Angeles, then co-developing solutions with affected communities to realize a more equitable energy transition.

This community engagement process is critical to achieving *procedural justice* in energy decision-making. Those decisions inform the design and implementation of energy-related programs that aim to address *recognition* and *distributional injustices.* Realizing a more inclusive energy transition necessitates analyzing how past engagement strategies and tools have been understood and assessed in local communities. Accordingly, it is necessary to carefully analyze both the definitions of those concepts (i.e., community engagement, participation, and their links with energy equity and justice) and the ways they are operationalized in the design and implementation of all energy projects and programs.

2.3 Methods and Data

This chapter uses a mixed-methodological approach (further described in Chapters 1–3), including a literature review (Chapter 1), an exploratory analysis of 57 community engagement and energy equity programs from 52 U.S. utilities, and an analysis of LADWP engagement and equity strategies, with the goal of identifying potential options and next steps for LADWP in this domain.

We expanded the literature review described in Chapters 1–3 to include scholarly research that examines the links between community engagement and equity in energy infrastructure, technologies, and programs. Within this scope, we analyzed a body of literature that connects engagement practices in a wide array of projects and technologies, from solar to infrastructure siting, with the possibilities of enacting an equitable transition to renewable energy (Aitken, Haggett, and Rudolph 2016; Burningham, Barnett, and Thrush, n.d.; Webb, Tingey, and Hawkey 2017; Stadelmann-Steffen and Dermont 2021b). Four questions guided the literature review:

1. How are community engagement and energy equity defined and approached?
2. How are procedural, recognition, and distributional justice targeted?
3. What are the insights on engagement and its links to energy equity in the transition to renewable energy?
4. What lessons and options can be drawn to guide LADWP's engagement efforts?

The literature review allowed us to systematize knowledge on community engagement to inform and ground an exploratory analysis of select U.S. utilities' community engagement efforts. We conducted content analysis (Keller 2011; Romero-Lankao and Gnatz 2019) of 57 programs and initiatives from 52 U.S. utilities targeting community engagement and energy equity via web searches. This research was developed in partnership with the Smart Electric Power Alliance, who provided us with information and data on selected utilities' energy equity programs and initiatives. We included utilities that represent a range of types (i.e., private, public), sizes, and geographic regions, along with a range of programs or initiatives (Section 3). We used the following questions to guide this exploratory analysis:

- What level of community engagement is used in the utility program/initiative?
    - How, and with what level of engagement, is it operationalized?
- Is the utility targeting procedural justice in the program/initiative?
    - What procedures are used, and how are communities involved?
- Is the utility targeting distributional justice in the program/initiative?
    - What metrics are used to identify underserved communities and understand the distribution of benefits and negative impacts or program performance?
- Is the utility targeting recognition justice in the program/initiative?
    - How is the utility addressing the impacts of past inequities?

We utilized this exploratory analysis to understand how U.S. utilities currently connect community engagement with energy equity in their regions. These findings allowed us to identify potential opportunities and limitations for LADWP engagement practices.

We used a set of methodological tools to analyze LADWP's past and current community engagement strategies. These tools included one-on-one meetings with Steering Committee CBOs conducted in November 2021, 15 neighborhood-specific listening sessions conducted throughout 2022, LA100 Equity Strategies Advisory Committee meetings, and elicitation exercises conducted at Steering Committee meetings. We also reviewed the City of Los Angeles Civil Service Commission's current hiring regulations to understand the options and constraints posed by LADWP's internal structure to support engagement work. Finally, we analyzed LADWP Equity Metrics Data Initiative (EMDI) reports and presentations to ground LA100 Equity Strategies' engagement in past LADWP equity efforts.

The opportunities for strengthening LADWP's community engagement strategies, as described in this chapter, derive from an inclusive engagement process. Each of these community engagement activities was transcribed, anonymized to protect participants' personal information, coded[4] to identify key themes and concerns, and used to inform National Renewable Energy Laboratory (NREL) technical models for future energy justice strategies (Chapters 5–12). LADWP compensated all listening session participants for their time and expertise. We use highly mentioned themes (categorized into "codes"), along with the knowledge gained from content analysis of the material described above, to identify windows of opportunity for collaboratively developing LADWP's future equity strategies.

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[4] We used qualitative coding to identify categories and concepts in the data and link passages of the CBO interviews, as well as the 15 listening session transcriptions, to themes that became labeled with a particular "code." In this chapter, we analyze a set of high-frequency codes that address how participants experience and understand community engagement led by government entities and how to align future processes with community priorities.

3 U.S. Utility Engagement Practices and Programs

This section presents the results of the exploratory analysis of community engagement and energy justice in 57 programs and initiatives developed by 52 energy utilities in the United States.[5] Here, we focus on key findings and programs relevant to LADWP engagement and energy equity efforts and planning.

For these 57 programs, we employed content analysis on their public-facing materials available online to examine how these U.S. utilities engage with their customers, how they target the three justice tenets, and what equity topics they address (section 3.1., Table 4). We also highlight some examples of programs that are relevant for LADWP's efforts to incorporate the suggestions of Angelenos. One main finding from our analysis of these 57 U.S. utility programs is that the majority were run by investor-owned and public power utilities (Table 1 and Table 2). Although there are fewer investor-owned utilities than publicly owned or cooperative utilities, investor-owned utilities tend to be very large, serving three of every four utility customers nationwide (EIA 2019).

Table 1. Number of Programs by Utility Type

Utility Type	n = Programs
Power agency/G&T (generation and transmission)	2
Investor-owned	36
Public power	10
Distribution cooperative	3
Multiple utilities	4
Other	2
Unclear	2
Total	**57**

Table 2. Number of Programs by Utility U.S. Region

U.S. Region	n = Programs
East	13
North	14
Central	5
South	11
West	14
Total	**57**

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[5] See Appendix A for companies and programs analyzed. For the purposes of this content analysis, we counted national utility companies with local presences (i.e., Xcel Energy MN and Xcel Energy CO) that utilized different engagement programs in each locality as separate utility companies.

3.1 Utility Programs and Initiatives

Scholars argue that understanding the utility's methods and procedures for community engagement is a prerequisite for analyzing their engagement practices (Stadelmann-Steffen and Dermont 2021a; Chodkowska-Miszczuk, Martinat, and Cowell 2019; Stober et al. 2021). However, in our analysis of public-facing material about utility energy projects, we found that 51% of the utilities do not mention engagement with communities on their websites, and one-quarter mention informing and consulting communities for their energy projects (Table 3). Only 21% of the programs were publicized as involving their communities in program development (Table 3). Integrating community members in the development process is a foundational element of procedural justice. Through procedural justice, community engagement can redress recognition injustices and guarantee a more equitable distribution of benefits and burdens.

Table 3. Community Engagement in U.S. Utility Program or Initiative Development

Level of Community Engagement	Number of Programs
Utility informed	2
Utility consulted	10
Utility involved	12
Utility collaborated	0
Utility empowered	0
Engagement is suggested	3
Utility did not engage	29
Unclear	1
Total	**57**

Studies have found that engaging in participatory methods does not guarantee that energy equity will be enacted or perceived to be enacted (Aitken, Haggett, and Rudolph 2016; Johnston 2010; Hindmarsh 2010; Devine-Wright 2005; Baxter et al. 2020; Walker and Baxter 2017). They argue that promoters' efforts are thwarted either by a lack of engagement or engagement that utilizes top-down, one-way, instrumental approaches. Both a lack of engagement and instrumental forms of engagement are disconnected from local realities and community lived experiences needed to substantively improve program outcomes (Walker and Baxter 2017; Dunlap 2018; Mejía-Montero, Alonso-Serna, and Altamirano-Allende 2020; see Figure 1). In the table below (Table 4) we can see which topics are addressed by the analyzed programs and initiatives in their public-facing material. Most of the programs are related to workforce development, cross-cutting energy issues, transportation electrification and community engagement.

Table 4. Number of Programs or Initiatives by Topic

Topic	Number of Programs
Workforce development	11
Community engagement	8
Transportation electrification	8

Topic	**Number of Programs**
Equity metrics	6
Renewable energy	2
Energy efficiency	2
Diversity, equity, and inclusion plan	1
Energy affordability	1
Multiple/crosscutting	9
Other	9
Total	**57**

To analyze the engagement approaches used and their potential equity outcomes, we identified how each relates to the three tenets of energy justice. In our content analysis of public-facing materials available online, we found that utility programs and initiatives mostly target distributional justice (81%), followed by procedural justice (45%), and only 30% of the utility programs target recognition justice (Figure 1). Ideally, utilities would be able to incorporate all three tenets of justice and demonstrate that process transparently with the public. Distributional justice tends to focus on the symptoms. Yet it is through understanding recognition and procedural justice that utilities will be able to remedy the causes of these symptoms.

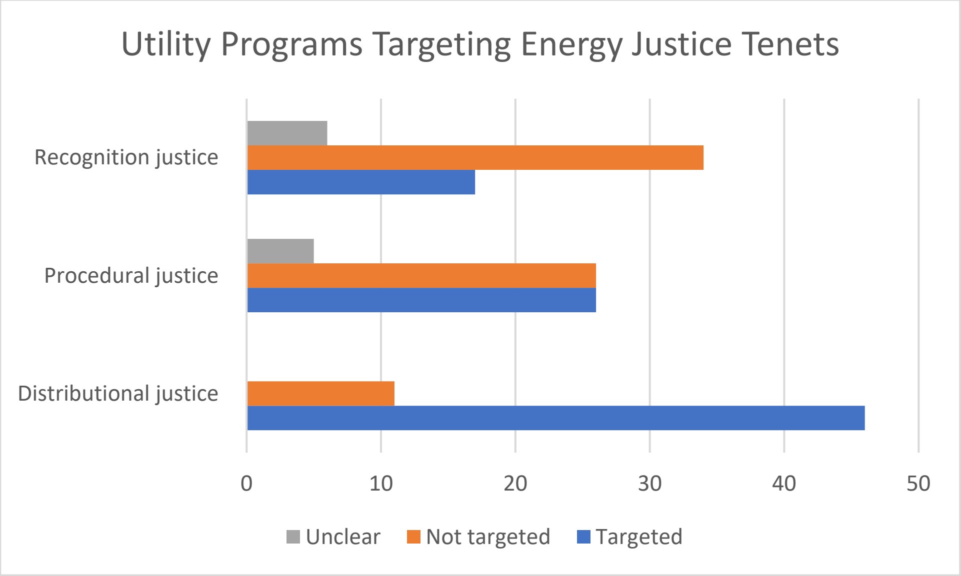

Figure 1. Utility programs and initiatives targeting energy justice tenets

Energy justice tenets are presented in the Glossary.

3.2 Insights and Lessons

To draw lessons and insights from U.S. utilities' engagement approaches, we analyze how they connect engagement with distributional, recognition, and procedural justice. LADWP can learn from some programs targeting distributional justice (see the list of programs in the appendix); for instance, the New York Power Authority's Community Distributed Generation and Con Edison's PowerReady Disadvantaged Community Areas. The latter intends to extend access to electric mobility. As part of Community Distributed Generation, the New York Power Authority identified larger customers (ones that use more energy) within underserved communities to serve as anchor tenants in a community solar program. The goals of this program are to increase access to community solar with resulting electric bill savings for low- to middle-income households and to reduce operating costs for affordable housing and nonprofit entities serving underserved communities.

Notable examples of utilities targeting procedural justice in their programs include Madison Gas and Electric, Pacific Gas and Electric, Duke Energy Carolinas, and Seattle City Light. For instance, Duke Energy Carolinas increased funding to educational organizations that specialize in providing utility workforce education and training to underrepresented workers. Madison Gas and Electric undertook a multistep engagement process, including community energy conversations, a customer survey, a community energy workshop, and a technical work group, to inform the development of its Energy 2030 framework (Madison Gas and Electric 2015) for a more sustainable future (list of programs in the appendix).

A few utilities, such as Pacific Gas and Electric and Austin Energy, are targeting the three energy justice tenets (list of programs in the appendix). In the Transportation Electrification chapter of its *2021 Austin Climate Equity Plan*, Austin Energy targets distributional justice by streamlining applications (Austin Energy 2021). This includes removing a program participation barrier in which the utility accepts income verification forms submitted to a separate program as proof of eligibility for the electric utility's programs. If the customer had a federally funded Low-Income Home Energy Assistance Program (LIHEAP) applied to their account within the past 24 months, they can submit a Customer Assistance Program application without additional proof of eligibility. To target procedural justice, this program relies on community climate ambassadors as trusted engagers with communities on topics such as public transit and electric vehicles. The climate ambassadors work with local community partners, grassroots organizations, the Customer Assistance Program, and the City of Austin's affordable housing programs to (a) complete a grassroots needs assessment, (b) hire residents to help conduct the needs assessment, and (c) host community input sessions to build ongoing inclusive relationships that will inform focused outreach to low-income communities and communities of color (Austin Energy 2021). Finally, to target recognition justice, the utility plans to install electric vehicle (EV) charging on publicly owned land and systematically excluded areas (e.g., multifamily properties, parks, community centers, libraries, and low-income communities and communities of color).

When energy utilities focus on equity, we found that five energy equity topics are mentioned in program and initiative descriptions: workforce development, community engagement, multilevel/crosscutting issues, transportation electrification (already discussed above), and equity metrics (list of programs in the appendix). Workforce development initiatives, including LADWP's Utility Pre-Craft Trainee program, range in their scope and reach. Some are clearly and transparently working toward more inclusive workforce development programs. Others lack clarity on their public-facing approach. On the transparent end of the spectrum, programs such as Baltimore Gas and Electric's Smart Energy Workforce Development Program helps students and other members from underserved communities earn jobs within Baltimore Gas and Electric and its contractor partners. Similar to the Utility Pre-Craft Trainee program, this joint effort brings Baltimore Gas and Electric's staff together with local workforce development organizations and career and technical education high schools to help underrepresented populations develop the necessary skills to compete for job opportunities and lifelong careers (list of programs in the appendix). On the other end, three Duke Energy operating companies are examples of philanthropic efforts to fund equity via CBO grants to support workforce training, initiatives, and projects to attract and retain underrepresented workers. It is unclear, however, how training organizations are selected and what metrics these utilities use in the grant process to ensure funds are reaching underrepresented workers. Utilizing an equity approach, those metrics would be clear and available to the public for transparency and accountability. Therefore, developing community-informed metrics and other evaluation tools is important to assess the performance of these programs—a point we will revisit in Section 5 (see also Chapter 3).

Powering Our Community's Future: Stakeholder Engagement and Public Input Report (City Public Service 2022) describes one of the nine utility programs targeting multiple crosscutting issues relevant to LADWP (see the list of programs in the appendix). Published by the public utility City Public Service in 2022, this report describes a process designed to reach out and encourage customers to participate in and inform decision-making by City Public Service's Board of Trustees. It features information about events and engagement tools to gather public feedback on generation planning objectives and portfolio options. It also includes communication toolkits that stakeholders can easily share with their networks, available in English and Spanish and in print and digital formats.

Of the 57 utility programs analyzed, six mention, in their public-facing material, energy equity metrics and tools that can inform their engagement efforts, including one developed by LADWP (see Section 4.2). For example, Seattle Public Utilities has access to a team and tools that center racial equity at early planning stages by determining where inequities are present, shaping and guiding the creation of an equity toolkit, and changing the way they do business, moving the utility toward equitable and inclusive outcomes. Sacramento Municipal Utility District uses a map to identify underserved or distressed areas in its service territory based on data on gaps in five areas of concern: past community engagement efforts, income, affordable housing, employment opportunities, and transportation. The map is intended to aid in future investment and program decision-making.

4 LADWP Engagement and Equity Initiatives

In this section, we review LADWP's recent community engagement efforts, options, and potential next steps toward advancing energy justice as LADWP continues institutionalizing diversity, equity, and inclusion into its organization and expands community investments via LA100 Equity Strategies. First, we review a set of current community engagement efforts that lay the groundwork for contextualizing the key engagement findings from the LA100 Equity Strategies listening sessions. Second, we review some of the institutional constraints that shape the possibilities for embedding energy justice into the organization. In Text Box 1, we draw lessons from the three decades of success of the Clean Cities Coalition Network for LADWP to develop a collaborative platform to formalize its existing partnerships with CBOs, trusted messengers, and underserved Angelenos.

Text Box 1. Learning from a Successful Collaborative Platform

Historically, efforts to transition away from fossil fuels have faced various social and political challenges (Koontz and Johnson 2004; Scott, Thomas, and Magallanes 2019). Energy utilities and city officials, among other energy actors, find it difficult to devise rules that balance unequal decision-making power and resources to initiate collaborative processes (Newig et al. 2018; Emerson, Nabatchi, and Balogh 2012).

We draw lessons from the long-term success of the Clean Cities Coalition Network,[6] a collaborative form of governance translating high-level policy goals into multiple, ongoing collaborative practices for more than 30 years (Romero-Lankao et al. 2023). Here we point to a series of attributes that explains the long-term success of Clean Cities coalitions as a collaborative platform (Newig et al. 2018).

First, Clean Cities provides a relatively stable *institutional structure* on which and through which more dynamic and distributed processes and activities are organized. Within this framework, the U.S. Department of Energy (DOE) and the national laboratories hold coalitions accountable to standards and requirements that ensure a minimum level of engagement: formal designation and redesignation, cooperative agreements with DOE, and annual reports, along with other expectations guiding their participation in Clean Cities activities (DOE 2023). As we will show in Section 5.1, LADWP could create a similar stable yet flexible structure to formalize its existing partnerships with CBOs, trusted messengers, and underserved Angelenos.

Second, each CBO in Los Angeles could operate like an individual coalition in the Clean Cities network. Each coalition is supported by DOE and its laboratories, yet they are *semiautonomous* organizations, making independent strategic and programmatic decisions. Like the coalitions, rather than representing LADWP, CBO directors would be independently hired, local, entrepreneurial leaders focused on achieving equity and other sustainability goals in the energy transition. This independence has allowed coalitions to build networks, design creative funding streams, and tailor messaging to local contexts in a manner that national labs or other federal entities cannot. Like an individual Clean Cities coalition, each collaborating CBO would require significant support from LADWP and the City of Los Angeles, thus grounding the CBO's independent efforts in an existing support structure.

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[6] In 1993, the U.S. Department of Energy (DOE) created Clean Cities in response to a requirement in the Energy Policy Act (EPAct) of 1992 to implement voluntary alternative fuel deployment efforts. See https://afdc.energy.gov/laws/key_legislation#epact92 for why Clean Cities was established.

Third, LADWP's collaborative platform could be structured to create *interdependent modularity*, an organizational property that allows participants to adapt to the complexity of equity in the energy transition. Interdependent modularity has two properties: (a) It is organized to allow inter-organizational coordination and to not require overt managerial control (Furlan, Cabigiosu, and Camuffo 2014); (b) It entails partnerships formed to achieve broader goals, which can change and grow over time, incorporating multiple collaborations around new programs, investments, and activities.

Fourth, integrating the prior attributes into the collaborative platform is crucial to *adaptability*. LADWP could learn from Clean Cities, utilizing that knowledge to facilitate a series of collaborative networks and activities that evolve and adapt to the changing circumstances involved in a just energy transition. Adaptability, defined as "the ability to adjust itself to a complex array of interlocking challenges," (Romero-Lankao et al. 2023) is a crucial attribute LADWP could pursue as they build on their existing administrative offices to create a collaborative platform that continuously reassesses its goals and priorities in partnerships with their communities.

4.1 LADWP Institutional Engagement Structure

The principal institutional arm of community engagement that LA100 Equity Strategies participants and NREL engaged with since 2021 is the Community Affairs team at LADWP. This team is made up of 5–7 members and sits within LADWP's Corporate Strategy and Communications Division. This small but mighty group is a stable, flexible, and nimble *institutional engagement structure* handling a wide range of LADWP engagement efforts, including but not limited to:

1. Stakeholder engagement processes
2. Steering Committees and Advisory Groups
3. Point of contact for all Neighborhood Councils
4. Community events (upward of 250–300 per year)
5. Construction outreach for large infrastructure projects
6. Customer service projects
7. The Speakers Bureau program
8. Staff-level speakers at the community level
9. Field trips
10. Tours of facilities.

To maximize their reach and build relationships with local communities over time, members of the team are assigned to certain regions of the city. This geographic approach has helped them build lasting partnerships with CBOs within their assigned regions (LADWP Representatives 2023).

Another important LADWP department for community engagement is the Customer Service Division. This division is responsible for (a) providing customers with information to help navigate LADWP bills and services; and (b) answering customer questions, investigating, and resolving complaints pertaining to utility billing procedures (211 LA 2023; LADWP News 2023). This division also approaches community engagement geographically, running LADWP's Customer Service Centers in neighborhoods across the city where ratepayers can make payments as well as resolve bill or service issues in person.

To complement its existing geographic representation, LADWP is currently developing a new institutional arm for community engagement that focuses more on Los Angeles' cultural and ethnic communities. This arm will be built out of the utility's Diversity, Equity, and Inclusion Office. Given this effort is still in its infancy, we will focus more on (a) the attributes this institutional engagement structure could nurture to be successful; (b) institutional limitations; (c) lessons learned from past engagement efforts, including LA100 Equity Strategies; and (d) potential future directions for LADWP as they expand their engagement infrastructure.

LADWP could build on its current institutional engagement efforts to outline the goals, programs, and tasks CBOs and other partners would be responsible for over the years leading to the city's 2035 clean energy transition objectives. While CBOs, trusted messengers, and other partners could apply for LADWP and City of Los Angeles programs and resources, they would be semiautonomous and make independent strategic and programmatic decisions. For instance, CBO directors are not representatives of any city agency. Rather, they are independently hired, local leaders that dedicate themselves to the CBO mission. In short, partners would be *semiautonomous* while benefiting from and contributing to LADWP's success.

Interdependent modularity (see Text Box 1, page 13) is an organizational property that would let LADWP engage with members of its steering and advisory committees among other network partners on an ongoing basis to adjust to the complex energy transition processes they are launching (i.e., be *adaptable*). Some of these processes involve tailored technical assistance to upgrade roofs, insulate houses, and install electric panels and charging stations, while others entail listening sessions, workshops, and other methods to involve communities in project development. Structured around the partner network that permits coordination of projects and programs while diminishing the need for overt managerial control (Furlan, Cabigiosu, and Camuffo 2014), modularity would allow LADWP to flexibly engage in an array of partnerships—such as advancing affordable and cost-effective clean energy and energy efficient systems—that would grow and change over time, including multiple partnerships, projects, and activities.

A wide range of sources, from listening session participants and NREL and LADWP community engagement professionals to scholarly research (Johnston 2010; Baxter et al. 2020), point to the benefits of using this partner network to developing deep, long-lasting ties with local communities that maintain trust and accountability over time (Chapters 2 and 3). Several approaches can be used to develop long-term feedback loops with local communities. One method is employing community members in public organizations as liaisons and trusted messengers with local expertise (Ishimaru et al. 2016). Another method is developing partnerships with CBOs that already have a network of trusted messengers and community expertise. However, as LADWP further develops its newest wing of community engagement, it must work within the hiring constraints set by the City of Los Angeles.

The upcoming community engagement positions for the Diversity, Equity and Inclusion Office will most likely be within the Management Analyst category (LADWP Representatives 2023). According to the City of Los Angeles Civil Service Commission, the professional duties of a Management Analyst class specification consist of, "researching, assembling, analyzing, and interpreting data and … preparing correspondence and reports with recommendations to management on a wide variety of administrative, fiscal, grants, budgetary, personnel, legislative, and managerial problems" (City of LA Civil Service Commission 1999). While this professional profile is skilled in the analysis of community data, they are not necessarily trained in building the relationships and on-the-ground qualitative research to develop a community engagement process and gather related data (e.g., to develop community-grounded performance measurements). Furthermore, community members applying for a potential community liaison position would most likely not have the skillset required to fill a management analyst position.

Given the City of Los Angeles' current hiring regulations, LADWP does not have the ability to institutionally incorporate local community members with engagement expertise into their organizational structure (LADWP Representatives 2023; City of LA Civil Service Commission 1999). However, there are other approaches to ensure trusted messengers maintain feedback loops with local communities and that their expertise influences internal decisions within LADWP. Section 5 discusses those potential engagement options. The following section lays out how LADWP first connected their community engagement efforts to explicit equity goals.

4.2 Equity Metrics Data Initiative

Beginning in 2016, LADWP planned and conducted a focused engagement process to develop the Equity Metrics Data Initiative (EMDI). The EMDI sought to establish a data-driven framework to evaluate the geographic and demographic distribution and use of all LADWP programs, services, and resources (LADWP 2016). The goal of EMDI was to ensure LADWP "provide(s) fair and reasonable services to all ratepayers. Stakeholder outreach and participation have been an important part of this initiative to ensure equity for our customers" (Stone 2018).

The EMDI's engagement process was designed to focus on refining preliminary evaluation measurements iteratively over time. LADWP describes its methodological approach to EMDI as follows:

> "LADWP began gathering information on these metrics upon Board approval in August 2016, and reported its findings March 7, 2017. Reports will follow every six months thereafter, concurrent with our reporting of our Rates Metrics. After the initial report, the LADWP will fine-tune the metrics to include any other areas that should also be evaluated and remove others that may be redundant or duplicative. In the formation and the development of EMDI, LADWP received many valuable suggestions from various stakeholders. Here [50 metrics] are suggestions and methods that were not included in the 15 selected metrics for the EMDI but will be regularly reconsidered for evaluation and reevaluation as EMDI is implemented and refined. LADWP presents the Equity Metrics Data Initiative (EMDI) Report to the Board of Water and Power Commissioners on a semiannual basis. Stakeholder meetings are also being held to seek input from interested

> parties about how equity metrics are used on LADWP programs and services" (LADWP 2022).

The foundational EMDI engagement process took place from 2016 to 2017 and included the following steps (derived from LADWP [2016]) to elicit and incorporate key stakeholder feedback from Los Angeles communities into the development of their equity metrics:

- Presenting "current and future programs for Equity Metrics Data Initiative and get[ing] feedback and direction from the [LADWP] Board [of Commissioners]"
- Working "with communication and operating organizations to get input from key stakeholders on the development of Equity Metrics"
- Establishing an electronic communications channel to receive input from stakeholders
- Hiring additional staff to support this initiative
- Conducting a follow-up meeting "with key stakeholders to review and finalize the equity metrics"
- Collecting data to develop the Equity Metrics
- Finalizing an "Initial Report on Equity Metrics" to present to the LADWP Board of Commissioners
- Developing semiannual reports moving forward that coincide with LADWP's Rates Metrics reporting.

The last engagement activity published on LADWP's website related to EMDI is a report of results from the February 2021 EMDI Stakeholders Workshops spearheaded by LADWP Board of Commissioners Vice President Susana Reyes. Along with that material, the last LADWP Rates and Equity Metrics Semi-Annual Report available to the public on LADWP's website is from February 2022. Section 5 points to the opportunities still available for incorporating the knowledge gained and relationships built during the EMDI into further LADWP engagement and equity efforts moving forward. The wealth of material gathered during the EMDI process from stakeholder engagement, as well as the expertise that was co-constructed with stakeholders during this engagement process and the partnerships it nurtured, are all valuable resources for advancing energy equity in Los Angeles. These results could be incorporated into a database of past and ongoing engagement resources that form part of an LADWP collaborative platform (see Section 5.1 for details).

4.3 LA100 Equity Strategies

> From the … last meeting we had, we talked about this being a follow-up, hopefully to the equity matrix [Equity Metrics Data Initiative]. I'm a stakeholder of that process. And I'm really hoping that it is. Because all of us engaged with [the EMDI] with the understanding that it was going to go forward. There was a deep commitment by [LA]DWP to go forward. … There should not be a question about equitable distribution of resources. Or even an analysis of where communities are. … And so, I think the real question is, why does it appear we are gathering the same information we gathered? It's not dated, I mean it hasn't been a decade. It may have been 4 years. …Why are we back asking the same questions, when the commitment was made? … So, it's almost as if we are being asked to participate in a circular communication. … So, our real question is, what

> is the commitment of [LA]DWP to carry out what it has already publicly made a statement it's committed to? Its commission has said it's publicly committed. There has been even rate increases since then, in order to fund it. So, why ask the same questions again?
>
> – South LA Listening Session Participant

The opening quote in this section points to both the consistencies of LA100 Equity Strategies—inviting some of the same community members and CBOs to participate in energy justice engagement—as well as the discontinuity of the process. The EMDI and LA100 Equity Strategies, while related, were not developed together via ongoing, connected engagement. Rather, their engagement processes were experienced by some listening session participants as a "circular communication" that is "asking the same questions" and inducing stakeholder fatigue. While LADWP's commitment to equity may have remained consistent from 2016 to today, these community stakeholders are not able to understand the throughlines between these two equity initiatives.

One reason for that lack of clarity and consistency is that LADWP does not currently have an internal organizational structure where all community engagement work is centrally stored for all LADWP departments to access and utilize. Thus, there is an opportunity for developing a master vision and coordinated knowledge of LADWP community engagement (LADWP Representatives 2023). This centralization can take the form of an internal database for storing information on past and ongoing community engagement strategies. Such a coordinated resource is both a tool and an institutional collaborative platform for guaranteeing accountability and continuity that allows LADWP to plan holistically across departments and maintain a transparent and continuous approach over time. For example, if specific equity issues are related to electrical upgrades in a particular neighborhood, a centralized engagement database could help LADWP locate the most relevant CBOs to engage on that topic. Furthermore, such a centralization of engagement efforts would allow LADWP employees working with community engagement to utilize equity metrics to develop solutions to track and hold their teams accountable (LADWP Representatives 2023). Beyond only guaranteeing distributional justice in the equitable distribution of resources, this coordinated equity approach would expand the potential for advancing procedural and recognition justice in current and future engagement processes.

While Chapters 1–3 provide a more detailed discussion of energy justice methods and our analysis of LA100 Equity Strategies' qualitative data, here, we highlight some key themes of importance related to engagement processes. Listening session comments related to "engagement continuity" and "circular conversations" became two key sub-themes within NREL's analysis code called "Building Trust and Confidence." This code describes segments of listening session narratives that relate to a need for an engagement process—i.e., practices and procedures—that builds community trust and confidence in government agencies, including LADWP. The codes, "Building Trust and Confidence" and "Lack of Accessible Information" were the two highest-frequency codes within the supra-category "Participation, Outreach, and Communications" that gathered participant narratives related to the community engagement process. Narratives related to "Building Trust and Confidence" were identified 104 times throughout the listening sessions, and the code "Lack of Accessible Information" was identified 132 times in segments of listening session narratives that relate to a need for community-tailored energy-related information that is easily accessible and comprehensible for all Angelenos. That is, when listening session participants referred to the community engagement process, their highest concerns reveal significant priorities for LADWP to:

1. Focus on building long-term relationships with community members and institutions that develop trust and confidence in the utility.
2. Simultaneously provide those local stakeholders with accessible information related to LADWP programs, services, and updates on Los Angeles' transition to clean energy.

Those two engagement priorities—trust-building and information access—create the groundwork for allowing community members to shape both the design of LADWP projects as well as their evaluation post-implementation (Chapter 3). Listening session participants also requested forms of guaranteeing that community members have decision-making power in their city's energy transition, including developing tools that allow ratepayers to hold LADWP accountable for their decisions (Chapter 3).

One such tool was related to transparency in the allocation of LADWP equity-related funds. In one specific listening session, the question of community access to LA100 Equity Strategies' budget for investing in their communities came up as a critical prerequisite for informed decision-making and substantive engagement on this topic. As one participant asked, "Has LADWP put forth a budget to say 'hey, this is how many dollars we are going to put into this'? Because that's really what's going to set how big the program is: have they committed money only for this, and how much?" He then elaborated on his initial question, linking his request "to know what the numbers are" to a community-driven effort "so that we can really start figuring out how […] we use this money. And where do we put it." Another participant added, "if there is hypothetically $100 million set aside, what does that look like and who goes first? ... What percentage comes to our communities?" This discussion that links financial transparency with community guidance in investments reveals an opportunity space for LADWP to ground their energy justice decision-making process and accountability mechanisms in the priorities of historically underserved and overburdened Los Angeles communities.

This request for budget transparency recalls an established method of participatory planning and democratic deliberation and decision-making called "participatory budgeting" (Cabannes 2004; Sintomer, Herzberg, and Röcke 2008; Avritzer 2009). First developed in Brazil in 1989, this process has expanded to cities across the globe, where public authorities design participatory budgeting processes that place the power to make decisions about how particular public funds are allocated into the hands of ordinary residents. Los Angeles is among those cities, with a new initiative called L.A. REPAIR (Los Angeles Reforms for Equity and Public Acknowledgement of Institutional Racism), which began in nine communities last year. This is one mechanism of strengthening LADWP's community engagement process as a form of developing more accessible information, building community trust, dedicating resources to collective decision-making, and holding LADWP accountable to their commitments.

5 Energy Justice and Community Engagement: Lessons and Options for LADWP

This section concludes with insights, lessons, options, and potential next steps for LADWP community engagement as a catalyst for advancing energy justice in Los Angeles. Some of these include *what* community engagement is and can be and what tools and activities it entails, while others point to *how* those goals can be accomplished or implemented. LADWP can learn from both the successes and challenges of U.S. utility programs seeking to enhance eligibility and increase parity in access for tenants and low- to moderate-income customers. This includes learning from efforts to streamline applications and remove barriers such as proof of eligibility. Focusing on accessibility, they can also develop community-tailored outreach and communication tools available in different languages and formats (Chapter 3).

While utilities tend to focus on distributional justice, energy justice scholarship as well as Chapters 1–3 have found that broadening transition approaches to other justice tenets is crucial to developing more equitable energy outcomes. Along with considering the distribution of benefits and burdens of their projects and programs, LADWP can take additional steps to ensure a more equitable energy transition in Los Angeles. Incorporating recognition and procedural justice includes (a) considering the legacies of past practices and policies that create energy inequalities and (b) creating an ongoing engagement approach that seeks to redress the social, cultural, and institutional processes of exclusion through which these inequalities are (re)produced.

Moving beyond the Spectrum of Public Participation into co-creation (see Glossary) via community engagement, we connect the below options to lessons learned from energy engagement scholarship. These scholars suggest a series of phases to structure a grounded engagement process (Drakellis 2022; Waters 2015; First Solar n.d.; New York State Department of Environmental Conservation 2009; Lezberg, Dane, and Mullins 2010; Ross and Day 2022; Ziegler and Forbes 2010):

- **Phase 1:** In the initial planning, LADWP would need to understand why it is engaging, with what goal (or whom) it plans to engage, and with what intended outcome or result (e.g., site infrastructure, create jobs, reduce health impacts).
- **Phase 2:** The next phase involves two components: a mapping of relevant actors created with residents, and understanding actors' aspirations, interests, and lived experiences. Equally important is to understand their potential to contribute to the goals of the project, and the ways in which the project can benefit them (or avoid burdening them).
- **Phase 3:** Building relationships with local actors is the next phase, where LADWP needs to select the engagement techniques, the engagement points in the process, the message(s), and the approaches to solicit and include residents' input.
- **Phase 4:** The final phase involves maintaining relationships and evaluating and redefining LADWP's strategy. Because engagement is an iterative and dynamic process, updating and adapting the engagement approach using evaluation tools is crucial to understand: 1) if the engagement efforts are working; 2) how to report back to your actors with progress and updates; 3) how to manage expectations; and 4) how to reflect new information and changing circumstances.

Although these best practices offer options for community engagement in specific initiatives and programs, a collaborative platform to be discussed in the next section could coordinate LADWP's long-term, multisectoral, and systemic energy transition programs, technologies, and policies. Furthermore, it could help LADWP integrate conflicting sectoral and local interests (e.g., market value versus equity) into citywide energy transition goals (Koontz and Johnson 2004; Scott, Thomas, and Magallanes 2019).

5.1 A Collaborative Platform

Given LADWP's institutional constraints on internal hiring, there are significant opportunities to build engagement via a collaborative platform that enables and facilitates a network of CBOs and trusted messengers to implement energy equity strategies with underserved communities (see Text Box 1, page 13). Engagement methods utilized by LADWP's Community Affairs team and LA100 Equity Strategies via the Steering Committee have already revealed the potential of this collaborative platform (Scott, Thomas, and Magallanes 2019). As for how these processes could be developed, the Corporate Strategy and Communications Division and the Diversity, Equity and Inclusion Office could enable and orchestrate a *collaborative platform* with dedicated personnel and resources for facilitating its multiple energy equity projects and programs in collaboration with CBOs, trusted messengers, and underserved communities.

As illustrated in Text Box 1, LADWP could rely on this organizational structure to formalize these partnerships into long-term agreements in ways that maintain a continuous feedback loop with community collaborators. This feedback loop would allow partner CBOs, underserved communities, and other actors to be semiautonomous, while benefiting from and contributing to LADWP success. As trusted sources of knowledge and opportunities in their communities, CBOs and trusted messengers could become critical nodes in LADWP's engagement network, connecting community challenges, needs, and priorities to institutional decision-making.

Our literature review showed that this approach has been found to be an effective means to further develop more effective and equitable community engagement strategies by partnering with community institutions and actors on co-designing, implementing, and evaluating energy initiatives to guarantee collective action and mutual benefits.[7] LADWP's Corporate Strategy and Communications Division and Diversity, Equity and Inclusion Office could enable and orchestrate this collaborative platform with dedicated personnel and resources to facilitate multiple collaborative energy equity projects and programs (Ansell and Gash 2008). As such, both the division and office would constructively strengthen LADWP's network of CBOs, trusted messengers, and other community actors around its just transition energy programs and services.

Scholars have identified four attributes for this collaborative platform to be successful: a stable and adaptable institutional engagement structure, semiautonomous collaborators, interdependent modularity, and adaptability (see Text Box 1, page 13). As we illustrate in Text Box 1, this platform could build on LADWP's long-term experience to allow communities, trusted messengers, and CBOs to be semiautonomous by benefiting from programs, making their own

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[7] Newig et al. 2018; Emerson, Nabatchi, and Balogh 2012; for an analysis of the Clean Cities Coalition, a U.S. example of a collaborative platform, see Romero-Lankao et al. 2023.

organizational decisions, and contributing to LADWP's success (Lee 2022; Patricia Romero-Lankao et al. 2023; Emerson, Nabatchi, and Balogh 2012; Scott, Thomas, and Magallanes 2019). LADWP would also need to strive for *interdependent modularity* by developing long-lasting reciprocal interdependencies around LADWP's programs and projects with communities, CBOs, and trusted messengers. To lessen the need for overt managerial control, interdependent modularity would involve a coordinated, long-lasting, and multi-directional engagement in the development of programs, technologies, and services. Lastly, this collaborative platform would need to be *adaptable*, to adjust itself to and take advantage of the complex series of interconnected challenges and opportunities involved in the just energy transition (Text Box 1, page 13).

This opportunity also implies a commitment to, as one listening session participant put it, "authentically engaging with us [community members] in the decision-making process." Authentic engagement entails moving away from status quo outreach practices, which often consist of one-off activities that community members experience as transactions to simply "check the box," rather than a process aimed at building a continuous, substantive relationship (Chapters 2 and 3).

Community members indicated that LADWP's commitment to authentic engagement that includes communities in the decision-making processes must be demonstrated with "intentional actions," rather than simply stated. Repairing existing community mistrust necessitates that LADWP invest time and build trust in these communities—trusting their knowledge and expertise—and allow that knowledge to inform institutional understanding and decision-making within the collaborative platform. Starting with the community and learning how to identify problems and solutions via their lived experiences, is a procedural shift in engagement methodology. For the community members' lived experiences to align with LADWP objectives, the suggested collaborative platform can enhance engagement practices and procedures that (1) disseminate accessible community-tailored information about concerns and opportunities for local residents to benefit from LADWP's energy equity strategies, and (2) create a consistent and flexible feedback loop between LADWP and local underserved residents that impacts the course of Los Angeles' energy transition toward more just outcomes.

5.2 Investing and Trusting in Community Knowledge and Capabilities

LADWP can learn from other utilities (see Section 3) and from participants' knowledge and capabilities by providing community members with the tools, information, and platform needed to help guide LADWP decision-making in their communities. Participants in LA100 Equity Strategies' engagement process offered various suggestions to strengthen LADWP's investment and trust in their knowledge, expertise, and capacities. One participant requested a participatory framework where LADWP asks community members for their expert advice by laying out their actions: "here are the decisions and the entry points" for community guidance. Another participant highlighted the importance of learning from successful community educational practices employed by other city departments. She suggested developing training opportunities such as those proposed by LA's Climate Emergency Mobilization Office, where leadership academies would "train community members with the vocabulary [and] narratives, so they can go out into the community."

The investment in community knowledge about energy practices, LADWP programs, and the energy transition provides residents with a toolkit for making informed decisions about their own energy future. Partnering with local trusted messengers as a form of knowledge sharing is a powerful educational method for providing residents with such a toolkit. Examples of such forms of knowledge sharing include the *promotora* method, described in Chapter 3, as well as the climate ambassadors used by Austin Energy (Section 3). While the *promotoras* are primarily utilized within the public health sector in Latinx communities, Angelenos' familiarity with this methodology—the existing knowledge and trust *promotoras* have already garnered—could be harnessed as its educational subject matter is adapted to energy justice. Adding energy to the *promotoras* educational repertoire could greatly expand LADWP's engagement reach, building both knowledge and trust in these communities via a robust network of trusted community members with local knowledge that informs their communities about Los Angeles' energy transition options and opportunities.

Another method of investing and trusting in community knowledge is by creating a dedicated institutional space for community members to share their expertise with LADWP. Chapter 3 presents a series of community-guided strategies for developing more grounded engagement practices. In this chapter, we highlight the suggestion to develop a Community Committee—another method that resonated with LADWP's current engagement objectives as they expand their diversity, equity, and inclusion efforts beyond their department. Like the CBOs in LADWP's LA100 Equity Strategies Steering Committee, an LADWP Community Committee could gather a group of representative local community members from underserved communities across Los Angeles to collectively review the accessibility and suitability of LADWP programs and services and suggest community-tailored adaptations. While these community members might be affiliated with local CBOs, they would not be employees of those organizations. This semi-autonomy would allow committee members to share their own experiences as ordinary LADWP ratepayers, rather than promoting organizational objectives. Thus, this consistent institutionalized feedback loop between community members and LADWP could help the utility develop community-driven program design and evaluation that is adapted to different underserved communities.

5.3 Co-Develop Community-Grounded Equity Metrics

As LADWP further expands their engagement efforts in LA communities, they could refine and elaborate on their current equity metrics through two additions to their current approach. Firstly, by utilizing ongoing engagement activities and long-term feedback loops to develop community-grounded indicators. Secondly, by building a more robust equity measurement methodology to evaluate the results of the implementation of LA100 Equity Strategies over time. This methodology could turn what EMDI currently defines as "metrics" into "indicators." With this refinement of the approach, an indicator, developed from either quantitative or qualitative data, is "used to measure, approximate, or translate aspects of social, economic, or environmental reality [qualitative data] or used to quantify the effort of allocating resources or producing goods and services by public/private organizations" (Jannuzzi 2021, 1; United Nations 1989). An example of a quantitative LADWP indicator could be the number of power outages per census tract per month. An example of a qualitative LADWP indicator could be the level of customer satisfaction on customer service calls related to power outages.

These indicators would be combined with others to develop a series of equity metrics. In this framework, a metric is understood as a composite measure based upon the two or more indicators or measures that are weighted in the calculation of the full metric. While they can be based upon qualitative and quantitative data, metrics are always quantitative measures. Metrics help place a variable in relation to one or more other dimensions. The more indicators are based on concrete experiences of a community, population, etc., the closer their metrics will be to measuring the effects of changes in these communities' experiences and realities. We call this community-grounded indicators aimed at building socially informed metrics (Blanco and Rosner 2023). A metric for the quantitative indicator discussed above could be equitable grid resilience, measuring the levels of grid resilience across the City of Los Angeles by creating a combined measurement that weighs several indicators, including the number of power outages per census tract per month.

LADWP's 50 "Additional Proposed Equity Metrics for Consideration" provide several options for transforming suggested equity metrics into critical indicators for assessing the equitable implementation of LA100 Equity Strategies. Transforming these suggested metrics into indicators implies a shift in methodology. Operationalizing this framework requires an iterative process where, "as soon as the social phenomenon—or public action—is proxied through preliminary versions of an indicator, its analyses and use allow us to evaluate its validity and go further into a new specification of concept—or action—and propose other possible 'approximate measures,' 'proxies,' or 'indicators'" (Jannuzzi 2021, 1–2; Neufville et al. 1975). This iterative refinement process is developed through the collaborative platform, that co-creates indicators and metrics with local communities and their trusted institutions. This methodological shift allows for more fine-tuned measurements that target specific equity priority areas co-defined with community members.

6 Glossary

Actions/Strategies: the means used to solve identified problems in an impact area; actions and strategies involve programs such as bills, regulations, rates, subsidies, and investments and how they are designed, implemented, and evaluated (Dubash et al. 2022)

Causal Factors: "Events, incidents, happenings that lead to the occurrence or development of a phenomenon" (Buckley and Waring 2013, 156).

Climate Justice: the remediation of the impacts of climate change on poor people and people of color, and compensation for harms suffered by such communities due to climate change (Burkett 2008)

Co-Creation: "a process through which two or more public and private actors attempt to solve a shared problem, challenge, or task through a constructive exchange of different kinds of knowledge, resources, competences, and ideas that enhance the production of public value in terms of visions, plans, policies, strategies, regulatory frameworks, or services, either through a continuous improvement of outputs or outcomes or through innovative step-changes that transform the understanding of the problem or task at hand and lead to new ways of solving it" (Torfing et al. 2019, 802)

Community Engagement: Community engagement often entails public participation through an ongoing, two-way or multidirectional process, ideally with an emphasis on relationships and trust-building rather than instrumental decisions. The latter are processes where engagement becomes the instrument to achieve social acceptance (Stober et al. 2021).

Disadvantaged Community: "Disadvantaged communities refers to the areas which most suffer from a combination of economic, health, and environmental burdens. These burdens include poverty, high unemployment, air and water pollution, presence of hazardous wastes as well as high incidence of asthma and heart disease. One way that the state identifies these areas is by collecting and analyzing information from communities all over the state. CalEnviroScreen, an analytical tool created by the California Environmental Protection Agency (CalEPA), combines different types of census tract-specific information into a score to determine which communities are the most burdened or "disadvantaged"" (California Public Utilities Commission 2023).

Energy Equity: the equitable distribution of social, economic, and health benefits and burdens of energy across all segments of society (Jenkins 2017)

Energy Justice: the provision of safe, affordable, and sustainable energy to all individuals, across all areas, (Jenkins 2017); this is done with a framework informed by justice movements, including attention to three core tenets:

- *Distributional justice* seeks to ensure a just and equitable distribution of benefits and negative impacts of the clean energy transition.
- *Justice as recognition* seeks to understand and address past and current energy inequities by analyzing structural causes of exclusion and vulnerability and specific needs associated with energy services among social groups.

- *Procedural justice* aims to actively engage partners and communities throughout the project, to co-design the analysis, and shape the resulting equity strategies (Energy Equity Project 2022).

Energy Transition: a large-scale or deep societal change in the production, distribution, and use of energy; this transition can entail transformations in social-technical systems and systems of policy and governance intended to substantially improve the outcomes out of unsustainable pathways, such as fossil fuel use (Carley and Konisky 2020)

Environmental Justice: the distribution of environmental hazards and access to all natural resources; it includes equal protection from burdens, meaningful involvement in decisions, and fair treatment in access to benefits (U.S. EPA 2023)

Equity Outputs: Equity outputs are the immediate, easily measurable effects of an action aimed at achieving equity (Dubash et al. 2022).

Equity Outcomes: Equity outcomes are the ultimate changes that a policy will yield (Dubash et al. 2022).

Equity: Equity refers to a measurement of fairness and justice. Unlike equality, which refers to the provision of the same to all, equity aims to recognize the historical and ongoing differences in experiences and outcomes between people, groups, and communities to redress those imbalances.

Frontline Community: a community, frequently a low-income community of color, that experiences the first and worst consequences of environmental and climate change including floods, heatwaves, and other climate extremes as well as the impacts of facilities that are used to extract, produce, process, and transport energy resources.

Impact Areas: particular sectors and subsectors of the energy system impacted by causal factors

Just Energy Transition: a deep societal change in the energy system that fulfills at minimum three of the tenets of justice: recognition justice, procedural justice, and distributional justice (McCauley and Heffron 2018)

Justice involves removing barriers that prevent equity through energy actions (strategies) that offer individuals and communities equal access to energy resources and options to self-determine their energy goals (Romero-Lankao and Nobler 2021).

Participation relates to the involvement of the public in infrastructure siting and other clean energy decisions and policies (Stober et al. 2021). Participation is an umbrella concept that includes processes of community engagement and public decision-making (Stober et al. 2021). Participatory decision-making denotes inclusion of actors such as underserved communities in an energy project as a decision-maker. Direct participation refers to the level of economic and/or political involvement of a local community or municipality in an energy project.

Underserved Community: a community, frequently a low-income community of color, that (a) does not benefit from energy programs, investments, and technologies, (b) is not recognized, considered, or able to participate in energy decision-making (Klinsky et al. 2017)

Values: the ethical paradigm that structures the sociocultural norms, beliefs, and practices guiding how a group of people prioritize and relate to the current energy transition (Jenkins 2017)

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Appendix: Energy Utility Programs and Initiatives by Key Indicators

Table A-1. Energy Utility Programs and Initiatives by Key Indicators

Utility Operating Company	Title	Utility Type	Region	Topic	Community Engagement Process	Community Engagement Level	Procedural Justice Targeted	Distributional Justice Targeted	Recognition Justice Targeted
Ameren Illinois	Market Development Initiative	Investor-owned	North	Energy Efficiency	Yes	3	Yes	Yes	Unclear
Ameren Missouri	Charge Ahead	Investor-owned	South	Transportation Electrification	No	—	No	Yes	No
AEP Ohio	Smart Columbus	Investor-owned	North	Transportation Electrification	No	—	No	Yes	No
Austin Energy	Austin Climate Equity Plan: Transportation Electrification	Public power	Central	Transportation Electrification	Yes	3	Yes	Yes	Yes
Eugene Water & Electric Board	Fast Track Approval - Income-Based Assistance Eligibility	Public power	West	Energy Affordability	No	—	Yes	Yes	No
Consumers Energy	Listen Up: Renewable Energy Program Design for All	Investor-owned	North	Renewable Energy	Yes	2	Yes	Yes	No
Consolidated Edison Company of New York, Inc.	PowerReady Disadvantaged Community Areas	Investor-owned	East	Transportation Electrification	No	—	No	Yes	No
CPS Energy	Powering Our Community's Future: Stakeholder Engagement and Public Input Report	Public power	Central	Community Engagement	Yes	3	Yes	Yes	No
Dominion Energy	Climate Report 2022	Investor-owned	South	Multiple/ Crosscutting	Yes	2	Yes	Yes	No
DTE Energy	Stakeholder Engagement Matrix	Investor-owned	North	Community Engagement	Yes	2	Yes	No	No
Duke Energy (FL)	Duke Energy ignites Florida's workforce with $697,000 in training, development grants	Investor-owned	South	Workforce Development	No	—	No	Yes	No
Duke Energy Carolinas, LLC	Duke Energy helps build North Carolina workforce with $615,000 in grants to community colleges, HBCUs and nonprofits	Investor-owned	South	Workforce Development	No	—	No	Yes	No

Utility Operating Company	**Title**	**Utility Type**	**Region**	**Topic**	**Community Engagement Process**	**Community Engagement Level**	**Procedural Justice Targeted**	**Distributional Justice Targeted**	**Recognition Justice Targeted**
Duke Energy Indiana	Duke Energy boosts Indiana's workforce readiness with more than $330,000 in training grants	Investor-owned	North	Workforce Development	No	—	No	Yes	No
Duquesne Light Co.	EV ChargeUp Pilot	Investor-owned	East	Transportation Electrification	No	—	No	Yes	No
Tampa Electric Company	Drive Smart	Investor-owned	South	Transportation Electrification	No	—	No	Yes	No
Evergy Missouri Metro	Community Involvement Program	Investor-owned	South	Community Engagement	Yes	1	No	No	No
Eversource Energy, Massachusetts	Petition of NSTAR Electric Company, doing business as Eversource Energy, pursuant to G.L. c. 164, § 94 and 220 CMR 5.00, for Approval of a General Increase in Base Distribution Rates for Electric Service and a Performance-Based Ratemaking Plan	Investor-owned	East	Other	Yes	4	Yes	Yes	Unclear
Eversource Energy, Massachusetts	Beyond Awareness: An In-Depth Look at Participation Barriers	Investor-owned	East	Community Engagement	Yes	2	Yes	Yes	No
Baltimore Gas & Electric	Smart Energy Workforce Development Program	Investor-owned	East	Workforce Development	No	-	Unclear	No	Yes
Commonwealth Edison Company	Diverse Energy Efficiency Service Provider Incubator Program	Investor-owned	North	Workforce Development	No	-	No	Yes	Unclear
Commonwealth Edison Company	Energy and Equity Agreement with City of Chicago	Investor-owned	North	Other	Yes	4	Yes	Yes	Yes
Potomac Edison Co.	N/A	Investor-owned	North	Transportation Electrification	No	-	No	Yes	No
Green Mountain Power	Vermont Electric Co-op and Green Mountain Power Announce New Broadband Deployment Program to Leverage Utility Infrastructure to Increase Access and Affordability for Hardest-to-Reach Customers	Investor-owned	East	Other	No	-	No	Yes	No
Hawaiian Electric	Integrated Grid Planning - Stakeholder and Community Engagement	Investor-owned	West	Community Engagement	Yes	2	Yes	No	No
Madison Gas & Electric Company	Energy 2030 Framework: Community Engagement	Investor-owned	North	Community Engagement	Yes	3	Yes	No	No

Utility Operating Company	Title	Utility Type	Region	Topic	Community Engagement Process	Community Engagement Level	Procedural Justice Targeted	Distributional Justice Targeted	Recognition Justice Targeted
Central Hudson Gas & Electric Corporation, Consolidated Edison Company, National Grid, New York State Electric & Gas Corporation, Orange and Rockland Utilities, Rochester Gas and Electric Corporation	NY DPS Docket 18-E-0138: Proceeding on Motion of the Commission Regarding Electric Vehicle Supply Equipment and Infrastructure	Multiple utilities	East	Transportation Electrification	No	—	No	Yes	No
Connecticut utilities	Connecticut Docket No. 22-06-29 (DER [distributed energy resource] Interconnection)	Multiple utilities	East	Other	No	—	Unclear	Yes	Unclear
Eversource, National Grid, Unitil, Fitchburg Gas & Electric, Cape Light Compact	MassSave Data [website]	Multiple utilities	East	Multiple/ Crosscutting	No	—	No	Yes	Yes
Massachusetts Electric Co	Reflecting on Incorporating Energy Equity Across Your Utility Organization	Investor-owned	East	Equity Metrics	No	—	Yes	Yes	No
Niagara Mohawk Power Corporation	NYS Workforce Development	Investor-owned	East	Workforce Development	Unclear	—	Unclear	Yes	No
New York Power Authority	Community Distributed Generation	Power Agency/G&T	East	Renewable Energy	No	—	No	Yes	No
Florida Power & Light Co.	STEM Grants & Scholarships	Investor-owned	South	Workforce Development	No	—	No	Yes	No
NYSERDA	Energy & Climate Equity Strategy	Multiple utilities	East	Community Engagement	Yes	2	Yes	Yes	Yes
Pacific Gas & Electric	California Docket No. A-21-06-022 (Pacific Gas & Electric - Microgrids)	Investor-owned	West	Other	No	—	Yes	Yes	Yes
Arizona Public Service	APS's plan for closing coal plants could be a gamechanger, analysts say, but who will pay?	Investor-owned	West	Multiple/ Crosscutting	No	—	No	No	Yes

Utility Operating Company	**Title**	**Utility Type**	**Region**	**Topic**	**Community Engagement Process**	**Community Engagement Level**	**Procedural Justice Targeted**	**Distributional Justice Targeted**	**Recognition Justice Targeted**
Portland General Electric	Creating an equitable energy future	Investor-owned	West	Multiple/ Crosscutting	Yes	4	Yes	Yes	Yes
Public Service Electric & Gas	Supplier Diversity Mentorship Program	Investor-owned	South	Workforce Development	No	—	No	Yes	No
Puget Sound Energy	Clean Energy Implementation Plan Process	Investor-owned	West	Multiple/ Crosscutting	Yes	2	Yes	No	No
Puget Sound Energy	Integrating Local Community Interests into Utility DER Procurement	Investor-owned	West	Other	No	—	Yes	Yes	No
Sacramento Municipal Utility District	Sustainable Communities Resource Priorities Map	Public power	West	Equity Metrics	Yes	3	Yes	Yes	Yes
Seattle City Light	Racial Equity Planning and Analysis Tools and Steps // see also, as applied in the Transportation Electrification Strategic Investment Plan	Public power	West	Equity Metrics	Yes	3	Yes	Yes	Unclear
Snohomish County PUD	N/A	Public power	West	Community Engagement	Yes	3	Yes	Yes	No
Los Angeles Dept of Water and Power	Equity Metrics Data Initiative	Public power	West	Equity Metrics	No	—	No	Yes	Unclear
Multiple	2021 Transformation Report: Moving to Equity	Investor-owned	South	Diversity, equity, and inclusion plan	No	—	No	Yes	No
Tacoma Power	2020 – 2021 CONSERVATION PLAN	Public power	Central	Multiple/ Crosscutting	Yes	2	No	Yes	No
Tennessee Valley Authority	Home Uplift Program	Power Agency/G&T	South	Energy Efficiency	Yes	3	Yes	Yes	Yes
Wisconsin Electric Power Company	Pathway to a Clean Energy Future: 2022 Climate Report	Investor-owned	North	Workforce Development	Yes	1	No	No	No
Xcel Energy, Colorado	Xcel Energy Partners in Energy Program—report for Pueblo County	Investor-owned	Central	Other	Yes	2	Unclear	Yes	No

Utility Operating Company	Title	Utility Type	Region	Topic	Community Engagement Process	Community Engagement Level	Procedural Justice Targeted	Distributional Justice Targeted	Recognition Justice Targeted
Xcel Energy, Minnesota	2021 ANNUAL REPORT: PERFORMANCE METRICS AND INCENTIVES, DOCKET NO. E002/CI-17-401	Investor-owned	North	Multiple/ Crosscutting	Yes	3	Yes	Yes	Yes
Xcel Energy, Minnesota	Xcel Energy's Conservation Improvement Plan Workforce Development program	Investor-owned	North	Workforce Development	No	—	Unclear	Yes	Yes
LADWP	LADWP Utility Pre-Craft Trainee program and others	Public power	West	Workforce Development	Yes	3	Yes	Yes	Yes
Tacoma Power	The 2030 Tacoma Climate Action Plan	Public power	West	Equity Metrics	Yes	3	Yes	Yes	Yes
Energy Trust of Oregon	OR UM1158 - Equity Metrics for Energy Trust of Oregon	Other	West	Equity Metrics	Yes	3	Yes	Yes	Yes
Delta-Montrose Electric Association	Delta-Montrose Electric Association Broadband Buildout	Distribution Cooperative	Central	Other	No	—	No	No	Yes
Holston Electric Co-op	Holston Electric Co-op looks Seeks Member Input on Broadband Access	Distribution Cooperative	South	Other	Yes	2	No	No	No
	Low Income Solar Pilot Program	Distribution Cooperative	North	Multiple/ Crosscutting	No	—	No	Yes	No
North Dakota Association of Rural Electric Cooperatives	NDAREC's Rural Development Program	Other	North	Multiple/ Crosscutting	No	—	No	No	Yes

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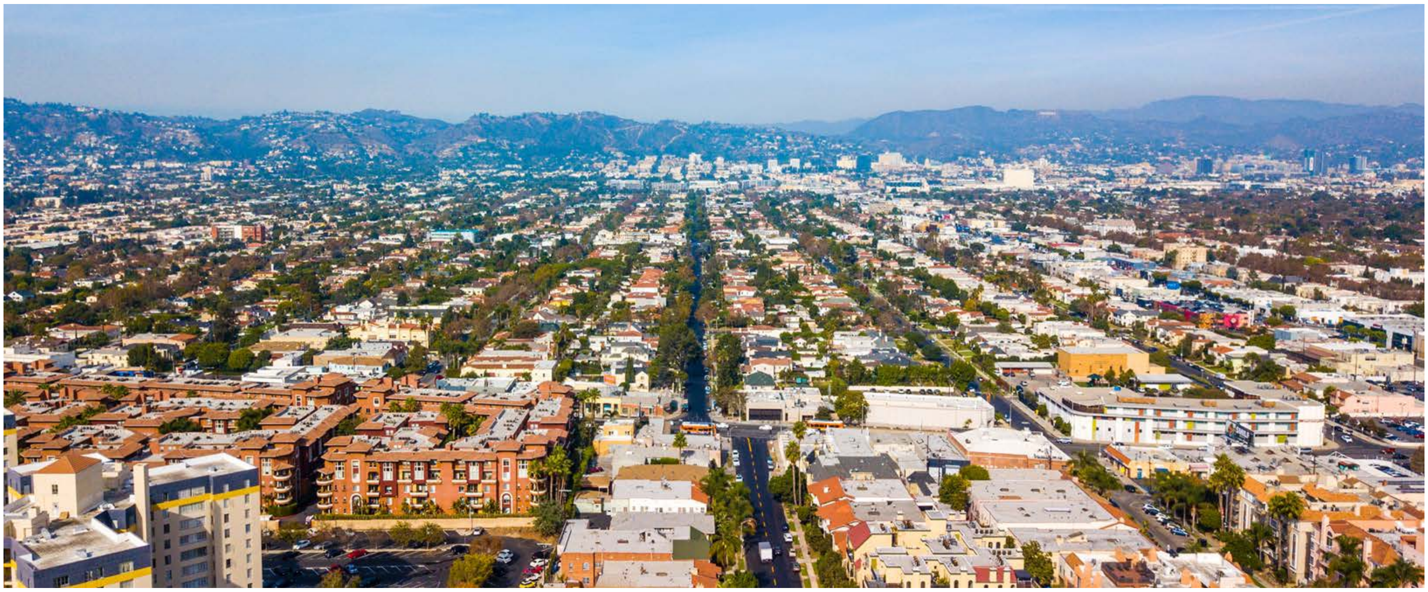
LA100 EQUITY STRATEGIES



Chapter 5. Low-Income Energy Bill Equity and Affordability

FINAL REPORT: LA100 Equity Strategies

Thomas Bowen, Christina Simeone, Katelyn Stenger, Lixi Liu,
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LA DWP NREL Transforming ENERGY

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November 2023

LA100 EQUITY STRATEGIES

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Preface

The Los Angeles 100% Renewable Energy Study, or LA100, revealed that although all communities in Los Angeles will share in the air quality and public health benefits of the clean energy transition, increasing equity in participation and outcomes will require intentionally designed policies and programs. The LA100 Equity Strategies project was specifically designed to help Los Angeles identify pathways to such policies and programs in the form of equity strategies. The project aimed to do this by incorporating research and analysis to chart a course toward specific, community-prioritized, and equitable outcomes from the clean energy transition outlined in the LA100 study.

The Project Partners

The Los Angeles Department of Water and Power (LADWP), the National Renewable Energy Laboratory (NREL), and the University of California Los Angeles (UCLA) partnered on the LA100 Equity Strategies project to develop strategies for engaging communities, funding equitable technology and infrastructure investments, expanding existing programs, and designing new programs and policies to improve equity by incorporating what community members themselves know is needed to achieve a more equitable energy future.

The Project Approach

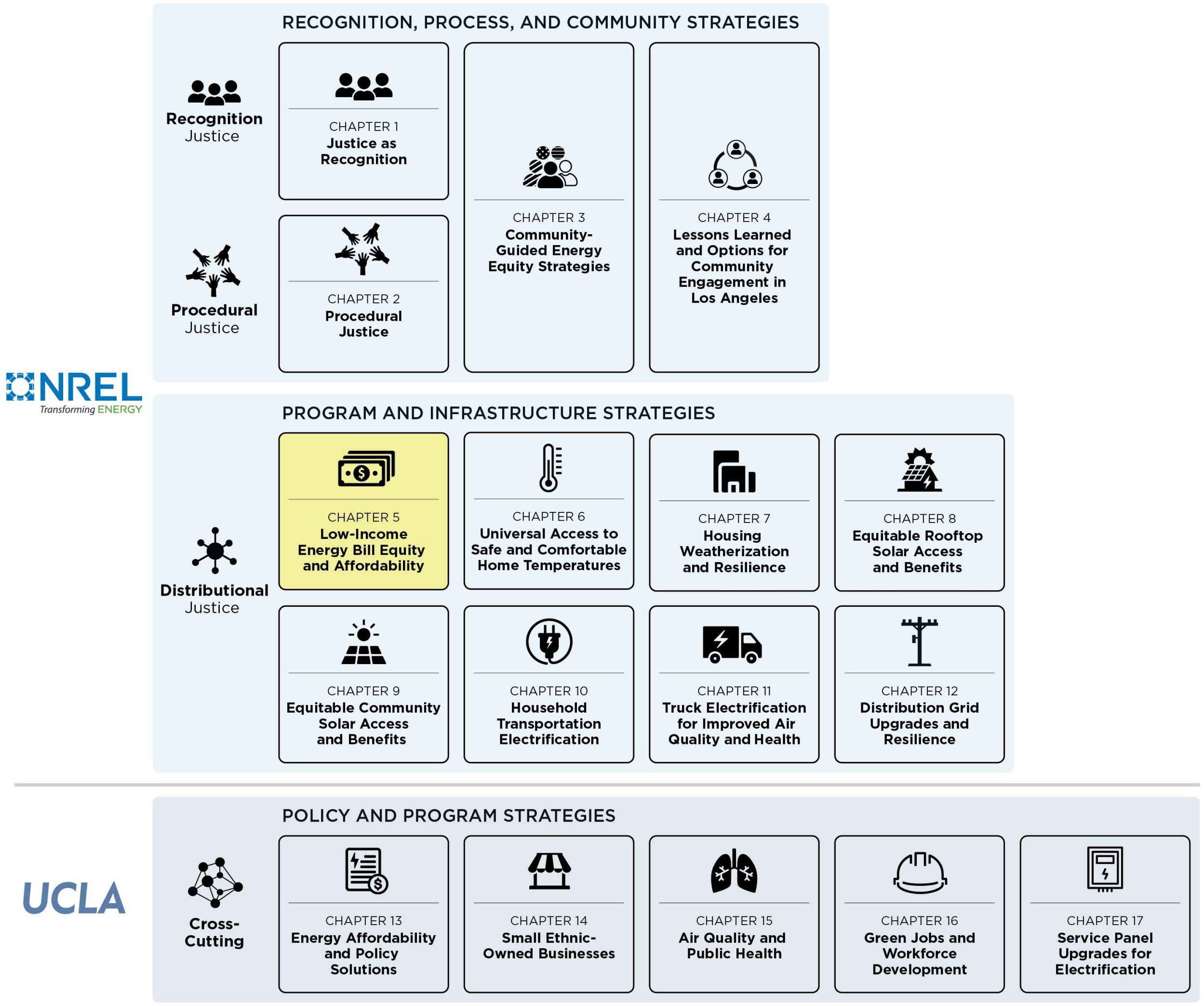
LA100 Equity Strategies employs a unique mixed-methodological approach utilizing three distinct—but connected—research efforts. Through these efforts, NREL and UCLA developed a range of strategy options for increasing equity in LA's transition to 100% clean energy.

A Project Summary

To get a high-level overview of the project, you can dive into the executive summary, interactive data visualizations, and more on the LA100 Equity Strategies website at maps.nrel.gov/la100/equity-strategies.

The Full Report

NREL's final full report for the LA100 Equity Strategies project encompasses seventeen chapters. The first twelve chapters, authored by NREL, are organized around the three tenets of justice. Chapters 1–4 address recognition and procedural justice, while Chapters 5–12 address distributional justice. The final five chapters, authored by UCLA, provide crosscutting policy and program strategies. Each chapter provides data, methods, insights, and strategies to help LADWP make data-driven, community-informed decisions for equitable investments and program development.



NREL Chapters

Chapter 1: Justice as Recognition

Chapter 2: Procedural Justice

Chapter 3: Community-Guided Energy Equity Strategies

Chapter 4: Lessons Learned and Options for Community Engagement in Los Angeles

Chapter 5: Low-Income Energy Bill Equity and Affordability

Chapter 6: Universal Access to Safe and Comfortable Home Temperatures

Chapter 7: Housing Weatherization and Resilience

Chapter 8: Equitable Rooftop Solar Access and Benefits

Chapter 9: Equitable Community Solar Access and Benefits

Chapter 10: Household Transportation Electrification

Chapter 11: Truck Electrification for Improved Air Quality and Health

Chapter 12: Distribution Grid Upgrades for Equitable Resilience and Solar, Storage, and Electric Vehicle Access

UCLA Chapters

Chapter 13: Energy Affordability and Policy Solutions Analysis

Chapter 14: Small Ethnic-Owned Businesses Study

Chapter 15: Air Quality and Public Health

Chapter 16: Green Jobs Workforce Development

Chapter 17: Service Panel Upgrade Needs for Future Residential Electrification

List of Abbreviations and Acronyms

ACC	Avoided Cost Calculator
AMI	area median income
AMY	actual meteorological year
BAU	business as usual
CAIRO	Customer Affordability, Incentives, and Rates Optimization
CARE	California Alternate Rates for Energy
CPUC	California Public Utilities Commission
dGen	Distributed Generation Market Demand
ESA	Energy Subsidy Adjustment
FERA	Family Electric Rate Assistance
HMW	hours at minimum wage
HOMES	Home Owner Managing Energy Savings
HSPF	heating seasonal performance factor
IBFC	income-based fixed charges
IOU	investor-owned utility
LADWP	Los Angeles Department of Water and Power
LBNL	Lawrence Berkeley National Laboratory
LMI	low and moderate income
MW$_{DC}$	megawatts-direct current
NER	net energy return
NREL	National Renewable Energy Laboratory
PV	photovoltaics
REPLICA	Rooftop Energy Potential of Low Income Communities in America
SB 100	California Senate Bill 100: The 100 Percent Clean Energy Act of 2018
SCE	Southern California Edison
SEER	seasonal energy efficiency ratio
SLTRP	Strategic Long-Term Resource Plan
TOU	time of use

Executive Summary

The LA100 Equity Strategies project integrates community guidance with robust research, modeling, and analysis to identify strategy options that can increase equitable outcomes in Los Angeles' clean energy transition. This chapter focuses on utility rates and low-income bill assistance programs as means to improve energy affordability, which is one of the community's highest priorities.

Specifically, NREL developed a model using Los Angeles Department of Water and Power (LADWP)-specific inputs to test 2035 rate design and low-income assistance program scenarios.

Utility bills were modeled based on the hourly household energy usage (electricity and gas) of each of the 50,000 prototypical LADWP residential households NREL developed with unique combinations of housing types (single-family, multifamily), climate zones, insulation levels, appliances, heating and cooling systems, solar adoption and generation, renter or owner occupancy, and income levels. We evaluated the results to assess the relative efficacy of each approach in reducing bills for LADWP's low-income households using customer affordability and equity metrics including energy burden and hours worked at minimum wage.

NREL modeling and results are bounded by LADWP-provided projected revenue requirements as of March 2023. Revenue forecasts were not validated due to lack of data and thus may overstate or understate actual future costs. Also, because we focused solely on affordability and equity impacts to low-income households, this work does not represent a holistic analysis of rate design.

Research was guided by input from the community engagement process, and associated equity strategies are presented in alignment with that guidance.

Community Guidance

Guidance from the LA100 Equity Strategies Steering Committee, listening sessions with community-based organizations and community members, and community meetings yielded the following:

- Energy affordability is one of the highest priorities.
- Low-income ratepayers and seniors suggested subsidies, free aid, and other support instruments to address communities' inability to pay electricity bills.

Steering Committee Member:

"Split incentives for affordable housing owners and operators must be addressed. They aren't able to recuperate costs of solar and other upgrades, electrification. Use the rate structure to make sure low-income households receive financial benefits from upgrades."

Community Member:

"Households in hotter areas of the city can't afford new technologies like solar and are hit with time-of-use charges. This is inequitable."

Steering Committee Member/Community-Based Organization Representative:

"Our constituents are concerned about utility debt."

- Participants suggested reassessing eligibility for LADWP programs, which could include:
    - Reassessing how to measure eligibility and burden.
    - Basing the criteria on an understanding of affordability and burden as context-specific.
    - Examining how energy burden affects household access to benefits such as homeownership.
    - Expanding access to moderate-income households.
- Participants suggested expanding eligibility for LADWP programs to renters.
- Participants suggested expanding programs to help low- and moderate-income (LMI) disadvantaged community residents maintain and upgrade their homes affordably, which also improves access to homeownership.

Baseline Affordability

Household energy burden—the percentage of household income spent on energy bills—is a common energy affordability metric. An energy burden of 6% or less is a common threshold for affordable utility costs, based on affordability thresholds of utility costs not exceeding 20% of housing costs and housing costs not exceeding 30% of income (Colton, Roger D. 2011; Brown et al. 2019). The U.S. West Census Region (which includes the Pacific and Mountain divisions) has the lowest average energy burden in the United States for low-income populations (≈8.5%, as measured by households eligible for the federal Weatherization Assistance Program)[1] (Rose and Hawkins 2020). Estimates for the same income group living in metropolitan areas of California suggest the low-income energy burden in Los Angeles (6.0%) has historically been lower than in San Francisco (6.1%), San Jose (6.5%), and Riverside (8.7%) (Drehobl, Ross, and Ayala 2020).

Though energy burden can be a useful metric, it alone is an incomplete measure of both affordability and overall need. County-level data on federal low-income energy assistance indicates the concentration of need is far greater in Los Angeles County than in other California counties. For example, low-income households in Los Angeles County received almost 30% of total 2016 need-based statewide weatherization program funding, followed by Sacramento County at 5.1% (California Department of Community Services and Development 2016). This is consistent with the fact that Los Angeles County is home to about 30% (about 1.3 million in 2020) of the state's population living in poverty, which is more than in any other California county (USDA Economic Research Service 2020).

Over a 15-year period, LADWP spent more than $173 million in low-income program assistance[2] and more than $313 million in Lifeline program assistance.[3] Our analysis of program equity indicates assistance programs appropriately benefitted households in disadvantaged

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[1] Federal Weatherization Assistance Program-eligible households are those living at or below 200% of U.S. federal poverty guidelines.

[2] These funds were spent as part of the EZ-SAVE program.

[3] Lifeline program eligibility is based on income qualification for customers who are 62 years of age or older or who are permanently disabled.

communities,[4] and mostly non-White, Hispanic, renter, and lower-income census tracts. Despite these significant program investments, the same demographic groups have the most utility disconnections stemming from bill payment failures. In 2022, LADWP ended its practice of disconnects for a limited set of customers (primarily EZ-SAVE enrollees and Lifeline customers) as a debt collection tool (Haley Smith 2022). Although long-term low-income assistance investments have been significant, LADWP's January 2022 Rates and Equity Metrics Board Package noted the low-income assistance program has "minimal outreach efforts by LADWP to customers," "no targeted communications to customers," "no formal engagement with community-based organizations," and has experienced a "reduction in customers recertifying for the program" (Santilli, Ann and Adams, Martin 2022).

Key Findings

Continuing LADWP's current rate design and low-income assistance programs through 2035 is estimated to result in low-income[5] households experiencing disproportionately higher bill increases. Under the existing LADWP rate design and low-income assistance programs, modeling indicates average electricity bills will increase by $83/month across all households between 2019 and 2035 (a 79% increase), while low-income households see an average expected increase of $110/month (a 131% increase).[6]

Electricity bill affordability metrics modeled for 2035 include:

- Average electricity burdens, or the percentage of income spent on electricity bills, by income level.
- Average monthly electricity bills by income level.
- Average hours worked at minimum wage required to pay for monthly electricity bills, per income level.

LADWP's ability to revise rate design is inhibited by California Proposition 218 and Proposition 26, which classify municipal utility rates as taxes and restrict certain government tax increases unless approved by voters. Beyond existing programs grandfathered in at current funding levels, the propositions also functionally prohibit the practice of supporting low-income assistance programs through funds recovered from non-low-income customers (League of California Cities 2021). These regulatory constraints prevent LADWP from increasing the budget for low-income bill assistance.

Leveraging federal funding through the Inflation Reduction Act, LADWP could potentially implement an on-bill tariff program (e.g., Pay-As-You-Save) for heat pump water heaters or

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[4] Disadvantaged communities as defined by SB 535 and the California Office of Environmental Health Hazard Assessment, oehha.ca.gov/calenviroscreen/sb535.

[5] Throughout this report, low-income households are defined as those 0%–50% of area median income (AMI), which includes the "extremely low" (0%–30% AMI) and "low" (30%–50% AMI) income bins.

[6] Unless otherwise indicated, all dollar results are based in 2021 dollars, assuming an average annual inflation of 2.5% to 2035. While this is not in keeping with actual inflation observed, it aligns with LADWP Strategic Long-Term Resource Plan forecasts, which were used to inform the analysis.

enhanced insulation that has the technical potential to provide energy bill (gas and electricity) savings to 154,000 or 72,000 low-income customers, respectively.

Modeling results indicate that for 2035, converting from LADWP's current complex multiperiod rate structure[7] to a simplified tiered rate,[8] or a default time-of-use (TOU)[9] rate structure that does not apply to certain low-income customers—as well as replacing net metering solar compensation with net billing compensation and establishing a policy to modestly boost low-income solar adoption—modestly improves low-income bill affordability and significantly improves equity between solar adopters (who tend to have higher incomes) and non-adopters (who tend to have lower incomes). This applies *even without* EZ-SAVE or Lifeline low-income assistance programs. For affordability, average low-income bills are also reduced by about $14-15 per month. For equity, the cost spread between average monthly bills for a solar photovoltaics (PV) adopter and non-adopter in 2035 drops from $162 under business as usual (BAU) to $55 and $65 under the simplified tiers and TOU models, respectively. This scenario is useful to understand the impact of rate design changes, as well as the loss of the EZ-SAVE and Lifeline discount programs that may not survive a proposition challenge. Potential administrative and system cost reductions (e.g., peak load reductions) from more understandable and cost-reflective rates and customer responsiveness are not quantified.

Low-income affordability would be significantly improved by replacing EZ-SAVE and Lifeline programs with robust low-income assistance programs modeled after the California Public Utilities Commission's (CPUC's) California Alternate Rates for Energy (CARE) and Family Electric Rate Assistance Program (FERA) programs. These programs have larger monthly discounts and higher enrollment rates compared to the EZ-SAVE and Lifeline programs. As a result, compared to a BAU rate approach, in 2035, the combination of updated rate design, revised solar compensation, and robust low-income assistance reduces average low-income monthly bills by $55 per month. Equity is also improved as the cost spread between solar PV adopter and non-adopter average monthly bills drops to between $29 and $39. However, these robust assistance programs have program costs of between 9.6% and 10% of the residential requirement, or between $307 million and $335 million. These revenues are transferred from customers not participating in CARE and FERA to participating customers, violating Proposition 26 and Proposition 218.[10]

Income-based fixed charges (IBFC), where certain utility costs are assigned to customers scaled to their income, achieve the greatest affordability for low-income customers and reduce energy

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[7] The 15 rate periods are based on the intersection of (1) a three-tier, two-season set of tiered rates and (2) a four-season set of incremental ordinances (see Appendix C).

[8] NREL modeled a tiered "inclining block rate" structure recommended by the California Public Utilities Commission, which charges customers more per kilowatt-hour as their usage increases past certain thresholds (or blocks).

[9] LADWP does not currently have the smart meter infrastructure required to implement default TOU rates, but it is assumed that by 2035 sufficient metering infrastructure is in place.

[10] Note that even customers *eligible* for CARE and FERA that are not ultimately enrolled shoulder the transfer costs associated with participating customers.

burdens below the 6% affordable threshold for all customers.[11] IBFC require customer-level income verification, a substantial implementation challenge. In addition, IBFC require increasing higher-income average bills for reasons not related to the energy consumption of these customers, which likely violates Proposition 26 and Proposition 218. IBFC design tends to increase solar adopter average monthly bills because solar adopters tend to have higher incomes (thus higher fixed costs driving up the average). Solar adopters in all income bins continue to see lower bills than non-adopters under IBFC. IBFC are currently being investigated for implementation in California by the CPUC.

Equity Strategies

Our modeling indicates equity and affordability outcomes could be improved through rate design and programmatic reforms.

- *On-bill tariffs for efficiency can deliver bill savings*. LADWP could use Inflation Reduction Act funds to establish an on-bill tariff program for heat pump water heaters or enhanced insulation that has the technical potential to deliver energy bills savings to about 154,000 or 72,000 low-income customers, respectively. This strategy may not require a rate case and may not violate Proposition 26 and Proposition 218, as it is supported by federal funds and only participating customers are assessed bill riders.[12]
- *Revised rate design and solar compensation mechanisms improve equity*. Converting LADWP's complex rate structure to a simplified tiered rate or TOU rate structure, replacing net metering with net billing for solar compensation, and implementing a modest program to boost low-income solar adoption would provide modest low-income bill savings (approximately $14-15/month) and drastically improve equity between solar adopters and non-adopters. Low-income bill affordability improvements occur even in the absence of LADWP's EZ-SAVE and Lifeline low-income assistance programs.
- *Robust low-income assistance programs improve affordability*. Establishing robust low-income assistance strategies with larger discounts and higher enrollment rates compared to EZ-SAVE and Lifeline could significantly improve low-income affordability.
- *Income-based fixed charges can achieve affordability*. IBFC most effectively reduce the affordability disparity between high- and low-income households and ensure customers in all income levels remain below the 6% affordability threshold.

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[11] Six percent is a common affordability threshold for total energy burden. Here we use the 6% affordability threshold with the electricity burden, which slightly overstates affordability for these warm-weather climate households.

[12] Note that this study models an on-bill tariff program leveraging federal funds in 2035 to facilitate comparisons to other scenarios. An on-bill tariff program implemented sooner could see different results or focus on other technologies.

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1 Introduction

In this report, the National Renewable Energy Laboratory (NREL) explores whether and how California-relevant rate design practices and more robust low-income assistance strategies could improve affordability for the Los Angeles Department of Water and Power's (LADWP's) low-income customers. As LADWP pursues its clean energy goals, state policy constraints inhibiting the utility from pursuing alternative rate designs could result in inequitable outcomes for low-income customers.

Modeling and Analysis Approach

NREL modeled customer bills in 2019 baseline and 2035 rate and low-income assistance program scenarios to compare affordability and other equity metrics. Bills were modeled based on the hourly household energy usage (electricity and gas) of each of the 50,000 prototypical LADWP residential households developed by NREL with unique combinations of housing types (single-family, multifamily), climate zones, insulation levels, appliances, heating and cooling systems, solar adoption and generation, renter or owner occupancy, and—most importantly for this analysis—income levels. Figure 1 presents a graphical overview of the rate scenarios and program strategies modeled for this study.

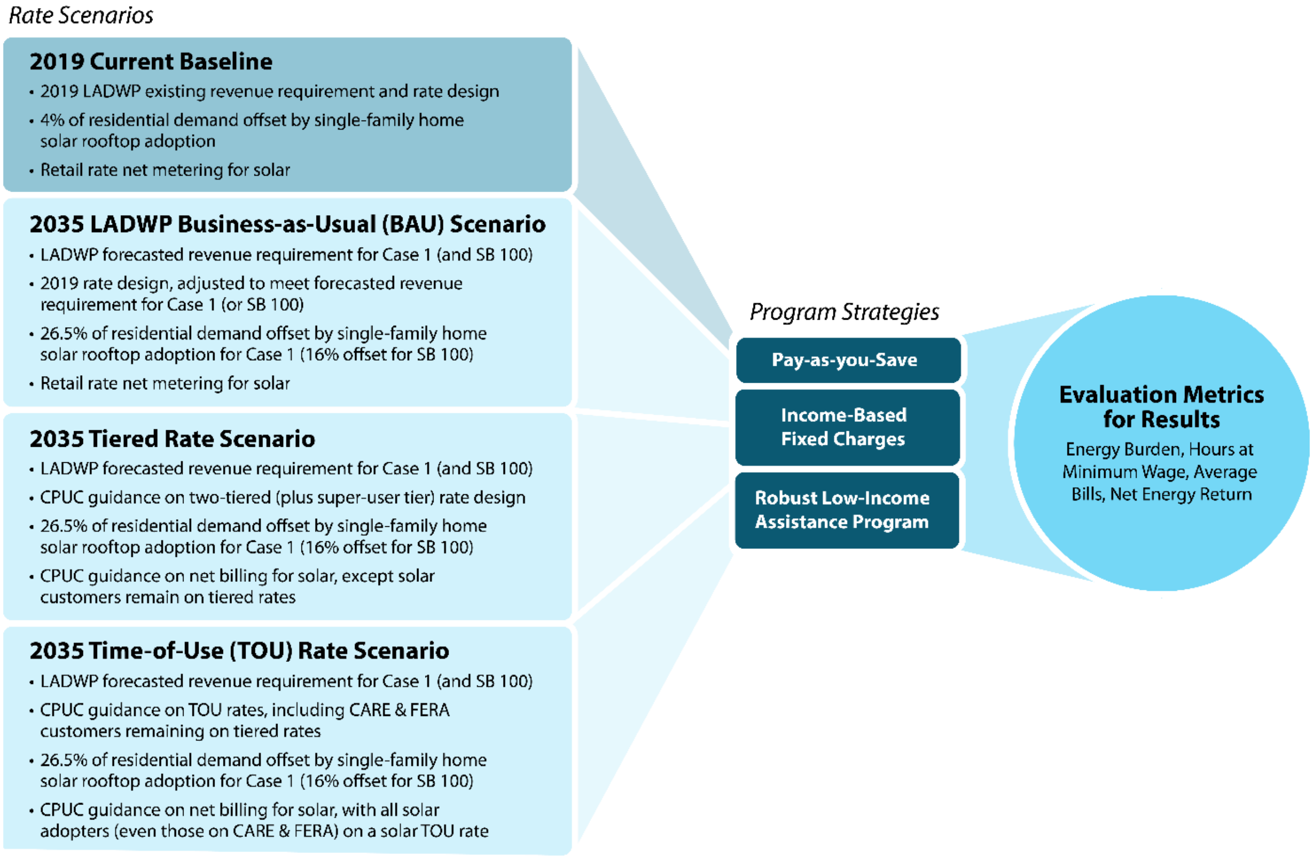

Figure 1. Rate scenarios, program strategies, and evaluation metrics modeled

Three future rate design scenarios are modeled to meet LADWP's Strategic Long-Term Resource Plan (SLTRP) 2022 revenue requirements and rate increase projections for Case 1 and California Senate Bill 100 (SB 100).[13] Rate design scenarios compare LADWP's existing rates approach to rate design strategies recommended by the California Public Utilities Commission (CPUC) and implemented by California investor-owned utilities. Rate design scenarios include:

- **2019 LADWP Baseline:** This scenario provides a baseline against which to compare evaluation metrics from forecast scenarios. The scenario uses LADWP's 2019 revenue requirement and respective energy-year tariff, including residential tiered rate schedules for Jan. 1–June 30, 2019, and July 1–Dec. 31, 2019 (see Appendix C).
- **2035 LADWP Business-as-Usual (BAU) Forecast:** Under this scenario, using the Case 1 revenue requirement, we model LADWP's 2035 rates by extending its existing tariff design and rate schedule in place in 2019. We incorporate LADWP's existing EZ-SAVE and Lifeline low-income assistance program enrollment and discounts at percentage levels consistent with average nominal levels between 2016 and 2019.[14] More recent data on enrollment are not used due to potential anomalies experienced from the COVID-19 pandemic.
- **2035 Simplified Tiered Rates:** Using the Case 1 revenue requirement, we design a two-tiered inclining block rate design where rates increase once a consumption threshold is met, with a third super-user tier, consistent with the CPUC 2015 rate reform order (California Public Utilities Commission 2015) (see Appendix C). This scenario does not include any low-income bill assistance programs.
- **2035 Default Time-of-Use (TOU) Rates:** Under this scenario, using the Case 1 revenue requirement and proxy marginal system costs, we design a default TOU rate consistent with CPUC guidance (California Public Utilities Commission 2017; 2019; 2020) (see Appendix C). This approach prevents certain low-income customers from being defaulted into TOU rates, and they therefore remain on the tiered rate structure. We model this rate structure even though LADWP currently does not have the smart meter infrastructure required to implement default TOU rates. This scenario does not include any low-income bill assistance programs.

This rate analysis uses projected LADWP customer energy demand in 2035 calibrated against historical customer load data (see Chapters 6 and 7). To inform how distributed solar rooftop photovoltaics (PV) and associated compensation policies impact rates and customer bills, we use customer-sited solar offsets about 4% of residential load in 2019, 16.2% in 2035 under SB 100, and 26.5% in 2035 under Case 1 based on LA100 study models (Jacquelin Cochran and Paul Denholm 2021). We assume net metering for LADWP baseline and BAU rate scenarios and net

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[13] SB 100 requires renewable energy and zero-carbon resources to supply 100% of electric retail sales to end-use customers by 2045. See "SB 100 Joint Agency Report," California Energy Commission, https://www.energy.ca.gov/sb100.

[14] Participation in EZ-SAVE across the entire residential customer class (not just eligible population) was 7.1572% in 2019 with discounts of \$8.17/month. Enrollment for 2035 is 9.2993% with a nominal discount of \$8.17/month. The discount does not change given it is held constant at this nominal value in the current LADWP tariff. This is because the funding mechanisms for EZ-SAVE and Lifeline have reached their cap and would require a rate case to increase funding.

billing compensation for CPUC simplified tiered and TOU rate scenarios.[15] We use historic data on solar adopter household income distributions to randomly assign solar to individual households, as well as to model the impacts of increasing solar adoption in LMI households by 20% (compared to 2035 forecasts). The solar analysis aimed to identify residential intra-class transfers and resultant equity and affordability metrics that occur when we vary the level of solar penetration and solar compensation strategies. Our solar analysis does not aim to precisely predict aggregate future solar penetration levels, household adoption probability (e.g., logit model), or likely future adopter household income distributions.

We analyze the potential impacts of certain low-income strategies, including establishing robust low-income assistance programs modeled after the California Alternate Rates for Energy (CARE) and Family Electric Rate Assistance (FERA) programs,[16] on-bill efficiency tariff programs (e.g., Pay As You Save), and income-based fixed charges (IBFC). These strategies are chosen to represent a range of options from contemporary California utility practice (i.e., CARE and FERA) to strategies that could leverage federal Inflation Reduction Act funding (on-bill tariff) and innovative rate design approaches currently under consideration such as IBFC.

To enable this analysis, we develop a new Customer Affordability, Incentives, and Rates Optimization (CAIRO) model to calculate and analyze residential retail electricity rates based on a set of user-defined criteria on tariff design elements, input data requirements, low-income assistance strategy design, and output evaluation metrics. Required data inputs include:

- **8760 Load Patterns:** A sample of 50,000 prototypical LADWP residential customers developed by NREL is used to model hourly household energy usage (electricity and gas) patterns for both the 2019 baseline and 2035 scenarios. The load patterns incorporate household solar adoption consistent with the criteria previously discussed, as well as household-level solar resource availability data from the Distributed Generation Market Demand (dGen) model and ResStock.
- **Customer Metadata:** These demographic data include income, persons per household, housing type and tenure, and other parameters.
- **Utility Revenue Requirement:** The 2035 revenue requirement associated with the SLTRP Case 1 scenario for 2035 is $4.552 billion in 2035$.[17] The 2035 revenue requirement associated with the SLTRP SB 100 scenario, and specifically compliance for the residential sector, is $3.341 billion in 2035$.
- **Marginal System Costs:** LADWP's marginal system costs for 2035 were not available, so marginal system cost estimates from CPUC's Avoided Cost Calculator are used for the

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[15] In basic terms, net metering provides retail rate compensation for customer-generated solar exported to the grid, while net billing provides avoided cost compensation for solar exports to the grid. Net billing compensation tends to be lower than net metering compensation.

[16] California investor-owned utilities are required to offer 30%–35% discounts to eligible low-income customers under the CARE program and 18% discounts for eligible middle-income families under the FERA program.

[17] LADWP's residential revenue requirement for Case 1 and SB 100 are from a March 2023 forecast.

investor-owned utility (IOU) service territory surrounding LADWP, Southern California Edison (SCE).[18] These costs are used for the TOU rates and IBFC modeling.

- **Fixed and Adjustable Tariff Design Elements:** Inputs including the number and timing of rate periods, rate price differentials, and tariff schedule distribution guide the model's optimization engine ("Model Run" in Figure 2).

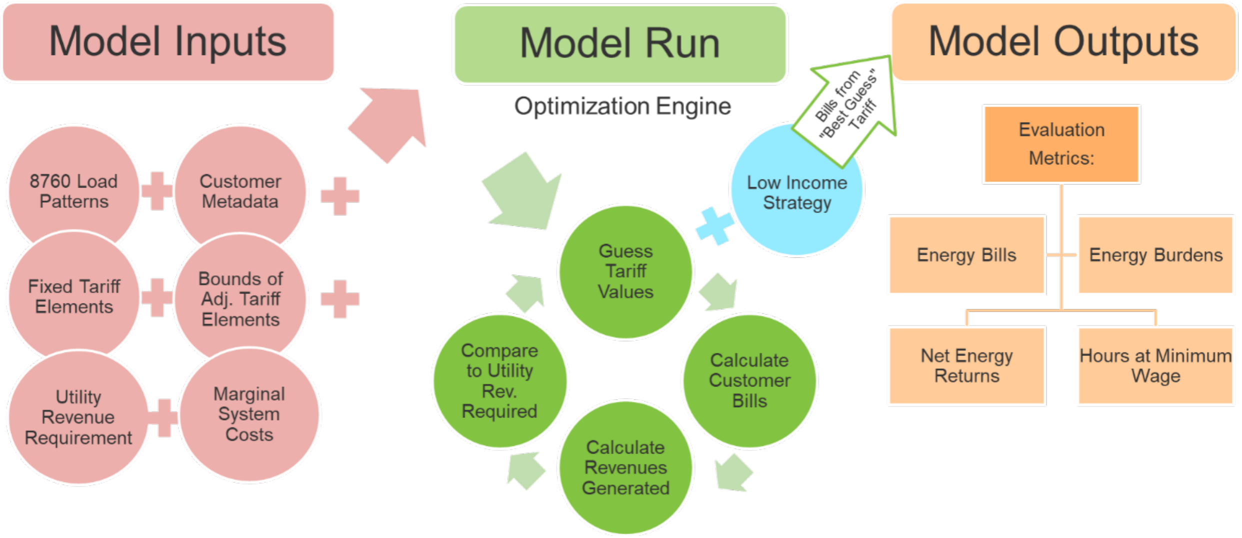

Figure 2. CAIRO model workflow summary

Using regulatory criteria on rate design, CAIRO identifies the optimal rate values that recover the utility's required revenues (i.e., the residential revenue requirement). These rates are then used to calculate customer bills based on individual household electricity usage. Low-income strategies are applied to customer bills based on criteria (e.g., customer location and income) mapped to individual customers. This step often requires customer bills to be recalculated, depending on the source of low-income assistance strategy funding. For example, low-income customer discount program costs may be recovered in rates charged to non-low-income customers through a volumetric line-item charge. The final customer-level bill outputs are evaluated by a series of equity and affordability metrics that help identify affordability trade-offs among rate design and assistance program strategies. The evaluation of the final electricity bills is performed by comparing four metrics:

- **Average Monthly Electricity Bills by Income Bin:** Here, we separate households by income bin, then calculate average monthly bill data (annual bill, divided by 12 months).
- **Energy Burden (electricity only):** This is a widely used metric to describe energy affordability. It is derived by dividing annual household-level income by annual household energy expense. If income is zero or bills are greater than income, energy burden metrics become infinite or negative.

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[18] For SB 100, 2035 values were used directly as both LADWP and SCE are forecasted to have the same approximate share of renewable energy on their systems. For Case 1, 2045 values for SCE were used and adjusted to 2035$ as LADWP would have 100% renewable energy on its system in 2035, which SCE does not reach until 2045.

- **Hours at Minimum Wage (HMW):** This is a version of an affordability metric used by the CPUC that describes how many hours a person working at minimum wage would need to work to pay for an essential quantity of energy. We modify this metric by replacing essential energy quantity with the customer's average monthly electricity bill. The metric is calculated by dividing the monthly bill by the prevailing (and projected in the 2035 case) minimum wage rate.
- **Net Energy Return (NER):** This unitless metric describes the ratio of income dollars earned by a household for every dollar spent on energy (here, electricity only). It is calculated by subtracting annual electricity costs from annual income and then dividing by electricity costs. Higher NER values are more desirable than lower values. Compared to energy burden, this metric provides more useful treatment of income extremes such as households with zero or negative incomes, energy expenditures that exceed incomes, or higher incomes (Scheier and Kittner 2022).

These evaluation metrics are intended to contextualize bill costs in terms of affordability, equity, and disparate impacts, and to facilitate comparison and rank ordering. Where applicable, we contextualize the cost of a program strategy through the intra-class transfer cost metric. This transfer metric represents the low-income program costs that must be recovered from noneligible residential customers. For example, the transfer cost included in Table 2 (page 13) 13is the low-income assistance strategy cost as a percentage of the residential class revenue requirement.

Modeled evaluation metrics are included in Table 213, where all dollar values and metrics are in 2021 terms. The following are the scenario-strategy model combinations we evaluate. More information on these model scenarios can be found in Appendix A:

- **Model Run A: 2019 Baseline LADWP Rates** serves as a baseline to compare against future projections. It includes LADWP's 2019 calendar year tariff (see Appendix C), existing EZ-SAVE and Lifeline program, and 2019 residential revenue requirement. Residential single-family home rooftop solar PV generation offsets 4% of residential load, and net metering compensation is applied.
- **Model Run B: 2035 LADWP BAU Forecast** uses LADWP's projected Case 1 revenue requirement for 2035 and extrapolates tariff rates based on LADWP's current tariff rate design pattern and EZ-SAVE and Lifeline program enrollment levels. Residential single-family home rooftop solar PV generation offsets 26.5% of residential load, and net metering compensation is applied.
- **Model Run C: 2035 CPUC Tiered Rates** uses LADWP's 2035 Case 1 revenue requirement, CPUC guidance on tiered inclining block rate structure, and no low-income assistance program. Residential single-family home rooftop solar PV generation offsets 26.5% of residential load, net billing compensation is applied, and solar customers remain on tiered rates.
- **Model Run D: 2035 CPUC TOU Rates** uses LADWP's 2035 Case 1 revenue requirement, CPUC guidance on TOU rate structure and participation, and no low-income assistance program. Residential single-family home rooftop solar PV generation offsets 26.5% of

residential load, net billing compensation is applied, and all solar customers are put on a special TOU rate.

- **Model Run E: 2035 LADWP BAU with CARE and FERA** is the same as Model B, but it replaces the EZ-SAVE program with low-income bill assistance modeled after CARE and FERA programs offered by California IOUs and models similar discount and enrollment levels as the IOUs.
- **Model Run F: 2035 Tiered Rates with CARE and FERA** is the same as Model C, but it adds CARE and FERA bill assistance programs.
- **Model Run G: 2035 Tiered Rates with IBFC** uses the same rate design as Model C for recovery of marginal costs, but recovers residual cost[19] through fixed charges assigned to customers based on their income levels.
- **Model Run H: 2035 Tiered Rates with CARE and FERA and IBFC** is the same as Model G except it includes the CARE and FERA programs.
- **Model Run I: 2035 TOU Rates with CARE and FERA** is the same as Model D with CARE and FERA programs.
- **Model Run J: 2035 TOU Rates with IBFC** recovers marginal costs through TOU rates and recovers residual costs through fixed charges assigned to customers based on their income levels.
- **Model Run K: 2035 TOU Rates with CARE and FERA and IBFC** is the same as Model J with CARE and FERA programs.

The following models incorporate electrification of natural gas end-use technologies and therefore incorporate both gas and electricity bill cost data:

- **Model Run N2: 2035 LADWP BAU with On-Bill Tariff for Heat Pump Water Heaters** is the same as Model B but enrolls eligible customers in an on-bill tariff program for installing an energy-efficient heat pump water heater.
- **Model Run N5: 2035 LADWP BAU with On-Bill Tariff for Enhanced Insulation** is the same as Model B but enrolls eligible customers in an on-bill tariff program for installing enhanced insulation.

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[19] Residual costs equal the total residential revenue requirement minus total system marginal costs. The residential revenue requirement is the amount of revenue the utility is permitted by regulators to collect from customers. Total system marginal costs are economic costs associated with serving customers.

2 Modeling and Analysis Results

A selection of equity metrics for most of the models explored is included in Table 2. These metrics summarize the following modeling and analysis results:

- If BAU continues, under the SLTRP Case 1's 233% (nominal) or 124% (real) residential revenue requirement increase, average monthly customer bills for the residential class will increase by 79% between 2019 and 2035.
- Under a continued net metering solar compensation structure, the inequity that exists in 2019 between solar adopters (who on average have much lower bills than non-adopters) is significantly exacerbated by 2035. Modeling indicates solar adopter average monthly bills were $69 lower than non-adopters in 2019 and will be $162 lower than non-adopters in 2035.
- The net metering-induced intra-class transfer from non-adopters, who are predominantly lower-income, to solar adopters, who tend to have higher income, is one contributor to the finding that in 2035 average monthly bills for the low-income customer are higher than average bills for the rest of the residential class. The average percent of household income spent on electricity bills for low-income customers increases from 7.8% in 2019 to 16.1% in 2035, and the number of households over 100% electricity burden increases from 4,760 to 23,000.

LMI Bill Savings Within the Existing Rate Structure

- On-bill tariff could reduce energy bills for some LMI households. Six technologies were tested within an on-bill tariff framework, partially subsidized through Inflation Reduction Act funds, to determine if bill savings could be achieved without requiring up-front investment from capital-constrained customers or cross-subsidization from other customers. Only LMI customers were considered eligible, the bill rider was limited to less than $50/month,[20] and threshold bill savings was defined as savings on total energy (power and gas) 25% higher than the bill rider applied. It is important to clarify that we identify technical potential for total potential customers served assuming the most cost-efficient use of funds. We do not consider implementation challenges, lack of customer awareness or interest, or other factors (e.g., larger portion of high-cost projects served) that would reduce the reach of this program. The technologies tested include:
    - Heat pumps (air-source or mini-split).
    - Heat pump water heaters.
    - Whole-home electrification: heat pumps, heat pump water heaters, induction ranges, electric clothes dryers, ENERGY STAR refrigerators.
    - Heat pumps and basic insulation.
    - Enhanced insulation.

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[20] The $50/month threshold was based on an approximate non-weighted average of bill riders from on-bill tariffs implemented by electric utilities; see Deason, Murphy, and Leventis (2022).

- LEDs, as a test case (see details in Appendix A).

The only technologies that delivered sufficient bill savings at a reasonable monthly bill rider were LED lighting, heat pump water heaters, and enhanced insulation. For heat pump water heaters, the participant-wide monthly bill rider was $17/month with the potential to serve 154,000 LMI on-bill tariff customers; see electricity bill and total energy bill (gas and electricity) savings shown in Figure 3. For enhanced insulation, the monthly rider was $17/month and the number of customers potentially served was 72,000 (see Figure 4). On-bill tariff-eligible customers are in the LMI groups and tend to have higher energy bills than customers who are not eligible for the on-bill tariff program due to income ineligibility or lower energy bills.

The on-bill tariff approach recovers costs over time from the customers receiving benefits, and the efficiency technologies modeled receive Inflation Reduction Act funding. Additionally, bill riders only apply to enrolled customers. Because this program approach may not trigger a ballot action or violate Proposition 26 and Proposition 218, we model the on-bill tariff program with heat pump water heaters and enhanced insulation using the 2035 LADWP BAU rate strategy.

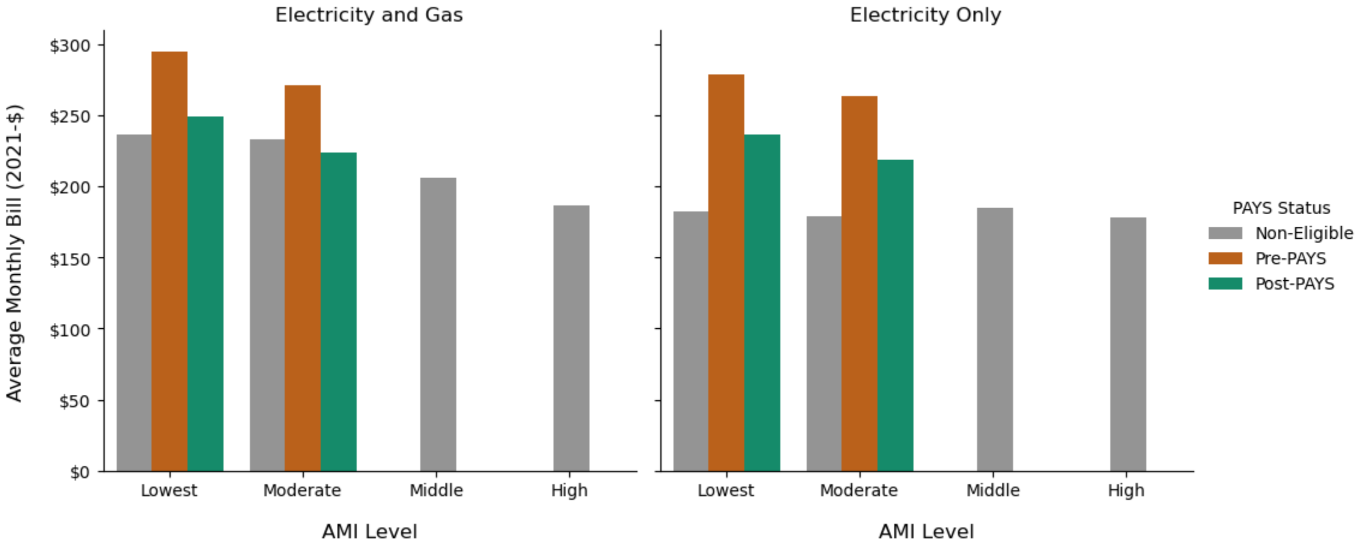

Figure 3. Average monthly bills for on-bill tariff with heat pump water heater customers and noneligible customers using LADWP BAU rates in 2035

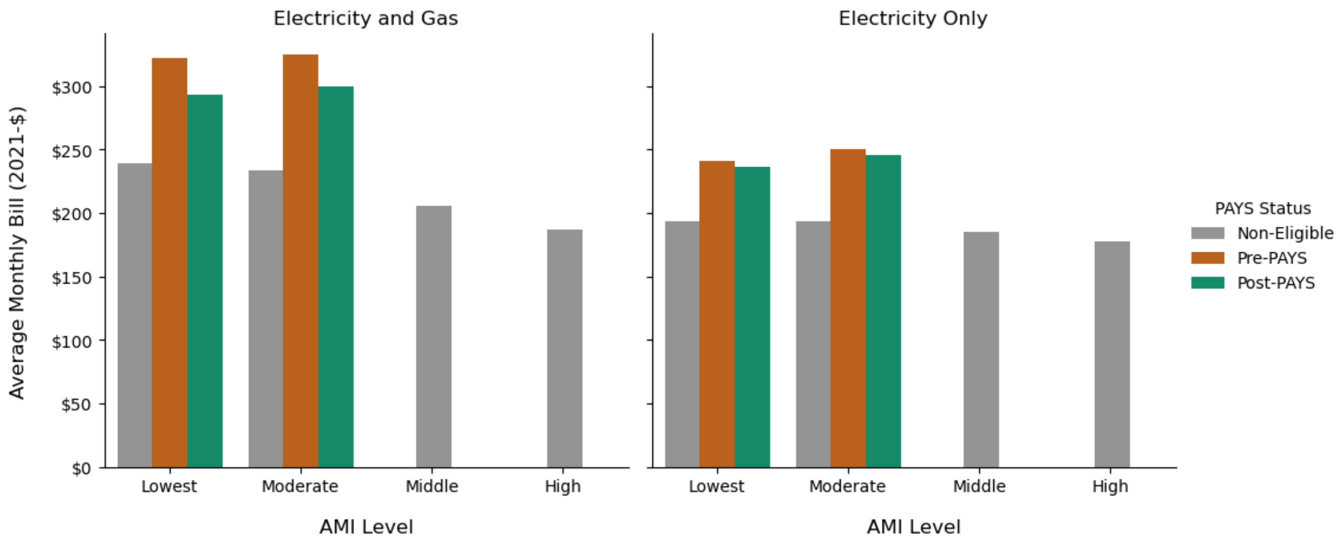

Figure 4. Average monthly bills for on-bill tariff with enhanced insulation customers and noneligible customers using LADWP BAU rates in 2035

As shown in Figures 3 and 4, total energy bills of higher-income customers are expected to decline by 2035 (left panels), as these customers are projected to electrify end uses with high-efficiency appliances, reducing natural gas use and costs and increasing the efficiency of electricity usage (right panels). See Appendix F for additional details.

Only LMI households were enrolled for the on-bill tariff program. Of the households that achieved bill savings from an on-bill tariff-funded heat pump water heater, 68% of the dwellings were built before 1980 and had electric water heating. In addition, 65% of these households had cooling. Heat pump water heaters can provide a co-benefit of cooling by removing heat from conditioned spaces.

Of the households that achieved bill savings from on-bill tariff-funded enhanced insulation, more than 67% have natural gas heating fuel and live in dwellings built before 1980. Of the household enrolled for enhanced insulation, 81% of the household have access to whole-home or partial cooling. For more information, please see Appendix G.

Changes to Rate Design and Solar Compensation Policy Improve Equity

Even without the EZ-SAVE and Lifeline programs, outcomes for low-income customers improve by changing rate design to simplified tiers or a TOU rate, switching from net metering to net billing for solar compensation, and adding a program to incrementally boost LMI solar adoption.[21,22] These reforms decrease inequity between solar adopters and non-adopters and incrementally improve affordability for low-income customers.

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[21] See Appendix A for a description of the low-income solar adoption program modeled.

[22] Our focus with changing solar compensation strategies is limited to determining if more equitable and affordable outcomes may exist for low-income customers. We do not evaluate how the change in compensation strategies may impact total solar penetration; rather, we hold these penetration levels constant at target levels.

- Inequity is reduced as the cost spread between solar adopter and non-adopter average monthly bills shrinks from $162 in the BAU scenario to $55 for the simplified tiers and $65 for TOU rates. Compared to tiered rates, solar adopters see lower bills with TOU rates, as the timing of solar generation allows these customers to avoid grid electricity use during certain high-price periods. The improvement in equity between solar adopters and non-adopters can be seen in Figure 5, where moving to net billing with simplified tiers or TOU rates results in a narrower spread between adopter and non-adopter average monthly bills, in all income bins.
- Affordability improves as average monthly bills for low-income households fall about $10 below the average monthly bills for the entire residential class. However, average electricity burdens are still high for low-income households at approximately 15% for both simplified tier and TOU, and there are at least 19,500 households with electricity burdens over 100%.

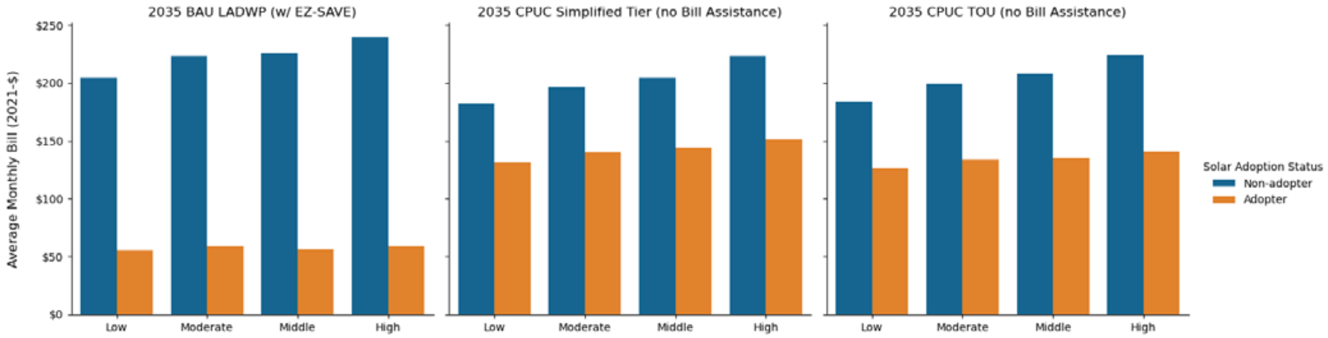

Figure 5. Average monthly bills by scenario and area median income group for solar adopters and non-adopters in 2035

For the 2035 BAU LADWP (with EZ-SAVE), solar PV is compensated under a net metering scheme, while for the other two scenarios solar PV is compensated under a net billing scheme.

Robust Low-Income Assistance Programs Improve Affordability

The addition of robust low-income assistance programs to updated rate design and reformed solar compensation mechanisms results in significant improvements to low-income energy bill affordability. Establishing robust assistance programs modeled after CARE and FERA results in higher bill savings and enrollment rates than LADWP's existing EZ-SAVE and Lifeline programs.

Equity further improves as the spread between solar adopter and non-adopter average monthly bills decreases to $29 (simplified tiers) and $39 (TOU).

- Compared to only updating rate design and solar compensation, affordability improves significantly as low-income average monthly bills drop by $40, electricity burdens are reduced from 15.2% to 12.2% (simplified tiers) and 15.4% to 12.4% (TOU), and households over 100% electricity burdens decrease by at least 8,300 households.

Establishing robust low-income assistance programs requires a significant subsidy ranging from $307 million to $335 million, or 9.5%–10.4% of the residential revenue requirement. We model this cross-subsidy coming from non-enrolled residential customers. In practice, this program would also be supported by customers from the commercial, industrial, and other classes.

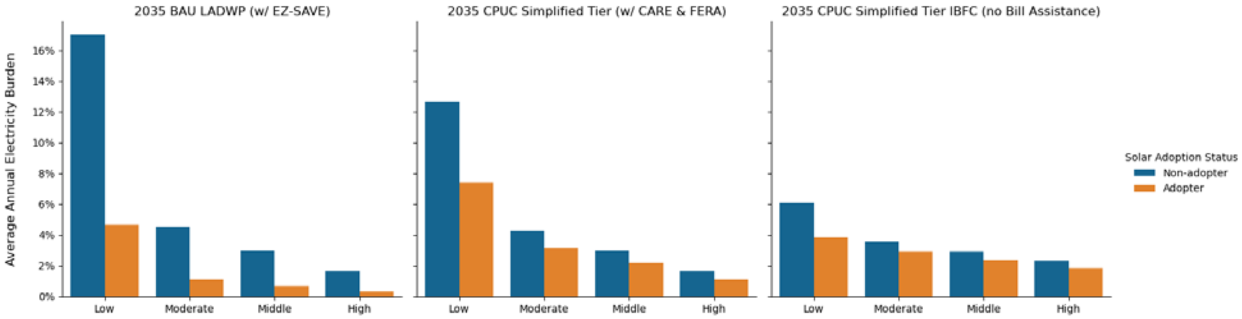

Figure 6. Annual electricity burden by scenario and area median income group for solar adopters and non-adopters in 2035

For the 2035 BAU LADWP (with EZ-SAVE), solar PV is compensated under a net metering scheme, while for the other two scenarios solar PV is compensated under a net billing scheme.

Income-Based Fixed Charges Achieve Affordability

The strategies discussed thus far *improve* equity and affordability for low-income households; however, affordability is *achieved* through IBFC. Here, we define affordability as an electricity-only burden under 6%.[23] Even as higher-income energy burdens are slightly increased, the IBFC strategy brings average electricity burdens for all customers under 6% (Figure 5 and Appendix E). As shown in Figure 6, IBFC narrows the energy burden disparity across income groups more than other approaches modeled.

- Although affordability is achieved, higher-income customers are charged a larger portion of fixed costs based on their ability to pay, and not related to their actions (e.g., usage). Furthermore, higher fixed charges could conflict with other energy policy priorities such as incentivizing energy efficiency investments. IBFC in this regard will require consideration for the trade-offs in policy priorities, between equity and affordability on the one hand and energy conservation priorities on the other.
- Also in this scenario, on average, solar adopters tend to have higher average monthly bills than non-adopters, which could impact residential rooftop solar adoption. However, these higher average bills are a function of weighted averages. Table 1 shows the solar adopter and non-adopter customer counts for each income group, along with their average monthly bills. The table confirms that solar adopters on average are saving money, and the majority of solar adopters have higher incomes and higher average bills, therefore driving up the adopter-wide average monthly bill.

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[23] The 6% affordability threshold is typically associated with energy burden (i.e., all household energy use, including electricity and natural gas). In the absence of a threshold for electricity-only burden, we use the 6% threshold as an approximation for an affordable level.

Table 1. Customer Counts and Average Bills by Solar Adopter and Non-Adopter Status Using TOU Rates with IBFC and with CARE and FERA programs (2035)

TOU Rates with IBFC, CARE, and FERA				
Area Median Income (AMI) Bin	**Solar Non-Adopter**		**Solar Adopter**	
	Count	**Avg. Bill ($2021)**	**Count**	**Avg. Bill ($2021)**
Very Low	327,700	$30.93	26,000	$21.29
Low	192,400	$113.98	27,300	$99.38
Moderate	218,600	$175.42	54,400	$161.83
Middle	207,600	$224.61	60,100	$208.06
High	316,100	$342.58	141,400	$322.11

As shown in Table 2 (and Appendix E), electricity affordability decreases for moderate-income households between the 2019 baseline and 2035 BAU model forecasts. Most strategies explored in this analysis do not meaningfully improve affordability for moderate-income households. We ran sensitivity analyses to determine if increasing the FERA program participation rate from 14.6% to 89% of eligible households would improve moderate-income affordability. The results indicate enrollment expansion alone would not lead to significant bill savings or improved affordability metrics for moderate-income households. More research is required to identify strategies to target this income group and could include raising the eligible income threshold or increasing discounts.

This analysis is not a comprehensive review of all rate and program design options available to LADWP, nor does the analysis attempt to categorize all the costs, benefits, and trade-offs that occur among design choices. The analysis focuses on impacts to low-income households, defined here as including households with annual income of 0%–50% area median income (AMI). The rate and program design approaches modeled are currently or soon to be implemented by other California utilities based on CPUC guidance. A more holistic analysis of rate design would include metrics to identify intra-class cross-subsidies, deadweight loss,[24] and other trade-offs.

Table 2 summarizes the rate affordability and equity modeling results, excluding on-bill tariff results, which are shown in Table 3. Results were reported separately for the on-bill tariff program, as both gas and electricity costs to the customer must be accounted for when comparing the bill impacts of electrifying end uses.

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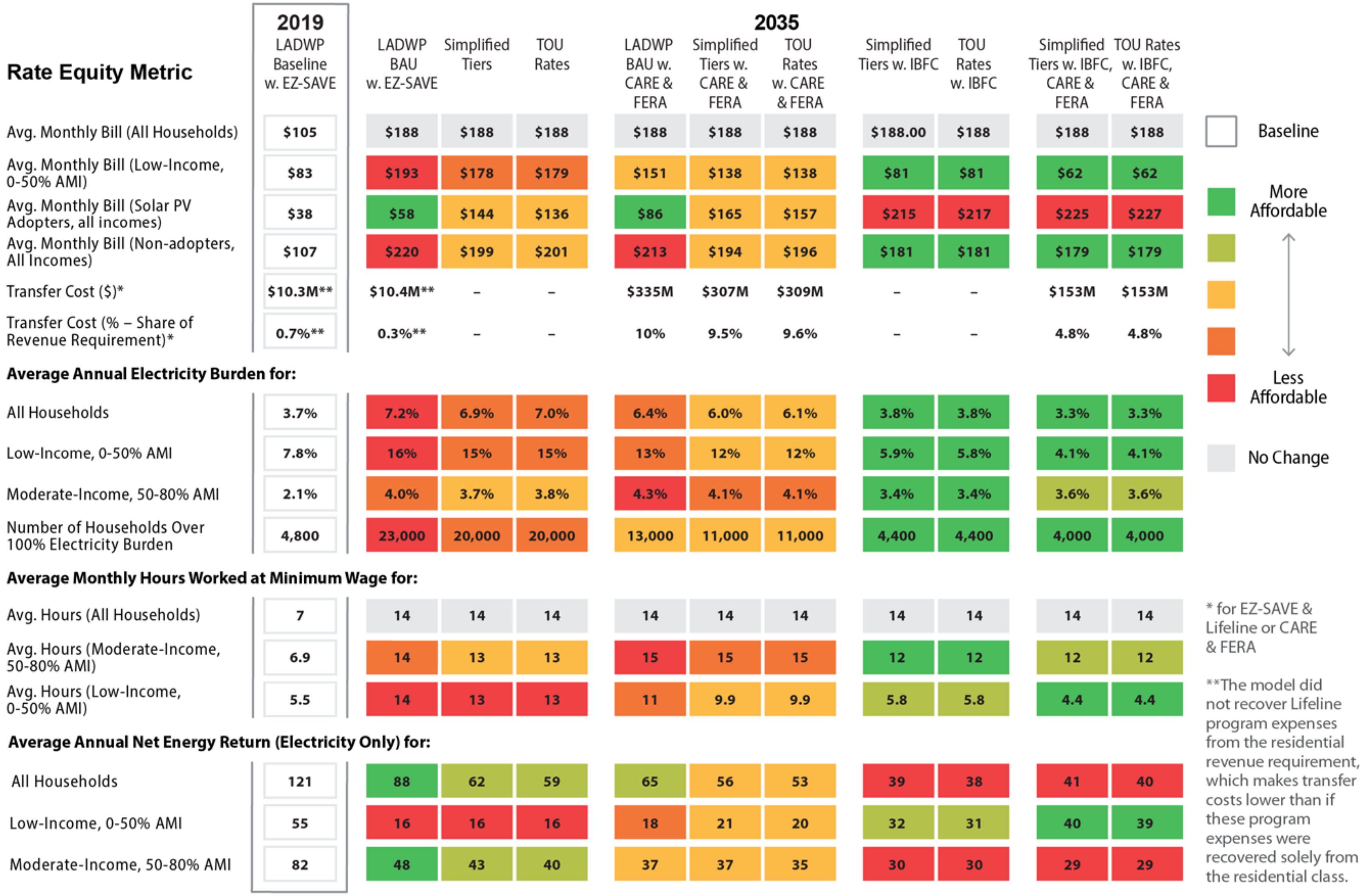
[24] Deadweight loss is a metric that describes how efficiently (zero or no deadweight loss) or inefficiently (high deadweight loss) a resource such as electricity was utilized. In simple terms, deadweight loss typically occurs through a mismatch of supply-and-demand market forces. For example, if a pizza store bakes 50 pizzas for an event but only sells 45 pizzas, and the remaining 5 pizzas go unsold and rot, these 5 unsold, rotten pizzas are considered deadweight loss.

Table 2. Rate Affordability and Equity Modeling Results



Rate Equity Metric	2019	2035									
	LADWP Baseline w. EZ-SAVE	LADWP BAU w. EZ-SAVE	Simplified Tiers	TOU Rates	LADWP BAU w. CARE & FERA	Simplified Tiers w. CARE & FERA	TOU Rates w. CARE & FERA	Simplified Tiers w. IBFC	TOU Rates w. IBFC	Simplified Tiers w. IBFC, CARE & FERA	TOU Rates w. IBFC, CARE & FERA
Avg. Monthly Bill (All Households)	$105	$188	$188	$188	$188	$188	$188	$188.00	$188	$188	$188
Avg. Monthly Bill (Low-Income, 0-50% AMI)	$83	$193	$178	$179	$151	$138	$138	$81	$81	$62	$62
Avg. Monthly Bill (Solar PV Adopters, all incomes)	$38	$58	$144	$136	$86	$165	$157	$215	$217	$225	$227
Avg. Monthly Bill (Non-adopters, All Incomes)	$107	$220	$199	$201	$213	$194	$196	$181	$181	$179	$179
Transfer Cost ($)*	$10.3M**	$10.4M**	–	–	$335M	$307M	$309M	–	–	$153M	$153M
Transfer Cost (% – Share of Revenue Requirement)*	0.7%**	0.3%**	–	–	10%	9.5%	9.6%	–	–	4.8%	4.8%
Average Annual Electricity Burden for:											
All Households	3.7%	7.2%	6.9%	7.0%	6.4%	6.0%	6.1%	3.8%	3.8%	3.3%	3.3%
Low-Income, 0-50% AMI	7.8%	16%	15%	15%	13%	12%	12%	5.9%	5.8%	4.1%	4.1%
Moderate-Income, 50-80% AMI	2.1%	4.0%	3.7%	3.8%	4.3%	4.1%	4.1%	3.4%	3.4%	3.6%	3.6%
Number of Households Over 100% Electricity Burden	4,800	23,000	20,000	20,000	13,000	11,000	11,000	4,400	4,400	4,000	4,000
Average Monthly Hours Worked at Minimum Wage for:											
Avg. Hours (All Households)	7	14	14	14	14	14	14	14	14	14	14
Avg. Hours (Moderate-Income, 50-80% AMI)	6.9	14	13	13	15	15	15	12	12	12	12
Avg. Hours (Low-Income, 0-50% AMI)	5.5	14	13	13	11	9.9	9.9	5.8	5.8	4.4	4.4
Average Annual Net Energy Return (Electricity Only) for:											
All Households	121	88	62	59	65	56	53	39	38	41	40
Low-Income, 0-50% AMI	55	16	16	16	18	21	20	32	31	40	39
Moderate-Income, 50-80% AMI	82	48	43	40	37	37	35	30	30	29	29

* for EZ-SAVE & Lifeline or CARE & FERA

**The model did not recover Lifeline program expenses from the residential revenue requirement, which makes transfer costs lower than if these program expenses were recovered solely from the residential class.

Dollar values are adjusted to 2021$. Each row is color-coded relative to other values in the row: green signifies more affordable outcomes for low-income customers, red represents less affordable outcomes, and yellow denotes values midway between green and red. Gray indicates functionally equal results. Results for all income groups are available in Appendix E.

	2035 BAU LADWP (with EZ-SAVE)	**2035 LADWP BAU On-Bill Tariff Heat Pump Water Heaters (No Bill Assistance)**		**2035 LADWP BAU On-Bill Tariff Enhanced Insulation (No Bill Assistance)**	
Table 3. Heat Pump Water Heater On-Bill Tariff (e.g., Pay-As-You-Save) Energy Bill Impacts	**All Customers**	**Participating Customers Only**		**Participating Customers Only**	
		Pre-Installation	**Post Installation**	**Pre-Installation**	**Post Installation**
Average monthly combined electricity and gas bill (all households)	$222	$285	$238	$323	$296
Average monthly combined electricity and gas bill (low income)	$245	$295	$249	$322	$293
Average monthly combined electricity and gas bill (solar adopters, all incomes)	$90	$128	$101	$177	$145
Average monthly combined electricity and gas bill (non-adopters, all incomes)	$254	$291	244	$341	$315
Transfer costs ($)	$10,400,000	$0	$0	$0	$0
Transfer costs (share of revenue requirement)	0.3%	0%	0%	0%	0%
Average combined electricity and gas burden (all households)	8.3%	14.2%	13.3%	15.1%	14.4%
Average combined electricity and gas burden (low income)	18.7%	21.3%	20.2%	20.3%	19.3%
Average combined electricity and gas burden (moderate income)	4.9%	5.6%	4.7%	6.6%	6.1%
Households over 100% combined electricity and gas burden (all households)	32,900	8,350	6,180	3,120	2,580
Average month HMW (all households)	15	19	16	22	20
Average month HMW (moderate income)	16	18	15	22	20
Low-cost month HMW (low income)	12	16	13	15	15
Average month HMW (low income)	16	20	17	22	20
High-cost month HMW (low income)	23	25	21	33	27
Average annual NER (all households)	108	19	23	17	19
Average annual NER (low income)	15	10	12	11	12
Average annual NER (moderate income)	43	31	38	27	30

3 Equity Strategies Discussion

As LADWP pursues clean energy goals, model results indicate continuing the current rate and bill assistance program approaches with the existing complex rate design will lead to more inequitable and unaffordable outcomes for low-income households. Though LADWP is constrained from pursuing solutions available to most utilities under current state statutes, if these barriers were removed, several approaches would increase electricity rate equity and affordability in LA's transition to 100% clean energy. In addition, an on-bill tariff program for at least two efficiency technologies could reduce bills within the existing rate approach. Strategies include:

- **Update rate design and solar compensation method:** Low-income average electricity bills would decrease by $14–$15/month, and the disparity in the share of system costs paid by solar adopters and non-adopters would decrease by revising rate design from LADWP's existing multiperiod, complex rates with the EZ-SAVE and Lifeline programs and net metering policy to (1) either a simplified tiered inclining block rate structure or a default TOU rate structure, both as recommended by the CPUC, and (2) shifting from net metering to net billing customer-sited solar compensation. A change in rate design strategy would likely result in loss of the annual transfer to the city's General Fund (Carmen A. Trutanich 2012).[25] Eliminating the transfer requirement from customers to the city of Los Angeles would reduce rates for all customers while reducing the city's General Fund. Such a rate design change might also lead to challenges maintaining existing low-income bill assistance programs like EZ-SAVE and Lifeline.
- **Enhance low-income assistance programs:** Replacing the EZ-SAVE and Lifeline programs with a more robust low-income energy assistance program approach modeled after the CARE and FERA programs results in 22% lower monthly electricity bills for low-income customers, even if BAU rate design remains. This low-income assistance program approach requires funding from non-low-income customers, which is explicitly prohibited by California Proposition 26 and California Proposition 218 (League of California Cities 2021). It is unclear how LADWP could fund a robust low-income program without triggering a proposition challenge.
- **Explore innovative IBFC to achieve affordability:** IBFC would reduce low-income electricity bills by nearly $100/month and improve affordability more than all other approaches modeled. California passed Assembly Bill 205 in June 2022, allowing for implementation of IBFC for IOUs in the state. The CPUC is currently considering design and implementation approaches. Implementation presents practical challenges, particularly related to income verification (Severin Borenstein, Meredith Fowlie, and James Sallee 2022).

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[25] The city of Los Angeles receives money through electricity bills via two mechanisms: the Utility User Tax and the annual transfer (known as the Power Revenue Transfer). The former appears as an explicit line item of 10% in nonexempt customers' bills. The latter is integrated into LADWP rates, as it must recover its revenue requirements and the city transfer costs. The Utility User Tax would be unaffected by a rate design change. In the 2022–2023 city budget, the Utility User Tax represented $614.1 million in revenue (8.25% of the General Fund) and the Power Revenue Transfer represented $229.7 million in revenue (3.09% of the General Fund) (City of Los Angeles 2022).

Implementing IBFC would likely violate the California propositions because residual costs would be assigned to customers based on income and not costs.

- **Leverage federal Inflation Reduction Act funding through an on-bill-tariff program for LMI customers:** Modeling indicates a heat pump water heater or enhanced insulation on-bill tariff program could reduce energy bills for nearly 154,000 or 74,000 LMI customers, respectively. This strategy could potentially be implemented without violating Proposition 26 and Proposition 218.

Most options to improve low-income equity and affordability are not currently available for LADWP given its unique constraints as a municipal utility subject to the restrictions of California Proposition 26 and California Proposition 218. In addition, as a municipal utility, LADWP is not subject to CPUC jurisdiction. Compared to 2019, modeling indicates a BAU approach with the existing, complicated rate design practices with layered cost-based adjustment factors and line-item bill riders would increase inequity and result in decreased electricity bill affordability for low-income households by 2035. The clean energy transition does not need to be inequitable; however, electric utilities could evolve their approach to rates and rate-making to ensure affordable outcomes for low-income populations.

Table 4. Equity Strategy Options: Benefit, Cost, Timeline, Responsibility, and Evaluation Metrics

NREL modeled the impacts of rate design changes, an on-bill tariff program for energy efficiency technologies, and low-income assistance strategies. Implementation of some strategies is likely to conflict with California Proposition 26 and California Proposition 218.

Equity Strategy	Benefit/Impact	Cost[a]	Timeline	Responsible Party	Metric
Implement an on-bill tariff program leveraging Inflation Reduction Act funds, to support heat pump water heater or enhanced insulation installation for low-income customers	Technical potential for nearly 154,000 and 74,000 LMI customers to save on energy bills through on-bill financed heat pump water heaters and enhanced insulation, respectively.	Leverages Inflation Reduction Act funds. Only participating customers are assessed monthly bill riders	Possible rate case or other action to establish on-bill tariff, then identify program implementor and launch program	LADWP could initiate the program. May or may not need rate case to establish the on-bill tariff.	Income-eligible customers who qualify for the program will see energy (gas and electricity) bill savings 25% higher than the program bill rider. Number of participating households
Update rate design to simplified tiers or default TOU, switch from net metering to net billing solar compensation, and moderately boost low-income solar adoption	Low-income electricity bills would decrease by $14–$15/month. Reduces disparity between solar adopter and non-adopter contributions toward system costs. 3,300–3,500 fewer customers with >100% energy burdens than BAU	Uncalculated cost of moderate low-income solar adoption program. Improved price signals could promote cost savings if customers respond by avoiding consumption in higher-priced periods	Referendum or legislative change and rate case with rate redesign required	Government entity, citizen, or LADWP initiates, and LADWP's board and city council approve results of rate case.	Average monthly electricity bill savings. Reduced intra-class cross-subsidization for solar compensation. Reduced number of customers over 100% energy burden. Customer satisfaction and customer understanding surveys preapproved and post-approved rate design changes[b]

Equity Strategy	Benefit/Impact	Cost[a]	Timeline	Responsible Party	Metric
Implement robust CARE/FERA-type low-income assistance program	22% lower electricity bills for low-income customers Monthly assistance increases from $5.78/month under EZ-SAVE to ~$54/month under CARE and ~$37/month under FERA. Increase in assistance recipients from 150,000 under EZ-SAVE to 436,000 under CARE and FERA Larger cross-subsidy from nonparticipating to participating customers[c]	On average, $307–$335 million/year in reallocated funds (compared to $35 million for EZ-SAVE, Lifeline, and two smaller assistance programs in 2020)	Referendum or legislative change and rate case with rate redesign required	Government entity, citizen, or LADWP initiates, and LADWP's board and city council approve results of rate case.	Equitable access to bill discount programs can be measured in reference to California utility averages of 30%–35% discount on electric bills for enrollees. Eligible enrollment rates of 89% for CARE and 15% for FERA
Explore IBFC	58% (nearly $100) lower average monthly electricity bills for low-income customers With IBFC, all customers are under the 6% energy burden affordability threshold.	No direct low-income program budget required. Costs for income verification. Higher fixed costs and bills for higher-income customers. Potential for weaker price signals to reduce incentive to conserve, which may incentivize electrification	Referendum or legislative change and rate case with rate redesign	Government entity, citizen, or LADWP initiates, and LADWP's board and city council approve results of rate case.	Change in energy burden by different income bins

[a] Any strategy that requires a rate case with departure from LADWP's BAU rate design is likely to result in cessation of the ≈$220-million annual transfer to the city of Los Angeles, which in turn would reduce customer rates.

[b] For example, see Hiner & Partners "Residential Rate OIR Customer Survey Key Findings," April 16, 2013, available in Appendix A.1 of Pacific Gas and Electric Company's 2013 rate design proposal (Christopher Warner and Gail L. Slocum 2013).

[c] Under BAU, customers save on average $5.78/month (7.5% of their monthly bill) with approximately 150,000 participating customers in 2035 for a total program cost of $10 million (0.3% of revenue requirement). Under CARE/FERA and renter's discount programs, customers save on average $14–$55/month (10%–33% of their monthly bill), depending on the program; a total of approximately 520,000 customers participate across all programs, and the total program cost ranges from $310 million to $340 million (9.5%–10% of revenue requirement).

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Appendix A. Low-Income Bill Equity and Affordability Detailed Methodology

A.1 Basic Model Inputs

The Customer Affordability, Incentives, and Rates Optimization (CAIRO) tool developed by the National Renewable Energy Laboratory (NREL) and used for this analysis leverages data inputs for customer loads and demographics, utility revenue requirement, hourly system marginal costs, and information on tariff design to estimate how retail tariffs and associated energy bills and burdens will evolve under different scenarios. These data include:

- **Customer Loads:** Hourly load profiles for electricity and natural gas consumption generated for 50,000 representative Los Angeles households using the ResStock model (see Chapters 6 and 7) are used in the model to calculate customer bills based on modeled tariff design and rates. Solar generation is assigned to single-family homes based on historical income-differentiated household adoption patterns and maximum aggregate solar penetration.
- **Customer Metadata:** Demographic metadata associated with each representative customer are used to determine energy burden (e.g., income estimates), eligibility for certain rates and/or bill assistance programs (e.g., income estimates, renter or owner occupancy status, and location), and to analyze trends across customer types.
- **Revenue Requirement:** Revenue targets are used within the optimization process to set rate values by adjusting rates until the target revenue for the utility is reached. Revenue targets are provided, exogenously, by the Los Angeles Department of Water and Power (LADWP).
- **Hourly System Marginal Costs:** Marginal costs are used to inform the development of rates based on recommended rate-making principles and guidance from the California Public Utilities Commission (CPUC), as well as the development of income-based fixed charges (IBFC) for low-income strategies.
- **Customer Mapping:** The CAIRO model requires the user to indicate how information such as load profiles and retail tariffs should be mapped to prototypical customers. These model mapping files connect building and customer data in the prototypes to key model inputs.
- **User-Determined Tariff Guidance:** The model requires the user to distinguish between fixed and variable tariff elements, with the former being held constant across a given scenario and the latter being adjusted to meet the revenue requirement.[26] For variable tariff elements, the user also supplies the bounds within which the model can explore.

A.2 Customer Loads and Metadata

For this analysis, 50,000 8760 hourly energy use (electricity and natural gas) profiles were generated from ResStock using a combination of 100 housing characteristics to form a representative sample of prototypical LADWP residential customers. Each prototypical customer was associated with a weight capturing how prevalent the customer "type" was in LADWP's territory. This weight was used to scale the prototypical customers to represent hourly energy usage and associated bills for LADWP's more than 1.57 million estimated residential customers

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[26] An example of fixed tariff elements includes the number and associated consumption limits of each rate tier. An example of variable elements includes the charge ($/kWh) associated with each rate tier.

in 2035. In addition to generating energy use profiles, the ResStock model associates metadata with each prototypical customer, including information such as housing tenure, vintage, number of occupants, household income estimates, and climate zone. These metadata were used to determine eligibility for low-income bill assistance programs such as California Alternate Rates for Energy (CARE), Family Electric Rate Assistance (FERA), and EZ-SAVE; produce estimates for energy burden and net energy return (NER) metrics; and organize results along different defining characteristics (e.g., multifamily homes versus single-family homes and low-income families versus high-income families). Detailed income assumptions based on 2019 American Community Survey data were used for each prototypical customer in 2019$ for 2019. These income levels were assumed to stay constant in real dollar values (i.e., income grew at the pace of inflation such that real wages remained constant), and they were converted to 2021$ before determining eligibility criteria for bill assistance programs or for calculating energy burden. For additional information on how these demand profiles were generated, see Chapter 6.

Weather Differences for 2012, 2019, and 2035

Weather is an essential element of residential building energy usage, as more than half of energy use in average U.S. residential buildings is due to space heating and cooling (U.S. Energy Information Administration 2022). We used weather forecasted in 2035 by weighting 2012 actual meteorological year (AMY) weather data using the methodology described in Chapter 3 of the LA100 study (Hale et al. 2021). In contrast, the rate analysis used 2019 AMY to calibrate the rate models and align modeled customer demand with actual customer demand for LADWP.

We compared 2012 and 2019 AMY weather files to estimate the potential impacts on residential building loads. Using 2012 AMY as a substitute for 2019 weather year increases cooling demand by about 4.7% and increases heating demand by 8.8% for most LA households (i.e., households in Climate Zone 9). Therefore, using 2012 AMY results in a slight overestimation of residential building loads.

A.3 Revenue Requirements

LADWP supplied actual and projected revenue targets by customer class for historical and future years (LADWP uses a fiscal year that runs from July 1 to June 30). For future years, these revenue targets were based on results of LADWP’s Strategic Long-Term Resource Plan (SLTRP). The model and results relied on two SLTRP scenarios:

- California Senate Bill 100 (SB 100) assumes LADWP reaches 100% clean energy by 2045 and 80% clean energy by 2035.
- Case 1 assumes LADWP reaches 100% clean energy by 2035.

The residential revenue requirement for the fiscal year ending June 30, 2019, was $1.369 billion. The SLTRP SB 100 scenario projects a residential sector revenue requirement of $3.341 billion and SLTRP Case 1 projects $4.552 billion for 2035 (all in nominal dollar-year terms). These revenue requirement projections were developed by LADWP in March 2023.[27]

The revenue requirement is the main driver of rate and bill increases in this analysis. Validating LADWP's revenue requirement forecasts was not in NREL's scope of work. If LADWP's revenue requirement overstates or understates required LADWP costs, then the rates identified in this report will be higher or lower than what is needed to achieve compliance.

Certain customer-level activities have the potential to reduce costs to LADWP, in turn reducing the revenue requirement. In our analysis, these activities include energy efficiency and conservation from the on-bill tariff program, and on-site solar generation that offsets customer loads. These activities lead to "avoided costs" to LADWP, which we do not separately quantify. While LADWP's revenue requirement forecasts do incorporate certain on-site solar-related avoided costs, we do not validate these projections against the solar penetration levels in the rates analysis, which were informed by LA100 study estimates.

Note: Results for select rate scenarios under the SB 100 revenue requirement are available in Appendix D. These results provide an indication for the sensitivity of the analysis' results to assumptions around revenue requirements.

Hourly Marginal Costs

LADWP-specific marginal cost projections were unavailable to NREL, which results in a significant shortcoming of this analysis. As an alternative, we relied on the CPUC's Avoided Cost Calculator's (ACC's) annual hourly marginal costs for the Southern California Edison (SCE) service territory that surrounds the LADWP territory (California Public Utilities Commission 2022a). LADWP's marginal costs are likely different from SCE's marginal costs. Therefore, use of the SCE ACC for LADWP likely result in certain misrepresentations. For example, inaccurate intra-daily supply cost patterns and inaccurate total residual costs (total revenue requirement minus marginal costs) potentially distort metrics associated with IBFC. The marginal cost data are also required for calculation of the TOU rates and the IBFC. For SB 100, we used the SCE marginal costs in 2035 because the utility must also comply with SB 100. For Case 1, we use SCE's marginals costs in 2045, when the utility is expected to meet the 100% clean energy requirement,[28] and adjust dollar values from 2045$ to 2035$. This allows us to keep the marginal cost patterns consistent with 100% clean energy compliance while eliminating the 2% rate of annual inflation incorporated by the ACC. There are several climate zones within SCE that are present in the ACC. This model "blends" 8760 hourly marginal cost estimates for the four climate zones that overlap LADWP and SCE territories (6, 8, 9, and 16) to arrive at a

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[27] Bill and burden results in this analysis are extremely sensitive to assumptions around the revenue requirements for future years. The estimated revenue requirements used for this analysis were taken exogenously from LADWP and there was no opportunity to independently verify or confirm these estimates. As part of its planning exercises, LADWP will be constantly adjusting these estimates, and in future years the revenue requirements may ultimately be significantly higher or lower than what was used here. Regardless, the authors believe that the general directionality of the results will remain, even under different assumptions for revenue requirements.

[28] In 2045 the ACC assumes SCE meets a certain portion of the 100% clean energy requirement through use of "greenhouse gas adders" or offsets.

single set of LADWP-representative hourly marginal costs. Hourly load by each zone is used to weight the corresponding marginal cost estimates and then averaged.

A.4 Customer Mapping

Prototypical LADWP customers from ResStock were mapped to additional data as needed to inform the modeling exercise. This included:

- **Tiered Rate Zones:** Customers were mapped to either Climate Zone 1 or Zone 2 based on geospatial data supplied by LADWP. This is consistent with LADWP's current rate structures, which set higher consumption limits for customers in Zone 2 for the tiered rates (R1-A) to accommodate higher loads due to hotter climate conditions. These zones were also used when allocating tier consumption levels under the tiered rate structure, based on guidance from the CPUC. Zones were not relevant for time-of-use (TOU) rates.
- **Tariffs:** Customers were mapped to tariffs based on the modeling scenario and unique customer attributes. For most model runs A, B, C, E, F, G, H, L, and M, all customers within a given model run shared the same residential retail tariff structure (although the tariffs differed across model runs).[29] Model runs A, B, E, and N relied on tiered rates aligned with LADWP's current residential tariffs. Model runs C, F, G, H, and L relied on simplified tiered rates matching CPUC guidance. For model runs D, I, J, K, and M, however, customers were assigned to *either* TOU rates (if eligible) *or* tiered rates based on assumed customer income and monthly demand, in line with CPUC guidance to investor-owned utilities (IOUs) and resulting in approximately 73% of residential customers assigned to TOU rates and 27% on inclining block rates. For model runs with TOU rates, the same inclining block energy charge rates were used from scenarios where all customers were assigned inclining block rates. In other words, the TOU energy charges were optimized in isolation to recover the remaining revenue requirement after revenues from customers on the already-optimized inclining block rates had been removed.
- **Loads:** Customers were mapped to specific load profiles by a combination of weather, climate, occupancy, behavioral patterns, and technology adoption. While most of these variables were held constant across all model runs, for certain runs (e.g., on-bill tariff), different technology adoption patterns were implemented to measure the impact of energy efficiency and electrification measures on affordability. Specifically, customer loads were decreased or increased in certain hours consistent with the use patterns for the relevant efficiency or electrification technology or technologies. In addition, certain ResStock building load profiles were adjusted to incorporate generation from rooftop solar systems on single-family homes. Solar was randomly assigned to single-family homeowners based on the adopter household income distribution and total aggregate solar generation targets. Maximum solar generation for each household was based on load and Distributed Generation Market Demand (dGen) data for developable rooftop space and system capacity factor.

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[29] See Section 1 for a list of the models.

A.5 User-Defined Tariff Inputs

In addition to the above input data, the model requires the user to identify tariff design constraints for fixed and variable elements of the optimization. Fixed tariff elements are inputs not eligible for adjustment by the optimization. Variable elements serve as bounds for values within which the model can select when running through the optimization process. Generally, only volumetric energy charges were allowed to be optimized within the model to meet (1) forecasted revenue collected through specific rate components from LADWP or (2) guidance for the California IOUs from the CPUC.

Fixed charges, minimum bills, and demand charges (if applicable) were not considered optimizable within the model, because either (1) the CPUC discouraged their use, (2) they were calculated based on fixed values (e.g., residual costs and number of customers), or (3) LADWP forecasts indicated these values would not change by 2035. The timing of TOU periods and the consumption levels associated with tiered (inclining block rates) were also not considered optimizable. TOU periods were set to reflect the cost of serving load in particular periods, which were considered set by the CPUC within this framework (see Section A.11: Limitations). Tiered consumption levels were either set by CPUC guidance or based on LADWP input; both approaches are oriented toward the concept of "baseline usage," which would not change in response to tariff structures.

A.6 Model Optimization

The model leverages the Bayesian optimization open-source Python package (Fernando Nogueira 2014) to determine the retail rate values needed to achieve revenue sufficiency given information on tariff value bounds and customer consumption, among other constraints. Bayesian optimization is a valuable way to find near-optimal solutions to problems (functions) that may be computationally intensive to sample. The Bayesian optimization process takes the function to be optimized (in this case, the absolute difference between the revenues collected and the revenue requirement) and user-defined bounds for parameters that the model can adjust when sampling (solving) the function. An example of such a bound might be setting the energy charge associated with the lowest tier of consumption to be between $0.05/kWh and $0.25/kWh.

In determining an optimal set of rate values, the model samples (guesses) values between these bounds for the variable parameters. It then applies these rates to the individual customer loads, which are aggregated to reflect which load would receive a particular rate, and it calculates the customer's monthly bills. The model then aggregates the bills across all customers and months (scaling the bills by the appropriate prototype weight) to arrive at a "revenue collected" value, which is compared to the revenue requirement. The model was given 65 guesses to return an optimal solution,[30] defined as one that respects all user-provided bounds and returns a total revenue collected from customers within ±0.1% of the revenue requirement.

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[30] The model (based on the Bayesian optimization package) differentiates an "exploration" phase and an "exploitation" phase, with the former randomly sampling the bounds provided to help map out and diversify the potential solution space and the latter designed to find the best solution.

One exception to this process was the Model A run, which used only known historical LADWP rate values to both serve as a calibration for the model and provide a baseline of evaluation metrics for future years.

A.7 Residential Solar Rooftop PV Assumptions

Incorporating residential customer-sited generation enables estimation of impacts (e.g., affordability, intra-class transfers) that occur from rate design options, solar compensation strategies, and low-income solar strategies.

Aggregate Solar Penetration

This analysis considers three levels of residential solar penetration on single-family home rooftops based on the revenue requirement scenario explored. We exclude consideration of renters and multifamily homes, as these customers were considered more likely to participate in community solar or other alternatives to rooftop solar investments (Chapter 9). Solar penetration levels are based on Chapter 4 of the LA100 report and electricity demand projections based on Chapter 3 of the LA100 report (Jacquelin Cochran and Paul Denholm 2021):

- **2019 Baseline:** Includes 216 MW_{DC} of cumulative single-family rooftop solar photovoltaics (PV), which equates to offsetting about 4% of total annual residential electricity demand in the relevant year.[31]
- **2035 Case 1:** Includes 1,826 MW_{DC} cumulative single-family rooftop solar PV, which equates to offsetting about 26.5% of residential load in the relevant year.[32]
- **2035 SB 100:** Includes 1,118 MW_{DC} cumulative single-family rooftop solar PV, which equates to offsetting about 16.2% of residential load in the relevant year.[33]

Solar Compensation Strategy

For solar compensation, we assume the 2019 baseline and 2035 LADWP business-as-usual (BAU) rate design scenarios use net metering consistent with LADWP's current practice.

For the tiered rate and TOU rate design scenarios, we use net billing informed by CPUC guidance. CPUC issued its net billing order in December 2022 establishing a replacement for net metering compensation that was found to negatively impact nonparticipating ratepayers, disproportionately harming low-income ratepayers, and not cost-effective (California Public Utilities Commission 2022d). After a 5-year glide path (that we ignore given our focus on 2035), net billing retail export compensation will be based on a 576 period of average monthly values for each hour, differentiated by weekend and weekday, and the most recently passed annual

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[31] 216.21 MW_{DC} (in 2020) × 96% inverter efficiency × 20% capacity factor × 8,760 hours per year = 363,648 MWh per year, or about 4% of annual residential demand in the 2020 high electrification SB 100 scenario of 9,129,853 MWh (excluding losses).

[32] 1,826.02 MW_{DC} (in 2035) × 96% inverter efficiency × 20% capacity factor × 8,760 hours per year = 3,071,220 MWh per year, or about 26.5% of annual residential demand in the 2035 early, no biofuels, high electrification scenario of 11,578,692 MWh (excluding losses).

[33] 1,117.74 MW_{DC} (in 2035) × 96% inverter efficiency × 20% capacity factor × 8,760 hours per year = 1,879,949 MWh per year, or about 16.2% of annual residential demand in the 2035 SB 100 high electrification scenario of 11,578,692 MWh (excluding losses).

ACC. The net billing order requires all net billing customers to use a specific form of TOU rates (e.g., excludes baseline credit). For the tiered rate design scenario, we keep all solar customers on tiered rates. For the TOU rate design scenario, all solar customers are switched to a net-billing-compliant TOU rate, even if they are CARE- or FERA-eligible customers.

Solar Adopter Income Distribution

For this analysis, we preserve existing income distributions of residential solar adopters to baseline the analysis and identify impacts of intra-class transfers and low-income solar adoption strategies. We use historical (2010–2021) rooftop solar adopter data for Los Angeles County by AMI bin from Lawrence Berkeley National Laboratory (LBNL) (Sydney Forrester et al. 2022), which are slightly different than the Rooftop Energy Potential of Low Income Communities in America (REPLICA) income bins used in the LA100 Equity Strategies study.[34] The initial distribution for the 2019 baseline is based on the 2019 LBNL adopter income distribution. The 2035 projections use the most recent adopter income distribution from LBNL, for 2021. These distributions are shown in Table A-1. We did not have access to data that would otherwise guide us toward establishing a different adopter income distribution. We did not use the solar adopter income distributions from Chapter 4 of the LA100 study (Jacquelin Cochran and Paul Denholm 2021), as those projections assume strong solar uptake from low-income households—specifically that low-income households adopt solar at equal measures as high-income households and that low-income households have equal access to financing. Here, we take a constrained approach recognizing low-income households may have less disposable income, unequal access to financing, inability to take on additional debt, a time preference for immediate consumption, and other barriers to solar adoption This also led us to adopting a strategy aimed at increasing solar adoption in low- and moderate-income (LMI) households.

Table A-1. Solar Adopter Income Distributions by AMI Bin for 2019 and 2035

	0%–60% AMI	60%–80% AMI	80%–100% AMI	100%–120% AMI	>120% AMI
2019 baseline	16.4%	10.6%	9.8%	10.2%	53%
2035 projections (2021 distribution)	18.6%	11%	10.2%	10.4%	49.9%

Low-Income Solar Adoption Initiative

We model a hypothetical policy aimed at increasing LMI household (defined here as <80% AMI) solar adoption by 20%, while holding aggregate solar penetration constant. We do not specify the policy design, only achieving a 20% increase in LMI solar adoption compared to the 2035 BAU projections (shown in Table A-2). To increase LMI solar adoption and keep total aggregate solar constant, the percentages of adopters in other AMI bins are reduced

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[34] REPLICA income bins: (high >120%, middle 80%–120%, moderate 50%–80%, low 30%–50%, very low 0%–30%); LBNL income bins: (>120%, 100%–120%, 80%–100%, 60%–80%, <60%). ResStock provides estimates for customer prototype incomes (in 2019$), making it possible to calculate into which AMI bin a customer would fall in, regardless of which set of bins is used. The model assumed that both sets of AMI bins relied on the same AMI estimate from the U.S. Department of Housing and Urban Development.

proportionately. A 20% increase in LMI solar adoption boosts the lowest AMI bin (0%–60% AMI) from 18.6% to 22.3%, and the second lowest AMI bin (60%–80%) from 11% to 13.2%.

Table A-2. Solar Adoption Income Distribution for 20% Increase in LMI Household Adoption

	0%–60% AMI	60%–80% AMI	80%–100% AMI	100%–120% AMI	>120% AMI
2035 increase LMI adoption by 20%	22.3%	13.2%	9.3%	9.5%	45.7%

Solar Data and Methods

To calculate customer-sited solar generation, this analysis draws upon certain solar data from dGen, building data from ResStock, and various simplifying assumptions. dGen data on household developable rooftop space per building and system-specific annual average capacity factors were determined for 2035.[35] The specific data were developable rooftop space per building, associated maximum solar system size (MW_{DC}), and system-specific capacity factor. Where multiple dGen agents were represented by the same ResStock agent, the weighted average of mean values was used, based on the number of customers represented by each dGen agent associated with the ResStock agent. The system size was taken to be the smaller of either a “consumption limit” (such that annual PV generation did not exceed annual consumption) or a “rooftop limit” such that the PV system would not exceed the maximum developable rooftop space, while no minimum system size constraints were applied. Annual hourly solar generation for each adopter household was calculated based on the maximum allowable system size,[36] 96% DC-to-AC inverter conversion efficiency, and an hourly capacity factor from dGen that was unique to each census tract. While net energy metering compensated systems would be constrained to be no larger than the annual consumption, net billing systems would not face such a constraint. To simplify comparisons across scenarios, the same system size is deployed for adopting customers regardless of whether they are compensated under net metering or net billing (i.e., at no larger than 100% annual consumption). In practice, the compensation mechanism employed could have a significant impact on the system sizes deployed, the distribution of systems across LADWP’s customer class, and the total capacity deployed, as customers see different value from investing in solar PV.

A.8 Residential Natural Gas Bill Assumptions

Customers are impacted by their overall obligations (e.g., electricity, gas, water, trash, rent/mortgage payments) rather than any individual component in isolation. Given the limitations around accurately forecasting gas or water bills, however, this analysis focuses on electricity bills in particular. For certain low-income strategies (discussed in the next section) it was necessary to estimate both electricity *and* gas bills. For instance, for energy efficiency upgrades that involve the electrification of end uses like heating, capturing the overall bill savings to

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[35] dGen generates data for even-numbered years. To arrive at 2035 values, the average values for 2034 and 2036 were taken as appropriate.

[36] In reality, a customer might choose to site a system that is smaller than the maximum allowable system, either because they are financially constrained from investing in a larger system or because a larger system would provide a poorer return on investment.

customers requires appropriately accounting for the changes of both electricity and gas bills. For these cases, gas bills were calculated using hourly gas consumption as forecasted by ResStock and the latest tariff for SoCal Gas,[37] which serves LADWP customers (see Appendix C). Regardless of the year the model was run, bills were first calculated using the latest available tariff in 2023$, then scaled to account for changes in natural gas prices between 2023 and the model year run (either 2019 or 2035) using the California Energy Commission's "Form 2.3: California Energy Demand 2021–2035 Baseline Forecast for the Mid Demand Case Natural Gas Rates by Sector" for SoCalGas (California Energy Commission 2021).[38] Finally, the bills were adjusted again to update the dollar year into either 2035$ or 2019$ so that they matched the dollar year from the electricity bills (all results presented in this report are converted a final time into 2021$ across all model runs). This analysis, while capturing individual changes to natural gas consumption, does not consider how a larger push for electrification concentrated in higher-income homes could lead to increased natural gas prices for low-income customers. Given the analysis' focus on electricity bills, no sensitivities around natural gas price forecasts were used.

A.9 Equity and Affordability Scenarios and Strategies

The model first determines the best-guess tariff based on the rate design scenario inputs. Then, low-income strategies are applied to customer bills based on criteria (e.g., location and income) mapped to individual customers. The details of the rate design scenarios and low-income assistance strategies are discussed in this section.

Rate Design Scenarios

This section details the specific rate designs or rate design inputs designated for each scenario.

Model A: 2019 LADWP Rates—A Baseline

The 2019 LADWP baseline uses historical rates and serves as a benchmark for comparing evaluation metrics to forecast scenarios. Historical tariff values for calendar year 2019 were used for the 2019 LADWP model run (see Appendix C). The optimization model relied on revenue requirements from LADWP, which for 2019 were provided for the fiscal year of July 1, 2018, to June 30, 2019. A different set of rates was used for the first and second half of the fiscal year.[39] EZ-SAVE discounts were applied to qualifying customer bills, as outlined in the EZ-SAVE section (page 34). Modeled 2019 loads were used when calculating customer bills.

2035 LADWP BAU Forecast

Based on guidance from LADWP and leveraging data from the SLTRP scenarios, the 2035 LADWP BAU case used the same general rate design from calendar year 2019. The only values that were allowed to increase over time to collect additional revenue were incremental

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[37] The applicable SoCalGas tariff Schedule No. GR for Residential Service effective July 10, 2023, is available at https://tariff.socalgas.com/regulatory/tariffs/tm2/pdf/tariffs/GAS_G-SCHEDS_GR.pdf (accessed July 13, 2023), where there is a customer charge of $0.16439 per meter per day, non-baseline rate of $0.177923/therm, and a public purpose charge of $0.06681/therm.

[38] The rates provided in California Energy Commission's Mid Demand Case forecast for SoCalGas rates are given in 2020$, but are converted into a unitless price escalator that results in a forecasted 1.402× increase in natural gas prices for the residential sector in real terms between 2023 and 2035.

[39] 2018 rate values (2018–2019 rates) and 2019 rate values (2019–2020 rates) can be found on LADWP's website: https://rates.ladwp.com/Contentpage.aspx?SubCatID=1040 (accessed 2023).

ordinances, which are volumetric energy charges applied to all residential customer consumption and that vary by season. Based on data provided by LADWP, the model considers four incremental ordinances (i-base, i-itca, i-eca, and i-rca) that are set independently of one another and in 3-month increments. The range for the values was set to approximately recover the anticipated revenues from each incremental ordinance based on data provided by LADWP. Seasonal patterns in the values were based on historical changes in today's incremental ordinances, taken from LADWP rates for 2019–2020.

2035 CPUC Simplified Tiered Rates

Relevant CPUC guidance on tiered rates (or inclining block rates) to the California IOUs is shown in the following list. These directions from the CPUC were incorporated into the model by adjusting the tariff fixed and variable elements to ensure the model's optimal solution for the CPUC tier run would reflect CPUC guidance.

- **Simplified Tiered Residential Rate Structure:** A two-tiered structure with a third super-user tier using an inclining block rate structure was preferred because, for example, the CPUC found customers prefer simple rate structures, customers do not understand structures with more tiers, and a two-tiered structure makes it easier to adjust other rate components to achieve energy efficiency and other policy goals (California Public Utilities Commission 2015, sec. 5.2).
- **Reasonable Tier Differential:** The tier differential is the percentage difference in price between the two tiers. A 10% differential means the price of the second tier is 110% of the first-tier price. The CPUC settled on a 25% differential (California Public Utilities Commission 2015).
- **Baseline Quantities and Usage Amount per Tier:** By law, the baseline quantities must be 50%–60% of the average residential consumption in each geographic area, set for the appropriate climate zone and adjusted for seasonal variation. The CPUC allowed the baseline quantities to be determined in individual rate proceedings of the IOUs (California Public Utilities Commission 2015, sec. 5.5). For LADWP, baseline quantities are differentiated between "zones," with Zone 1's baseline quantity being set at 225 kWh/month and Zone 2's being set at 260 kWh/month, based on a fraction of the average monthly consumption by zone, in line with CPUC guidance. Zone 2 is in a warmer climate, and the higher baseline quantity reflects the additional cooling energy required in this zone to ensure the same comfort levels under Zone 1's baseline quantity.
- **Seasonal Rates:** The CPUC initially indicated that tiered rates should include seasonal components to reflect differences in costs across the year (California Public Utilities Commission 2015, sec. 5.6). However, CPUC Decision 19-07-004 subsequently found seasonally differentiated tiered rates not to be in the public interest, and they were therefore excluded from this scenario.
- **Super-User Electric Surcharge:** To send price signals to high-usage customers who would otherwise benefit from tier consolidation, the CPUC required implementation of a super-user electric surcharge on customers with usage over 400% of the baseline. The differential between the Tier 1 price and the super-user electric surcharge was targeted at 119%. This surcharge was modeled after the CARE program, which notifies high-usage customers of the

need to reduce usage to remain on the assistance program (California Public Utilities Commission 2015, sec. 5.7).

- **Minimum Bill:** The CPUC rejected new or increased fixed charges proposed by the IOUs and instead allowed the alternative of a minimum bill. Doing so allowed all customers, even those with little or no usage, to contribute to fixed cost recovery. The minimum bill would only apply to customers below baseline tier usage. The minimum bill amount was set at $10/month for non-CARE customers and $5/month for CARE customers (California Public Utilities Commission 2015, sec. 7.6).
- **Discount Programs:** Assembly Bill 327 required the average effective CARE program per-unit rate discount to be between 30% and 35%. The CPUC settled on a 12% discount for all FERA customers,[40] who include LMI customers with larger households (California Public Utilities Commission 2015, sec. 8).

2035 CPUC Default TOU Rates

We modeled this scenario even though LADWP does not currently have the smart meter infrastructure required to implement default TOU rates. The default TOU rate design is informed by CPUC's Phase 2B TOU order for SCE (California Public Utilities Commission 2019), which generally followed the CPUC's 2017 policy guidelines applicable to TOU rate design and implementation (California Public Utilities Commission 2017). We assumed by 2035, default TOU implementation was fully implemented and no longer in the TOU-lite or glide path phase-in period. Per the 2019 CPUC order, CARE/FERA-eligible and/or enrolled customers in hot climate zones, medical baseline, and certain other customers are not to be defaulted into TOU rates and therefore remain on the tiered rate plan.

- **Peak Periods:** We used SCE's 4–9 p.m. peak period, as it matches better with LADWP's system than the 5–8 p.m. peak period option. These periods define times when system costs are higher (peak) and lower (super off-peak), so system cost-reflective rates can be developed.
- **Rate Period Price Ratios:** The ratios determine how costs should escalate between the base (lowest cost) period and higher cost periods. Table A-3 shows the rate period ratios used to develop the TOU prices.
- **Seasonal Rate Differential:** The TOU rate includes a $0.01/kWh differential between summer and winter seasons within the TOU rate period ratios (we assumed this is $0.01 higher for the summer off-peak period than the winter super off-peak period). Summer is June through September and winter is October through May.
- **Minimum Charge:** For default TOU rates, the CPUC did not allow for new or increased fixed charges but permitted inflation adjustments to minimum bills (California Public Utilities Commission 2020). For SCE, the minimum charge applies when the delivery service charges plus the applicable basic charge are less than the minimum charge. We did not model SCE's grandfathered basic charge, and we used a bundled generation and delivery charge as we did not break down the split between generation, transmission, and delivery costs or

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[40] It was subsequently raised to an 18% discount, effective January 2019.

charges in our optimization model. This modification likely results in under-application of minimum charges. A minimum daily charge of approximately $0.346/day or about $10/month was taken from SCE's residential TOU-D schedule effective January 1, 2023 (Southern California Edison 2023).

- **Baseline Credit:** A baseline credit was provided as a consumer protection mechanism. This is a credit for each kilowatt-hour of baseline energy usage and is applied against TOU rate charges. We used the credit of $0.09759/kWh that was in place for SCE in January 2023 (Southern California Edison 2023). Baseline energy usage is defined in the SCE tariff by region (e.g., 17 kWh/day in Region 5 during the summer) and applied to LADWP customer TOU bills. For example, assume a 31-day month of July in Region 5 using 800 kWh. First calculate the bill using the TOU rate schedule. Then subtract $51.44 (31 days × 17 kWh/day × $0.0976/kWh) for the monthly baseline credit from the total TOU rate charges.

The model leverages hourly marginal cost data for SCE's territory in the CPUC ACC to develop TOU rates in line with CPUC guidance on default TOU rate design. The CAIRO model currently does not attempt to calculate how TOU rates impact consumer usage, a shortcoming we discuss in Section A.11: Limitations.

Table A-3. Periods and Period Ratios Used for TOU Rate Prices

Rate Type	Period		Period Ratios
Energy charge ($/kWh)	Summer on-peak	(4–9 p.m., weekdays)	1.6
	Summer mid-peak	(4–9 p.m., weekends)	1.3
	Summer off-peak	(all other hours)	1.0
	Winter mid-peak	(4–9 p.m., all days)	1.45
	Winter off-peak	(9 p.m.–8 a.m., all days)	1.1
	Winter super off-peak	(8 a.m.–4 p.m., all days)	1.0

Low-Income Assistance Strategies

This section describes the details of the various low-income assistance strategies modeled, including the EZ-SAVE and Lifeline programs, CARE and FERA programs and associated renter's discount program, IBFC, and the on-bill tariff program.

LADWP EZ-SAVE and Lifeline Programs

LADWP's EZ-SAVE program offers qualifying low-income customers a fixed discount on their bills. Table A-4 shows the household income eligibility requirements for EZ-SAVE assumed in the model. These values are based on 2022 eligibility requirements, whereas the prototypical customer household income levels provided by ResStock were provided in 2019 $ values for 2019. The same eligibility requirements were used for model runs based in 2019 and in 2035 assuming both eligibility requirements and incomes would increase at the same rate.

Table A-4. Household Income Requirements for LADWP's EZ-SAVE

Members in Household	Maximum Annual Gross Income
1	$36,620
2	$36,620
3	$46,060
4	$55,500
5	$64,940
6	$74,380
7	$83,820
8	$93,260
Each additional member	+$9,440

Source: LADWP (2023)

Discounts under EZ-SAVE for 2019 were determined to be $8.17/month (nominal) for qualifying customers.[41] Monthly discounts under EZ-SAVE were assumed to be fixed in nominal terms, as the rider that funds EZ-SAVE has reached its maximum threshold. In the absence of a new or modified funding source, we assumed (1) the total budget available for EZ-SAVE does not grow to account for inflation or increased energy charges, and (2) the corresponding real discount that low-income customers receive decreases over time, arriving at $5.78/month in 2035 (in 2021$).

The model uses census-level program enrollment data provided by LADWP to model the EZ-SAVE program. A systemwide "participation target" (calculated as the total number of EZ-SAVE participating customers divided by the total number of residential customers within LADWP in 2019) was established based on average EZ-SAVE enrollment rates between 2016 and 2019 and assuming 1,349,209 total residential customers (Table A-5). The resultant average enrollment rate across this period was 9.2993%, which is used for 2035 (but applied to the estimated 1.57 million customers anticipated in 2035), and the actual EZ-SAVE enrollment rate of 7.1572% was used for 2019. LADWP's "Energy Subsidy Adjustment" (ESA) funds the EZ-SAVE, Lifeline, and other smaller assistance programs. ESA revenues ranged from $35 million to $36 million between 2016 and 2019, with about 74% of ESA revenues collected from LADWP's commercial class and 26% collected from the residential class.[42] For this analysis, we assume an $8.17/month subsidy (nominal, established in 2009) and hold this nominal value constant (i.e., unadjusted) through 2035.[43] As a simplifying assumption, to avoid the

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[41] As of June 2023, in the "LL/LI" residential rate tariff, LADWP's website advertised an EZ-SAVE subsidy of $16.34 every 2 months. Although some LADWP customers in 2019 were eligible to apply their water discounts toward their electricity bills, if they did not pay their water bills, the discounts were not incorporated in the model, and they were discontinued in 2019.

[42] LADWP provided these program enrollment and ESA revenue data directly to NREL.

[43] See the LADWP Electric Rate Ordinance established on July 1, 2008, where the Residential R-1 Rate D Low Income Service discount of $8.17/month was established effective July 1, 2009: https://www.ladwp.com/cs/idcplg?IdcService=GET_FILE&dDocName=OPLADWP009439&RevisionSelectionMethod=LatestReleased (accessed June 29, 2023).

complexities of modeling inter-class cross-subsidization, we collect all revenues required to support EZ-SAVE expenses from the residential class.

Table A-5. Bill Subsidy Program Enrollment Data

Fiscal Year End	EZ-SAVE Enrollment	Lifeline Enrollment
2016	153,273	93,432
2017	135,173	95,644
2018	116,858	96,902
2019	96,566	98,300

To better capture geographic patterns in participation, the model uses historical participation rates by census tract for 2016 and scales those rates to ensure the total participation target is reached. Doing so ensures the model accurately captures the magnitude and spread of EZ-SAVE participation.

EZ-SAVE discounts were applied after the tariff values had been set by the model in the optimization process and the customer bills had been calculated. Eligible customers (based on household income) were selected to receive the monthly discounts (based on participation rates), which were subtracted from their bills. The model funds the program through a time-invariant volumetric energy charge (i.e., a nonvarying rate in $/kWh) that is applied to all *non*participating customers' consumption. Total discounts for participating customers were aggregated throughout the year to arrive at a program cost, and it was divided by aggregated annual nonparticipating load to arrive at the energy charge, which was then applied to each nonparticipating customer's bills based on consumption within each billing cycle.

The Lifeline program is available to LADWP customers who are either senior citizens or disabled citizens and have a combined adjusted gross income of all household members of less than $47,650 (in the past calendar year, 2023$). The Lifeline program offers a combination of a nominal $17.71/month subsidy[44] plus an exemption from paying the 10% utility user tax. The direct subsidy is funded by LADWP residential and commercial customers, and the municipality foregoes collection of the tax revenues. The municipality processes applications for program qualification and enrollment.[45] We use the actual Lifeline 2019 enrollment rate of 7.2858% for Model Run A (baseline 2019) and the average enrollment rate from the 4 years of data in Table A-5 (i.e., 7.1204%) for Model Run B (2035 LADWP BAU). We randomly assign eligible customers to the Lifeline program based on historic census-tract-level patterns of enrollment until we reach the target level. In the limited instances where the Lifeline program reduces a monthly bill below $10/month, the $10/month minimum bill is instead charged. We recover

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[44] See the LADWP Electric Rate Ordinance established on July 1, 2008, where the Residential R-1 Rate E Lifeline Service discount of $17.17/month was established effective July 1, 2009: https://www.ladwp.com/cs/idcplg?IdcService=GET_FILE&dDocName=OPLADWP009439&RevisionSelectionMethod=LatestReleased (accessed June 29, 2023)

[45] An example of the Lifeline program application is available at https://finance.lacity.gov/sites/g/files/wph1721/files/2023-04/Lifeline%20Application%20English%20revised%20040623.pdf (accessed June 26, 2023).

Lifeline program expenses outside of the residential revenue requirement through a post-processing step. In practice, the majority of EZ-SAVE and Lifeline expenses are recovered from LADWP's commercial class. For simplicity, and given the approximate program budgets, we recover EZ-SAVE program costs through the residential revenue requirement and Lifeline program costs through a theoretical commercial class that is not financially accounted for in our model. This results in incremental improvements to affordability metrics from the Lifeline program without factoring in incremental additional required revenues.

CARE and FERA Low-Income Assistance Programs

Under the CARE program, the CPUC requires California IOUs and electrical corporations with 100,000 or more customer accounts to offer eligible and enrolled customers a 30%–35% discount on electric bills and a 20% discount on natural gas bills. Eligibility is based on total household income, scaled for persons per household.[46] The CPUC also requires the three large IOUs (SCE, San Diego Gas & Electric, and Pacific Gas and Electric Company) to offer 18% discounts through the FERA program to families whose household incomes are slightly higher than the CARE limits but less than 250% of the federal poverty guideline.[47]

The model applies 32.5% CARE and 18% FERA discounts to eligible participating customers. Customer participation is established in a similar fashion as with EZ-SAVE with three modifications:

- "Participation targets" for CARE and FERA are based on the average annual IOU-wide participation targets for California's IOUs for the pre-COVID-19 pandemic period of 2017–2019 (see Table A-6), which result in average targets of 89.4% for CARE and 14.6% for FERA.
- The geographic distribution of CARE and FERA participation by census tract is held to be approximately the same as the geographic distribution of participation for EZ-SAVE by census tract while observing the above overall targets.
- "Participation targets" are calculated as "participating customers" divided by "eligible customers" instead of "total residential customers."

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[46] For more information on household income and eligibility criteria, see https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-costs/care-fera-program (accessed Jan. 6, 2023).

[47] Several other programs—including but not limited to the Energy Savings Assistance Program—provide no-cost weatherization services to CARE-eligible customers, utility company emergency assistance programs, and medical baseline programs. These are in addition to federally funded programs such as California's Low-Income Weatherization Program and the federal Low-Income Home Energy Assistance Program. For the purposes of our analysis, we will limit modeling to programs structured like the CARE and FERA programs implemented by the IOUs.

Table A-6. CARE and FERA Participation Rates, Counts, and Budgets by IOU and Year

		SCE				**San Diego Gas & Electric**				**Pacific Gas and Electric Company**			
Program	**Year**	**Enrolled (% of eligible)**	**Subsidy Expense (millions)[a]**	**Participants Enrolled**	**Subsidy per Participant**	**Enrolled (% of eligible)**	**Subsidy Expense (millions)***	**Participants Enrolled**	**Subsidy per Participant**	**Enrolled (% of eligible)**	**Subsidy Expense (millions)***	**Participants Enrolled**	**Subsidy per Participant**
CARE	2017	84%	$458	1,222,526	$375	85%	$114	281,274	$405	89%	$644	1,406,396	$458
	2018	85%	$376	1,205,539	$312	92%	$126	297,103	$425	90%	$611	1,376,003	$444
	2019	89%	$365	1,185,146	$308	95%	$118	301,810	$391	96%	$639	1,382,663	$462
FERA	2017	9%	$5	19,184	$276	18%	$1	7,853	$164	17%	$6	29,072	$218
	2018	9%	$3	19,344	$160	17%	$1	8,229	$175	15%	$5	25,257	$208
	2019	9%	$9	19,734	$454	25%	$2	9,577	$234	13%	$7	21,815	$314

[a] Subsidy expense is limited to the direct subsidy to participants and does not include programmatic or administrative expenses that are a much smaller portion of total CARE and FERA implementation costs. Sources: For CARE programs in the applicable years 2017, 2018, and 2019 for SCE, [48,49,50] San Diego Gas & Electric,[51,52,53] and Pacific Gas and Electric Company.[54,55,56] For FERA programs in the applicable years 2017, 2018, and 2019 for SCE, [14,17,20] San Diego Gas & Electric, [57,58,59] and Pacific Gas and Electric Company[60,61,62]

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[48] Southern California Edison Company's 2018 Annual Report for 2017 Low Income Programs, filed with CPUC May 1, 2018, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M220/K593/220593857.PDF

[49] Southern California Edison Company's 2019 Annual Report for 2018 Low Income Programs, filed with the CPUC May 1, 2019, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M290/K365/290365295.PDF

[50] Southern California Edison Company's 2020 Annual Report for 2019 Low Income Programs, filed with the CPUC May 1, 2020, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M335/K511/335511400.PDF

[51] Annual Report Activity of San Diego Gas and Electric Company on Low-Income Assistance Programs for 2017, filed with the CPUC May 1, 2018, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M220/K564/220564108.PDF

[52] Annual Report Activity of San Diego Gas and Electric Company on Low-Income Assistance Programs for 2018, filed with the CPUC May 1, 2019, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M292/K932/292932678.PDF

[53] Annual Report Activity of San Diego Gas and Electric Company on Low-Income Assistance Programs for 2019, filed with the CPUC May 1, 2020, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M335/K511/335511405.PDF

[54] Annual Report of Pacific Gas and Electric Company on the Results of its Energy Savings Assistance and California Alternate Rates for Energy Programs, filed with the CPUC May 1, 2018, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M220/K116/220116913.PDF

[55] Annual Report of Pacific Gas and Electric Company on the Results of its Energy Savings Assistance and California Alternate Rates for Energy Programs, filed with the CPUC on May 1, 2019, https://liob.cpuc.ca.gov/wp-content/uploads/sites/14/2020/12/PGE-2019-PY2018-ESA-CARE-Annual-Report.pdf

[56] Annual Report of Pacific Gas and Electric Company on the Results of its Energy Savings Assistance and California Alternate Rates for Energy Programs, filed with the CPUC May 1, 2020, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M335/K526/335526334.PDF

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[57] Annual Report for Family Electric Rate Assistance (FERA) Program of San Diego Gas and Electric Company for Program Year 2017, filed with the CPUC May 1, 2018, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M220/K755/220755069.PDF

[58] Annual Report for Family Electric Rate Assistance (FERA) Program of San Diego Gas and Electric Company for Program Year 2018, filed with the CPUC May 1, 2019, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M292/K289/292289096.PDF

[59] Annual Report for Family Electric Rate Assistance (FERA) Program of San Diego Gas and Electric Company for Program Year 2019, filed with the CPUC May 1, 2020, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M335/K710/335710570.PDF

[60] Annual Progress Report of Pacific Gas and Electric Company of the Family Energy Rate Assistance (FERA) Program, 2017, filed with the CPUC May 1, 2018, located at https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M219/K473/219473976.PDF

[61] Annual Progress Report of Pacific Gas and Electric Company of the Family Energy Rate Assistance (FERA) Program, 2018, filed with the CPUC May 1, 2019, located at https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M309/K591/309591690.PDF

[62] Annual Progress Report of Pacific Gas and Electric Company of the Family Energy Rate Assistance (FERA) Program, 2019, filed with the CPUC May 1, 2020, located at https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M335/K832/335832720.PDF

Similar to the EZ-SAVE program, within the model, the bills are first calculated for all customers using the model-determined retail tariff values. Then, eligible and participating customers receive the CARE and FERA discounts. The total program costs for CARE and FERA are calculated to be the total discounts received over the year of analysis. The program costs are recovered through a time-invariant volumetric energy charge ($/kWh) applied to all nonparticipating load.[63] The final bills are the initial bills minus discounts and plus program costs applied to participating and nonparticipating customers as appropriate.

CARE and FERA Renters Discount Program

This strategy aims to provide targeted discounts to income-qualified households that are renters and may not qualify for CARE and FERA programs because they are not submetered. In the absence of submeters, LADWP cannot confirm the household is an actual LADWP customer and cannot understand the household's energy usage. The NREL load data set from ResStock does not include information on which percentage of renters are submetered. We therefore conservatively assume all renters are not submetered and therefore are not qualified for the CARE and FERA programs. Instead, we offer renters that meet the CARE and FERA income qualifications a flat monthly discount based on the average dollar value of the CARE or FERA program, minus a small reduction. The value reduction applied given monthly energy usage cannot be verified. We assume $24.77/month for CARE and $14.15/month for FERA in 2021$. The renters program would require a verification process, perhaps involving landlord validation, to confirm the household receiving the monthly discount is living in a building that is an LADWP-metered customer. Models indicate participation in the CARE renters program to be high and in line with participation for CARE (>85%), but FERA renters program participation is low due to the limited number of households that meet the qualification criteria. The results of the renters program are integrated into the larger CARE and FERA program model results.

Income-Based Fixed Charges (IBFC)

Concurrent with this study, the CPUC is actively deliberating implementation of IBFC for California IOUs. This effort was enabled by the passage of California Assembly Bill 205 in June 2022, which, among other things, allows for fixed charges to be established on an income-graduated basis.[64] The CPUC began exploring income-graduated fixed charges with its July 2022 rulemaking that included fixed charge reforms (California Public Utilities Commission 2022b). In November 2022, the CPUC instituted a separate track of the rulemaking, dedicated to income-graduated fixed charges, and it is actively deliberating design principles (California Public Utilities Commission 2022c). Given the active nature of the CPUC's deliberations, this study could not rely on CPUC regulatory guidance to inform IBFC design. Rather, this strategy is modeled after Borenstein, Fowlie, and Sallee's recommendation for California IOUs (Severin Borenstein, Meredith Fowlie, and James Sallee 2022). A complete discussion of the benefits and drawbacks of IBFC is beyond the scope of this report, but they can be explored in the relevant

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[63] California IOUs recover costs for the CARE and FERA programs from all noneligible customers, including customers from other classes (e.g., commercial, industrial).

[64] Assembly Bill No. 205, Legislature Information, https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220AB205, accessed April 19, 2023.

CPUC proceeding.[65] In general, proponents argue the high residual costs of many California utilities are more equitably recovered through income-sensitive methods. Opponents argue IBFC may distort marginal cost price signals to consumers with negative implications for distributed resources such as energy efficiency and will increase costs to high-income customers.

For our IBFC model, all customers are charged such that the marginal system costs are recovered based on customer usage and the applicable rate design (e.g., tiered, TOU). All residual costs (i.e., revenue requirement minus total marginal system costs) are charged to customers based on an income-scaled fixed rate. IBFC could only be explored under CPUC guidance rates, where economic and residual costs could be calculated and separately apportioned. In other words, IBFC could not be added to the existing LADWP rate design without fundamentally altering the existing LADWP approach to rates.

Marginal system costs are derived from CPUC's ACC for SCE's territory for 2035 (SB 100) or for 2045 adjusted to 2035 $ (Case 1). The hourly total levelized marginal cost[66] was preserved for every climate zone in both LADWP's and SCE's territory (California Energy Commission Climate Zones 6, 8, 9, and 16). Hourly load data were then aggregated by hour and climate zone and scaled to provide an hourly estimate of all residential load in each hour of 2035. This hourly climate-zone-specific load was then multiplied by the appropriate hourly marginal cost estimate and aggregated across all hours and climate zones to provide an estimate of the marginal systems cost for usage for all of LADWP's residential customers. Using the same guidance as provided for the CPUC tiered and TOU rates, this new marginal system cost was set to be the new revenue requirement, and the model optimized the energy charges to recover the marginal system costs.

To set the IBFC to recover the residual cost, customers were binned into fractions of the AMI (0%–30%, 30%–50%, 50%–80%, 80%–120%, and 120% and above). Based on the approach in Borenstein, Fowlie, and Sallee (2022), the IBFC were set so that the lowest bin paid no fixed charge, the second lowest bin paid a fixed charge of "X" per month, the third lowest paid a fixed charge of 1.23 × X per month, the fourth lowest a charge of 1.66 × X, and the highest bin a charge of 2.8 × X.[67] For Case 1, these resulted in the fixed charges in Table A-7.

Table A-7. Modeled Monthly IBFC Results for Case 1

AMI Bin	1 (0%–30% AMI)	2 (30%–50% AMI)	3 (50%–80% AMI)	4 (80%–120% AMI)	5 (>120% AMI)
IBFC $/month (2035$)	$0.00	$127	$156	$211	$355

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[65] Income-graduated fixed charges (a form of IBFC) are explored in Track A of the CPUC's Demand Flexibility Rulemaking (R.22-07-005). More information, including a link to the docket, can be found at https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-costs/demand-response-dr/demand-flexibility-rulemaking (accessed May 18, 2023)

[66] Assuming a 10-year levelized period and a weighted average cost of capital of 7.52%, the default in the ACC.

[67] In Borenstein, Fowlie, and Sallee (2022), these relative values were set to achieve a distribution of burdens across the richest four quintiles that is equal to the burden of raising the revenue through the sales tax.

AMI Bin	1 (0%–30% AMI)	2 (30%–50% AMI)	3 (50%–80% AMI)	4 (80%–120% AMI)	5 (>120% AMI)
IBFC $/month (2021$)	$0.00	$90	$110	$149	$251

Although these fixed charges are higher for all but the first quintile, some higher fixed costs are offset by a reduction in energy rates. For example, marginal cost-based rates are not upwardly adjusted to recover residual costs, as residual costs are solely recovered through fixed charges. The joint proposal for income-graduated fixed charge design submitted to the CPUC by California IOUs in April 2023 included just four household income brackets, with the lowest-income bracket (household income up to 100% of the federal poverty level) receiving "extra discounted" fixed charges but not zero fixed charges (Joint IOUs 2023).

On-Bill Tariff for Energy Efficiency Deployment

Low-income households often do not have the luxury of investing in energy efficiency measures due to lack of homeownership, discretionary income, and up-front costs. Under an on-bill tariff energy efficiency program, the utility or another third party deploys energy efficiency measures and appliances with reduced or no up-front costs and recovers the costs of those deployments by applying a rider (i.e., extra charge) on participating customer bills. Though on-bill tariff cannot address all the barriers to low-income energy efficiency adoption, it is one avenue jurisdictions are exploring for equitable efficiency programs. On-bill tariff is different from traditional on-bill financing because it is not considered debt to the customer.

As a customer protection measure, on-bill monthly riders are calculated to be less than the expected monthly savings from the efficiency measures/appliances deployed (for both electricity and gas bills; see above methodology for discussion on gas bill estimations), and the payments are designed to last less than the anticipated lifetime of the appliance. Therefore, the customer is expected to benefit from a slightly reduced bill and financing-based access to the new appliance or measure. On-bill tariff programs should be designed so that the bill rider is less than 80% of the projected bill savings and the payments last less than 80% of the shortest-lived component of the appliance or measure. On-bill tariff programs are designed to address low-income barriers to efficiency finance by being structured to be cash-flow positive, and designed as a utility investment attached to the utility meter rather than a loan to a customer (Leventis, Kramer, and Schwartz 2017). This design reduces customer concerns about taking on new debt or discouraging participation associated with renting or moving.

Within this analysis, the on-bill tariff strategy assumes Inflation Reduction Act funding can contribute to lowering on-bill tariff program costs for low-income consumers. Specifically, based on the fiscal year 2022 budget for the U.S. Department of Energy allocated to California through formula grants compared to the total fiscal year 2022 budget from the U.S. Department of Energy, we estimate approximately 6.78% of the U.S. 50122 Electric Program (U.S. 50122 High-Efficiency Electric Home) and the U.S. 50121 Home Owner Managing Energy Savings (HOMES) program budgets will be available to California. We further assume the city of Los Angeles will be able to secure 10% of the total state budget for each of these programs and that the municipal utility LADWP will be able to secure 75% of the city's funds for a total of $43.58

million across the High-Efficiency Electric Home and HOMES programs. We estimate 20% of this will be allocated for administrative, outreach, and technical assistance costs and 80% will be allocated to customers in the on-bill tariff program as rebates to reduce the required bill riders.

As a result of these bill rider values, we excluded certain technologies based on the assumption of limited discretionary income, and independent of whether the overall investment was economically rational. We only include Technology 2 (heat pump water heaters) and Technology 5 (enhanced insulation) in the final report, given their low monthly bill rider costs. It should be noted that some technologies were assumed to already have achieved significant penetration of the housing stock by 2035, thereby limiting the number of eligible dwellings that could benefit from the on-bill tariff program. See Chapter 6 for additional information on how technologies were assumed to diffuse through the housing stock in the ResStock model.

It should be noted that the bill riders and potential eligible customer counts identified below for the heat pump water heaters and enhanced insulation represent the technical potential of an LADWP on-bill tariff program assuming maximum economic efficiency (i.e., only enrolling the most cost-effective projects). In practice, there are multiple barriers to customer participation, program implementation challenges, and economic inefficiencies that would likely result in far fewer customers being served (National Association of Regulatory Utility Commissioners 2022). For example, a review of utility on-bill tariff programs implemented over multiple years shows a range of 75–2,475 total projects per program (Deason, Murphy, and Leventis 2022).

For both sets of Inflation Reduction Act programs, the following technologies were modeled under an on-bill tariff program:

- **Technology 1: Heat Pumps:** Air-source heat pump (seasonal energy efficiency ratio [SEER] 26) or mini-split heat pump (SEER 31).
- **Technology 2: Heat Pump Water Heaters:** Individual heat pump water heaters.
    - Bill rider: $17/month. Participating customer count: 154,010.
- **Technology 3: Whole-Home Electrification:** Heat pumps, heat pump water heaters, induction ranges, electric clothes dryer, ENERGY STAR refrigerators.
- **Technology 4: Heat Pumps and Basic Insulation:** Heat pump (minimum efficiency) with attic and roof insulation and duct sealing.
- **Technology 5: Enhanced Insulation:** Attic and roof insulation, air sealing, duct sealing, and drill and fill insulation.
    - Bill rider: $17/month. Participating customer count: 72,403.
- **Technology 6: LEDs (used as a test case):** 100% LED usage in the home.

For the U.S. 50121 HOMES program, for all technologies above, the rebates were contingent on the estimated energy savings and the AMI level, as outlined in Table A-8, with both a fraction of project costs covered as well as a maximum rebate available.

Table A-8. Modeled HOMES Rebates Available Under the Inflation Reduction Act

	Fraction of Project Costs (maximum rebate)		
Energy Savings	**<80% AMI**	**80%–120% AMI**	**>120% AMI**
>35% modeled	80% ($8,000)	50% ($4,000)	50% ($4,000)
20%–35% modeled	80% ($4,000)	50% ($2,000)	50% ($2,000)
15%–20% measured	80% ($4,000)	50% ($2,000)	50% ($2,000)

For the U.S. 50122 High-Efficiency Electric Home program, for all technologies above, the rebates were contingent on the AMI level, as outlined in Table A-9, with both a fraction of project costs covered as well as a maximum rebate available. Rebates were not available for LEDs or households above 120% of the AMI.

Table A-9. Modeled High-Efficiency Electric Home Rebates Available Under the Inflation Reduction Act

	Fraction of Project Costs (Maximum Rebate)		
Energy Savings	**<80% AMI**	**80%–120% AMI**	**>120% AMI**
Heat pumps	100% ($8,500)	50% ($8,500)	0% ($ -)
Heat pump water heater	100% ($2,250)	50% ($2,250)	0% ($ -)
Heat pump and basic insulation	100% ($10,100)	50% ($10,100)	0% ($ -)
Enhanced insulation	100% ($2,100)	50% ($2,100)	0% ($ -)
Whole-home electrification	100% ($14,500)	50% ($14,500)	0% ($ -)

For incorporating the on-bill tariff equity strategy, the model first compares *baseline* energy usage and bills (electricity and natural gas) before a particular technology (e.g., heat pumps) is deployed against a set of *upgrade* usages and bills for each prototypical customer, where the technology has been deployed wherever physically possible. These energy savings, combined with metadata on customer incomes, indicate the level of rebates for which each customer is eligible. Technology costs for capital costs and installation and technology lifetimes are also tracked by customer prototype. Then, the model initiates an optimization routine (similar to how the rates model functions as outlined above) to determine the bill rider that fully recovers the cost of the program to LADWP. First, the model guesses a bill rider for the on-bill tariff technology program, and it then determines which customers (with rebates applied) would see bill savings 25% higher than the guessed bill rider (the 80% rule outlined above). All customers who pass this constraint are enrolled in the on-bill tariff program, subject to limits on the number of customers LADWP could feasibly enroll in a given year and the total number of customers LADWP could enroll over the life of the on-bill tariff program. The limit on new annual customers was based on estimates for the number of installations a contractor could install per day, the number of contractors LADWP would hire over a given year, and the number of working days in the year.

For each program year, the number of new customers enrolled, the total number of customers enrolled, total annual bills savings for customers (modeled as a loss of revenue to LADWP), total capital costs per year, total rebates applied, and total costs to LADWP (assuming that all capital costs not covered by rebates would be financed by LADWP through debt) are tracked. Administrative and outreach costs are assumed to be 30% of the capital expenditure costs of the technology deployed in years where new customers are added and 1% in years where no new customers are added to the program. Admin and outreach costs are offset by the portion of the Inflation Reduction Act funding set aside for LADWP for such costs until the budget is exhausted. The net present value of the program costs (capital and administrative) is then compared against the net present value of the revenues from the bill rider, and the model optimizes to minimize this difference.

We recognize any strategy that involves energy efficiency or conservation measures has the potential to reduce LADWP's projected revenue requirement and reduce system costs with the potential to lower costs for all customers. We calculate the potential avoided marginal system costs associated with the on-bill tariff program, but we do not adjust rates accordingly. We do not calculate potential system peak reductions associated with this program. We track avoided sales from energy efficiency measures, but we also do not try to capture this impact on rates for nonparticipating customers.

A.10 Evaluation Metrics

The city of Los Angeles' 10% residential "electricity users tax" (without exemptions) [68] and California's electric energy resources surcharge of $0.0003/kWh are applied to customer bills as a last step.[69] All bills are calculated in nominal terms, and the evaluation metrics are then calculated. Evaluation metrics in dollar values (e.g., average monthly bill) are converted to 2021$, whereas evaluation metrics that calculated by percentage, calculated by hours worked, or are unitless (e.g., NER) are unadjusted. Inflation assumptions were used to convert future bills into 2021$, and the U.S. Bureau of Labor Statistics' average annual Consumer Price Index was used to convert historical dollars into 2021$. Inflation for future years was assumed to be a constant 2.5% starting in 2022, which is in line with guidance from LADWP on assumptions used in the SLTRP. For converting dollar values from past years, the Consumer Price Index annual average was used (Bureau of Labor and Statistics n.d.).

The following affordability and equity metrics were calculated to help rank order scenarios and strategies and identify trade-offs between various approaches. The metrics included:

- **Energy Burden (electricity only):** This is a widely used metric to describe energy affordability. It is derived by dividing annual income by annual household electric energy expense.

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[68] The City of Los Angeles' Electricity Users Tax is codified in Section 21.1.4 of the Los Angeles Municipal Code (https://codelibrary.amlegal.com/codes/los_angeles/latest/lamc/0-0-0-125957, accessed Feb. 3, 2023) with exemptions at Section 21.1.12 for older adults, disabled individuals, and very-low-income customers who complete applications. These exemptions were ignored in this model due to a lack of granular data on exemption eligibility.

[69] "Energy Resources (Electrical Energy) Surcharge Guide," California Department of Tax and Fee Administration, https://www.cdtfa.ca.gov/taxes-and-fees/energy-res-surcharge-electrical.htm

- **Hours at Minimum Wage (HMW):** HMW are the hours at minimum wage required to pay for an essential quantity of utility services. To make this more applicable to our analysis, we used the customer's average monthly electric bill instead of essential quantity. The HMW metric was calculated by dividing the household's average monthly bill by the minimum wage for the household's area. As of July 1, 2022, the city of Los Angeles had a minimum wage of $16.04, which increases every July 1 based on inflation adjustments using the U.S. Bureau of Labor Statistics' Consumer Price Index for urban wage earners and clerical workers for the LA metropolitan area (U.S. Bureau of Labor and Statistics n.d.). For example, a $200 monthly electricity bill in an area with a $16.04 minimum wage would equate to an HMW of 12.46 hours, meaning a customer would have to work 12.46 hours at minimum wage to pay the monthly bill.
- **Net Energy Return (NER):** This metric describes how many dollars are earned by a household for every dollar spent on energy (here, electric only). It is calculated by subtracting annual electricity costs from annual income and then dividing it by electricity costs. Compared to energy burden, this metric provides more useful treatment of income extremes—for example, households with zero/negative incomes, with energy expenditures that exceed incomes, and with higher incomes (Scheier and Kittner 2022).

A.11 Limitations

Customer load data are approximated for LADWP customers, not actual customer data. Solar on-site rooftop generation was estimated to provide the flexibility needed to identify intra-class transfers. These solar projections were developed solely for the rates analysis and are unlikely to comport to more detailed solar projections identified in other chapters of this report.

This rates analysis does not incorporate consideration of electric vehicle residential home-based charging and associated rate design. This is a meaningful omission because California has significant electric vehicle incentives (e.g., zero-emissions sales mandate) and has banned the sale of new internal combustion engine vehicles after 2035. The potential effect of incorporating residential electric vehicle charging could include incrementally increased loads for customers adopting electric vehicles who are likely to have higher incomes. This has the potential to increase LADWP system costs. Intra-class transfers could be impacted based on electric vehicle charging rate design, net effect on system costs, and incentive and compensation policy choices.

Our analysis holds electricity demand steady across all the model runs except for the on-bill tariff energy efficiency scenarios (where load is reduced based on high-efficiency appliance deployment). The reality is electricity consumption will change based on how customers respond to price changes (i.e., price elasticity of demand). Rate design changes that are easier for customers to understand (i.e., CPUC two-tier rates) or that more accurately reflect the inter-daily fluctuation in energy system costs (i.e., CPUC TOU rates) may incentivize beneficial consumer behavior. Specifically, rates that accurately reflect system costs that consumers understand may help reduce consumption in peak hours when costs are high. Such beneficial behavior has the potential to result in reduced energy consumption that could lower costs for all consumers. By holding demand constant, our analysis fails to capture an important, iterative relationship between rate design change and consumer behavior change in the face of price signals. We do not iteratively reduce the utility's revenue requirement when we avoid system costs, such as through energy efficiency or distributed generation. Avoided system costs would reduce the revenue requirement and therefore reduce customer rates. Here, we hold LADWP's revenue requirement constant. However, we do calculate total avoided costs in certain scenarios (e.g., on-bill tariff program).

Another limitation is this study used proxy system marginal costs for LADWP's system rather than utility-specific system marginal costs. This may lead to imprecise results associated with calculation of total marginal costs and total residual costs, as well as aligning rates to actual system cost patterns. This primarily impacts TOU rates and IBFC rates. For TOU rates, more accurate local marginal cost data could inform the development of more cost-reflective price periods that better align customer behavior with power system needs. For IBFC rates, more accurate local marginal cost data could provide more accurate assumptions for how much revenue should be recovered from energy charges versus through (income-based) fixed charges.

These model runs look explicitly and exclusively at the residential class alone; they do not consider the behavior or impacts of other customer classes. Though rates are designed to recover costs by customer classes, certain elements (e.g., the funding of low-income bill assistance programs) occur across multiple classes, which this study was unable to incorporate.

These model runs are exceptionally sensitive to utility revenue requirement assumptions. For this analysis the revenue requirements were taken exogenously, directly from the utility, and were not assessed. Actual revenue requirement in 2035 will be different than what was assumed here or within the SLTRP, as technology prices change, load forecasts are updated, and new federal, state, and local policies are implemented, among many factors. While these will change the actual bills and burdens seen in 2035, the findings here indicate the *directionality* of changes under various scenarios.

Appendix B. Data Sources and Assumptions

Table B-1. Summary of Low-Income Bill Affordability Modeling Data Sources

Data	Source	Description	Resolution	Vintage
Residential electrical loads	NREL buildings team; ResStock	8760 hour building loads (no electric vehicles or solar) for 50,000 prototypical customers in LADWP service territory	Census tract	2019, 2035
SB 100 residential class revenue requirement	LADWP, March 2023 forecast	$3,341,331,261	Utility-wide, residential class only	2035
Case 1 residential class revenue requirement	LADWP, March 2023 forecast	$4,552,052,517	Utility-wide, residential class only	2035
2019 LADWP residential class revenue requirement	LADWP	$1,369,329,000	Utility-wide, residential class only	2019
CPUC two-tier rate design guidance	CPUC (California Public Utilities Commission 2015)			
CPUC default TOU guidance	CPUC (California Public Utilities Commission 2019)			
Marginal cost projections	CPUC ACC for SCE territory (California Public Utilities Commission 2022a)	8760 hour marginal cost projections	Climate zone and utility territory for the CA IOUs	2035, 2045
Solar PV projections as a fraction of residential load	LA100 Report, Ch. 3 and 4. (Jacquelin Cochran and Paul Denholm 2021)	2019: 4.0% 2035 – SB 100: 16.2% 2035 – Case 1: 26.5%	Annually per scenario for all of LADWP	2019, 2035
Distribution of solar projects by income bin	LBNL (Sydney Forrester et al. 2022)	Solar rooftop PV adopter data by income	Annually by AMI bin for Los Angeles County	2010–2021
Natural gas price forecasts	CEC (California Energy Commission 2021)	Natural gas rate projections for 2035 for SoCalGas territory	Annual	2035

Appendix C. Tariffs Overview

Tariffs used for this analysis can be found in the NREL Data Catalog at https://data.nrel.gov/submissions/218.

The LADWP FY2019 Residential Rates file shows the LADWP rates used for fiscal year 2019 for Model Run A (2019 baseline). These rates are a combination of the residential R-1 (A) tariff for fiscal year 2018–2019 (effective July 1, 2018) and the R-1 (A) tariff for fiscal year 2019–2020 (effective July 1, 2019). Both historic tariffs are available on the LADWP website.[70] In addition to the rates listed below, there is a minimum bill of $10/month.

The LADWP 2035 Residential Tariff (Case 1) file shows the rate used for 2035 LADWP BAU (Model Run B). All results are in 2035 $. Note that only the incremental ordinances change between the 2019 tariff values (effective July 1, 2019) and the 2035 values.

The CPUC 2035 Simplified Tier Rate 2035 file shows the rate values for the CPUC simplified tier rate for Model Run C, in 2035$, and the tiered consumption limits.

The CPUC TOU Rate for 2035 file shows the results for the CPUC TOU rate for Model Run D. This does not include the baseline credit that is described in the methods section above.

The CPUC Simplified Tier Rate with IBFC for 2035 file shows the results for the CPUC simplified tier rate with IBFC that is used for Model Run G.

The CPUC TOU Rate with IBFC for 2035 file shows the results for the CPUC TOU rate with IBFC used for Model Run J.

The SoCalGas Residential Natural Gas Tariff file provides an overview of the tariff used for calculating natural gas bills across all applicable model runs, in 2023$.

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[70] LADWP's archive of electric rate and adjustment factor summaries is available at https://rates.ladwp.com/Contentpage.aspx?SubCatID=1040 (accessed June 28, 2023)

Appendix D. SB 100 Results

This section details the results from the sensitivity analysis exploring how rates evolve under a significantly lower revenue requirement, in line with LADWP complying with SB 100. Under these scenarios, LADWP is forecasted to achieve 80% clean energy by 2035 before reaching 100% clean energy in 2045. As with the SLTRP Case 1 results detailed in the body of this report, the following results are based on the SB 100 forecasted revenue requirements taken exogenously from LADWP totaling $3.341 billion in 2035 $. In addition to the new revenue requirement, there are two key differences between SB 100 and Case 1 results. In the following SB 100 results, total rooftop solar PV generation from single-family residences was forecasted to offset 16.2% of total residential load (compared to 26.5% under Case 1). Additionally, whenever marginal cost estimates from the CPUC ACC were used, for SB 100 the 2045 results for SCE were used and the dollar year converted to 2035$, assuming a 2.5% annual inflation rate.

Table D-1. Sample Results Comparing Case 1 and SB 100 Revenue Requirements

	2035 BAU LADWP (w/ EZ-SAVE)		2035 CPUC Simplified Tier (no Bill Assistance)		2035 CPUC TOU (no Bill Assistance)	
Revenue Requirement	**Case 1**	**SB100**	**Case 1**	**SB100**	**Case 1**	**SB100**
Avg. Monthly Bill (All Households)	$ 188	$ 136	$ 188	$ 138	$ 188	$ 138
Avg. Monthly Bill (Lowest-Income)	$ 193	$ 127	$ 178	$ 126	$ 179	$ 127
Avg. Monthly Bill (Solar PV adopters, all incomes)	$ 58.0	$ 39.7	$ 144	$ 90.8	$ 136	$ 87.3
Avg. Monthly Bill (Nonadopters, all incomes)	$ 220	$ 149	$ 199	$ 144	$ 201	$ 145
Transfer Costs ($)	$ 10,400,000	$ 10,400,000	$ -	$ -	$ -	$ -
Transfer Costs (share of revenue requirement	0.323	0.44	0	0	0	0
Avg. Electricity Burden (All Households)	7.18	5.37	6.89	5.39	6.96	5.42
Avg. Electricity Burden (Lowest-income)	16.1	11.9	15.2	11.9	15.4	12
Avg. Electricity Burden (Moderate-income)	3.96	2.81	3.73	2.73	3.77	2.75
Households over 100-percent Eletricity Burden (All Households)	23,000	9,580	19,500	9,710	19,700	9,740
Avg. Month HMW (All Households)	13.5	9.77	13.5	9.9	13.5	9.9
Avg. Month HMW (Moderate-Income)	14	10	13.3	9.76	13.4	9.8
Low-cost Month HMW (Lowest-Income)	10.2	6.84	9.24	6.58	9.45	6.69
Avg. Month HMW (Lowest-Income)	13.9	9.09	12.7	9.05	12.8	9.09
High-cost Month HMW (Lowest-Income)	19.2	12.7	19.1	13.7	18.9	13.5
Avg. Annual NER (All Households)	87.5	107	61.7	85	58.7	81.4
Avg. Annual NER (Lowest-Income)	16	32.2	16.3	23.4	15.6	22.7
Avg. Annual NER (Moderate-Income)	47.8	63.5	42.5	59.5	39.8	56.3

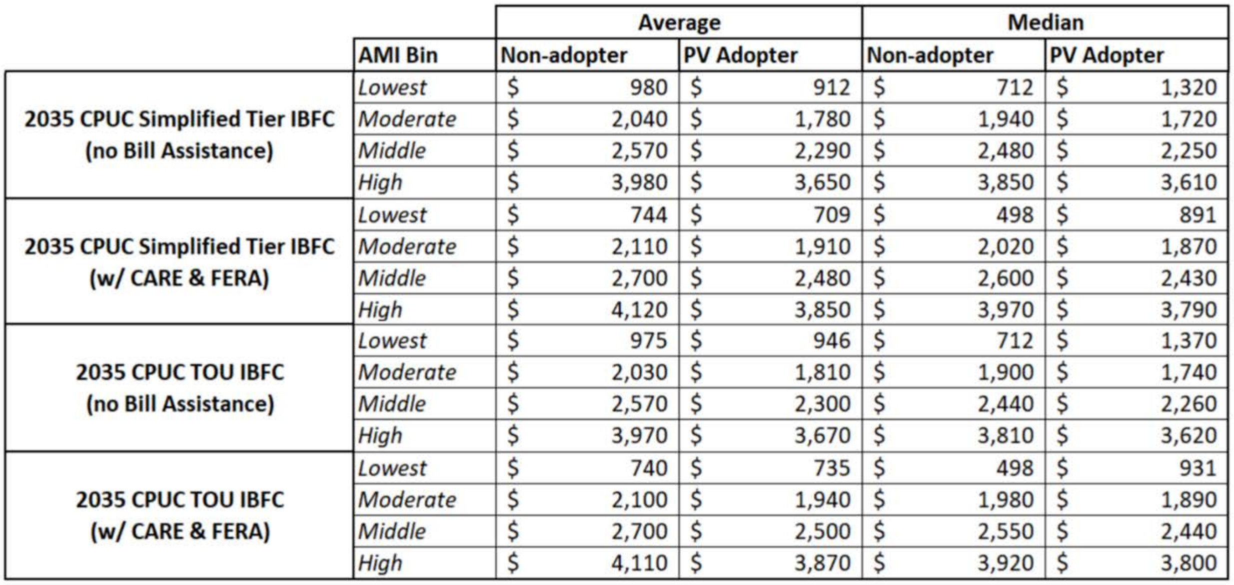
Across the three rate scenarios, average household electricity bills decreased by approximately $50/month, or a 26% reduction. Lowest-income household bills decreased by $66/month (34%) in the BAU case, $52/month (29%) under a simplified tier rate and TOU rate. Solar adopter bills under net energy metering frameworks (2035 BAU LADWP) saw the smallest change between the Case 1 and SB 100 revenue requirement scenarios, reflecting the fact that solar adopters under net metering are mostly insulated from energy prices. As stated before, the model used for this analysis is very sensitive to assumptions around the revenue requirement. The revenue requirement under SB 100 ($3.341 billion) is approximately 73% of the revenue requirement under Case 1 ($4.552 billion), and the average bills across the scenarios reflect a similar reduction in magnitude. *Aside from changes in absolute values, the general trends observed under the Case 1 revenue requirement hold for the SB 100 revenue requirement.*

The model was run with SB 100 revenue requirements to determine how sensitive the trends observed under Case 1 were to assumptions around the costs of operating and building the power system of the future. These results are not a complete picture of the differences between meeting LADWP's current policies and target (100% by 2035) versus under California state mandates (100% by 2045). For instance, the model does not capture benefits or costs associated with reduced air pollution, job impacts, or mitigating the worst effects of climate change. Given the results above, however, we should note that (1) the general trends around equity and affordability seem to hold, and LADWP should have more confidence in our recommendations; and (2) as LADWP continues to improve its forecasts for revenue requirements in line with its SLTRP process, it should consider re-evaluating in detail the impacts to lowest-income customers as done in this analysis.

Appendix E. Complete IBFC Model Results

This appendix contains a more detailed breakdown of certain IBFC model results, showing both the average and median electricity bills and electricity burdens. The focus on these results is to highlight how high-income customers would be impacted by the transition to IBFC tariff design. The median results are included here to illustrate what would happen to a typical customer as the average was skewed by customers with exceptionally high or low bills and burdens. Bill and burden results are broken down by AMI bin and solar PV adoption status.

Table E-1. Average and Median Annual Electricity Bills by Scenario for Solar PV Adopters and Non-Adopters for Income-Based Fixed Charge Model Runs



		Average		Median	
	AMI Bin	**Non-adopter**	**PV Adopter**	**Non-adopter**	**PV Adopter**
2035 CPUC Simplified Tier IBFC (no Bill Assistance)	*Lowest*	$ 980	$ 912	$ 712	$ 1,320
	Moderate	$ 2,040	$ 1,780	$ 1,940	$ 1,720
	Middle	$ 2,570	$ 2,290	$ 2,480	$ 2,250
	High	$ 3,980	$ 3,650	$ 3,850	$ 3,610
2035 CPUC Simplified Tier IBFC (w/ CARE & FERA)	*Lowest*	$ 744	$ 709	$ 498	$ 891
	Moderate	$ 2,110	$ 1,910	$ 2,020	$ 1,870
	Middle	$ 2,700	$ 2,480	$ 2,600	$ 2,430
	High	$ 4,120	$ 3,850	$ 3,970	$ 3,790
2035 CPUC TOU IBFC (no Bill Assistance)	*Lowest*	$ 975	$ 946	$ 712	$ 1,370
	Moderate	$ 2,030	$ 1,810	$ 1,900	$ 1,740
	Middle	$ 2,570	$ 2,300	$ 2,440	$ 2,260
	High	$ 3,970	$ 3,670	$ 3,810	$ 3,620
2035 CPUC TOU IBFC (w/ CARE & FERA)	*Lowest*	$ 740	$ 735	$ 498	$ 931
	Moderate	$ 2,100	$ 1,940	$ 1,980	$ 1,890
	Middle	$ 2,700	$ 2,500	$ 2,550	$ 2,440
	High	$ 4,110	$ 3,870	$ 3,920	$ 3,800

Appendix F. 2035 Housing Stock

The residential loads were simulated using a projected 2035 housing stock. The 2035 housing stock is projected off the 2019 housing stock used in other housing analysis in this report (Stenger et al. 2023). Projections were done under a BAU frame where more-intensive residential energy efficiency investments are done by wealthier homeowners than lower-income, renting households (Solà et al. 2020). AMI and tenure were used to sort the housing characteristics, where higher-income households were ordered before lower-income, and then owners were ordered before renters. After ordering the housing stock, housing technology packages were applied in percentages shown in Table F-1.

Table F-1. Housing Stock Package Saturation

Package #	Package Description	Package Saturation
1	• 100% LED lighting • 25% reduced infiltration (minimum at 1 ACH50) • Induction cooking range • Wall insulation (R-19) • Double-pane windows • Heat pump clothes dryer • Attic insulation (R-49; only applicable to single-family dwellings with vented attics) • Heat pump water heater • Heat pump (air-source heat pump SEER 26.1, 11 heating seasonal performance factor [HSPF] for dwellings with ducts; mini-split heat pump SEER 33.1, 13.5 HSPF for dwellings without ducts)	25%
2	• 100% LED lighting • 25% reduced infiltration • Induction cooking range • Wall insulation (R-19) • Double-pane windows • Heat pump clothes dryer • Attic insulation (R-49; only applicable to single-family dwellings with vented attics) • Heat pump water heater	10%
3	• 100% LED lighting • 25% reduced infiltration • Induction cooking range • Wall insulation (R-19) • Double-pane windows • Heat pump clothes dryer • Attic insulation (R-49; only applicable to single-family dwellings with vented attics)	15%

Package #	Package Description	Package Saturation
4	• 100% LED lighting • 25% reduced infiltration • Induction cooking range • Heat pump clothes dryer • Attic insulation (R-49; only applicable to single-family dwellings with vented attics)	10%
5	• 100% LED lighting • 25% reduced infiltration • Heat pump clothes dryer • Attic insulation (R-49; only applicable to single-family dwellings with vented attics)	15%

The 2035 housing stock has a different profile of energy use than the 2019 housing stock. The average household energy use is shown in Figure F-1 disaggregated by AMI. On average, electricity and natural gas use decrease from 2019 (shown in Figure F-1) to 2035 (shown in Figure F-2) for higher-income households (>120% AMI). The decrease in natural gas usage and electricity usage is attributed to the larger percentage of energy efficiency and decarbonizing technologies to higher-income households. In comparison, extremely low-income (0%–30% AMI) households do not see a notable difference between 2019 and 2035 for electricity or natural gas use, largely because these households did not receive energy efficiency or decarbonizing technologies in the BAU case.

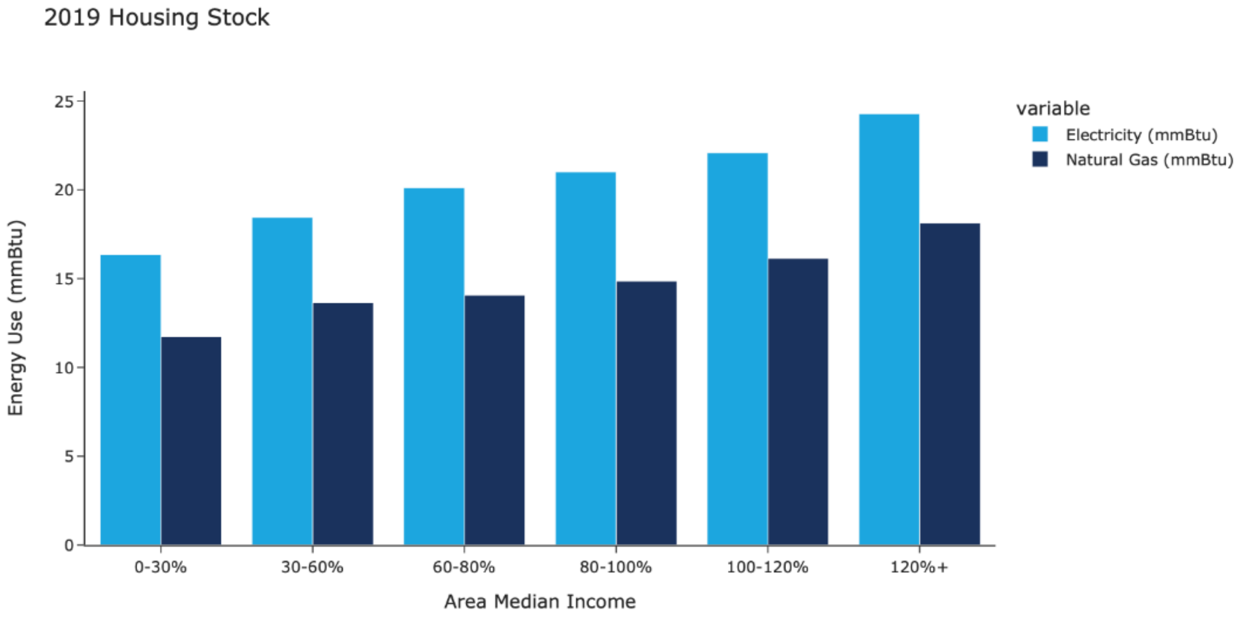


Figure F-1. Average dwelling energy use in 2019 housing stock

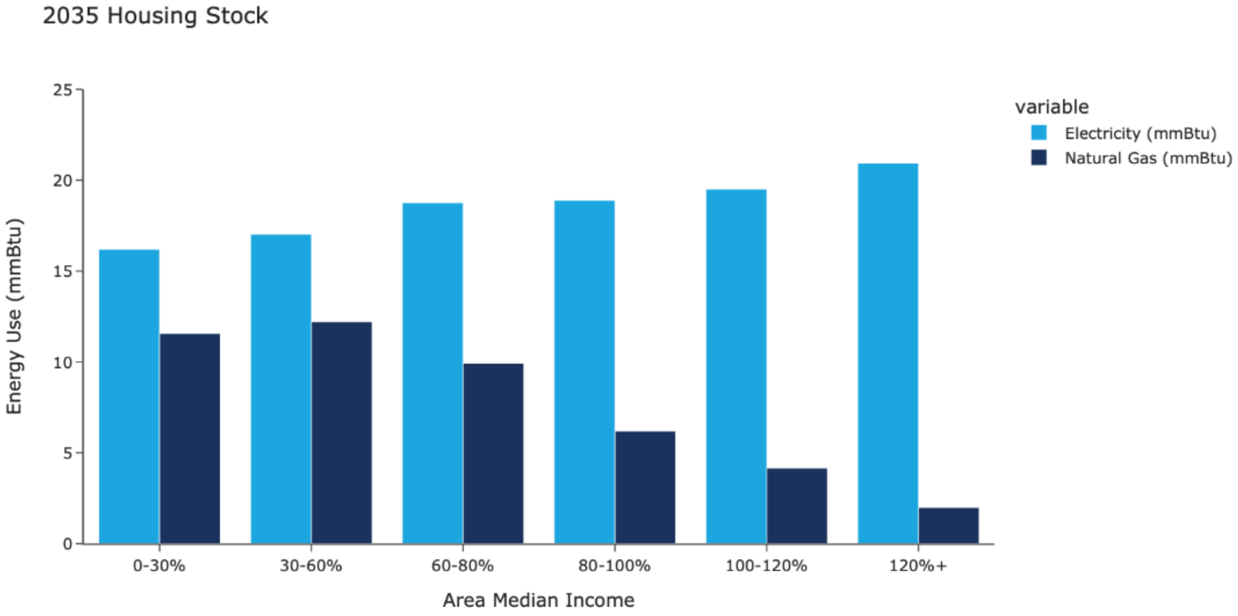


Figure F-2. Average dwelling energy use in 2035 housing stock

Appendix G. On-Bill Tariff Technical Potential Enrollment Demographics

The on-bill tariff program examined viable technologies to decrease energy use. Of the technologies examined, heat pump water heaters and enhanced insulation proved to be most economically viable. For our technical potential analysis, Figure G-1 and Figure G-2 show the demographics of the potentially served households in an on-bill tariff program to receive heat pump water heaters. Figure G-3 and Figure G-4 show the demographics of the potentially served households to receive enhanced insulation.

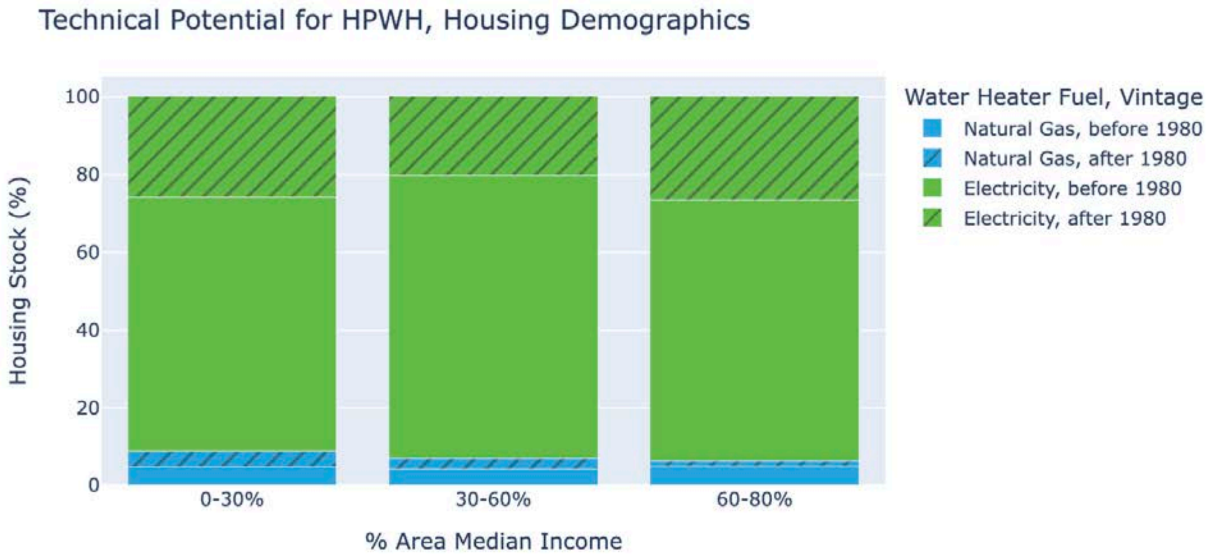


Figure G-1. Building characteristics of households achieving bill savings from on-bill, tariff-funded heat pump water heaters

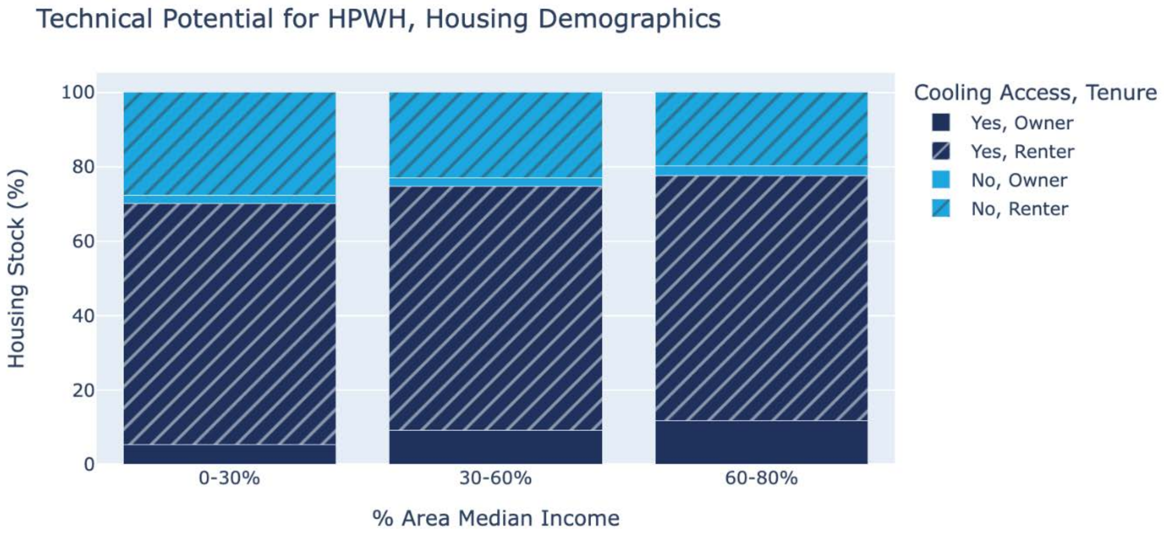


Figure G-2. Demographics of households achieving bill savings from on-bill, tariff-funded heat pump water heaters

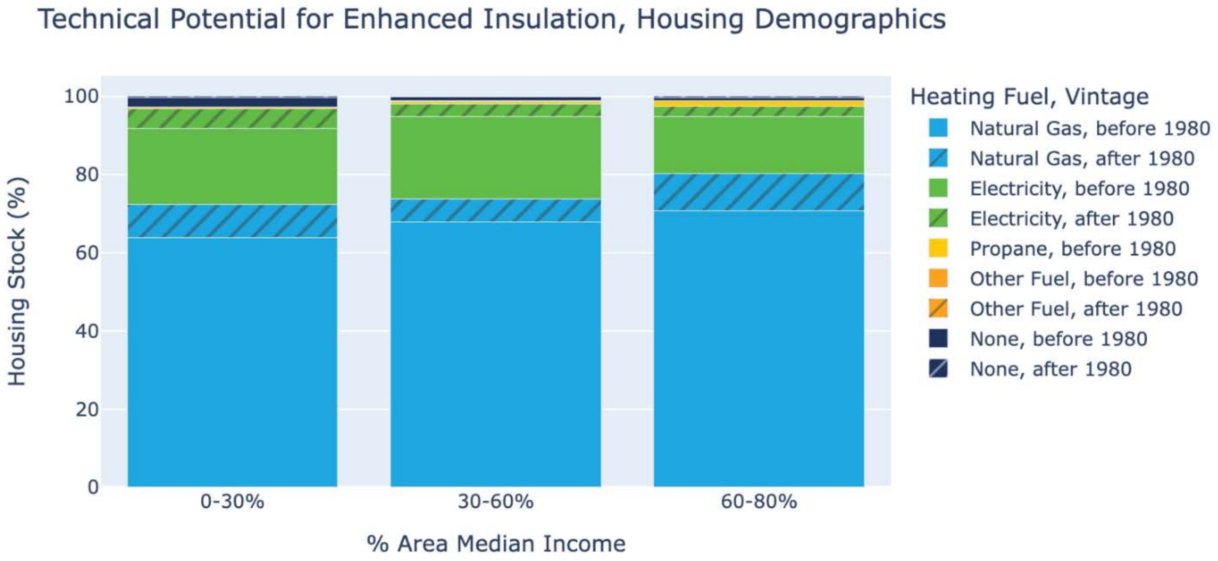


Figure G-3. Building characteristics of households achieving bill savings from on-bill, tariff-funded enhanced insulation

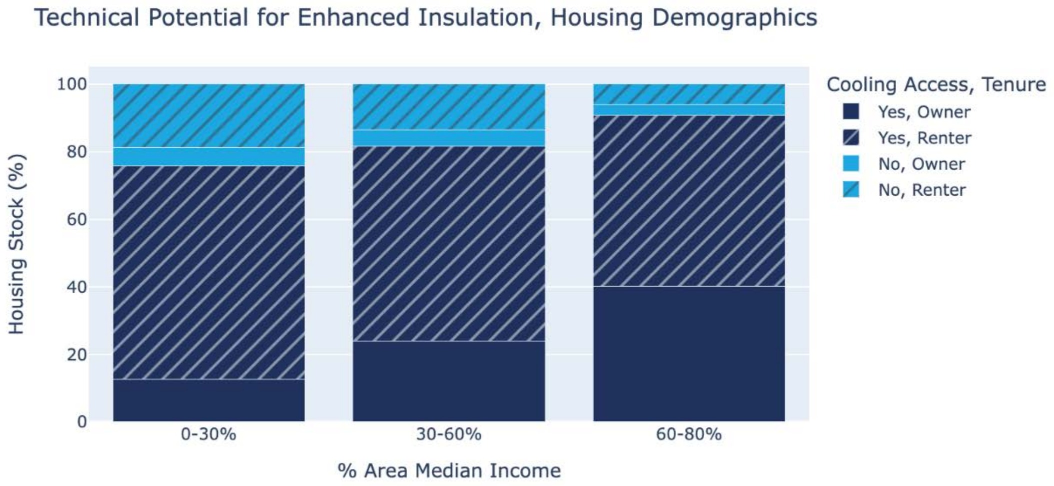


Figure G-4. Demographics of households achieving bill savings from on-bill, tariff-funded enhanced insulation

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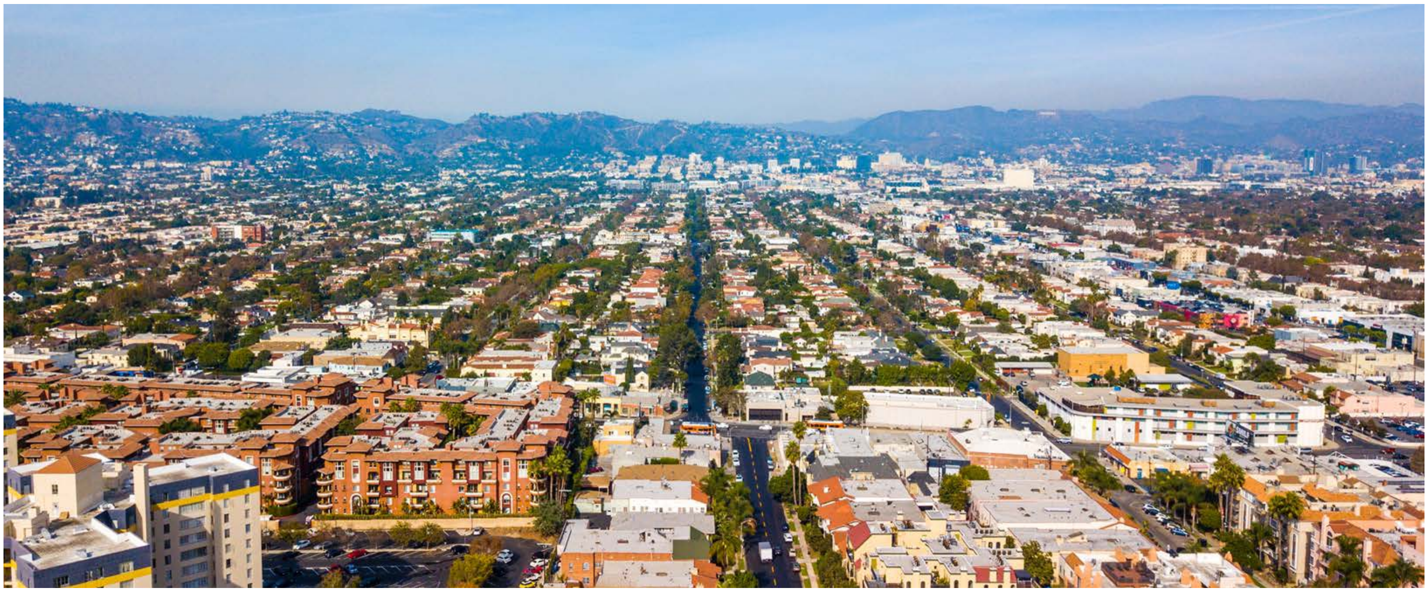
November 2023

LA100 EQUITY STRATEGIES



Chapter 6: Universal Access to Safe and Comfortable Home Temperatures

FINAL REPORT: LA100 Equity Strategies

Noah Sandoval, Katelyn Stenger, Anthony Fontanini, Lixi Liu, Janet Reyna, Philip White, Ry Horsey, Patricia Romero-Lankao, and Nicole Rosner

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November 2023

LA100 EQUITY STRATEGIES

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Preface

The Los Angeles 100% Renewable Energy Study, or LA100, revealed that although all communities in Los Angeles will share in the air quality and public health benefits of the clean energy transition, increasing equity in participation and outcomes will require intentionally designed policies and programs. The LA100 Equity Strategies project was specifically designed to help Los Angeles identify pathways to such policies and programs in the form of equity strategies. The project aimed to do this by incorporating research and analysis to chart a course toward specific, community-prioritized, and equitable outcomes from the clean energy transition outlined in the LA100 study.

The Project Partners

The Los Angeles Department of Water and Power (LADWP), the National Renewable Energy Laboratory (NREL), and the University of California Los Angeles (UCLA) partnered on the LA100 Equity Strategies project to develop strategies for engaging communities, funding equitable technology and infrastructure investments, expanding existing programs, and designing new programs and policies to improve equity by incorporating what community members themselves know is needed to achieve a more equitable energy future.

The Project Approach

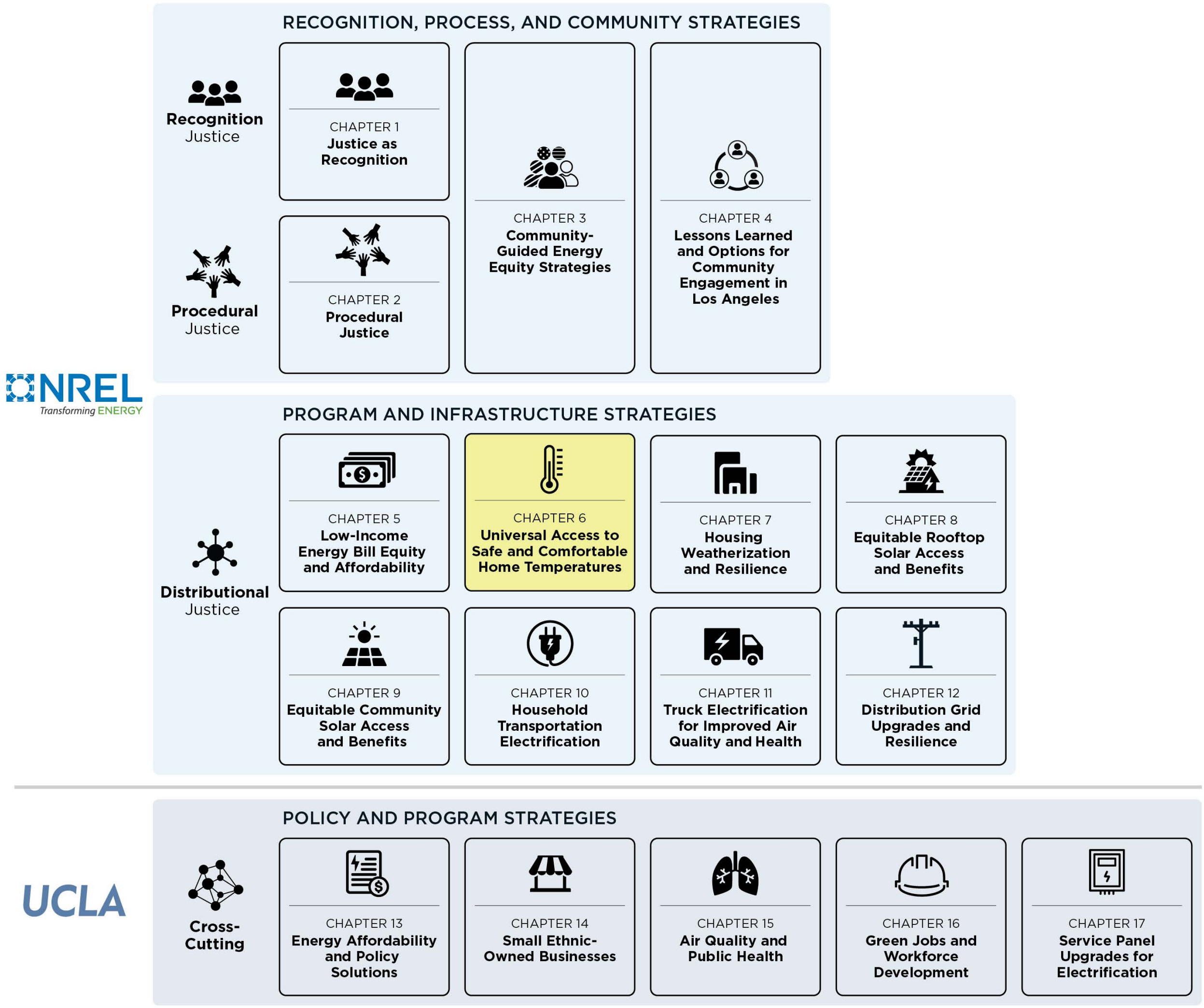
LA100 Equity Strategies employs a unique mixed-methodological approach utilizing three distinct—but connected—research efforts. Through these efforts, NREL and UCLA developed a range of strategy options for increasing equity in LA's transition to 100% clean energy.

A Project Summary

To get a high-level overview of the project, you can dive into the executive summary, interactive data visualizations, and more on the LA100 Equity Strategies website at maps.nrel.gov/la100/equity-strategies.

The Full Report

NREL's final full report for the LA100 Equity Strategies project encompasses seventeen chapters. The first twelve chapters, authored by NREL, are organized around the three tenets of justice. Chapters 1–4 address recognition and procedural justice, while Chapters 5–12 address distributional justice. The final five chapters, authored by UCLA, provide crosscutting policy and program strategies. Each chapter provides data, methods, insights, and strategies to help LADWP make data-driven, community-informed decisions for equitable investments and program development.



NREL Chapters

Chapter 1: Justice as Recognition

Chapter 2: Procedural Justice

Chapter 3: Community-Guided Energy Equity Strategies

Chapter 4: Lessons Learned and Options for Community Engagement in Los Angeles

Chapter 5: Low-Income Energy Bill Equity and Affordability

Chapter 6: Universal Access to Safe and Comfortable Home Temperatures

Chapter 7: Housing Weatherization and Resilience

Chapter 8: Equitable Rooftop Solar Access and Benefits

Chapter 9: Equitable Community Solar Access and Benefits

Chapter 10: Household Transportation Electrification

Chapter 11: Truck Electrification for Improved Air Quality and Health

Chapter 12: Distribution Grid Upgrades for Equitable Resilience and Solar, Storage, and Electric Vehicle Access

UCLA Chapters

Chapter 13: Energy Affordability and Policy Solutions Analysis

Chapter 14: Small Ethnic-Owned Businesses Study

Chapter 15: Air Quality and Public Health

Chapter 16: Green Jobs Workforce Development

Chapter 17: Service Panel Upgrade Needs for Future Residential Electrification

List of Abbreviations and Acronyms

AC	air conditioning/air conditioner
ACCA	Air Conditioning Contractors of America
AMI	area median income
ASHP	air-source heat pump
CEC CZ	California Energy Commission climate zone
CMU	concrete masonry unit
DAC	disadvantaged community
eTRM	electronic technical reference manual
GWh	gigawatt-hours
HEIP	Home Energy Improvement Program
HOMES	Home Owner Managing Energy Savings
HSPF	heating seasonal performance factor
HUD	Housing and Urban Development
HVAC	heating, ventilating, and air conditioning
IRA	Inflation Reduction Act of 2022
LADWP	Los Angeles Department of Water and Power
LBL	Lawrence Berkeley National Laboratory
LEAD	Low-Income Energy Affordability Data
NREL	National Renewable Energy Laboratory
NREMDb	National Residential Efficiency Measures Database
NYSERDA	New York State Energy Research Development Authority
PUMA	Public Use Microdata Area
SGHC	solar heat gain coefficient

Executive Summary

The LA100 Equity Strategies project integrates community guidance with robust research, modeling, and analysis to identify strategy options that can increase equitable outcomes in Los Angeles' clean energy transition. This chapter focuses on housing weatherization and cooling technologies as means to increase access to safe and comfortable home temperatures. Lack of cooling access and use can have severe health impacts on building occupants during heat waves.

Specifically, NREL developed and used a residential building stock model to simulate the energy use of 50,000 dwellings representing the diversity of housing types, appliances, climate zones, and household incomes across Los Angeles. We compared a baseline scenario with seven upgrade scenarios. Five scenarios cooled the entire household and featured cooling systems at varying efficiency levels with various improvements to the envelope, roof, and shading, and two scenarios cooled a single room in a household with no prior cooling using either a room air-conditioning or a heat pump system. For each scenario, we evaluated impacts on utility bills, payback periods, and changes in energy burdens, as well as ability to achieve safe and comfortable temperatures. We also examined the effects of building types (multifamily vs. single-family) on indoor air temperatures.

Based on the results of modeling, analysis, and community guidance, we identified six short-term and two long-term strategies for improving access to building envelope upgrades and cooling strategies that could save lives and maintain safe home temperatures for Los Angeles' low-income households during heat waves.

Research was guided by input from the community engagement process, and associated equity strategies are presented in alignment with that guidance.

Community Guidance

Analysis was tailored to incorporate guidance from the LA100 Equity Strategies Steering Committee, listening sessions with community-based organizations and community members, and community meetings. The following community concerns and priorities relate to universal cooling and comfort:

Steering Committee member:

"Passive cooling is critical, not just air conditioning. Reflective surfaces, cool roofs, insulation, planting trees on the southwest corner of homes should all be considered."

- The need for safe living conditions
- Concerns that upgrades will raise rents and cause displacement
- More diversified and community-tailored outreach and support, such as feedback channels
- Affordable program options that require fewer upfront costs
- Maintenance and safety upgrade support for home improvements needed for upgrades like electrical panels or mold abatement
- Amended eligibility requirements for ratepayers experiencing disadvantages that do not fit current criteria (e.g., moderate-income household eligibility)
- Revised Los Angeles Department of Water and Power (LADWP) programs that address the split incentive problem between renters and property owners
- Need for apprenticeship programs and local knowledge.

Steering Committee member:

"We have a housing crisis throughout the city with a burgeoning homelessness crisis … landlords are flipping people out of buildings, using temperature/climate to push tenants out by diminishing the habitability, or they will pass costs on to tenants to increase rents. We need a code that no public money will be given to landlords without tenant protections. It has to be written into any strategies from this work—legal mechanisms to ensure habitability without increasing rent or utility burden."

Distributional Equity Baseline

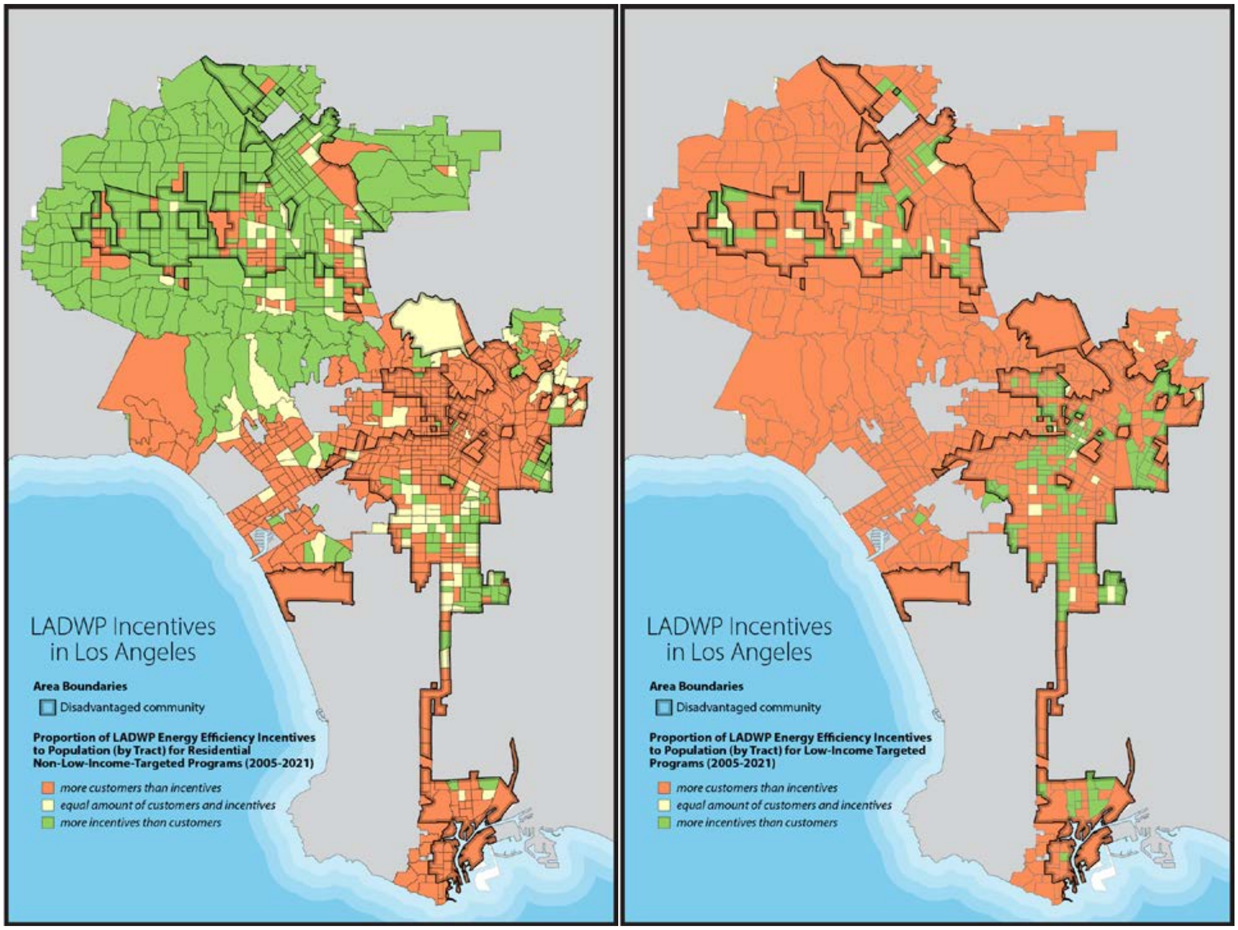
Distributional equity analysis found that most LADWP residential energy efficiency programs analyzed disproportionately benefited non-disadvantaged, mostly White, non-Hispanic, mostly home-owning, and mostly above-median-income communities (Figure ES-1).

LADWP RESIDENTIAL INVESTMENTS		NUMBER OF YEARS	TOTAL AMOUNT SPENT	AVG. AMOUNT PER CUSTOMER DAC/Non-DAC	% OF INCENTIVES Normalized by # of Customers DAC/Non-DAC	WHICH COMMUNITIES DISPROPORTIONATELY BENEFITED FROM PROGRAMS?				
						DAC/ Non-DAC	Mostly Non-White/White	Mostly Hispanic /Non-Hispanic	Mostly Renters/Owners	Below/Above Median Income
ENERGY EFFICIENCY	Home Energy Improvement Program	3	$3,378,869	$3 $2	61% 39%	DAC		Hispanic	Owners	
	Refrigerator Turn-In and Recycle Program	5	$2,667,307	0.01 refrigerators 0.014 refrigerators	42% 58%	Non-DAC	White	Non-Hispanic	Owners	Above
	Consumer Rebate Program	6	$93,248,144	$64 $74	46% 54%	Non-DAC	White	Non-Hispanic	Owners	Above
	Other Non-Low-Income-Targeted Programs	15	$36,343,548	$20 $34	35% 65%	Non-DAC	White	Non-Hispanic	Owners	Above
	Energy Savings Assistance Program*	5	$7,897,260	$11 $1	92% 8%	DAC	Non-White	Hispanic	Renters	Below

* Low-Income Targeted

Figure ES-1. Statistical analysis of LADWP residential energy efficiency investments (2007–2021)

Of the residential energy efficiency programs analyzed, one program, the Energy Savings Assistance Program, targeted low-income households and, by design, benefited disadvantaged communities (DACs)[1]. Areas such as Central Los Angeles, Northeast Los Angeles, Boyle Heights, Lincoln Heights, and the Harbor saw disproportionately fewer benefits from energy efficiency programs that did not target low-income households (Figure ES-2).



(a) **(b)**

Figure ES-2. Distribution of LADWP residential efficiency incentives not targeted to low-income households (a) and distribution of LADWP residential efficiency incentives targeting low-income households (b), where number of incentives are compared to number of customers

Areas in orange indicate a lower number of incentives per customer, and areas in green indicate a higher number of incentives per customer.

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[1] Disadvantaged communities are identified by CalEPA based on criteria defined in Senate Bill (SB) 535, as described here: https://oehha.ca.gov/calenviroscreen/sb535

Key Findings

NREL developed a building stock model that simulated the energy use of 50,000 representative dwellings.[2] These dwelling units represent the diversity of housing types, appliances, climate zones, and household incomes across Los Angeles. A baseline scenario was compared with seven upgrade scenarios. Five upgrade scenarios cool the entire household and feature cooling systems at varying efficiency levels with various improvements to the envelope, roof, and shading. Two upgrade scenarios cool one room in a household without cooling in the baseline by using either a room air conditioner (AC) or mini-split heat pump system.

Economic impacts, as well as a dwelling unit's ability to achieve safe and comfortable temperatures, were evaluated for each scenario. Key findings include:

- More than 27% of low-income (0%–80% AMI) households in Los Angeles lack access to cooling and are projected to experience the equivalent of nearly two months of exposure to dangerous indoor temperatures in 2035. Cooling one room with a room AC for 230,000 households would have an installed cost of $160 million total or $13 million per year between 2024 and 2035.[3]
- In the baseline scenario, households in multifamily buildings are projected to experience more than a month of dangerous indoor heat exposure in 2035 compared to households in single-family homes, which are projected to experience a median of less than one day of dangerous temperatures. More than 95% of low-income renters live in multifamily dwellings.[4]
    - *Providing cooling for the entire dwelling eliminated exposure to dangerous indoor temperatures* regardless of income, building type, or access to cooling before upgrades. However, these upgrades have high initial costs of $6,000–$16,000.
- *Cooling use alone dramatically improves access to safe and comfortable home temperatures*. Whole-home cooling with a heat pump reduces the maximum living space temperature by an average of 13°F and reduces hours above the dangerous temperature threshold (86°F) by over 99% for low-income, multifamily households.

Housing resilience equity metrics include:

- Level and duration of exposure to unsafe home temperatures (>86°F)
- Upgrade costs and utility bill impacts
- Household income
- Renter or owner occupancy status
- Housing type (multifamily, single-family)

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[2] A dwelling is a place of residence.

[3] Assuming a set point between 74°F and 78°F, this would increase annual average per household utility costs by $181. NREL cannot verify how much partial cooling will meet the cooling set point, decrease the maximum indoor home temperature, or decrease the number of hours above 86°F that a dwelling unit will experience. Temperatures are modeled for whole-home cooling systems, which are more effective at delivering comfort but increase costs.

[4] See Chapter 7: Housing Weatherization and Resilience (Stenger et al. 2023) for additional Los Angeles housing data by income, tenure, and building type.

- *In Los Angeles' mild climate, additional envelope efficiency upgrades do not reduce exposure to dangerous temperatures*. While improved insulation, air sealing, and window performance can increase energy efficiency and utility bill savings, whole-home cooling equipment access and use is the most effective way to reduce exposure to dangerous temperatures.
- *13% of Los Angeles households are energy-burdened and extremely low-income.* Providing low-income households that do not have cooling with a whole-home, maximum efficiency cooling system increases the number of energy-burdened households by 12,000—this increased burden is a result of the added cooling service and resulting energy demand. Providing whole-home, maximum efficiency cooling to low-income households with existing whole-home cooling, however, reduces energy-burdened households among this group by 15,000, because more efficient cooling saves on utility bills.
- Minimum efficiency cooling systems for the whole home have the shortest payback period across income levels among whole-home cooling upgrade scenarios evaluated. Low-income owners have a simple payback period of 16 years, and renters have a simple payback period of 24 years. Using the Inflation Reduction Act of 2022 (IRA) rebates reduces the simple payback to less than a year. However, limited IRA program budgets can fund systems in less than 1% of 0%–150% area median income (AMI) households. Where funding is insufficient to provide whole-home cooling, partial space conditioning can provide some cooling at 65%–90% lower costs to dwellings without any cooling.

Equity Strategies

Modeling, analysis, and community engagement identified the following strategies for achieving more equitable outcomes in the distribution of benefits and burdens in Los Angeles' transition to clean energy and universal cooling.

- **Short Term:** Provide affordable access to whole-home cooling through a heat pump before envelope improvements, particularly in multifamily residential buildings.
- **Short Term:** Deliver direct installation to cool one room in extremely low-income households (0%–30% AMI) or deploy rebates used at point of purchase.
- **Short Term:** Issue rebates for heat pumps as part of the Cool LA Program to provide up to 29% more energy-efficient cooling for total lifecycle costs equivalent to current rebates for window-unit ACs.
- **Short Term:** Reduce application time and/or auto-enroll extremely low-income households who receive Cool LA rebates for partial conditioning (i.e., room AC) into a bill assistance program to avoid increased energy burdens.
- **Short Term:** Combine federal IRA or Weatherization Assistance Program funding with existing LADWP rebates to augment LADWP's Home Energy Improvement Program (HEIP), Cool LA program, and other programs to lower the equipment costs of heat pumps and envelope efficiency upgrades for low-income households.

- **Short Term:** Expand LADWP's HEIP (LADWP 2023) to include funding for necessary renovations and electrical upgrades to ensure the ability to install a heat pump.
- **Long Term:** Evaluate contractors representing DACs in current LADWP contracts and support apprenticeship programs in DACs for heating, ventilating, and air conditioning (HVAC) entrepreneurship and educational opportunities—importantly, heat pump installation training and demonstrations.
- **Long Term**: Partner with the Housing Authority to install upgrades in public housing and establish a mechanism to mitigate rent increases due to LADWP-supported upgrades elsewhere.

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1 Introduction

The LA100 Equity Strategies project seeks to increase equity in Los Angeles' transition to 100% clean energy. This report identifies strategies to increase access to safe and comfortable home temperatures through housing weatherization and cooling technologies.

1.1 Modeling and Analysis Approach

To provide universal access to safe and comfortable home temperatures in Los Angeles, the National Renewable Energy Laboratory (NREL) explored the impact of universal access to cooling along with building envelope improvements using the ResStock™ model. Figure 1 provides an overview of the modeling workflow. The applied methods, which were developed with input from the LA100 Equity Strategies Steering Committee and community members in Los Angeles, are described in detail below.

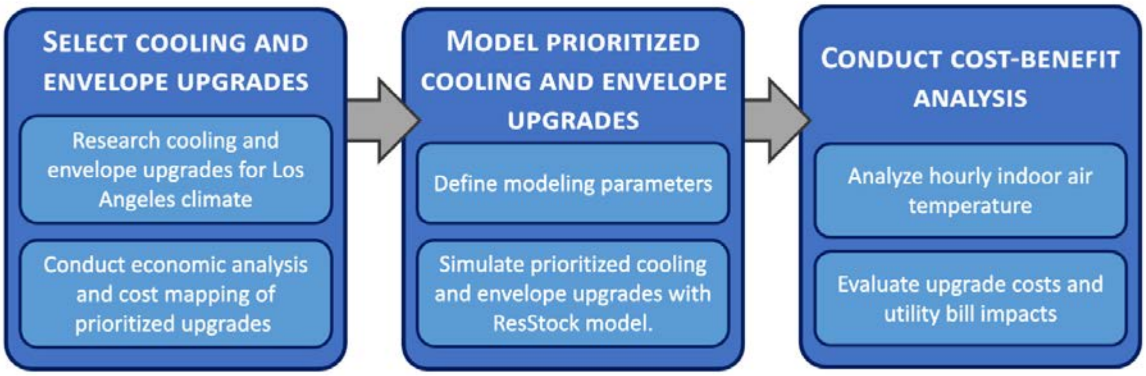

Figure 1. Modeling workflow for the analysis

1.1.1 Cooling and Building Envelope Upgrade Scenario Selection and Modeling

NREL chose eight combinations of cooling systems and building envelope upgrades—or upgrade scenarios—to model indoor air temperatures and utility usage changes:

- Baseline
- Whole-Home Cooling
  - Max. Efficiency Cooling System
  - Min. Efficiency Cooling System
  - Min. Efficiency Cooling System, Cool Roof, and Shading
  - Min. Efficiency Cooling System and Low-Cost Envelope Improvements
  - Min. Efficiency Cooling System and Title 24[5] Envelope Improvements
- One-Room Cooling
  - Min. Efficiency Partial Space Conditioning

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[5] "Building Energy Efficiency Standards: Title 24," California Energy Commission, https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards.

- Max. Efficiency Partial Space Conditioning.

We modeled cooling to the entire dwelling under maximum[6] and minimum[7] efficiency conditions. We selected heat pumps for cooling because they provide up to 29% more energy-efficient cooling for equivalent total lifecycle costs compared to window-unit air conditioners (Booten, Winkler, and Faramarzi 2022) and will be eligible for the widest selection of federal rebates. LA100 Equity Strategies Steering Committee input and current LADWP policies informed the envelope efficiency upgrades that were modeled in combination with entire dwelling cooling.

In addition to the upgrades listed above, NREL investigated the effects of providing cooling to one room for dwellings that would otherwise not have any cooling. These upgrades and results are discussed in Section 2.2 (page 17).

Cooling can be achieved through methods other than the ones presented in these upgrade scenarios. The focus of this analysis was to provide cooling through central air-source and mini-split air-source heat pumps. It is also possible to lower indoor air temperature through traditional AC systems, shading, or mechanical ventilation. Given the mild climate of Los Angeles, measures taken by residents to cool their dwelling units, such as precooling homes on off-peak hours or installing operable windows, may be cost-effective. Furthermore, some dwelling units may be best served by individual, less costly envelope upgrades (e.g., increased ceiling insulation) rather than full envelope retrofits. Another cooling technology being explored by LADWP to improve equity through demand response is internet-connected AC systems. This technology was not investigated in this report.

1.1.2 Cost Analysis

We conducted a cost analysis for whole-home cooling technology and building envelope upgrades. We reviewed the data from various technology cost databases (see Appendix C) and summarized costs for each upgrade by technology type, fuel type, efficiency, capacity, total project costs, material costs, labor costs, hourly labor rates, and labor hours. Next, costs were compared to costs from local hardware retailers and online wholesalers and suppliers (see Appendix C) to determine whether the costs were reasonable for the LA area. If upgrade costs were unavailable or if costs were outside an acceptable range compared to local hardware retailer or wholesaler and supplier prices, we used the lowest cost from the retailer or wholesaler for the material price. Labor costs were included in total project costs if they were available. If not, labor costs were calculated by determining the type of labor needed (e.g., electrician), the associated hourly rate for that labor type, and the labor hours based on RSMeans data (Doheny 2021). Upgrade cost information is in Section C.2 in Appendix C (page 39). All cost data are in 2022 dollars (2022$).

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[6] For ASHP (SEER 26.1, 11 HSPF), for MSHP (SEER 33.1, 13.5 HSPF)

[7] Based on DOE guidelines, for ASHP (SEER 15, 9.0 HSPF); for MSHP, same as maximum because MSHP costs do not vary with efficiency, but rather system size. Thus, installing a lower efficiency model would be cost the same but consume more energy.

2 Modeling and Analysis Results

2.1 Whole-Home Cooling

Table 1 presents the median home temperature and economic effects of cooling and envelope improvement upgrades simulated in the baseline and first five (whole-home cooling) upgrade scenarios.

Table 1. Median Effect of Building Upgrade Scenarios (2035)

Upgrade Scenario	Hours Above 86°F	Maximum Indoor Air Temperature for a Single Hour (°F)	Annual Utility[a] Bill (2022$)	Upgrade Cost (2022$)
Baseline	590	93	1,100	—
Max. Efficiency Cooling System	0	79	1,100	11,000
Min. Efficiency Cooling System	0	80	1,200	7,900
Min. Efficiency Cooling System, Cool Roof, and Shading	0	79	1,200	10,300
Min. Efficiency Cooling System and Low-Cost Envelope	0	80	1,200	9,700
Min. Efficiency Cooling System and Title 24 Envelope	0	80	1,200	14,000

[a] Maximum indoor air temperatures rise a few degrees above the cooling sets points even with highly insulated and air sealed dwelling units in part because mechanical ventilation expels conditioned air to ensure indoor air quality when building envelopes are tight, and there are limitations of sizing heat pumps using ACCA Manual J/S to size for cooling loads (ACCA Manual J 2016).

[b] Utility refers to the combination of electricity and natural gas energy services.

[c] A positive value indicates utility bill savings.

Adding cooling to the entire dwelling through a heat pump reduced the maximum temperature from a dangerous indoor temperature of 93°F to safe temperatures of 79°F and 80°F for maximum and minimum efficiency cooling systems, respectively. Though utility bills generally increase, this is a result of increased access to and use of cooling, which is discussed in detail in the utility bill impacts sections, which start on page 8.

Of the upgrades selected for analysis, the minimum efficiency cooling systems have the lowest median upgrade cost ($7,900).

2.1.1 Universal Access to Safe and Comfortable Home Temperatures

We measured access to safe and comfortable home temperatures by determining the maximum living space temperature over a year and the number of hours above the dangerous temperature threshold, 86°F described in Chapter 7 (Stenger et al. 2023).

2.1.1.1 Maximum Indoor Temperatures

The maximum indoor temperature of a dwelling characterizes the warmest temperature experienced by a dwelling unit throughout the entire year. Figure 2 shows the maximum living space temperature by area median income (AMI) across upgrade scenarios.

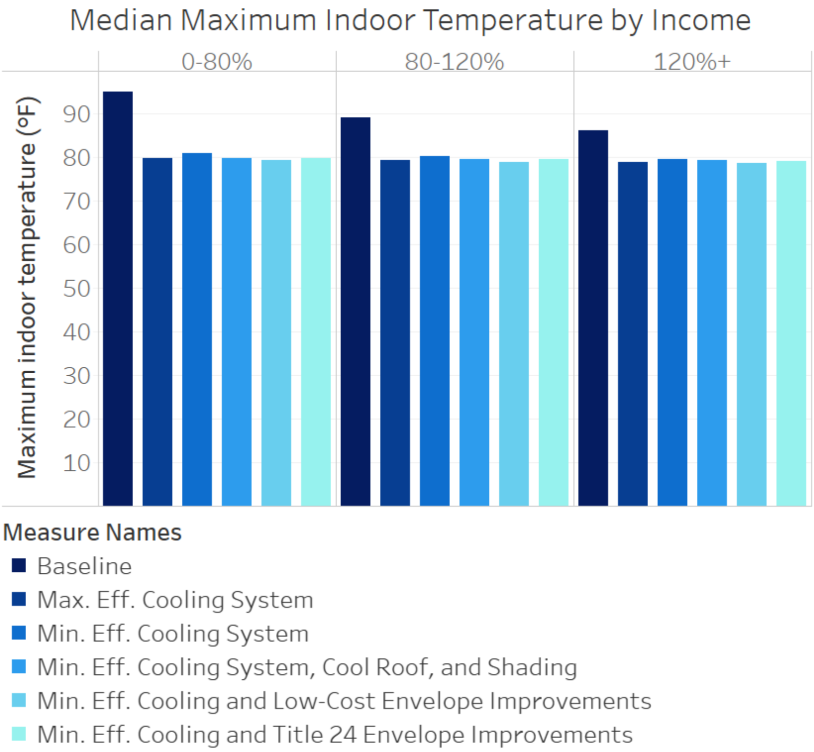

Figure 2. Maximum living space temperature by percentage AMI (2035)

In the baseline scenario, more than half of low-income (0%–80% AMI) households will experience dangerous indoor air temperatures of 95°F at least once a year by 2035, which exceeds the safe indoor temperature threshold of 86°F. Regardless of upgrade or efficiency level, providing cooling decreases maximum indoor temperatures to below the dangerous temperature threshold for low-income households. Additional results for maximum indoor air temperatures are provided in Appendix B.

2.1.1.2 Hours of Dangerous Temperatures

The number of hours at dangerous temperatures is shown in Table 2, which indicates the median number of hours above 86°F for the baseline and each upgrade by income level.

Table 2. Median Number of Hours Above 86°F Annually by Percentage AMI (2035)

Upgrade Scenario	0%–80% AMI	80%–120% AMI	+120% AMI
Baseline	1,400	100	2
Max. Efficiency Cooling System	0	0	0
Min. Efficiency Cooling System	0	0	0
Min. Efficiency Cooling System, Cool Roof, and Shading	0	0	0
Min. Efficiency Cooling System and Low-Cost Envelope	0	0	0
Min. Efficiency Cooling System and Title 24 Envelope	0	0	0

Table 2 shows that each upgrade scenario eliminates dangerous temperature exposure for dwelling units across income levels. In the baseline condition, low-income households (0%–80% AMI) experience dangerous temperatures 16% of the year (1,391 of 8,760 hours) and moderate-income (80%–120% AMI) households experience dangerous temperatures 1.2% of the year (104 of 8,760 hours). All upgrades, regardless of cooling system efficiency level, presence of cool roofs, shading, or improvements in envelope, reduced the median number of hours above 86°F to zero across all income levels.

We also examined the effects of building types. In the baseline condition, multifamily buildings experience dangerous temperatures 14% of the year, 1,235 more hours than single-family buildings. However, with any upgrade, the median number of hours above 86°F drops to zero for both building types (Table 3).

Table 3. Median Number of Hours Above 86°F Annually by Single-Family/Multifamily and Upgrade (2035)

Upgrade Scenario	Single-Family	Multifamily
Baseline	15	1,300
Max. Efficiency Cooling System	0	0
Min. Efficiency Cooling System	0	0
Min. Efficiency Cooling System, Cool Roof, and Shading	0	0
Min. Efficiency Cooling System and Low-Cost Envelope	0	0
Min. Efficiency Cooling System and Title 24 Envelope	0	0

2.1.2 Economic Impacts

We also examined the economic impacts on utility bill savings, upgrade costs, simple payback periods, and changes in energy burden. These results provide context for the costs and benefits of the upgrades simulated.

2.1.2.1 Upgrade Costs

Upfront capital costs prevent many households, particularly low- and moderate-income households, from installing energy-efficient building technologies that often result in utility bill savings (Dadzie et al 2018; Klöckner and Nayum 2017). Table 4 shows the median upgrade cost in 2022$ disaggregated by income level. We provide the lower (25%) and upper (75%) quartiles to provide statistical context. Upgrade costs differ by household income because higher-income households tend to have larger homes; therefore, larger floor, wall, and ceiling areas in these homes increase the amount of insulation or the size of a cooling system required. Importantly, the upgrade costs are highly variable for cooling systems because costs are a function of both efficiency level and system size. More information about upgrade costs is provided in Appendix C.

Table 4. Upgrade Costs by AMI (2022$)

Upgrade Scenario	0%–80% AMI			80%–120% AMI			120%+ AMI		
	Lower Quartile Upgrade Cost	Median Upgrade Cost	Upper Quartile Upgrade Cost	Lower Quartile Upgrade Cost	Median Upgrade Cost	Upper Quartile Upgrade Cost	Lower Quartile Upgrade Cost	Median Upgrade Cost	Upper Quartile Upgrade Cost
Max. Efficiency Cooling System	$5,700	$10,300	$12,000	$9,600	$12,000	$15,000	$11,000	$13,000	$16,000
Min. Efficiency Cooling System	$5,700	$7,200	$9,000	$6,900	$8,400	$11,000	$7,300	$9,600	$12,000
Min. Efficiency Cooling System, Cool Roofs, and Shading	$7,000	$8,900	$13,000	$8,000	$11,000	$17,000	$8,900	$14,000	$20,000
Min. Efficiency Cooling System and Low-Cost Envelope Improvements	$7,000	$8,800	$11,000	$8,200	$10,000	$14,000	$8,900	$12,000	$17,000
Min. Efficiency Cooling System and Title 24 Envelope Improvements	$9,800	$13,000	$18,000	$11,000	$15,000	$22,000	$12,000	$18,000	$26,000

Across all income levels, upgrades without incentives required an investment between $5,700 and $26,000.

The lowest cost whole-home cooling system upgrade for all income levels is the minimum efficiency cooling system, which increases access to safe and comfortable indoor air temperatures. The second-lowest cost upgrade is the minimum efficiency cooling system with low-cost envelope improvements. Chapter 7 (Stenger et al. 2023) finds that cooling access and use and envelope improvements increase the passive survivability of households during a power outage.

2.1.2.2 Utility Bill Impacts by Cooling Access

Impacts on monthly utility bills were a primary concern voiced during LA100 Equity Strategies Steering Committee meetings, community listening sessions, and community meetings. Increases in utility bills have serious consequences for households that struggle to pay their utility bills and can result in utility shutoffs, which pose both immediate and lasting health and economic repercussions (Hernández 2013; Cook et al. 2008).

We approximated utility bills using a fixed rate, which is a flat rate that all customers must pay each year to simply receive utility service, and a volumetric rate, which is the price per unit of energy, kilowatt-hour or therm, for electricity and natural gas respectively. For each of the 50,000 representative households, we multiplied modeled annual electricity and natural gas consumption by the respective volumetric rates and then added to this the flat rate. The fixed and volumetric rates we used for this calculation are shown in Table 5, which is a simplification of utility bills to approximate impact in 2022$.

Table 5. Fixed and Volumetric Rates for Electricity and Natural Gas

Utility Service	Rate Type	Rate	Source
Electricity	Fixed rate ($/year)	$27.6	OpenEI n.d.a.
	Volumetric rate ($/kWh)	$0.187	OpenEI n.d.b.; LADWP
Gas	Fixed rate ($/year)	$59.2	SoCalGas 2022
	Volumetric rate ($/therm)	$1.87	SoCalGas 2022

Utility bill change is the baseline utility bill minus the upgrade scenario utility bill; therefore, a positive value is a decrease in a utility bill (i.e., bill savings) from the baseline to the upgrade scenario. See Chapter 4 (Bowen et al. 2023), for detailed utility bill modeling.

We analyzed results by dwellings that use cooling systems and dwellings that do not have or use cooling. Adding and using a new cooling system increases energy demand, and therefore cost, while also increasing comfort and safety. Figure 3 shows utility bill change in 2022$ across upgrades disaggregated by income (AMI), where a positive value indicates bill savings, and a negative value indicates a bill increase.

Table 6. Annual Utility Bill Change by Income and Cooling Use

Upgrade Scenario	Uses Cooling in Baseline	0%–80% AMI (HUD)	80%–120% AMI (HUD)	120%+ AMI (HUD)
Max. Efficiency Cooling Systems	No	-$120	-$160	-$190
	Yes	$120	$170	$210
Min. Efficiency Cooling System	No	-$160	-$220	-$270
	Yes	$26	$23	$25
Min. Efficiency Cooling System, Cool Roofs, and Shading	No	-$130	-$180	-$230
	Yes	$59	$71	$84
Min. Efficiency Cooling System and Low-Cost Envelope Improvements	No	-$150	-$210	-$250
	Yes	$29	$34	$45
Min. Efficiency Cooling System and Title 24 Envelope Improvements	No	-$190	-$230	-$260
	Yes	$9	$35	$67

Dwellings that have and use cooling in the baseline scenario save on utility bills due to the increased efficiency of the heat pump systems modeled, whereas dwellings without cooling increase utility bills due to increased cooling area served (i.e., none to whole-home cooling) and therefore energy demand. Maximum efficiency cooling systems save $120–$210 compared to minimum efficiency savings of $23–$26 annually. Therefore, while the higher efficiency systems are more expensive initially, they provide greater utility bill savings.

2.1.2.3 Utility Bill Impacts by Dwelling Size

Utility bills for dwellings with cooling use in the baseline were normalized by the size of the dwelling to explore utility costs per square foot by housing type, as shown in Figure 3.

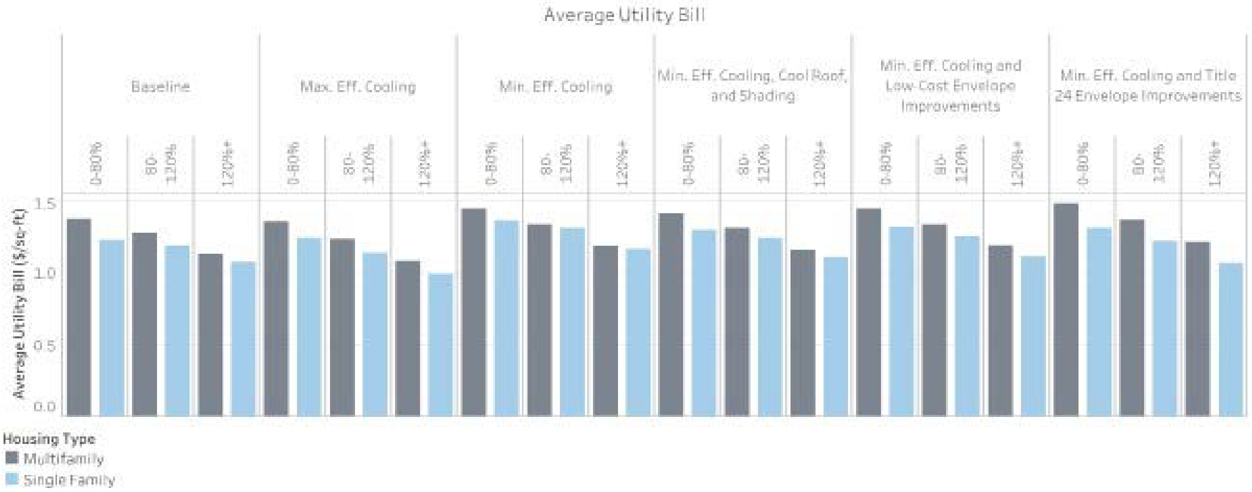

Figure 3. Annual utility bill change by income and cooling access

Multifamily dwelling units have higher utility bills per square foot than single-family units regardless of upgrade type, in part, because of fixed utility charges. It is important to note that multifamily dwelling units have a lower median annual utility bill compared to single-family dwelling units; approximately $910 and $1550 for multifamily and single-family, respectively. Single-family dwelling units are larger than multifamily dwelling units, which is a key driver of utility bills.

2.1.2.4 Impact of Federal Funding

Using federal rebates and funding can enable more low-income households to adopt technologies that provide long-term savings but have higher upfront costs. The Inflation Reduction Act of 2022 (IRA)[8] funds rebates, administered through state energy offices, for homeowners to decrease home energy consumption (IRA Section 50121) and electrify their homes (IRA Section 50122). The U.S. Department of Energy allocated $292,000,000 for the Home Owner Managing Energy Savings (HOMES) rebate program and $290,000,000 for the Home Electrification rebate program for the State of California (DOE 2022a). If Los Angeles receives a budget proportional to its population (approximately 10%), and 20% is allocated for program administration, technical assistance, and outreach, LA households could anticipate receiving $23 million in HOMES rebate funding and $23 million in Home Electrification funding. For the HOMES rebate program, all households, regardless of income, are eligible for funding, but 0%–80% AMI households receive higher rebates. For the Home Electrification program, 100% of the funds are allocated for 0%–150% AMI households and 0%–80% AMI households receive a higher rebate.

Table 7 shows the distribution of income and eligibility for IRA rebates by low- and moderate-income households in Los Angeles. If all 0%–80% AMI households receive the maximum combined rebate of $8,000 from HOMES and $14,500 from Home Electrification, this would cost $19.2 billion. If all 80%–150% AMI households received the maximum combined rebate of $4,000 from HOMES and $14,500 from Home Electrification, this would cost $4.8 billion. Given the program budgets, HOMES could fund retrofits in approximately 0.12% of 0%–150% AMI households, and Home Electrification could fund retrofits in approximately 0.48% of 0%–150% AMI households. Therefore, significant additional funding would be required to supplement federal funding.

Approved projects for the Home Electrification rebates could be a part of new construction, replace nonelectric appliances, or be first-time purchases, and could include electric heat pumps for space heating and cooling (up to $8,000); insulation, air sealing, and material to improve ventilation (up to $1,600); electric wiring (up to $2,500), and electric panel upgrades (up to $4,000). For the lowest income households (0%–80% AMI), 100% of the project costs can be covered.

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[8] "H.R.5376: Inflation Reduction Act of 2022," https://www.congress.gov/bill/117th-congress/house-bill/5376/text

Table 7. Distribution of Eligibility for IRA Rebates by Low- and Moderate-Income Households

	Household Income	
	0%–80% AMI	**80%–120% AMI**
Eligible LA Renter (number of households)	665,000	152,000
Eligible LA Owner (number of households)	187,000	108,000
Total Eligible Households	**852,000**	**260,000**
IRA Section 50121 HOMES rebate: 20%–35% savings	80% of cost up to $4,000	50% of cost up to $2,000
IRA Section 50121 HOMES rebate: 35%+ savings	80% of cost up to $8,000	50% of cost up to $4,000
IRA Section 50122 Home Electrification rebate	100% of cost up to $14,000 plus $500 for installation	50% of cost up to $14,000 plus $500 for installation

With IRA Section 50122 rebates, LADWP could generally install mini-split heat pumps—at an average cost of $7,000 per pump—in low-income households (0%–80% AMI) without incurring any debt or payment plans through a direct installation plan. For more information on using IRA rebates with building technologies and the potential for a pay-as-you-save program, see Chapter 4 (Bowen et al. 2023).[9]

In addition, the federal Weatherization Assistance Program reduces energy costs for low-income households by increasing the energy efficiency of their homes while ensuring their health and safety. The program supports 8,500 jobs and provides weatherization services to approximately 35,000 homes every year using U.S. Department of Energy funds. In 2023, the average cost-per-unit limit for cost-effective upgrades, such as air sealing, shell, and heating and cooling measures in low-income, single-family, and multifamily dwellings was $8,250 (DOE 2022b). The Weatherization Assistance Program also provides training and resources for workforce development.[10]

IRA Section 50123 provides $200 million to reduce the cost of training, testing, and certifying contractors, as well as partnering with nonprofit organizations to develop and implement a program. Recruiting and prioritizing individuals from disadvantaged communities (DACs) can be a strategic and equitable approach to deploying and building energy efficiency programs. Using fiscal year 2022 allocations from the Department of Energy, California may receive

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[9] We do not consider the measured energy savings of 15%–20% as specified in the HOMES rebate because leadership in the Department of Energy's State and Community Energy Programs, the office administering the IRA rebate program, expressed concerns that it may require a complicated system of verification that will be difficult for municipalities and utilities to implement. https://www.energy.gov/scep/ira-home-energy-rebate-programs-informational-webinar-text-version

[10] "Workforce Development Toolkit for the Weatherization Assistance Program," U.S. Department of Energy, https://www.energy.gov/scep/wap/workforce-development-toolkit-weatherization-assistance-program.

approximately 6.8%, or $13,500,000, of IRA Section 50123 contractor education and training funding. If Los Angeles receives a budget proportional to the city population (approximately 10%), approximately $1,400,000 would be available for contractor education and training in Los Angeles.

2.1.2.5 Simple Payback Period

We calculated the simple payback period for whole-home cooling upgrade scenarios for dwellings with existing cooling access in the baseline case. Some dwellings without cooling access might never see a payback because the added cooling equipment increases electricity use (and cost) by providing a service that was initially unavailable. In Table 8, we show the median simple payback period for households that have cooling access in the baseline condition. We segment cooling access by dwellings in the baseline condition with full space conditioning (i.e., whole-home cooling) and dwellings with partial space conditioning. Simple payback period is calculated by dividing the total upgrade costs by the annual utility bill savings. These payback periods are conservative estimates because they do not consider the avoided costs of replacing the baseline heating and cooling systems. In addition, we do not consider the health benefits of increased comfort or decreased exposure to heat.

Table 8. Simple Payback Period (years) by Income, Tenure, and Initial Cooling Access Type

		Owner		**Renter**	
Upgrade Scenario	**Income (% AMI)**	**Full Space Conditioning**	**Partial Space Conditioning[a]**	**Full Space Conditioning**	**Partial Space Conditioning[a]**
Max. Cooling Efficiency System	0%–80%	31	N/A	40	26
	80%–120%	31	20	40	23
	120%+	30	19	41	15
Min. Cooling Efficiency System	0%–80%	16	N/A	24	N/A
	80%–120%	15	N/A	24	N/A
	120%+	17	N/A	25	N/A
Min. Cooling Efficiency System, Cool Roofs, and Shading	0%–80%	29	N/A	33	32
	80%–120%	29	N/A	32	26
	120%+	30	N/A	34	N/A
Min. Cooling Efficiency System and Low-Cost Envelope Improvements	0%–80%	23	N/A	28	N/A
	80%–120%	23	N/A	28	N/A
	120%+	23	N/A	28	N/A
Min. Cooling Efficiency	0%–80%	36	N/A	39	N/A
	80%–120%	35	N/A	36	N/A

		Owner		Renter	
Upgrade Scenario	**Income (% AMI)**	**Full Space Conditioning**	**Partial Space Conditioning[a]**	**Full Space Conditioning**	**Partial Space Conditioning[a]**
System and Title 24 Envelope Improvements	120%+	36	N/A	36	N/A

[a] N/A means there was no simple payback period because of increased service (and thus an increased utility bill) from partial to full space conditioning.

The whole-home minimum cooling efficiency upgrade provides the quickest payback of any upgrade, which aligns with similar analysis for Southern California (Booten, Winkler, and Faramarzi 2022). For this upgrade, low-income owners have the quickest payback period of 16 years, whereas renters have a simple payback of 24 years. Across all whole-home upgrades, owners generally have a lower payback period than renters because owners have a higher utility bill savings than renters, largely due to larger dwelling sizes. In most scenarios, these conservatively estimated payback periods exceed system lifetimes for Los Angeles. Therefore, we examined the effects of IRA rebates and partial cooling for dwellings without cooling.

We evaluated the simple payback period of the same whole-home upgrades with IRA rebates. We examined two different rebates, the Home Energy Performance-Based, Whole-House rebate of the HOMES program and the High-Efficiency rebate of the Electric Home program. We applied the HOMES rebate to dwelling units over 120% AMI, based on energy saved, and the High-Efficiency Electric Home rebate to dwellings under the 120% AMI level.

Table 9. Simple Payback Period (years) with Maximum IRA Rebates

Upgrade Scenario	Income (% AMI)	Owner		Renter	
		Full Space Conditioning	**Partial Space Conditioning***	**Full Space Conditioning**	**Partial Space Conditioning***
Max. Efficiency Cooling System	0–80%	2.6	2.7	3.7	3.7
	80%–120%	2.4	2.2	3.5	2.8
	120%+	2.3	2.2	3.7	3.6
Min. Efficiency Cooling System	0%–80%	0.4	0.3	0.45	0.63
	80%–120%	0.4	0.4	0.19	0.23
	120%+	0.3	0.3	0.45	0.56
Min. Efficiency Cooling System, Cool Roof, and Shading	0%–80%	2.7	2.6	3.8	4.1
	80%–120%	2.4	2.1	3.0	3.1
	120%+	2.3	2.2	3.8	4.1

Upgrade Scenario	Income (% AMI)	Owner		Renter	
		Full Space Conditioning	Partial Space Conditioning*	Full Space Conditioning	Partial Space Conditioning*
Min. Efficiency Cooling System and Low-Cost Envelope Improvements	0%–80%	0.94	0.75	1.2	1.5
	80%–120%	0.88	0.67	0.76	0.53
	120%+	0.72	0.67	1.1	1.4
Min. Efficiency Cooling System and Title 24 Envelope Improvements	0%–80%	4.3	4.3	6.2	6.5
	80%–120%	4.1	4.3	5.4	5.8
	120%+	3.8	3.7	6.0	5.8

With IRA rebates, the simple payback period for whole-home cooling decreases to 0–6 years across all upgrades, income levels, and tenure, which is well under the expected lifetimes of the technologies included in the upgrades. However, rebate program budgets are limited and can fund retrofits in less than 1% of 0%–150% AMI households. Therefore, significant additional funding or alternative implementation strategies would be required to supplement federal funding.

2.1.2.6 Energy Burden

Energy burden measures utility bills as a percentage of household income, where 6% is considered high energy burden and needs attention or intervention (Colton 2011). Figure 4 shows the average energy burden by upgrade scenario and income level.

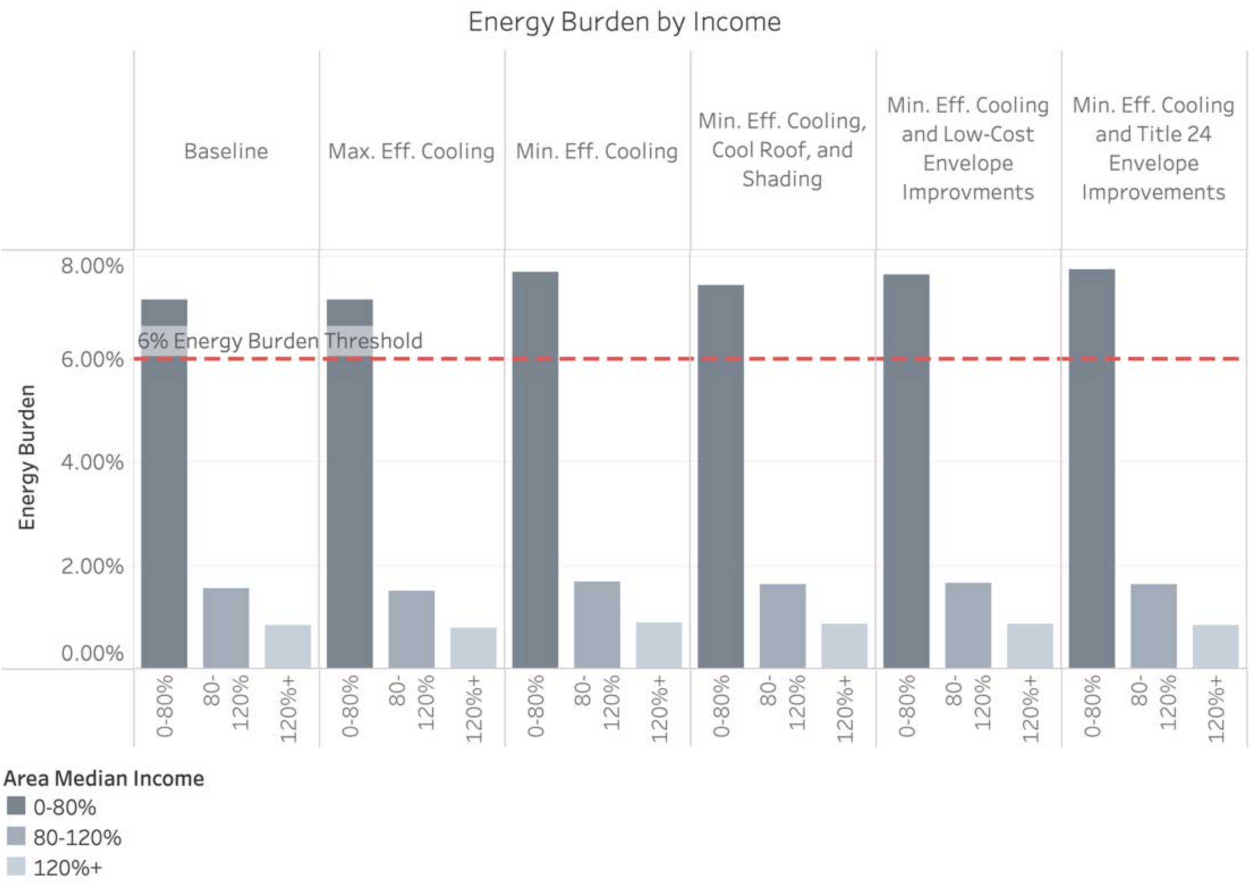

Figure 4. Average energy burden by income under the five whole-home cooling upgrade scenarios

On average, low-income households (0%–80% AMI) are above the 6% energy burden threshold regardless of whole-home cooling upgrade scenario, whereas moderate- and higher-income households are below the threshold.

The upgrades slightly increased the average energy burden for low-income dwellings, in part because of increased cooling access and use. For low-income households, we estimated the number of Los Angeles households that were energy-burdened by type of cooling access for the baseline and minimum efficiency cooling access.

When a household increases access to cooling, electricity demand and utility bills can increase. Given that low-income households are most energy-burdened, the number of low-income (0%–30%, 30%–60%, and 60%–80%) dwellings in the baseline and minimum effeciency cooling system upgrade scenarios that are above this 6% threshold are shown in Table 10.

Table 10. Estimated Number of Los Angeles Households Above Energy Burden of 6.0%

Baseline Cooling Access	Income (% AMI)	Dwelling Units in Baseline Scenario	Dwelling Units in Max. Efficiency Cooling System Upgrade Scenario	Percentage Change from Baseline to Min. Efficiency Cooling System
None	0%–30%	59,000	69,000	17%
	30%–60%	1,300	2,800	120%
	60%–80%	63	63	0%
Partial Space Conditioning	0%–30%	39,000	41,000	5%
	30%–60%	2,200	2,400	7%
	60%–80%	250	220	-13%
100% Conditioned	0%–30%	110,000	104,000	-7%
	30%–60%	13,000	6,700	-48%
	60%–80%	880	350	-61%

Currently, 13.4% of Los Angeles households are both energy-burdened and extremely low-income (0%–30% AMI), including an estimated 59,000 households without cooling access. When maximum efficiency cooling (through a heat pump that cools and heats 100% of the dwelling floor area) is provided for these households with no existing cooling, extremely low-income, the number of energy-burdened households increases by 17%, yet when households who already have whole-home cooling receive a maximum efficiency cooling, energy burden decreases by 7%. Providing maximum efficiency, whole-home cooling to 30%–60% and 60%–80% AMI households with cooling can reduce energy burden by 48% and 61%, respectively. In short, the increase in area of a dwelling cooled and duration of cooling increases both energy usage and energy burden. Yet, more efficient whole-home cooling systems for low-income households with whole-home cooling reduces energy burden relative to the baseline.

Low-income families will more likely have less disposable income to spend on these upgrades, and less access to low-interest financing and credit (Albanesi, DeGiorgi, and Nosal 2017). Because their basic survival needs are met, high-income households have the flexibility for upfront capital expenditures with deferred savings. Low-income households do not have this flexibility because they are driven to meet basic needs and might be confined to technologies with a rapid return and opt out of technologies with larger long-term savings potential (Newell and Siikamaki 2015).

2.2 Cooling One Room for Those Without Cooling

Nearly a quarter of LA households have no cooling technologies in their dwellings. As shown in Section 2.1.2.2 (page 8), adding whole-home cooling for dwelling units without cooling access means high upfront costs and can increase utility bills. The purpose of this analysis is to understand the costs of providing cooling to one room in a dwelling through a window/individual room cooling unit to a critical area of a dwelling unit, such as a bedroom or a living room.

We modeled a minimum and maximum efficiency system for dwelling units that did not have access to cooling in the baseline scenario. The minimum efficiency system models the lowest efficiency and least expensive room AC unit available on the market. The maximum efficiency system models a mini-split heat pump that only provides cooling to a single room and is somewhat less expensive than sizing a mini-split heat pump to cool an entire dwelling. To approximate cooling access for a single, critical room in the dwelling unit, we varied the percentage of conditioned space based on the number of bedrooms in each dwelling unit.

Cooling is provided year-round as needed, regardless of cooling season. Normally, a set of buildings has a wide range of cooling set points. We found that cooling set point is highly correlated with building type. To replicate this distribution, we assigned the following cooling set points:

- Single-family attached, single-family detached, and mobile homes were assigned a cooling set point of 76°F.
- Multifamily buildings with two to four units were assigned a cooling set point of 74°F.
- Multifamily buildings with more than four units were assigned cooling set point of 78°F.

Table 11 shows the upgrade costs associated with the minimum and maximum efficiency partial space conditioning cooling systems modeled for the lower quartile (25%), median, and upper quartile (75%).

Table 11. Upgrade Costs by Income to Cool One Room

	0%–80% AMI			**80%–120% AMI**			**120%+ AMI**		
Upgrade	25%	50%	75%	25%	50%	75%	25%	50%	75%
Min. Efficiency Partial Space Conditioning (2022$)	530	660	800	530	700	920	550	750	1,000
Max. Efficiency Partial Space Conditioning (2022$)	2,200	2,800	3,500	2,200	3,000	4,200	2,300	3,300	4,800

Cooling one room costs much less than whole-home cooling with minimum efficiency systems. The maximum and minimum efficiency partial space conditioning systems are approximately 65% ($4,400) and 90% ($6,500) less expensive, respectively, than minimum efficiency whole-home cooling systems, Table 4 (page 7).

Table 12 shows estimated labor and equipment costs if LADWP provided one-room cooling for all households without cooling by income.

Table 12. Estimated Costs to Cool One Room in Dwellings Without Cooling Access

Upgrade	0%–80% AMI	80%–120% AMI	120%+ AMI
Number of LA households without cooling	230,000	56,000	87,000
Min. Efficiency Partial Space Conditioning	$160,000,000	$44,000,000	$74,000,000
Max. Efficiency Partial Space Conditioning	$720,000,000	$190,000,000	$330,000,000

Table 13 shows the annual utility bill change for both maximum and minimum efficiency partial space conditioning systems (a negative number indicates a bill increase).

Table 13. Median Annual Utility Bill Change (2022$) for Partial Space Conditioning by Income

Upgrade Scenario	0%-80% AMI	80%-120% AMI	120%+ AMI
Min. Efficiency Partial Space Conditioning	-180	-170	-160
Max. Efficiency Partial Space Conditioning	-150	-150	-140

For low-income (0%–80% AMI) households, both partial space conditioning upgrades increase the annual utility bill. As income level decreases, utility bills increase. This may be, in part, because low-income households tend to be older and less insulated than higher-income households, which results in more energy to cool. Cooling one room is less expensive in upfront costs than cooling the entire household but delivers only a fraction of the cooling load. Because of model limitations, we cannot determine whether the systems will maintain the cooling set point in the room in which they are located.[11]

Cooling one room for low-income (0%–80% AMI) households without cooling in the baseline increases utility bills by $150 for maximum efficiency partial cooling and $180 for minimum efficiency partial cooling. In comparison, cooling the entire dwelling for the same group increases utility bills by $120 for maximum efficiency cooling systems and $160 for minimum efficiency cooling systems. In short, whole-home cooling with a heat pump, while having higher upfront costs, is generally less costly to operate than cooling one room.

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[11] Modeling results for cooling one room cannot be compared directly to the costs and benefits delivered by providing whole-home cooling.

3 Equity Strategies Discussion

Residential building stock modeling indicates extremely low-income households will experience dangerous indoor temperatures for roughly one-third of the year by 2035. Lack of access to and use of cooling is a key driver of dangerous temperature exposure among low- and moderate-income households: less than 50% of low-income households in Los Angeles use cooling and more than 30% of extremely low-income (0%–30% AMI) households lack access to cooling. Risk of dangerous temperature exposure is much higher for multifamily building residents, and most low-income households live in multifamily buildings.

Our modeling indicates access to and use of cooling could be a critical strategy to maintain safe and comfortable home temperatures, especially as the climate warms. Combining envelope improvements with cooling systems was found to not provide added benefits for maintaining safe temperatures but added substantial upfront costs. Utility bill savings from heat pumps, as well as heat pumps combined with envelope improvements or cool roofs and shading interventions, were found to be substantially higher for owner-occupied, single-family homes than for multifamily homes.

Our modeling results align with Chapter 7 (Stenger et al. 2023), which describes findings on resilience in a power outage during a heat wave. Access to cooling through a heat pump enables households to start a power outage at safe temperatures.

To improve equitable outcomes in LA's transition to clean energy, the following strategies synthesize baseline equity analysis, community guidance, and integrated housing stock and sociodemographic modeling:

- **Short Term**: Provide affordable access to whole-home cooling through a heat pump before envelope improvements for households most at risk for dangerous heat exposure: low-income households in multifamily residential buildings.
- **Short Term**: Deliver direct installation to cool one room in extremely low-income households (0%–30% AMI) or deploy rebates used at point of purchase.
- **Short Term**: Issue rebates for heat pumps as part of the Cool LA Program to provide up to 29% more energy-efficient cooling for equivalent total lifecycle costs than the current rebates for window-unit ACs.
- **Short Term**: Reduce application time and/or auto-enroll extremely low-income households who receive Cool LA rebates for partial conditioning (i.e., room AC) into a bill assistance program to mitigate increased energy burdens.
- **Short Term**: Combine federal IRA or Weatherization Assistance Program funding with existing LADWP rebates to augment LADWP's Home Energy Improvement Program, Cool LA program, and other programs to lower the equipment costs of heat pumps and envelope efficiency upgrades for low-income households.
- **Short Term**: Expand LADWP's Home Energy Improvement Program (LADWP 2023) to include funding for necessary renovations and electrical upgrades to ensure the ability to install a heat pump.

- **Long Term**: Evaluate contractors representing DACs in current LADWP contracts, and support apprenticeship programs in DACs for HVAC entrepreneurship and educational opportunities—importantly, heat pump installation training and demonstrations.

Table 14 (page 21) summarizes the expected benefit and cost (where known) of each strategy, as well as the timeline for implementation (short or long term), the party responsible for implementing the strategy, and metrics for measuring the success of the strategy. The estimated costs summarize the materials and labor costs for each dwelling to receive the upgrade for the demographic as described in the equity strategy.

Equity strategies to provide program outreach and technical assistance and to support apprenticeship programs are discussed in detail in Chapter 3 (Romero-Lankao, Blanco, and Rosner 2023).

The synthesis of baseline equity conditions, community solutions guidance, and modeling and analysis key findings into equity strategies is shown in Figure 5 (page 23). These figures were shared with the LA100 Equity Strategies Steering Committee and Advisory Committee and were revised based on their feedback and guidance.

Table 14. Equity Strategy Benefit, Cost, Timeline, Responsible Party[12], and Evaluation Metrics

Equity Strategy	Benefit/Impact	Cost	Metric
Short term: Deliver direct installation to cool one room in extremely low-income households (0%–30%) or deploy rebates used at point of purchase.	Extremely low-income households are projected to experience more than two months of exposure to dangerous indoor temperatures in 2035. Providing whole-home cooling eliminates dangerous heat exposure.	Whole home min. efficiency cooling system upgrade costs are $5,700–$9,000 and one-room minimum efficiency cooling costs for low-income households are $530–$800 per home. Installing Min. Efficiency cooling for one room in all extremely low-income households without cooling would cost $79 million.	110,000 extremely low-income LA households lack cooling $7.2 million/year 2024–2035
Short term: Issue rebates for heat pumps as part of the Cool LA Program to provide up to 29% more energy-efficient cooling for equivalent total lifecycle costs than the current rebates for window-unit ACs.	32% of extremely low-income (0%–30% AMI) households in Los Angeles lack access to cooling. Cool LA provides up to $225 on new cooling units and a $25 rebate to dispose of an old AC system.	If the City of Los Angeles provided the maximum Cool LA rebate for the purchase of a new AC system and the removal of an old system ($250) for every extremely low-income household without cooling, it would cost $58 million.	230,000 0%–80% AMI LA households without cooling
Short term: Auto-enroll extremely low-income households who receive Cool LA rebates for a room AC unit into a bill assistance and level pay programs to mitigate increased energy burdens.	Assuming a set point between 74°F and 78°F, cooling one room of dwelling would increase annual average utility costs between $140 and $180.	If LADWP covered 20% of utility bills for low- and moderate-income households with an energy burden of 6% or more, it would cost $4 million per year.	Percentage of eligible households enrolled in program. Average bill assistance enrollment time of less than 10 minutes on a smart phone.
Short term: Install upgrades in public housing where upgrades will not increase rents. Establish a mechanism to mitigate rent increases from upgrades elsewhere.	Improve comfort and health without increased rent. More than 95% of low-income households living in multifamily buildings are renters.	Potentially limited to administrative costs for implementing rent increase restrictions post-upgrade.	Number or percent of upgrades implemented in public housing.

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[12] LADWP is the primary responsible party for the equity strategies.

Equity Strategy	Benefit/Impact	Cost	Metric
Short term: Combine IRA or Weatherization Assistance Program funding with LADWP rebates to augment LADWP's Home Energy Improvement Program, Cool LA, and other programs to lower heat pump and envelope efficiency upgrade costs for low-income households.	The Weatherization Assistance Program covered an average of $8,250 per dwelling in low-income households for energy efficiency upgrades. IRA Section 50122 covers up to $8,000 for heat pumps in low-income households.	A total of 1,500 low-income (0%–80% AMI) households could be covered by federal funding available through IRA Section 50122. Providing the $250/dwelling rebate would reduce upfront cost of low-income households (0%–80% AMI) by 3.7%.	Number of households with upgrades a result of rebates.
Short term: Expand LADWP's Home Energy Improvement Program[a] to include funding for necessary renovations and electrical upgrades to ensure the ability to install a heat pump.	Cooling through heat pumps can require electrical panel upgrades. IRA Section 50122 provides rebates up to $2,500 for electrical wiring and $4,000 for electrical panel upgrades.	Electric panel upgrade costs were estimated to be between $1,300 and $5,000 (NV5 2022).	Number of electrical panel upgrades as a result of energy efficiency and cooling improvements.
Long term: Support apprenticeship programs in DACs for HVAC entrepreneurship and educational opportunities, especially heat pump installation training and demonstrations.	If Los Angeles receives a budget proportional to the city population (approximately 10% of California population), approximately $1,350,000 would be available for contractor education and training from IRA Section 50123.	Implementing apprenticeship programs requires effective coordination with existing trade unions and contractors to demonstrate effective technologies. Centering DACs within these trades will require investments with educational systems to recruit and retain talent.	Number of apprentices enrolled in supported programs from DACs. Number and percentage of contractors representing DACs in LADWP contracts.

[a] "LADWP's 'Cool Roof' Rebates Reduce Costs and Save Energy," LADWP, accessed April 14, 2023, https://www.ladwpnews.com/ladwps-cool-roof-rebates-reduce-costs-and-save-energy/.

Baseline Equity

- Less than 50% of low-income households (0–80% AMI) use cooling. More than 30% of extremely low-income (0–30% AMI) households lack access to cooling.
- The majority of LADWP residential energy efficiency programs analyzed disproportionately benefited mostly White, mostly non-Hispanic, mostly home-owning, and mostly above-median-income communities.

Community Solutions Guidance

- Ensure LADWP-supported improvements do not increase rents or cause displacement.
- Transparent explanation of benefits and costs of weatherization measures
- Simplified application materials and methods.
- Deliver benefits to low- and moderate-income, renter, energy-burdened households and households in multifamily housing.
- Consistent disadvantaged customer support for safety and comfort maintenance and efficiency upgrades.
- Funded, staffed, culturally informed, and consistent outreach and communication through door-to-door, promotora-type approach

Modeling and Analysis Key Findings

- Low-income (0%-80% AMI) households in Los Angeles are projected to experience nearly two months of exposure to dangerous indoor temperatures by 2035.
- Adding whole-home cooling decreases maximum indoor air temperatures from 93°F to 80°F across all dwelling units.
- Providing cooling for one room with a room AC in every Los Angeles low-income household without cooling would increase annual average utility costs by $181.
- Compared to the baseline, households with cooling access save on their utility bills for all upgrades, income levels and housing types.

Equity Strategies

- **Short term:** Deliver direct installation to cool one room in extremely low-income households or deploy rebates used at point of purchase.
- **Short term:** Issue rebates for heat pumps as part of the Cool LA Program to provide up to 29% more energy-efficient cooling for equivalent total lifecycle costs than the current rebates for window-unit ACs.
- **Short term:** Auto-enroll extremely low-income households who receive Cool LA rebates for a room AC unit into a bill assistance and level pay program to mitigate increased energy burdens.

Figure 5. Synthesis of baseline equity conditions, community solutions guidance, and modeling and analysis key findings into equity strategies

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Appendix A. Data Sources and Assumptions

Table A-1 describes the modeling input data sources.

Table A-1. Summary of Universal Cooling Modeling Data Sources

Data	Source	Description	Resolution	Vintage
DACs	SB 535	DACs are identified as tracts with the highest 25% CalEnviroScreen scores.	Census tract	2022
Residential Energy Consumption Survey (RECS)	U.S. Energy Information Administration	Residential building geometries, characteristics, building types, building technologies, etc.	California	2009 and 2015
California Residential Appliance Saturation Study	RASS 2019	Residential building stock and appliance saturation study for the LADWP service territory	LADWP service territory and other building stock segments	2019
American Community Survey	U.S. American Community Survey	Income, tenure (renter/owner), Federal Poverty Level, % AMI	Public Use Micro Area (PUMA) data	2015–2019
Weather File	AMY3	Weather data used for forecasting into 2035	ZIP code	2012
LADWP Low-Income Assistance Program Eligibility	LADWP	Low-income eligibility for LADWP assistance programs	Census tract	2022
California Alternative Rate for Energy eligibility	California Public Utility Commission	Income eligibility and limits	Census tract	2022
California electronic Technical Reference Manual (eTRM)	California Technical Forum	Wall insulation, ceiling insulation, water heating, cooking range, clothes drying, HVAC (air-source heat pump, mini-split heat pump, furnace,	Material costs, labor costs, labor hours	2012

Data	Source	Description	Resolution	Vintage
		wall/floor furnace, AC, room AC)		
LBL Cost Data	Lawrence Berkeley National Laboratory (LBL)	Water heating, air sealing, wall insulation, ceiling insulation, windows, clothes drying, HVAC (ASHP, mini-split heat pump, natural gas furnace, AC)	Total project costs	2020
National Residential Efficiency Measures Database	NREL	Water heating, cooking range, clothes drying, air sealing, wall insulation, ceiling insulation, windows, HVAC (ASHP, baseboards, boilers, mini-split heat pump, furnaces, wall/floor furnaces, AC, room AC)	Total project costs	2010
RSMeans data	RSMeans	Water heating, wall insulation, ceiling insulation, lighting, windows, HVAC (boiler, furnace, fan coil AC, ASHP)	Material cost, differentiated labor hourly rate, labor hours, location material and labor factors	Varied

ASHP = air-source heat pump, LADWP = Los Angeles Department of Water and Power, LBL = Lawrence Berkeley National Laboratory, NREL = National Renewable Energy Laboratory.

A.1 Assumptions

Table A-2 provides the detailed building upgrades modeled for full space conditioning.

Table A-2. Characteristics of Full Space Conditioning Upgrades Modeled

Upgrade	Heat Pump	Window U-Factor	Window SHGC	Ceiling R-Value	Wall R-Value	Infiltration	Shading and Roofing
Baseline	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Maximum Efficiency Heat Pump	ASHP SEER 26.1, 11 heating seasonal performance factor (HSPF) Mini-split heat pump SEER 33.1, 13.5	N/A	N/A	N/A	N/A	N/A	N/A
Minimum Efficiency Heat Pump	ASHP SEER 15, 9.0 HSPF Mini-split heat pump SEER 33.1, 13.5	N/A	N/A	N/A	N/A	N/A	N/A
Min. Efficiency Heat Pump, Cool Roof, and Shading	ASHP SEER 15, 9.0 HSPF Mini-split heat pump SEER 33.1, 13.5	N/A	N/A	N/A	N/A	N/A	South side, Space-dependent Tree shading Roof replaced with reflective materials
Min. Efficiency Heat Pump and Low-Cost Envelope	ASHP SEER 15, 9.0 HSPF Mini-split heat pump SEER 33.1, 13.5	N/A	N/A	N/A	Wood Stud: R-13	25% reduction	N/A

Upgrade	Heat Pump	Window U-Factor	Window SHGC	Ceiling R-Value	Wall R-Value	Infiltration	Shading and Roofing
Min. Efficiency Heat Pump and Title 24 Envelope	ASHP SEER 15, 9.0 HSPF Mini-split heat pump SEER 33.1, 13.5	0.37	0.3	Single Family Wood Stud: R-30 (CEC CZ 6); R-2 (CEC CZ 8, 9, & 16) Single Family CMU/Brick: R-13 (CEC CZ 6, 8, & 9) R-17 (CEC CZ 16) Multifamily: R-22	Single Family Wood Stud: R-15 (CEC CZ 6); R-2 (CEC CZ 8, 9, & 16) Single Family CMU/Brick: R-13 (CEC CZ 6, 8, & 9); R-17 (CEC CZ 16) Multifamily Wood Stud: R-13 Multifamily CMU/Brick: R-2	5 ACH50	N/A

SGHC = solar heat gain coefficient, CEC CZ = California Energy Commission climate zone, CMU = concrete masonry unit

A.2 Upgrade Technologies

Heat pumps were sized following the Air Conditioning Contractors of America's Manual J (Rutkowski 2016), and after envelope upgrades were applied to the building model. The minimum efficiency heat pumps were selected, as described by California[13] and federal energy codes (DOE 2022c).

LA100 Equity Strategies Steering Committee members emphasized the importance of passive means to achieve cooling (e.g., shading and cool roofs) so as not to increase the energy usage and thus utility bills. Furthermore, cool roofs were considered because on January 1, 2023, the Los Angeles Municipal Building Code required cool roofs to be installed on new and refurbished homes to reduce AC loads and the possibility of heat-related injuries or death. Along with this, LADWP offers a cool roof rebate program that offsets \$0.20/ft^2 and \$0.30/ft^2 of roof material cost at or above building code requirements respectively (LADWP 2023).

In terms of envelope improvements, NREL investigated the energy efficiency effect of increasing envelope robustness through two distinct envelope improvements: (1) low-cost envelope improvements including R13 insulation for dwelling units with stud wall construction and 25% reduced infiltration for all dwelling units and (2) Title 24 envelope improvements standards required by the California Energy Commission for all new housing units.

Cooling one room of dwelling (i.e., partial space conditioning) was modeled for dwellings without cooling access in the baseline condition. We modeled a low-efficiency room air conditioner (EER 10.7) and a high-efficiency, cooling-only mini-split heat pump (SEER 20.0).

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[13] "Building Energy Efficiency Standards: Title 24," California Energy Commission, https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards.

Appendix B. Modeling Universal Cooling Access in Los Angeles Housing Stock Using ResStock

We developed upgrade scenarios for cooling use and various kinds of building upgrades. To ensure universal access to cooling, we changed two key upgrade parameters in the ResStock model. First, we stipulated that every dwelling unit in Los Angeles receive whole-home cooling through either an air-source heat pump or mini-split heat pump based on whether the unit did or did not have ducts, respectively. With this change, all units, regardless of whether they had cooling access in the baseline, would be upgraded to a whole-home cooling with a highly efficient heat pump. Second, we adjusted a parameter that controls whether cooling is used in units where a cooling technology is present. This parameter is used to represent those units that choose to not turn on their cooling systems to save on energy and utility costs. For all upgrades, we switched this parameter so that all units that have cooling systems use those systems to cool the units when needed.

For each upgrade category (e.g., wall insulation), we ensured that units in the Los Angeles building stock were addressed regardless of unit characteristics (e.g., wood stud, concrete masonry unit, or brick wall construction). In this way, we could specify the upgrades for units with different types of wall construction, ceiling construction, foundation construction, and floor construction, along with units in different California Energy Commission climate zones and those of different building types.

The second step to modeling universal cooling access in Los Angeles was to simulate the energy consumption of these units. Simulating this energy consumption was done following this sequence:

1. Create a custom version of the ResStock model.
2. Generate a representative building stock for Los Angeles.
3. Model and calibrate the energy consumption of the representative building stock.
4. Model the energy consumption of the representative building stock with the specified upgrades.

A custom version of ResStock was created by querying public data sources for conditional probability distributions of the building stock characteristics based on national data used in the original ResStock model (e.g., the U.S. Energy Information Administration Residential Energy Consumption Survey) along with more granular data (listed below). And we made the following ResStock updates to enable the use of simulated residential building loads for equity strategy analyses using these more granular data:

- Integrated income (in 2019 U.S. dollars) and housing tenure (renter/owner status) metadata from the 2019 5-year American Community Survey from the U.S. Census Bureau
- Downscaled model geography from the U.S. Census Bureau Public Use Microdata Areas (PUMAs; ResStock's native resolution) to a census tract level using crosswalks weighted by housing unit counts from the 2020 Census Redistricting data

- Calculated income measures using 2019 federal, local, and other relevant program income definitions: AMI, Federal Poverty Level, California Alternate Rate for Energy eligibility, LADWP Low-Income Eligibility, and Disadvantaged Community (DAC)
- Updated appliance saturation and housing characteristic distributions using the 2019 California Residential Appliance Saturation Study[14] to capture the income and tenure differentiation as well as the diversity specific to Los Angeles.

This approach leverages a robust classification suitable for building stock energy models in energy policymaking, where different data sources are mapped together using shared parameters such as location, building type, and year (Langevin et al. 2019).

ResStock uses deterministic quota sampling, with probabilistic combination of non-correlated parameters. For Los Angeles, ResStock used 50,000 samples to represent 1,600,000 dwelling units (approximately 1:31). The samples inform physics-simulation models, specifically EnergyPlus®.

Model construction and articulation are facilitated by the OpenStudio® software development kit and associated residential modeling workflows. We used 2012 TMY3 weather data and forecasted weather to 2035 using the methodology described in the LA100 study (Cochran et al. 2021). Climate zones were specified at the ZIP code level by the California Energy Commission to generate granular weather patterns. Calibration involved numerous improvements to model input data and refinement of probability distribution dependencies.

With the calibrated model, it was possible to apply a specified upgrade and model the energy consumption of the building stock. The building upgrades were applied as what-if scenarios to Los Angeles housing stock and then compared to assess their performance in reducing the maximum living space temperature, thus reducing the time and magnitude of the living space temperature above the cooling set point along with a number of economic analyses of costs associated with these upgrades.

Model outputs include both annual and hourly time series energy use outputs for each sample for major and minor end uses (e.g., electricity and on-site natural gas, propane, and fuel oil use). Outputs for each sample also include HVAC system capacities along with hourly outdoor and living space temperatures for the baseline home and the hypothetical upgraded home.

B.1 Residential Housing Stock

ResStock is a physics-simulation tool that generates statistically representative households (Wilson 2017). It considers the diversity in the age, size, construction practices, installed equipment, appliances, and resident behavior of the housing stock across U.S. geographic regions. ResStock enables a new approach to large-scale residential energy analysis by combining large public and private data sources, statistical sampling, and detailed subhourly

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[14] "2019 Residential Appliance Saturation Study," CEC, https://www.energy.ca.gov/data-reports/surveys/2019-residential-appliance-saturation-study.

building simulations. The tool generates a group of statistically representative building simulation models from a housing parameter space derived from existing residential stock data.

We down-selected the national ResStock model to Los Angeles using the spatial geographies defined by the 2010 U.S. Census Bureau geographies and city boundaries. The down-selected residential model represents 1,500,000 dwelling units, which were taken from the Los Angeles City Planning website (LA City Planning 2023). The dwelling units were distributed to census tracts by the combined use of the 2020 Census Redistricting Data, National Historical Geographic Information System 2020-to-2010 block crosswalk file, and the American Community Survey 2016 5-year dwelling unit counts. ResStock dwelling unit distributions are specified by census tract based on the American Community Survey 2016 5-year survey. A mapping of the dwelling units from census tracts to census blocks was performed using census tract to census block distributions from the 2020 Redistricting Data. The 2020 Redistricting Data were mapped to 2010 U.S. Census geographies using the National Historical Geographic Information System 2020-to-2010 block crosswalk file. The dwelling units were then reaggregated by census tract based on the census blocks in Los Angeles.

The finest geographic granularity of the national version of ResStock is by Public Use Micro Area. PUMAs are a collection of census tracts with an average population of 200,000 and a minimum of population 100,000. For the LA100 Equity Strategies study, census tracts were also added to the model to increase the geographic specificity of the dwelling unit representative models.

For more information about equity metrics, measuring building performance, dimensional blending, impacts of upgrades on DACs, and access to cooling, see Chapter 6 (Stenger et al. 2023).

B.2 Impact of Upgrades in Multifamily Buildings

In Figure B-1, we can see that multifamily dwelling units experience much higher maximum indoor temperatures than single-family dwelling units. However, all upgrades decrease the median maximum indoor temperature significantly. With all upgrades median maximum indoor temperatures are under 82°F, which is under the dangerous temperature threshold of 86°F.

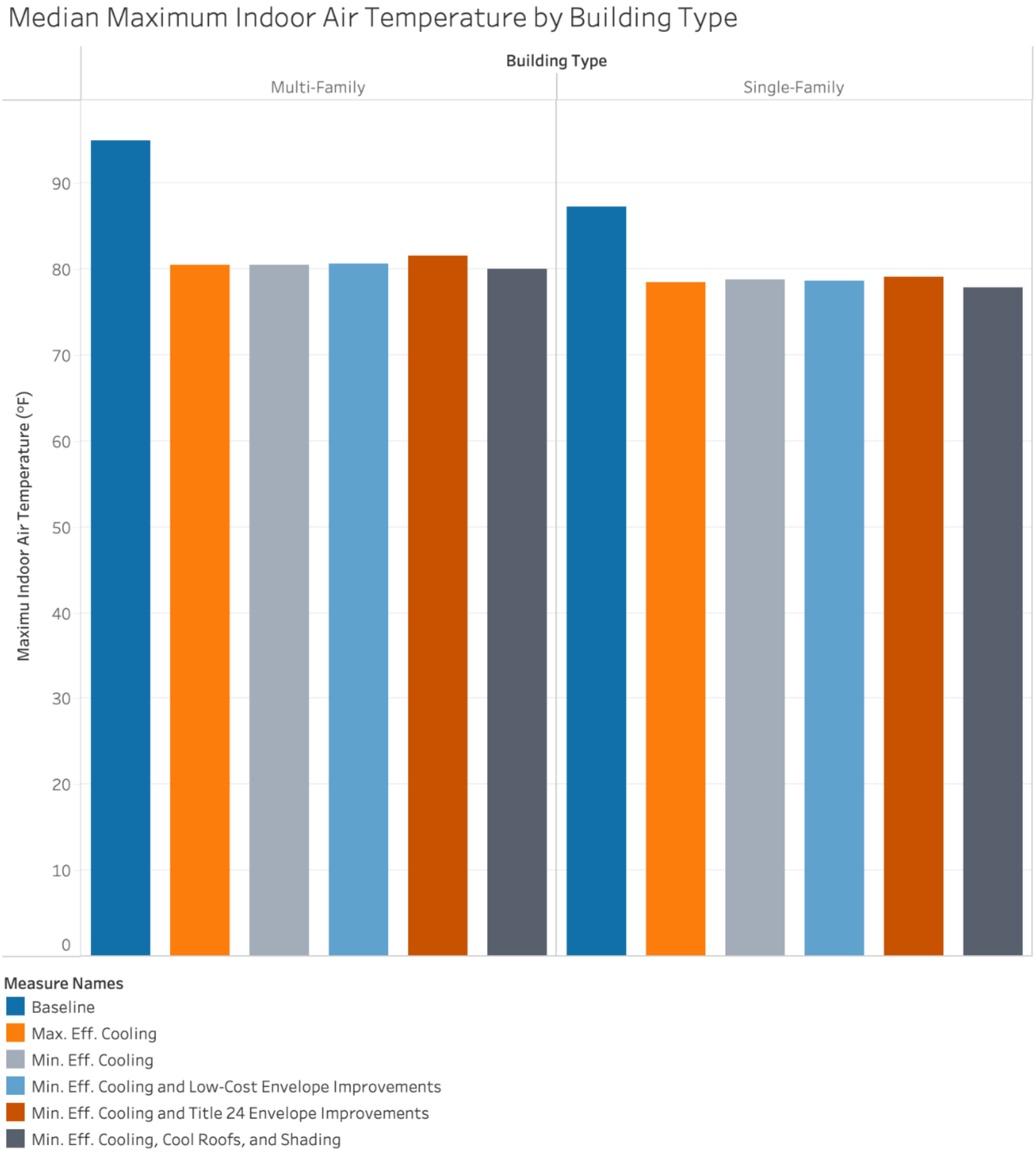

Figure B-1. Maximum indoor temperature by building type

In the baseline upgrade scenario, multifamily dwelling units experience indoor temperatures above 86°F nearly 15% of the year. Regardless of upgrade scenario, the number of hours above 86°F drops to zero for the median value in the building stock simulations.

B.3 Impact of Upgrades by Baseline Access to Cooling

In Table B-1, the average number of hours above 86°F is shown for the baseline and each upgrade, disaggregated by units that used their cooling systems in the baseline compared to those who either did not use their cooling system or who did not have access to cooling in the baseline.

Table B-1. Average Hours Above 86°F by Cooling Use in the Baseline

Upgrade	Uses Cooling	Does Not Use Cooling
Baseline	400	2,700
Heat Pumps	12	12
Heat Pumps, Cool Roofs, and Shading	11	11
Heat Pumps and Low-Cost Envelope Improvements	14	14
Heat Pumps and Title-24 Envelope Improvements	15	170

For all upgrades, units experience a decrease in hours above 86°F regardless of whether cooling was in the baseline. Improved envelope characteristics do not provide for marked improvements in access to safe and comfortable home temperatures, in terms of decreasing the hours above 86°F.

An important consideration in any building upgrade study is the change in fuel consumption. In our analysis, we only applied upgrades to dwelling units connected to the utilities providing electricity and natural gas. Table B-2 and Table B-3 show the median annual electricity and natural gas consumption per dwelling unit.

Table B-2. Median Annual Electricity Consumption (kWh) per Dwelling Unit

	Multifamily			Single-Family		
	0%–80%	80%–120%	120%+	0%–80%	80%–120%	120%+
Baseline	4,400	4,700	4,500	6,900	8,000	8,900
Max. Efficiency Cooling	4,300	4,500	4,300	7,100	7,800	8,300
Min. Efficiency Cooling	4,500	4,600	4,400	6,800	7,300	7,700
Min. Efficiency Cooling, Cool Roof, and Shading	4,700	4,900	4,800	7,900	9,100	9,900
Min. Efficiency Cooling and Low-Cost Envelope Improvements	4,500	4,800	4,600	7,500	8,600	9,300
Min. Efficiency Cooling and Title 24 Envelope Improvements	4,700	4,900	4,800	7,600	8,700	9,500

Table B-3. Median Annual Natural Gas Consumption (therms) per Dwelling Unit

	Multifamily			Single-Family		
	0-80%	80-120%	120%+	0-80%	80-120%	120%+
Baseline	93	88	92	200	230	240
Max. Efficiency Cooling	91	83	88	160	180	180
Min. Efficiency Cooling	90	83	87	160	180	180
Min. Efficiency Cooling, Cool Roof, and Shading	91	83	88	160	180	180
Min. Efficiency Cooling and Low-Cost Envelope Improvements	91	83	88	160	180	180
Min. Efficiency Cooling and Title 24 Envelope Improvements	90	83	87	160	180	180

Based on the upgrades, electricity consumption stays within approximately 15% of the original value regardless of building type or income level, both increasing and decreasing based on the specific upgrade. Single-family buildings have a larger increase due to their larger average sizes, and we see that the Minimum Efficiency Cooling and Title 24 Envelope Improvements show the greatest increase in electricity demand. For natural gas, consumption decreases for dwelling units regardless of upgrade, income level, or building type because space heating is electrified in all dwelling units. Though the largest increases in electricity consumption are in single-family buildings, these dwelling units see a commensurate decrease in natural gas consumption. Again, this is due to energy savings from heating larger spaces.

B.4 Impact on Electrical Grid

One key consideration in building upgrades is the resultant impact on the grid. A shift to electric technologies could create a substantial increase in demand for electricity. This increased demand could impact the grid's ability to provide reliable electricity and could require expansion or upgrade of the grid to support this new, larger load. We sum the total electricity use for all the dwelling units under each upgrade scenario and then compare this total across scenarios. Table B-4 shows the total annual electricity use for all dwelling units for each upgrade scenario.

Table B-4 shows that the baseline modeled LA housing electricity demand will total 9,270 megawatt-hours (MWh) in 2035. The minimum efficiency cooling upgrade scenario increases the total annual electricity demand by slightly more than 10%.

Table B-4. Total Annual Electricity Use for LA Housing Stock in 2035 (MWh)

Baseline	Max. Eff. Cooling	Min. Eff. Cooling	Min. Eff. Cooling, Cool Roofs, and Shading	Min. Eff. Cooling and Low-Cost Envelope Improvements	Min. Eff. Cooling and Title 24 Envelope Improvements
9,300	9,100	10,300	9,800	10,100	10,000

Appendix C. Upgrade Cost Data and Cost Databases

This appendix synthesizes the upgrade cost data for the cooling and envelope efficiency upgrades. For each technology, a table lists the total costs that account for material costs, labor costs, and estimated labor hours. We provide sources for these estimations as well as granularity when costs vary based on square footage or the current state of the dwelling's technology (i.e., insulation). Tables are detailed for cost databases, hardware and online retailers, material costs for air sealing, wall insulation, roof material, tree shading, mechanical ventilation, foundation insulation, windows, attic insulation, HVAC heat pumps, and partial space conditioning.

The cost databases in Table C-1 were used to estimate labor costs, labor hours, and material costs across different envelope efficiency upgrades.

Table C-1. Cost Databases

Name	Who (Where)	Data Collection/Year	Type of Cost Data	Technologies
eTRM	California Technical Forum (California)	Various (Itron Report 2010-2012; RSMeans, various). Data collected from online retailers, wholesalers, suppliers, and others.	Material costs Labor costs Labor hours	Wall insulation, ceiling insulation, HVAC (ASHP, mini-split heat pump)
LBL Cost Data	LBL (Primarily California, Massachusetts, and North Carolina with data from 12 other states)	Survey to contractors with incentives for completion, 2020	Total project costs	Air sealing, wall insulation, ceiling insulation, windows, mechanical ventilation, HVAC (ASHP, mini-split heat pump)
National Residential Efficiency Measures Database	NREL (Nationwide)	2010	Total project costs	Air sealing, wall insulation, ceiling insulation, windows, mechanical ventilation, HVAC (ASHP, mini-split heat pump)
Navigant	Navigant Consulting (MA)	Contractor survey, "webscraping," rebate program invoices, 2018	Total project costs	HVAC (furnace, boiler)
Building construction costs with RSMeans data	RSMeans, (Nationwide)	2022	Material cost, differentiated labor hourly rate, labor hours, location material and labor factors	Wall insulation, ceiling insulation, lighting, windows, HVAC (ASHP)

C.1 Local Hardware Retailers and Online Wholesalers and Suppliers

Table C-2 lists the hardware retailers, online wholesalers, and suppliers whose websites were used to inform the upgrade costs, particularly the equipment costs.

Table C-2. Hardware and Online Retailers

Local Hardware Retailers	Online Wholesalers/Suppliers
Home Depot Lowes	AC Wholesalers Consumers Supply Company Craft Supply eComfort HighSEER National Pump Supply Oswald Supply Supply House The Furnace Outlet

C.2 Technologies

Air Sealing

Air sealing data were only available in the National Residential Efficiency Measures Database (NREMDb) and from the Lawrence Berkeley National Laboratory (LBL) Cost Database. However, only some of the LBL data had pre- and post-ACH50 values, and of that data, few data entries aligned with the project upgrades we specified. The NREMDb had data for some of, but not all, the project upgrades we specified; however, these data were more consistent than the LBL data. Therefore, we chose to use NREMDb data along with a regression to estimate data for the missing project upgrades.

Table C-3. Material Costs for Air Sealing

Labor costs are included in material costs. Unit costs are not applicable. NREMDb is the source of the cost data.

Technology	Variable Cost ($/ft^2)	Source
50 to 37.50 ACH50	2.17 (2010$)	NREMDb[a,b]
40 to 30 ACH50	1.78 (2010?)	NREMDb[a,b]
30 to 22.5 ACH50	1.39 (2010$)	NREMDb[a,b]
25 to 18.75 ACH50	1.20 (2010$)	NREMDb[a,b]
20 to 15 ACH50	1.20 (2010$)	NREMDb[a,b]
15 to 11.25 ACH50	1.20 (2010$)	NREMDb[a,b]
10 to 7.5ACH50	0.63 (2010$)	NREMDb[a,b]
8 to 6 ACH50	0.52 (2010$)	NREMDb[a,b]
7 to 5.25 ACH50	0.52 (2010$)	NREMDb[a,b]

Technology	Variable Cost ($/ft^2)	Source
6 to 4.5 ACH50	0.41 (2010$)	NREMDb[a,b]
5 to 3.75 ACH50	0.31 (2010$)	NREMDb[a,b]
4 to 3 ACH50	0.31(2010$)	NREMDb[a,b]
3 to 2.25 ACH50	0.31 (2010$)	NREMDb[a,b]
2 to 1.5 ACH50	0.31 (2010$)	NREMDb[a,b]
6 to 5 ACH50	0.31 (2010$)	NREMDb
7 to 5 ACH50	0.52 (2010$)	NREMDb
8 to 5 ACH50	0.73 (2010$)	NREMDb
9 to 5 ACH50	0.97 (2010$)	NREMDb, NREMDb[c]
10 to 5 ACH50	1.20 (2010$)	NREMDb
15 to 5 ACH50	2.20 (2010$)	NREMDb
20 to 5 ACH50	3.30 (2010$)	NREMDb
25 to 5 ACH50	4.30 (2010$)	NREMDb
30 to 5 ACH50	5.37 (2010$)	NREMDb[a]
40 to 5 ACH50	7.48 (2010$)	NREMDb[a]
50 to 5 ACH50	9.59 (2010$)	NREMDb[a]
2 to 1 ACH50	0.31 (2010$)	NREMDb
3 to 1 ACH50	0.52 (2010$)	NREMDb
4 to 1 ACH50	0.73 (2010$)	NREMDb
5 to 1 ACH50	0.94 (2010$)	NREMDb
6 to 1 ACH50	1.20 (2010$)	NREMDb
7 to 1 ACH50	1.40 (2010$)	NREMDb
8 to 1 ACH50	1.60 (2010$)	NREMDb
9 to 1 ACH50	1.80 (2010$)	NREMDb, NREMDb[c]
10 to 1 ACH50	2.00 (2010$)	NREMDb
15 to 1 ACH50	3.00 (2010$)	NREMDb
20 to 1 ACH50	4.10 (2010$)	NREMDb
25 to 1 ACH50	5.10 (2010$)	NREMDb
30 to 1 ACH50	6.16 (2010$)	NREMDb[a]
40 to 1 ACH50	8.24 (2010$)	NREMDb[a]
50 to 1 ACH50	10.32 (2010$)	NREMDb[a]

[a] Costs are not exact numbers from the National Residential Efficiency Measures Database, but rather are based on a regression of the available data.

[b] The value used was the original value from the NREMDb, which is in 2010$.

[c] A model linearly interpolated at the starting condition of 8 ACH50 and 10 ACH50 to the upgrade value.

Wall Insulation

For this upgrade, two costs were considered: the cost to upgrade from no insulation to R-19 and the cost to upgrade from either R-7, R-11, or R-15 to R-19. The latter set of insulation upgrades was costed at the same amount. Wall insulation data were available from NREMDb, RSMeans, and the LBL Cost Data. However, only some of the LBL data had pre- and post-insulation values, and wall area was not reported. RSMeans had the most up-to-date data, but it only included batt insulation and sprayed-on insulation. NREMDb had data for the first cost (uninsulated to R-19) for both fiberglass and cellulose insulation. These costs were averaged for the final cost used in this analysis. We assumed the cost to upgrade from an uninsulated wall to a partially insulated wall (R-7, R-11, and R-15 to R-19) would be half the cost to upgrade an uninsulated wall to R-19.

Table C-4. Material Costs for Wall Insulation

Labor costs estimated the type of labor, rate of labor, and number of hours, which are included in the material costs. Unit costs are not applicable. Costs vary based on area of dwelling unit exterior walls (ft^2).

Technology	Variable Cost ($/ft^2, 2019$)	Source
Wood Stud Insulation (Loose fill)	$3.00[a]	NREMDb[b]
Brick Insulation (Loose fill)	$4.40[a]	NREMDb[b]
CMU Insulation (Loose fill)	$4.40[c]	NREMDb[b]
Wood Stud (Uninsulated to R-13)	$2.24[c]	Less 2021
Wood Stud (R-7 or R-11 to R-13)	$0.83[c]	NREMDb: Retrofit Measures for Wood Stud
Wood Stud (Uninsulated to R-20)	$3.10	NREMDb: Retrofit Measures for Wood Stud
Wood Stud (R-7, R-11, R-15, or R-19 to R-20)	$1.65	NREMDb: Retrofit Measures for Wood Stud
Wood Stud (Uninsulated to R-30)	$4.95d	NREMDb: Retrofit Measures for Wood Stud
Wood Stud (R-7 to R-30)	$3.80d	NREMDb: Retrofit Measures for Wood Stud
Wood Stud (R-11to R-30)	$3.14d	NREMDb: Retrofit Measures for Wood Stud
Wood Stud (R-15 to R-30)	$2.48d	NREMDb: Retrofit Measures for Wood Stud
Wood Stud (R-19 to R-30)	$1.82d	NREMDb: Retrofit Measures for Wood Stud

[a] These values are an average of cellulose and fiberglass for the insulation material. The value used was the original value from the NREMDb, which is in 2010$.

[b] These values were available from NREMDb in August 2022. However, these upgrade options are not available in the most recent version of NREMDb.

[c] This is the same value used for the brick insulation (loose fill).

[d] A regression based on two wall insulation levels.

Roof Material

Roof material upgrade data were only available from NREMDb. It had data for some of, but not all, the project upgrades we specified. Missing data were estimated based on similar data that were available.

Table C-5. Material Costs for Roof Material

Labor costs estimated the type of labor, rate of labor, and number of hours, which are included in the material costs. Unit costs are not applicable. Costs vary based on area of dwelling roof (ft^2).

Technology	Variable Cost (2019$)	Source
Asphalt single, white or cool colors	$3.2[a]	RSMeans
Metal, white	$4.0	RSMeans
Tile, white	$9.0[a]	RSMeans

[a] Used for asphalt and composition shingle types.

Tree Shading

Cost information for this upgrade was not available from any of the cost databases nor any of the local hardware retailers and online wholesalers/suppliers (Table C-2). For this upgrade, we researched tree varieties local to the Southern California region that are commonly used in residential areas, and we researched the most affordable trees and suppliers. See Table C-6 for details on the tree we selected, its supplier, and cost. Trees take multiple years to reach mature age for shading a dwelling, which should be taken into account when evaluating this upgrade for potential implementation.

Table C-6. Material Costs for South Shading

Labor costs estimated the type of labor, rate of labor, and number of hours, which are included in the material costs.

Technology	Cost Breakdown	Value (2019$)	Source	Notes
South Shading	Unit cost	$600	Pulled	This is the cost of a Coast Live Oak (*Quercus agrifolia*) sapling in a 24” box (5-10’ tall). The Coast Live Oak is native to Southern California, does well in hardiness zones 9 and 10 and does well in full sun.
	Variable cost	N/A		
	Variable unit			

Mechanical Ventilation

Mechanical ventilation upgrade data were only available from NREMDb and LBL. LBL had records of 65 projects, which included mechanical ventilation; however, these were split among low-cost exhaust fan, energy recovery ventilation, and heat recovery ventilation units, and the LBL records cited only the median heat recovery ventilation unit cost. The NREMDb, on the other hand, gave both a unit and variable cost based on the size of the unit so, we used the data from NREMDb.

Table C-7. Material Costs for Heat Recovery Ventilation

Labor costs estimated the type of labor, rate of labor, and number of hours, which are included in the material costs.

Technology	Cost Breakdown	Value (2019\$)	Source
Heat recovery ventilation (70%)	Unit cost	\$1,300	NREMDb: Retrofit Measures for Mechanical Ventilation
	Variable cost	3.6	
	Variable unit	Flow Rate (cfm)	

Foundation Insulation

Foundation upgrade data were only available from NREMDb. It had data for some of, but not all, the project upgrades we specified; missing data were estimated based on similar data that were available. These substitutions are documented in the Notes column.

Table C-8. Material Costs for Foundation Insulation

Labor costs estimated the type of labor, rate of labor, and number of hours, which are included in the material costs.

Technology	Cost Breakdown (Value 2019\$)	Source	Notes
Slab insulation (uninsulated to R-14)	Unit cost: N/A Variable cost: \$2.6 ft^2 roof	NREMDb: Retrofit Measures for Slab	This cost is associated with R15 exterior, extruded polystyrene, rigid foam board insulation
Foundation wall insulation (uninsulated to R-14)	Unit cost: N/A Variable cost: \$2.2 ft^2 roof	NREMDb: Retrofit Measures for Crawlspace	This cost is associated with R15 exterior, extruded polystyrene, rigid foam board insulation
Foundation wall insulation (R-5 to R-14)	Unit cost: N/A Variable cost: \$1.41 ft^2 roof	NREMDb: Retrofit Measures for Crawlspace	This cost is based on a regression from the Uninsulated to R-14 value
Foundation wall insulation (R-10 to R-14)	Unit cost: N/A Variable cost: \$0.62 ft^2 roof	NREMDb: Retrofit Measures for Crawlspace	This cost is based on a regression from the Uninsulated to R-14 value

Windows

Window upgrade data were available from NREMDb, RSMeans, and the LBL Cost Data. However, some of the LBL data reported only the number of windows replaced and not the window area replaced. The NREMDb includes a cost for the type of window we specified in the upgrade, but these data are not very current. The best data we found were from RSMeans. The cost data were given by specific window type and dimensions. From the window dimensions, we were able to determine the cost per square foot (ft^2) of window for each window in each size and type. For the analysis, we averaged the costs of picture, single-hung, and double-hung windows. Labor costs were estimated based on the type of labor, rate of labor, and number of hours, which are included in the material costs.

Table C-9. Material Costs for Windows

Labor cost included in material cost. Unit cost is not applicable. Costs vary based on area of dwelling windows (ft^2).

Technology	Variable Cost (2019$)	Source
Low-E Double, Non-metal, Air, L-Gain Windows	$31.3	RSMeans
Passive Standard Window (Low-E, Triple, Non-metal, L-Gain)	$46.0	NREMDb: Retrofit Measures for Windows

Attic Insulation

Ceiling insulation data were available from NREMDb, RSMeans, and the LBL Cost Database. However, only some of the LBL data had pre- and post-insulation values, and attic area was not reported. RSMeans had the most up-to-date data, but those data gave only information for batt insulation and sprayed-on insulation. The NREMDb has a variety of datapoints, but those data only correspond with some of the upgrade values in which we were interested. To determine the costs that were unavailable, known values were averaged to get approximate costs. It is important to note that floor insulation was also considered for this study. In multistory buildings, floor and ceiling insulation have the same meaning for dwelling units not on the ground floor. Therefore, these costs are the same where applicable. Labor costs estimated the type of labor, rate of labor, and number of hours, which are included in the material costs.

Table C-10. Material Costs for Attic Insulation

Unit costs are not applicable. Costs vary based on area of attic ceiling (ft^2).

Technology	Variable Costs (2019$)	Source
Uninsulated to R-49	$2.82	Averaged NREMDb costs
R-7 to R-49	$2.31	Averaged NREMDb costs
R-13 to R-49	$2.05	Averaged NREMDb costs
R-19 to R-49	$1.66	Averaged NREMDb costs
R-30 to R-49	$1.05	Averaged NREMDb costs
R-38 to R-49	$0.61	Averaged NREMDb costs
Uninsulated to R-30	$1.50	NREMDb: Ceilings/Roofs
R-7 to R-30	$1.00	NREMDb: Retrofit Measures for Unfinished Attic
R-13 to R-30	$0.77	NREMDb: Retrofit Measures for Unfinished Attic
R-19 to R-30	$0.48	NREMDb: Retrofit Measures for Unfinished Attic
Uninsulated to R-38	$1.90	NREMDb: Retrofit Measures for Unfinished Attic
R-7 to R-38	$1.40	NREMDb: Retrofit Measures for Unfinished Attic

Technology	Variable Costs (2019$)	Source
R-13 to R-38	$1.10	NREMDb: Retrofit Measures for Unfinished Attic
R-19 to R-38	$0.87	NREMDb: Retrofit Measures for Unfinished Attic
R-30 to R-38	$0.87	NREMDb: Retrofit Measures for Unfinished Attic
Uninsulated to R-22	$1.00	NREMDb: Retrofit Measures for Unfinished Attic
R-7 to R-22	$0.54	NREMDb: Retrofit Measures for Unfinished Attic
R-13 and R-19 to R-22	$0.27	NREMDb: Retrofit Measures for Unfinished Attic
Uninsulated to R-60	$2.90	NREMDb
R-7 to R-60	$2.40	NREMDb
R-13 to R-60	$2.10	NREMDb
R-19 to R-60	$1.90	NREMDb
R-30 to R-60	$1.40	NREMDb
R-38 to R-60	$0.99	NREMDb
R-49 to R-60	$0.49	NREMDb

HVAC Heat Pumps

Though several data sources had information on HVAC heat pumps, their cost data were for models that were significantly less efficient than the upgrades we used. The only source with heat pumps with efficiencies close to what we used was a regression created with the LBL Cost Data. For ASHPs, this regression was based on heating seasonal performance factor (HSPF) and capacity; mini-split heat pump costs were based on only capacity. Labor costs estimated the type of labor, rate of labor, and number of hours, which are included in the material costs.

Table C-11. Material Costs for Heat Pumps

Labor costs are included in material costs.

Technology	Cost Breakdown	Value (2019$)	Source
Max. Efficiency ASHP (SEER 26.1, 11 HSPF)	Unit cost	$9,400 (2022$)	Chan, Less, and Walker 2021
	Variable cost	$160 (2022$)	
	Variable unit	kBtu-h	
Min. Efficiency ASHP (SEER 15, 9 HSPF)	Unit cost	$5,700 (2022$)	Chan, Less, and Walker 2021
	Variable cost	$160 (2022$)	
	Variable unit	kBtu-h	
Mini-split heat pump (all efficiencies)	Unit cost	$2,330 (2022$)	Chan, Less, and Walker 2021
	Variable cost	$300 (2022$)	
	Variable unit	kBtu-h	

Partial Space Conditioning

Though several data sources had information on HVAC heat pumps, their cost data were for models that were significantly less efficient than the upgrades we used. The only source with heat pumps with efficiencies close to what we used was a regression created with the LBL Cost Data. For ASHPs, this regression was based on HSPF and capacity; mini-split heat pump costs were only based on capacity. Labor costs estimated the type of labor, rate of labor, and number of hours, which are included in the material costs.

Table C-12. Technology Cost Assumptions

Technology	Cost Type	Cost Breakdown	Value (2019$)	Source
Min. Efficiency Partial Space Conditioning Cooling System (Room AC, EER 10.7)	Material costs	Unit cost	$530 (2022$)	AC wholesalers
		Variable cost	$15.8 (2022$)	
		Variable unit	kBtu-h	
	Labor costs	Labor type	Skilled worker	eTRM
		Labor hours	2	
		Hourly rate	$75	
Max. Efficiency Partial Space Conditioning Cooling System (mini-split air conditioner)	Material costs	Unit cost	$1130 (2022$)	AC wholesalers
		Variable cost	$80 (2022$)	
		Variable unit	kBtu-h	
	Labor costs	Labor type	Electrician/ plumber	eTRM
		Labor hours	7.5	
		Hourly rate	$138.50	

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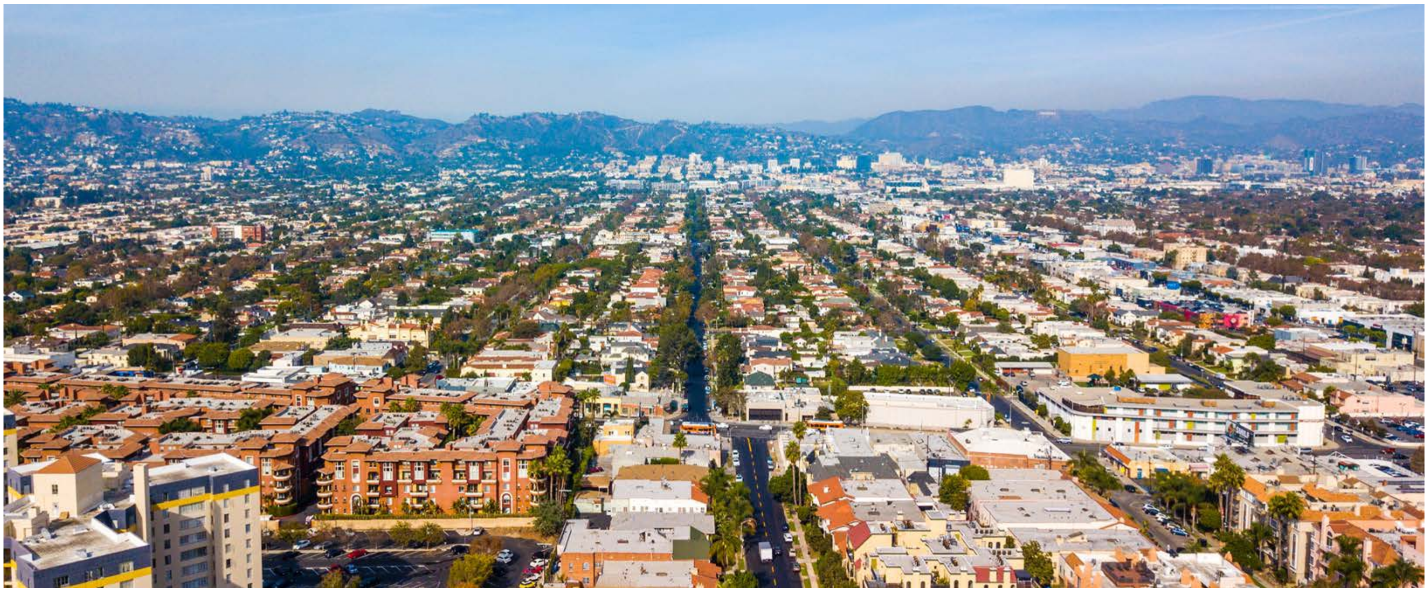
LA100 EQUITY STRATEGIES



Chapter 7: Housing Weatherization and Resilience

FINAL REPORT: LA100 Equity Strategies

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November 2023

LA100 EQUITY STRATEGIES

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Preface

The Los Angeles 100% Renewable Energy Study, or LA100, revealed that although all communities in Los Angeles will share in the air quality and public health benefits of the clean energy transition, increasing equity in participation and outcomes will require intentionally designed policies and programs. The LA100 Equity Strategies project was specifically designed to help Los Angeles identify pathways to such policies and programs in the form of equity strategies. The project aimed to do this by incorporating research and analysis to chart a course toward specific, community-prioritized, and equitable outcomes from the clean energy transition outlined in the LA100 study.

The Project Partners

The Los Angeles Department of Water and Power (LADWP), the National Renewable Energy Laboratory (NREL), and the University of California Los Angeles (UCLA) partnered on the LA100 Equity Strategies project to develop strategies for engaging communities, funding equitable technology and infrastructure investments, expanding existing programs, and designing new programs and policies to improve equity by incorporating what community members themselves know is needed to achieve a more equitable energy future.

The Project Approach

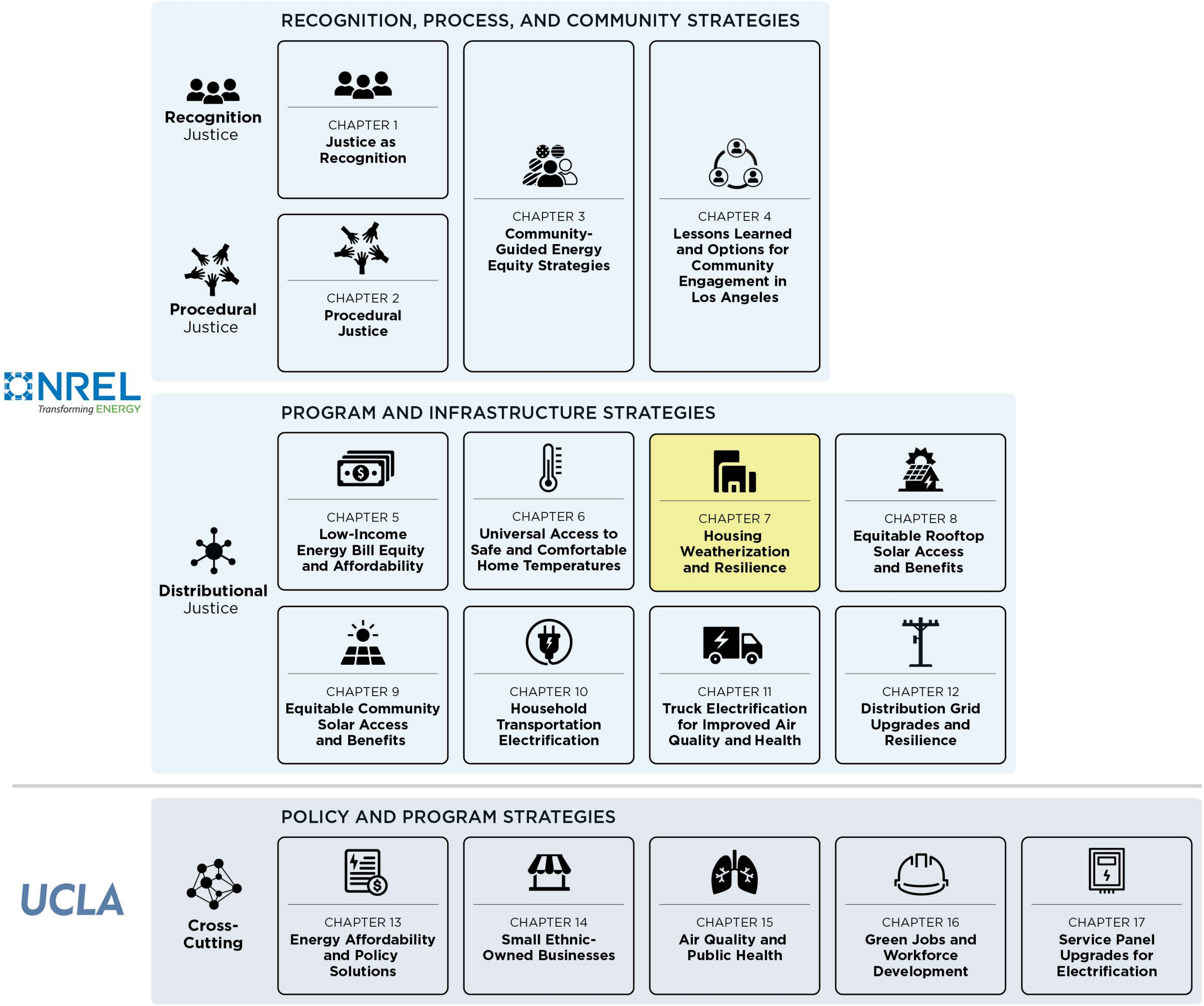
LA100 Equity Strategies employs a unique mixed-methodological approach utilizing three distinct—but connected—research efforts. Through these efforts, NREL and UCLA developed a range of strategy options for increasing equity in LA's transition to 100% clean energy.

A Project Summary

To get a high-level overview of the project, you can dive into the executive summary, interactive data visualizations, and more on the LA100 Equity Strategies website at maps.nrel.gov/la100/equity-strategies.

The Full Report

NREL's final full report for the LA100 Equity Strategies project encompasses seventeen chapters. The first twelve chapters, authored by NREL, are organized around the three tenets of justice. Chapters 1–4 address recognition and procedural justice, while Chapters 5–12 address distributional justice. The final five chapters, authored by UCLA, provide crosscutting policy and program strategies. Each chapter provides data, methods, insights, and strategies to help LADWP make data-driven, community-informed decisions for equitable investments and program development.



NREL Chapters

Chapter 1: Justice as Recognition

Chapter 2: Procedural Justice

Chapter 3: Community-Guided Energy Equity Strategies

Chapter 4: Lessons Learned and Options for Community Engagement in Los Angeles

Chapter 5: Low-Income Energy Bill Equity and Affordability

Chapter 6: Universal Access to Safe and Comfortable Home Temperatures

Chapter 7: Housing Weatherization and Resilience

Chapter 8: Equitable Rooftop Solar Access and Benefits

Chapter 9: Equitable Community Solar Access and Benefits

Chapter 10: Household Transportation Electrification

Chapter 11: Truck Electrification for Improved Air Quality and Health

Chapter 12: Distribution Grid Upgrades for Equitable Resilience and Solar, Storage, and Electric Vehicle Access

UCLA Chapters

Chapter 13: Energy Affordability and Policy Solutions Analysis

Chapter 14: Small Ethnic-Owned Businesses Study

Chapter 15: Air Quality and Public Health

Chapter 16: Green Jobs Workforce Development

Chapter 17: Service Panel Upgrade Needs for Future Residential Electrification

List of Abbreviations and Acronyms

AMI	area median income
AMY	actual meteorological year
CAIDI	Customer Average Interruption Duration Index
CARE	California Alternative Rates for Energy
DAC	disadvantaged community
DOE	U.S. Department of Energy
EIA	U.S. Energy Information Administration
HEIP	Home Energy Improvement Program
HOMES	Home Owner Managing Energy Savings
HVAC	heating, ventilating, and air conditioning
IRA	Inflation Reduction Act of 2022
LADWP	Los Angeles Department of Water and Power
LEED	Leadership in Energy and Environmental Design
LMI	low- and moderate-income
MF	multifamily
NREL	National Renewable Energy Laboratory
NSRDB	National Solar Radiation Database
PUMA	Public Use Microdata Area
RASS	Residential Appliance Saturation Study
SET	standard effective temperature
WBGT	wet-bulb globe temperature

Executive Summary

The LA100 Equity Strategies project integrates community guidance with robust research, modeling, and analysis to identify strategy options that can increase equitable outcomes in Los Angeles' clean energy transition. This chapter focuses on housing weatherization and access to cooling as means to achieve more equitable resilience to heat waves during unplanned power outages.

Specifically, NREL used weather, housing, and socioeconomic data to characterize LA's residential building stock. We developed a residential building stock model to simulate the energy use of 50,000 dwellings representing the diversity of housing types, appliances, climate zones, and household incomes across Los Angeles. We then simulated and evaluated the impacts of 10 building envelope and cooling upgrades on indoor temperature—a main cause of heat-induced health risks—over a 4-day power outage during a heat wave. We examined occupant exposure to extreme heat and how heat exposure changes with each upgrade across income, tenure (renter/owner status), building type, and disadvantaged community (DAC) status. We also examined upgrade costs and utility bills.

Based on the results of our analysis and community guidance, we identified building envelope upgrades and cooling strategies that could save lives and maintain safe home temperatures for LA's low-income households in the event of a planned or unplanned power outage during a summer heat wave.

Research was guided by input from the community engagement process, and associated equity strategies are presented in alignment with that guidance.

Community Guidance

Guidance from the LA100 Equity Strategies Steering Committee, community meetings, and listening sessions with community members cohosted with community-based organizations included the following:

Community Concerns

- The next power outage and heat wave in Los Angeles will have negative effects.
- Upgrades (i.e., weatherization and increased cooling access) will raise rents and cause displacement.
- The cost of energy efficiency upgrades will be unaffordable for some homeowners.
- Lack of access to safe and comfortable locations during heat waves.
- Energy inefficient housing, lack of approval to change cooling infrastructure, and cost of operating cooling systems can result in health risks for renters.

East LA Resident:

"So, the mayor says to go to a local library or senior center to cool off, right? The closest library here, which is only a block away from where I work, has been closed for three years … So where are the seniors supposed to go? It'd been closed since the pandemic … before that the air-conditioning had gone down. I had called the mayor and told them, you know what, if it would be somewhere in West Hollywood, they would fix it like this (snaps fingers)."

- Mistrust of energy efficiency service providers prevents some residents from improving housing efficiency.

Community Priorities

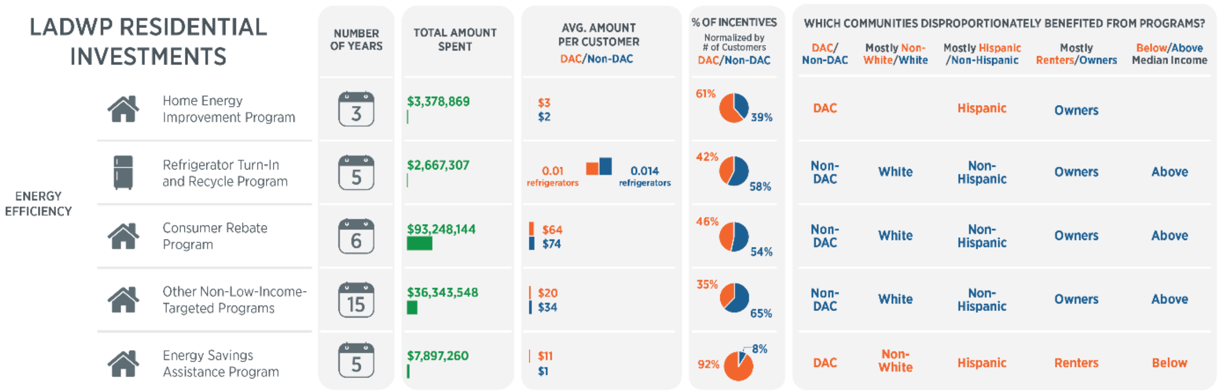
- More diversified and community-tailored outreach and support (e.g., feedback channels) to co-develop, access, and utilize energy efficiency program benefits
- Affordable program options that do not require up-front costs
- Support for home improvements needed for upgrades, such as electrical panels or mold abatement
- Amended eligibility requirements for equity-deserving ratepayers that do not fit current criteria (e.g., moderate-income household eligibility)
- Maintenance and safety upgrade support
- Revised LADWP programs that address the split incentive problem between renters and homeowners
- Development of apprenticeship programs for energy efficiency retrofits that build on local knowledge and skillsets.

Equity Strategies Steering Committee member on how they handled a recent heat wave:

"I have a window [AC] unit and it's in a different room than what I spend most of my time in. It was quite difficult. I would just go sit in my car for relief."

Distributional Equity Baseline

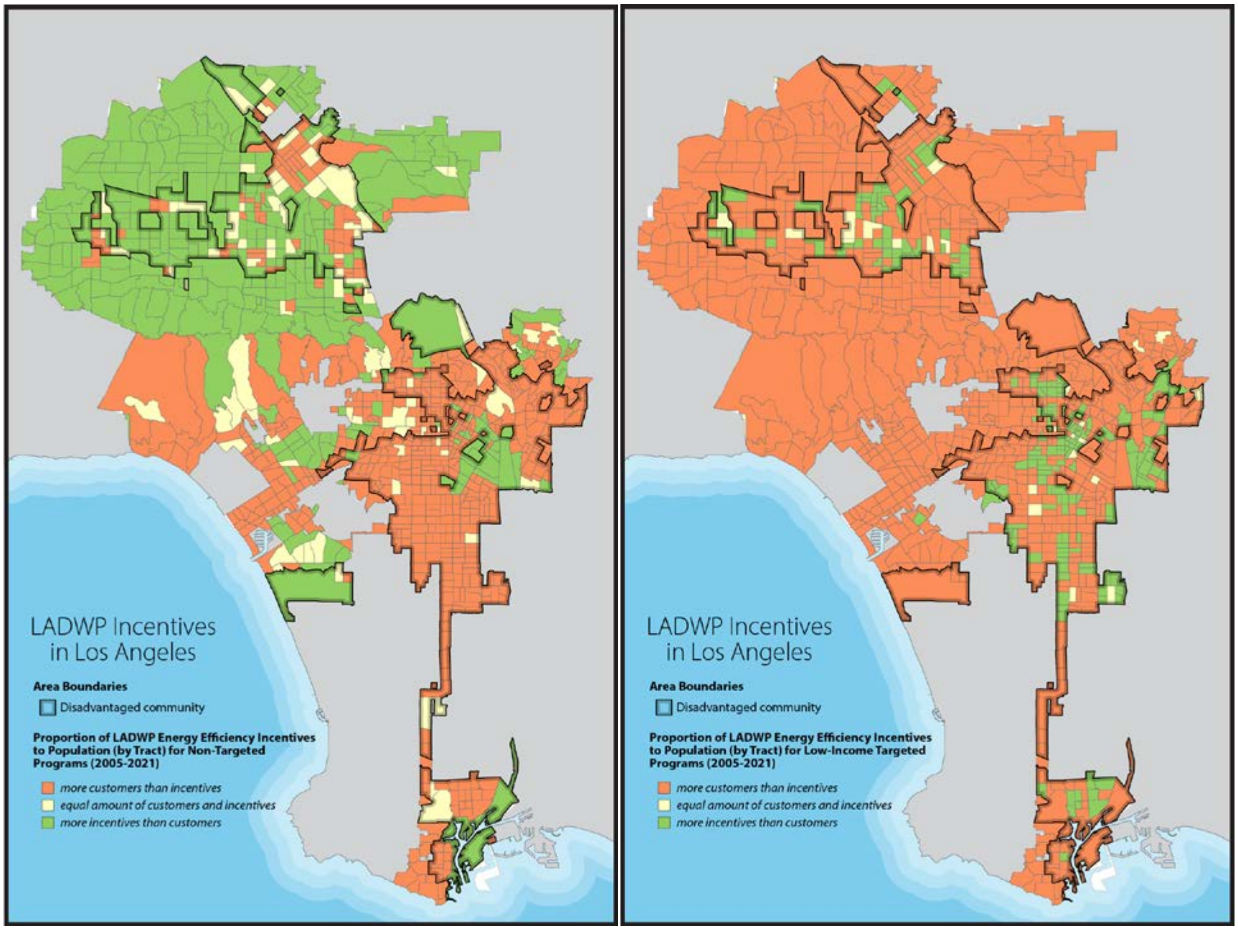
Equitable distribution of energy efficiency improvements can lead to more equitable resilience to power outages during heat waves. Distributional equity analysis found that LADWP residential energy efficiency investments between 2005 and 2021 disproportionately benefited non-disadvantaged, mostly White, mostly non-Hispanic, mostly home-owning, and mostly above-median-income communities (Figure ES-1).



LADWP RESIDENTIAL INVESTMENTS		NUMBER OF YEARS	TOTAL AMOUNT SPENT	AVG. AMOUNT PER CUSTOMER DAC/Non-DAC	% OF INCENTIVES Normalized by # of Customers DAC/Non-DAC	WHICH COMMUNITIES DISPROPORTIONATELY BENEFITED FROM PROGRAMS?				
						DAC/ Non-DAC	Mostly Non-White/White	Mostly Hispanic /Non-Hispanic	Mostly Renters/Owners	Below/Above Median Income
ENERGY EFFICIENCY	Home Energy Improvement Program	3	$3,378,869	$3 $2	61% 39%	DAC		Hispanic	Owners	
	Refrigerator Turn-In and Recycle Program	5	$2,667,307	0.01 refrigerators 0.014 refrigerators	42% 58%	Non-DAC	White	Non-Hispanic	Owners	Above
	Consumer Rebate Program	6	$93,248,144	$64 $74	46% 54%	Non-DAC	White	Non-Hispanic	Owners	Above
	Other Non-Low-Income-Targeted Programs	15	$36,343,548	$20 $34	35% 65%	Non-DAC	White	Non-Hispanic	Owners	Above
	Energy Savings Assistance Program	5	$7,897,260	$11 $1	92% 8%	DAC	Non-White	Hispanic	Renters	Below

Figure ES-1. Statistical analysis of LADWP energy efficiency investments (2005–2021)

Of the 14 residential energy efficiency programs analyzed, one program—the Energy Savings Assistance Program—targeted low-income households and proportionately benefited DACs. Relevant to cooling access, LADWP increased rebates for small, window-unit air conditioners to $225 as part of the Cool LA program (LADWP 2022). For the other 13 energy efficiency programs that did not target low-income households, areas such as South LA did not receive energy incentive benefits proportional to their populations (Figure ES-2).



(a) (b)

Figure ES-2. (a) Distribution of LADWP incentives for programs not targeting low-income households and (b) Distribution of LADWP incentives for programs targeting low-income households

Key Findings

Modeling results showed using air conditioning before a power outage occurs can mitigate heat-induced health risks. Occupants can also employ strategies such as closing blinds during sunny conditions or opening windows when temperatures are cooler outside.

Modeling indicated many low-income households would start a power outage at unsafe temperatures, either because of a lack of access to or use of a cooling system. Access to and use of cooling, combined with robust building envelope improvements such as insulation, air sealing, and window replacements, reduces dangerous indoor heat exposure by 84%–96% over a four-day power outage; and in the first day of the outage, households reaching dangerous temperatures decreases from 85% to 33%. The duration of safe temperatures for low-income households increases from 0 hours in the baseline condition to 24 hours when cooling is used.

Both DACs and non-DACs have significant potential to increase resilience through broader cooling access and building weatherization; therefore, identifying policy and program actions that lower barriers to realizing the resilience benefits in these communities is key for equitable outcomes in Los Angeles.

Key takeaways include:

- *Multifamily building residents, which are predominantly renters, are disproportionately negatively impacted by heat exposure*. Multifamily households without cooling (or those that do not use cooling) started and remained at unsafe temperatures throughout the simulated power outage. Less than one-half of renters use cooling (Palmgren et al. 2021), placing them at a higher risk of unsafe heat exposure before and during an outage.
- *Access to and use of cooling reduces exposure to extreme heat* for all income levels, building types, and tenures. Cooling use with Title 24 envelope improvements, which are required for all new housing units in California, decrease average 4-day heat exposure between 84% and 96%.
- *Cooling use alone is insufficient in reducing dangerous heat exposure in single-family dwellings during an outage*. 74% of all dwelling types with cooling use reach unsafe indoor air temperatures within the first 24 hours of the outage. Cooling use decreases the starting temperature for most single-family dwellings by approximately 9°F. However, by the end of the first day of the power outage, single-family dwellings with cooling use prior to the outage follow similar indoor air temperature profiles as single-family dwellings without cooling.
- *Cooling use is effective and cooling use combined with Title 24 envelope upgrades are most effective at increasing the time before extreme heat exposure is reached*, particularly for low-income households. In the baseline condition, 85% of Los Angeles housing stock reaches the dangerous temperature threshold (86°F) in the first 24 hours of the outage. 37% of low-income households start the outage at the dangerous temperature threshold—meaning there are 0 hours until unsafe temperatures are reached. With a Title 24 envelope, 57% of the Los Angeles housing stock reaches dangerous temperatures within the first 24 hours, compared to 33% with cooling use and a Title 24 envelope. For the low-income dwellings included in this 33%, the hours until unsafe temperatures are reached are extended from 0 hours in the baseline to 24 hours when using cooling with Title 24 envelope. More time until unsafe temperatures are reached means more time for households and the city to plan and act.
- *Envelope improvements do not substantially reduce dangerous heat exposure for five or more unit multifamily building residents (who are predominantly renters).* Low-cost envelope improvements provide, on average, a 33% decrease in heat exposure for homeowners, but a 10%–12% decrease for renters. More than three-quarters of renters live in multifamily dwellings, and those dwellings have less natural ventilation, more thermal mass, and more insulated shared walls, resulting in more heat retention throughout the day. On average, Title 24 envelope improvements reduced exposure by 41% for renters and 77% for owners, whereas cooling use reduced exposure by 31% for owners and by 41% for renters across income levels. These findings suggest the need for differentiated strategies between renters and multifamily building residents and owners and single-family home residents.

Housing resilience equity metrics include:

- Level and duration of exposure to unsafe home temperatures (>86°F)
- Upgrade costs and utility bill impacts
- Household income
- Renter or owner occupancy status
- Housing type (multifamily, single-family)

- *Dangerous heat exposure can be reduced at the lowest cost in multifamily buildings*. Upgrade costs are lower in multifamily dwellings compared to single-family dwellings because these dwellings are generally smaller and better insulated (including by adjacent units), resulting in smaller cooling system sizes and, therefore, costs.
- *Inflation Reduction Act of 2022 (IRA) rebates can reduce or eliminate the cost of upgrades for low- and moderate-income households*. With IRA Section 50122 rebates, LADWP could install cooling with mini-split heat pumps in low-income (0%–80% area median income [AMI]) households without households incurring any debt by using a direct install program. However, IRA program budgets are limited, and current funds would cover upgrades in less than 1% of 0%–150% AMI households in Los Angeles.

Equity Strategies

Modeling, analysis, and community engagement identified the following strategies for achieving more equitable outcomes in building weatherization and cooling for resilience:

- *Target cooling access and envelope improvements by housing type*, where multifamily homes receive cooling access to address their greater exposure to dangerous temperatures, and single-family homes receive building envelope improvements to mitigate their increased exposure to outside temperatures.
- *Combine federal funding from the IRA or Weatherization Assistance Program* with existing LADWP rebates to augment existing programs—particularly the Home Energy Improvement Program (HEIP) and Cool LA program—to expand opportunities for direct installation of cooling through heat pumps and lower-cost building weatherization upgrades for low-income households. Expand LADWP's HEIP to include funding for renovations and electrical upgrades necessary to support cooling through a heat pump, when feasible, by leveraging up to $6,500 in IRA rebates for low-income households.
- *Shift to direct install* instead of rebates for low- and moderate-income households.
- *Fund and staff program outreach and technical assistance* in partnership with community organizations through neighborhood resource centers as well as door-to-door outreach approaches targeting areas that historically received disproportionately fewer efficiency incentives.
- *Mitigate the potential for LADWP-supported weatherization and cooling upgrades to increase rents and contribute to displacement among low- and moderate-income renters*.
    - Partner with the Housing Authority to install upgrades in public housing.
    - Identify mechanisms to mitigate rent increases for nonpublic housing receiving low-income-qualified cooling and weatherization interventions. Options include renter protections, "right to return" provisions if renovations temporarily displace renters, and mechanisms to prevent short-term rent increases for multifamily rental properties receiving utility-supported upgrades. Add cooling access by leveraging up to $8,000 in IRA rebates for low-income households.
- *Support apprenticeship programs in DACs* for HVAC entrepreneurship and educational opportunities by coordinating IRA funds for workforce development (IRA Section 50123) (see Chapter 12 for details).

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1 Introduction

The LA100 Equity Strategies project seeks to increase equity in Los Angeles' transition to 100% clean energy. This report focuses on identifying strategies to increase equity in the distribution of benefits from building weatherization and cooling upgrades that can maintain safe temperatures within Los Angeles households in the event of a power outage during a heat wave.

1.1 Community Guidance

Analysis incorporated guidance from the LA100 Equity Strategies Steering Committee, community meetings, and Listening Sessions with community members cohosted with community-based organizations. The community expressed concerns and priorities related to resilience to power outages during heat waves.

Community concerns include:

- The next power outage and heat wave in Los Angeles will have negative effects.
- Upgrades (i.e., weatherization and increased cooling access) will raise rents and cause displacement.
- The cost of energy efficiency upgrades will be unaffordable for many homeowners.
- Lack of access to safe and comfortable locations during heat waves.
- *Energy inefficient housing, lack of approval to change cooling infrastructure, and cost of operating cooling systems can result in health risks for renters*. Many low- and moderate-income Angeleno renters live in energy inefficient housing conditions that can increase health risks due to extreme heat or cold. Furthermore, renters are often unable to change the cooling and heating infrastructure within their homes (i.e., they need homeowner approval and/or investment to install ceiling fans and air conditioning). In addition, if the existing equipment provided to the renter is inefficient or poorly maintained, then operating that equipment could be cost-prohibitive for the renter. For these reasons, the resulting unconditioned housing environment can become detrimental to the residents' health.
- *Mistrust of energy efficiency service providers prevents some residents from improving housing efficiency*. As Chapter 2 discusses in more detail, some residents mistrust Los Angeles Department of Water and Power (LADWP) subcontracted service providers—such as those providing ratepayers with energy efficient appliances—because they have received poor-quality products and service from LADWP contractors in the past. In the absence of accountability, this leads to community mistrust, dissuading residents from seeking efficiency upgrades and causing them to question the benefits of clean and efficient energy technologies and services more generally.

Community priorities include:

- More diversified and community-tailored outreach and support (e.g., feedback channels) to co-develop, access, and utilize energy efficiency program benefits
- Affordable program options that do not require up-front costs
- Support for home improvements needed for upgrades, such as electrical panels or mold abatement
- Amended eligibility requirements for equity-deserving ratepayers that do not fit current criteria (e.g., moderate-income household eligibility)
- Maintenance and safety upgrade support

- Revised LADWP programs that address the split incentive problem between renters and homeowners
- Development of apprenticeship programs for energy efficiency retrofits that build on local knowledge and skillsets.

1.2 Modeling and Analysis Approach

The National Renewable Energy Laboratory (NREL) modeled how indoor temperature, a main cause of heat-induced health risks, changes with building envelope and cooling upgrades in a power outage during a heat wave. Figure 1 provides an overview of the modeling workflow. The applied methods, which were developed with input from the LA100 Equity Strategies Steering Committee and community members, are described in detail in the appendix.

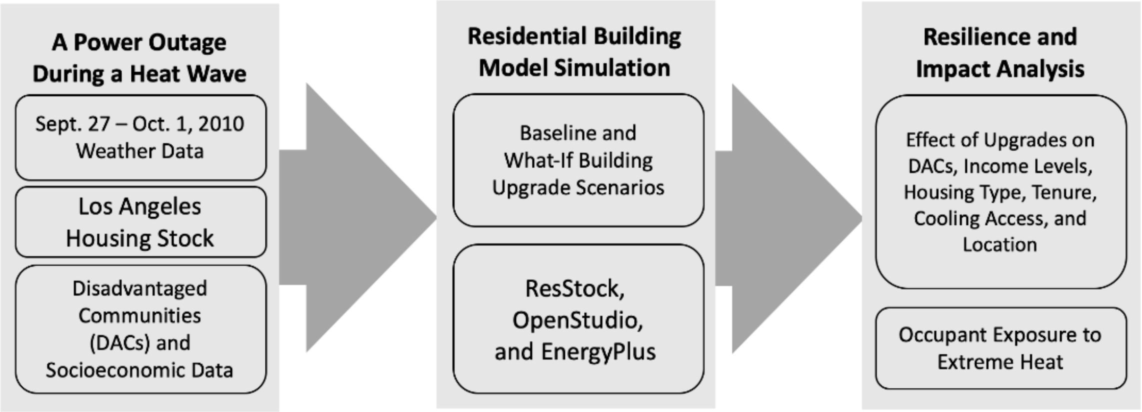

Figure 1. Residential building power outage modeling workflow

The modeling and analysis approach uses weather, housing, and socioeconomic data to characterize Los Angeles' residential building stock. The data informed representative building energy models via ResStock™ (Wilson et al. 2017), which uses EnergyPlus® to simulate the representative buildings. The baseline models are then modified and re-simulated to evaluate various building upgrades and investment scenarios. NREL examined occupant exposure to extreme heat and how heat exposure changes with each upgrade and across income, tenure (renter/owner status), building type, and disadvantaged community (DAC) status. Our approach aligns with energy resilience assessment methodologies described by Anderson et al. (2019).

We modeled eight conditions, described in detail in the appendix:

- Baseline
- Cooling use
- Cooling use, cool roof, and shading
- Cooling use and low-cost envelope improvements
- Cooling use and Title 24 envelope improvements
- Cool roof and shading
- Low-cost envelope improvements
- Title 24 envelope improvements.

The building upgrades are applied as what-if scenarios to Los Angeles' housing stock, and then compared to assess their performance in a power outage during a heat wave. We modeled heat pumps for cooling because they deliver cooling with similar or lower total purchase and operational costs than room air conditioning (Booten et al. 2022) and will be eligible for the widest selection of federal rebates, while other options are not. The model sized heat pumps after applying the effect of other building improvements. In addition, we modeled the resilience effect of increasing envelope robustness through low-cost envelope improvements and Title 24 envelope improvements that meet standards upheld by the California Energy Commission and are required for all new housing units (California Energy Commission 2023). See Table A-2 in the appendix for a summary of modeled upgrade specifications.

1.2.1 Simulating Resilience to a Power Outage During a Heat Wave

Extreme heat index days are expected to increase in frequency during the next century (Dahl et al. 2019). A power outage during a heat wave is considered a disaster, and being resilient to disasters through building weatherization is imperative to ensuring the health and safety of the public (National Research Council 2012). Communities also use resilience strategies, such as cooling centers, natural ventilation, and window coverings, to decrease heat exposure. NREL modeled a heat wave in 2010 using Actual Meteorological Year (AMY) weather data in Los Angeles County.

Two power outages were analyzed. First, NREL analyzed a 4-day outage, from September 27, 2010, at 15:00, through October 1, 2010, at 21:00, which is the hottest four-day period of the year in the weather data. While a four-day outage is extremely rare, modeling a long-duration power outage allows assessment of the impacts of building weatherization and cooling upgrades as living space temperatures increase in dwellings during the outage. Second, a power outage of 180 minutes was analyzed, results of which can be found in the appendix. The reported Customer Average Interruption Duration Index (CAIDI) for LADWP reliability reporting was 183 minutes in 2021 (EIA 2022). We assume all dwellings do not have access to back-up power supplies. In Chapter 8, the resilience benefits of microgrids and back-up power are investigated.

1.2.2 Measuring Risk Due to Heat Exposure

NREL measured exposure to extreme heat by both magnitude of temperature (how hot the air in the building is) and duration (how long a person is exposed). These passive survivability metrics indicate the ability to shelter in place during extreme weather such as a heat wave. Standard effective temperature (SET) and SET degree-hours were used to measure passive survivability, which is a measure derived from air temperature and air velocity. We use the Leadership in Energy and Environmental Design (LEED) Pilot Credit IPpc100 – *Passive Survivability and Back-Up Power During Disruptions* to quantify risk due to heat exposure, which specifies a SET threshold above 86°F SET for residential buildings and a 216 SET°F-hours limit for the duration of heat exposure (USGBC 2023). SET-hours describe the magnitude above the threshold as well as the duration over the 4-day power outage. For example, if an indoor living temperature reached 96°F SET for 3 hours each day, the household would experience 120 SET°F-hours ([96°F–86°F] × 3 hours/day × 4 days). A representational diagram showing the methodology for SET°F-hours is provided in the appendix. We analyze how many hours a dwelling would have until the indoor living space temperature reaches 86°F SET, and the maximum number of hours above the 86°F SET threshold. The passive survivability metrics are simulated using EnergyPlus (version 22.2.0).

1.2.3 Developing Community-Informed Strategies

In addition to the modeling, NREL collected input on concerns related to power outages during heat waves and potential solutions from the LA100 Equity Strategies Steering Committee and Listening Sessions with community members cohosted with community-based organizations, as well as community meetings, as described in Chapter 2. The analysis was tailored to incorporate guidance related to resilience to power outages during heat waves.

2 Modeling and Analysis Results

Table 1 presents the effects of building weatherization upgrades during a power outage in a heat wave. The lower (25%), middle (50%), and upper quartile (75%) effects are shown to provide statistical context. For each upgrade, we calculate the exposure in 4 days, the average change in four-day exposure, the exposure in the first 24 hours of the outage, the exposure by CAIDI, and the maximum number of hours above the 86°F threshold for each upgrade relative to the baseline.

The results in Table 1 indicate that the exposure to extreme heat in the first 96 hours decreases most significantly with a combination of robust building envelope improvements and cooling access and use, enabling households to start the outage at lower temperatures. Combining building envelope improvements with cooling use reduced exposure by at least 90%. The median exposure by the fourth day of the outage is reduced by 97% across LA's housing stock when robust building envelope improvements (i.e., Title 24) are provided to dwellings. The results indicate that the median exposure is reduced by 56% when cooling is used or when dwellings have cool roofs and shading.

Table 1. Effects of Building Weatherization Upgrades on Exposure to Extreme Heat

Upgrade	4-Day Exposure (SET°F-hours)			Exposure in 24 hours (SET°F-hours)			Exposure by CAIDI (SET°F-hours)			Max. Hours Above Threshold (hours)		
	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
Baseline + outage only	11	79	170	0.6	24	77	0.0	9.0	23	6.8	13	22
Cooling use	0.0	35	110	0.0	1.6	26	0.0	0.0	4.5	0.0	8.3	12
Cooling use, cool roof, and shading	0.0	5.8	53	0.0	0.0	13	0.0	0.0	1.8	0.0	5.5	9.8
Cooling use and low-cost envelope	0.0	7.3	67	0.0	0.0	8.9	0.0	0.0	0.4	0.0	5.8	11
Cooling use and Title 24 envelope	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5
Cool roof and shading	0.3	35	110	0.0	13	58	0.0	4.8	19	1.8	9.8	17
Low-cost envelope	0.8	44	140	0.0	13	65	0.0	4.6	19	3.0	12	22
Title 24 envelope	0.0	2.2	58	0.0	0.1	35	0.0	0.0	10	0.0	5.0	15

2.1.1 A Power Outage During a Heat Wave by Building Type

We examined the effects of four distinct upgrade scenarios—baseline, cooling use, cooling use and Title 24 envelope improvements, and Title 24 envelope improvements—by building type (single-family versus multifamily), as shown in Figure 2 and Figure 3. The vertical dotted lines indicate when the outage starts and ends, with the outage period shaded in white. The black line shows the outdoor air temperature, and the blue and purple shaded regions represent the 25%–75% quartiles in indoor air temperature. The horizontal line indicates the dangerous temperature threshold (86°F). The goal of the upgrades is to ensure indoor air temperatures remain below the 86°F threshold.

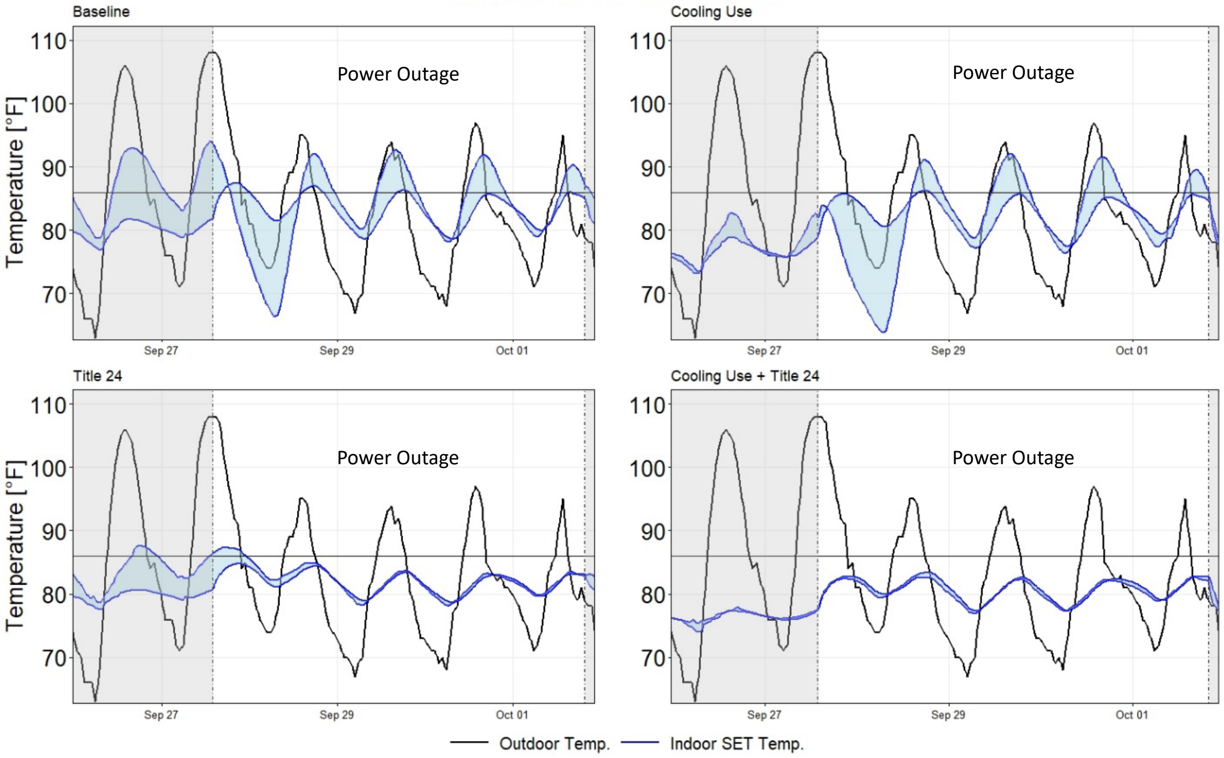

Figure 2. Indoor and outdoor air temperature during a power outage in single-family dwellings

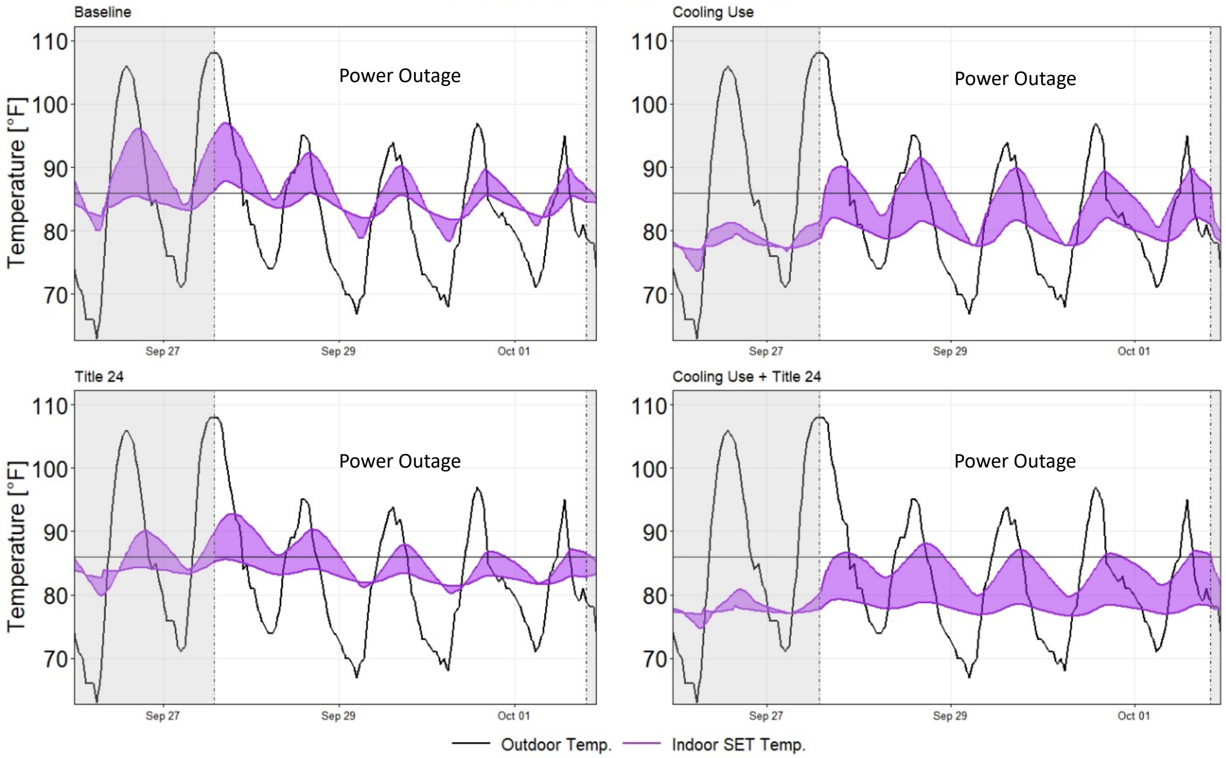

Figure 3. Indoor and outdoor air temperature during a power outage in multifamily dwellings

Results show multifamily dwellings experience slightly greater exposure to dangerous temperatures than single-family dwellings, both before and immediately after the simulated power outage for the baseline case; 57% of multifamily dwellings are at or above the threshold of 86°F SET, while 54% of single-family dwellings are at or above the 86°F threshold.

Title 24 envelope improvements alone reduce heat exposure below the dangerous threshold in nearly all hours in single-family dwellings but are not as effective in multifamily dwellings. Sixty percent of single-family dwellings with a Title 24 envelope improvement remain at safe indoor living conditions because of efficient natural ventilation. In comparison, the Title 24 envelope improvements result in 32% of multifamily dwellings remaining at safe indoor living conditions. Single-family dwellings naturally ventilate accumulated heat more quickly than multifamily dwellings. Single-family dwellings have larger window areas and multiple facades to allow for ventilation, while multifamily dwellings have smaller window areas and only one or two facades to allow for ventilation. On average, multifamily dwellings have 41% of the natural ventilation that single-family dwellings have in the baseline condition, and 47% of the natural ventilation that single-family dwellings have with the Title 24 envelope upgrades on a cubic-foot-of-air per minute basis. A summary and analysis of natural ventilation and infiltration rates can be found in the appendix.

In single-family dwellings, cooling use is insufficient in reducing heat exposure below the dangerous threshold. For single-family dwellings, cooling use decreases the starting temperature in the upper quartile (75%) by approximately 9°F. However, by the end of the first day of the power outage, single-family dwellings with cooling use before the outage follow similar indoor air temperature profiles as single-family dwellings in the baseline condition. For multifamily dwellings, cooling use is sufficient for the lowest quartile of multifamily dwelling temperatures (25%), which remain at a safe indoor living condition (i.e., below 86°F). However, the highest quartile frequently exceeds the 86°F dangerous threshold.

The most effective solution is a combination of cooling use and Title 24 envelope improvements, which decreases dangerous heat exposure above 86°F (SET) for 68% of single-family and multifamily dwellings. However, this solution is also the costliest, as described in the appendix.

We examined the effects of the upgrades by building type, as shown in Figure 4, segmented by single-family dwellings (Single-Family), multifamily units in a building with two to four units (MF 2–4 Units), and multifamily units in a building with five or more units (MF 5+ Units). For context, approximately 56% of the Los Angeles population lives in multifamily buildings, and 44% live in single-family (mobile homes included) buildings.

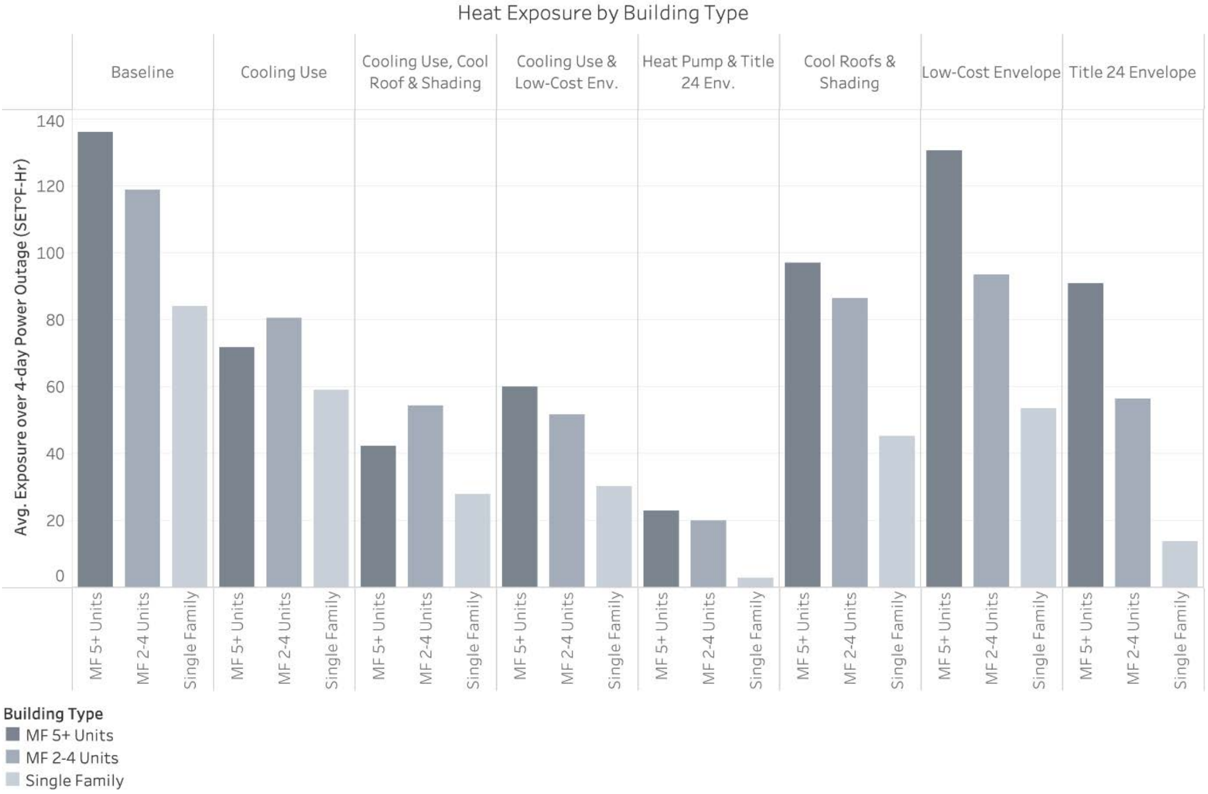

Figure 4. Average heat exposure during 4-day outage by building type

MF = multifamily

Without upgrades, households living in multifamily buildings with five or more units experience substantially greater exposure to dangerous temperatures than households in smaller multifamily buildings and single-family homes. Using cooling more effectively reduces exposure than envelope improvements in MF 5+ units, whereas robust envelope improvements more effectively reduce exposure than cooling access in single-family dwellings. A combination of cooling use and building weatherization reduced exposure across all building types. Consistent with previous findings, cooling use and Title 24 envelope improvements resulted in the greatest reduction in exposure, where single-family detached residences decreased from 84 SET°F-hours to

0.3 SET°F-hours on average, and MF 5+ units decreased from 136 SET°F-hours to 7.9 SET°F--hours.

Multifamily and single-family dwellings exhibited different magnitudes in decreased exposure as a result of building upgrades. In MF 5+ units, low-cost envelope improvements marginally decreased exposure by 4%, whereas in single-family buildings, low-cost envelope improvements decreased exposure by 37%. In single-family dwellings, robust envelope improvements, such as Title 24, significantly reduced exposure by an average of 84%. By contrast, in MF 5+ units, exposure was reduced by only 44% with Title 24 envelopes. Cool roofs and shading reduced exposure for MF 5+ units by 29% and decreased exposure in single-family dwellings by 46%. Cooling use reduces exposure by 53% in MF 5+ units, but by only 30% in single-family dwellings.

2.1.2 Cooling Access and Use

Using cooling increases the resilience of a household during a power outage. From the ResStock Los Angeles residential building stock energy model,[1] the percentages of Los Angeles households that have access to cooling, along with the percentages of Los Angeles households that use that cooling, are shown in Figure 5 by percentage area median income (AMI).

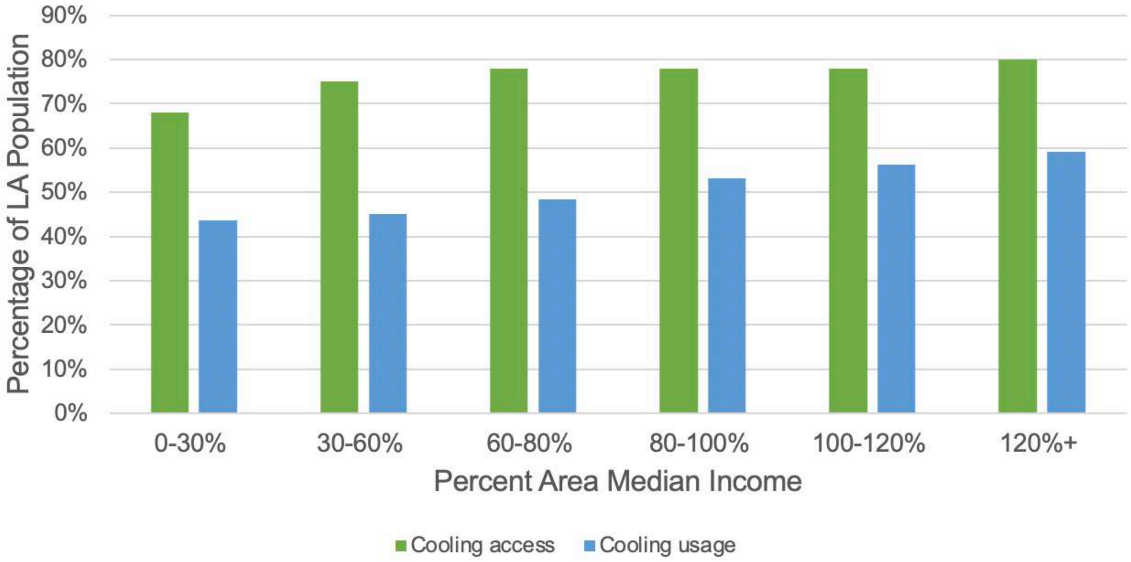

Figure 5. Percentage of population with cooling access and use by % AMI for Los Angeles

Cooling access and use generally increase as income increases. Less than one-half of extremely low-income (0%–30% AMI), very low-income (30%–60% AMI), and low-income (60%–80% AMI) households use cooling. Only 70% of extremely low-income households have access to cooling. See the appendix for more information about access to cooling.

In LA100 Equity Strategies Listening Sessions, participants identified several barriers they experience to accessing and using cooling technologies in their homes. Barriers include the cost

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[1] Informed by RASS 2019.

of the equipment, the cost to run the equipment, limitations in existing housing infrastructure (i.e., old wiring and/or electrical panels), and housing tenure. Tenure affects Angelenos' eligibility for energy efficient cooling technologies, such as LADWP's Cool LA initiative. Renters are disqualified from most energy efficiency housing benefits, which prioritize homeowners. Homeowners with low to moderate incomes who struggle to pay their bills and monthly expenses are often disqualified because of income eligibility limits. Participants highlighted that access is not only about having the cooling technology available in the home, but also having the ability to use that technology affordably and safely. Broadening eligibility requirements related to income restrictions as well as tenure status could increase access to and use of cooling. For more information on community-informed solutions, see Chapter 13. Table 2 presents the percentage of households with space conditioning by tenure, building type, and DAC status.

Table 2. Percentages of Households with Space Conditioning by Demographic

Original Space Conditioning	Tenure		Building Type		DAC	
	Renter	Owner	Single Family	Multifamily	Yes	No
No Cooling or Space Conditioning	26%	20%	22%	25%	26%	21%
Partial Space Conditioning	18%	17%	20%	16%	19%	16%
Full Space Conditioning	56%	63%	58%	59%	55%	62%

2.1.3 Income and Tenure

We examined how the effects of upgrade scenarios differ across household income levels and tenure statuses, as shown in Table 3 and Table 4. 37% of low-income households (10,000 of 27,000 models representing low-income households) start the outage at dangerous temperatures.

Renters experience much higher exposure to dangerous temperatures than homeowners in baseline conditions. Results differ by tenure, primarily because more than 70% of renters live in multifamily buildings with two or more units, and more than 85% of owners live in single-family attached or detached dwellings. Cooling use and Title 24 envelope improvements reduce heat exposure the most, regardless of income or tenure. Title 24 envelope improvements decrease exposure by between 41% and 46% for renters and 77% and 79% for owners. Cooling use decreases exposure by between 41% and 43% for renters and 31% and 33% for owners. Cool roofs and shading reduce exposure by between 30% and 33% for renters and 44% and 45% for owners.

Table 3. Four-Day Exposure (SET°F-hr) by Income and Tenure

Upgrade	4-Day Exposure (SET°F-hour)					
	Renter			Owner		
	0%–80% AMI	80%–120% AMI	120%+ AMI	0%–80% AMI	80%–120% AMI	120%+ AMI
Baseline	140	120	110	92	85	73
Low-cost envelope	120	110	93	62	57	49
Cool roofs and shading	96	83	71	51	47	41
Title 24 envelope	80	67	57	21	19	15
Cooling use	78	71	60	62	59	50
Cooling use, cool roof, and shading	46	41	34	30	28	23
Cooling use and low-cost envelope	59	53	44	33	32	26
Cooling use and Title 24 envelope	21	18	14	5.3	4.5	2.7

Table 4. Percent Change in 4-Day Exposure by Income and Tenure

Upgrade	Change Relative to Baseline (%)					
	Renter			Owner		
	0%–80% AMI	80%–120% AMI	120%+ AMI	0%–80% AMI	80%–120% AMI	120%+ AMI
Low-cost envelope	10	11	12	33	33	33
Cool roofs and shading	30	32	33	44	44	45
Title 24 envelope	41	44	46	77	78	79
Cooling use	43	41	43	33	31	32
Cooling use, cool roof, and shading	66	66	68	68	67	68
Cooling use and low-cost envelope	57	56	58	64	63	64
Cooling use and Title 24 envelope	84	85	87	94	95	96

Exceeding the cumulated heat exposure of 216°F-hour indicates a high amount of exposure that poses a serious threat to building occupants during a 4-day power outage. A total count of households that exceeded the threshold that did not have cooling in the baseline condition were calculated by income and building type.

Table 5. Dwellings Without Cooling Exceeding the Limit of Passive Survivability in 4-Day Outage

Dwelling Type	0%–80% AMI	80%–120% AMI	120%+ AMI
Multifamily	58,000	11,000	14,000
Single-family	11,000	2,600	4,700

Low-income multifamily dwellings have the most households exceeding passive survivability limits of 58,000. To provide context, the distribution of building type and income level was investigated for household in Los Angeles.

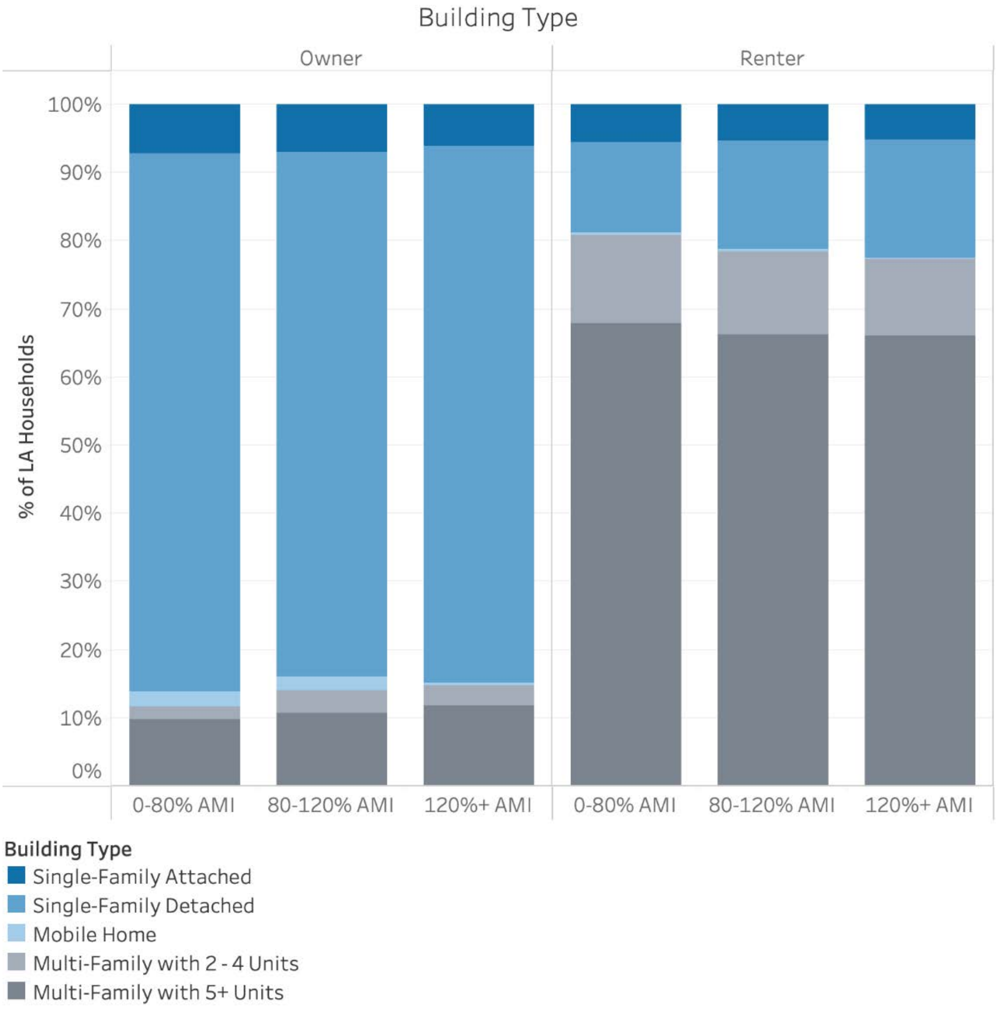


Figure 6. Housing type by tenure in Los Angeles

As income increases, exposure generally decreases across all baseline and upgrade scenarios. Low-income renters experience the highest exposure, which suggests a one-size-fits-all approach to residential building technology deployment may reproduce existing inequities in exposure.

Upgrades that decrease the amount of difference between income levels support more equitable outcomes (i.e., where exposure is similar regardless of income). When considering building weatherization and cooling separately, Title 24 envelope upgrades reduce income-based exposure differences the most to 5.6 SET°F-hours for owners, whereas cooling use reduces income-based exposure differences the most to 17.6 SET°F-hours for renters. Combining cooling upgrades and envelope upgrades minimizes the income-based differences between 6.5 to 15 SET°F-hours for low-cost envelopes and heat pumps. Conversely, low-cost envelope upgrades alone have the largest inequity in upgrade impacts, with an exposure range of 30 SET°F-hours between low- and higher-income renters and 19 SET°F-hours between low- and higher-income owners.

For context, Los Angeles households are approximately 64% renters and 36% owners (see the appendix for analysis). Of the renters with cooling access, 47% regularly use cooling equipment, whereas 58% of owners with cooling access regularly use cooling equipment. The average heat exposure (SET°F-hours) was calculated for each upgrade by tenure, as shown in Figure 7.

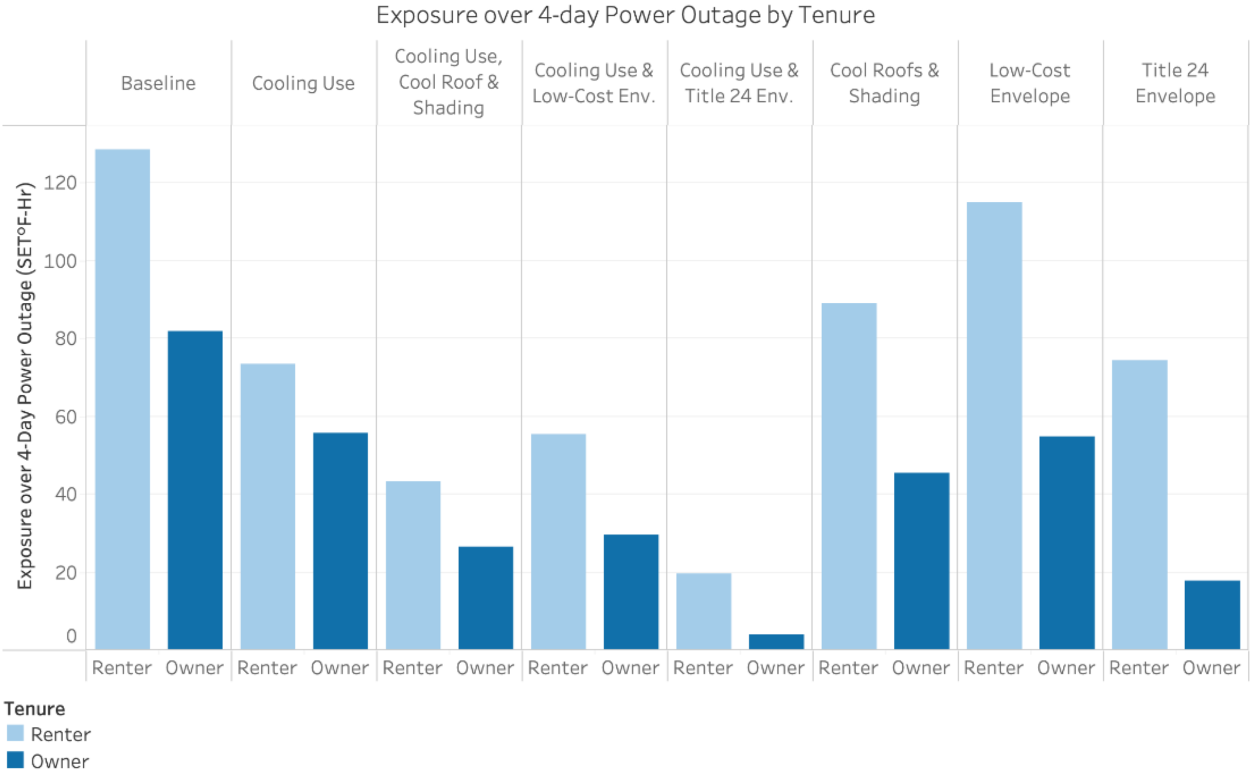


Figure 7. Average SET°F-hours over a 4-day power outage in Los Angeles by tenure

Renters experience higher exposure to heat than owners in the baseline condition and across upgrade scenarios—again, primarily because renters live in multifamily buildings, which retain heat and have less effective natural ventilation more than single-family buildings. On average, cooling use decreases renters' heat exposure from 130 SET°F-hours to 73 SET°F-hours and Title

24 envelope improvements decrease exposure to 74 SET°F-hours. In comparison, owners decrease exposure from 82 SET°F-hours in the baseline to 55 SET°F-hours with cooling access, and 18 SET°F-hours with a Title 24 envelope improvement.

2.1.4 Hours Until Threshold

In the baseline condition, 85% of the Los Angeles housing stock reach the dangerous temperature threshold (86°F) in the 4-day outage period, as shown below in Table 6. Upgrades reduce the percent of dwellings that reach this threshold, with combined cooling use and Title 24 envelope upgrades providing the greatest reduction, and low-cost envelope improvements providing the least reduction.

Table 6. Percentage of Housing Stock Reaching Dangerous Threshold of 86°F in First 24 hours

Upgrade	Households Reaching Threshold	% Housing Stock
Baseline + outage only	1,300,000	85
Cooling use	1,200,000	74
Cooling use, cool roof, and shading	970,000	62
Cooling use and low-cost envelope	980,000	62
Cooling use and Title 24 envelope	510,000	33
Cool roof and shading	1,200,000	77
Low-cost envelope	1,200,000	78
Title 24 envelope	890,000	57

More time until unsafe temperatures are reached means more time for households and the City of Los Angeles to plan and act. For the dwellings that reach dangerous temperatures, Table 7 shows the number of hours until this threshold is reached.

For the housing stock that reached dangerous temperatures in the first 24 hours, cooling use was the main determinant in extending the number of safe hours. Modeling indicates many low-income households start an outage at unsafe temperatures, either because these households lack access to cooling, or they do not use cooling because of the cost of running inefficient air conditioners. When cooling is available and used before an outage, the number of hours households remain at a safe temperature following the power outage increases from 0 hours in the baseline condition to 2.5 hours for low-income, multifamily dwellings. Cooling use and envelope improvements, such as Title 24 envelopes, increase the number of hours households remain at a safe temperature from 0 hours in the baseline condition to 23 hours or more across all building types and income levels. Cooling use and low-cost envelope improvements increase the number of safe hours from 0 to 5.5 hours for low-income, multifamily dwellings. Upgrades that do not include cooling remain at a median of 0 hours, meaning most dwellings start the power outage at dangerous temperatures.

Table 7. Median Hours Until Dangerous Temperatures by Income and Building Type

Upgrade	0%–80% AMI		80%–120% AMI		120%+ AMI	
	Multifamily	Single Family	Multifamily	Single Family	Multifamily	Single Family
Baseline	0.0	0.0	0.0	0.0	0.0	0.0
Cooling use	2.5	1.5	2.0	1.3	2.5	1.3
Cooling use, cool roof, and shading	2.8	1.8	2.5	1.8	2.8	1.5
Cooling use and low-cost envelope	5.5	3.0	4.0	2.5	5.8	2.5
Cooling use and Title 24 envelope	23	24	23	24	24	24
Cool roof and shading	0.0	0.0	0.0	0.0	0.0	0.0
Low-cost envelope	0.0	0.0	0.0	0.0	0.0	0.0
Title 24 envelope	0.0	0.0	0.0	0.0	0.0	0.0

2.1.5 *Federal Funding for Upgrades*

Using federal rebates and funding can enable more low-income households to adopt technologies that provide long-term savings but have higher up-front costs. The Inflation Reduction Act of 2022 (IRA)[8] funds rebates, administered through state energy offices, for homeowners to decrease home energy consumption (IRA Section 50121) and electrify their homes (IRA Section 50122). The U.S. Department of Energy (DOE) allocated $292,000,000 for the Home Owner Managing Energy Savings (HOMES) rebate program and $290,000,000 for the Home Electrification rebate program for the State of California (DOE 2022a). If Los Angeles receives a budget proportional to its population (approximately 10%), and 20% is allocated for program administration, technical assistance, and outreach, LA households could anticipate receiving $23 million in HOMES rebate funding and $23 million in Home Electrification funding. For the HOMES rebate program, all households, regardless of income, are eligible for funding, but 0%–80% AMI households receive higher rebates. For the Home Electrification program, 100% of the funds are allocated for 0%–150% AMI households and 0%–80% AMI households receive a higher rebate.

Table 8 shows the distribution of income and eligibility for IRA rebates by low- and moderate-income households in Los Angeles. If all 0%–80% AMI households receive the maximum combined rebate of $8,000 from HOMES and $14,500 from Home Electrification, this would cost $19.2 billion. If all 80%–150% AMI households received the maximum combined rebate of $4,000 from HOMES and $14,500 from Home Electrification, this would cost $4.8 billion. Given the program budgets, HOMES could fund retrofits in approximately 0.12% of 0%–150% AMI households, and Home Electrification could fund retrofits in approximately 0.48% of 0%–150% AMI households. Therefore, significant additional funding would be required to supplement federal funding.

Approved projects for the Home Electrification rebates could be a part of new construction, replace nonelectric appliances, or be first-time purchases, and could include electric heat pumps for space heating and cooling (up to $8,000); insulation, air sealing, and material to improve ventilation (up to $1,600); electric wiring (up to $2,500), and electric panel upgrades (up to $4,000). For the lowest income households (0%–80% AMI), 100% of the project costs can be covered.

Table 8. Distribution of Eligibility for IRA Rebates by Low- and Moderate-Income Households

	Household Income	
	0%–80% AMI	**80%–120% AMI**
Eligible LA Renter (number of households)	665,000	152,000
Eligible LA Owner (number of households)	187,000	108,000
Total Eligible Households	**852,000**	**260,000**
IRA Section 50121 HOMES rebate: 20%–35% savings	80% of cost up to $4,000	50% of cost up to $2,000
IRA Section 50121 HOMES rebate: 35%+ savings	80% of cost up to $8,000	50% of cost up to $4,000
IRA Section 50122 Home Electrification rebate	100% of cost up to $14,000 plus $500 for installation	50% of cost up to $14,000 plus $500 for installation

With IRA Section 50122 rebates, LADWP could generally install mini-split heat pumps—at an average cost of $7,000 per pump—in low-income households (0%–80% AMI) without incurring any debt or payment plans through a direct installation plan. For more information on using IRA rebates with building technologies and the potential for a pay-as-you-save program, see Chapter 4 (Bowen et al. 2023).[9]

In addition, the federal Weatherization Assistance Program reduces energy costs for low-income households by increasing the energy efficiency of their homes while ensuring their health and safety. The program supports 8,500 jobs and provides weatherization services to approximately 35,000 homes every year using U.S. Department of Energy funds. In 2023, the average cost-per-unit limit for cost-effective upgrades, such as air sealing, shell, and heating and cooling measures in low-income, single-family, and multifamily dwellings was $8,250 (DOE 2022b). The Weatherization Assistance Program also provides training and resources for workforce development.[10]

IRA Section 50123 provides $200 million to reduce the cost of training, testing, and certifying contractors, as well as partnering with nonprofit organizations to develop and implement a program. Recruiting and prioritizing individuals from disadvantaged communities (DACs) can be a strategic and equitable approach to deploying and building energy efficiency programs. Using fiscal year 2022 allocations from the Department of Energy, California may receive approximately 6.8%, or $13,500,000, of IRA Section 50123 contractor education and training funding. If Los Angeles receives a budget proportional to the city population (approximately 10%), approximately $1,400,000 would be available for contractor education and training in Los Angeles.

3 Equity Strategies Discussion

Both DAC and non-DAC communities have significant potential to increase resilience through building weatherization, but the analysis of distributional equity in energy efficiency incentives shows residential energy efficiency programs disproportionately benefit non-disadvantaged, mostly White, mostly non-Hispanic, mostly home-owning, and mostly above-median-income communities. Therefore, identifying policy actions that prioritize DACs, as well as addressing factors that lower barriers to realizing the resilience benefits in these communities, is key for equitable outcomes in Los Angeles.

This analysis modeled building weatherization and resilience impacts during a power outage in a heat wave. By simulating 10 upgrade options, our analysis finds that significant technical potential exists to reduce dangerous heat exposure. Applying a combined upgrade package of cooling access and a Title 24 building envelope upgrade decreased exposure between 85% and 96%. Combining cooling and robust envelope upgrades provides the greatest opportunities to reduce heat exposure during a power outage across income levels, tenure, and building type.

Lack of access to cooling—most acute among lower-income households and renters—increases exposure to unsafe temperatures significantly. Providing access to cooling reduces heat exposure by between 31% and 43%, decreases the percentage of the housing stock experiencing unsafe temperatures by 11%, and reduces exposure for a lower cost than most other upgrades modeled for low-income households. Low-cost envelope improvements reduce heat exposure in owner-occupied buildings by 33% and renter-occupied buildings by 11%. These differences in benefits require crafting different, targeted program interventions for the different populations.

Based on community guidance and modeling and analysis, the following strategies were developed to achieve more equitable outcomes in building weatherization and cooling for resilience:

- *Target cooling access and envelope improvements by housing type:*
    - *Deploy cooling systems* in low- and moderate-income, multifamily households with no cooling or heating to address their greater exposure to dangerous temperatures. Within this category, prioritize multifamily renters. Window-unit heat pumps could be deployed as property of the renter, avoiding the split incentive, the risk of rent increases, and increasing equity.
    - *Deploy cooling systems and envelope upgrades* in low- and moderate-income, single-family households without cooling to mitigate their increased exposure to outside temperatures. Within this category, prioritize very-low-income (0%–30% AMI), owner-occupied, single-family housing with upgrades, as these households experience the highest energy burdens.
- *Partner with the Housing Authority to provide upgrades in public housing*. Establish mechanisms to mitigate rent increases due to upgrades in nonpublic housing. More than 95% of low-income households living in multifamily buildings are renters. Options include renter protections, "right to return" provisions if renovations temporarily displace renters, and mechanisms to prevent short-term rent increases for multifamily rental properties receiving utility-supported upgrades.
- *Combine federal funding from the IRA and Weatherization Assistance Program with existing LADWP rebates* to augment existing programs, particularly the Home Energy Improvement Program (HEIP) and Cool LA program, to expand opportunities for direct installation (in lieu of rebates) of cooling

through heat pumps and lower-cost building weatherization upgrades for low-income households. Expand LADWP's HEIP to include funding for renovations and electrical upgrades required to add cooling access by leveraging up to $6,500 in IRA rebates for low-income households.

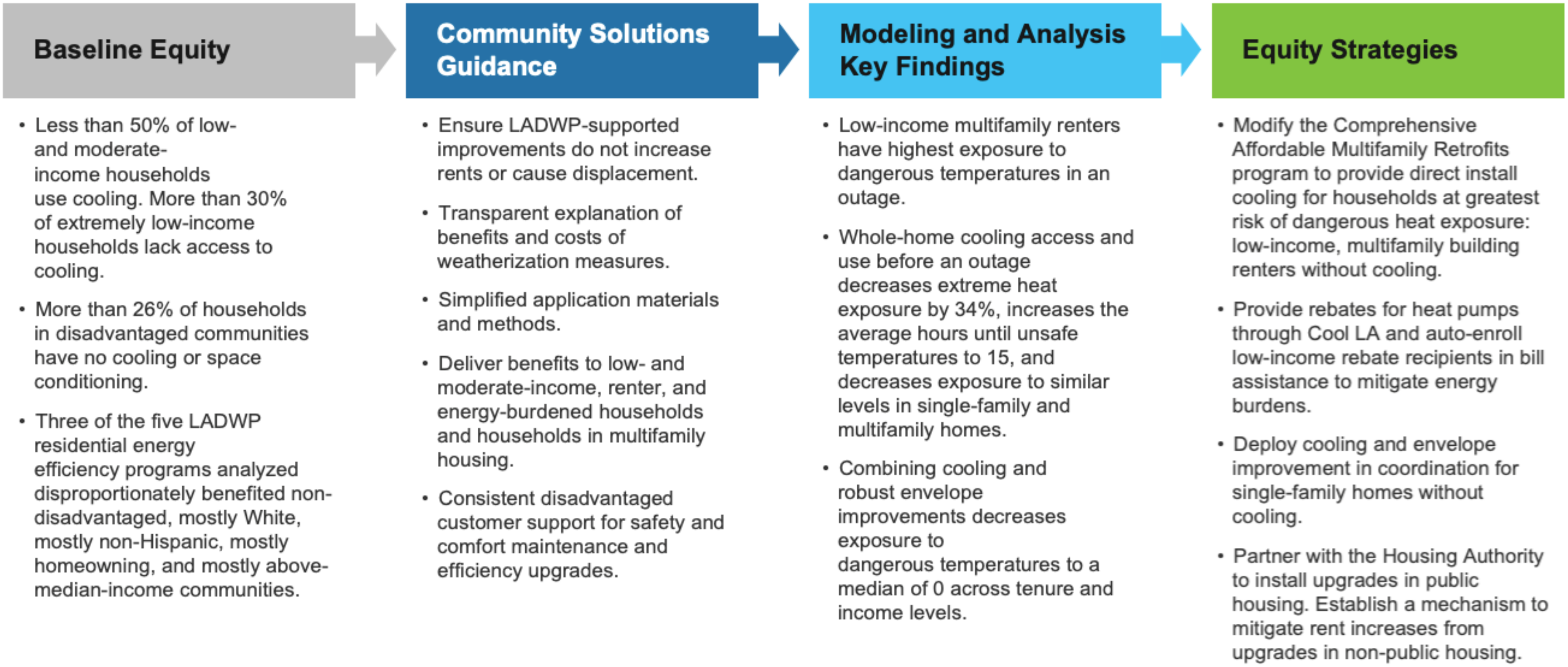
- *Fund and staff program outreach and technical assistance* in partnership with community organizations through neighborhood resource centers, as well as door-to-door outreach approaches targeting areas that received disproportionately fewer LADWP efficiency incentives.
- *Support apprenticeship programs* in DACs for HVAC entrepreneurship and educational opportunities by coordinating IRA funds for workforce development (IRA Section 50123).

Table 9 summarizes the expected benefit and cost (where known) of each strategy, as well as the timeline for implementation (short or long term), the party responsible for implementing the strategy, and metrics for measuring the success of the strategy. The estimated costs summarize the materials and labor costs for each dwelling to receive the upgrade for the demographic as described in the equity strategy.

Table 9. Equity Strategy Benefit, Cost, Timeline, Responsible Party, and Evaluation Metrics

Equity Strategy	Benefit/Impact	Cost	Timeline	Responsible Party	Metric
Deploy cooling in low- and moderate-income, multifamily households with no cooling	Reduce dangerous indoor heat exposure by 84%–100% and increase duration of safe temperatures from 0 to 24 hours in a 24-hour outage 58,000 low-income and 11,000 moderate-income multifamily households have no cooling and are at risk of dangerous heat exposure during a 4-day outage	$430 million – cumulative upgrade costs including materials and labor for adding whole-home cooling to LMI multifamily households without cooling and exceed 216 SET °F-hours in 4-day outage; offset by ~$23 million in IRA 50122 funds	Short-term	LADWP	-Number of systems deployed in LMI households -Percent of LMI multifamily households with cooling
Deploy cooling and envelope upgrades in low- and moderate-income single-family households without cooling	Reduce dangerous indoor heat exposure by 84%–100% and increase duration of safe temperatures from 0 to 24 hours in a 24-hour outage 11,000 low- and 2,500 moderate-income single-family homes without cooling and are at risk of dangerous heat exposure during a 4-day outage	$230 million – cooling and envelope upgrade costs for LMI single-family households without cooling and exceed 216 SET °F-hours in 4-day outage; offset by ~$23 million IRA HOMES funds	Short-term	LADWP	-Number of systems deployed in LMI households -Percent of LMI single-family households with cooling and envelope upgrades
Partner with the Housing Authority to provide upgrades in public housing. Establish mechanisms to mitigate rent increases due to upgrades in nonpublic housing	More than 95% of low-income LA households living in multifamily buildings are renters Improve health and resilience without increased rent	Potentially limited to administrative costs for implementing rent increase restrictions post-upgrade	Short-term	LADWP	-Number of public housing units with LADWP-supported upgrades -Number of LADWP-supported upgrades with rent increase mitigation measures
Use federal funding to expand direct installation of cooling and weatherization upgrades for low-income households	Increased deployment of cooling and weatherization upgrades and increased safety in emergency outages IRA 50122 covers up to $8,000 for heat pumps in low-income households.	Administrative costs, IRA funding, and unknown additional costs	Short-term	LADWP	-Federal funding accessed -Number of upgrades implemented with federal funding in LMI households

The synthesis of baseline equity conditions, community solutions guidance, and modeling and analysis key findings into equity strategies is shown in Figure 8. These strategies were shared with the LA100 Equity Strategies Steering Committee and Advisory Committee and were revised based on their feedback and guidance.



Baseline Equity

- Less than 50% of low- and moderate-income households use cooling. More than 30% of extremely low-income households lack access to cooling.
- More than 26% of households in disadvantaged communities have no cooling or space conditioning.
- Three of the five LADWP residential energy efficiency programs analyzed disproportionately benefited non-disadvantaged, mostly White, mostly non-Hispanic, mostly homeowning, and mostly above-median-income communities.

Community Solutions Guidance

- Ensure LADWP-supported improvements do not increase rents or cause displacement.
- Transparent explanation of benefits and costs of weatherization measures.
- Simplified application materials and methods.
- Deliver benefits to low- and moderate-income, renter, and energy-burdened households and households in multifamily housing.
- Consistent disadvantaged customer support for safety and comfort maintenance and efficiency upgrades.

Modeling and Analysis Key Findings

- Low-income multifamily renters have highest exposure to dangerous temperatures in an outage.
- Whole-home cooling access and use before an outage decreases extreme heat exposure by 34%, increases the average hours until unsafe temperatures to 15, and decreases exposure to similar levels in single-family and multifamily homes.
- Combining cooling and robust envelope improvements decreases exposure to dangerous temperatures to a median of 0 across tenure and income levels.

Equity Strategies

- Modify the Comprehensive Affordable Multifamily Retrofits program to provide direct install cooling for households at greatest risk of dangerous heat exposure: low-income, multifamily building renters without cooling.
- Provide rebates for heat pumps through Cool LA and auto-enroll low-income rebate recipients in bill assistance to mitigate energy burdens.
- Deploy cooling and envelope improvement in coordination for single-family homes without cooling.
- Partner with the Housing Authority to install upgrades in public housing. Establish a mechanism to mitigate rent increases from upgrades in non-public housing.

Figure 8. Equity strategies for resilience through strategic deployment of cooling access and weatherization

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Appendix. Buildings Modeling and Analysis Methodology and Detailed Results

A.1 Data Sources

Table A-1. Summary of Building Weatherization and Resilience Modeling Data Sources

Data	Source	Description	Resolution	Vintage
Disadvantaged Communities (DACs)	SB 535	DACs are identified as tracts with the highest 25% CalEnviroScreen scores.	Census tract	2022
Residential Energy Consumption Survey (RECS)	U.S. Energy Information Administration	Residential building geometries, characteristics, building types, building technologies, etc.	California	2009 and 2015
California Residential Appliance Saturation Study (RASS)	RASS 2019	Residential building stock and appliance saturation study for the LADWP service territory	LADWP service territory and other building stock segments	2019
American Community Survey (ACS)	U.S. American Community Survey	Income, tenure (renter/owner), Federal Poverty Level, % Area Median Income	Public Use Microdata Area (PUMA)	2015–2019
Weather	AMY 2010	Weather data	California Energy Commission Climate Zones	2010
LADWP Low Income Assistance Program Eligibility	LADWP	Low-income eligibility for LADWP assistance programs	Census tract	2022
California Alternative Rates for Energy (CARE) Eligibility	California Public Utility Commission	CARE eligibility	Census tract	2022

Data	Source	Description	Resolution	Vintage
eTRM	California Technical Forum	Wall insulation, ceiling insulation, water heating, cooking range, clothes drying, HVAC (ASHP), MSHP, furnace, wall/floor furnace, AC, room AC	Material costs, labor costs, labor hours	2012
LBNL Cost Data	LBNL	Water heating, air sealing, wall insulation, ceiling insulation, windows, clothes drying, HVAC (ASHP, MSHP, NG furnace, AC)	Total project costs	2020
National Residential Efficiency Measures Database	NREL	Water heating, cooking range, clothes drying, air sealing, wall insulation, ceiling insulation, windows, HVAC (ASHP, baseboards, boilers, MSHP, furnaces, wall/floor furnaces, AC, room AC)	Total project costs	2010
RSMeans data	RSMeans	Water heating, wall insulation, ceiling insulation, lighting, windows, HVAC (boiler, furnace, fan coil AC, ASHP)	Material cost, differentiated labor hourly rate, labor hours, location material and labor factors	Varied

HVAC = heating, ventilating, and air conditioning; AC = air conditioning; ASHP = air-source heat pump; MSHP = mini-split heat pump; NG = natural gas; LADWP = Los Angeles Department of Water and Power; LBNL = Lawrence Berkeley National Laboratory; NREL = National Renewable Energy Laboratory.

A.2 Modeling and Analysis

Modeling Los Angeles' Housing Stock Using ResStock

ResStock is a physics-simulation tool for generating statistically representative households (Wilson 2017). The tool considers the diversity in the age, size, construction practices, installed equipment, appliances, and resident behavior of the housing stock across U.S. geographic regions. ResStock enables a new approach to large-scale residential energy analysis by combining large public and private data sources, statistical sampling, and detailed sub-hourly building simulations. The tool generates a group of statistically representative building simulation models from a housing parameter space derived from existing residential stock data.

Each residential building model is based on building and sociodemographic characteristics, including building geometries (e.g., single-family versus multifamily), building technologies, cooling technologies, tenure (i.e., renter versus owner), and income. Los Angeles' housing stock is modeled using ResStock, as described in the following sections.

Stock Characterization

Public data sources, such as the U.S. Energy Information Administration Residential Energy Consumption Survey, are queried for conditional probability distributions for building stock characteristics and demographics. This approach leverages a robust classification suitable for building stock energy models in energy policymaking, where the different data sources are combined and mapped together using shared parameters such as location, building type, and year (Langevin et al. 2019).

Sampling

ResStock uses deterministic quota sampling, with probabilistic combination of non-correlated parameters. For Los Angeles, 50,000 samples were used in ResStock to represent 1,571,692 dwelling units (a ratio of approximately 1:31).

The residential building modeling team downselected the national ResStock model Los Angeles using the spatial geographies defined by the 2010 U.S. Census geographies and city boundaries. The down-selected residential model represents 1,600,000 dwelling units (U.S. Census Bureau 2021). The dwelling units were distributed to census tracts by the combined use of the 2020 Census Redistricting Data (U.S. Census Bureau 2021), the National Historical Geographic Information System (NHGIS) 2020 to 2010 block crosswalk file (IPUMS NHGIS 2020), and the ACS 2016 5-year dwelling unit counts. ResStock dwelling unit distributions are specified by census tract based on the ACS 2016 5-year survey. A mapping of the dwelling units from census tracts to census blocks was performed using census tract to census block distributions from the 2020 Redistricting Data. We mapped the 2020 Redistricting Data to 2010 U.S. Census geographies using the NHGIS 2020 to 2010 block crosswalk file. The dwelling units were then reaggregated by census tract based on the census blocks in Los Angeles.

The finest geographic granularity of the national version of ResStock is by Public Use Microdata Area (PUMA). PUMAs are a collection of census tracts with an average population of 200,000 and a minimum of 100,000. For the LA100 Equity Strategies study, census tracts were also added into the model for increased geographic specificity of the dwelling unit representative models.

Physics Simulation

The samples inform physics-simulation models, specifically EnergyPlus (EnergyPlus 2023). Model construction and articulation are facilitated by the OpenStudio® software development kit and associated residential modeling workflows.

Calibration and Validation

We use 2010 AMY weather data, which are a combination of ground-based measurement from the National Oceanic and Atmospheric Administration (Smith, Lott, and Vose 2011) and satellite-derived solar radiation data from the National Solar Radiation Database (NREL 2021).

Calibration involved numerous improvements to model input data and refinement of probability distribution dependencies.

Model Outputs and Post-Processing

Model outputs include both annual and hourly or sub-hourly time series energy use outputs for each sample for major and minor end uses (e.g., electricity and on-site natural gas, propane, and fuel oil use). Outputs for each sample also include HVAC system capacities and the hours the heating and cooling setpoints were not met, time series indoor zone air (i.e., dry-bulb) temperature, outdoor dry-bulb temperature, indoor Standard Effective Temperature (SET), mean radiant temperature, relative humidity, and derivative outputs specific to passive survivability, such as SET and heat index.

The building simulations use 2010 AMY, which serve as inputs into the EnergyPlus model to reflect the extreme weather events in this study.

Upgrades

The physics simulation answers questions in what-if scenarios; for example: *What if homes with no wall insulation were retrofitted with dense-packed cellulose? What if homes in disadvantaged communities were retrofitted to Title 24?* Outputs include annual and sub-hourly energy use (and home conditions such as indoor/outdoor temperature and humidity) for the baseline home and the hypothetical upgraded home. We analyzed eight potential building weatherization upgrades, as described in detail in Table A-2.

Equity Metrics

DACs, as defined by SB 535 CalEnviroScreen data, were integrated and used to consider inequities within Los Angeles. In addition, household income and tenure (renter/owner status) were added to ResStock. Using income, occupant count (household size), and U.S. Department of Housing and Urban Development-generated income guidelines, several income disparity metrics were derived, which include the Federal Poverty Level, AMI, California Alternate Rates for Energy (CARE) eligibility, and LADWP low-income eligibility. Having these metrics readily available in ResStock allows for segmentation of simulated building loads in a manner that is consistent with the means-testing requirement of existing federal, state, and local assistance programs.

Measuring Passive Survivability

Passive survivability metrics estimate the risk of heat exposure, primarily through measures of heat index, wet-bulb globe temperature (WBGT), or SET. The modeling team selected the SET approach detailed by LEED Pilot Credit IPpc100 (USGBC 2023). The cooling should not exceed 216 SET°F-hours above 86°F SET for residential buildings. For heat waves, the credit specifies that SET-hours should be calculated by the sum of the difference between the zone-calculated SET and 86°F, only if the zone SET is greater than 86°F, for all hours of the power outage.

Figure A-1 shows a heat wave over a 4-day period. The regions shaded in red indicate SET temperatures exceeding the 86°F SET. The summed area (i.e., integral) of the instances is the duration of the exposure, measured by SET-hours.

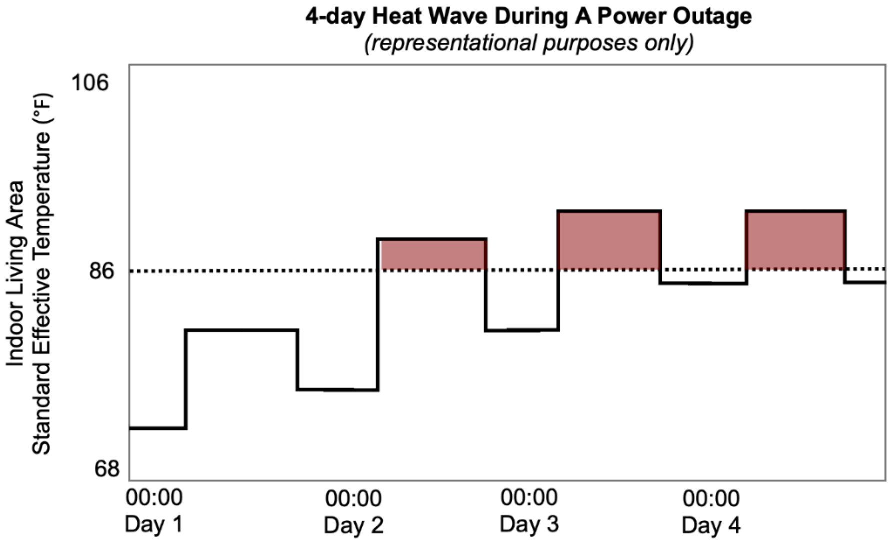

Figure A-1. A representational diagram showing the methodology for exposure (SET°F-hours)

Dimensional Blending

NREL implemented dimensional blending to ingest multiple sources of data. Dimensional blending resolves conditional distributions where many of their dependency combinations have small sample sizes. This often happens when a distribution is conditional to many dependencies and/or a survey has few datapoints, thus making the segmentation of the data by dependency combination too thin. Dimensional blending splits the required dependency set into two or more subsets "blending" together the distribution created from each subset of dependencies. The blending method assumes that dependency subsets are conditionally independent of each other, given the housing characteristics, and ignores possible interactions between them.

Upgrades

Table A-2 provides the detailed building upgrades modeled. In this appendix, cooling use is represented as "heat pump" upgrades.

Table A-2. Building Upgrades

Upgrade	Heat Pump	Window U-Factor	Window SHGC	Ceiling R-Value	Wall R-Value	Infiltration	Floor R-Value	Foundation Wall R-Value	Slab Edge R-Value	Duct Leakage	Duct Insulation	Shading and Roofing
Baseline	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heat Pump	Air-source heat pump (ASHP) SEER 26.1, 11 HSPF Mini-split heat pump (MSHP) SEER 33.1, 13.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Heat Pump, Cool Roof, and Shading	ASHP SEER 26.1, 11 HSPF MSHP SEER 33.1, 13.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Space-dependent Tree shading Roof replaced with light-colored or white materials
Heat Pump and Low-Cost Envelope	ASHP SEER 26.1, 11 HSPF MSHP SEER 33.1, 13.5	N/A	N/A	N/A	Wood Stud: R-13	25% reduction	N/A	N/A	N/A	N/A	N/A	N/A

Upgrade	Heat Pump	Window U-Factor	Window SHGC	Ceiling R-Value	Wall R-Value	Infiltration	Floor R-Value	Foundation Wall R-Value	Slab Edge R-Value	Duct Leakage	Duct Insulation	Shading and Roofing
Heat Pump and Title 24 Envelope	ASHP SEER 26.1, 11 HSPF MSHP SEER 33.1, 13.5	0.37	0.3	Single Family Wood Stud: R-30 (CEC CZ 6); R-2 (CEC CZ 8, 9, & 16) Single Family Concrete Masonry Unit (CMU)/Brick: R-13 (CEC CZ 6, 8, & 9) R-17 (CEC CZ 16) Multifamily: R-22	Single Family Wood Stud: R-15 (CEC CZ 6); R-2 (CEC CZ 8, 9, & 16) Single Family CMU/Brick: R-13 (CEC CZ 6, 8, & 9); R-17 (CEC CZ 16) Multi-Family Wood Stud: R-13 Multi-Family CMU/Brick: R-2	5 ACH50	N/A	N/A	N/A	N/A	N/A	N/A
Cool Roof and Shading	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Space-dependent Tree shading Roof replaced with light-colored or white materials
Low-Cost Envelope	N/A	N/A	N/A	N/A	Wood Stud: R-13	25% reduction	N/A	N/A	N/A	N/A	N/A	N/A

Upgrade	Heat Pump	Window U-Factor	Window SHGC	Ceiling R-Value	Wall R-Value	Infiltration	Floor R-Value	Foundation Wall R-Value	Slab Edge R-Value	Duct Leakage	Duct Insulation	Shading and Roofing
Title 24 Envelope	N/A	0.37	0.3	Single Family Wood Stud: R-30 (CEC CZ 6); R-2 (CEC CZ 8, 9, & 16) Single Family CMU/Brick: R-13 (CEC CZ 6, 8, & 9) R-17 (CEC CZ 16) Multifamily: R-22	Single Family Wood Stud: R-15 (CEC CZ 6); R-2 (CEC CZ 8, 9, & 16) Single Family CMU/Brick: R-13 (CEC CZ 6, 8, & 9); R-17 (CEC CZ 16) Multi-Family Wood Stud: R-13 Multi-Family CMU/Brick: R-2	5 ACH50	N/A	N/A	N/A	N/A	N/A	N/A

Natural Ventilation Modeling

Natural ventilation (i.e., outside airflow into the dwelling via windows) is modeled for all dwellings before, during, and after the outage. When an outage is not active, natural ventilation flow during cooling months will occur if the outdoor temperature is lower than the indoor temperature, the outdoor relative humidity is less than 0.7, and the outdoor humidity ratio is less than 0.0115. During an outage, the humidity constraints of natural ventilation availability are dropped, and natural ventilation will occur exclusively if the outdoor temperature is less than the indoor temperature. The model calculated the available window area by taking a fraction of the window's operable window area (i.e., how much the window could feasible be open), which ranges between 0.2 and 0.5. The 0.5 fraction accounts for the assumption that 50% of the area of an operable window can be open, and the 0.2 fraction accounts for the assumption that 20% of the openable window area is open. Further details on natural ventilation assumptions can be found in Wilson et al. (2014, Section 4.2.1).

Within the analysis, we noticed an increase in heat exposure in MF 5+ units with only envelope-based improvements. We hypothesized this increase is caused by the lack of ventilation available (particularly in middle units without access to operable windows or cross-ventilation). The model outputs of natural ventilation and infiltration by the mean, standard deviation, and 25%, 50%, and 75% quartiles help to confirm this hypothesis, as shown in Table A-3 and Table A-4.

Table A-3. Natural Ventilation in Multifamily Buildings

	Mean Natural Ventilation (cfm)		
	Baseline	**Low-Cost Envelope**	**Title 24**
Mean	98	97	84
Std	77	77	65
25%	43	42	38
50%	77	75	67
75%	130	130	110
	Mean Infiltration (cfm)		
	Baseline	**Low-Cost Envelope**	**Title 24**
Mean	29	22	8.7
Std	22	17	7.3
25%	14	10	5.1
50%	23	17	7.4
75%	37	28	11

Table A-4. Natural Ventilation in Single-Family Buildings

	Mean Natural Ventilation (cfm)		
	Baseline	**Low-Cost Envelope**	**Title 24**
Mean	240	220	180
Std	190	180	150
25%	120	110	82
50%	190	170	140
75%	300	290	230
	Mean Infiltration (cfm)		
	Baseline	**Low-Cost Envelope**	**Title 24**
Mean	60	45	20
Std	41	31	15
25%	33	25	12
50%	50	37	16
75%	77	58	23

Single-family dwellings see larger amounts of natural ventilation and infiltration, regardless of upgrade, than multifamily dwellings. On average, multifamily units have 41% of the natural ventilation that single-family buildings have in the baseline condition. Similarly, infiltration in multifamily buildings is 47% of that in single-family homes in baseline conditions. Multifamily dwelling units generally have fewer exterior walls and windows compared to single-family dwellings.

Outage Considerations, Including Temperature Capacitance

Outage simulation is achieved in this work by adjusting availability schedules to 0 for the duration of a specified date range. This method leaves the indoor temperature of the dwellings to "float" with no set-point control. The simulated heat capacity of air in the node being solved by the EnergyPlus software can influence the rate of change of indoor temperature heavily. This heat capacity can be modified by its default value via the Zone Sensible Heat Capacity Multiplier to stabilize the simulation or better calibrate the simulation to empirical data. In a survey of literature about the Zone Sensible Heat Capacity Multiplier, a range of values has been chosen for similar analyses: from 3.0 to 15 (Chintala, Winkler, and Jin 2021; German and Hoeschele 2014). This study used a value of 7.0 based on recently performed experiments that matched a value of 7.0 for a thoroughly characterized existing house (Sparn et al. 2014).

Exposure in Disadvantaged Communities

We investigated the impacts of upgrades on DACs and non-DACs. Figure A-2 shows the average 4-day exposure.

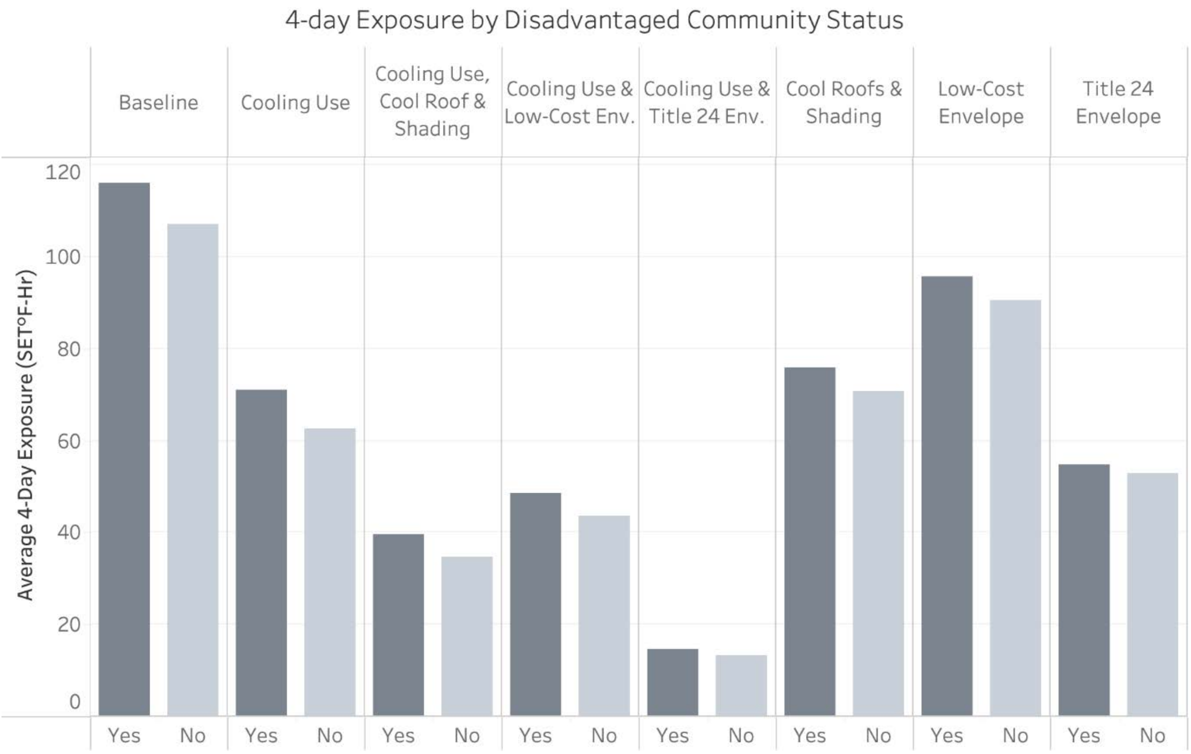

Figure A-2. 4-day exposure by DAC status

We noticed limitations in measuring DACs, as indicated by the small difference of exposure shown in Figure A-2. Across all scenarios, DACs were exposed to higher levels of dangerous temperatures than non-DACs. The data informing the housing characteristics are specified at the PUMA level or larger. PUMAs are a collection of census tracts, and DACs are census tracts. Since DACs are defined at a smaller geography than PUMAs, we believe the distribution of DACs becomes obfuscated in our modeling. Throughout the report, we investigate other demographics to identify equitable pathways for building weatherization and resilience.

Exposure During an Average Power Outage

We measured exposure during the heat wave at the time of an average power outage (i.e., CAIDI with major events) for Los Angeles. At 180 minutes, the exposure for different scenarios is shown in Table A-5.

In the baseline condition, low-income renters experience the highest amount of exposure during an average power outage (14 SET°F-hours), whereas owners in 120%+ AMI experience the lowest amount of exposure (10 SET°F-hours). A combination of cooling use and Title 24 envelope decreases the exposure to approximately zero across income levels and tenure status.

Table A-5. Exposure (SET°F-hours) at 180 Minutes During a Power Outage

Upgrade	Owner			Renter		
	0%–80%	80%–120%	120%+	0%–80%	80%–120%	120%+
Baseline	13	12	10	14	13	12
Low-Cost Envelope	9.2	8.0	6.9	13	11	9.9
Cool Roofs and Shading	9.2	8.1	7.0	12	11	9.6
Title 24 Envelope	3.7	3.2	2.4	8.9	7.5	6.5
Heat Pump	3.1	2.6	2.0	8.0	6.4	5.8
Heat Pump, Cool Roof and Shading	2.2	2.3	1.9	2.1	2.1	1.9
Heat Pump and Low-Cost Envelope	1.6	1.6	1.3	1.6	1.7	1.5
Heat Pump & Title 24 Envelope	0.3	0.2	0.1	0.5	0.5	0.4

Cost for Upgrades

For a complete description of the labor and equipment costs for upgrades, see Chapter 5. We examined the costs relative to the benefits of these improvements, as shown in Table A-6. The costs of upgrades were generated using the total costs, which include the material costs as well as the labor costs to install upgrades. The details of the costing methodology are provided in detail in Chapter 5. We calculated the benefits by subtracting the cumulative 4-day exposure simulated with an upgrade, as measured in SET°F-hours, from the exposure in the baseline condition in an outage for each of the 50,000 building models. We omitted dwellings that showed no change in exposure because they resulted in an infinite value, which primarily resulted from dwellings who received cooling use in the upgrade but had cooling used in the baseline condition.

In low- and moderate-income (0%–120% AMI) households, providing cool roof and shading was the lowest cost per reduced heat exposure in multifamily and single-family dwellings. Yet, the benefits of tree shading are often only available after multiple years of growth. Low-cost envelope improvements provide the lowest cost for immediate benefit across income and housing types. Cooling use provides cost-effective, immediate benefits for single-family dwellings, whereas Title 24 envelopes provide more cost-effective, immediate benefits for multifamily dwellings. Heat pump and Title 24 envelope improvements were the most expensive for the reduction in exposure across all housing and income types. This analysis approximates the relative costs to benefits for resilience. For more analysis on the utility bill effects and other economic effects, see Chapter 5.

Table A-6. Median Cost Relative to Reduced Exposure ($-2022/SET°F-hour) by Income and Housing Type

Upgrade	Single-Family			Multifamily		
	0%–80% AMI	80%–120% AMI	120%+ AMI	0%–80% AMI	80%–120% AMI	120%+ AMI
Cooling Use	260	330	350	79	91	98
Cooling Use, Cool Roof, and Shading	260	340	430	99	120	140
Cooling Use and Low-Cost Envelope	240	310	390	95	110	130
Cooling Use and Title 24 Envelope	250	310	400	110	130	150
Cool Roof and Shading	140	170	210	34	39	43
Low-Cost Envelope	110	130	160	61	69	79
Title 24 Envelope	170	200	250	91	99	110

Multifamily dwellings have lower costs than single-family dwellings. Lower-income households have lower costs than higher-income households. Low-income, multifamily dwellings have the lowest costs relative to the resilience benefits across all upgrades.

A.3 Demographics of Los Angeles

Tenure and Income

More than 70% of renters in Los Angeles live in multifamily buildings with two or more units, as illustrated in Figure A-3. More than 85% of owners live in single-family attached or detached dwellings.

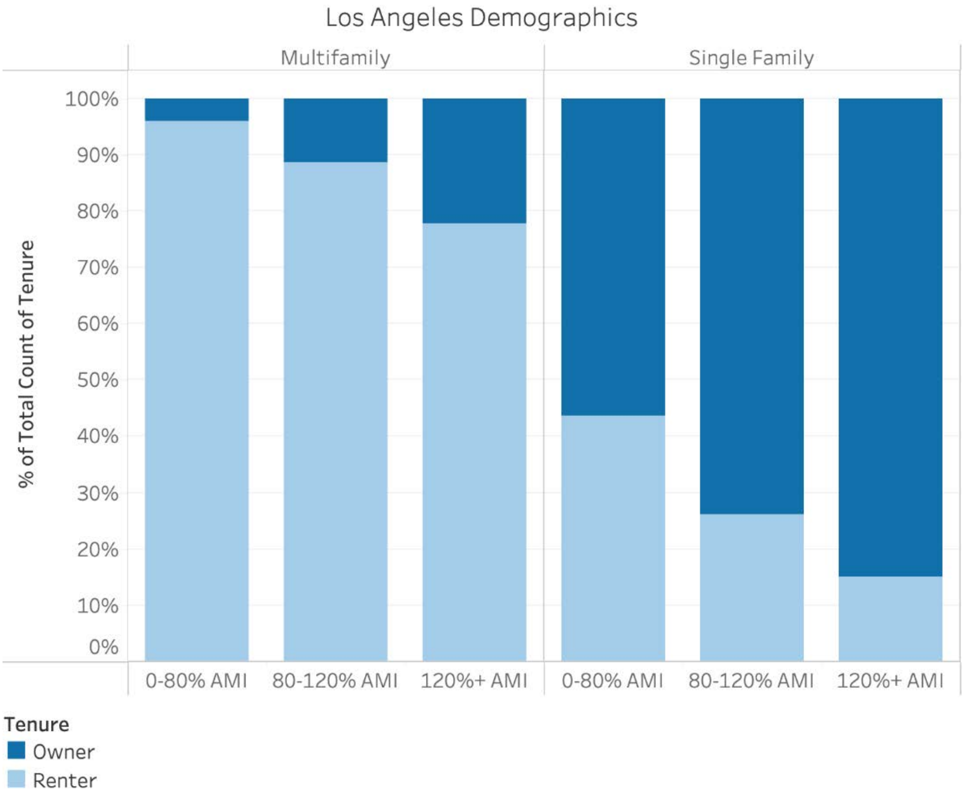

Figure A-3. Los Angeles demographics by tenure, income, and building type

Access to Cooling

We calculate access to cooling in the baseline condition across demographics, as shown in Table A-7. More than 25% of renters, DAC residents, and multifamily building units have no cooling or space conditioning—a key risk factor for heat exposure in an outage, as these households start an outage at unsafe temperatures. Partial space conditioning includes cooling equipment such as small window AC units and mini-split heat pumps that only cool one or two rooms. Full space conditioning includes cooling equipment that is generally centralized and distributed throughout the dwelling.

Table A-7. Percentages of Population with Space Conditioning by Demographic

Original Space Conditioning	**Tenure**		**Building Type**		**DAC**	
	Renter	**Owner**	**Single Family**	**Multifamily**	**Yes**	**No**
No Cooling or Space Conditioning	26%	20%	22%	25%	26%	21%
Partial Space Conditioning	18%	17%	20%	16%	19%	16%
Full Space Conditioning	56%	63%	58%	59%	55%	62%

Use of Cooling

We calculate use of cooling by tenure and building type, as shown in Figure A-4.

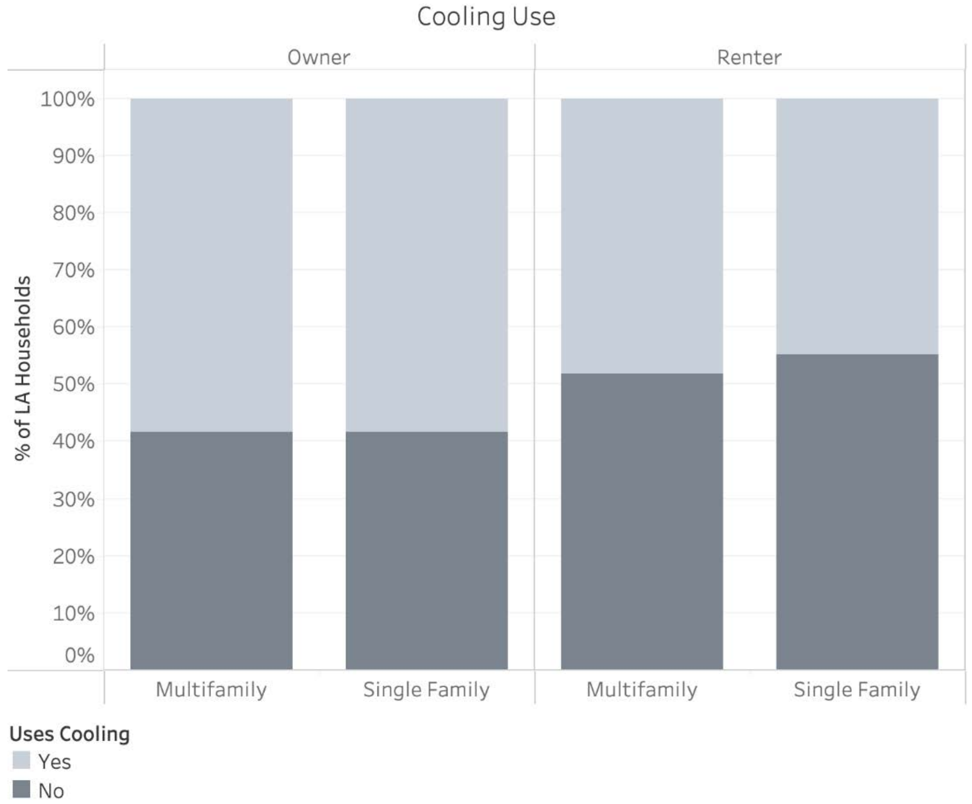

Figure A-4. Cooling use in Los Angeles by tenure and building type

Less than half of all renters use cooling for both multifamily and single-family dwellings. Cooling use provides safe and comfortable living temperatures during heat waves.

Heading Type

We examined the percentage of Los Angeles dwelling units using heating fuel types by tenure and income levels, as shown in Figure A-5.

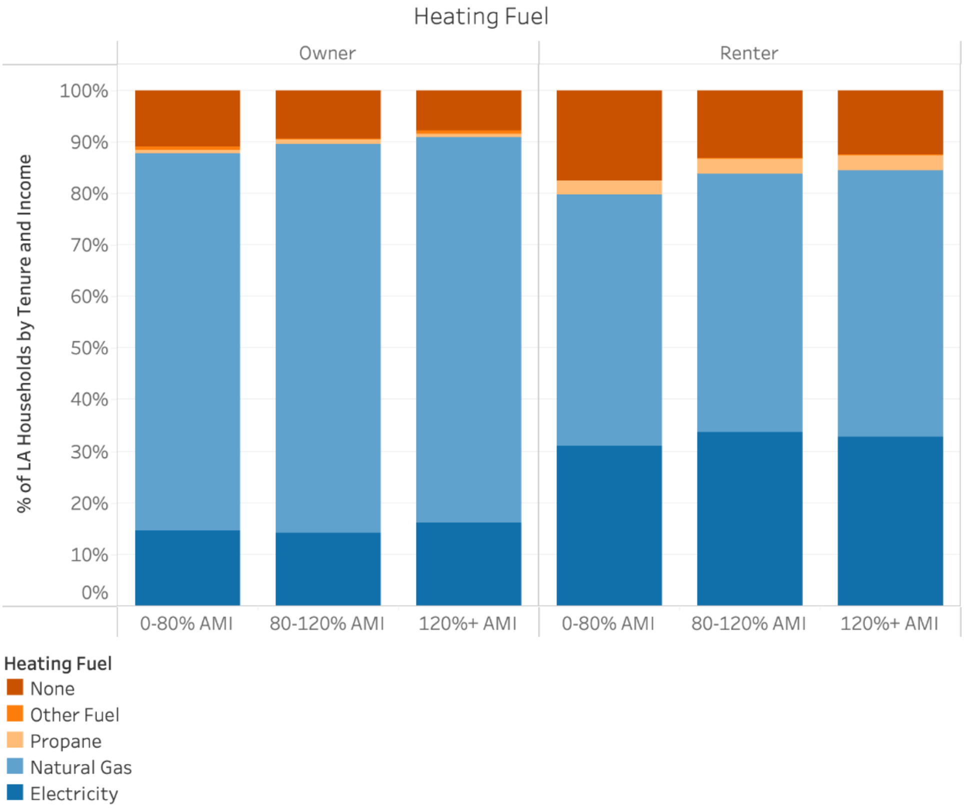

Figure A-5. Heating fuel by income and tenure

Twenty percent of low-income renters either do not have heating fuel or use propane or another type of fuel. Natural gas has the highest usage for heating fuel—over 70% for owners across all income bands and 50% for renters across all income bands. The high use of fossil fuel (or lack of heating) supports the additional benefits of switching to heat pump technologies, which provide cooling during warm temperatures and heating during cool temperatures.

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Strategic Partnership Project Report
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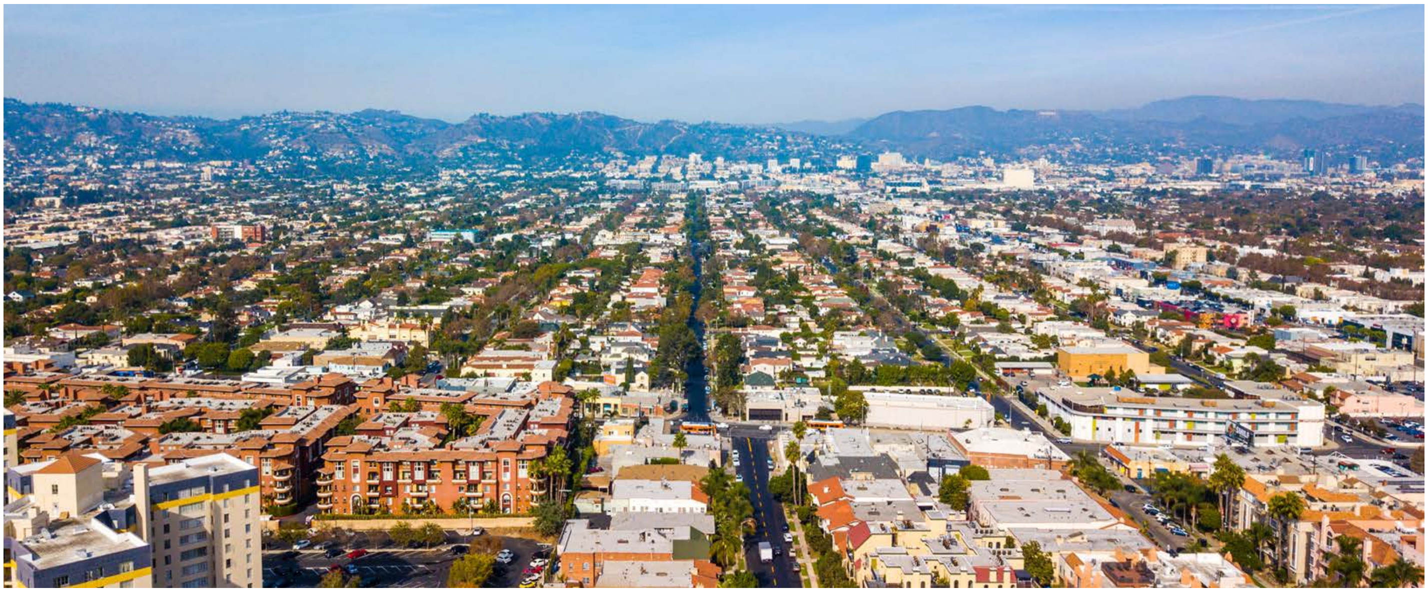
LA100 EQUITY STRATEGIES



Chapter 8: Equitable Rooftop Solar Access and Benefits

FINAL REPORT: LA100 Equity Strategies

Ashok Sekar, Ashreeta Prasanna, Paritosh Das, Megan Day, and Kate Anderson

LA DWP

NREL Transforming ENERGY

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November 2023

LA100 EQUITY STRATEGIES

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Preface

The Los Angeles 100% Renewable Energy Study, or LA100, revealed that although all communities in Los Angeles will share in the air quality and public health benefits of the clean energy transition, increasing equity in participation and outcomes will require intentionally designed policies and programs. The LA100 Equity Strategies project was specifically designed to help Los Angeles identify pathways to such policies and programs in the form of equity strategies. The project aimed to do this by incorporating research and analysis to chart a course toward specific, community-prioritized, and equitable outcomes from the clean energy transition outlined in the LA100 study.

The Project Partners

The Los Angeles Department of Water and Power (LADWP), the National Renewable Energy Laboratory (NREL), and the University of California Los Angeles (UCLA) partnered on the LA100 Equity Strategies project to develop strategies for engaging communities, funding equitable technology and infrastructure investments, expanding existing programs, and designing new programs and policies to improve equity by incorporating what community members themselves know is needed to achieve a more equitable energy future.

The Project Approach

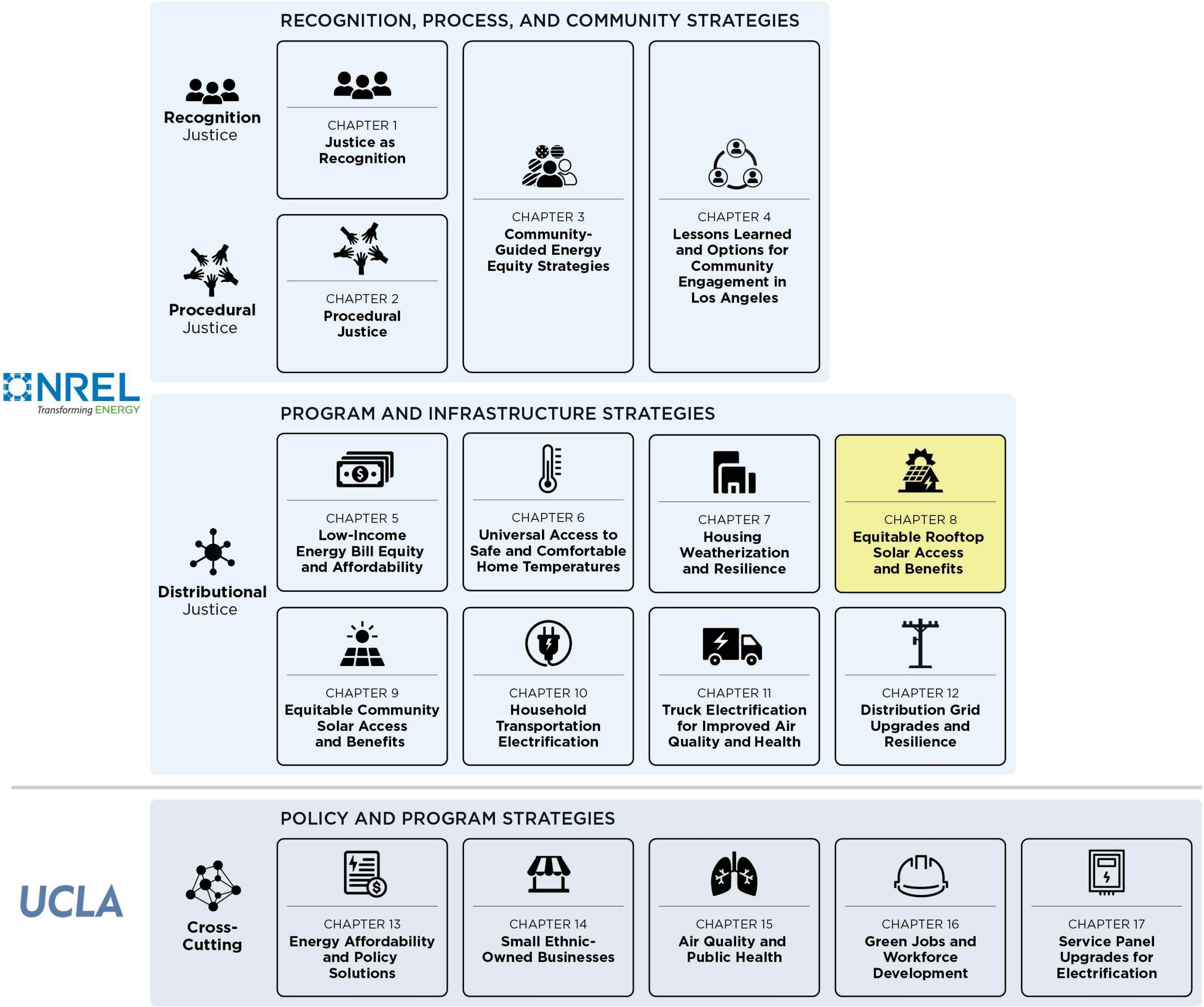
LA100 Equity Strategies employs a unique mixed-methodological approach utilizing three distinct—but connected—research efforts. Through these efforts, NREL and UCLA developed a range of strategy options for increasing equity in LA's transition to 100% clean energy.

A Project Summary

To get a high-level overview of the project, you can dive into the executive summary, interactive data visualizations, and more on the LA100 Equity Strategies website at maps.nrel.gov/la100/equity-strategies.

The Full Report

NREL's final full report for the LA100 Equity Strategies project encompasses seventeen chapters. The first twelve chapters, authored by NREL, are organized around the three tenets of justice. Chapters 1–4 address recognition and procedural justice, while Chapters 5–12 address distributional justice. The final five chapters, authored by UCLA, provide crosscutting policy and program strategies. Each chapter provides data, methods, insights, and strategies to help LADWP make data-driven, community-informed decisions for equitable investments and program development.



NREL Chapters

Chapter 1: Justice as Recognition

Chapter 2: Procedural Justice

Chapter 3: Community-Guided Energy Equity Strategies

Chapter 4: Lessons Learned and Options for Community Engagement in Los Angeles

Chapter 5: Low-Income Energy Bill Equity and Affordability

Chapter 6: Universal Access to Safe and Comfortable Home Temperatures

Chapter 7: Housing Weatherization and Resilience

Chapter 8: Equitable Rooftop Solar Access and Benefits

Chapter 9: Equitable Community Solar Access and Benefits

Chapter 10: Household Transportation Electrification

Chapter 11: Truck Electrification for Improved Air Quality and Health

Chapter 12: Distribution Grid Upgrades for Equitable Resilience and Solar, Storage, and Electric Vehicle Access

UCLA Chapters

Chapter 13: Energy Affordability and Policy Solutions Analysis

Chapter 14: Small Ethnic-Owned Businesses Study

Chapter 15: Air Quality and Public Health

Chapter 16: Green Jobs Workforce Development

Chapter 17: Service Panel Upgrade Needs for Future Residential Electrification

List of Abbreviations and Acronyms

AMI	area median income
DAC	disadvantaged community
dGen	Distributed Generation Market Demand (model)
DI	direct-install
EE	energy efficiency
GW	gigawatts
hr	hour
ITC	investment tax credit
kW	kilowatt
kWh	kilowatt-hour
LADWP	Los Angeles Department of Water and Power
LMI	low- and moderate-income
MW	megawatts
MWh	megawatt-hours
NEM	net energy metering
NREL	National Renewable Energy Laboratory
PV	photovoltaic
REPLICA	Rooftop Energy Potential of Low Income Communities in America
SB	Senate Bill (California)
SI	split incentive
W	watt
WACC	weighted average cost of capital
yr	year

Executive Summary

The LA100 Equity Strategies project integrates community guidance with robust research, modeling, and analysis to identify strategy options that can increase equitable outcomes in Los Angeles' clean energy transition. This chapter focuses on analysis of customer-sited rooftop solar and storage as a means to reduce electricity bills for low- and moderate-income (LMI) households, multifamily building residents, and renters, who traditionally lack access to bill savings from rooftop solar.

Specifically, NREL modeled customer-sited solar and storage adoption using the Distributed Generation Market Demand (dGen™)[1] model through 2035 and developed scenarios to identify programs or policies that could support equitable access to bill savings from rooftop solar or solar-plus-storage. Scenarios tested include a direct-install program for LMI customers, net metering for LMI customers, and equitable distribution of benefits from installing solar between owners and renters of renter-occupied buildings.

Research was guided by input from the community engagement process, and equity strategies are presented in alignment with that guidance.

Community Guidance

Guidance from the LA100 Equity Strategies Steering Committee, listening sessions with community-based organizations and community members, and community meetings includes the following:

- Address the cost of rooftop solar
- Provide community solar access
- Deliver customized information on investments and payback periods to address skepticism about the value of solar
- Protect residents from predatory solar developers.

Wilmington, LA Harbor Resident

"I'm a homeowner. And I have a duplex, so I rent out … And we're trying to get solar from the Department of Water and Power, it's difficult. Yes, you have subsidies and stuff. But you gotta put up almost 20 grand just to get the solar power. Who's going to take on all that with my tenants?"

Steering Committee Member

"More outreach in low- and moderate-income communities and communities of color is needed on options for solar and storage."

South LA Public Housing Resident

"… they were trying to put solar panels on the roof, on the projects. But some people from the community gathered around and then they were telling me to vote no for them to put it [solar on the roof]. Because they were like, what's the point of them putting solar panels on the roof when they're going to start charging us or you may never know even if they're going to work or how long they're going to last. So, a lot of people rejected that offer, so ... they still tried to convince us to get it. But mostly all of us voted no."

---

[1] "Distributed Generation Market Demand Model," NREL, https://www.nrel.gov/analysis/dgen

Distributional Equity Baseline

Analysis of Los Angeles Department of Water and Power (LADWP) residential net energy metering programs (Figure ES-1) indicates 62% of LADWP net energy metering program incentives delivered between 1999 and 2021 went to households in non-disadvantaged communities. In addition, the $341 million in LADWP net energy metering incentives over these 22 years disproportionately benefited predominantly White, non-Hispanic, home-owning, and wealthier neighborhoods.

Figure ES-1. Statistical analysis of LADWP residential solar investments by disadvantaged community status (1999–2021)

Geospatial analysis of the distribution of LADWP solar incentives finds that disadvantaged communities (DACs), particularly in South LA and the Harbor region, did not receive solar incentives proportional to their populations (Figure ES-2).

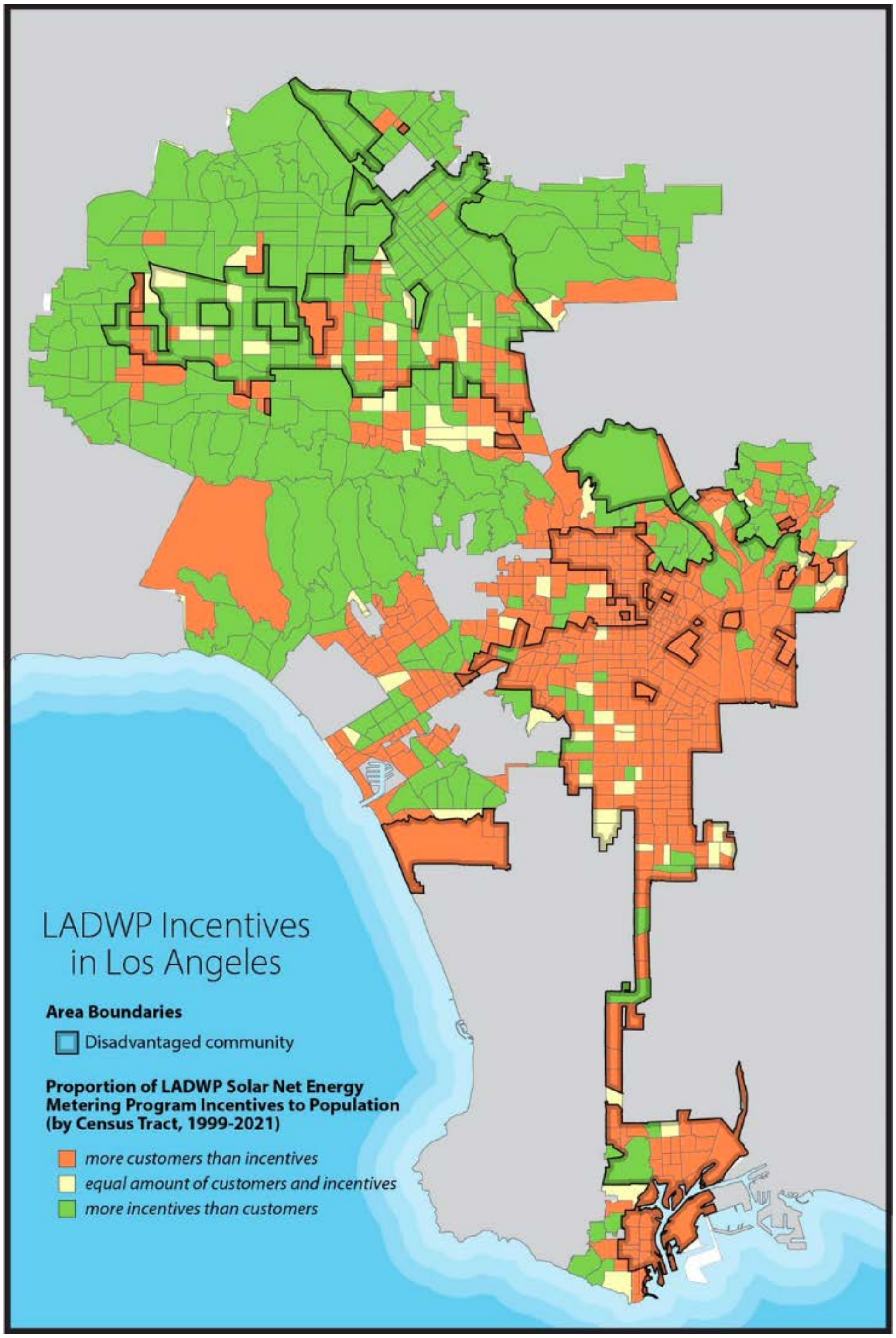


Figure ES-2. Distributional equity analysis of LADWP residential solar net energy metering incentive programs (1999–2021)

Key Findings

- A substantial portion of suitable rooftop solar area lies outside of the types of households who have received most incentives to date. LMI households occupy buildings representing

57% of all solar photovoltaic (PV)-suitable roof area in Los Angeles. Multifamily households represent 60%, and 55% of suitable rooftop area is occupied by renters.

- Baseline scenario modeling indicates 1.4 gigawatts (GW) of cumulative rooftop solar adoption by 2035 in Los Angeles. With current incentives extended into the future, single-family, owner-occupied, non-LMI households will account for approximately 70% of that adoption.
- Rooftop PV adoption among LMI customers could increase by 85% (up to 530 megawatts [MW] of solar and 520 MW of storage) under a direct-install program for LMI customers funded by LADWP, combined with strategies to convey solar savings to renters and resolve the split incentive challenge. LMI rooftop PV adoption could increase by 40% (up to 280 MW of solar and 0 MW of storage) under a net metering program for LMI customers combined with strategies to convey solar savings to renters.
- New solar capacity adoption in DACs is lower than in non-disadvantaged tracts in most scenarios in the initial years. Analysis shows that implementing LADWP direct-install programs, combined with strategies to convey solar savings to renters, substantially increases solar capacity additions in DACs as compared to non-DACs as we approach 2035.
- Under a net metering for LMI households scenario, moderate-, low-, and very low-income households see additional average electricity bill savings of 30%, 30%, and 34%, respectively, compared to the Baseline scenario. Under a net billing with direct-install and renter solar bill savings scenario, average electricity bill savings increase by 16%, 17%, and 18% for moderate-, low-, and very low-income customers, respectively, compared to the Baseline scenario.
- The total program costs over 16 years for direct-install of 530 MW of solar and 520 MW of storage for LMI households is $2.2 billion or $140 million/year. Total program costs for 280 MW of net metered solar (with no storage) for LMI households is $2.7 billion or $170 million/year. These costs would be recovered from rate increases, leading to higher bills for households without access to solar bill savings.

Rooftop solar equity metrics include:

- Annual electricity bill savings
- By income, housing type, disadvantaged community status, and renter/owner status.

Equity Strategies

- Offering net energy metering to LMI customers enables these customers to achieve an average of 30% additional electricity bill savings ($460/year [yr]) if they install solar compared to the Baseline scenario.
- Implementing direct-install programs results in higher-capacity deployment, which could benefit the LADWP distribution grid if the program is targeted to specific geographic regions. Net metering programs result in higher bill savings for low-income customers.
- Resolving renter-owner split incentives through programs such as virtual net energy metering, community solar, green leases, on-bill financing, or property-assessed clean energy programs can increase solar electricity bill savings by up to 84% for renters.

- A discounted LMI Shared Solar rate delivers similar savings to rooftop solar approaches modeled here, is easily accessible to multifamily building residents and renters, and is essentially cost-neutral for LADWP (see Chapter 9, Prassana et al. 2023).

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1 Introduction

This analysis focuses on improved access to bill savings from solar and storage for low-income households, multifamily building residents, and renters. NREL modeled adoption of customer-sited rooftop solar (with storage, where it was economic) using the Distributed Generation Market Demand (dGen™) model under multiple scenarios. Scenarios consider electrification, targeted incentives, and future utility rates and are simulated in dGen from 2020 to 2035 to inform incentive and program design and investment prioritization.

Rooftop solar historically has had limited reach in these communities because of barriers like financing challenges, monetization of investment tax credits, costs to upgrade electrical panels or replace roofs, and split incentives. Split incentives refer to situations where upgrades like solar would be paid for by a building owner, yet savings would accrue to renters, disincentivizing the investment. Policies including solar leasing, property-assessed clean energy financing, and LMI-specific incentives may increase access to bill savings among lower-income households and renters. In addition to addressing split incentives, direct-install programs where solar and storage systems are installed at no cost or net metering programs are also methods to increase access to solar bill savings among low-income households. Such programs would also allow the Los Angeles Department of Water and Power (LADWP) to provide resiliency services or monetize aggregated distributed energy resources under Federal Energy Regulatory Commission Order 2222.

1.1 Modeling and Analysis Approach

Census tract-level information about LADWP's residential customers were input into the dGen model to identify strategies to achieve increased equity in access to bill savings from rooftop solar (and storage where it was economic).

The dGen model is a geospatially rich, bottom-up, market-penetration model that simulates the potential adoption of distributed energy resources, such as rooftop solar photovoltaics (PV), for residential, commercial, and industrial customers at high spatial and temporal resolutions. For Chapter 4 of the completed Los Angeles 100% Renewable Energy Study (Sigrin et al 2021), the dGen model was used to simulate solar adoption at a premise level and the model incorporated several characteristics to estimate the probability of adoption, including socioeconomic characteristics such as income, sensitivity to prices, and parameters to capture the social diffusion of technology (Sigrin et al. 2021). The LA100 Equity Strategies project builds on that analysis by using the same characteristics to further identify the probability of adoption based on income, building type, and ownership status, specifically in the residential sector.

Figure 1 outlines the main dGen adoption modeling steps, and Figure 2 provides an overview of the spatial layers in dGen used to characterize representative customers. Results from dGen include several financial output metrics, such as the net present value of solar and storage systems that are sited at customer premises, electricity bills of customers with and without solar and storage systems, excess electricity exported to the grid, and payback periods of solar and storage systems. Energy burden, calculated as annual utility bills divided by annual household income, is calculated for each customer demographic before and after the adoption of solar and storage technologies. Thus, the impact on energy burden for low-income customers from access to solar and storage can also be determined. In addition to financial output metrics, results include the modeled cumulative capacity of solar and storage systems at high spatial resolution for future years by income class, building type, and household ownership status under multiple scenarios. By modeling representative customers across all income levels and calibrating the model to account for differences in the propensity to adopt, the results from the model reflect the differences in adoption patterns by customer type and location.

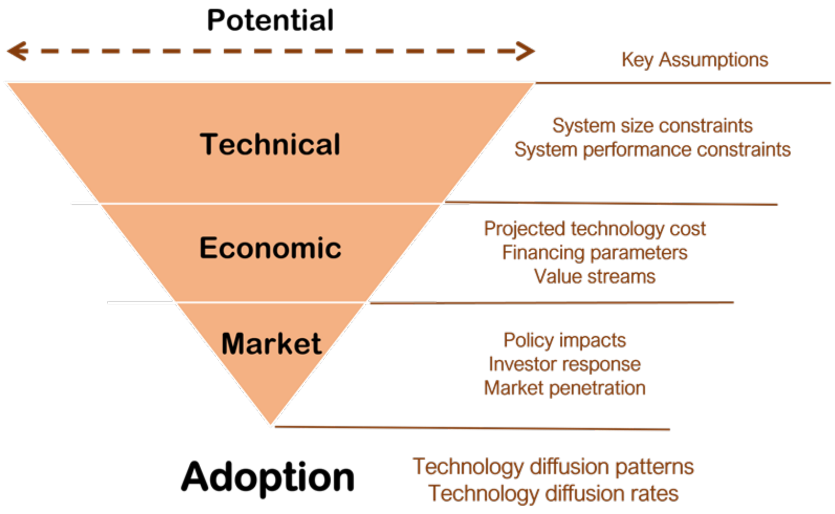

Figure 1. Overview of the dGen model used for rooftop solar and storage analysis

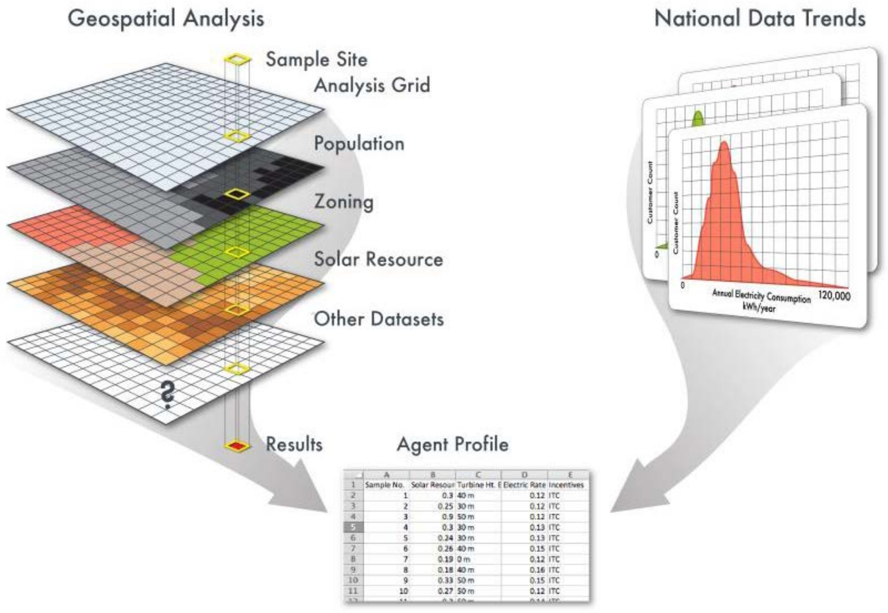

Figure 2. Schematic of spatial layers in dGen

Historically, dGen has modeled single-family, owner-occupied households only. Preparing the dGen model for the LA100 Equity Strategies project involved first updating customer characteristics, such as:

- Electricity consumption
- Load profile
- Total PV-suitable roof area
- Economic and financial parameters that include—but are not limited to—incentives, tariff rates, and inflation rates, as well as the future outlooks of these parameters.

Next, new representations of customers were developed to model non-single-family, owner-occupied households. Representative customers modeled in dGen include LADWP households by five income classes:

- Very low (0%–30% area median income [AMI])
- Low (30%–60 % AMI)
- Moderate (60%–80% AMI)
- Mid (80%–120% AMI)
- High (120%+ AMI).

These households are further categorized by eight building classifications:

- 2 Unit (multifamily)
- 3 or 4 Unit (multifamily)
- 5 to 9 Unit (multifamily)
- 10 to 19 Unit (multifamily)
- 20 to 49 Unit (multifamily)
- 50 or more Unit (multifamily)
- Single-Family Attached
- Single-Family Detached.

Households are also classified by ownership status: owner and renter.

Appendix A provides details on the data sets and methods used to develop representative customers.

1.2 Scenarios

Several scenarios were developed to guide equity strategy development. These scenarios were selected to model benefits for low- and moderate-income (LMI) multifamily building residents and renters from solar and storage access or adoption. Modeled scenarios include the following.

1.2.1 Baseline Scenario

Under the Baseline scenario, we assume customers have baseline electricity consumption modeled using ResStock as described in Chapter 5 (Prasanna et al. 2023). Tiered rates are assigned to customers based on their zone and average monthly consumption.[2] Retail rate escalation is based on LADWP Strategic Long-Term Resource Plan projections under the California Senate Bill (SB) 100 scenario. The federal investment tax credit (ITC) is applied based on the Inflation Reduction Act of 2022. We assume the existing LADWP net metering program will be discontinued and transitioned to a program modeled after Net Energy Metering (NEM) 3.0, which was passed by the California State Legislature and enforced for investor-owned utilities in the state. NEM 3.0 provides lower compensation for excess electricity reduction than NEM 2.0. Therefore, export rates are set to be comparable to wholesale electricity prices, or net billing. Wholesale prices are flat rates that increase yearly from 2.6 cents/kilowatt-hour (kWh) in 2020 to 4.3 cents/kWh in 2035. All other financial parameters are modeled based on NREL's 2022 Annual Technology Baseline projection data (NREL 2022).

1.2.2 Direct-Install for LMI (DI for LMI) Scenario

Under this scenario, solar and storage systems are installed at zero cost for LMI households between 2020 and 2035. The cost of the systems is assumed to be borne by LADWP. We assume LADWP can claim the 30% ITC for these systems and that costs are recovered through state funds or through rate recovery. We do not model the impact of recovering program costs through retail rate increases. Also, despite systems being offered at no cost, not all LMI households adopt the systems because of several barriers, such as distrust (Reames 2016) or general lack of interest in installing solar (Wolske 2020). A recent analysis of adoption data for California's low-income solar programs, managed by GRID Alternatives, showed that between 2009 and 2018, only 10% of all households contacted adopted solar despite being offered a solar system at no cost; although this was often due to ineligibility, many lost interest despite being qualified leads (Sigrin, Sekar, and Tome 2022).

1.2.3 Split Incentives Resolved (No SI) Scenario

Renters and multifamily households face a split incentive problem where residents of the housing units do not have agency over the rooftop and building owners pay for upgrades, but bill savings accrue to tenants who pay utility bills. To model the impact of split incentives in this scenario, two edge cases are considered: split incentives being fully resolved and split incentives being partially resolved. There is no existing work to mathematically characterize split incentive phenomena at fine spatial resolution. Therefore, we fully resolve split incentives by assuming the weighted average cost of capital (WACC) is the same for tenants who are renters and tenants who are owners of their units. In the Baseline scenario, we assume WACC for tenants who are renters is significantly higher than for tenants who are owners. The assumptions are based on updated WACC cost estimates from NREL's 2022 Annual Technology Baseline (NREL 2022) and Heeter et al. (2021) as part of the Solar Futures Study.[3] The effect of this assumption impacts all multifamily households and renters irrespective of their income class or the building type in which they reside. In practice, solutions to split incentives between owners and tenants

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[2] "Customer Service: Electric Rates," LADWP, https://www.ladwp.com/ladwp/faces/ladwp/residential/r-customerservices/r-cs-understandingyourrates/r-cs-ur-electricrates.

[3] "Solar Futures Study," U.S Department of Energy, https://www.energy.gov/eere/solar/solar-futures-study.

include programs such as property-assessed clean energy,[4] green leases, and other strategies (Castellazzi, Bertoldi, and Economidou 2017). Such programs aim to formalize and realign the financial incentives from energy measures between the owner and the renter. Because these programs are new, the propensity of adopting these measures is unavailable. The case of split incentives being fully resolved assumes such programs are 100% effective, such that multifamily renters behave similarly to single-family owners.

1.2.4 Net Metering for LMI (NEM for LMI) Scenario

In this scenario, LMI customers are assumed to benefit from net energy metering where the excess generation is compensated at retail rates (greater than 20 cents/kWh). The net metering for LMI customers cost is assumed to be borne by LADWP. Net metering for LMI is modeled in combination with resolving split incentives because resolving split incentives is a necessary precursor to renters accessing net metering benefits.

1.2.5 High Energy Efficiency (High EE) Scenario

This scenario is modeled based on Chapter 7 (Stenger et al. 2023), where a high uptake of energy efficiency measures, such as weatherization and end-use technology upgrades, is modeled as an equity strategy. High uptake of energy efficiency measures reduces the annual electricity consumption of LADWP customers in this scenario, which in turn impacts the cost savings from—and, therefore, the adoption propensity for—solar and storage systems.

We develop five combinations of the above equity scenarios in addition to the Baseline scenario to investigate equity strategies (Table 1). Additional assumptions, inputs, and financial assumptions are described in Appendix A.

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[4] "Commercial Property Assessed Clean Energy (C-PACE)," October 2017, DOE/EE-1697, https://www.energy.gov/scep/slsc/articles/commercial-property-assessed-clean-energy-fact-sheet-state-and-local-governments

Table 1. Summary of Scenarios Modeled in dGen

Scenario Name	Scenario Short Name	Load Profile	Split Incentives	External Incentives	Compensation Style
Baseline	Baseline	Baseline	Partially resolved	ITC only	Net billing
High Adoption of Energy Efficiency Measures	High EE	Equity	Resolved	ITC only	Net billing
Split Incentives Resolved	No SI	Baseline	resolved	ITC only	Net billing
Direct-Install for LMI	DI for LMI	Baseline	Partially resolved	ITC and no system cost for LMI customers	Net billing
Split Incentives Resolved and Direct-Install for LMI	No SI and DI for LMI	Baseline	Resolved	ITC and no system cost for LMI customers	Net billing
Split Incentives Resolved and Net Metering for LMI	No SI and NEM for LMI	Baseline	Resolved	ITC only	Net metering for LMI customers and net billing for others

2 Modeling and Analysis Results

2.1 Rooftop Solar Technical Potential

Table 2 shows the demographic characteristics and technical rooftop PV potential of residential customers by income, tenure, and building type. The number of households represents the 1.55 million rate payers in the LADWP service territory. Of LADWP customers, 57% are LMI households, 60% are multifamily households, and 55% are renters (Mooney and Sigrin 2018; Sigrin et al. 2021; U.S. Census Bureau, 2021).

PV-suitable roof area is defined as the portion of the roof that is viable for solar installation based on shading and roof orientation analysis (Gagnon et al. 2016). LMI households, multifamily households, and renters have substantially less PV-suitable roof area and lower average electricity consumption than non-LMI households, single-family households, and owners (Table 2).

Table 2. Characteristics of LADWP Customers by Income, Building Type, and Tenure

Category	**Number of Households**	**Average PV-Suitable Roof Area per Household (ft^2)**	**Average Annual Household Consumption (kWh)**	**Aggregate Rooftop PV Technical Potential (GW)**
Income Level				
LMI	880,000	230	5,100	3.5 (48%)
Non-LMI (mid- and high-income)	670,000	340	6,400	3.9 (52%)
Building Type				
Multifamily	940,000	150	4,400	2.3 (32%)
Single-family	610,000	480	7,600	5.0 (68%)
Tenure				
Renter	860,000	210	4,800	3.1 (42%)
Owner	690,000	360	6,800	4.3 (58%)

Number of households and rooftop PV technical potential under each category sums to the total for all LADWP customers, and PV-suitable roof area and annual consumption are average values at the household level. The percentage values for number of households and aggregate rooftop PV technical potential should be interpreted as a percentage of that category to the total; for example, 48% of all rooftop PV technical potential is from LMI customers. The same statistic is not applicable for average suitable roof area or average annual consumption.

2.2 Overview of Modeled PV and Storage Adoption in Los Angeles

Cumulative rooftop PV adoption in the Baseline scenario is 1.4 gigawatts (GW) by 2035. The High EE scenario does not change adoption compared to the Baseline scenario. Resolving renter-owner split incentives (No SI) increases cumulative PV adoption to 1.7 GW by 2035. Combining resolution of split incentives with NEM for LMI customers (No SI & NEM for LMI) further increases adoption to 1.8 GW of cumulative PV adoption by 2035. Providing direct installs for LMI customers (DI for LMI) alone results in adoption of 1.9 GW of cumulative PV adoption by 2035. Combining resolution of split incentives with direct-install (No SI & DI for LMI) results in the highest adoption with 2.0 GW of cumulative PV adoption by 2035—a 41% increase in cumulative adoption compared to the Baseline scenario and 28% of total technical potential adopted by 2035.

In the Baseline scenario, a total of 5.3 megawatts (MW) of storage capacity is adopted in conjunction with residential rooftop installations by 2035; this is an additional 0.3 MW compared to 2020. Direct-install scenarios with no system costs for LMI customers result in significant increase in storage co-adopted with PV, and around 520 MW (1,000 megawatt-hours [MWh]) of storage is adopted by 2035 as battery costs are paid for by LADWP. In the Baseline, High EE, No SI/No SI & NEM for LMI scenarios, customers do not adopt solar and storage because the combined costs are uneconomic. Note dGen assumes all storage systems adopted have a 2-hour (hr) duration.

Figure 3 shows the cumulative adoption of rooftop PV and storage, and Table 3 summarizes key adoption statistics for 2035.

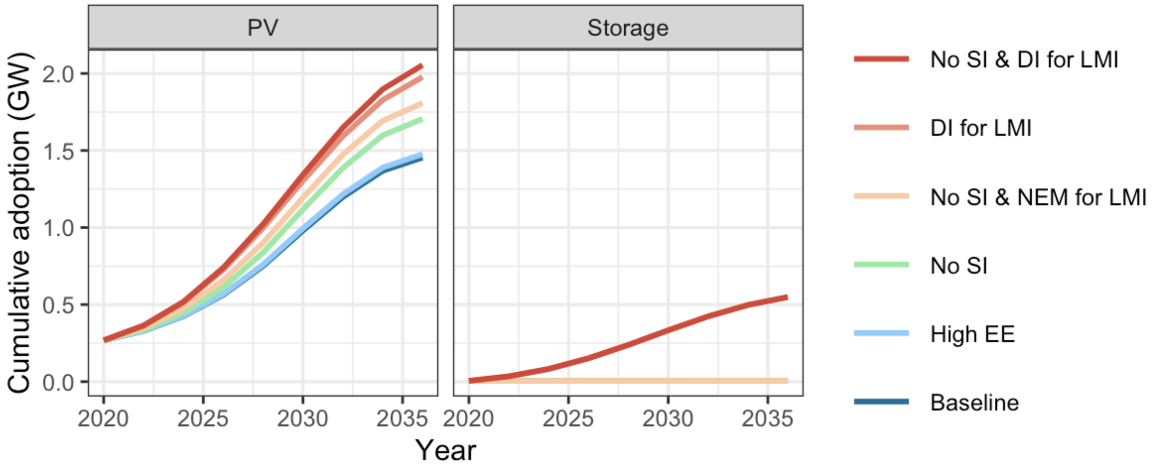

Figure 3. Cumulative rooftop solar adoption in Los Angeles by scenario

Table 3. Modeled PV and Storage Adoption by Scenario (2035)

Scenario	PV Market Potential (GW)	PV Economic Potential (GW)	Number of PV Adopters (millions)	PV Adoption (GW)	Storage Adoption (MW)
Baseline	2.4	1.7	0.80	1.4	5.3
High EE	2.4	1.8	0.80	1.4	5.3
No SI	2.9	2.1	0.80	1.7	5.3
No SI & NEM for LMI	2.9	2.2	0.85	1.8	5.3
DI for LMI	2.8	2.4	0.95	1.9	520
No SI & DI for LMI	3.0	2.5	0.96	2.0	520

2.3 PV and Battery Adoption by Demographic Segments

Combining direct-install for LMI households with the resolution of split incentives (No SI & DI for LMI) results in the highest PV adoption, followed by resolving split incentives plus net energy metering for LMI customers (No SI & NEM for LMI). Resolving split incentives alone has the least impact. See Figure 4 (page 11).

The increase in rooftop solar adoption for LMI households could vary between 26% and 83%, which translates to total adoption of 0.8 GW to 1.2 GW, depending on the scenario implemented. The increase in adoption for renters could vary between 48% and 94%, which translates to total adoption of 0.6 GW to 0.79 GW. Increases in adoption of multifamily households could vary between 37% and 80%, which translates to total adoption of 0.63 GW to 0.83 GW. In all categories, the High EE scenario leads to a slight decrease in uptake (about -1% to -2%) because high energy efficiency leads to a decrease in total load and therefore smaller PV system sizes.

The No SI scenario increases adoption the most for renters because it specifically targets renters. Direct-install and NEM programs impact only LMI households. There are LMI households within multifamily and renter populations; therefore, combining LMI-targeted programs (DI or NEM) with the No SI program results in higher adoption. In other words, program design targeting multiple population groups increases adoption.

Adoption potential is a high upper bound that does not take into consideration constraints such as that LMI households may have time scarcity, language issues, and lack of internet and phone access (Sigrin, Sekar, and Tome 2022). Multifamily building residents and renters have constraints such as split incentives.

LMI multifamily renters represent 30% of the total households in Los Angeles and have a technical rooftop PV capacity of 1.4 GW (19% of total technical capacity). Multifamily building renters represent 53% of the total LMI population, 50% of all multifamily building residents, and 55% of all renters in Los Angeles; in technical capacity terms, they are 39%, 59%, and 45% respectively. Technical capacity does not scale with the share of the population due to reduced

PV-suitable area. Table 4 (page 12) summarizes the population characteristics of these hard-to-reach LMI, multifamily, and renter households. Large portions of these households also live in disadvantaged communities. Figure 5 (page 13) shows the percentage of LMI, multifamily, and renter populations living in disadvantaged communities (DACs).

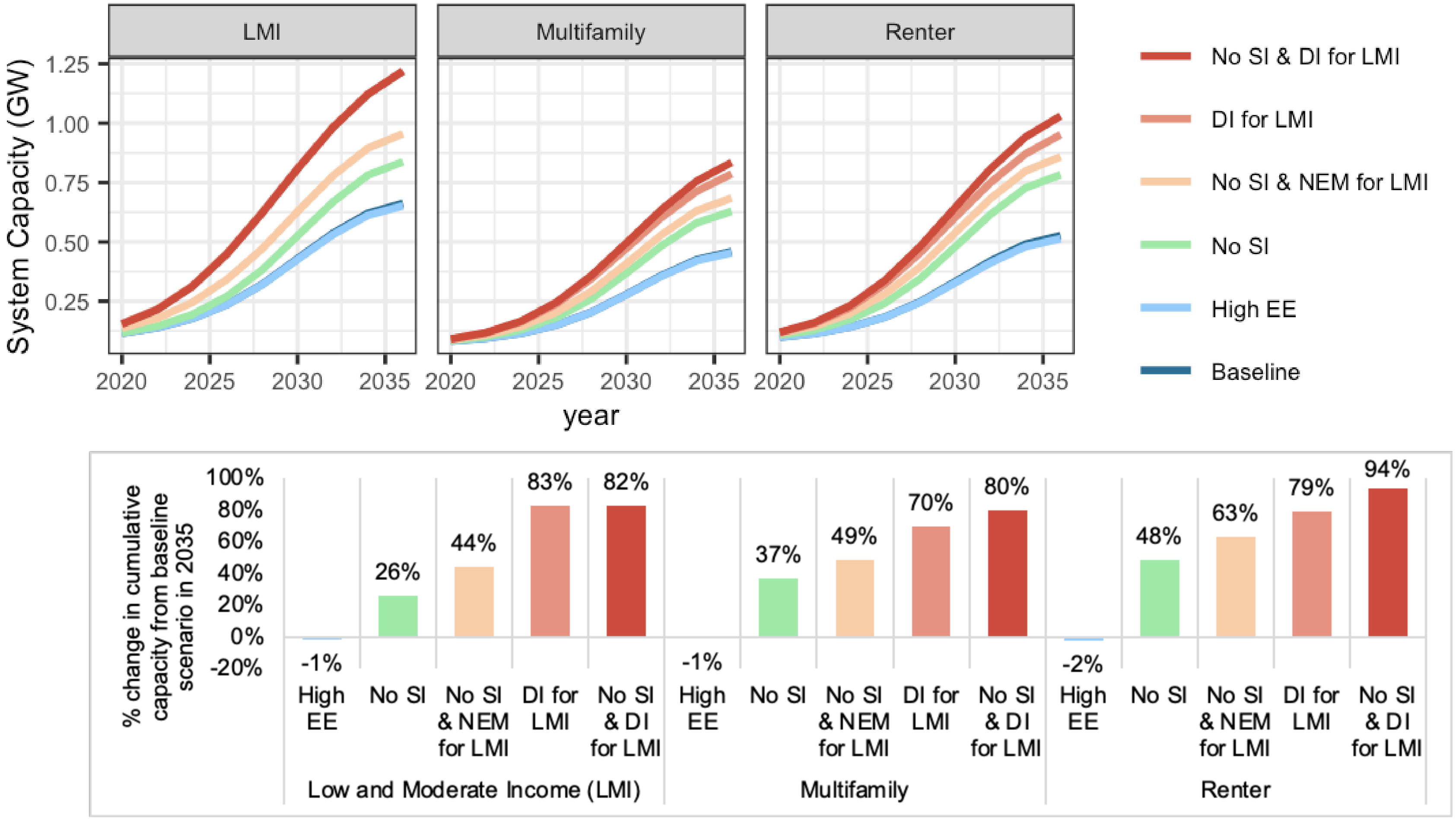

Figure 4. Cumulative system capacity changes, 2020–2035, by scenario for LMI, multifamily, and renter households (top panel) and percentage increase across the scenarios compared to the baseline in the year 2035 (bottom panel)

Table 4. Rooftop PV Characteristics of LMI Households, Multifamily Building Residents, and Renters in Los Angeles

Sources: Mooney and Sigrin 2018; Sigrin et al. 2021; U.S. Census Bureau, 2021

Category	Number of Households	Average PV-Suitable Roof Area per Household (ft^2)	Average Annual Household Consumption (kWh)	Aggregate Rooftop PV Technical Potential (GW)
LMI and multifamily and renter	470,000	170	4,300	1.4
All LMI households	880,000	230	5,100	3.5
All multifamily households	940,000	150	4,400	2.3
All renter households	860,000	210	4,800	3.1
All LADWP households	1,600,000	280	5,700	7.3

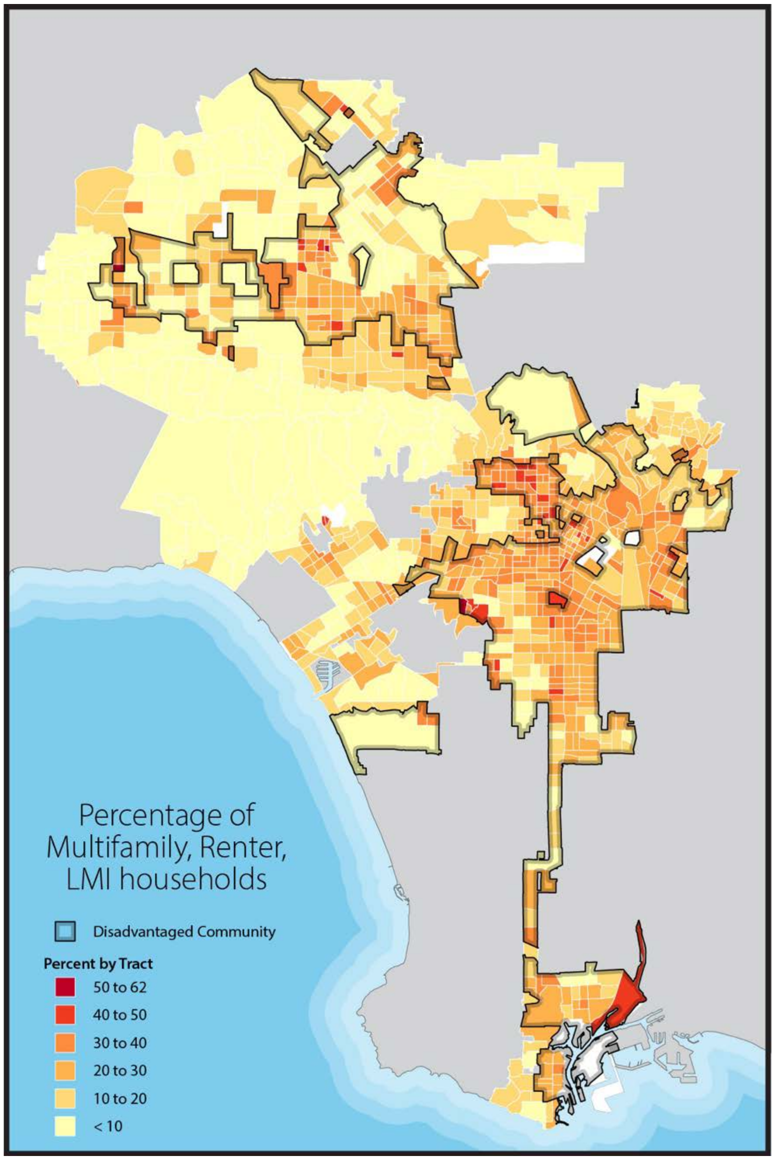

Figure 5. Percentage of combined multifamily, renter, and LMI households in DACs

In Figure 6, we show the percent increase in PV adoption in difficult-to-reach populations along with other subsets to compare scenario impacts. For example, the category “renter” includes subsets of both LMI and non-LMI renters as well as those living in single-family or multifamily households. We compare renters who are low income and living in multifamily buildings with all other renter populations. Results show that the highest-percentage increase in rooftop capacity across all the scenarios was the difficult-to-reach population. Again, this indicates the importance of targeting multiple population groups.

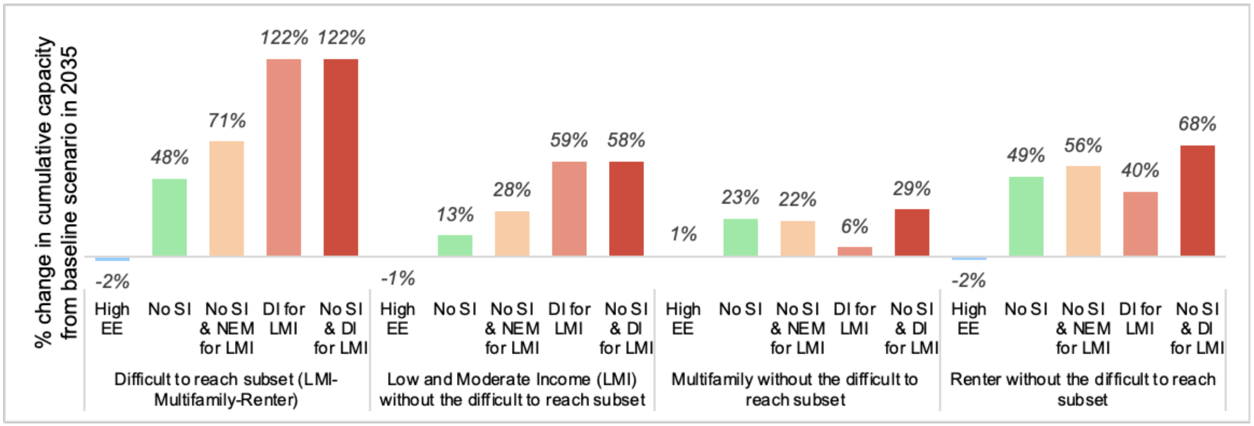

Figure 6. Percentage increase in PV adoption in difficult-to-reach populations compared to other subsets within the LMI, multifamily, and renter categories (2035)

Figure 7 shows the distribution of rooftop solar adoption by DAC status (SB 535[5]) under the considered scenarios. New solar capacity adoption in DACs is lower compared to non-disadvantaged tracts in most of the considered scenarios, with adoption in DAC communities ranging from 0.67 GW to 1.0 GW by 2035 and adoption in non-DACs ranging from 0.78 GW to 1.0 GW by 2035. The split incentive resolved and direct-install for LMI households scenario (No SI & DI for LMI) and the direct-install for LMI households scenario (DI for LMI) increase solar capacity additions in DACs the most by 2035.

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[5] "SB 535 Disadvantaged Communities," California Office of Environmental Health Hazard Assessment, oehha.ca.gov/calenviroscreen/sb535.

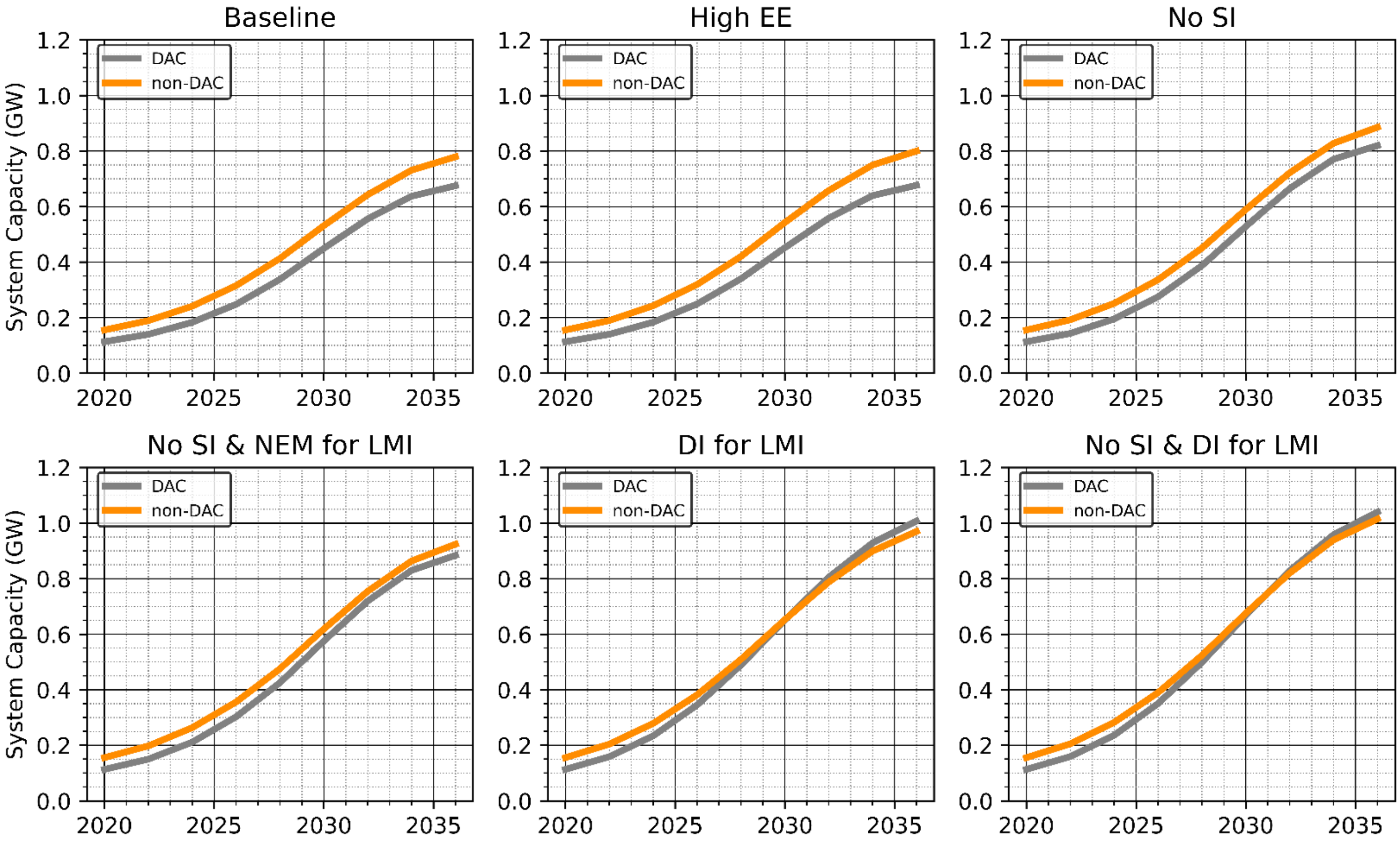

Figure 7. Cumulative solar adoption by scenario modeled for DAC and non-DAC communities

2.4 Electricity Bill Savings from Solar and Storage Adoption

One benefit of installing rooftop solar and storage systems is the electricity bill savings resulting from offsetting electricity use. For this analysis, we estimate electricity bill savings across modeled scenarios to determine whether modeled incentives can provide bill savings to customer segments that have historically not benefited from solar programs offered by LADWP, including LMI, multifamily, and renter households. Modeled average electricity bills without solar and storage adoption for LMI, multifamily, and renter households in 2022 are $1,300, $1,100, and $1,300 respectively.

Figure 8 shows annual electricity bill savings by scenario. The box plots summarize the minimum, first quartile, median, third quartile, and maximum electricity bill savings under each scenario. The High EE and No SI scenarios have lower average annual electricity bill savings ($390/year). This is because compensation for excess electricity generated by adopted solar and storage systems is lower under these scenarios, which assume LADWP transitions to NEM 3.0. Similarly, the No SI & DI for LMI and the DI for LMI (with no system cost) scenarios also have lower average annual electricity bill savings ($420/year [yr]), because these scenarios also assume a transition to NEM 3.0. Average electricity bill savings across all customers are highest under the No SI & NEM for LMI scenario, with average electricity bill savings of $450/yr. Savings are higher due to the higher compensation for excess electricity generated under these scenarios, which assume LADWP continues its current NEM program for LMI customers rather than transitioning to NEM 3.0 for all customers.

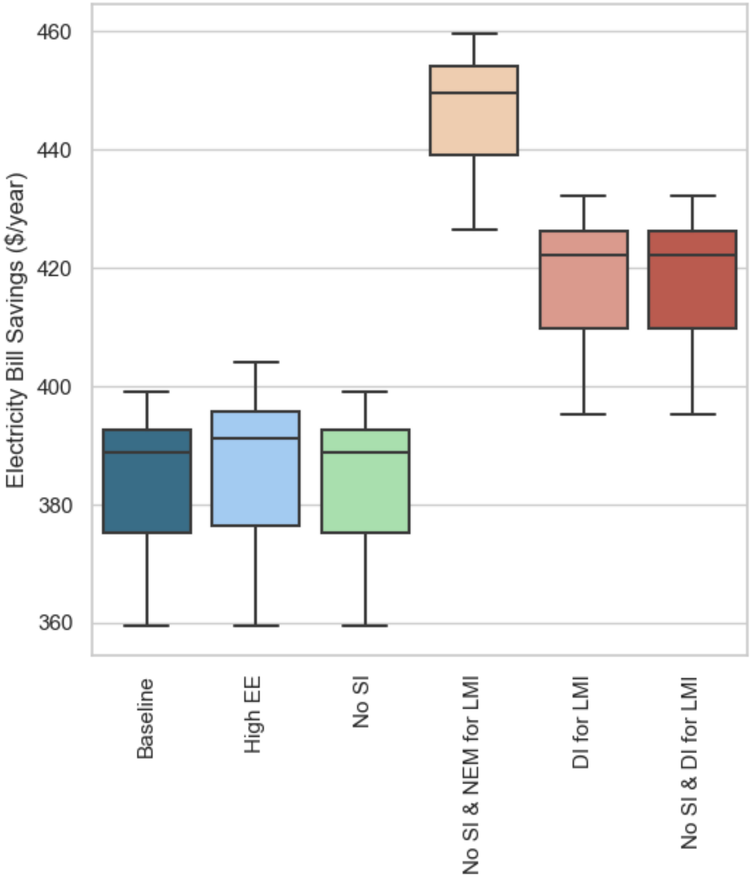

Figure 8. Annual electricity bill savings by scenario

Figure 9 shows electricity bill savings by income and scenario. The No SI & NEM for LMI scenario results in the highest bill savings for LMI customers, with an average savings of $460/yr. Under this scenario, moderate-, low-, and very low-income households see average savings of 30%, 30%, and 34%, respectively, compared to the Baseline scenario. Modeling indicates net metering (as compared to net billing, also known as NEM 3.0) increases bill savings available to LMI customers. High-income customers continue to have high average electricity bill savings ($460/yr) due to their high electricity consumption, which can be offset by installing solar and storage regardless of scenario, while mid-income customers have an average electricity bill savings of $380/yr.

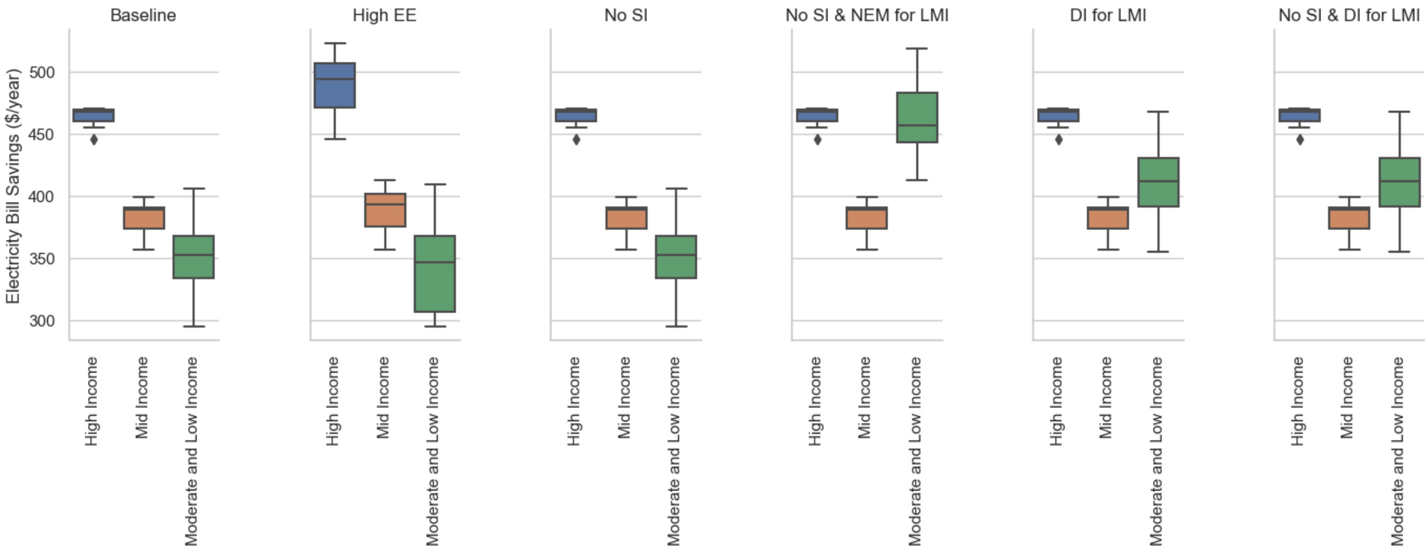

Figure 9. Electricity bill savings by income and scenario

Figure 10 shows electricity bill savings by scenario based on building type and tenure. Across all building types, single-family homes have higher average electricity bill savings. This is likely due to (1) their larger roof areas, which can host more solar panels, and (2) higher electricity consumption for this building type. Larger multifamily buildings have the lowest average electricity bill savings ($250/yr). Across the building types, resolving split incentives combined with net metering for LMI households (No SI & NEM for LMI) provides the highest bill savings, with average savings of 19% for smaller multifamily homes, 20% for larger multifamily homes, and 15% for single-family homes. A direct-install program with net billing (NEM 3.0) (No SI & DI for LMI) can provide an increase in average savings of 11% for smaller multifamily homes, 14% for larger multifamily homes, and 7% for single-family homes.

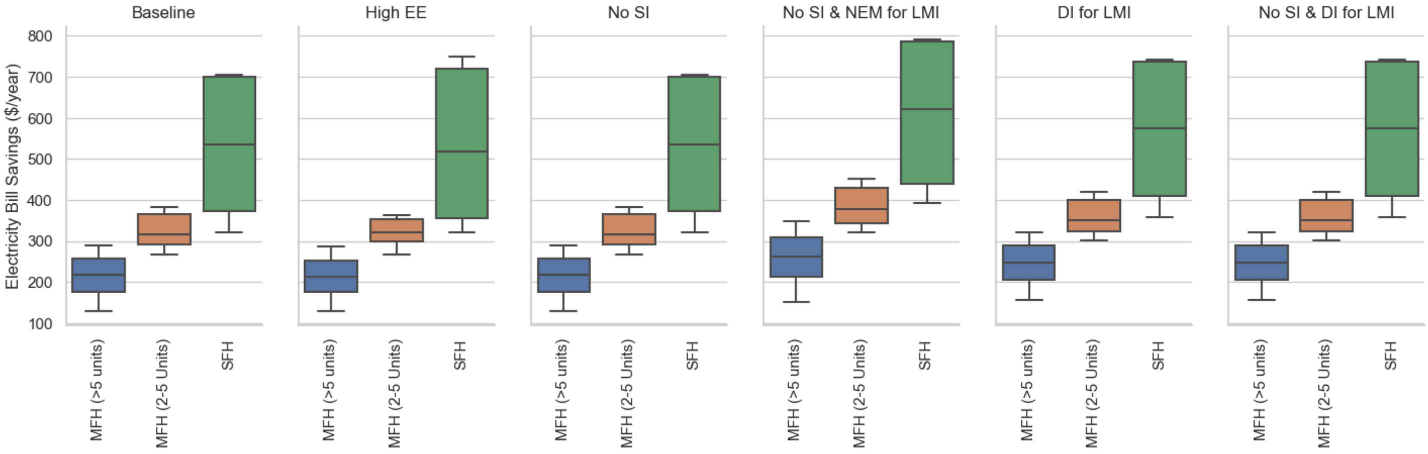

Figure 10. Electricity bill savings by scenario and building type

MFH = multifamily home, SFH = single-family home

Renters have lower electricity bill savings compared to owners across all scenarios. Combining resolved split incentives with net metering for LMI households provides the highest average electricity bill savings ($410/yr) for renters (an increase of 20% from Baseline) and $480/yr for owners (an increase of 13% from Baseline). Note that actual bill savings can vary compared to the modeled bill savings. Fikru (2019) suggests actual bill savings can be 20% higher than modeled bill savings.

2.5 Electricity Burden

Electricity burden is defined as the percentage of household income spent on electricity bills. We calculate electricity burden two ways: (1) without including solar and storage installation costs and (2) including the cost paid by the customer for the installed technology. Solar and storage costs are assumed to be paid by the household through on-bill financing for the life of the system (30 years).

Figure 11 shows the percentage change in electricity burden for LMI, multifamily, and renter households for the No SI scenario and the No SI & NEM for LMI scenario. The No SI and DI for LMI scenario assumes capital costs are not borne by the customer leading to a reduction of electricity burden for customers of more than 25%. In the No SI & NEM for LMI scenario, the electricity burden increases 10%–65% depending on the adoption year when including the cost of the technology.

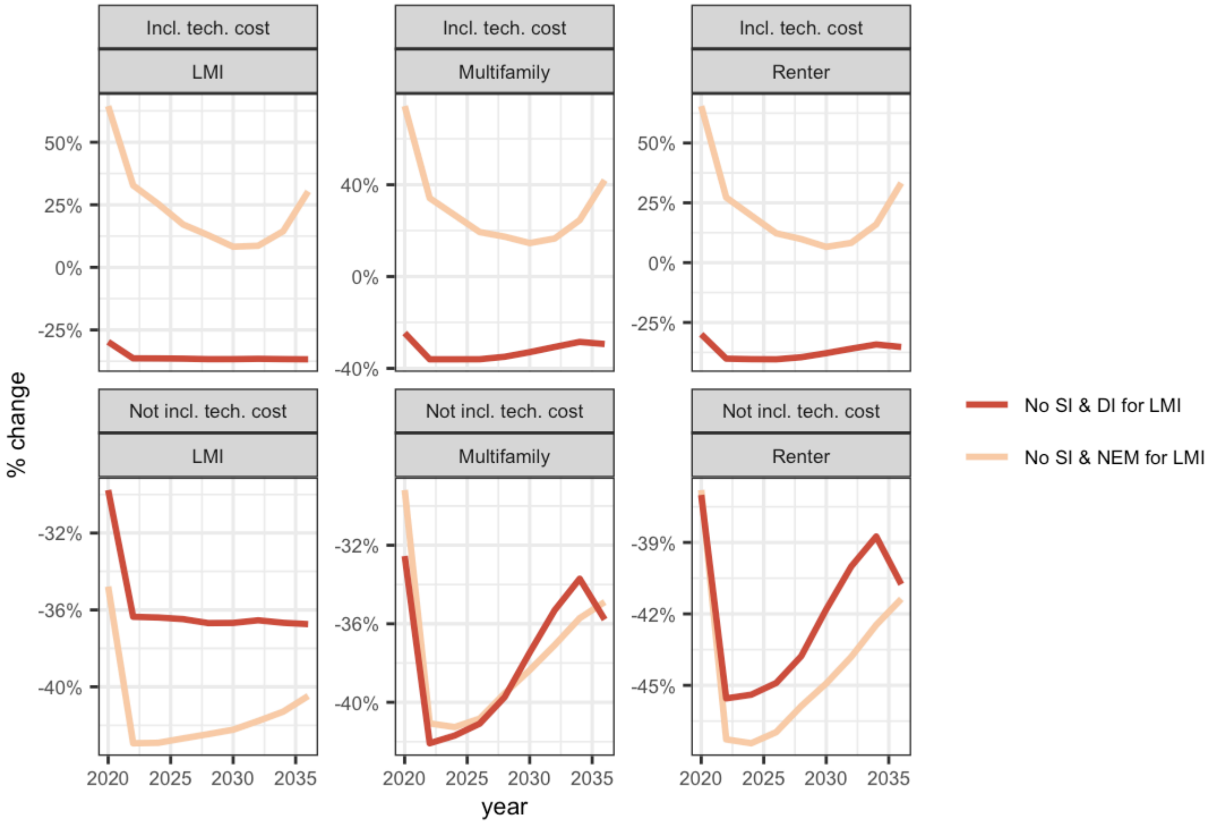

Figure 11. Percentage change in electricity burden when customer segments adopt solar and storage under No SI & DI for LMI and No SI & NEM for LMI scenarios

The top row shows electricity burden when technology cost of solar and storage systems is included. The bottom row shows change in electricity burden when technology costs of solar and storage systems are *not* included.

2.6 Incentive Program Costs

In this section, we compare the program costs of two incentive program scenarios for LMI households: (1) direct-install for LMI and (2) split incentives resolved and net metering.

DI for LMI Scenario

The total program cost for the direct-install program is calculated as the total kilowatts installed (for both solar and storage) multiplied by the cost ($/kW) of systems installed minus the credits from the 30% ITC schedule based on the Inflation Reduction Act of 2022, plus the operation and maintenance cost for the life of the system. The ITC Low-Income Communities Bonus Credit of an additional 20% is not considered because not all LMI households live in multifamily buildings or in low-income communities.

Formulas used to calculate program cost for direct-install of solar and battery are shown in Equations 1 and 2, respectively, where:[6]

- K_{pv}, K_{batt}, k_{batt} are the capital cost of the PV system, power and energy components of the battery system, respectively, and are depreciated over the system lifetime.
- S_{pv}, S_{batt}, s_{batt} are the system sizes quantified by dGen for LMI adopter *i* in year *y* of PV, power, and energy capacity of the batteries, respectively.
- f_{ITC} is the non-ITC fraction of capital cost.
- M_{pv}, M_{batt}, and m_{batt} are the operation and maintenance cost in $/unit-year of PV, power component, and energy component of the battery, respectively.
- L is the life of the PV and battery system.
- C is the linear constant in dollars used to adjust the battery cost.

$$\boldsymbol{PC_{pv}} = \sum_{\boldsymbol{i,y}} \left(\boldsymbol{K_{pv,y}} \times \boldsymbol{f_{ITC}} + (\boldsymbol{M_{pv,y}} \times \boldsymbol{L_{pv}})\right) \times \boldsymbol{S_{pv,i}} \tag{1}$$

$$\begin{aligned} PC_{batt} = \sum_{i} & \left(K_{batt,y} \times S_{batt,i} + k_{batt,y} \times s_{batt,i}\right) \times f_{ITC} \\ & + (M_{batt,y} \times S_{batt,i} + m_{batt,y} \times S_{batt,i}) \times L_{batt} \\ & + C \end{aligned} \tag{2}$$

No SI & NEM for LMI Scenario

The total program cost for the NEM program is calculated as the sum of the total bill savings through the life of solar and storage systems (30 years) for LMI customers purchasing a system

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[6] More information on these calculations can be found in NREL's 2022 Annual Technology Baseline (NREL 2022).

due to the incentives during the analysis period (2020–2035), where P_{elec} is electricity price and Gen_{PV} is solar generation in Equation 3:

$$\boldsymbol{Bill\ Savings}_{\boldsymbol{No\ SI\ \&\ NEM\ for\ LMI}} = \sum_{i} \boldsymbol{P}_{\boldsymbol{elec,i}} \times \boldsymbol{Gen}_{\boldsymbol{PV,i}} \tag{3}$$

Table 5 includes modeled outcomes for two scenarios.

Table 5. Modeled Outcomes for the Direct-Install (No SI & DI for LMI) and Net Metering (No SI & NEM for LMI) Scenarios that Target Only LMI Customers

Systems are installed 2020–2035 until their end of life

Scenario	PV Capacity Added (MW)	Battery Capacity Added (MW)	Additional LMI Customers with PV or Storage	Total Program Cost for LADWP (billion $)	Incentive Spent per Additional Capacity ($/W)
No SI & DI for LMI	530	520	160,000	2.2	2.10
No SI & NEM for LMI	283	0	52,000	2.7	9.70

Under the DI for LMI scenario, which models a direct-install program for LMI customers, an additional 530 MW of solar and an additional 520 MW of storage are adopted by 2035 at a cost of approximately $2.2 billion. Approximately 160,000 additional LMI customers adopt solar and storage over the program lifetime. The total program cost for this additional adoption is $2.06/watt (W) of combined solar and storage capacity. Note that this calculation does not consider any additional operation and maintenance costs, the costs of electric panel upgrades or of other upgrades required to install solar and storage systems, or program administration costs. Additionally, despite providing systems at no cost under a direct-install program, other factors might prevent these systems from being adopted, as projected in the model and described in Section 1.2 (page 3).

Under the No SI & NEM for LMI scenario, total bill savings for LMI customers, and therefore program costs, assuming NEM for the entire system lifetime of 30 years amounts to $2.7 billion, or $170 million/year. This scenario adds 52,000 additional adopters and 280 MW at a cost of $9.7/W of additional capacity. This scenario has significantly higher costs than LADWP's existing net metering program. The program cost calculated for the scenario:

- Considers only the total bill savings by the customer that is assumed to be paid by LADWP and does not include any grid impacts or programmatic costs
- Is applicable only for LMI customers who adopt solar, whereas, in the old program, NEM was applied for all customers who owned solar
- Assumes net metering continues until the end of life for the system

- Considers Strategic Long-Term Resource Plan SB 100 year-on-year retail rate increases, which are approximately 10% each year.

For customers who adopt in 2035 the program is expected to run until 2060.

Due to LADWP's projected increases in retail rates, future net metering compensation cost increases and increases in solar capacity adopted in later years are high. The direct-install program leads to more adopters at lower cost per adopter while the net metering for LMI program provides higher electricity bill savings to LMI customers.

2.7 Caveats

Model input caveats include the following:

1. The dGen model is run in 2-year increments between 2020 and 2036. Results for 2035 are calculated as an average of 2034 and 2036 results.
2. Historical data are calibrated until the year 2020.
3. We do not explore a storage-only scenario because the historical data available to calibrate storage adoption are insufficient. In the case of solar + storage adoption, the model assumes storage systems are adopted if they add additional monetary value to the customer who adopts PV. In this model formulation, customers who want to install storage systems that are uneconomic (i.e., have a negative net present value) are not considered.

2.8 Equity Strategies Discussion

In this section, we synthesize modeling, analysis, and community guidance to identify potential strategies for achieving more-equitable outcomes in the distribution of benefits and burdens in Los Angeles' transition to clean energy.

Analysis of baseline distributional equity indicates the $340 million in LADWP residential solar incentives and NEM compensation distributed over the 22 years analyzed and paid for by all ratepayers, disproportionately benefited non-disadvantaged, predominantly White, non-Hispanic, home-owning, and wealthier communities. Disadvantaged communities, particularly in South LA and the Harbor region, did not receive solar incentives proportional to their populations. This inequitable investment resulted in 39% more capacity installed per customer in non-disadvantaged communities than disadvantaged communities, and inequitable access to bill savings for adopters and contributions toward total electric system costs from non-adopters.

Continued residential solar investment through the same programmatic approaches will continue to inequitably shift funds from lower-income customers, renters, and multifamily building residents who cannot install rooftop PV to higher-income residential customers who can make the co-investment and then benefit from the bill savings. To redress these inequities and the disproportionate impact on low-income households from anticipated rate increases, we conducted solar and storage modeling and analysis to explore the following potential strategies:

- One potential strategy is to restrict NEM compensation to the 57% of LA households that are LMI customers.
    - This strategy or program approach is projected to result in an additional 52,000 additional LMI customers benefiting from rooftop PV and storage compared to the Baseline scenario.
    - The approach provides average annual electricity bill savings of $460 for low- to moderate-income customers, which equates to average annual savings of 30%–34% compared to the Baseline scenario.
    - If strategies are implemented to enable NEM benefits to accrue to the 55% of LA households that rent and the 60% of households that live in multifamily buildings as renters, LMI NEM could provide average annual electricity bill savings to renters of $410, or average savings of 15%–20% depending on building type.
    - Though this strategy leads to the highest LMI bill savings, it costs $2.7 billion over 16 years (with NEM being applicable through 2060 for systems installed in 2035). And, though the strategy is modified to benefit LMI customers, it continues net energy metering, which analysis indicates has been highly inequitably distributed.
- An alternative and lower cost option than NEM for LMI customers that delivers comparable bill savings is a direct-install program in which LADWP funds rooftop PV installations for LMI households.
    - This program approach is projected to result in 160,000 additional LMI households adopting solar.
    - The approach provides average annual electricity bill savings for LMI households of $420.
    - If bill savings can accrue to renters, the approach provides average annual electricity bill savings for renters of $380.
    - The approach could be targeted to specific regions where solar and storage capacity would benefit the distribution grid.
    - Though direct installations for LMI households and enabling of benefits to accrue to renters results in more LMI solar adoption than NEM for LMI households, a direct-install program for 160,000 LMI households is projected to cost $2.2 billion over 16 years.
- Implementing strategies to deliver rooftop solar bill savings to renters can dramatically increase rooftop PV adoption, open up the 42% of rooftop PV technical potential on renter-occupied buildings, and enable bill savings of $380/yr–$410/yr for the 470,000 LMI households that are also renters living in multifamily buildings. Potential strategies include on-bill financing, equipment leasing, property-assessed clean energy, green leases, and LMI renter enrollment in a discounted community or shared solar rate.

- Additional opportunities for LADWP to provide resiliency services or monetize aggregated distributed energy resources under Federal Energy Regulatory Commission Order 2222 are possible under both the modeled programs in the No SI & NEM for LMI scenario and the DI for LMI scenario. LADWP could specify additional program conditions that allow these systems to be controlled by LADWP to participate in wholesale markets or to provide resiliency services in the event of grid outages. Doing so would allow for multiple benefits including additional monetary benefit to LADWP accruing from providing resiliency services or from aggregation of distributed energy resources not modeled here.
- Another potential strategy is to deliver solar bill savings to LMI renters and multifamily building residents through community solar or virtual-net-metering enrollment. Community solar or virtual net energy metering is estimated to deliver LMI electricity bill savings of $480/yr with net present value-positive solar costs (i.e., essentially costs are recuperated) (see Chapter 9) compared to the net metering scenario (No SI & NEM for LMI) savings of $460/yr with program costs in the billions. Community solar enrollment also enables renters to take this benefit with them if they move.

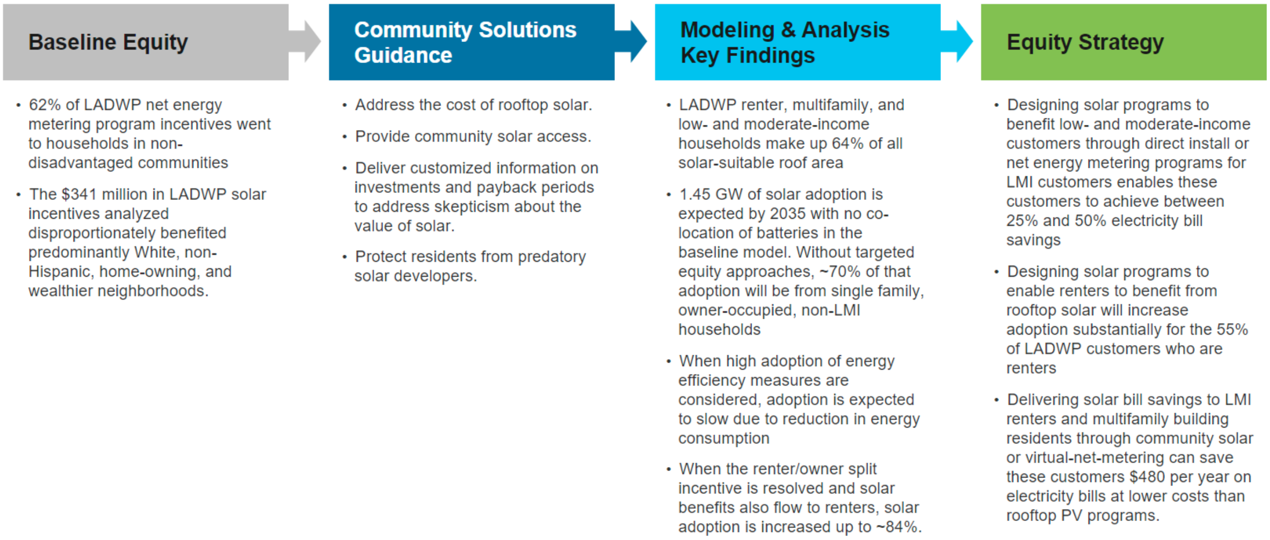
Table 6 summarizes these options and associated metrics.

Table 6. Equity Strategy Option Benefits, Costs, Timeline, Responsible Party, and Evaluation Metrics

Equity Strategy	Benefit/Impact	Cost	Timeline[a]	Responsible Party	Metric
Implement an NEM rooftop solar program for LMI customers with strategies to deliver bill savings to renters and multifamily building residents (No SI & NEM for LMI scenario)	LMI electricity bill savings of $460/yr, 10%–65% energy burden reduction 280 MW additional PV adoption potential	$2.7 billion total LADWP program cost for 0.7 GW installed $2.95/W installed	2024–2035	LADWP	Targeted portion of the 52,000 potential households
Implement a direct-install solar program for LMI customers with strategies to deliver bill savings to renters and multifamily building residents (No SI & DI for LMI scenario)	LMI electricity bill savings of $420/yr, 25% energy burden reduction 530 MW additional PV adoption potential	$2.2 billion total LADWP program cost for 0.5 GW installed $1.8/W installed plus operation and maintenance	2024–2035	LADWP with Inflation Reduction Act funding support	Targeted portion of the 160,000 potential households Targeted portion of the 520 MW battery storage potential
Implement strategies to deliver solar bill savings to LMI renters	55% of LADWP customers are renters Enabling access to solar bill savings for renters can increase their electricity bill savings ≈84%.	Primarily administrative costs	2024–2025	LADWP	Participation in and annual bill savings from on-bill financing, equipment leasing, green leases, virtual-net-metering, or enrollment in a discounted LMI shared solar rate
Deliver solar bill savings to LMI renters and multifamily building residents through community solar or virtual-net-metering enrollment	LMI electricity bill savings of $480/yr	NREL identified >4,000 suitable community solar sites 30 kW or more with positive net present value	2024–2035	LADWP	20% of LMI renters enrolled by 2030, 30% by 2035

[a] The timeline indicates the program covers all systems installed between 2024 and 2035. For systems installed in 2035, the program covers NEM until the end of life of the system, which is assumed to be 2060.

Baseline equity conditions, community solutions guidance, and modeling and analysis key findings were synthesized into equity strategies (see Figure 12). These figures were shared with the LA100 Equity Strategies Steering Committee and Advisory Committee and were revised based on their feedback and guidance.



Baseline Equity

- 62% of LADWP net energy metering program incentives went to households in non-disadvantaged communities
- The $341 million in LADWP solar incentives analyzed disproportionately benefited predominantly White, non-Hispanic, home-owning, and wealthier neighborhoods.

Community Solutions Guidance

- Address the cost of rooftop solar.
- Provide community solar access.
- Deliver customized information on investments and payback periods to address skepticism about the value of solar.
- Protect residents from predatory solar developers.

Modeling & Analysis Key Findings

- LADWP renter, multifamily, and low- and moderate-income households make up 64% of all solar-suitable roof area
- 1.45 GW of solar adoption is expected by 2035 with no co-location of batteries in the baseline model. Without targeted equity approaches, ~70% of that adoption will be from single family, owner-occupied, non-LMI households
- When high adoption of energy efficiency measures are considered, adoption is expected to slow due to reduction in energy consumption
- When the renter/owner split incentive is resolved and solar benefits also flow to renters, solar adoption is increased up to ~84%.

Equity Strategy

- Designing solar programs to benefit low- and moderate-income customers through direct install or net energy metering programs for LMI customers enables these customers to achieve between 25% and 50% electricity bill savings
- Designing solar programs to enable renters to benefit from rooftop solar will increase adoption substantially for the 55% of LADWP customers who are renters
- Delivering solar bill savings to LMI renters and multifamily building residents through community solar or virtual-net-metering can save these customers $480 per year on electricity bills at lower costs than rooftop PV programs.

Figure 12. Strategies for equitable access to solar bill savings

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Appendix A. Methodology

This appendix describes the methodology used to develop the agent data file, which is an input to the dGen model. The agent data file contains the characteristics of buildings and households within the LADWP territory, including roof area, energy consumption, utility tariff information, and financial parameters.

An agent is a statistical representation of a household in each census tract, classified by income class, ownership type/tenure, and building type. Approximately 1,059 census tracts are in the LADWP service area, listed by their six-digit code. There are eight different agent building types. Households are classified based on American Community Survey income data and U.S. Department of Housing and Urban Development area median income (AMI) bins. For each census tract, 80 agents are created, based on building type, ownership status, and income class. Table A-1 describes the agent classes considered in the model. For each agent type, household characteristics such as energy consumption, number of customers in that agent class, total PV-suitable roof area, financial parameters, and other decision parameters are assigned.

Table A-1. Descriptions of Agent Classes

Agent Classes	Descriptions
Tract	Census tract, each with a six-digit code
Building Type	2 Unit (multifamily) 3 or 4 Unit (multifamily) 5 to 9 Unit (multifamily) 10 to 19 Unit (multifamily) 20 to 49 Unit (multifamily) 50 or more Unit (multifamily) Single-Family Attached Single-Family Detached
Ownership Status or Tenure	Owner Renter
Income Class	Very low (0–30% AMI) Low (30–60 % AMI) Moderate (60–80% AMI) Mid (80–120% AMI) High (120%+ AMI)

The starting point in the agent generation process is an agents file (herein referred to as "base agents") from a previous study (Sigrin et al. 2021) that has agents characterized by tract ID and load subclass. This agent file also has only two of the core attributes of an agent to enable adoption of rooftop solar: the PV-suitable roof area and the number of customers in bin lacking electricity demand. PV-suitable roof area refers to available roof space onto which solar panels could be mounted. Customers in bin refers to the number of buildings of a particular type available in a geospatial grid that defines an agent. Electricity demand refers to annual electricity demand per household within a geospatial grid that defines an agent.

For the aforementioned reasons, we need ways to convert these agents from tract ID and load subclass characterization so they include further subcategories of tenure and income class. We also need to allocate electricity demand to agents. To achieve these two goals, we use data from other sources, as described in Appendix B, to convert the base agents from characterization by tract ID and load subclass to characterization by tract ID, load subclass, tenure, and income class.

A.1 Converting the Base Agents

To convert a base agent to the desired characterization, we use the Rooftop Energy Potential of Low Income Communities in America REPLICA (REPLICA) (Mooney and Sigrin 2018) data to create weights that help us disaggregate the PV-suitable roof area and number of customers in bin from a characterization comprising tract ID and load subclass to one that has tract ID, load subclass, tenure, and income class.

A.2 Weights Creation and Application

The weights are evaluated as products of ratios evaluated in REPLICA and ratios evaluated using the baseline agents data set. For the baseline agents, the ratios are tract ID, load subclass, and family type level values of PV-suitable roof area and customers in bin divided by tract ID, family type level totals. On the REPLICA data set, the ratios are tract ID, family type, tenure, and income class level values of PV-suitable roof area and customers in bin divided by the tract ID, family type level totals. Multiplying these ratios generates the fractions of these attributes at a desired agent characterization level. To get agent level customers in bin and PV-suitable roof area, the respective weights or fractions are multiplied by the baseline agents values. Areas in the base data are in square feet, and areas in REPLICA are in square meters; however, we assume this unit misalignment does not impact the calculations because the ratios are essentially unitless.

A.3 Conversion Issues and Solutions

When the REPLICA data imply there is PV-suitable roof area and/or customers in bin for a specific tract and family type but the corresponding tract in the base data imply those data do not exist, we base the final PV-suitable roof area and/or customers in the bin on the base data. Thus, for all the agents in that tract and building types, the final values are assigned zero (0) values.

When the REPLICA data imply there are no PV-suitable roof area or customers in bin for a specific tract and building type but the base data show those data do exist, we assign the REPLICA weights in a controlled and randomized manner by solving an optimization problem that constrains the sum of the weights to equal 1.

A.4 Allocating Electricity Demand to Agents

The building agents, together with the accompanying electricity demand data, are used to assign the electricity demand to the agents through the following steps:

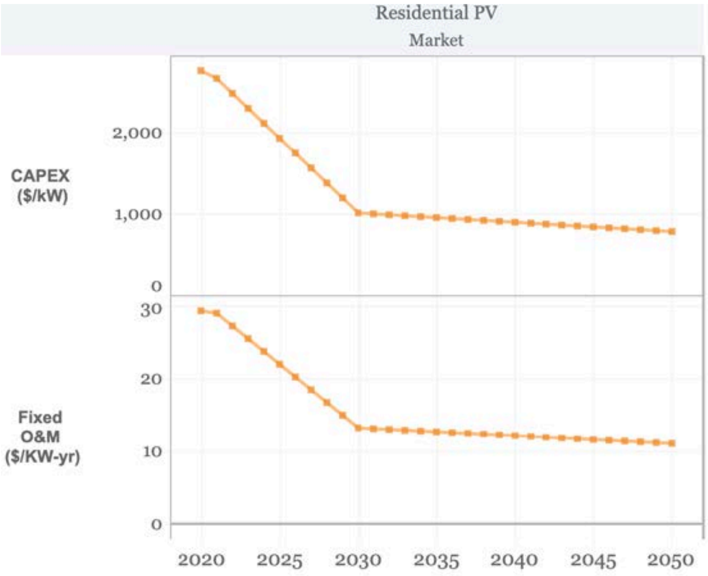
- Aggregate the building agents to tract ID, load subclass, income class, and tenure resolution by taking averages of the building ID-level data.
- For all matching agents in the newly created agents data set, allocate the electricity demand.
- For tracts in newly created agents but absent in the aggregated buildings agents, assign the average of the neighboring tracts' values.

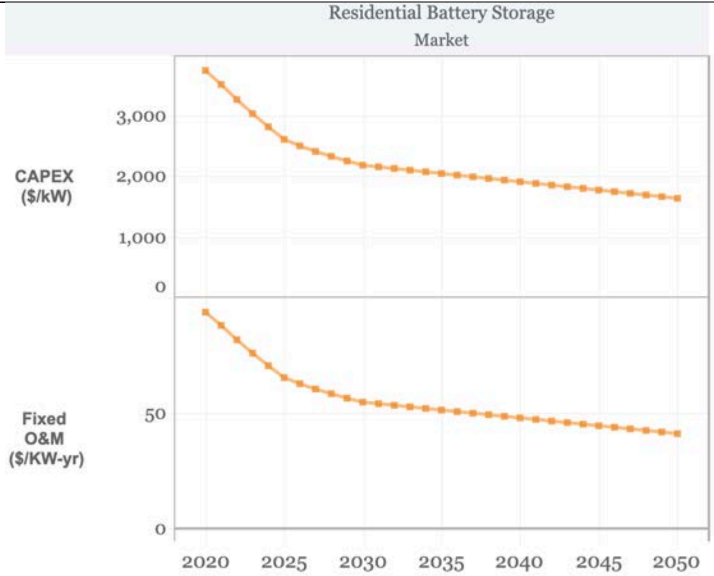
A.5 Allocating Load Profiles

The load profile data are provided at a building ID-level resolution. These load profiles are combined into groups of tract ID, load subclass, income class, and tenure using the building agents. For each agent, a load profile is allocated from a random selection in the load profiles from a corresponding group. For agents that do not have corresponding groups, a random load profile is allocated from groups with similar load subclass, income class, and tenure.

A.6 Other Modeling Assumptions

Table A-2. Summary of Additional Modeling Assumption Values and Sources

Variables	Description	Source
Tariff	Tariffs are assigned based on location of the households by zone and monthly energy consumption: • Residential Service (R1A): Zone 1 (<350 kWh) • Residential Service (R1A): Zone 1 (350–1,050 kWh) • Residential Service (R1A): Zone 1 (>1,050 kWh) • Residential Service (R1A): Zone 2 (<500 kWh) • Residential Service (R1A): Zone 2 (500–1,500 kWh) • Residential Service (R1A): Zone 2 (>1,500 kWh).	LADWP Summarized descriptions of the rates can be found in the associated hyperlinks in the Utility Rate Database.
Electricity price escalation	Strategic Long-Term Resource Plan SB 100 rate projections Compound annual growth rate of 2.56% between 2022 and 2035	LADWP
Load escalation	Yearly load escalation is derived from ResStock data. The load escalation varies by each household.	ResStock data
Model years	2020–2036 (dGen works with 2-year increments.)	
System costs	Modeling is based on NREL's 2022 Annual Technology Baseline projections (NREL 2022).  Solar PV cost trend are shown above.	NREL 2022

Variables	Description	Source
	 Residential battery storage costs are shown for a 5kW, 12.5kWh system.	
Wholesale electricity price	Varied between 2.6 cents/kWh in 2020 to 4.3 cents/kWh in 2035. Modeled based on projection data from NREL's 2022 Annual Technology Baseline (NREL2022). (Used for net billing compensation.)	NREL 2022
ITC	30% for the installation of which was between 2022 and 2032. 26% for systems installed in 2033. 22% for systems installed in 2034. 0% for system installed in 2035 and after.	Inflation Reduction Act of 2022

Appendix B. Data Sources and Assumptions

This appendix details the outsourced data used in the analysis for this chapter. The descriptions in Table B-1 cover data sources, attributes within the data set, and their granularity, spatial resolution, and vintage.

Table B-1. Solar and Storage Data: Sources and Descriptions

Data	Source	Description of Attributes Available	Resolution/ Characterization	Vintage
REPLICA	NREL Data Catalog: data.nrel.gov/submissions/81 (Mooney and Sigrin 2018)	PV-suitable roof area and customers in bin	Tract ID, income class, load subclass, and family type	2018
Building agents	ResStock[a]-customized modeling for the LA100 Equity Strategies project	Electricity demand and electricity demand profiles	Tract ID, building ID, load subclass, family type, income class, and tenure	2020, 2035
DACs	SB 535	DACs are identified as tracts with the highest 25% CalEnviroScreen scores.	Census tract	2021

[a] ResStock is NREL's large-scale residential energy analysis tool: "ResStock Analysis Tool," NREL, https://www.nrel.gov/buildings/resstock.html.

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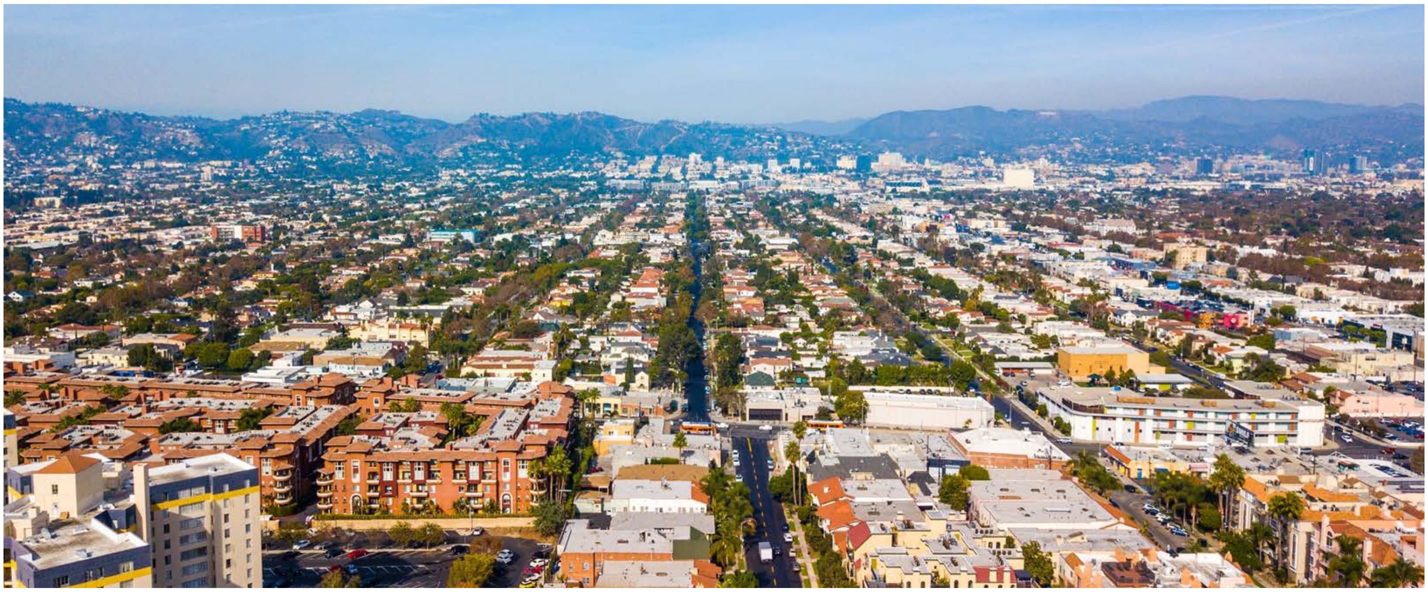
LA100 EQUITY STRATEGIES



Chapter 9: Equitable Community Solar Access and Benefits

FINAL REPORT: LA100 Equity Strategies

Ashreeta Prasanna, Jane Lockshin, Megan Day, and Kate Anderson

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November 2023

LA100 EQUITY STRATEGIES

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Preface

The Los Angeles 100% Renewable Energy Study, or LA100, revealed that although all communities in Los Angeles will share in the air quality and public health benefits of the clean energy transition, increasing equity in participation and outcomes will require intentionally designed policies and programs. The LA100 Equity Strategies project was specifically designed to help Los Angeles identify pathways to such policies and programs in the form of equity strategies. The project aimed to do this by incorporating research and analysis to chart a course toward specific, community-prioritized, and equitable outcomes from the clean energy transition outlined in the LA100 study.

The Project Partners

The Los Angeles Department of Water and Power (LADWP), the National Renewable Energy Laboratory (NREL), and the University of California Los Angeles (UCLA) partnered on the LA100 Equity Strategies project to develop strategies for engaging communities, funding equitable technology and infrastructure investments, expanding existing programs, and designing new programs and policies to improve equity by incorporating what community members themselves know is needed to achieve a more equitable energy future.

The Project Approach

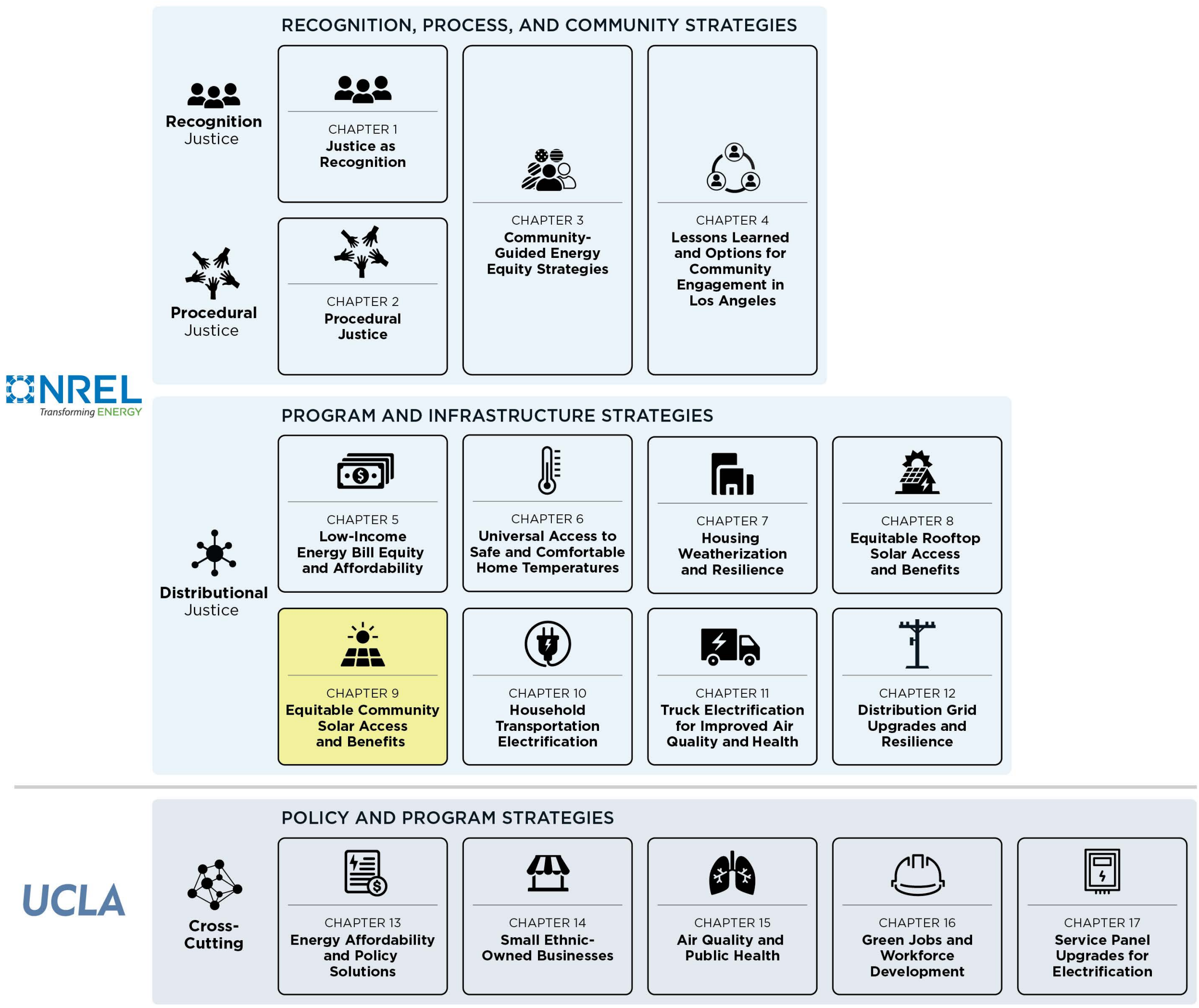
LA100 Equity Strategies employs a unique mixed-methodological approach utilizing three distinct—but connected—research efforts. Through these efforts, NREL and UCLA developed a range of strategy options for increasing equity in LA's transition to 100% clean energy.

A Project Summary

To get a high-level overview of the project, you can dive into the executive summary, interactive data visualizations, and more on the LA100 Equity Strategies website at maps.nrel.gov/la100/equity-strategies.

The Full Report

NREL's final full report for the LA100 Equity Strategies project encompasses seventeen chapters. The first twelve chapters, authored by NREL, are organized around the three tenets of justice. Chapters 1–4 address recognition and procedural justice, while Chapters 5–12 address distributional justice. The final five chapters, authored by UCLA, provide crosscutting policy and program strategies. Each chapter provides data, methods, insights, and strategies to help LADWP make data-driven, community-informed decisions for equitable investments and program development.



NREL Chapters

Chapter 1: Justice as Recognition

Chapter 2: Procedural Justice

Chapter 3: Community-Guided Energy Equity Strategies

Chapter 4: Lessons Learned and Options for Community Engagement in Los Angeles

Chapter 5: Low-Income Energy Bill Equity and Affordability

Chapter 6: Universal Access to Safe and Comfortable Home Temperatures

Chapter 7: Housing Weatherization and Resilience

Chapter 8: Equitable Rooftop Solar Access and Benefits

Chapter 9: Equitable Community Solar Access and Benefits

Chapter 10: Household Transportation Electrification

Chapter 11: Truck Electrification for Improved Air Quality and Health

Chapter 12: Distribution Grid Upgrades for Equitable Resilience and Solar, Storage, and Electric Vehicle Access

UCLA Chapters

Chapter 13: Energy Affordability and Policy Solutions Analysis

Chapter 14: Small Ethnic-Owned Businesses Study

Chapter 15: Air Quality and Public Health

Chapter 16: Green Jobs Workforce Development

Chapter 17: Service Panel Upgrade Needs for Future Residential Electrification

List of Abbreviations and Acronyms

CPUC	California Public Utilities Commission
DAC	disadvantaged community
FiT	feed-in tariff
FRAP	Fire and Resource Assessment Program
IRA	Inflation Reduction Act of 2022
ITC	investment tax credit
kW	kilowatts
kWh	kilowatt-hours
LADWP	Los Angeles Department of Water and Power
LMI	low-to-moderate-income
MW	megawatts
NPV	net present value
NREL	National Renewable Energy Laboratory
OEHHA	Office of Environmental Health Hazard Assessment
PPA	power purchase agreement
PV	photovoltaics
SAIFI	System Average Interruption Frequency Index
SAM	System Advisor Model
SB	California Senate Bill
SGIP	Self-Generation Incentive Program
yr	year

Executive Summary

The LA100 Equity Strategies project integrates community guidance with robust research, modeling, and analysis to identify strategy options that can increase equitable outcomes in Los Angeles' clean energy transition. This chapter focuses on community solar as a means to provide equitable access to local solar and storage benefits in Los Angeles.

Specifically, NREL identified potential community solar sites that could host 30 kilowatts (kW)[1] of solar or more (Figure ES-1, page x) and evaluated economic and equity metrics under various program design options. Analysis included a Baseline scenario (business-as-usual) and an Equity scenario, which modeled program enhancements to increase access and benefits to low-income customers. Both scenarios modeled the economics of solar and storage under the LADWP Feed-in Tariff (FiT) program (LADWP 2023b) and the LADWP Feed-in-Tariff Plus Pilot program (LADWP 2023d) compared to a community solar financial model (Figure ES-2, page xi).

This research was guided by input from the community engagement process, and associated equity strategies are presented in alignment with that guidance.

Community Guidance

Our analysis was tailored to incorporate guidance from the LA100 Equity Strategies Steering Committee, listening sessions with community-based organizations and community members, and community meetings. The following community priorities related to community solar and resilience were included:

Steering Committee Member:

"Find ways to financially incentivize community solar participation. We hear folks want to participate, but there is not enough incentive."

- Use community-informed methods to identify and address barriers to affordability and access—e.g., predatory practices, community mistrust, and lack of time.
- Provide community solar access and benefits through:
    - Incentives to overcome community solar price premium barriers
    - Programs tailored to both homeowners and renters
    - Revised eligibility criteria to include moderate-income customers
    - Accountability for solar developers and service providers
    - Educational, locally sensitive programs to prevent disinformation and mistrust

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[1] The 30-kW lower threshold is based on the minimum capacity required to participate in the LADWP FiT program (LADWP 2023b).

- Addressing intersectional barriers to access and actual use of LADWP programs—e.g., financial capital and homeownership.

- Pair community solar with batteries in community spaces for reliable power and cooling.
- Consider community solar on LADWP properties to create health and educational co-benefits, through a community-based program design.
- Ensure ground-mounted community solar does not prevent land uses such as affordable housing or parks.

Steering Committee Member:

"Siting solar farms in disadvantaged and low-income areas might be loading environmentally challenged neighborhoods with more industrialization. Is community solar being considered in higher-income neighborhoods as well?"

Distributional Equity Baseline

Analysis of the 2,116 LADWP Shared Solar program participants (as of December 31, 2021) indicates higher participation and subscribed capacity among non-disadvantaged, non-Hispanic, and above-median-income communities. While only multifamily building residents are eligible to participate, there was no statistically significant difference in program participation between mostly homeowner and mostly renter communities.

The LADWP FiT program enables property owners and developers to install 30-kW systems or greater and sell all the energy to LADWP through a power purchase agreement (PPA). The total installed FiT program capacity as of December 31, 2021, was 90 megawatts (MW). In 2021, LADWP launched the Feed-in Tariff Plus (FiT+) Pilot program, which expands the existing FiT program and promotes the development of paired solar-plus-energy-storage projects in Preferred Zones of Development specified by LADWP. Five projects, totaling 1.8 MW, were proposed as of December 31, 2021, under the FiT+ Pilot program (LADWP 2022, LADWP 2023b). An analysis of FiT projects found no statistically significant socioeconomic differences in communities with project sites. As FiT projects are generally developed at commercial or industrial sites with revenues going to businesses, the FiT program does not provide direct savings to residential customers, low-income or otherwise.

Key Findings

NREL identified more than 1,800 ≥30-kW potential sites totaling over 1,000 MW of potential capacity that could be economically viable as community solar projects on government-owned land, recreation centers, educational institutions, hospitals, and multifamily parcels. Additional market factors and other challenges in deployment, such as roof age, ownership structures, and zoning restrictions, reduce this economic potential further, which makes 1,000 MW a high upper bound of feasibility. Of these, more than 400 MW of capacity on over 1,400 sites are located in low-income tracts.

- Economically viable capacity is highest on commercial and industrial land parcels under both PPA and community solar financial models, followed by restaurants and retail land parcels, educational institutions, offices, multifamily buildings, and hospitals. Because these land parcels are commonly privately owned, solar developed under a net metering agreement is more likely than development for community solar or under a PPA contract.

- Projects financed under a community solar model are more profitable—with a 41% higher net present value (NPV) on average, compared to projects financed under a PPA financial model under the Baseline scenario—and have 22% higher NPV on average under the Equity scenario.
- This analysis identified more than 600 economically viable potential community solar sites on multifamily properties in low-income census tracts with a combined potential capacity of more than 250 MW.
- The maximum savings available to customers who subscribe to the LADWP Shared Solar program under our model assumptions are approximately $68/year (yr) over 10 years. Increasing the maximum subscription amount and establishing a 20% lower subscription rate for low-income customers can provide average savings of $480/yr for low-income customers.
- The above modifications to the current Shared Solar program would decrease the number of economically viable potential sites by 9% when compared to the current program structure.
- Sites in low-income census tracts that serve low-income subscribers through the modeled discounted rate are found on average to be more economically attractive (higher NPV) because of the Inflation Reduction Act of 2022 (IRA) additional 20% investment tax credit (ITC) for projects in which at least 50% of the financial benefits are provided to low-income households.
- Approximately 160 MW of storage (4-hour duration) colocated with 260 MW of solar on 430 sites would be economically viable under the LADWP Feed-in-Tariff Plus Pilot program.

Local solar equity metrics include:

- Annual electricity bill savings
- By income, housing type, and low-income community status

Equity Strategies

Based on the above findings, the following strategies can increase community solar equity:

- Modify the Shared Solar program to increase the maximum subscription to 500 kilowatt-hours (kWh)/month and lower the subscription rate 20% to $0.18 per kWh for low-income customers. The modeled impacts of these modifications have a relatively modest impact on profitability and number of viable projects.
- Develop Shared Solar on affordable housing multifamily sites, making them eligible for a combined 50% ITC, and deliver solar bill savings to LMI multifamily building renters.
- Expand Shared Solar program capacity on identified ≥30-kW economically viable sites to deliver bill savings to low- and moderate-income customers, renters, and multifamily building residents.
- Consider innovative use of solar in the urban environment, for example, solar on sidewalk canopies near public transit stations or parking canopies. Results indicate potential for 600 MW of economically viable parking canopy solar throughout Los Angeles. Establish a higher FiT PPA rate of $0.16/kWh for parking canopy systems in DACs
- Prioritize development for public benefit on identified NPV positive 30-kW+ potential solar+storage sites at government, hospital, and educational sites.

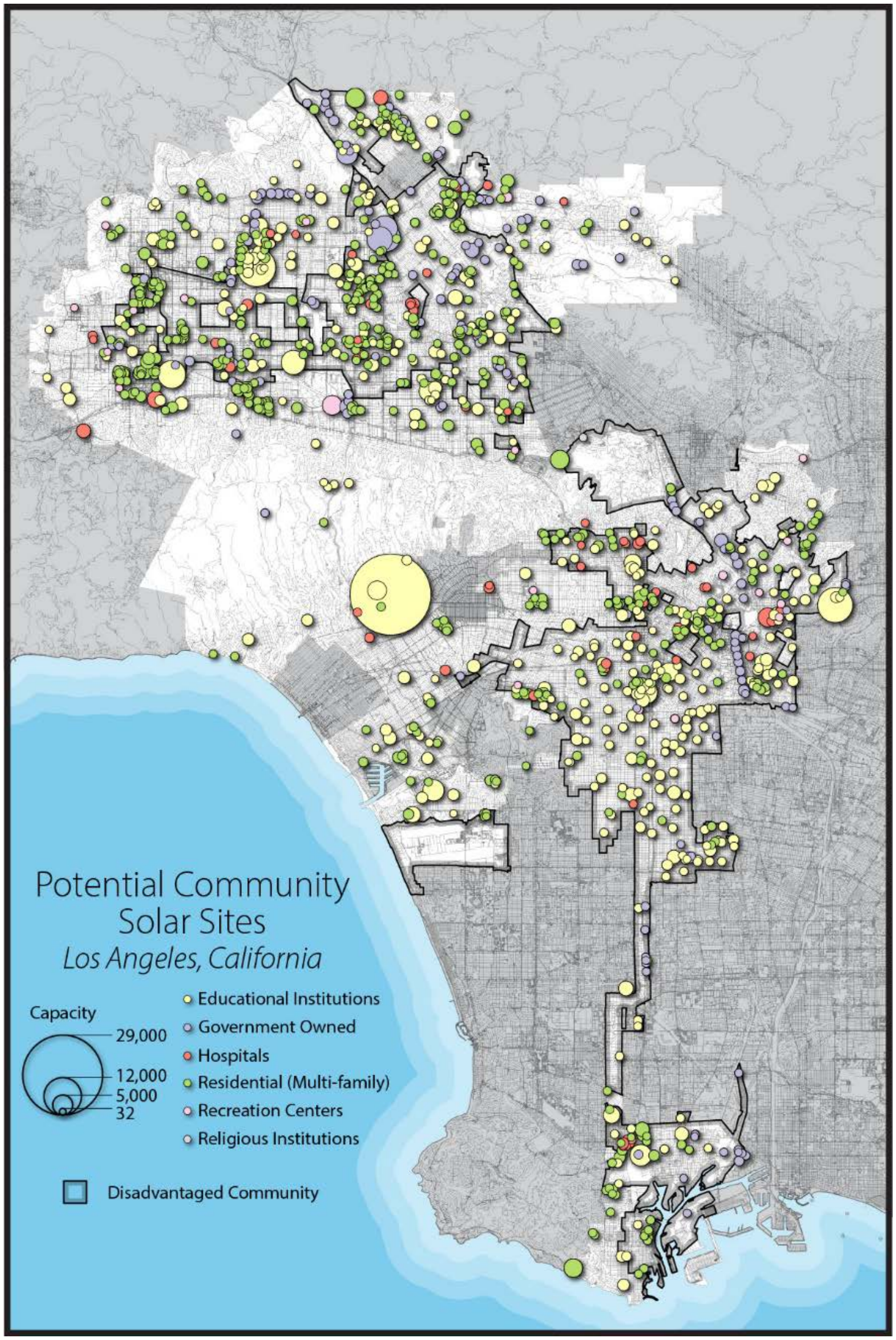

Figure ES-1. Potential community solar sites ≥30 kW on government-owned land, recreation centers, educational institutions, hospitals, and multifamily parcels with positive NPV under the Equity scenario and community solar financial mode

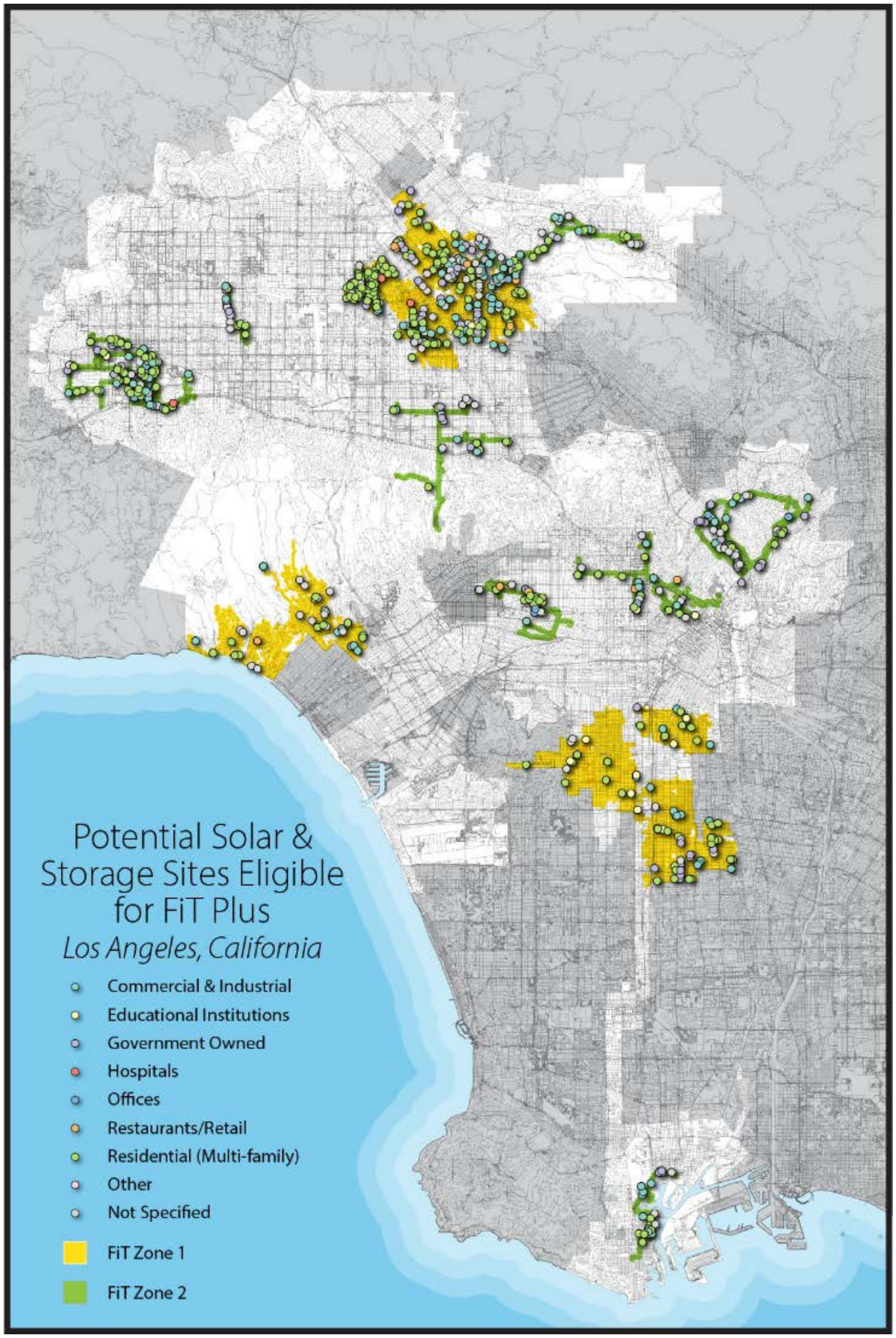

Figure ES-2. Potential solar and storage sites with positive NPV under the LADWP Feed-in-Tariff Plus Pilot program

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1 Introduction

The LA100 Equity Strategies project integrates community guidance with robust research, modeling, and analysis to identify strategy options that can increase equitable outcomes in Los Angeles' clean energy transition. This chapter focuses on identifying potential community solar sites as well as evaluating their economic attractiveness and ability to provide equitable access to bill savings from solar and storage in the city of Los Angeles.

Community solar programs allow energy consumers to purchase a share of electricity generated in an off-site solar facility. These customers can benefit from their subscription by having a portion of their electricity costs remain fixed over the duration of their contract, protecting against retail electricity price increases in the long term. Literature indicates community solar provides benefits to the utility—through development of ideal project locations—as well as the utility's customers, through the ability to achieve cost reductions via economies of scale, collaborative emissions goals, provision of resiliency, and enhanced community cohesion, among other positive attributes (Michaud 2020).

Launched in May 2019, the Los Angeles Department of Water and Power (LADWP) Shared Solar program allows residential customers in multifamily buildings to subscribe to either 50 kilowatt-hours (kWh) or 100 kWh of solar power monthly. (The monthly consumption of the average customer in Los Angeles is 500 kWh). Shared Solar participants are charged a fixed rate for this portion of their electric bill for up to 10 years, starting at a premium[2] but potentially leading to savings as utility rates increase. The blocks of clean electricity come from new solar energy facilities constructed in or near the LA Basin.

Our analysis in this chapter focuses on the following priorities:

- Identifying and ranking potential community-scale solar sites within Los Angeles according to their economic metrics, and further categorizing sites by brownfield (eligible for the 40% ITC), low-income community (eligible for the 50% ITC), land use type, and installation type.
- Identifying which sites are suitable to host storage (in addition to solar) based on available land area and an optimal colocated storage capacity for each site.

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[2] Based on a Standard Residential Rate (R-1A) January–March 2023 of \$0.19/kWh and the 2023 Shared Solar program rate of \$0.22/kWh (LADWP 2023c).

2 Modeling and Analysis Approach

Figure 1 provides an overview of the community solar analysis methodology. First, potential community solar site locations are identified based on suitable in-basin local solar ground-mount and parking canopy sites from the LA100 Study, Chapter 5 (Mooney et al. 2021), as well as potential rooftop solar sites (e.g., schools or hospitals) identified in the LA100 Study, Chapter 4 (Sigrin et al. 2021). Site types evaluated for community solar and storage include locations that can host fixed-tilt ground-mount solar installations; parking lots suitable for solar parking canopy installations; and rooftop solar on larger buildings that can serve as anchor tenants. Only sites with the potential to host 30 kW or more—the minimum capacity eligible for the LADWP Feed-in Tariff (FiT) program (LADWP 2023b)—are considered suitable for community solar.

These locations are then overlaid with census tract sociodemographic information that includes the percentage of low-income households, renter-occupied households, and households living in multifamily dwelling units, as well as other equity metrics and disadvantaged community (DAC) status (based on California Senate Bill [SB] 535 DAC designation). Each potential community solar site is simulated under the System Advisor Model (SAM)[3] community solar financial model to obtain financial output metrics. Simulations for thousands of potential sites in SAM are run using the Python wrapper for SAM or PySAM.[4] This information informs the ranking of potential community solar sites that indicate promising opportunities to provide bill savings.

Since potential solar sites can also be developed under the LADWP FiT program and solar-plus-storage under the LADWP Feed-in Tariff Plus Pilot program, the power purchase agreement (PPA) financial model available as part of SAM is used to obtain financial output metrics for these programs. Under the FiT program, property owners and developers can install 30-kW systems or greater and sell all the energy to LADWP through a PPA. A PPA financial model has no subscribers; therefore, no bill savings are available to low-income customers under this program.

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[3] System Advisor Model Version 2022.11.21 (SAM 2022.11.21) (sam.nrel.gov).

[4] PySAM Version 4.0.0 (github.com/nrel/pysam).

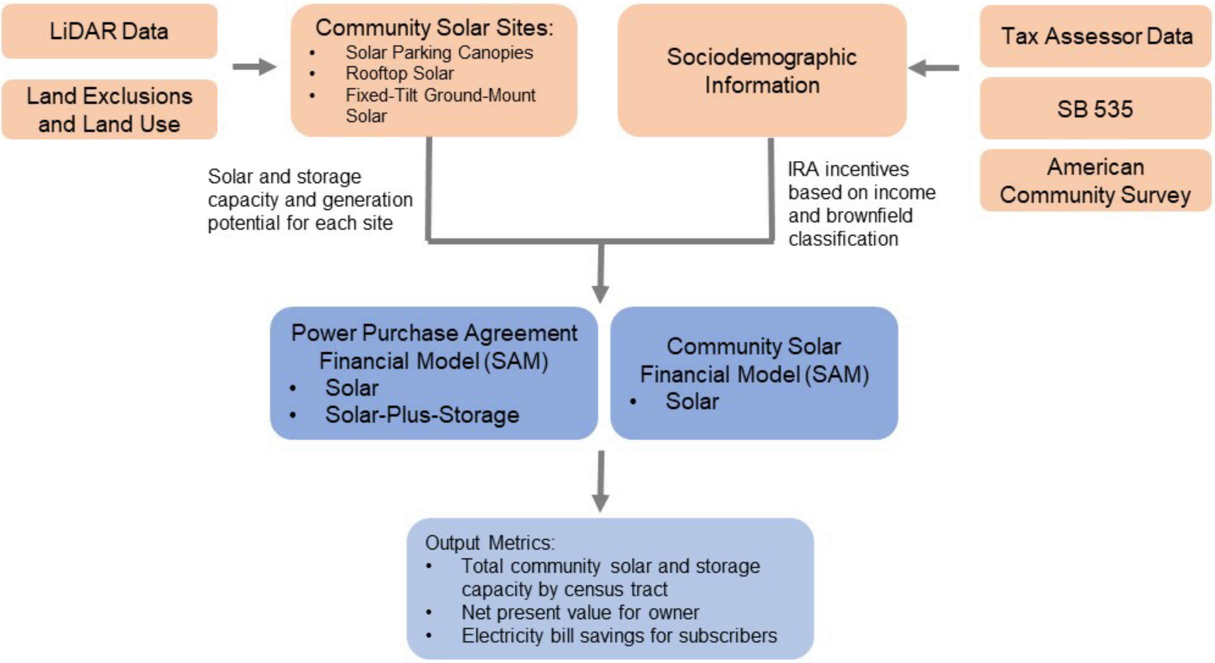

Figure 1. Overview of methodology for community solar and storage analysis

SAM is the System Advisor Model.

Community solar feasibility is analyzed for each potential site from both utility and subscriber perspectives. Two main scenarios are modeled in this analysis: a Baseline scenario and an Equity scenario. The Baseline scenario considers the current LADWP Shared Solar program, the FiT program, and the FiT+ program. The Equity scenario considers enhancements to the LADWP Shared Solar program to increase access by, and benefits for, low-income customers, while maintaining the same offering to other customers. The modeled enhancements to the LADWP Shared Solar program include:

1. The maximum subscription amount increases from 100 kWh/month to 500 kWh/month for low-income subscribers.
2. An offering for low-income customers is added where the current program subscription rate of $0.21665 per kWh is reduced to $0.18 per kWh (below the Standard Residential Rate [R-1A] January–March 2023 of $0.19/kWh [LADWP 2023c]).
3. Half of the capacity of new community solar projects is allocated to low-income customers with the above provisions.

The increase in maximum subscription amount for low-income subscribers allows a majority of annual consumption to be met through the community solar subscription, while the decrease in the current program subscription rate below the R-1A rate ensures the program provides immediate savings for low-income customers rather than requiring a premium payment for access to solar. The Equity scenario also considers a slightly higher FiT PPA rate ($0.16 per kWh) provided by LADWP for sites that are developed as parking canopies in DAC tracts. For the FiT+ program, the Equity scenario considers additional incentives offered for solar-plus-storage systems under the California Public Utilities Commission (CPUC) Self-Generation Incentive Program (SGIP) with equity and resiliency adders and incentive levels (CPUC 2021).

In both scenarios, potential sites are evaluated under the community solar financial model (which models economics for the LADWP Shared Solar program) as well as the PPA financial model (which models economics for the LADWP FiT and FiT+ programs).

This analysis also applies incentives available through the Inflation Reduction Act (U.S. Department of the Treasury 2023, Wood Mackenzie 2023, McGuireWoods 2023) to both scenarios, including a 20% bonus for sites located at a low-income residential building project and/or where at least 50% of the financial benefits of the electricity produced are provided to households with incomes of less than 200% of the poverty line or less than 80% of the area median gross income and a 10% bonus credit to all sites on parcels classified as brownfield by the U.S. Environmental Protection Agency (EPA 2019). Appendix A provides additional information on these incentives and other model input data and assumptions.

3 Modeling and Analysis Results

From the LA100 Study (Cochran and Denholm 2021), both DACs and non-DACs were found to have significant solar technical potential; therefore, identifying approaches that prioritize DACs and lower barriers to realizing the economic benefits from solar in these communities is key for equitable outcomes in Los Angeles. The LA100 Study did not assess community solar as a solar deployment strategy that could benefit low-income households or DACs. To address this limitation, this analysis focuses on financial analysis of sites suitable for community solar development that can provide bill savings for low-income customers and resilience benefits for DACs.

After further analyzing data generated as part of the LA100 Study, over 57,000 potential community solar sites or land parcels with potential to install 30 kW or more were identified within the LADWP service territory, totaling more than 13 GW. After accounting for historical solar adoption and removing potential sites where solar has already been installed, the total technical potential for community solar is 12.7 GW on over 56,000 potential community solar sites. Of this capacity, 3.5 GW can be cited on land parcels classified as government-owned, recreation centers, educational institutions, hospitals, religious institutions, and multifamily residential. Based on our model assumptions, 30% of this capacity, or approximately 1,050 MW on more than 1,800 sites, would be economic or have a positive net present value (NPV) if developed.

The following aspects are investigated to identify promising sites by land use type, installation type, and other characteristics:

- Optimal sites for community solar development, considering:
    - Land use type classifications (e.g., multifamily, government, educational institution)
    - Installation type (rooftop, ground-mount, parking canopy)
    - Sites located in tracts with low-to-median income, sites classified as brownfield, sites in DAC communities
- Project economic viability under the community solar financial model compared to the PPA financial model
- The impact of modifying the current LADWP Shared Solar program to increase benefits and access to low-income customers
- The impact of additional ITC incentives on project profitability
- The number of sites that have sufficient area to host storage in addition to solar and have storage technical potential.

Table 1 presents economic potential solar sites by land use type under the Baseline and Equity scenarios. Economic capacity is the capacity with positive NPV. The economic capacity under both financial models is largest on commercial and industrial land parcels, followed by multifamily buildings, restaurants or retail land parcels, educational institutions, offices, and hospitals. As these land parcels are commonly privately owned, development of solar under a net metering agreement is more likely than under a community solar or PPA contract. While net metering contributes to in-basin clean electricity generation, other benefits, such as lower or more stable electricity bills, are only available to the on-site consumer; thus, low-income customers and customers without access to solar would only benefit with virtual net metering.

Table 1. Economically Viable Solar Sites ≥30 kW by Land Use Type

Land Use	**Baseline Scenario**				**Equity Scenario**			
	Economic Capacity and Number of Sites: Community Solar		**Economic Capacity and Number of Sites: PPA**		**Economic Capacity and Number of Sites: Community Solar**		**Economic Capacity and Number of Sites: PPA**	
	MW	**Sites**	**MW**	**Sites**	**MW**	**Sites**	**MW**	**Sites**
Commercial, Industrial	2,200	2,800	830	190	1,900	2,100	870	210
Educational Institutions	380	470	86	20	330	370	86	20
LADWP-Owned	108	180	43	13	103	160	43	13
Hospitals	68	110	17	11	53	75	17	11
Offices	170	340	25	15	120	240	30	18
Other	440	410	240	60	7	13	2	2
Recreation Centers	12	28	5	1	9	21	5	1
Religious Institutions	1	2	0	0	1	2	0	0
Restaurants/Retail	450	660	76	37	350	440	89	44
Residential (Multifamily)	470	1,100	26	16	340	740	26	16
Total	4,299	6,100	1,348	363	3,213	4,161	1,168	335

Table 2 presents the economic attractiveness of potential solar sites categorized by installation type under the Baseline and Equity scenarios. Multiple installation types above 30 kW each could possibly be included on a single site or land parcel however the most economic installation type is selected. Results show most potential capacity is on rooftops. Only 9% of parking canopy installation sites are found to be economic. Therefore, a higher FiT rate of $0.16/kWh under consideration by LADWP[5] to encourage development of parking canopy solar in DAC tracts is also modeled under the Equity scenario. An increased FiT rate of $0.16/kWh results in additional sites (11% of parking canopy sites) and capacity becoming economic under the PPA financial model. Under the Equity scenario community solar financial model, fewer rooftop installations are economic (a decrease of 503 rooftop installations) due to the lower subscriber rate for low-income customers.

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[5] LADWP SME Meeting Discussions with NREL, November 10, 2022, and January 20, 2023.

Table 2. Economically Viable Solar Sites ≥30 kW by Installation Type

Installation Type	Baseline Scenario				Equity Scenario			
	Economic Capacity and Number of Sites: Community Solar		Economic Capacity and Number of Sites: PPA		Economic Capacity and Number of Sites: Community Solar		Economic Capacity and Number of Sites: PPA	
	MW	Sites	MW	Sites	MW	Sites	MW	Sites
Rooftop	2,900	4,400	650	220	2,400	3,200	650	220
Parking Canopy	601	480	260	34	480	250	340	74
Ground-Mount	890	1,400	450	120	840	1,200	450	120

Table 3 presents the economic attractiveness of potential solar sites classified as brownfield or located in a low-income census tract under the Baseline and Equity scenarios. Brownfield sites and sites in low-income tracts are shown because these sites are eligible for either a combined 40% ITC (for brownfield sites) or a 50% ITC (for sites in low-income tracts), while all other sites are assumed to be eligible for the 30% ITC. The bonus ITC results in a higher percentage of sites in low-income tracts with a positive NPV (11%), compared to sites not classified as brownfields or within low-income communities (where 5% of sites have a positive NPV). Under the Equity scenario, 260 MW of solar are found to be economically viable on more than 600 multifamily buildings in low-income tracts. Brownfield sites also benefit from the ITC, and 15% of sites have a positive NPV; however, this percentage could increase if these sites are also in low-income tracts and can additionally claim the 20% bonus ITC.

Table 1, Table 2, and Table 3 show the total economic capacity (capacity with a positive NPV) under a community solar financial model and a PPA financial model. Under the community solar financial model, project costs are financed through fixed customer subscriptions over a specified time period, while under the PPA financial model, project costs are financed through the sale of electricity from the project owner to LADWP at a fixed rate over the contract term. Details of the input parameters for both these financial models are provided in Appendix A. As shown in Table 1, economic capacity under PPA financing is lower compared to community solar. Sites with a positive NPV under both financial models have on average a 41% higher NPV under the community solar financial model compared to the PPA financial model under the Equity scenario, and 22% higher NPV under the Baseline scenario. The increase in economic capacity is primarily a result of the difference in the compensation for electricity produced; electricity sold for community solar subscriptions is valued at a subscription rate comparable to retail tariffs, while electricity sold under a PPA agreement (in this case, the LADWP FiT program) is valued at a PPA price comparable to average wholesale market prices.

Table 3. Economic Potential of ≥30-kW Solar Sites by Special Site Classifications

Site Classification	Baseline Scenario				Equity Scenario			
	Economic Capacity and Number of Sites: Community Solar		Economic Capacity and Number of Sites: PPA		Economic Capacity and Number of Sites: Community Solar		Economic Capacity and Number of Sites: PPA	
	MW	Sites	MW	Sites	MW	Sites	MW	Sites
All other parcels	1,100	1,400	340	160	800	950	350	170
Parcels in low-income tracts	3,300	4,800	1,010	210	2,900	3,600	1,080	250
Parcels classified as brownfield	4	9	2	1	3	6	2	1

To identify the impact of modifying the current LADWP Shared Solar program to increase benefits to and access by low-income customers, our analysis considers an Equity scenario. Results indicate the maximum savings potential for LADWP Shared Solar subscribers under the Baseline scenario is approximately $68/yr. If the program were modified to increase the maximum subscription to 500 kWh per month and lower the subscription rate to $0.18 per kWh for low-income customers, as modeled in the Equity scenario, the average savings could increase to approximately $480/yr for low-income customers and remain $68/yr for all other customers. These modifications to the current Shared Solar program would have a relatively moderate impact on project profitability. Based on model assumptions, we found the number of economically viable sites (with positive NPV) decreases by 9% compared to the current program structure.

The Equity scenario also ensures that community solar projects developed by LADWP would be eligible for the IRA low-income benefit ITC bonus, which requires at least 50% of subscribers to be low-income and benefit economically from the solar electricity produced.

Battery Storage

Approximately 820 MW (4-hour duration), or 3,300 MWh, of storage could be colocated with photovoltaics (PV) on 4,000 land parcels in Los Angeles based on land area requirements for storage (where the storage-to-PV capacity ratio is 0.71 for 4-hour storage and 1.0 for 8-hour storage),[6] but only 100 MW of storage colocated with 230 MW of solar is economically viable under the FiT+ Pilot program.

Sites with storage colocated with solar PV that are located in LADWP Preferred Zones of Development were simulated under the PPA financial model with assumptions reflecting the

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[6] Storage land-area requirements and sizing assumptions are provided in Table 3 of the LA100 Study, Chapter 5 (Mooney et al. 2021).

FiT+ Pilot program. Storage colocated with PV was not simulated under the community solar financial model because the current LADWP Shared Solar program does not specify addition of storage, nor does the program provide resiliency services to subscribers. In addition, the lack of time-varying compensation for storage or compensation for resiliency results in storage capacity not being economically viable.

Table 4 presents the economic attractiveness of potential solar sites with added storage capacity categorized by land use type under the Baseline and Equity scenarios. The PPA economic capacity represents the amount of colocated solar and storage that is feasible to install in the FiT+ Pilot program Preferred Zones of Development that have a positive NPV under the PPA financial model. If projects can qualify for additional incentives like the SGIP, modeled under the Equity scenario, the economic storage capacity increases to 160 MW colocated with 290 MW of solar capacity. Therefore, the FiT+ Pilot program provides sufficient incentives for solar and storage deployment if the PPA price is at least $0.25/kWh. Under the Equity scenario, 42 MW of storage colocated with 75 MW of solar is found to be economically viable on multifamily buildings in low-income tracts; note that this is a subset of all multifamily buildings where 72 MW of storage paired with 140 MW of solar is found to be economically viable.

Table 4. Positive NPV Solar-Plus-Storage Potential with FiT+ Pilot PPA in Preferred Zones of Development by Land Use Type

Land Use	Baseline Scenario			Equity Scenario		
	PPA Economic Solar Capacity	PPA Economic Storage Capacity	Number of Sites	PPA Economic Solar Capacity	PPA Economic Storage Capacity	Number of Sites
	MW	MW (4 hr)	Sites	MW	MW (4 hr)	Sites
Commercial and Industrial	86	45	100	97	66	190
Educational Institutions	9	4	18	10	4	24
Government-Owned	18	13	42	22	16	90
Hospitals	1	0.2	2	2	0.5	6
Offices	7	1	12	8	2	25
Other	0	0	0	0.1	0.1	1
Recreation Centers	0	0	0	0	0	0
Religious Institutions	0	0	0	0	0	0
Restaurants/Retail	10	2	8	11	3	18
Residential (Multifamily)	98	44	220	140	72	580

4 Equity Strategies Discussion

Substantially expanding development of community solar and establishing a low-to-moderate-income (LMI) subscription rate could result in annual bill savings of $480 for LMI customers and economically viable potential capacity of 340 MW on 740 multifamily sites, and 3 MW on 6 brownfield sites. Multifamily community solar sites with economic capacity can be examined to identify sites on qualified low-income residential building projects, making them eligible for a combined 50% ITC. Prioritizing community solar on affordable and rent-controlled multifamily sites can both deliver economic benefits to low-income building residents and ensure improvements do not cause rent increases and displacement.

Community guidance indicated concern that solar development could displace other, prioritized land uses, such as affordable housing development or parkland. One approach to mitigate this concern is targeting community solar development on brownfield sites that may not be suitable for other land uses and where solar development can also deliver mitigation benefits, such as toxic soil stabilization and revegetation.

Development of community solar economic capacity on privately owned sites under an anchor tenant model could expand access to community solar benefits, especially for sites where electricity generation would be greater than the on-site consumption. An anchor tenant is a large entity that can take a substantial sum (e.g., 40%) of the community solar production or shares and provide the developer a credit-worthy customer who “anchors” the project. An anchor tenant allows the developer to seek out and offer participation to other customers, i.e., homeowners and small business owners, who will take a smaller share from the project. The anchor tenant(s) could be a local school, government entity, or an established business that is likely to be in existence for a long period (Weissman and Brockway 2018). Because of regulations that only allow customers to purchase electricity from LADWP, projects would have to be developed and financed by LADWP with the land parcel owner serving as an anchor tenant for the project.

A challenge to community solar deployment identified from stakeholder interactions[7] is a lack of access to easy-to-use tools and data to identify and prioritize potential project sites. Appendix B includes the link to an interactive map with potential community solar sites with economic capacity of 30 kW or more, which further categorizes sites by brownfield (eligible for a 40% ITC), low-income community (eligible for a 50% ITC), land use type, and installation type. This map can inform equitable community solar site development prioritization and investment as well as goal setting and community engagement discussions. The analysis and results presented in this report aim to enable easy identification of economically viable potential sites, and the results from the economic analysis can be reproduced using the National Renewable Energy Laboratory’s (NREL’s) SAM.

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[7] LADWP SME Meeting Discussions with NREL, November 10, 2022, and January 20, 2023.

Feedback from LADWP SMEs indicated that the deployment of solar—and thus, the scaling up of the Shared Solar program—has been a challenge, with some of the main reasons being prohibitive installation and labor costs in the LA Basin and difficulty in staffing for solar deployment. Strategies to address these issues include:

- Subcontracting project development
- Collaborating with other city agencies to jointly develop solar on government-owned parcels
- Seeking technical assistance, as well as legal assistance, to ensure developed projects receive IRA incentives.

The U.S. Department of Energy Solar Energy Technologies Office provides technical assistance to nonprofit and for-profit organizations, state and local governments, and other entities working to address barriers and improve access to solar energy (DOE 2023).

Outreach and education, making programs more flexible and accessible for low-income customers (clear and streamlined eligibility requirements), as well as expansion of eligibility, are key to ensuring higher program participation and therefore increased access to benefits. NREL analysis of utility programs that target LMI customers (Heeter et al. 2018) found that several LMI customer types are particularly difficult to reach, including renters and foreign language-speaking households. For these reasons, piggybacking on existing LMI programs or partnering with groups that are regularly interacting with these LMI communities can be effective. A common method to facilitate LMI customer identification is to define program eligibility consistent with pre-existing programs. Referrals from friends and relatives can also provide a trusted source of information for LMI customers.

Storage development at solar sites can be accomplished through the FiT+ Pilot program, which was found to provide sufficient incentives to install storage with the modeled PPA price of $0.25/kWh. In programs like CPUC’s SGIP (CPUC 2021), incentives modeled under the Equity scenario lower the cost of energy storage technology by providing an incentive of $850 per kWh under the “Equity” category or $1,000 per kWh under the “Equity Resilience” category. Both of these incentives would mean an energy storage system for the home or facility would be almost, to potentially completely, free of cost.

These strategies, summarized in Table 5, can facilitate scaling of community solar development and associated bill savings opportunities for LMI customers via increased Shared Solar program development, community participation, and collaboration between LADWP, community members, and community-based organizations.

Table 5. Equity Strategy Benefit, Cost, Timeline, Responsible Party, and Metric for Evaluation

Equity Strategy	Benefit/Impact	Cost	Timeline	Responsible Party	Metric
Modify the Shared Solar program to increase the maximum subscription to 500 kWh/month and lower the subscription rate 20% to $0.18 per kWh for low-income customers	Maximum subscriber savings increases from $68/year average over 10 years to $480/year for LMI customers Expands access to solar bill savings to the 55% of LA households that are renters	Positive NPV (cost neutral) potential at 160 LADWP sites, 21 recreation centers, 740 multifamily sites	2024–2035	LADWP	50% of all new Shared Solar capacity delivered to LMI subscribers under the reduced rate makes projects eligible for 50% ITC
Develop Shared Solar on affordable housing multifamily sites, making them eligible for a combined 50% ITC and deliver solar bill savings to LMI multifamily building renters	Prioritizing affordable housing projects ensures improvements do not cause rent increases and displacement 610 economically viable multifamily sites in low-income census tracts totaling 250 MW	Positive NPV sites only. $1,840/kW installed costs Admin costs not calculated	2024–2025	LADWP, LA Housing Department, project developer and engineering, procurement, and construction partners Integrate with CAMR	Projects on low-income residential building projects qualify for IRA 20% ITC bonus 42 MW of storage colocated with 75 MW of solar is economically viable on 370 multifamily sites in low-income tracts
Expand community solar capacity at identified economically viable ≥30 kW sites to increase in-basin solar generation and access to solar bill savings for LMI, renters, and multifamily customers	Economically viable sites with reduced LMI rate include: 3 MW on 6 brownfield 340 MW on 740 multifamily sites 9 MW at 21 recreation centers 103 MW at 160 LADWP sites	Positive NPV (cost neutral)	2024–2035	LADWP	Set a development target for a portion of the economically viable capacity and sites identified
Establish a higher FiT PPA rate of $0.16/kWh for parking canopy systems in DACs	Provides shading, increases economically viable sites from 260 MW on 34 sites to 340 MW on 74 sites	$0.16/kWh FiT rate $2,640/kW installed cost assumed	2024–2035	LADWP	Set a development target for a portion of the 74 viable sites, e.g.,10 of the 67 economically viable parking canopy sites in DAC tracts and 5 of the 17 economically viable parking canopy sites in FiT zones 1 or 2
Prioritize development for public benefit on identified NPV positive 30 kW+ potential solar+storage sites at government, hospital, and educational sites	~160 MW of storage (4-hour duration) colocated with 260 MW of solar on 430 sites are NPV positive under FiT+ Pilot program	Existing FiT+ solar and storage PPA rates	Starting 2023	LADWP with developer, site host, and engineering, procurement, and construction partners	Set target for solar-plus-storage development of a portion of the economically viable public-benefit sites

Baseline Equity

- The LADWP Shared Solar program requires a premium payment for enrollment.
- The LADWP Shared Solar program has higher participation and subscribed capacity among non-disadvantaged, non-Hispanic, and above-median-income communities.

Community Solutions Guidance

- Current community solar programs have insufficient incentives for low- and moderate-income customers to participate.
- Conduct more outreach in low- and moderate-income communities and communities of color on solar and storage options.
- Technical assistance on solar and storage is needed (for affordable housing organizations and others).
- Ensure ground-mounted solar development does not prevent affordable housing development.

Modeling and Analysis Key Findings

- Increasing the maximum subscription amount to 500 kW/month and lowering the subscription rate to $0.18/kWh for low-income customers results in average savings of $480 per year for low-income subscribers and $68 per year for all other subscribers.
- IRA Investment Tax Credit bonuses make more than 600 potential ≥30 kW multifamily community solar sites in low-income census tracts economically viable.
- Approximately 160 MW of storage (4-hour duration) collocated with 260 MW of solar on 430 sites would be economically viable under the LADWP Feed-in-Tariff Plus Pilot program.

Equity Strategy

- Establish a reduced Shared Solar program subscription rate for low- and moderate-income customers and allocate 50% of all new capacity to these customers.
- Prioritize Shared Solar development at the 6 brownfield, 740 multifamily, 21 recreation centers, and 160 LADWP-owned economically viable sites identified.
- Establish a higher FiT PPA rate of $0.16/kWh for parking canopy systems in DACs.
- Provide customers in multifamily buildings the opportunity to have virtual-net-energy metering (VNEM) from nearby commercial or other privately owned sites through an anchor tenant model.

Figure 2. Strategies for equitable access to community solar bill savings

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Appendix. Data Sources and Assumptions

Table A-1 describes the data sources used for this analysis.

Table A-1. Summary of Data Sources for Local Solar and Storage Analysis

Data	Source	Description	Resolution	Vintage
Distributed Generation Market Demand (dGen) model agent database	LA100 analysis (NREL)	Agents created in LA100 1.0 will be used as inputs and outputs for dGen's agent-based modeling.	Parcel	2020–2050
Utility options for local solar and storage	LA100 analysis (NREL)	Agents ranked (by cost) for non-rooftop solar will be analyzed as potential sites for local solar and storage.	Parcel	2020–2050
Income-differentiated building loads	NREL Buildings team	Hourly building loads will be differentiated by income and tenure.	Census tract	2035
Existing LADWP programs for low-income customers	LADWP	Participation/cost information for: Low-Income, Lifeline, and Energy Savings Assistance Programs	Address/ census tract	2006–2021
Income	American Community Survey (ACS)	Detailed sociodemographic population data and housing information	Census tract	2019
Retail electric sales and demand forecast	LADWP	Residential retail electric sales and demand data	City/ service territory	2019–2022
LA100 Equity Strategies Deliverable #143 – Preliminary Results of Analysis, Factors Influencing Current Inequities	Statistical analysis (NREL); CalEnviroScreen 4.0	Distribution of programs by sociodemographic indicators inform sampling of agents and adoption criteria Disadvantaged communities are identified as tracts with the highest 25% CalEnviroScreen Scores.	Census tract	1999–2022 (LADWP program data) 2021 (CalEnviroScreen 4.0)
Shared Solar Program	LADWP	Customer enrollment/cost	Address/ census tract	1999–2022

Data	Source	Description	Resolution	Vintage
California Battery Storage Program	California Public Utilities Commission (CPUC)	Energy storage incentives customer enrollment	Address/ census tract	All program years
LADWP power infrastructure investments	LADWP	Programs for resilience analysis: power systems reliability; System Average Interruption Duration Index (SAIDI) / System Average Interruption Frequency Index (SAIFI)	Address/ census tract	All program years
Data on regions with very high fire hazard severity zones	California Department of Forestry and Fire Protection's Fire and Resource Assessment Program (FRAP) and CPUC FireMap	Regions with very high fire hazard severity zones	City	2017

Table A-2 describes the modeling assumptions used in this analysis.

Table A-2. Model Assumptions

Input Parameter	Value
Community solar analysis period	10 years
PPA analysis period	20 years
Land lease cost	$50 per kW
Total installed cost, rooftop or ground-mount solar	$1840/kW
Total installed cost, parking canopy solar	$2,640/kW
Inflation rate	2.5%
Real discount rate	6.4%
ITC	30%
ITC brownfield	40%
ITC low-income	50%
Community solar subscriber rate	$0.21665/kWh
Community solar low-income subscriber rate	$0.18/kWh
Site classification to receive low-income ITC bonus	Site is in a tract where the median income equals less than $66,750/yr

Input Parameter	Value
Bill credit rate modeled for community solar subscribers	$0.18857/kWh
Bill credit escalation	9.5%/year, applied year on year until 2035
FiT PPA rate	30 kW – 500 kW: $0.145/kWh > 500 kW – 3 MW: $0.14/kWh > 3 MW: $0.135/kWh
FiT PPA rate for parking canopy solar in DAC	$0.16/kWh
FiT+ PPA rate	$0.25/kWh
FiT+ PPA rate multipliers	South LA Multiplier Table specified in the FiT+ Pilot Program Guidelines

IRA incentives are included in both the Baseline and Equity scenarios as described below (U.S. Department of the Treasury 2023, Wood Mackenzie 2023, McGuireWoods 2023):

- Projects that are 5 MW or less qualify for a bonus tax credit if they are in a low-income area, located on Indian land, benefit an affordable housing building, or qualify as a low-income economic benefit project (for full details see Internal Revenue Service Notice 2023 17 [U.S. Department of the Treasury 2023]). Projects will be awarded either a 10% or a 20% bonus tax credit, depending on which subcategory they qualify for. Bonus adders cannot be stacked (i.e., a project cannot earn a 30% adder). If a project qualifies for both a 10% category and a 20% category, they will earn the 20% adder and the project's capacity will be assigned to the corresponding 20% category. Eligible projects will qualify under one of four subcategories:
  - The facility is located in a low-income community, which is currently defined as a census tract where the poverty rate is at least 20% or where the median family income does not exceed 80% of the statewide median family income.
  - Facility is located on Indian land defined in the Energy Policy Act of 1992 as (1) any land located within the boundaries of an Indian reservation or land not located within the boundary of an Indian reservation but held (a) in trust by the United States for the benefit of an Indian tribe, (b) by an Indian tribe or individual Indian, or (c) by a dependent Indian community.
  - The facility is part of a qualified low-income residential building project. A facility is considered part of a qualified building project if the facility is installed on a residential rental unit that participates in an affordable housing program. The financial benefits of the electricity produced must be allocated equitably among the facility's occupants.
  - The facility is part of a qualified low-income economic benefit project. A facility is considered part of a low-income benefit project if at least 50% of the financial benefits of the electricity produced are provided to households with incomes of less than 200% of the federal poverty line or less than 80% of the area median gross income.

- In this analysis, we apply the maximum bonus adder of 20% for sites located in tracts that have a median income of less than 80% of the area median gross income. We also consider 50% of the subscribers of the community solar project to qualify as low-income under the equity scenario.
- Solar generation projects placed in service after Dec. 31, 2022, and located within an "energy community" will be entitled to a 10% additional ITC (2% for base credit). An energy community is defined to include:
    - A brownfield site
    - A census tract or any adjoining tract in which a coal mine closed after Dec. 31, 1999, or a coal-fired electric power plant was retired after Dec. 31, 2009
    - An area that has (or, at any time during the period beginning after Dec. 31, 1999, had) significant employment or local tax revenue related to the extraction, processing, transport or storage of coal, oil or natural gas.
- In this analysis, we apply a 10% bonus credit to all sites on parcels classified as brownfield by the U.S. Environmental Protection Agency (EPA 2019).
- If a parcel is in a low-income tract and also classified as brownfield, we apply the 20% (higher) bonus credit and report it as a parcel in low-income tract under the Equity scenario.

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Strategic Partnership Project Report
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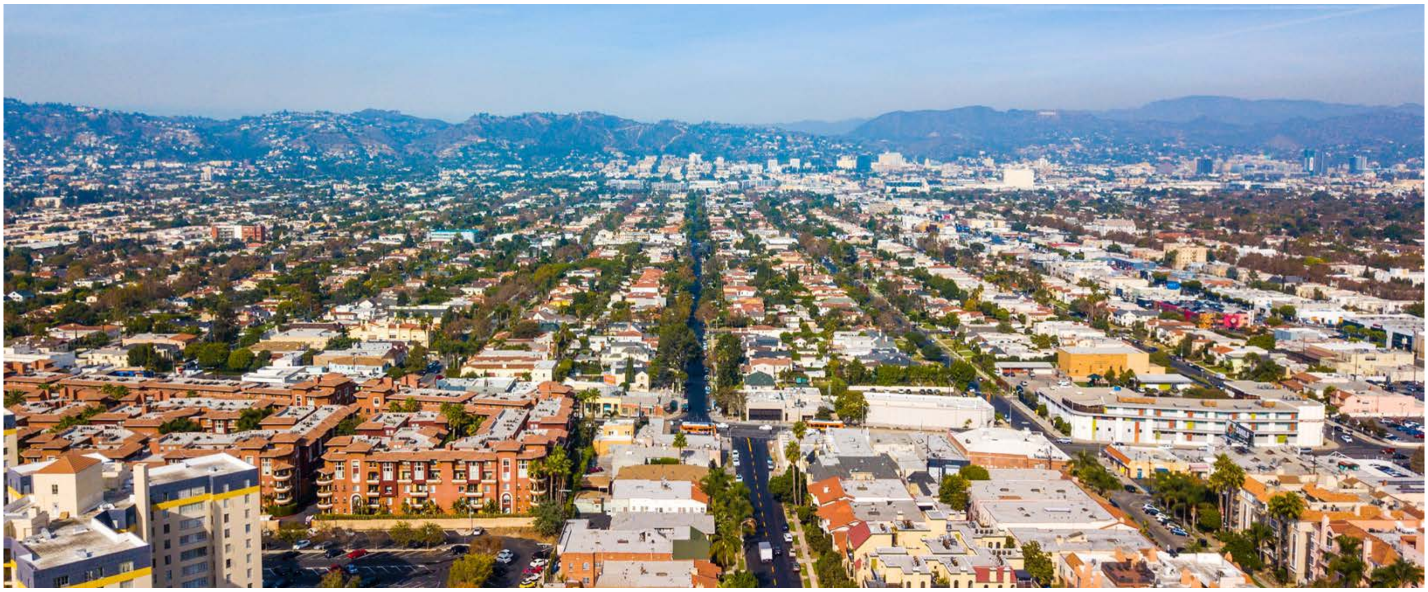
November 2023

LA100 EQUITY STRATEGIES



Chapter 10: Household Transportation Electrification

FINAL REPORT: LA100 Equity Strategies

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November 2023

LA100 EQUITY STRATEGIES

Produced under direction of the Los Angeles Department of Water and Power by the National Renewable Energy Laboratory (NREL) under Work for Others Agreement number ACT-18-00039.

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LA DWP

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Preface

The Los Angeles 100% Renewable Energy Study, or LA100, revealed that although all communities in Los Angeles will share in the air quality and public health benefits of the clean energy transition, increasing equity in participation and outcomes will require intentionally designed policies and programs. The LA100 Equity Strategies project was specifically designed to help Los Angeles identify pathways to such policies and programs in the form of equity strategies. The project aimed to do this by incorporating research and analysis to chart a course toward specific, community-prioritized, and equitable outcomes from the clean energy transition outlined in the LA100 study.

The Project Partners

The Los Angeles Department of Water and Power (LADWP), the National Renewable Energy Laboratory (NREL), and the University of California Los Angeles (UCLA) partnered on the LA100 Equity Strategies project to develop strategies for engaging communities, funding equitable technology and infrastructure investments, expanding existing programs, and designing new programs and policies to improve equity by incorporating what community members themselves know is needed to achieve a more equitable energy future.

The Project Approach

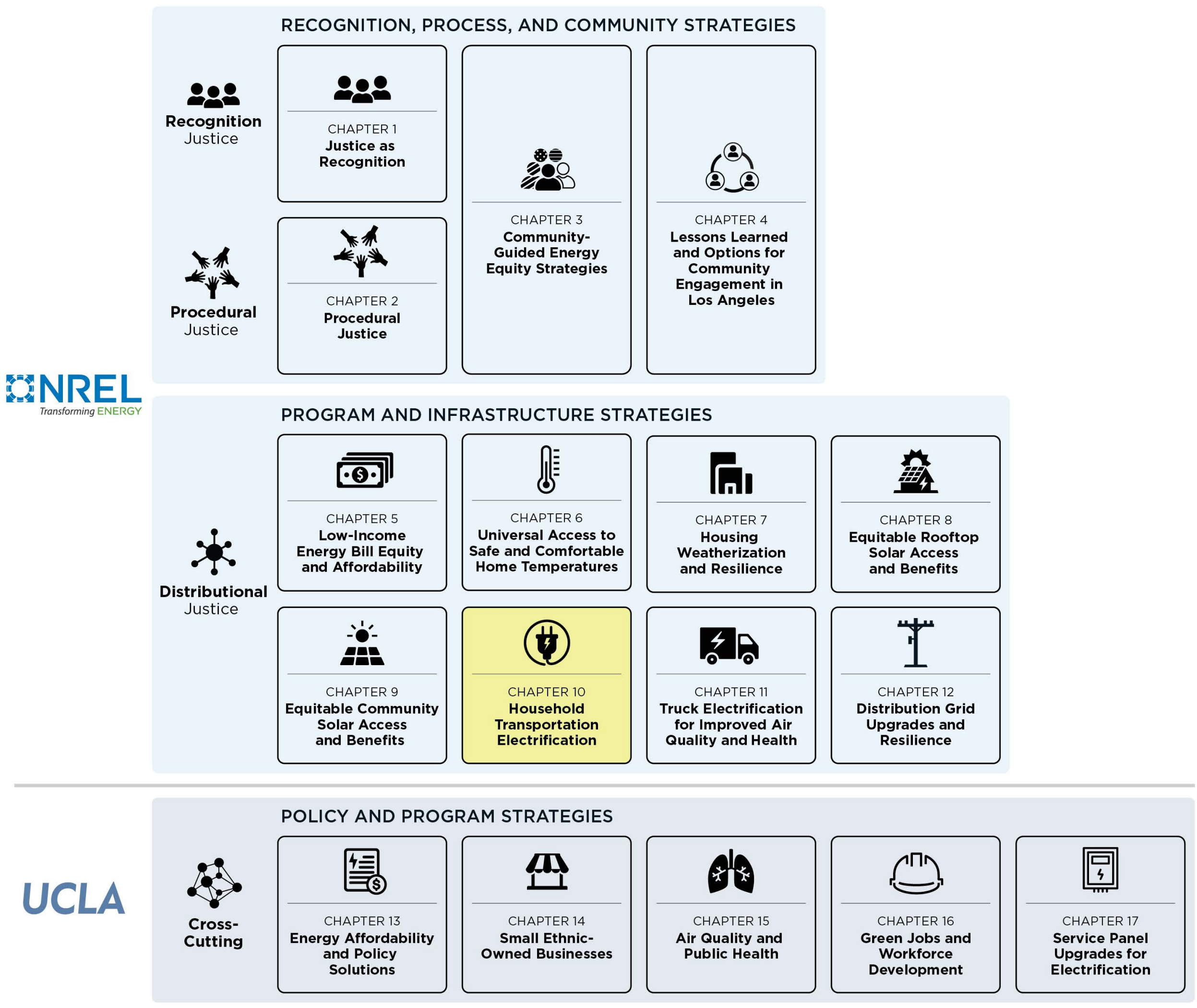
LA100 Equity Strategies employs a unique mixed-methodological approach utilizing three distinct—but connected—research efforts. Through these efforts, NREL and UCLA developed a range of strategy options for increasing equity in LA's transition to 100% clean energy.

A Project Summary

To get a high-level overview of the project, you can dive into the executive summary, interactive data visualizations, and more on the LA100 Equity Strategies website at maps.nrel.gov/la100/equity-strategies.

The Full Report

NREL's final full report for the LA100 Equity Strategies project encompasses seventeen chapters. The first twelve chapters, authored by NREL, are organized around the three tenets of justice. Chapters 1–4 address recognition and procedural justice, while Chapters 5–12 address distributional justice. The final five chapters, authored by UCLA, provide crosscutting policy and program strategies. Each chapter provides data, methods, insights, and strategies to help LADWP make data-driven, community-informed decisions for equitable investments and program development.



NREL Chapters

Chapter 1: Justice as Recognition

Chapter 2: Procedural Justice

Chapter 3: Community-Guided Energy Equity Strategies

Chapter 4: Lessons Learned and Options for Community Engagement in Los Angeles

Chapter 5: Low-Income Energy Bill Equity and Affordability

Chapter 6: Universal Access to Safe and Comfortable Home Temperatures

Chapter 7: Housing Weatherization and Resilience

Chapter 8: Equitable Rooftop Solar Access and Benefits

Chapter 9: Equitable Community Solar Access and Benefits

Chapter 10: Household Transportation Electrification

Chapter 11: Truck Electrification for Improved Air Quality and Health

Chapter 12: Distribution Grid Upgrades for Equitable Resilience and Solar, Storage, and Electric Vehicle Access

UCLA Chapters

Chapter 13: Energy Affordability and Policy Solutions Analysis

Chapter 14: Small Ethnic-Owned Businesses Study

Chapter 15: Air Quality and Public Health

Chapter 16: Green Jobs Workforce Development

Chapter 17: Service Panel Upgrade Needs for Future Residential Electrification

List of Abbreviations and Acronyms

ADOPT	Automotive Deployment Options Projection Tool
BAU	business as usual
BEV	battery electric vehicle
CA	California
Caltrans	California Department of Transportation
CEC	California Energy Commission
CSTDM	California Statewide Travel Demand Model
CY	calendar year
DCFC	direct current fast charger
EIA	U.S. Energy Information Administration
ES	equity scenario
EV	electric vehicle
FPL	federal poverty level
GWh	gigawatt-hours
HCA	home charging access
ICEV	internal combustion engine vehicle
LADWP	Los Angeles Department of Water and Power
LEAD	Low-Income Energy Affordability Data
NHTS	National Household Travel Survey
NREL	National Renewable Energy Laboratory
PEV	plug-in electric vehicle
PHEV	plug-in hybrid electric vehicle
SB	California Senate Bill
TAZ	transportation analysis zone
VMT	vehicle miles traveled
ZVHH	zero-vehicle households

Executive Summary

The LA100 Equity Strategies project integrates community guidance with robust research, modeling, and analysis to identify strategy options that can increase equitable outcomes in Los Angeles' clean energy transition. This chapter focuses on residential electric vehicle (EV) incentive programs and multimodal electrified transportation services as means to increase equity in household transportation electrification.

Specifically, NREL modeled EV adoption and affordability under business-as-usual and enhanced low-income incentives scenarios and transportation-related energy burdens under multimodal electric travel scenarios, including shared EVs, e-bikes, and improved transit services.

Based on our analysis and community guidance, we identified strategies for 1) increasing equity in new and used light-duty EV adoption and EV charging infrastructure distribution, focused on household used EV ownership and home charging access and 2) affordable, time-efficient, and equitable multimodal electrified transportation options, specifically considering the non-vehicle-owning population.

In the context of this chapter of LA100 Equity Strategies:

- *Electric vehicle* refers to a personal light-duty (plug-in) EV.
- *Micromobility* refers to the use of e-bikes and e-scooters.
- *Multimodal* includes shared EVs, shared micromobility, and improved transit services.
- *Low-speed EVs* refers to electric low-speed vehicles, also referred to as neighborhood EVs or electric micro-cars. Low-speed EVs are less than 3,000 pounds gross weight.

Research was guided by input from the community engagement process, and associated equity strategies are presented in alignment with that guidance.

Community Guidance

Guidance from the LA100 Equity Strategies Steering Committee, listening sessions with community members co-hosted with community-based organizations, and community meetings included the following, organized under three themes:

- Tailor LADWP incentives and outreach to meet community needs.
    - Develop and use culturally informed, transparent, community-tailored, and consistent outreach and communication related to Los Angeles Department of Water and Power (LADWP) transportation electrification program benefits.

East LA Resident:

"As of right now, **gas prices are so expensive**, so … I'm choosing to not … go to certain places, like **sometimes even skip work because I work so far away, like a cost-benefit is [not going to work]. It's really impacting my financial decisions.** Right? Will it be affordable for everybody?"

    - Simplify application materials and methods for LADWP transportation-related incentives; for example, by partnering with community-based organizations to adapt applications to local communities, increasing accessibility, and providing organizational support throughout the application and implementation process.
- Expand accessible electric mobility infrastructure.
    - Ensure EV charging stations are sited in locations that meet daily household routines and community needs.
    - Co-design and implement low-income community infrastructure for transportation electrification without adding environmental and socioeconomic burdens.
    - Build inclusive electric mobility (e-mobility) infrastructure for charging household EVs, shared EVs, e-bikes, and other electric options (e.g., electric public transit, low-speed EVs).

Steering Committee member:

"Pacoima received a DWP grant for emissions reduction: 100 e-bikes to rent out to people for the whole year. This is the way to go—piloting projects."

- Expand e-mobility options.
    - Co-develop affordable, reliable, and accessible electric mobility options with local communities to improve access and affordability and reduce pollution.
    - Tailor strategies to access affordable e-mobility technologies based on user needs, similar to the current Los Angeles Department of Transportation Universal Basic Mobility Pilot in South LA.
    - Expand existing e-bike, e-scooter, and EV-sharing programs.
    - Improve the quality of public transit.
    - Increase street safety (e.g., street lighting, shaded transit stops, protecting people on bikes).

The following sections of this executive summary discuss the distributional equity baseline, key modeling and analysis findings, and equity strategies.

Distributional Equity Baseline

Analysis of distributional equity in LADWP's residential EV incentive programs—a used EV rebate program and a residential EV charging station rebate program[1]—found that only 23% of incentives went to disadvantaged communities (DACs)[2] (based on the number of incentives and normalized by the number of customers in each census tract). In addition, the approximately $5.4 million in LADWP incentive investments disproportionately benefited predominantly White, non-Hispanic, home-owning, and wealthier neighborhoods (Figure ES-1).

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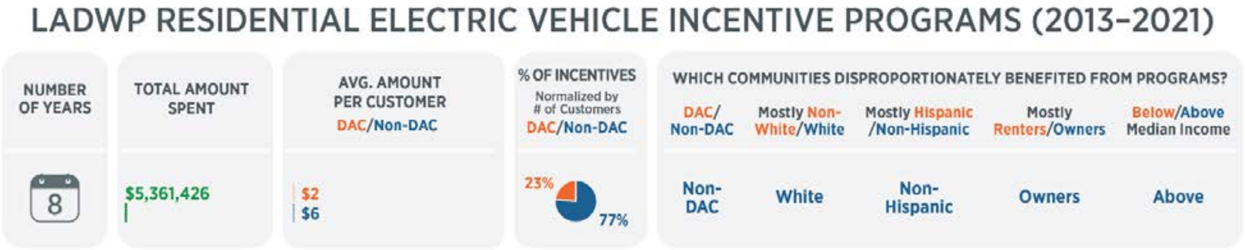
[1] "Electric Vehicles (EVs)," LADWP, https://www.ladwp.com/ladwp/faces/ladwp/residential/r-gogreen/r-gg-driveelectric.

[2] Based on the 2022 disadvantaged community designations from California Senate Bill 535 (https://oehha.ca.gov/calenviroscreen/sb535).



LADWP RESIDENTIAL ELECTRIC VEHICLE INCENTIVE PROGRAMS (2013–2021)

NUMBER OF YEARS	TOTAL AMOUNT SPENT	AVG. AMOUNT PER CUSTOMER DAC/Non-DAC	% OF INCENTIVES Normalized by # of Customers DAC/Non-DAC	WHICH COMMUNITIES DISPROPORTIONATELY BENEFITED FROM PROGRAMS?				
				DAC/ Non-DAC	Mostly Non-White/White	Mostly Hispanic /Non-Hispanic	Mostly Renters/Owners	Below/Above Median Income
8	$5,361,426	$2 $6	23% 77%	Non-DAC	White	Non-Hispanic	Owners	Above

Figure ES-1. Statistical analysis of distributional equity in LADWP residential used EV and EV charging rebates (2013–2021) using SB 535 definition of "disadvantaged community" (DAC)

Percentages and benefits based on the number of rebates distributed within census tracts normalized by the number of residential customers in the tract.

Analysis of the geographic distribution of incentives (Figure ES-2) of the two programs found that areas including South LA and the San Fernando Valley did not receive EV and EV charging incentives proportional to their populations. Areas including West LA received more incentives than their share of the population. California Senate Bill (SB) 535-designated disadvantaged communities, identified with the black border, are overwhelmingly underrepresented in incentive distribution (orange areas), while non-DACs received disproportionately more incentives relative to the number of customers in these communities (green areas).

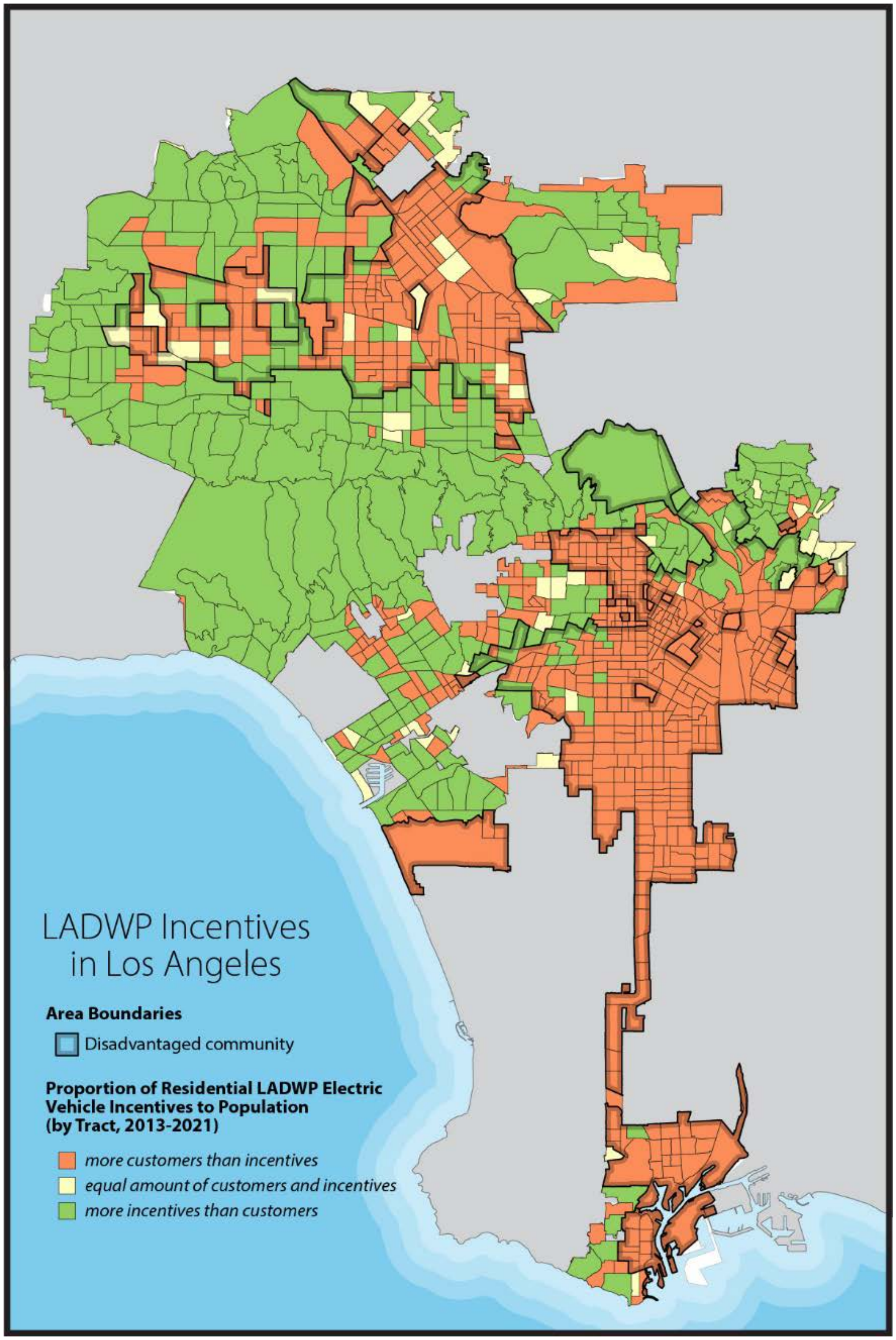


Figure ES-2. Distribution of LADWP Residential EV incentives (2013–2021)

Analysis of public EV charging station locations (Figure ES-3) indicates mostly non-Hispanic communities have more charging stations than mostly Hispanic communities, while no statistically significant disparities are found in distribution across income, race, or disadvantaged community status.

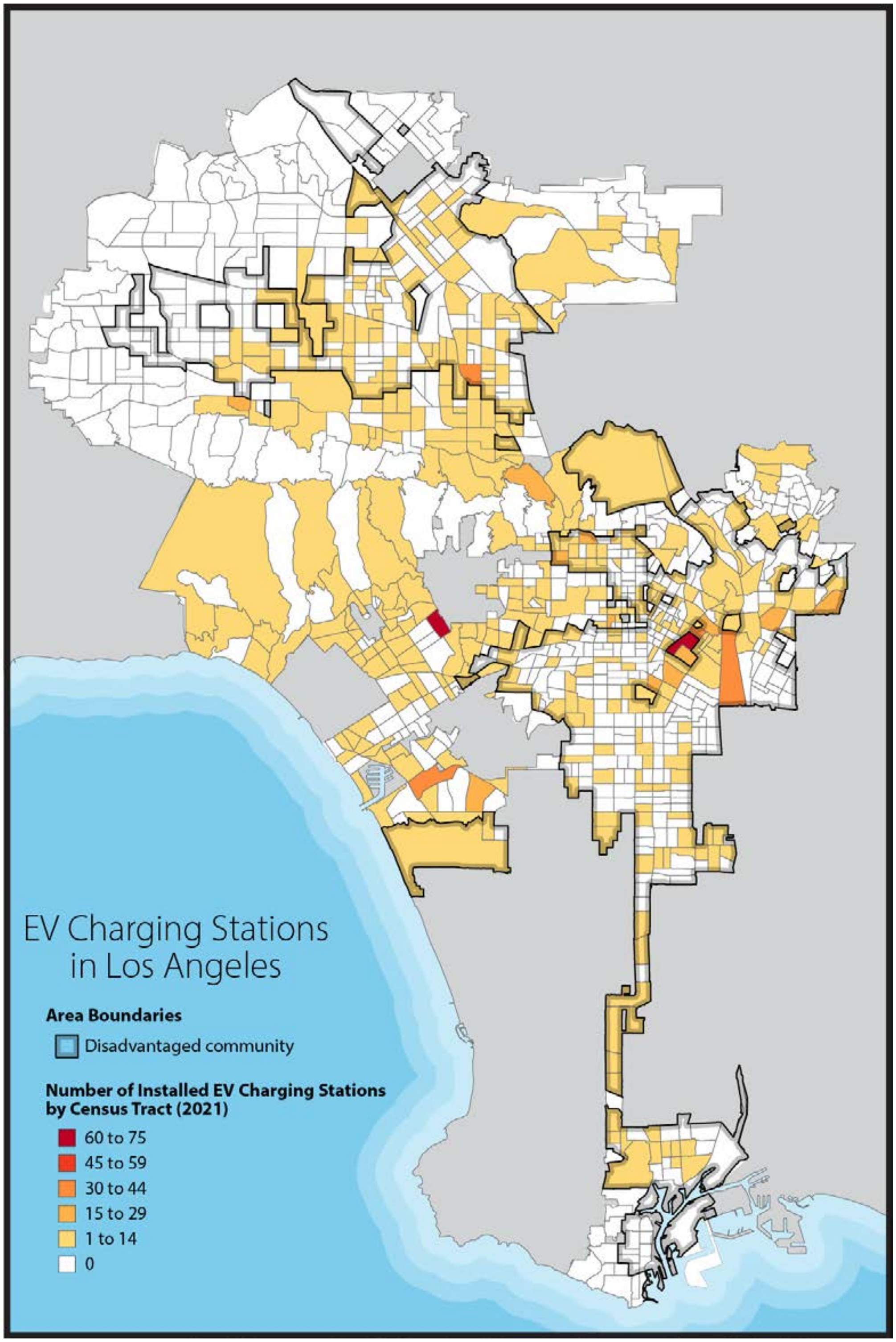


Figure ES-3. Public EV charging stations in Los Angeles (2021)

Source: Alternative Fuels Data Center

Key Findings

We used community guidance and baseline data to conduct modeling and analysis, then identify strategies to improve equity in EV adoption, charging access, and multimodal transportation electrification, including e-bikes, public transit, and shared EVs. Key takeaways are described in the following sections regarding used EV adoption and affordability, EV charging access, and multimodal transportation electrification.

Used EV Adoption and Affordability

- In 2035, households making $75,000 or less (2019 dollars) are predicted to comprise a significant portion of EV owners. These households are more likely to rely on used EVs, compared to households making more than $75,000 a year. Achieving equitable EV adoption for these households requires providing both financial and logistical support for the purchase of used EVs.
- Projections for 2035 indicate that, on average, households in Los Angeles that make $75,000 or less annually and adopt *used* EVs will reduce their average household expenditures by 3%, scaled by income, compared to the case adopting *new* EVs.
- Increasing used EV rebates for low-income households from the current $2,500 to $4,000 could result in a 2% increase in used EV adoption among low-income households in Los Angeles, or approximately 50,000 vehicles.

Household transportation electrification equity metrics include:

- Used EV affordability as a percentage of household expenses
- Access to home and public charging
- Household vehicle ownership rates, public transit access, time and cost of shared EV, e-bike, and transit options
- Proximity to bike lanes
- Income and disadvantaged community status

EV Charging Access

- Approximately 20% of EV owners in Los Angeles in 2035 are predicted to lack at-home charging access, of which about 80% are those living in multifamily buildings. Improving equitable EV adoption requires expanding charging opportunities for EV owners who lack home charging access. Alternative charging options include building code modifications, financial support for EV charging infrastructure installments in multifamily buildings, and curbside or other public chargers.
- Because public charging is typically more expensive than home charging, lack of home charging access results in higher charging costs and leads to an average 1% increase in household expenditures, scaled by income, compared to households with home charging access. This is equivalent to $300 per year for a household with an annual income of $30,000. Public charging vouchers or subsidies could reduce the cost burden and help increase EV adoption for households who lack home charging access.
- Neighborhoods including Little Tokyo, Crenshaw, Leimert Park, Central City, and Hollywood are projected to have high EV adoption potential with low home charging access. Neighborhood chargers can compensate for the lack of home charging access and enable increased low-income EV adoption and affordability.

- In a 2035 Business-as-Usual scenario that continues current EV adoption trends, residential EV home charging occurs predominantly in West LA (wealthier neighborhoods are more likely to have home charging access), indicating EV adoption and charging access and benefits will continue to be heavily inequitable without a deliberate program that includes partnership between the local government and utility and incentive equity focus.

Multimodal Transportation Electrification

- More than 11% of LA households do not currently own a vehicle (American Community Survey 2015–2019), including 16% of households in SB 535-designated DACs (American Community Survey 2015–2019). These households and many others are not likely to adopt a new or used personal EV in the next 10 years in a Business-as-Usual EV adoption scenario. To identify transportation electrification strategies best suited to these households, we identified 19 transportation disadvantaged communities (Figure ES-4) with high rates of zero-vehicle households, low-quality transit, and SB 535-designated DACs (California OEHHA 2022).
- Modeling indicates that providing shared EV programs, shared e-bike programs, and improved transit service could reduce trip travel time up to 12%, save up to 18% in transportation costs, and increase access to destinations up to 3% in neighborhoods with very low car ownership rates, with the optimized multimodal solution varying across communities (see Figure ES-4).
- Geospatial analysis found that fewer than 50% of households eligible for California Air Resources Board e-bike incentives (up to 300% of the federal poverty level) are within 1,000 feet of existing bike lanes or paths (not including sharrows, which are road markings indicating which part of a roadway shared with motor vehicles should be used by cyclists).
- Widespread access to e-bikes could reduce total vehicle miles traveled in Los Angeles by an estimated 4.7%, saving 316,000 tons of CO_2e annually relative to gasoline-powered cars and avoiding 187 gigawatt-hours (GWh) of electricity demand, relative to those miles being traveled in light-duty EVs.

🚲 Shared e-bike access 🚗 Shared EV access 🚌 Improved transit

Transportation Analysis Zone ID & Neighborhood	Most affordable	Most time efficient	Access to most opportunities	Transportation Analysis Zone ID & Neighborhood	Most affordable	Most time efficient	Access to most opportunities
3718 – Panorama City	🚲	🚲	🚌	4111 – Boyle Heights	🚲	🚲	🚗
3731 – Panorama City	🚲	🚲	🚌	4114 – Boyle Heights	🚲	🚗	🚗
3734 – North Hills	🚲	🚲	🚌	4115 – Boyle Heights	🚗	🚗	🚗
3737 – Panorama City	🚲	🚲	🚌	4150 – Boyle Heights	🚲	🚗	🚗
3864 – Reseda	🚲	🚲	🚌	4335 – East Hollywood	🚗	🚲	🚗
3866 – Canoga Park	🚗	🚲	🚗	4611 – Wilmington	🚗	🚲	🚗
3872 – Winnetka	🚲	🚲	🚌	4612 – Wilmington	🚗	🚲	🚗
3877 – Van Nuys	🚗	🚲	🚗	4614 – San Pedro	🚗	🚲	🚗
4067 – Boyle Heights	🚗	🚗	🚗	4630 – Wilmington	🚗	🚲	🚗
4105 – Boyle Heights	🚲	🚗	🚗	*Calculated for low-vehicle ownership, low transit access, disadvantaged communities*			

Figure ES-4. Modeling results identifying neighborhood-specific multimodal strategies for affordability, time efficiency, and access to opportunities

Equity Strategies

Modeling, analysis, and community engagement identified the following strategies for achieving more equitable outcomes in the distribution of benefits and burdens in Los Angeles' transition to clean energy and electrified transportation. Strategies are organized by community guidance theme.

Tailor LADWP Incentives and Outreach to Meet Community Needs

- Increase the LADWP low-income used EV incentive from $2,500 to $4,000 and establish a purchase price cap of $25,000 for incentive eligibility.
- Shift from delayed rebates to a point-of-sale discount.
- Partner with community-based organizations to fund and staff networks of educators to target outreach to DACs, renters, and multifamily residents about incentives and low-barrier financing options (e.g., for those with low/no credit), and to co-design or refine those incentives with them.

Expand Accessible Electric Mobility Infrastructure

- Expand at- or near-home charging access for renters and multifamily residents to enable more equitable access to and use of EVs. Prioritize charging infrastructure development in DACs in charging deserts with a high prevalence of multifamily buildings, including Boyle Heights, South LA, San Pedro, Crenshaw, Canoga Park, Winnetka, and Sylmar. Acknowledging that installing charging infrastructure in all neighborhoods may be a long-term process. In the short term, Los Angeles could focus on programs and incentives that increase workplace charging or interstate fast charging, which may have lower barriers and may increase equitable access to charging (see Box 4 of Kneeland et al. [2020]).

- Develop EV-ready building codes and incentives to address EV charging infrastructure barriers (e.g., panel upgrades, service ratings, circuits) to make households EV ready.
- Provide vouchers or charging subscriptions for public EV charging infrastructure for low-income households, especially those without home charging access.

Expand E-Mobility Options

- Design a community-guided portfolio of electrified transportation options, including EV car share, e-bike, and e-scooter programs, that best serve the needs of each of the 19 neighborhoods identified as the most transportation disadvantaged and other priority areas identified by the City of Los Angeles and communities. Areas include the Boyle Heights, Wilmington, and Panorama City neighborhoods.
- Pair e-bike incentives with the expansion of safe and accessible bike infrastructure and safe charging options at home or away from home.

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1 Introduction

The LA100 Equity Strategies project seeks to inform an increase in equity in Los Angeles' transition to 100% clean energy. This chapter identifies:

- Strategies for increasing equity in new and used light-duty electric vehicle (EV) adoption and EV charging infrastructure distribution, focused on household used EV ownership and home charging access
- Affordable, energy efficient, and equitable multimodal electrified transportation options, specifically considering the non-vehicle-owning population. This research was guided by input from the community engagement process, and associated equity strategies are presented in alignment with that guidance.

1.1 EV and EV Charging Infrastructure Modeling and Analysis Approach

As depicted in Figure 1, for evaluating future scenarios of personally owned EVs and corresponding EV charging infrastructure, we leveraged three models: the Automotive Deployment Options Projection Tool (ADOPT) (NREL 2022a), the Electric Vehicle Infrastructure – Projection (EVI-Pro) (NREL 2022b) tool, and the Electric Vehicle Infrastructure for Equity (EVI-Equity) (NREL 2022c) model. ADOPT examined the impact of federal and state rebates on EV deployment, based on personal car market dynamics, technological advances, vehicle component costs, socioeconomics, and policy scenarios. EVI-Pro estimated charging demands for EVs, for which travel patterns, vehicle attributes, charging needs, and charging costs were considered. EVI-Equity assessed equitable distribution and affordability of used EVs, as well as access to EV charging infrastructure, and charging loads. EVI-Equity estimated household-level personal vehicle purchases, ownership, and utilization, as well as refueling preferences and behavior in the context of heterogeneous socioeconomic and demographic characteristics of individual households.

This analysis considered the latest EV rebates available from the federal, state, and city governments, as illustrated in Figure 2. We modeled two scenarios:

- **Business-as-Usual (BAU):** A $7,500 federal and $2,000–$7,500 state rebate for new battery electric vehicles (BEVs) ($1,000–6,500 for plug-in hybrid electric vehicles [PHEVs]) (Figure 2a) and a $4,000 federal and $1,500–$2,500 city rebate for used EVs (Figure 2b) were modeled based on income thresholds in the BAU scenario.
- **Equity:** To investigate the impact of increased rebates for used EVs for low-income consumers, an Equity scenario was evaluated in which the city rebate increases from $2,500 to $4,000 for households with annual incomes up to $40,000 (Figure 2c). The income threshold of $40,000 was determined based on LADWP requirements—only those participating in the Lifeline or EZ-SAVE low-income customer assistance programs are qualified to apply for the low-income rebate program (LADWP 2021a, 2021b).

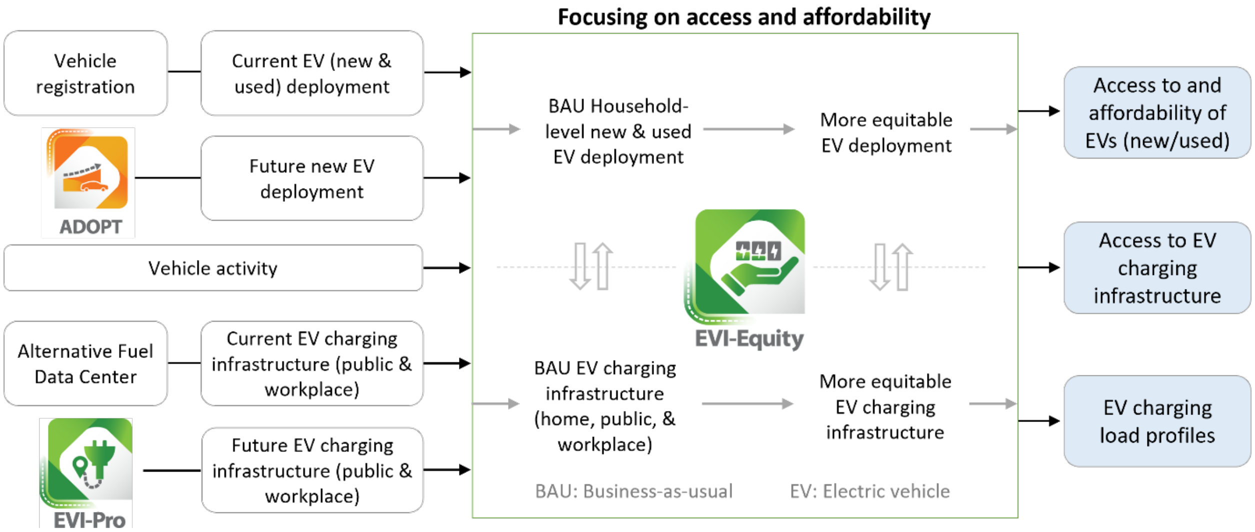
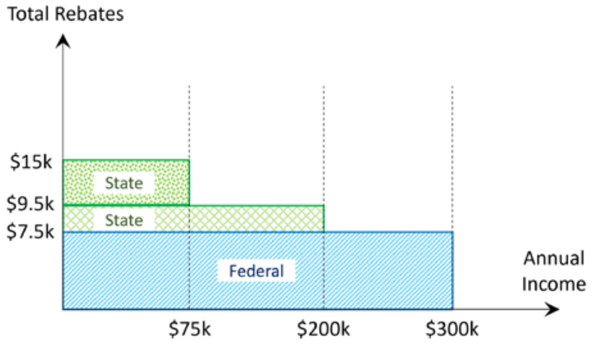


Figure 1. EV and EV charging infrastructure modeling workflow

(a) Rebates for ***New*** EVs



(b) Rebates for ***Used*** EVs – Business-as-Usual

(c) Rebates for ***Used*** EVs – Equity Scenario

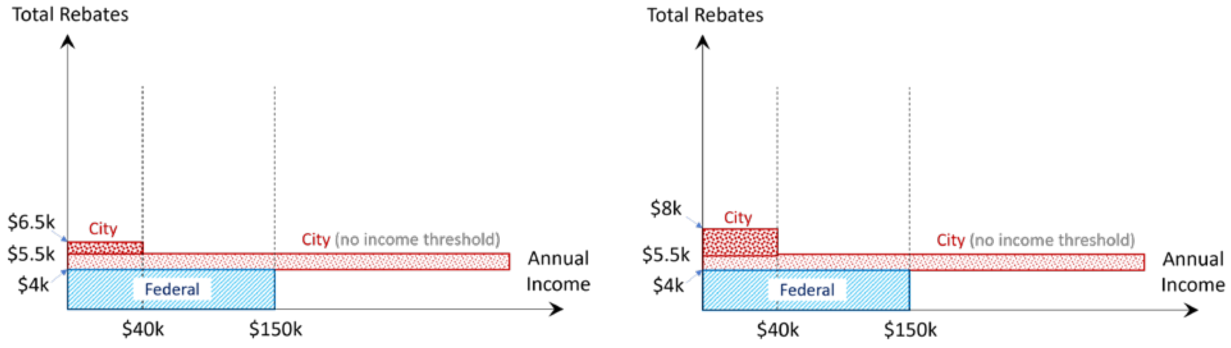


Figure 2. Considered scenarios for federal, state, and city rebates for (a) new EVs, and used EVs under (b) Business-as-Usual and (c) Equity scenarios

Key outputs include projected 2035 distributions of EVs by household income, purchase price, technology (PHEV versus BEV), used versus new vehicle status, and sociodemographic and economic characteristics, as well as the influence of purchase incentives on adoption. Affordability of EVs was characterized as expenditure-to-income ratio, including vehicle purchase and financing, fuel, and maintenance and repair costs. Access to EV charging infrastructure focused on the distribution of households who were predicted to own EVs but lack home charging capability. This can inform the city on the neighborhoods in which installing public EV charging infrastructure would best address the lack of access to home charging. Outputs also include EV charging infrastructure deployment by census tract, home charger access by tract, public EV charging infrastructure by tract, and associated EV charging load profiles. The results are modeled at the spatial resolution of census tracts and presented for BAU and Equity scenarios in Section 2.1 (page 6) for EVs and EV charging infrastructure.

1.2 Multimodal Modeling and Analysis Approach

This analysis investigates opportunities to provide multimodal electrified transportation services to disadvantaged community (DAC) households,[3] who are less likely to have access to privately owned electric vehicles (American Community Survey 2015–2019). Modeling evaluates reductions in transportation-related costs and travel time and increases in access to opportunities based on different modes (e-bike, improved public transit, and EV car share). We then use both model results and other resources to compare alternative multimodal equity strategies and understand their impacts on DACs. This comparison is intended to inform LADWP and City of Los Angeles decisions on options to improve access to electric mobility for residents who have higher levels of transportation disadvantage.

We built a behavioral model (details can be found in the appendix) that predicts how people choose among different travel modes (Figure 3). The model estimates mode choice based on the trips made in the study region from the National Household Travel Survey (NHTS) – California Add-On (U.S. DOT Federal Highway Administration 2017) data set. The model incorporates factors like the time and cost of using each mode. The underlying mode choice preference is used to predict the mode choice decisions of individuals when certain transportation services become lower in cost or new transportation services become available (e.g., an EV car sharing or e-bike sharing program). The multimodal modeling and analysis aim to answer the following questions:

- How much DAC daily travel can be supported by clean energy-powered transportation modes when they become available?
- How can providing alternative electrified travel modes, other than privately owned vehicles, help DACs reach more activity opportunities and reduce DAC transportation-related expenditures and time spent on transportation?
- What are the relative energy and emissions impacts from these mode options?

Travel demand forecast data from the California Department of Transportation (Caltrans) in the California Statewide Travel Demand Model (Caltrans 2022), as well as city mode shift targets,[4] are used to estimate the impacts in baseline and equity scenarios. The spatial resolution of the California Statewide Travel Demand Model is transportation analysis zones, which have similar boundaries to census tracts.

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[3] Disadvantaged communities as defined by the California OEHHA (2022) Senate Bill 535.
[4] "Targets*," L.A.'s Green New Deal Sustainability Plan 2019, plan.lamayor.org/targets/targets_plan.html

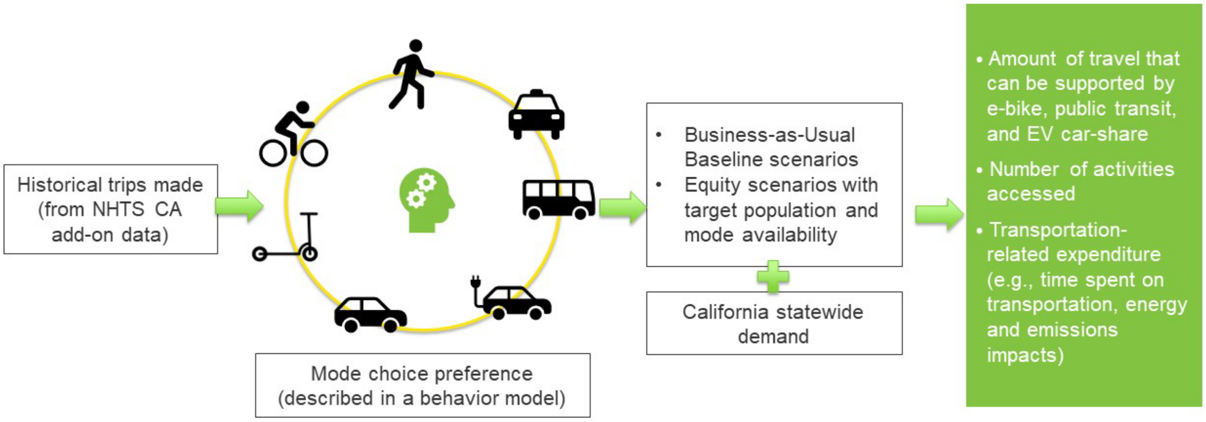

Figure 3. Multimodal transportation modeling workflow

The multimodal analysis began by first identifying areas of priority for transportation equity. Transportation disadvantaged priority DACs are where DACs meet the following three criteria (Figure 4):

- Transportation analysis zones in the top 40% for zero-vehicle households, or households that do not own a personal vehicle (Figure 4)—defined as 12% or more of households without vehicles—for Los Angeles based on American Community Survey data (2015–2019 5-year product).
- Transportation analysis zones in the top 40% for low-quality transit based on 2020 U.S. Environmental Protection Agency Smart Location Database data.
- Transportation analysis zones with 50% or more of their area in California Senate Bill (SB) 535-designated DAC census tracts.

These criteria are used because they indicate relative transportation disadvantage in a city that is widely considered to have an auto-centric transportation system. Areas that meet all three criteria have especially limited transportation options and services and represent transportation electrification equity-deserving communities requiring attention to meet residents' mobility needs.

To quantify the impact of potential multimodal transportation electrification strategies, a baseline scenario and three equity scenarios with different multimodal solutions were evaluated, including:

- **Baseline Scenario**: DAC residents without personal vehicles only have access to travel options that are currently available (i.e., transit with current service level, taxis, biking, and walking); DAC residents who have access to personal vehicles have one more travel option available (driving).
- **Equity Scenario 1:** DAC residents have access to a shared EV program.
- **Equity Scenario 2:** DAC residents have access to a shared micromobility (e-bike or e-scooter) program.

- **Equity Scenario 3:** DAC residents have access to improved transit services (i.e., adding transit service connecting DACs with frequently visited destinations if there is currently no transit service available, shorter access time or waiting time).

See the appendix for the detailed service level of each modeled travel option.

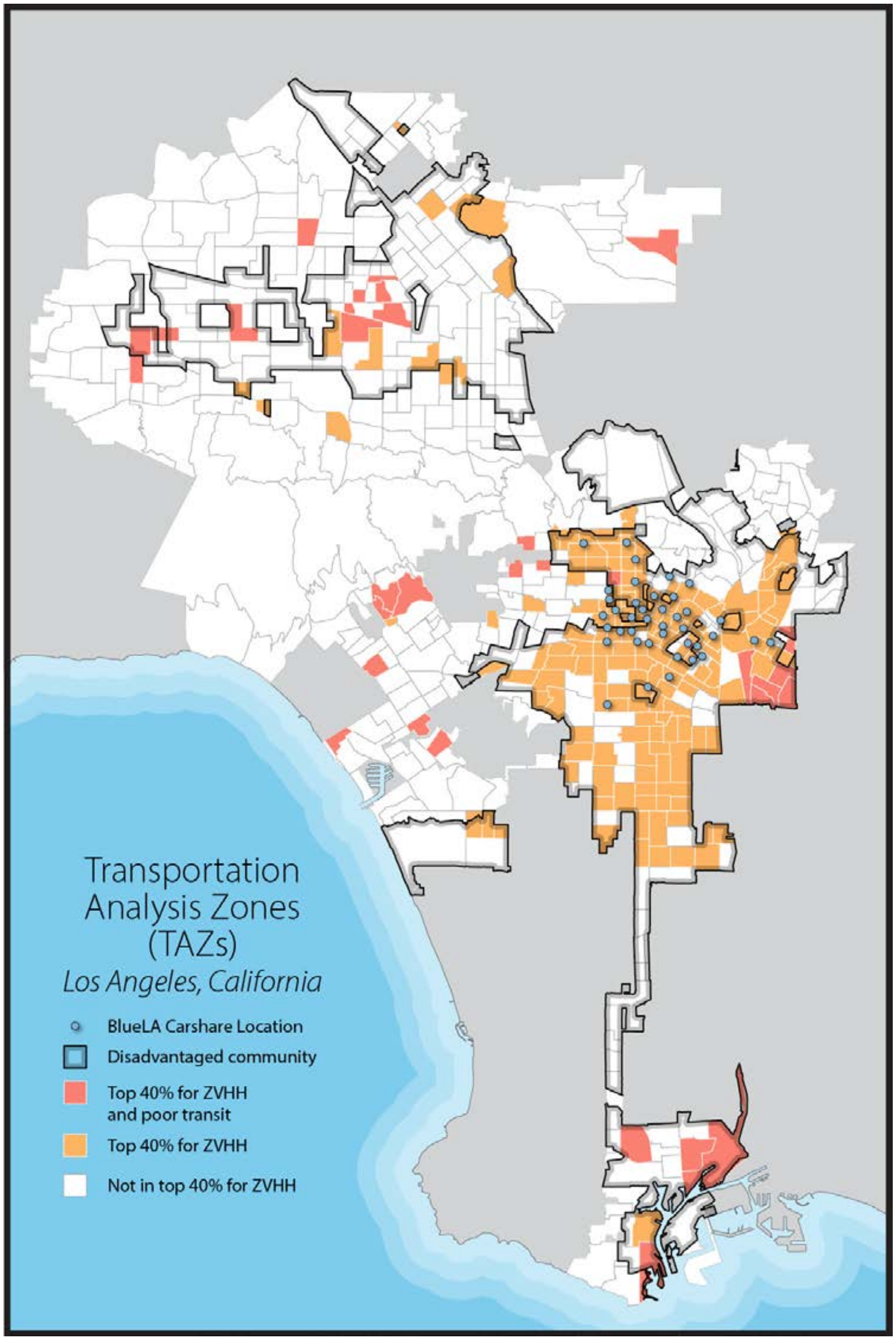

Figure 4. Metrics used to define transportation disadvantaged areas of Los Angeles for multimodal analysis, where ZVHH means zero-vehicle households

2 Modeling and Analysis Results

2.1 EV and EV Charging Infrastructure Access and Affordability

Access to EVs depends on the price of EVs and purchasing power of potential consumers, which, in turn, are influenced by socioeconomic factors. Analysis first evaluated longitudinal evolution of new and used EV stock and purchase price. Influx of new EVs was estimated by the ADOPT model, and the flow between new and used EVs in the personal car market was determined by the EVI-Equity model, which accounts for the average length of vehicle ownership after purchase (IHS Markit 2016), average vehicle age, scrappage rate (NHTSA 2006), and average age of used vehicles purchased (Papandrea 2022). Figure 5 shows the estimated stock of EVs through 2035 by technology (PHEV versus BEV) and vintage (or model year). By 2035, Los Angeles is expected to have about 1.6 million plug-in EVs, which include both BEVs and PHEVs. This estimate is based on California's zero-emission vehicle mandates (100% of new cars sold in the state to be zero-emission vehicles by 2035) as well as the LA100 study (NREL 2021; CARB 2022). In 2035, most EVs on the road in Los Angeles are expected to be BEVs, and about 50% of all EVs are expected to be 5 years old or younger. Around 90% of EVs on the road in 2035 are predicted to be 10 years old or younger, which is an indication of a still-growing and maturing EV market.

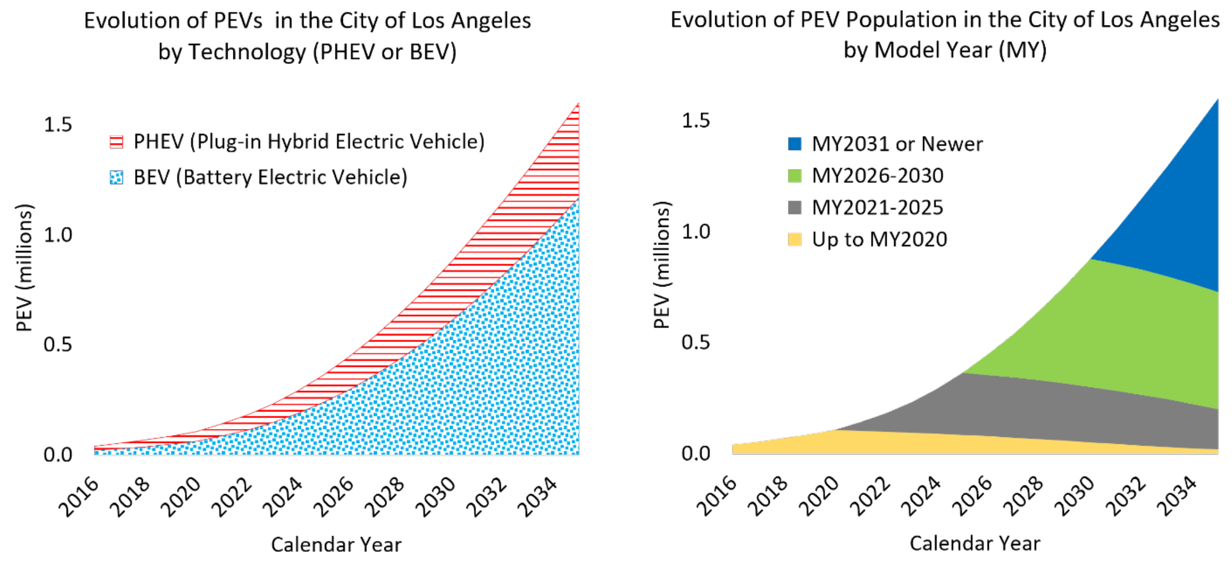

Figure 5. EV stock in Los Angeles by technology (PHEV versus BEV) and model year

Source: EVI-Equity
MY = model year)

In addition to EV stock, EV price (at the point of purchase—new or used) was also estimated by the EVI-Equity model. Figure 6 illustrates that EV prices decline over time, as lower-cost models are introduced in the new EV market and used EV prices depreciate over the vehicle lifetime, which improves the affordability of EVs. The overall cumulative sales-weighted average purchase price for EVs on the road in Los Angeles in 2035 is projected to be $35,000 (ranging from $32,000–$38,000) for new EVs and about $23,000 (ranging from $20,000–$25,000) for used EVs. The price in Figure 6 is the modeled market value consumers pay at the point of purchase for all new or used EVs in Los Angeles for each calendar year. For example, an EV in operation in calendar year 2035 may have been purchased as a used car in 2030 at $15,000 (without rebates), while another EV in operation in calendar year 2035 may be purchased in 2035 as a new car at $160,000 (without rebates). As such, the fleet-wide purchase price of EVs, for example, in 2035, includes all purchases made in 2035 or preceding years. The overall weighted purchase price for all EVs declines (Figure 6), because of the growth of lower-cost new EVs in the market and the depreciation of used EVs' market value over time. As Figure 6 suggests, the structure of the purchase price of EVs in Los Angeles through 2035 differs significantly between PHEVs and BEVs, as well as between new and used vehicles.

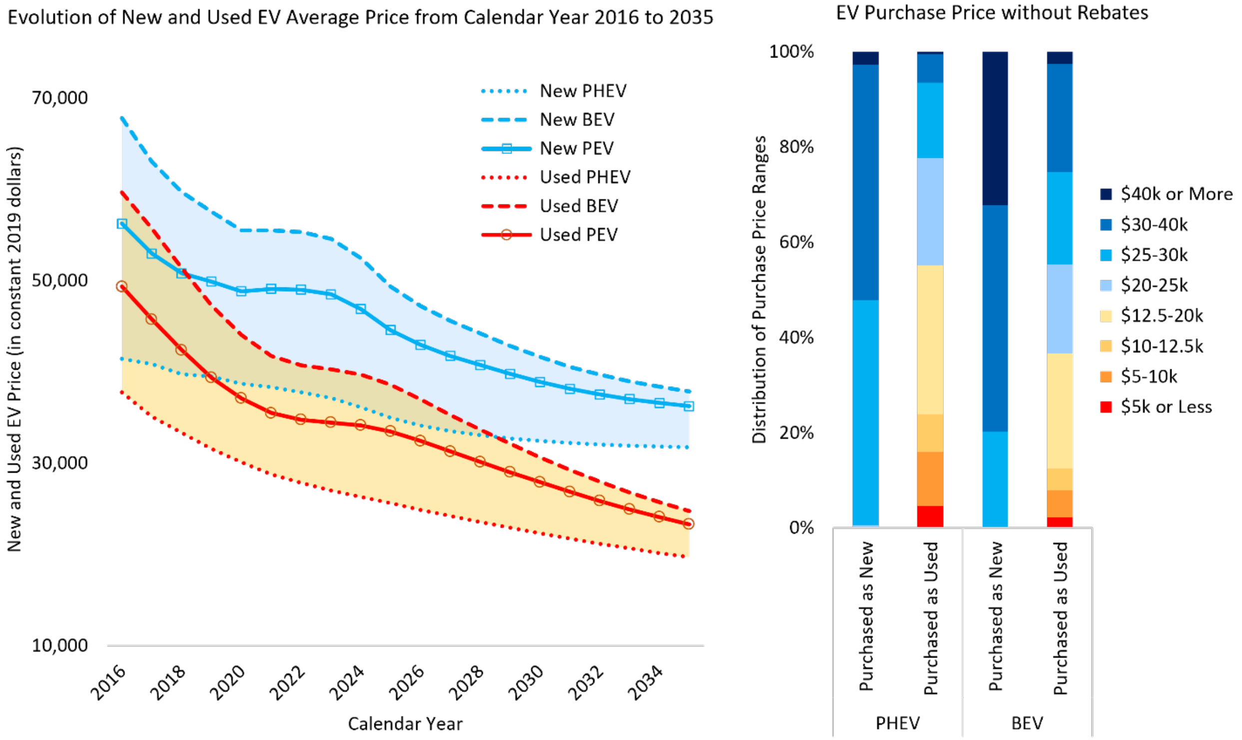

Figure 6. Projected purchase price for new and used EVs

EV = plug-in electric vehicles, including both BEVs and PHEVs; Source: EVI-Equity

The distribution of new and used EVs is expected to differ by income. The EVI-Equity model projects under these assumptions that about one-half of EV owners in Los Angeles in 2035 will be households making more than $75,000 per year, and one-half will be those making $75,000 or less (Figure 7). This is similar to the income breakdown of existing personal gasoline car owners. Partially because of the transitional nature of the EV market between now and 2035 and a significant influx of new vehicles, most EVs are expected to be purchased as new, but households making $75,000 or less a year are expected to purchase approximately equal shares of new and used EVs. In 2035, households making $75,000 or less are predicted to represent the majority of used EV purchasers. Therefore, improving access to EVs for those households may require two strategies: (1) introducing more affordable EV models in the new vehicle market; and (2) providing both financial and logistical support for the purchase of used EVs.

Access to home charging is expected to differ by housing type. Approximately 55% of EV owners in Los Angeles in 2035 that make more than $75,000 a year are estimated to reside in single-family homes. More than 50% of EV owners that make $75,000 or less in Los Angeles in 2035 are estimated to live in multifamily homes and be primarily renters. This is consistent with the nature of the housing stock in Los Angeles, which has a significant share of multifamily homes and has implications for access to home charging. Around 20% of EV owners in Los Angeles in 2035 are predicted to lack home charging access, of which about 80% are those living in multifamily homes. For EV owners who lack home charging access, policy changes and/or alternative charging options can support EV access and use, including building code modification, financial support for EV charging infrastructure installment in multifamily homes, and curbside or other public chargers in those neighborhoods.

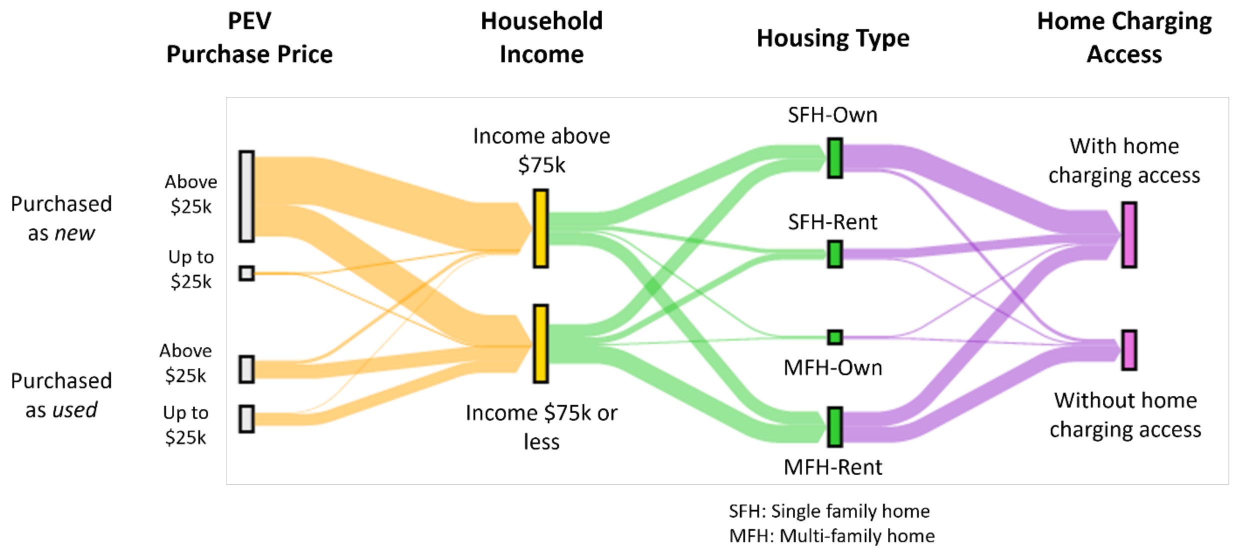

Figure 7. Breakdown of EV owners in Los Angeles in 2035 by household income, housing type, and access to home charging (based on BAU scenario), where plug-in EVs (PEVs) include both BEVs and PHEVs.

Source: EVI-Equity

To understand EV and EV charging infrastructure affordability, we assess the affordability of used EVs in terms of expenditure-to-income ratio using EVI-Equity, California-specific used EV market data, and heterogeneity in financing new versus used vehicles (e.g., interest rates for used vehicles are 40% higher than interest rates for new vehicles [Motor1.com 2023]), depending on the credit rating of potential EV consumers. Figure 8 shows an example for a household in Los Angeles making 20% less than the median income ($60,000 annual income), with two personal vehicles and a good credit score (700–800). Without an EV, this household has expenditures as illustrated in the far left of Figure 8, where transportation using personally owned vehicles makes up about 15% of total expenditures (relative to income). When adopting an EV, transportation makes up 12%–26% of total expenditures, depending on whether the adopted EV is new or used, whether rebates are available or not, whether they purchase a sub-premium (e.g., Tesla Model 3) or standard (e.g., Nissan Leaf) vehicle, and whether the household has home charging access or not.

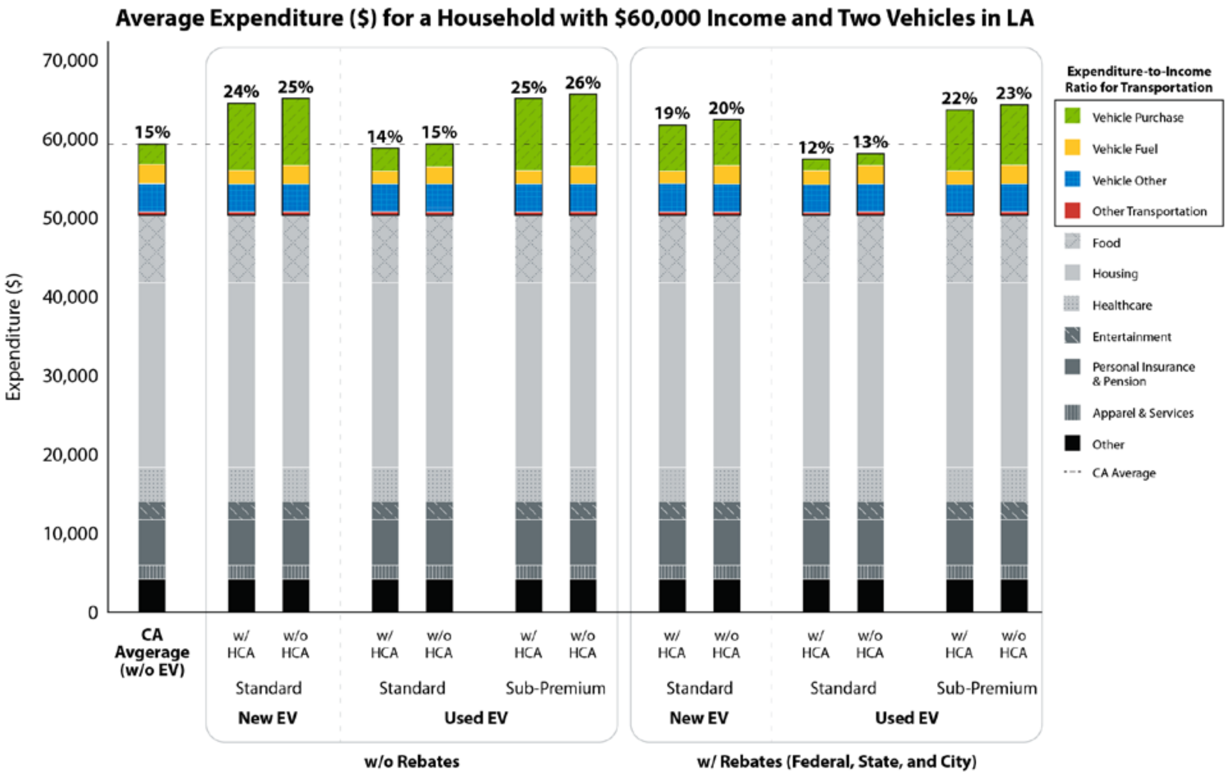

Figure 8. 2022 household expenditures related to EV and home charging access (based on today's market conditions)

Source: EVI-Equity
HCA = home charging access, CA = California

w/o = without, w/ = with

Results indicate that new vehicles (EVs or gasoline vehicles) in today's market are generally not affordable for households making $60,000 or less, as they increase household expenditures by about 10% relative to statewide average transportation expenditures without EVs. The availability of used EVs in the transition to electric vehicles can help mitigate this issue. For example, used EVs in the standard group (e.g., Nissan Leaf, Kia EV6) maintain a similar level of household expenditures or reduce expenditures, even without rebates in the case of the Nissan Leaf. Including all available federal and local rebates for used EVs (Figure 2), the results show a used Nissan Leaf could reduce overall household expenditures by 5% and decrease the transportation-related expenditure-to-income ratio from 15% to 12% for households with home charging access, and from 15% to 13% for households without home charging access. The analysis reveals the importance of standard model used EVs for improving access and affordability of EVs for lower-income households, which, in turn, highlights the need to increase support for standard EV model purchases and home charging for lower-income households.

Improving Access to and Affordability of EV and EV Charging Infrastructure

Introducing more affordable EVs in the new EV market will increase access to and affordability of EVs upstream. Improving access to and affordability of EVs for a broader group of consumers also requires tackling the problem downstream—the used EV market, as used EVs are relatively more affordable, and many low-income households rely on the used vehicle market for their personal car purchases. This is an area where the City of Los Angeles could play an important role. As depicted in Figure 2, LADWP currently provides $1,500 rebates for used EV purchases, and an additional $1,000 for low-income consumers with annual gross incomes of $40,000 (or less for two- or three-person households). Figure 9 illustrates the impact of LADWP increasing low-income rebates for used EVs from $2,500 to $4,000, reflecting federal rebate levels shown in Figure 2c.

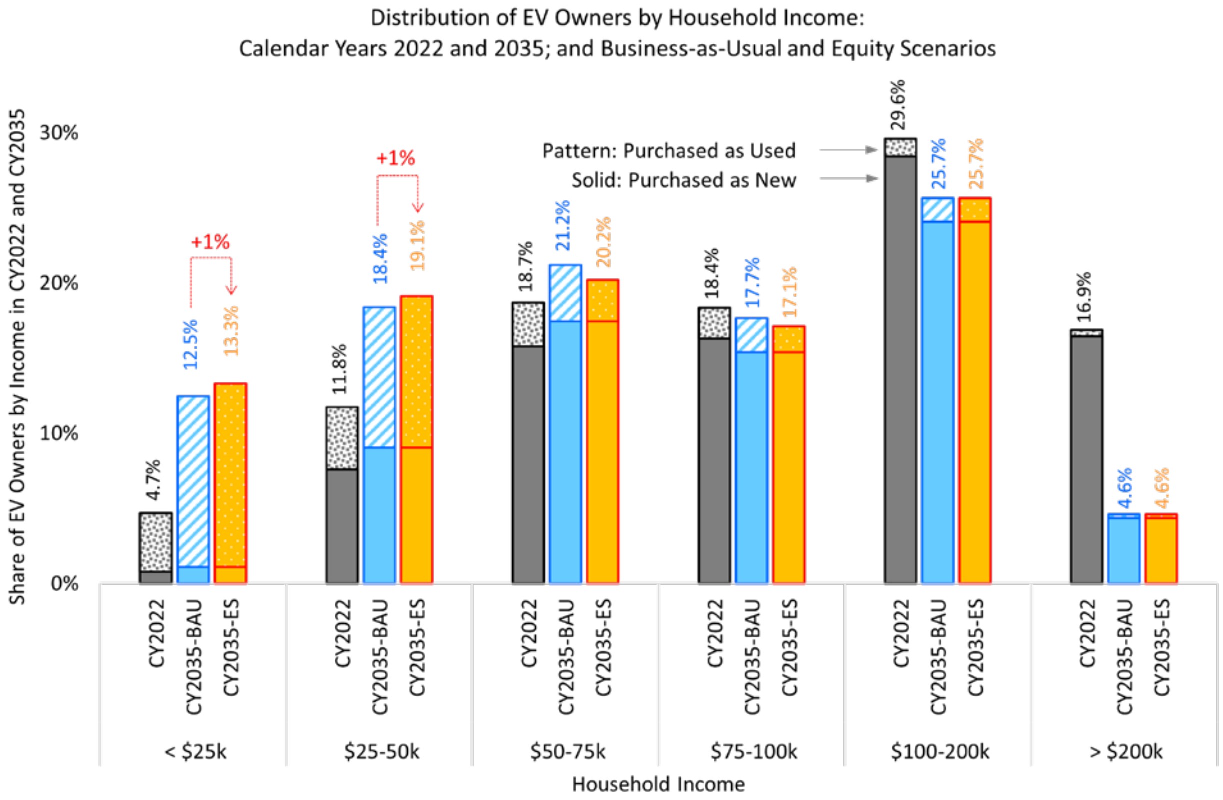

Figure 9. Share of predicted EV owners in Los Angeles in 2035 by household income and EV market (purchased as new versus used) in Business-as-Usual and Equity scenarios

Source: EVI-Equity
CY = calendar year, BAU = Business-as-Usual, ES = Equity scenario

Increasing used EV rebates for low-income households by 60% from the current $2,500 to $4,000 could result in a 2% increase in used EV adoption among low-income households in Los Angeles, as shown in Figure 9, or approximately 50,000 vehicles by 2035. When evaluating the impact of changes in EV rebates, EVI-Equity assumes increasing rebates by a certain amount will increase purchasing power by that amount, and thus, consumers will behave as if their income had increased by the same amount. The 60% increment from $2,500 to $4,000 represents a little less than 4% of an annual income of $40,000. The distribution of EVs across income groups will largely remain the same, regardless of the predicted 2% migration.

EVI-Equity estimates that the change in *used* EV rebates would not affect *new* EV deployment patterns (Figure 10), and high-income groups would not change their EV purchase behavior because of the change in used EV rebates targeted toward low-income households. The new and used vehicle markets could interact (for example, automakers adjusting their strategies due to the used vehicle market dynamics), but that is not considered in this analysis. Also, the migration of used EV share from the $50,000–$100,000 groups in Figure 9 to the lower-income groups is an artifact of the assumption that the citywide EV population will remain the same, regardless of revamped rebates for used EVs. This analysis did not consider potential competition for used EVs between different socioeconomic groups within the city or areas beyond the city, which may lead to an increase in the demand and thus price of used EVs. Another artifact of the assumption that the total EV population will remain the same in 2035 could be a masking of potential increased total EV adoption as a result of low-income incentives.

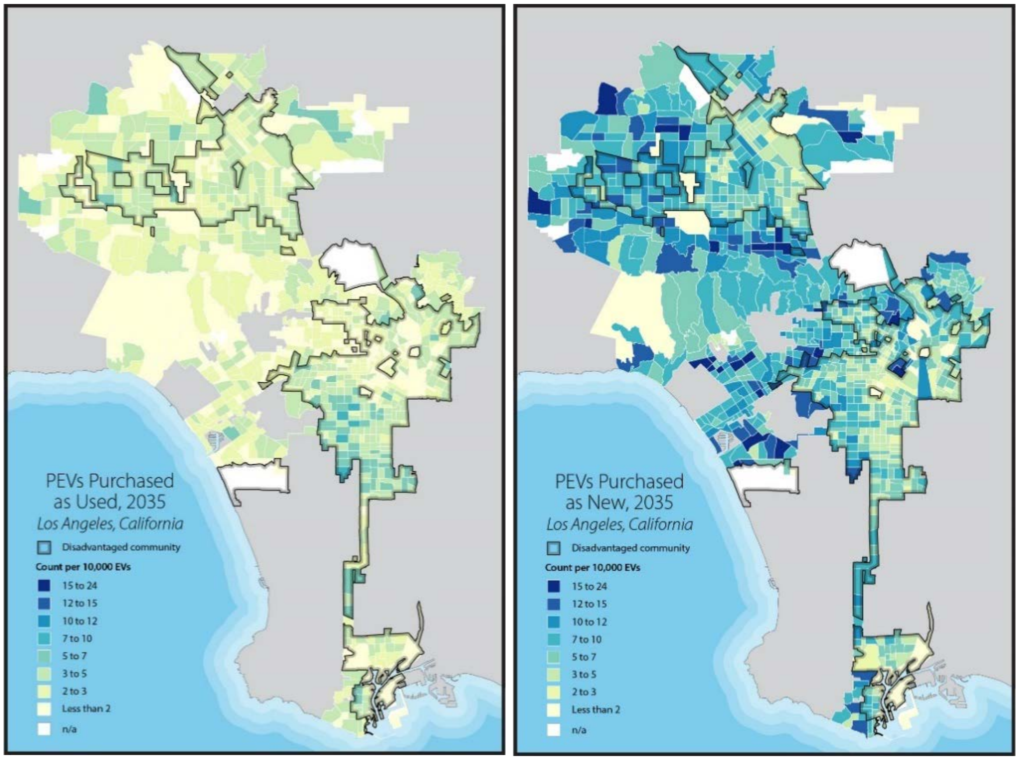

Figure 10. Projected spatial distribution of EVs in Los Angeles, calendar year 2035, purchased as new versus used. PEVs include both BEVs and PHEVs.

Source: EVI-Equity

The data are normalized to show EV adoption distribution using the following equation: (modeled adopted EV count per tract) / (total modeled EV count in LA [1.6 million]) x 10,000

Figure 11 shows the impact new versus used EVs could have on expenditure-to-income ratio for households in Los Angeles that make $75,000 or less per year. Household expenditure estimation in EVI-Equity is based on a consumer expenditure survey (BLS 2020), local fuel prices (gasoline and electricity), future evolution of fuel prices (EIA 2023), and maintenance and repair cost differentials between gasoline vehicles versus EVs (Burnham et al. 2021). In the left section of Figure 11 (Vehicle Purchase and Financing), we see that on average, households in Los Angeles adopting used EVs could save about 3% of their household expenditures (a reduction from 7% to 4% for vehicle purchase and financing), scaled by income, compared to adopting new EVs. Buying new EVs is predicted to increase the expenditure share for most households that make $75,000 or less a year. While the levelized cost of driving new EVs, without rebates, is predicted to be lower than the levelized cost of driving new gasoline cars by

2035 for general consumers of new vehicles, lower-income households do not typically drive new vehicles. For this population, a new EV would increase expenditures, as shown in Figure 11.

EVs decrease fuel cost burden in all scenarios, whether with home charging access or not, as shown in the middle section of Figure 11. EVs decrease maintenance and repair burden by 35%, which is equivalent to a 0.5% decrease in household expenditure-to-income ratio compared to households with gasoline cars, as shown in the right section of Figure 11. Regarding fuel cost, compared to households with home charging access, not having home charging access could lead to a 1% increase in household expenditures, scaled by income, due to higher costs of public charging. This is equivalent to about $300 a year. To reduce the cost burden for those households who drive EVs while having no home charging access to the level for those with home charging access, about $300 per year of financial support would be needed. This could help alleviate the financial burden associated with the lack of home charging access and thus having to use public chargers that tend to be more expensive.

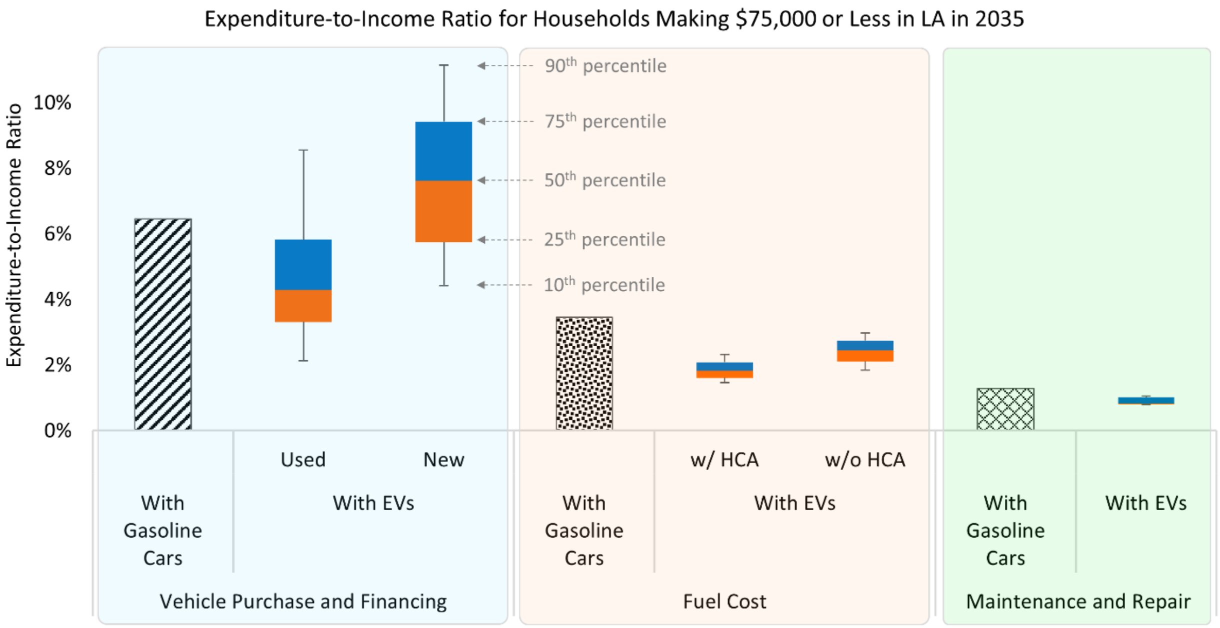

Figure 11. Expenditure-to-income ratio for households with an income of $75,000 or less that adopted EVs in Los Angeles by 2035

HCA = home charging access

Households who drive EVs while having no home charging access are sometimes referred to as "home charger orphans." In addition to offsetting higher costs of public charging, addressing the lack of home charging access may also require installing chargers in the neighborhoods where home charger orphan households are located. Figure 12 shows the projected concentration of home charger orphans across the city in 2035, which can inform where neighborhood chargers can compensate for the lack of home charging access and enable increased low-income EV adoption and affordability. Neighborhoods including Downtown, Mid-Wilshire, West LA, Hollywood, and North Hollywood are projected to have high EV adoption potential with low home charging access. Overall, census tracts not designated as DACs by SB 535 are projected to have 99,000 EV home charger orphans with an average of 9.6% and median of 7.8% of EVs per census tract, whereas tracts designated as DACs by SB 535 are projected to have 320,000 EV home charger orphans with an average of 10.2% and a median of 9.1% of EVs per census tract.

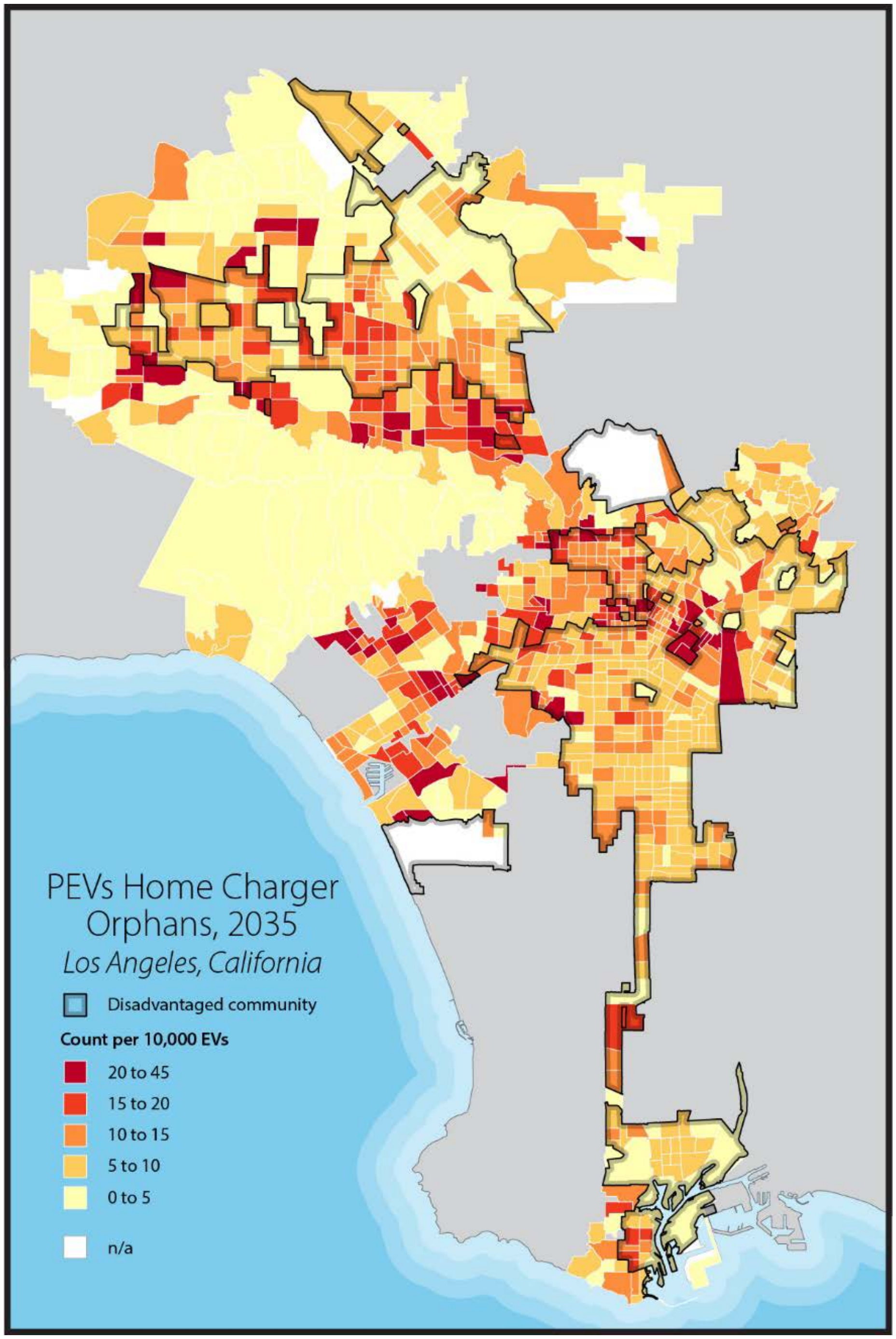

Figure 12. Projected spatial distribution of EV adopters without home charging access requiring neighborhood charging options or installation of home chargers (2035), where PEVs include both BEVs and PHEVs

Source: EVI-Equity

The data are normalized to show EV adoption distribution using the following equation: (modeled adopted EV count per tract) / (total modeled EV count in LA [1.6 million]) x 10,000

2.2 Reducing Transportation Energy Burdens Via Multimodal Solutions

Recognizing many LA households do not currently own a vehicle and are not likely to adopt a new or used EV in the next 10 years, we next examined non-personally owned electric mobility options to increase equity in transportation electrification.

2.2.1 Mode Choice Modeling and Metrics

We modeled the extent to which providing multimodal electric travel options, including shared EVs, shared micromobility, or improved transit services, can reduce transportation-related energy burdens for DAC residents. We modeled Baseline and Equity scenarios to identify the impact of gaining additional travel modal options on: (1) travel time, (2) travel cost, and (3) the number of opportunities that can be accessed. The modeling results are presented as the comparison between the Baseline scenario (i.e., BAU scenario) and Equity scenarios where new transportation services became available. The results are shown for the 19 transportation analysis zones that meet all three criteria for transportation disadvantage (i.e., high rates of zero-vehicle households, poor quality transit, and SB 535 DAC). Table 1 shows aggregated results.

Table 1. Usage of New Services and Impacts of Multimodal Solutions on Travel Time, Travel Cost, and Opportunities Reached

Strategy	Percentage of Trips Using New Services (%)		Reduction in Travel Time		Reduction in Travel Cost		Increase in Opportunity Reached	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Shared EV Access	6.8%	3.9%	3.2%	4.2%	7.4%	11.5%	1.8%	3.5%
Shared E-Bikes	16.9%	3.1%	-0.4%	4.2%	6.6%	8.6%	0.41%	0.88%
Improved Transit	10.0%	4.6%	11.7%	7.9%	18.5%	22.1%	3%	4.7%

The mode choice behavioral model evaluates the cost and time needed to use each travel option in daily travel and estimates the likelihood people would use different travel options. The percentage of DAC travel demand that utilizes newly added travel options is 3.5% to 26% (Figure 13). This percentage varies across DACs, and also by mode. In most cases, the shared micromobility program attracts the most DAC demand, followed by improved transit. The shared EV program ranks first in two DACs (4614 and 4067).

The newly added travel options can reduce DAC daily travel expenditures in most cases. Transit service with a fixed fare provides, on average, the greatest reduction in DAC residents' travel expenditures. However, the newly added travel options do not always help DAC residents reduce costs. Depending on the locations and travel demand patterns of a neighborhood, they can bring zero reduction, or even an increase in travel-related expenditures, while decreasing travel time and providing access to more destinations. This also indicates that, for some portion of DAC residents' demand, new travel modes that cost a little more than existing options but save time are also useful.

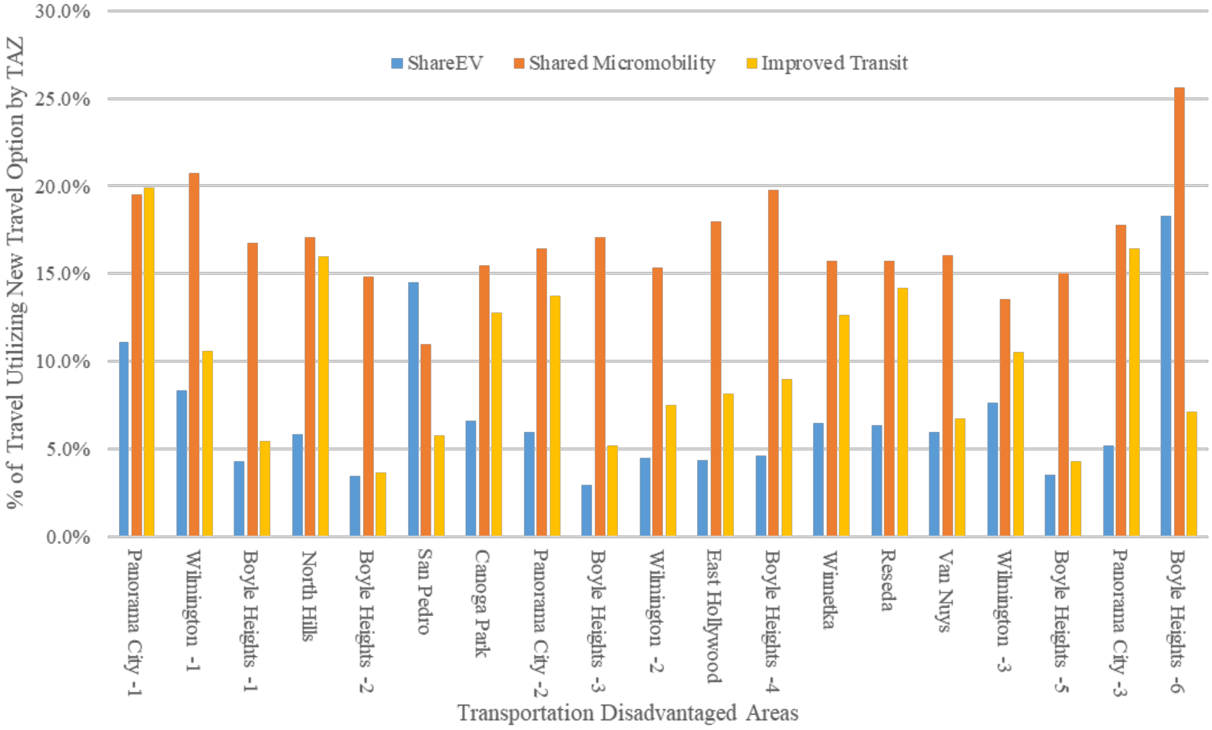

Figure 13. Percentages of DAC residents' travel using newly added travel options

Similarly, providing new travel options to DACs could help reduce the time they need to spend on transportation (Table 1). On average, improved transit reduces travel time the most (12% on average, with the highest savings reaching 30%). Shared micromobility service is the most attractive option for DACs based on consideration of cost, travel time, and accessible opportunities, although it saves the least amount of travel time due to its slower speed.

The new travel options modeled here can also help DAC residents access more destinations (e.g., restaurants, medical service, education), given that further distances can be traveled with faster travel modes in the same amount of time. As shown in Table 1, on average, improved transit services result in the greatest increase in accessible opportunities. Shared micromobility brings the least increase (0.41% on average). Different communities can benefit at different levels when provided with new travel options, which leads to a relatively high standard deviation of changes in increased opportunities. Figure 14 shows neighborhood-specific multimodal strategies for affordability, time efficiency, and access to opportunities. Detailed results can be found in the appendix section A.1.

🚲 Shared e-bike access 🚗 Shared EV access 🚌 Improved transit

Transportation Analysis Zone ID & Neighborhood	Most affordable	Most time efficient	Access to most opportunities
3718 – Panorama City	🚲	🚲	🚌
3731 – Panorama City	🚲	🚲	🚌
3734 – North Hills	🚲	🚲	🚌
3737 – Panorama City	🚲	🚲	🚌
3864 – Reseda	🚲	🚲	🚌
3866 – Canoga Park	🚗	🚲	🚗
3872 – Winnetka	🚲	🚲	🚌
3877 – Van Nuys	🚗	🚲	🚗
4067 – Boyle Heights	🚗	🚗	🚗
4105 – Boyle Heights	🚲	🚗	🚗
4111 – Boyle Heights	🚲	🚲	🚗
4114 – Boyle Heights	🚲	🚗	🚗
4115 – Boyle Heights	🚗	🚗	🚗
4150 – Boyle Heights	🚲	🚗	🚗
4335 – East Hollywood	🚗	🚲	🚗
4611 – Wilmington	🚗	🚲	🚗
4612 – Wilmington	🚗	🚲	🚗
4614 – San Pedro	🚗	🚲	🚗
4630 – Wilmington	🚗	🚲	🚗

Calculated for low-vehicle ownership, low transit access, disadvantaged communities

Figure 14. Modeling results identifying neighborhood-specific multimodal strategies for affordability, time efficiency, and access to opportunities

These modes should be given strong consideration when developing community-guided portfolios of e-mobility options.

2.2.2 Multimodal Solutions

Modeling and analysis results indicate providing optimized multimodal solutions to DACs reduces travel time and costs and improves access to DAC residents' destinations. Implementation of multimodal solutions requires associated infrastructure investments, such as bike lanes to increase safety, covered bus stops with lighting, and well-lit, accessible sidewalks to access shared micromobility options such as e-bikes and e-scooters. Such infrastructure planning and development requires collaboration across multiple city agencies.

Priority Areas for Multimodal Strategies

The map shown in Figure 4 highlights areas of the city where at least 12% of the households do not own personal vehicles, as well as existing locations of BlueLA EV car sharing vehicles. Expanding access to BlueLA and other EV car share programs can be informed by the relative rates of vehicle ownership, as shown in Figure A-7 (appendix); for example, the top quintile where more than 18% of households are zero-vehicle households. Some areas with low vehicle ownership that do not currently have BlueLA vehicles include the Watts, Wilmington, and Boyle Heights neighborhoods.

Forthcoming e-bike incentives from the California Air Resources Board of $1,000 for regular e-bikes, and up to $1,750 for cargo or adaptive e-bikes, will be limited to households with incomes at or below 300% of the federal poverty level (FPL). Households at less than 225% of the FPL are eligible for an extra $250. The total budget is about $10 million, with an estimated 7,000 incentives provided. The expectation is that there will be far more demand for e-bike incentives than what this initial round of funding can provide, similar to what has been seen in other locations, such as Denver, Colorado,[5] where the January 2023 rebates were claimed within 20 minutes.[6] Initial insights from the Denver e-bike rebate program, where 67% of funds went to income-qualified residents and 30% of recipients surveyed were new bike riders, estimate about 1 lb carbon dioxide equivalent (CO_2e) saved per year per dollar invested.[7]

Figure 15 shows the census block groups in Los Angeles where the median household income is at or below 300% FPL and therefore most households would be eligible for the California Air Resources Board e-bike incentive. This amounts to 49% of the city's census block groups, shown in red and yellow on the map. Out of these areas, fewer than one-half of the census block groups are within 1,000 feet of existing bike infrastructure (based on census block group centroid). Therefore, light green areas on the map are where more than half of households are eligible for the e-bike incentive but most do not have nearby access to bike infrastructure. In addition, some existing Metro Bike stations are not within 1,000 feet of existing bike infrastructure. Without access to safe and convenient routes for riding bicycles, the full potential benefit of prospective mode shift described in Section 2.2.3 (Table 2) will be unrealized. This is especially noticeable in the Hollywood and East Hollywood neighborhoods. Note that demand for other existing e-bike incentives far exceeds supply. For example, Denver's rebates have consistently been claimed within minutes each time a new round is available[8].

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[5] "Electric Bikes (E-Bikes)," City and County of Denver, denvergov.org/Government/Agencies-Departments-Offices/Agencies-Departments-Offices-Directory/Climate-Action-Sustainability-Resiliency/Sustainable-Transportation/Electric-Bikes-E-Bikes-Rebates

[6] "Denver's Latest Round of Electric Bike Rebates Were GONE in 20 minutes," Micah Toll, electrek, February 8 2023, electrek.co/2023/02/08/denvers-electric-bike-rebates-gone-in-20-minutes/.

[7] "8 New Insights From Denver's EBike Incentive Program ," Nelle R. Pierson, Ride Report, March 7, 2023, www.ridereport.com/blog/ebike-inventive-programs.

[8] "The Latest Round of e-Bike Rebates Ran Out Fast Again," Rebecca Tauber, *Denverite*, January 31, 2023, https://denverite.com/2023/01/31/the-latest-round-of-e-bike-rebates-ran-out-fast-again/.

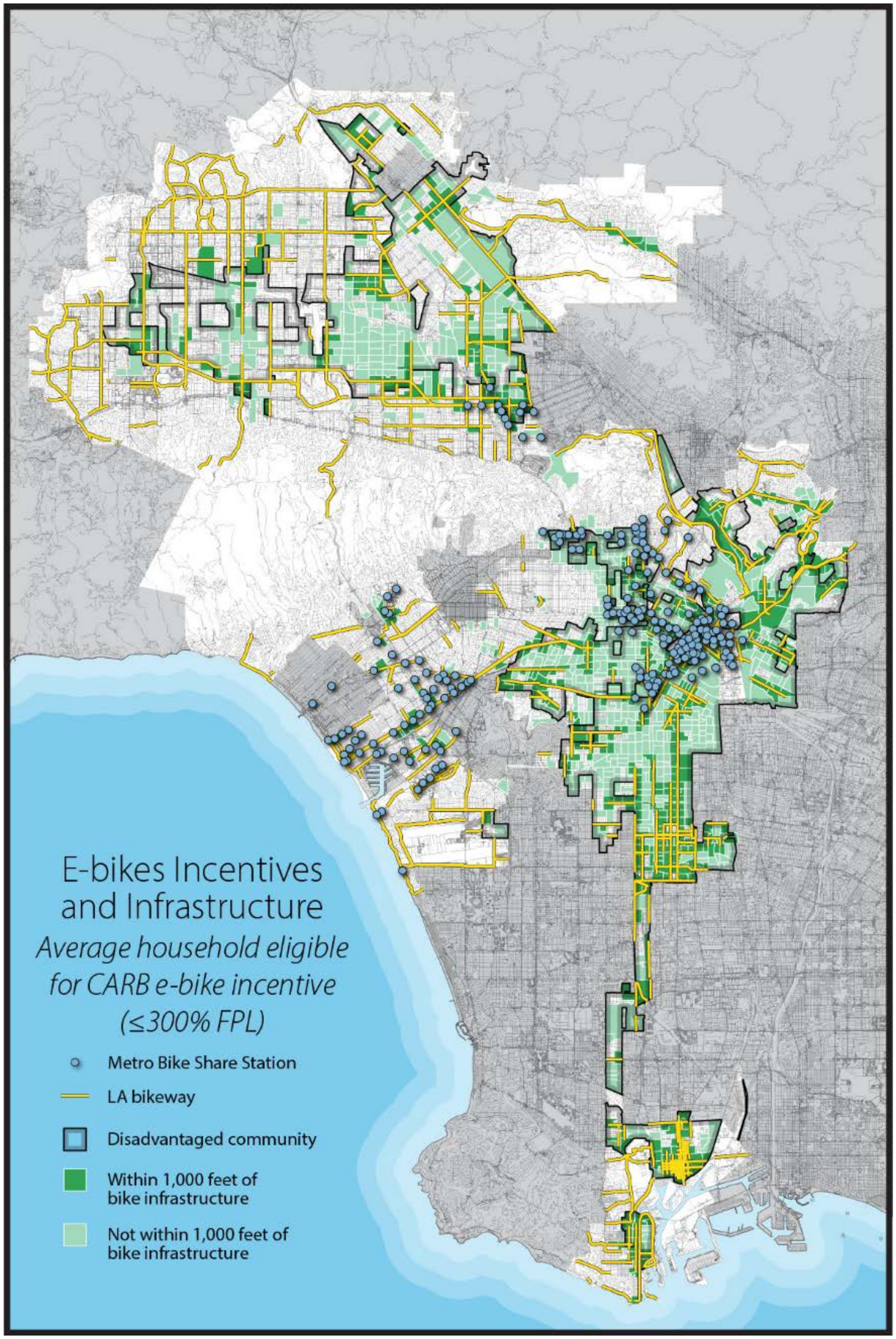

Figure 15. Existing bike infrastructure (bike paths and lanes) relative to areas of the city where the most households will be eligible for the forthcoming California Air Resources Board e-bike incentive (income less than 300% FPL)

Map uses American Community Survey 2015–2019 household income and 2019 FPL

2.2.3 The Case for Incentivizing Multimodal Transportation Electrification

In tandem with other literature and evidence, modeling results demonstrate at least four ways that investments in expanding access to multimodal transportation electrification can address transportation equity and make measurable progress on city goals. The primary metrics discussed above in the context of transportation equity are cost savings and the number of opportunities accessible by different modes. The primary metrics discussed below in terms of city goals are vehicle miles traveled (VMT) reduction and reduction in CO_2e emissions.

The March 2023 report on Denver's e-bike incentive program provides detailed insights on program design, implementation, and evaluation metrics. See the sidebar[9] for highlights of the program's success.

This analysis includes all trips originating in Los Angeles for an average weekday that are less than 35 miles one-way, with total miles traveled of 59,000,000. Thirty-five miles was used as the one-way trip distance threshold, as it encompasses approximately 99% of daily trips originating inside the city limits. That total is used as the denominator for the VMT reduction analysis that follows. Approximately 60% of those daily trips were modeled and evaluated in the mode shift baseline and equity scenario analysis, and the mode shift potential of the remaining trips was estimated through a linear regression using trip distance and a per mile mode shift conversion factor derived from the modeled trips. More detailed methods and results can be found in the appendix section A.1 Multimodal Solutions.

Denver's E-Bike Program

- 67% of funding and 49% of vouchers went to income-qualified residents.
- Operational emissions: e-bikes emit 3% of the CO_2e emissions as EVs and 1% of internal combustion engine vehicles.
- Per dollar spent, 0.94 lb of CO_2e was avoided, for a per-year total of 2,040 metric tons

Surveyed participants

- Ride an average of 26 miles per week, replacing about 7 vehicle trips.
- Use their gas vehicles less often (71% of respondents).
- Are new bike riders (29%).
- Use their e-bikes nearly 50% more than others if they are income-qualified residents.

Implications for LA

LA100 Equity Strategies modeling results suggest broad e-bike access could result in:

- Up to 4.7% reduction in total VMT/year
- Up to 316,000 tons reduced in CO_2e/year.
- Up to 187 GWh/year reduction in electricity demand compared to EV trips

Table 2 is split into three sections showing metrics on VMT, CO_2e emissions, and electricity demand for existing baseline trips, the modeled modes, and the combined impact of the two. CO_2e and electricity estimates for transit were not included due to high variability in potential emissions and electricity impact based on vehicle type, occupancy, and variable lifecycle emissions.

The first section of the table shows metrics from the perspective of avoided VMT, CO_{2e}, and GWh given the baseline rates of walking/bike and existing transit service use compared to if

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[9] Information on Denver's e-bike rebate program is from the March 2023 report *Denver's 2022 Ebike Incentive Program: Results and Recommendations* (City and County of Denver et al. 2023).

these same trips were done driving alone. In other words, these avoided impacts indicate the significance of preserving existing walk/bike/transit trips, in addition to the value of shifting existing vehicle trips to other modes. The middle section of the table uses modeling results to show metrics for trips that are taken by providing expanded access to shared e-bikes and improved transit service. These two modes are used to estimate reduction potential for the metrics of interest when the new modes are used compared to these trips being taken in light-duty EVs driving alone. The bottom section considers the impact of both trip types together (existing non-auto modes plus potential future trips shifted to the e-bike mode).

Table 2. Vehicle Miles, Emissions, and Energy Impacts of Existing and Modeled Walk/Bike and Transit Trips, in Comparison to Driving Alone

Table figures estimate 99% of trips in Los Angles that were included in the mode choice modeling and the results are for an average weekday. Results are rounded.

Metrics for Existing (Baseline) Non-Driving Modes		
Daily Impacts (relative to light-duty vehicles)	**Baseline Walk/Bike Trips**	**Baseline Transit Trips**
Private light-duty VMT avoided	2,000,000	6,600,000
CO_2e avoided by existing modes (tons) (compared to light-duty EV)	280[c]	N/A
CO_2e avoided by existing modes (tons) (compared to ICEV)	440[c]	N/A
MWh avoided by existing modes (compared to light-duty EV)	580[a]	N/A
Metrics for Future, New, Non-Driving Modes (modeled)		
Daily Impacts (relative to light-duty vehicles)	**Trips Switched to Shared E-Bike**	**Trips Switched to Improved Transit**
VMT reduced (miles) (compared to baseline driving VMT)	2,800,000	12,000,000
VMT reduced (%)	4.7%	20%
CO_2e reduced (tons) (compared to light-duty EV)	200[a]	N/A
CO_2e reduced (tons) (compared to ICEV)	1,300[b]	N/A
MWh reduced (compared to light-duty EV)	780[a]	N/A

Metrics for Existing (Baseline) Non-Driving Modes	
Daily and Annual Metrics for Both New E-Bike Mode and Existing Non-Driving Modes	
Total Daily VMT avoided (by existing modes) and reduced (by e-bike mode)	11,400,000 miles/day
Total Daily MWh avoided (by existing walk/bike modes) and reduced (by e-bike mode) (compared to LD EV)	1,400 MWh/day
Total annual VMT avoided (by existing modes) and reduced (by new e-bike mode) [weekdays only, 48 weeks per year]	2,700,000,000 miles/year (weekdays)
Total annual MWh avoided (by existing walk/bike modes) and reduced (by e-bike mode) (compared to LD EV) [weekdays only, 48 weeks per year]	330,000 MWh/year (weekdays)

[a] Lent and Lutzker, 2019

[b] Metro Bike Share CO_{2e} estimate: https://bikeshare.metro.net/about/data/

[c] MIT Energy Initiative, 2019

2.2.4 Energy Demand Impacts

The multimodal analysis provides information on how future mode shifts may impact peak electricity demand. To investigate peak demand impacts, we used the hourly data from sub-meters that received a rebate from LADWP for time-of-use metering for EV charging infrastructure. While only 36 addresses had 2019–2022 hourly data, several patterns emerged. The following observations and conclusions were drawn from the data of the 36 locations; however, this small sample size means the conclusions may not be representative. Hourly data was used to enable consideration of shifting designated low and high peak periods. Charging during LADWP's high peak hours (1 p.m.–5 p.m.) for these sub-meters is largely concentrated in the downtown area, while overnight charging hours occur more in the periphery. This geographic distinction is largely associated with commercial customers located downtown and residential customers in the periphery (shown in Figure 16, as red dots and yellow dots, respectively).

We analyzed residential and commercial customer charging across 4 years (2019–2022) for patterns in charging during high peak, low peak (10 a.m.–1 p.m. and 5 p.m.–8 p.m.), overnight (8 p.m.–6 a.m.), and other (6 a.m.–10 a.m.) hours (Figure 16 and Figure A-9). Nearly 20% of total EV charging analyzed takes place during low or high peak periods, except in 2021. Residential sub-meters charge overnight more than 70% of the time, while commercial customers charge overnight around 40% of the time. Apartments had the lowest peak charging of the commercial or multifamily chargers analyzed, indicating increased at-home or near-home EV charging infrastructure for multifamily residents and renters will likely not increase peak demand, at least while EV ownership remains relatively low among these residents. For the eight locations that host BlueLA EV car sharing vehicles (Figure A-10 in the appendix), approximately 50% of charging in 2021 and 2022 occurred overnight, and about 22% of charging occurring during peak hours. Note that for this data set, all charging was reported during the end hour of the charging event.

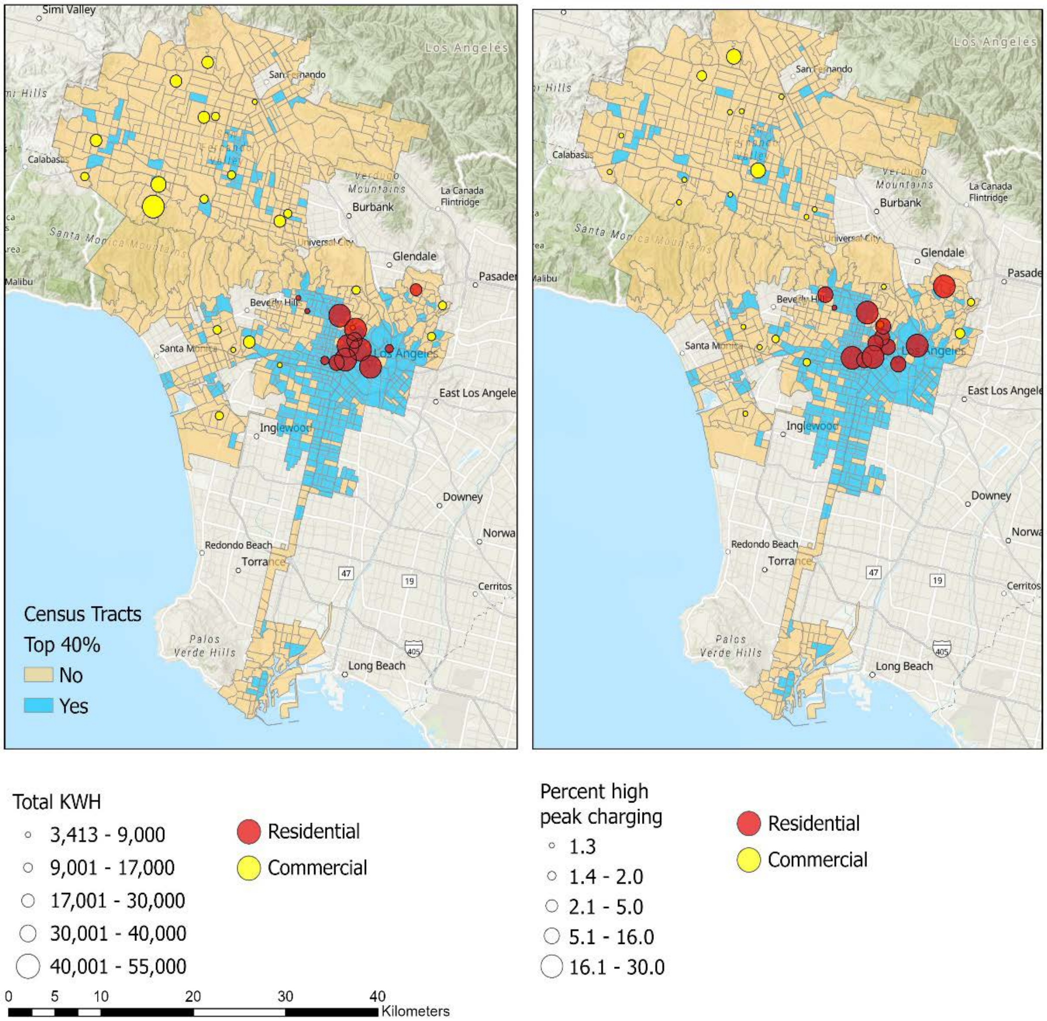

Figure 16. Time-of-use EV charging infrastructure sub-meter analysis (2019–2022)

In both maps, commercial meters are in red and residential meters in yellow, and both show whether each tract is in the top 40% of zero-vehicle households. The map on the left shows total kWh used at each sub-meter and the map on the right shows the percentage of kWh at each sub-meter used during the LADWP peak (1 p.m.–5 p.m.).

Base map source: Esri

3 Equity Strategies Discussion

Modeling, analysis, and community engagement identified the following strategies for achieving more equitable outcomes in the distribution of benefits and burdens in the LA transition to clean energy and electrified transportation. Strategies are organized by community guidance theme.

Tailor LADWP Incentives and Outreach to Meet Community Needs

- **Increase the LADWP low-income used EV incentive from $2,500 to $4,000 and establish a purchase price cap of $25,000 for incentive eligibility. Consider making low-speed EVs eligible for the rebate.** Vehicle adoption modeling indicates by 2035 in a Business-as-Usual case, the majority of predicted used EV consumers are households that make less than $75,000 per year. Increasing used EV rebates for low-income households by 60% from the current $2,500 to $4,000 could result in a 2% increase in used EV adoption among low-income households in Los Angeles by 2035, an increase of approximately 50,000 vehicles. Used, standard EV model purchase and use results in an estimated 2% reduction in total household expenditures. Modeling indicates high-income groups would not change their EV purchase behavior because of this modeled change in used EV rebates. Low-speed electric vehicles are available at a much lower price point (~$10,000[10]). Any consideration of removal of the existing 8 year model limit for used EV incentives should account for community concerns about the remaining useful life of batteries in older EVs and associated potential risks to low-income consumers.
- **Shift from delayed rebates to a point-of-sale discount.** This approach, consistent with the Inflation Reduction Act, allows car buyers to transfer the credit to dealers at the point of sale to directly reduce the purchase price (U.S. Department of the Treasury 2022).
- **Offer an incentive to test-drive EVs or ride e-bikes to low- and moderate-income households and households in communities that received disproportionately fewer LADWP EV incentives.** Pair this with education about the technology. For example, for e-bikes: educate consumers on how to ride, how to get a helmet, how and where to charge, how to keep bike safe from theft, and available adaptive e-bike options. Partner with e-mobility or advocacy groups to do this outreach, test rides, etc. Technology exposure can lead to increased interest and confidence in adoption. Set an incentive amount per participant (e.g., the Orlando, Florida utility offers a $50 gift card for electric car test drives and survey completion[11]).
- **Partner for used EV battery testing or certification.** Battery life can be an equity issue for used EV consumers. The city could develop a partnership with vehicle dealerships to test used EV batteries and replace them if needed, to prevent purchase of vehicles with low

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[10] "Low-Cost Tiny Electric Cars Like These Could Be the Next Big Thing," Micah Toll, electrek, January 23, 2023, https://electrek.co/2023/01/23/low-cost-tiny-electric-cars-lsv-nev/

[11] "Electric Vehicles & Charging," Orlando Utilities Commission, https://www.ouc.com/residential/save-energy-water-money/electric-vehicles

battery life. The city could also partner on a certified used EV program and service technician training programs.

- **Partner with community-based organizations to fund and staff networks of educators to target outreach to DACs, renters, and multifamily residents about incentives and low-barrier financing options (e.g., for those with low/no credit), and to co-design or refine those incentives with them.** Community-based organizations will be most effective if they can work across LADWP and city agencies including transportation, mobility, and parking; housing; planning and community development; and public works.
- **Conduct e-bike outreach and education paired with test rides and drives.** Provide detailed information on incentives, safe bike routes, where public charging is available, how to charge, how to secure the bike, and how to avoid battery fires.
- **Consider electrification incentives for taxi and ride-hailing services**. While large ride-hailing platforms (i.e., Lyft and Uber) are on a state-mandated timeline to electrify, incentives could encourage others to electrify.
- Create an incentive for use of EV technician training or infrastructure training participants in DAC neighborhoods.
- **Partner with other agencies on their statewide e-bike rebate data collection.** The California Air Resources Board has an e-bike rebate program. The implementer, Pedal Ahead, is partnering with the University of California, Davis to study and understand the effectiveness of the e-bike rebate program. The University of California, Davis will be using an NREL tool, OpenPath, to track energy and behavior impacts of the incentives. LADWP and the City of Los Angeles can partner to learn more about the impacts of e-bikes or provide incentives for participation. That information can be used to inform the rollout of local incentives. Out of a population of 10,000 (estimated range of statewide incentives), a sample size of about 400 across demographic groups would be considered representative.

Expand Accessible Electric Mobility Infrastructure

- **Expand at- or near-home charging access for renters and multifamily residents to enable more equitable access to and use of EVs. Include 120V outlets at all charging stations. Include a list of co-benefits that might be included with the installation. Prioritize charging infrastructure development in DACs in charging deserts with a high prevalence of multifamily buildings, including Boyle Heights, South LA, San Pedro, Crenshaw, Canoga Park, Winnetka, and Sylmar.** About 45% of LA households that make less than $75,000 a year and are predicted to be used EV consumers live in rented properties and/or multifamily homes. About 50% of those predicted EV consumers living in multifamily buildings will not have access to power outlets near where their vehicles park. Additionally, current public charging availability is found to be lower in predominantly Hispanic communities compared to predominantly non-Hispanic communities. The high potential for used EV adoption among less-than-median-income households may be at risk if home or near-home charging is not available. Making charging available to renters and multifamily residents will require overcoming barriers to home charging (lack of dedicated off-street parking for multifamily dwellings, upfront cost of home charging, and lack of actionable information for property owners) as well as to public charging (unclear payback for installing and maintaining public chargers, cost of using public chargers, unclear price structures, and need for cash payment options). LADWP can build on its existing efforts in neighborhoods like Crenshaw, where LADWP installed chargers at its Crenshaw Customer Service Center, available to motorists at no cost (LADWP 2019). LADWP utility poles in public rights-of-way in existing on-street parking areas can also be used to offer low-cost, scalable, and equitable access to overnight charging. *LADWP can leverage EV infrastructure investments to benefit multiple modes by include 120V outlets at each charging station. Offering other co-benefits, such as sidewalk improvements, crosswalk enhancements, benches, or other amenities can increase the number of residents who benefit from the infrastructure.* These plugs can serve low-speed electric vehicles, e-bikes, etc. This program will require partnership between the local government and LADWP to own, operate, and maintain Level 2 chargers (with 120V outlets) in dedicated on-street EV-charging-only spaces, using an approved tariff designed to be comparable to the cost of home charging.

- **Provide vouchers or charging subscriptions for public EV charging infrastructure for low-income households, especially those without home charging access.** While modeling finds adopting EVs decreases fuel cost burdens, not having home charging access can lead to a 1% increase in fuel cost burden compared to homes with charging access, equivalent to about $300 a year. That incrementally higher cost of public charging means that access to home charging (or access to public charging for a similar cost to home charging) is likely to influence used EV adoption, as lower-income households are especially sensitive to price differences.
- **Develop charging installation and infrastructure upgrade incentives for locations that are "near-home" for households without home charging access.** Acknowledging that installing charging infrastructure in all neighborhoods may be a long-term process, in the short term, the City of Los Angeles could focus on programs and incentives that increase workplace charging or interstate fast charging, which may have lower barriers and may increase equitable access to charging (see Box 4 of Kneeland et al. [2020]).
- **Create a program for EV readiness audits by trusted partners in designated neighborhoods.** Use the promotora model with trusted partners to help households identify underlying barriers to home charging access (e.g., new panel, higher service rating, running new circuit) and inform residents of federal funds to cover costs.
- **Develop EV-ready building codes and incentives to address EV charging infrastructure barriers (e.g., panel upgrades, service ratings, circuits) to make households EV-ready.** This strategy could be paired with workforce training for electricians to make electrical upgrades and monitor, operate, and maintain charging infrastructure. One such example is the Electric Vehicle Infrastructure Training Program.[12]
- **Incentivize employers to provide secure e-bike parking and charging.** Enabling employees to safely store and charge e-bikes at work can encourage more individuals to

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[12] https://evitp.org/

commute by bicycle or other small electric mobility options. Employers who provide the amenity could receive an incentive from the city or utility.

Expand E-Mobility Options

- **Design a community-guided portfolio of electrified transportation options, including EV car share, e-bike, and e-scooter programs, that best serve the needs of each of the 19 neighborhoods identified as the most transportation disadvantaged and other priority areas identified by the city and communities, including the Boyle Heights, Wilmington, and Panorama City neighborhoods.** Recognizing that in LA disadvantaged communities, 16% of households do not have vehicles (compared to 11% citywide) and cannot be expected to purchase EVs in the near term, equitable transportation electrification requires extending the distribution of benefits to these households as well. Modeling shows the benefits of travel time and cost savings differ across e-bike, improved transit, and EV car share modes depending on the neighborhood. Shared e-bikes provided the highest travel time and cost savings for Panorama City, North Hills, Reseda, Winnetka, and in some parts of Boyle Heights. EV car share provided the most affordable, time efficient, and increased access to destinations in other parts of Boyle Heights and the most affordable and opportunity access in Canoga Park, East Hollywood, Wilmington, and San Pedro. Improved transit service mostly could help increase the opportunity access for Panorama City, Winnetka, and North Hills. Adding electrified multimodal electric travel options could cover up to 26% of travel demand in some of these communities. Ultimately, providing transportation choices for residents allows individuals and families to pick the best mode for different trip types or purposes. The Los Angeles Department of Transportation's implementation of a Universal Basic Mobility Pilot in South LA[13] since 2022, in partnership with LADWP and others, is an excellent example of providing such choices.
- **Expand community-guided multimodal shared programs to transportation disadvantaged communities citywide.** While homeowners can invest in home chargers, renters must rely on building owners, employers, or public chargers. As a result, EV ownership is low among renters. In Los Angeles, many low-income residents have had to relocate to less central areas of the city where housing is more affordable, yet vehicle ownership is often necessary due to a lack of convenient, safe, and efficient alternatives, such as rapid transit and dedicated bicycle infrastructure. Expanding multimodal opportunities citywide will help address this gap. Equitable access to and use of such programs will require enabling payment options for residents who rely on cash and do not own smartphones.
- **Establish a personally owned e-bike incentive.** In the United States, approximately 100 million bicycles are privately owned, far surpassing shared micromobility vehicles (232,000 in total, including e-bikes). Additionally, e-bikes are currently outselling electric cars (2022 sales were estimated at 800,000 electric cars and 1 million e-bikes). Therefore,

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[13] "LADOT Launches Universal Basic Mobility Pilot," City of Los Angeles Department of Transportation, April 26, 2022, https://ladot.lacity.org/dotnews/ladot-launches-universal-basic-mobility-pilot; https://ladot.lacity.org/ubm#about

incentives for personally owned e-bikes are likely to be important for cost and time savings, increased access to destinations, and wider adoption by multimodal users. LADWP incentives should be stackable with federal, state, and other local incentives. Successful implementation will require secure storage with charging near transit locations.

- **Pair e-bike incentives with the expansion of safe and accessible bike infrastructure and safe charging options at home or away from home.** When e-bikes are an option, they are the top choice for many of these communities. However, many of these same communities lack bike infrastructure, such as protected bike lanes, to make this mode choice a safe one. Community engagement also highlighted the critical nature of safety, including street lighting, shaded transit stops, and safe pedestrian access, in making e-bikes, e-scooters, and EV car sharing accessible. Creation of dedicated infrastructure for safe travel by different modes is an essential element of a multimodal system. While not considered in all elements of the multimodal modeling work, this topic was highlighted during the community engagement. For example, one community member shared their experience: "I used to ride my bike until I was run off the road. So it's not a safe mode of transportation in LA. The roads from my house [in East LA] to my work areas are beat up and they don't fix them. So there's no real reliable bicycle lanes, so I stopped."
- **Consider vehicle incentives for low-speed EVs or neighborhood EVs.** Low-speed and/or neighborhood EVs are energy efficient and much lower in cost.
- **Consider discounted or free charging for taxi and ride-hailing vehicles in DAC neighborhoods**. A large portion of taxi or ride-hailing drivers come from DACs. Providing discounted or free charging for taxi and ride-hailing vehicles can both reduce operational costs for these drivers and help facilitate fleet electrification. Discounted and free charging can also attract more taxis and ride-hailing vehicles to serve DACs.

Strategies and Associated Metrics

For strategies that were quantified in this analysis, Table 3 summarizes the expected benefit and cost, the timeline for implementation (short or long term), the party responsible for implementing the strategy, and metrics for measuring the success of the strategy.

Table 3. Equity Strategy Options: Benefit, Cost, Timeline, Responsible Party, and Metric for Evaluation

Equity Strategy	Benefit/Impact	Cost	Timeline	Responsible Party	Metric
Community Guidance Theme: Tailor Incentives					
Increase the LADWP low-income used EV incentive from $2,500 to $4,000 and establish a purchase price cap of $25,000 for incentive eligibility. Establish e-bike and electric low-speed vehicle rebates.	Increasing low-income used EV rebates could result in 50,000 more vehicles adopted among low-income households by 2035. Low-speed EVs are available at a much lower price point.	$6.2 million/yr. May be offset by $25,000 purchase price cap	2024–2035	LADWP	Incentive uptake of 4,200 low-income households per year for 12 years
Shift from delayed rebates to a point-of-sale discount	A point-of-purchase price discount will shift some administrative burden off the customer and lower credit and loan qualification barriers.	Neutral	2024–2035	LADWP and local car dealerships	Number of participating dealerships in the city. Incentive uptake of 4,200 low-income households per year for 12 years
Offer an incentive to test-drive EVs or test-ride e-bikes to low- and moderate-income households and households in communities that received disproportionately fewer LADWP EV incentives	Technology exposure can lead to increased interest and confidence in adoption.	$50 per participant	2024–2026	LADWP	Number of ride and drive event participants from DACs and/or identifying as LMI.
Partner for used EV battery testing or certification	Prevent purchase of vehicles with low battery life	Unknown	2024–2028	City, vehicle dealerships, EV maintenance providers	Number of used EVs tested and/or certified

Equity Strategy	Benefit/Impact	Cost	Timeline	Responsible Party	Metric
Community Guidance Theme: Expand Infrastructure Access					
Expand at- and near-home charging access for renters and multifamily residents to enable more equitable access to and use of EVs. Include 120V outlets at all stations for use by smaller EVs.	Apply the LADWP $5,000 Level 2 charging station in DACs rebate and other incentives to achieve 50,000 chargers by 2035 to meet charging needs of the projected 340,000 home charger orphans in DACs. Support Level 1 charging (120V outlet) access at workplaces and public locations, specifically for PHEVs, low-speed EVs, e-bikes, and other smaller electric mobility.	$22 million/yr through 2035 $260 million total	2024–2035	LADWP, private sector, property managers, EV car share programs	50,000 chargers by 2035, 4,200 chargers/year in predicted low-income EV adopter areas with low charging access. Two charging ports/location. Rebates calculated by: 70% Level 2 in DACs: 20% Level 2 non-DAC: 10% direct current fast charger (DCFC)
Provide vouchers or charging subscriptions for public EV charging infrastructure for low-income households, especially those without home charging access	Public charging costs approximately $300/year more than home charging in Los Angeles. Consider LADWP's desired locations and times for L2 and DCFC charging demand and adjust incentives accordingly.	$1.7 million/yr through 2035	2024–2035	LADWP, private sector, property managers, EV car share programs	Provide each low-income used EV incentive recipient with $300/year EV charging infrastructure voucher

Equity Strategy	Benefit/Impact	Cost	Timeline	Responsible Party	Metric
Community Guidance Theme: Expand Mobility Options					
Partner to establish community-guided EV car share, e-bike, and e-scooter shared programs that best serve the 19 neighborhoods identified as the most transportation disadvantaged	Grants for program establishment and e-bike and e-scooter purchase. Support with EV charging infrastructure rebates of $5,000 for Level 2 in DACs.	See universal basic mobility pilot in South LA (LADOT) costs[14]	2024–2026	LADOT, LADWP, (rebates), private sector (mobility as a service)	Apply the DAC EV charging infrastructure rebate for each installed charger for the program
Expand community-guided multimodal shared programs to transportation disadvantaged communities citywide	Grants for program establishment and e-bike and e-scooter purchase. Support with EV charging infrastructure rebates of $5,000 for Level 2 carshare chargers in DACs.	See universal basic mobility pilot in South LA (LADOT) costs	2026–2030	LADOT, LADWP, (rebates), private sector (mobility as a service)	Apply the DAC EV charging infrastructure rebate for each installed charger for the program
Establish a personally owned e-bike incentive program	Stackable with CA state incentive and prospective federal incentive.	CARB $13 million 2023 budget will fund 4,000–7,000 rebates. Denver provided 4,734 rebates in 2022 with $4.7 million.	2024– 2035	LADWP	Number of participants; VMT reduction brought by personally owned e-bikes and associated emission reduction, travel time reduction and cost saving

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[14] "Universal Basic Mobility (UBM): South Los Angeles," https://ladot.lacity.org/ubm#about.

Equity Strategy	Benefit/Impact	Cost	Timeline	Responsible Party	Metric
Pair e-bike incentives with the expansion of safe and accessible bike infrastructure and charging options	Collaborate on charging and protected bike infrastructure planning, provide financial support for program development. Support electrification of high-volume or other strategic docking stations for shared or personal e-bikes through rebates to provide seamless recharging. Include 120V outlets at all light-duty EV charging stations, for use by smaller electric vehicles or mobility devices (e.g., low-speed vehicles and e-bikes).	Universal e-bike charging station equipment is available for $1,500 and up.[a] Chicago's Divvy bikeshare stations are being electrified but cost info is not public.	2024–2035	LADWP, LADOT, CBOs	E-bike incentive recipients within 1,000 ft of bike lanes. Opportunities include collaboration on Bipartisan Infrastructure Law Safe Streets for All (SS4A)[b] funded bike lane and charging infrastructure planning and investment

[a] Example: "Saris Infrastructure Releases Public e-Bike Charger Station," Bicycle Retailer and Industry News, June 9, 2022, https://www.bicycleretailer.com/new-products/2022/06/09/saris-infrastructure-releases-public-e-bike-charger-station

[b] "Safe Streets and Roads for All (SS4A) Grant Program," U.S. Department of Transportation, https://www.transportation.gov/grants/SS4A.

Equity strategies and the analysis of baseline equity, community guidance, and modeling results that informs them are outlined by community guidance theme in Figure 17, Figure 18, and Figure 19.

Baseline Equity	Community Solutions Guidance	Modeling & Analysis Key Findings	Equity Strategies
• 77% of LADWP EV and EV charging infrastructure incentives went to households in non-disadvantaged communities. • The $5.4 million in LADWP EV incentives disproportionately benefited predominantly White, non-Hispanic, home-owning, and wealthier neighborhoods.	• Establish culturally informed, transparent, community-tailored, and consistent outreach and communication related to LADWP transportation electrification programs. • Simplify application materials and methods for LADWP transportation-related incentives.	• By 2035, the majority of predicted used EV consumers will be households making less than $75,000 per year. • Used, standard EV model purchase and use results in an estimated 3% reduction in total household expenditures. • Increasing the LADWP low-income used EV incentive from $2,500 to $4,000 and adding a purchase price cap of $25k could result in 50,000 more used EVs adopted by low-income households by 2035. • High-income groups would not change their EV purchase behavior because of this change in used EV rebates.	• Increase the low-income used EV incentive from $2,500 to $4000 and establish a purchase price cap of $25k for incentive eligibility. • Shift from delayed rebates to point-of-sale discount. • Offer an incentive to test drive used EVs to LMI households. • Partner for used EV battery testing or certification. • Partner with CBOs to fund and staff networks of educators to target incentive and financing outreach to disadvantaged communities, renters, and multifamily residents.

Figure 17. Equity strategies for LADWP electric vehicle incentives and outreach

Equity strategies that redress distributional inequity in LADWP incentives and increase equity in vehicle electrification can include strategies to shift the used EV rebate to support affordability for lower-income customers. A price cap, informed by the EV market analysis shown in Figure 6 and/or excluding premium EV models from eligible vehicles can shift incentives toward lower-income customers. Converting from a rebate to an incentive at the purchase point managed by dealerships can further reduce cost barriers. Partnering with trusted community organizations to establish funded and staffed resource centers and educators in DACs can provide targeted technical assistance. Evaluation metrics include continued tracking of rebates by DAC and sociodemographic metrics and setting a goal and timeline for percentage of incentives provided to DACs.

Baseline Equity

- Mostly non-Hispanic communities have more charging stations than mostly Hispanic communities.

Community Solutions Guidance

- Ensure EV charging stations are located to meet daily household routines.
- Co-design and implement low-income community infrastructure for transportation electrification without adding environmental and socioeconomic burdens.
- Build inclusive charging infrastructure for charging personal EVs, shared EVs, e-bikes, and other electric options (e.g., electric public transit, low-speed EVs).

Modeling & Analysis Key Findings

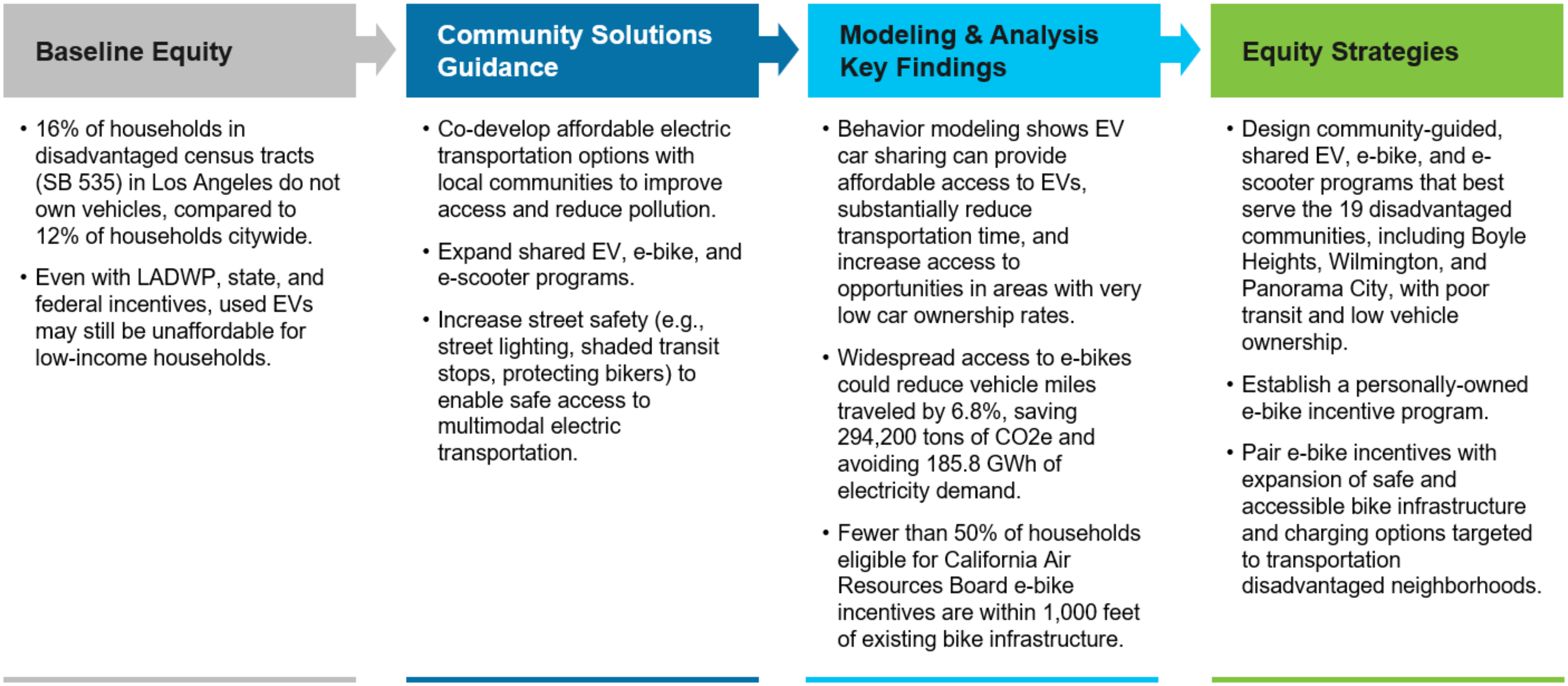
- By 2035, ~50% of potential LMI used EV consumers will be renters or live in multifamily buildings.
- 40% of households living in multifamily homes lack access to charging at or near their homes.
- Home charging is more affordable than public charging and can make the difference between used EVs increasing or decreasing expenditures for median income households.
- Commercial customers are 4-6× more likely to charge during peak hours than residential customers. Apartments had the lowest peak charging of commercial/multi-family chargers analyzed.

Equity Strategies

- Expand at- or near-home charging access for renters and multifamily residents to enable more equitable access to and use of EVs.
- Develop public, near-home charging in disadvantaged communities in charging deserts including Boyle Heights, South LA, San Pedro, Crenshaw, Canoga Park, Winnetka, and Sylmar.
- Develop publicly accessible EVSE at LADWP and other city facilities.
- Provide vouchers or charging subscriptions for low-income households relying on public EVSE.

Figure 18. Equity strategies for charging infrastructure

A focus on expanding access to affordable at-home or near-home charging for renters and multifamily residents can expand EV adoption. Evaluation and goal setting metrics include the number of DAC households receiving charging incentives and proportion of EV charging infrastructure incentives going to DAC versus non-DAC communities.



Baseline Equity

- 16% of households in disadvantaged census tracts (SB 535) in Los Angeles do not own vehicles, compared to 12% of households citywide.
- Even with LADWP, state, and federal incentives, used EVs may still be unaffordable for low-income households.

Community Solutions Guidance

- Co-develop affordable electric transportation options with local communities to improve access and reduce pollution.
- Expand shared EV, e-bike, and e-scooter programs.
- Increase street safety (e.g., street lighting, shaded transit stops, protecting bikers) to enable safe access to multimodal electric transportation.

Modeling & Analysis Key Findings

- Behavior modeling shows EV car sharing can provide affordable access to EVs, substantially reduce transportation time, and increase access to opportunities in areas with very low car ownership rates.
- Widespread access to e-bikes could reduce vehicle miles traveled by 6.8%, saving 294,200 tons of CO2e and avoiding 185.8 GWh of electricity demand.
- Fewer than 50% of households eligible for California Air Resources Board e-bike incentives are within 1,000 feet of existing bike infrastructure.

Equity Strategies

- Design community-guided, shared EV, e-bike, and e-scooter programs that best serve the 19 disadvantaged communities, including Boyle Heights, Wilmington, and Panorama City, with poor transit and low vehicle ownership.
- Establish a personally-owned e-bike incentive program.
- Pair e-bike incentives with expansion of safe and accessible bike infrastructure and charging options targeted to transportation disadvantaged neighborhoods.

Figure 19. Equity strategies for multimodal transportation electrification

Transportation electrification equity requires consideration of households without personally owned vehicles. Goal setting and evaluation metrics for expanding multimodal electrified transportation options for transportation disadvantaged neighborhoods include number of car share EVs in DACs, number of low-income e-bike incentives distributed, and number of public e-bike sharing and charging locations in DACs, with specific goals for transportation disadvantaged communities.

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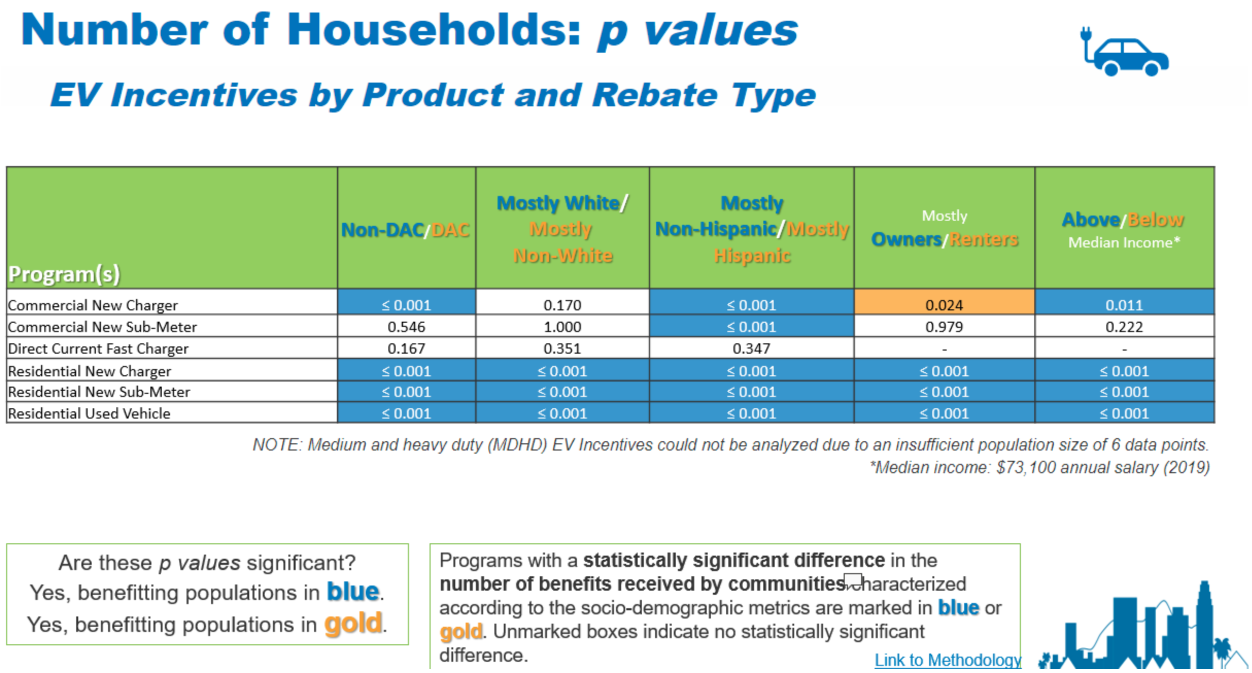
Appendix. Transportation Modeling and Analysis: Supplementary Methodology and Results

A.1 Detailed Methods and Additional Results

Baseline Equity Analysis

The baseline equity analysis presented in the Chapter 10: Household Transportation Electrification Executive Summary included a breakdown of statistical significance of incentive investments by program type (Figure A-1, Figure A-2, and Table A-1). These show that distribution of residential chargers and used vehicle spending amounts are similar, both by number of households (Figure A-1) and by dollars spent (Figure A-2).



Number of Households: *p values*

EV Incentives by Product and Rebate Type

Program(s)	Non-DAC/DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/Mostly Hispanic	Mostly Owners/Renters	Above/Below Median Income*
Commercial New Charger	≤ 0.001	0.170	≤ 0.001	0.024	0.011
Commercial New Sub-Meter	0.546	1.000	≤ 0.001	0.979	0.222
Direct Current Fast Charger	0.167	0.351	0.347	-	-
Residential New Charger	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001
Residential New Sub-Meter	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001
Residential Used Vehicle	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001

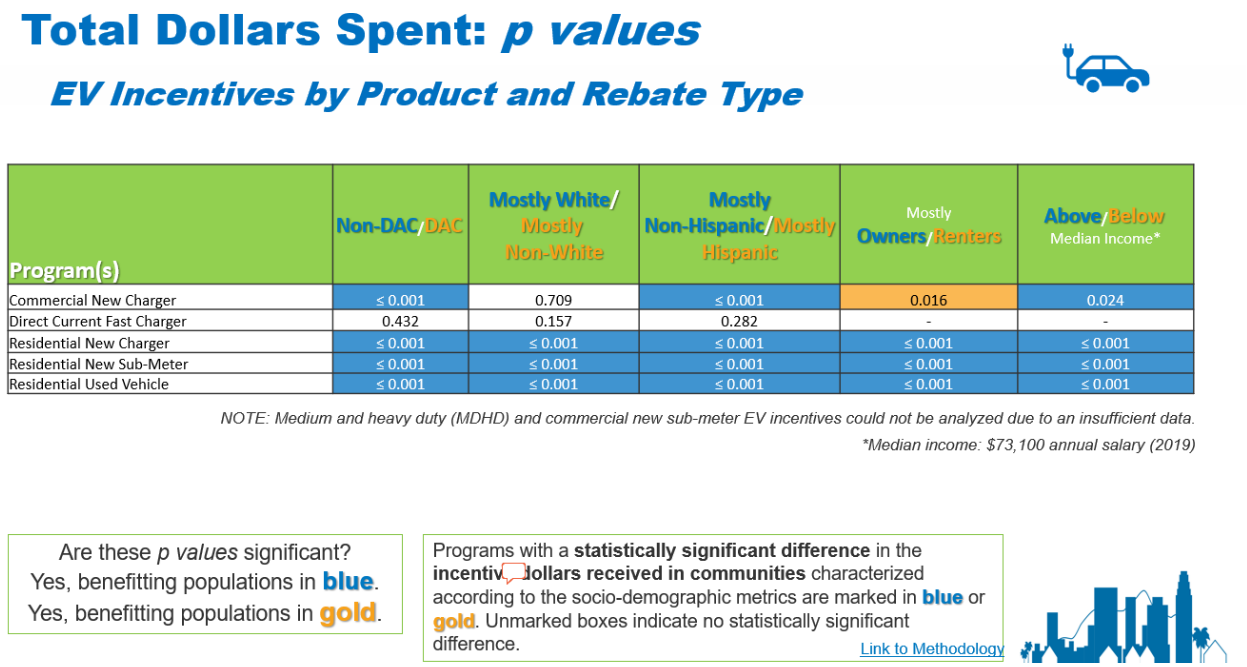
NOTE: Medium and heavy duty (MDHD) EV Incentives could not be analyzed due to an insufficient population size of 6 data points.
**Median income: $73,100 annual salary (2019)*

Are these *p values* significant?
Yes, benefitting populations in **blue**.
Yes, benefitting populations in **gold**.

Programs with a **statistically significant difference** in the **number of benefits received by communities** characterized according to the socio-demographic metrics are marked in **blue** or **gold**. Unmarked boxes indicate no statistically significant difference.

Link to Methodology

Figure A-1. Number of LADWP EV related incentives by program, in areas of the city with various indicators of advantage versus disadvantage



Total Dollars Spent: *p values*

EV Incentives by Product and Rebate Type

Program(s)	Non-DAC/DAC	Mostly White/ Mostly Non-White	Mostly Non-Hispanic/Mostly Hispanic	Mostly Owners/Renters	Above/Below Median Income*
Commercial New Charger	≤ 0.001	0.709	≤ 0.001	0.016	0.024
Direct Current Fast Charger	0.432	0.157	0.282	-	-
Residential New Charger	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001
Residential New Sub-Meter	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001
Residential Used Vehicle	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001	≤ 0.001

NOTE: Medium and heavy duty (MDHD) and commercial new sub-meter EV incentives could not be analyzed due to an insufficient data.

**Median income: $73,100 annual salary (2019)*

Are these *p values* significant?
Yes, benefitting populations in **blue**.
Yes, benefitting populations in **gold**.

Programs with a **statistically significant difference** in the **incentive dollars received in communities** characterized according to the socio-demographic metrics are marked in **blue** or **gold**. Unmarked boxes indicate no statistically significant difference.

Link to Methodology

Figure A-2. Dollar value of LADWP EV related incentives by program, in areas of the city with various indicators of advantage versus disadvantage

Table A-1. Characteristics of EV related LADWP incentives (2013-2021)

Program Name	Used in This Analysis?	Years	Number of Unique Locations	Total Number of Records	Total Dollars	Customer Sector	Description	Notes
Electric Vehicle Incentives	X	2013-2021	6,910	987	$63,647,945	Commercial	Commercial New Charger	Rebate
	X			339	*no data*	Commercial	Commercial New Sub-Meter	Rebate
				6	$430,000	Commercial	MDHD	Insufficient population size of 6 data points.
	X			14	$1,800,000	Commercial	DCFC	Rebate
	X			5,678	$3,017,576	Residential	Residential New Charger	Rebate
	X			374	$92,500	Residential	Residential New Sub-Meter	Rebate
	X			1,967	$2,251,350	Residential	Residential Used Vehicle	Rebate

Evolution of Levelized Cost of Driving for EVs

In addition to household expenditure analysis, this study also evaluated levelized cost of driving for EVs in comparison with conventional internal combustion engine vehicles (ICEVs). For levelized cost of driving ($/mile) estimation, this analysis considered the manufacturer's suggested retail price by model year and costs associated with financing, tax and fees, fuel, insurance, maintenance, and repair. The manufacturer's suggested retail price was estimated by ADOPT (NREL 2022a). Historical motor gasoline price was assumed to be between $3.5/gallon and $5.5/gallon (Los Angeles Almanac 2022; AAA 2023), of which future price evolution was based on EIA projections (EIA 2023). Electricity fuel price for home charging was assumed to be between $0.19/kWh and $0.31/kWh (LADWP 2023; NREL 2022b), of which future evolution was based on EIA projections (EIA 2023). Charging costs paid by EV drivers in public charging stations were assumed to be between $0.27/kWh and $0.49/kWh (NREL 2022b). Vehicular energy efficiency (miles/gallon for gasoline cars, and kWh/mile for electric vehicles) was based on NREL's Transportation Decarbonization Analysis project (NREL 2023). A discount rate for 15 years of vehicle lifetime was assumed to be 5% (Lee et al. 2013). Other cost parameters related to financing, tax and fees, insurance, maintenance, and repair are based on (Burnham et al. 2021).

EV adoption in Los Angeles will be dominated by BEVs rather than PHEVs. For that reason, levelized cost of driving analysis here is focused on BEV versus ICEV. In this study, levelized cost of driving includes vehicle purchase (without rebates), maintenance, repair, insurance, financing, taxes and fees, and fuel costs over the vehicle lifetime of 15 years. Also, note that levelized cost of driving values in this analysis are based on sales-weighted aggregation of all new light-duty vehicles for each model year. As shown in Figure A-4, the levelized cost of driving of BEVs is currently higher, compared to ICEVs. However, BEV is expected to achieve levelized cost of driving parity with ICEVs in around 2025. For model year 2035 new BEVs, LCOD is estimated to be 8%–12% lower in comparison with ICEV counterparts, depending on whether home charging access is available or not.

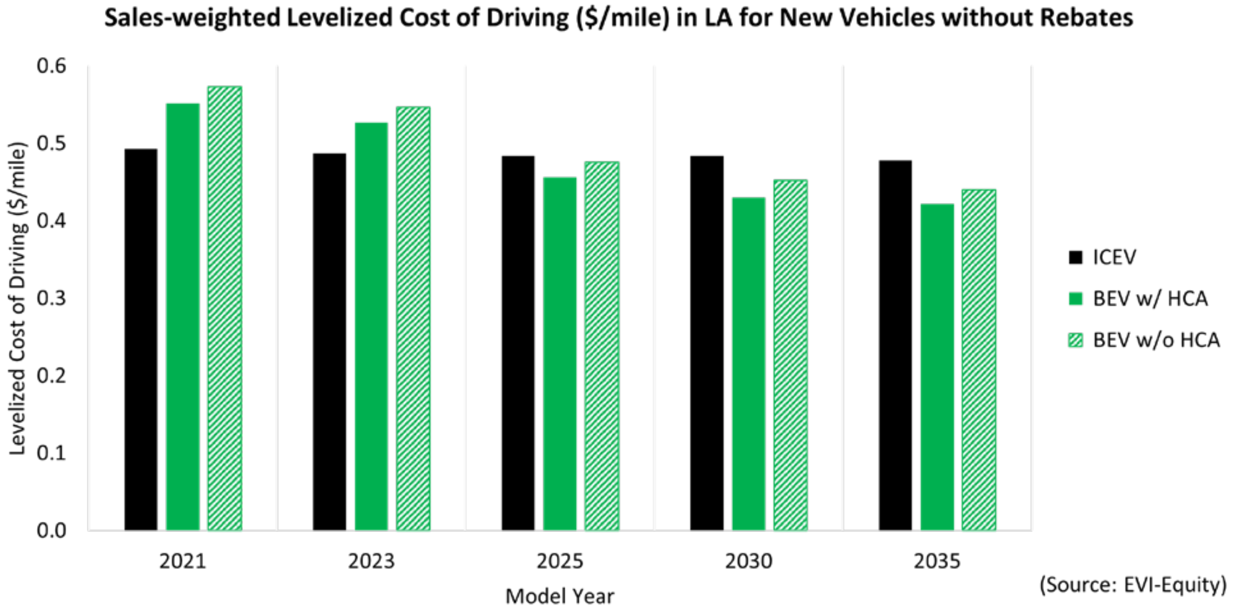


Figure A-4. Levelized cost of driving for different vehicle technologies and model years

EVs and Home Charging Access in DACs versus Non-DACs

Table A-2 shows varying concentrations of EVs and home chargers between DACs and non-DACs. As the table shows, EV owners in Los Angeles would be more or less evenly distributed between DACs and non-DACs by 2035, but EV owners in DACs tend to have lower income than those in non-DACs and to rely more on used EVs (see Figure 9, page 10). Also, note that the number of "home charger orphans"—those without home charging access (HCA)—in DACs is

26% greater than that in non-DACs. This implies that relatively more support (e.g., measures to compensate the lack of home charging access) may be necessary for EV owners in DACs.

Table A-2. Number of Households (in thousands) in Los Angeles That Own EVs

Annual Income	**Non-DAC**				**DAC**			
	Single-Family Home		**Multifamily Housing**		**Single-Family Home**		**Multifamily Housing**	
	w/ HCA	**w/o HCA**	**w/ HCA**	**w/o HCA**	**w/ HCA**	**w/o HCA**	**w/ HCA**	**w/o HCA**
< $25,000	22	8.0	5.9	9.7	42	17	14	22
$25,000–$50,000	31	7.4	14	25	53	14	26	46
$50,000–$75,000	34	3.6	23	25	44	5.0	30	33
$75,000–$100,000	36	2.3	25	18	33	2.3	24	17
$100,000–$150,000	52	3.7	29	22	35	2.7	21	16
$150,000–$200,000	32	2.1	14	10	14	1.0	6.9	5.1
> $200,000	38	2.9	3.5	3.2	6.9	0.5	1.0	0.9
Total	**245**	**30**	**114**	**114**	**229**	**42**	**124**	**139**
	275		**227**		**271**		**262**	
	503				**533**			

Charging Load Profiles for Personally Owned EVs

Most of the EV/ EV charging infrastructure analysis in this study was conducted using NREL's EVI-Equity, ADOPT, and EVI-Pro tools, as described in the main text. Some new features were created and/or updated specifically for this study, including predicted charging load profiles associated with personal car EVs on a census tract level in the City of Los Angeles by 2035, as well as underlying distribution of home and public (including workplace) EV charging infrastructure.

EV charging load profiles, previously generated in the LA100 study (NREL 2021), were based on an older version of EVI-Pro that has been updated over the past few years (CEC 2021). This study utilized one of the more recent versions of EVI-Pro (CEC 2021) for charging load profiles for personally owned EVs, documented in the Assembly Bill 2127 Staff Report (CEC 2021). Different versions of EVI-Pro, used in the LA100 study versus this analysis, lead to different shape and structure of charging load profiles.

For this analysis, EVI-Pro's simulated charging events for generic EVs, including PHEVs and BEVs, for Los Angeles County were utilized, distinguishing vehicle technology (PHEV versus BEV), home charging access (with versus without), and vehicle type (small car, large car, sport car, small SUV, large SUV, van, and pickup truck). As noted in the main text, this study assumes Los Angeles will have about 1.6 million EVs (PHEVs and BEVs) by 2035. To break down EVs to different vehicle types (e.g., small car, large car) adopted in EVI-Pro, this study employed projected distribution of vehicle types in the CARB's zero-emission vehicle mandates (CARB 2022).

The generic charging events from EVI-Pro contained the type of destination, including home, workplace, or public; type of EV charging infrastructure, such as Level 1 (L1), Level 2 (L2), and DC fast charger (DCFC); day of the week—weekday or weekend; and charging load in kW with the timestamp for the start and end of charging event. To assign charging events and loads to different locations across the city, this study assumed that home charging events will occur in home census tracts to which EVs are likely to be registered to, which is determined by the EVI-Equity model, as discussed in the main text. For all the other charging events related to workplace and public locations, this analysis treated them as charging loads in commercial sites or facilities for simplicity. In other words, EV charging load profiles in this analysis are categorized as home or commercial.

While home charging loads are assigned to home census tracts for EV owners in Los Angeles, commercial charging loads are distributed according to the projected concentration of public EV charging infrastructure across the city. For this, two assumptions were made. First, the concentration of commercial EV charging infrastructure across the city will be mostly proportional to the land area share of commercial sites between different census tracts, for which LA-specific land use data were leveraged (City of Los Angeles 2022). Second, census tracts that currently have high concentration of public EV charging infrastructure will continue to have significant level of concentration of EV charging infrastructure in 2035. In other words, a census tract that has that has one of the highest concentrations of public EV charging infrastructure today is assumed to be not likely to have the least share of public EV charging infrastructure in 2035.

As such, for each census tract, this analysis aggregated the generic charging events for home and commercial locations (not on a site, but census tract level) for weekday and weekend; PHEVs and BEVs; different vehicle types; and with and without home charging access, which were all used to identify target/candidate samples among the original set of generic charging events. Among the identified candidates that qualify for corresponding criteria, including day of the week, EV technology, location type, vehicle type, and home charging access, a sample was drawn randomly to constitute a load profile for each EV in each census tract.

The aggregated charging load profiles are shown in Figure A-5. The overall shapes or patterns of load profiles may appear to deviate from the statewide load profiles documented in the CEC Staff Report (CEC 2021), as this study is based on a simulation specific to Los Angeles County that has different characteristics of EV fleet, housing types, and so on from those for the entire state of California.

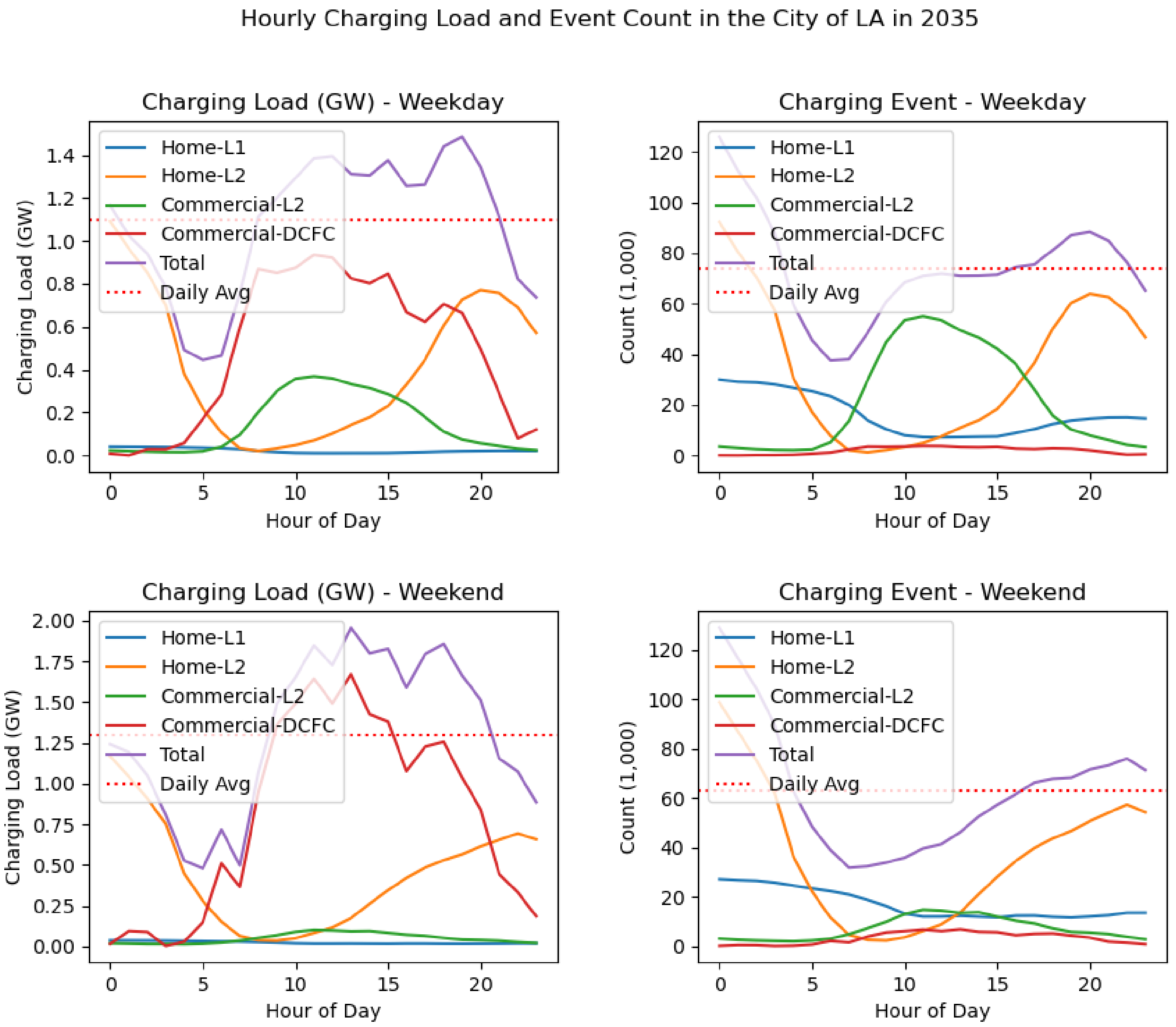


Figure A-5. Hourly EV charging load profiles in Los Angeles in 2035: Business-as-Usual scenario

The load profiles (Figure A-5) show that home charging is estimated to be the dominant form of refueling for EVs during nighttime and commercial during daytime. The relative significance of home or overnight charging during nighttime is more pronounced during weekdays in comparison with weekends. The load profiles also reveal the impact of different charger types: L1, L2, and DCFC. Regarding charge event count, L1 home charging has a significant share, but the overall impact on load profiles is negligible, as L1 (1 kW) is generally much less powerful than L2 (7–19 kW) (US DOT 2022). The same applies to the relative magnitude of DCFC in charge event count versus charging load. DCFC (50–350 kW) appears to be very small in the charge event count chart, but its aggregated impact on load profiles is very significant. Between weekday and weekend, the frequency and load impact of commercial L2 charging activity decreases during the weekend, in part because workplace charging diminishes significantly on the weekend. On the other hand, DCFC has the opposite pattern between weekday (smaller) versus weekend (greater) in terms of charge event count and overall charging load.

Note that these simulated load profiles are for a typical day of the year, without accounting for potential seasonal or longitudinal variation of travel pattern, energy price, and so on. Also note that the load profiles are scaled to be consistent with the LA100 study in terms of the total electrical energy drawn from the grid per day for charging. The focus of this analysis is the distribution (or redistribution) of EVs and EV charging infrastructure, while maintaining the high-level consistency with the preceding LA100 study, especially for the size of the EV fleet in Los Angeles and corresponding overall load profiles.

For a more rigorous analysis incorporating travel pattern into EV charging simulation, the study considered the travel pattern across and beyond Los Angeles that is estimated in the CSTDM (California Statewide Travel Demand Model) (Caltrans 2022). However, due to the level of detail that the study had for CSTDM's modeled travel pattern in and around Los Angeles, it was not feasible to allocate the generic simulated charging events from EVI-Pro to different areas of the city corresponding to the travel volume or pattern in the CSTDM. For example, a vehicle may travel from downtown to the northwest side of the city in the morning and return to the downtown in the evening, but chaining trips for individual vehicles as such was not possible, as it was not supported by the resolution of the data that the study had access for CSTDM. Even if the study had detailed vehicle activity data, for example, telematics, simulating those trips through EVI-Pro was out of the scope of this study.

For similar reasons, the study did not make spatial or temporal connections between where individual EV owners/drivers live and where they charge their EVs outside their homes (e.g., workplace, grocery store). Although a significant portion of the vehicle activity is related to intra-city travel, the CSTDM indicated that there is considerable vehicle movement between the city and the neighboring areas, for instance, between Los Angeles and Riverside, Irvine, or San Bernardino. This implies that charging activity, mostly influenced by travel pattern or vehicle activity, in Los Angeles may require region-wide travel plus charging simulation, but that was not feasible within the scope of timeline of this study. This also has an important implication for the question of who is benefiting from EV charging infrastructure in commercial locations within the city boundary. Given the significant travel activity between the city and neighboring areas, it is very possible that many EV owners/drivers using EV charging infrastructure in commercial locations within the city boundary may be from another city or area, or vice versa. That is why the study focused on home charging access that is presented in the main text, rather than public/private EV charging infrastructure in commercial locations.

With regards to vehicle activity beyond the city boundary and corresponding charging demands as well as load profiles in commercial locations in Los Angeles, the study assumed that the vacuum created by outbound travel volume (e.g., from Los Angeles to Irvine) will be filled with similar level of inbound activity (e.g., from neighboring areas to LA), resulting in mostly similar level of charging demands in the city. In other words, having 1.6 million EVs in Los Angeles in 2035 does not necessarily mean that all EV charging infrastructure in the city will exclusively serve those 1.6 million EVs registered in the city. Assuming that the net gain or loss of vehicle activity across the city boundary is close to zero, and that the EV adoption level in neighboring cities/areas is similar to that in Los Angeles, the study estimates that the load profiles shown in Figure A-5 would be citywide EV charging loads in 2035.

From the perspective of Business-as-Usual versus Equity Scenario, the overall load profiles are very similar (Figure A-6), mostly due to the assumptions discussed earlier, for example, respecting or inheriting the overall citywide energy consumed for EV charging that was estimated in the LA100 study (NREL 2021). Also, even if the distribution of EV charging infrastructure within the city boundary is adjusted, that would not necessarily show up in the overall load profiles. Nevertheless, the inner structure of load profiles across the city is different between the two scenarios, as Equity scenario assumes that there will be relatively higher concentration of public EV charging infrastructure, compared to Business-as-Usual scenario, in the neighborhoods where home charger orphans live—presented in the main text.

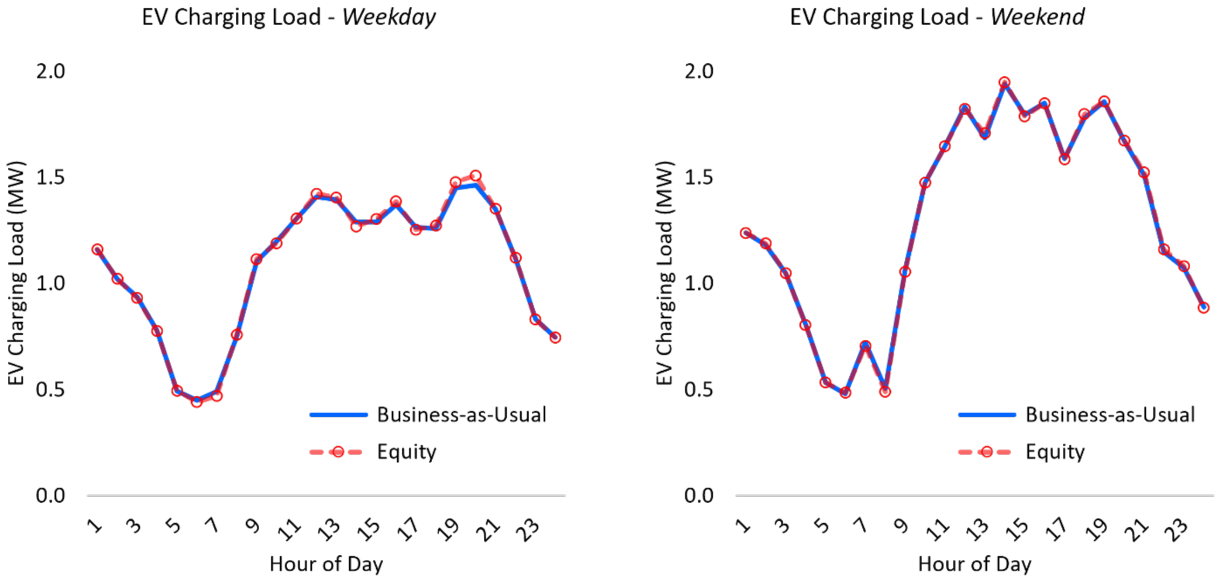


Figure A-6. Citywide hourly EV charging load profiles: Business-as-Usual versus Equity scenarios

Multimodal Solutions

Methods Background

The multimodal work used three factors to identify “transportation disadvantage.” The proportion of zero-vehicle households by transportation analysis zone are shown in Figure A-7. While only 19 of these transportation analysis zones (TAZs) were in the top 40% for zero-vehicle households, poor quality transit, and also designated DACs, this map shows all areas of the city where travel by modes other than personally owned automobiles should be prioritized and improved to meet the needs of households that don’t own cars.

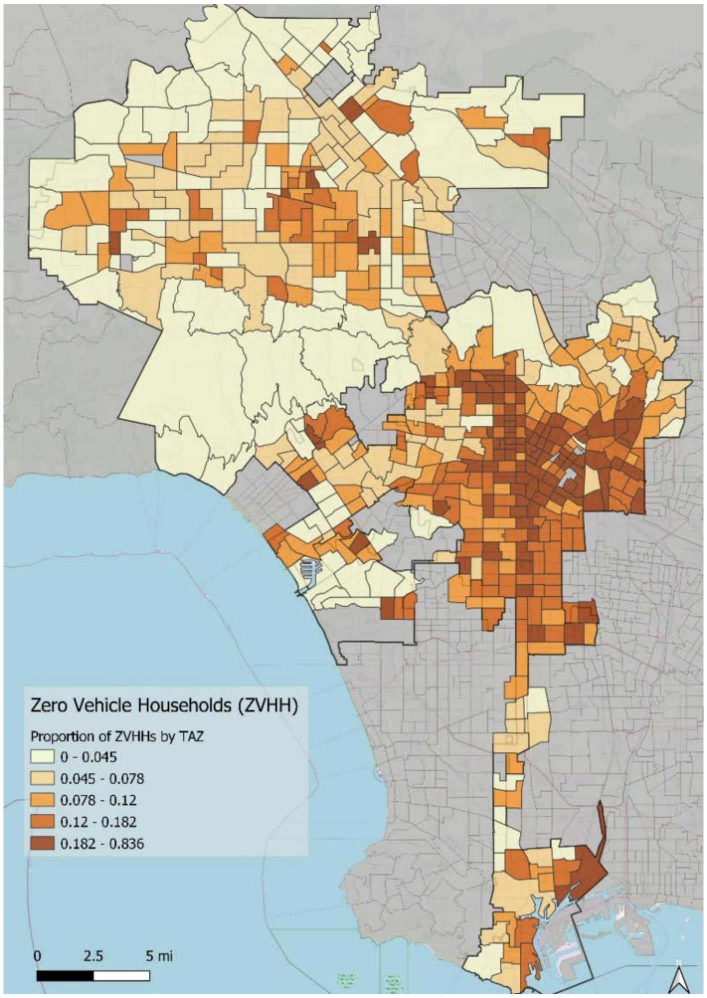


Figure A-7. Proportion of zero-vehicle ownership households by TAZ, Los Angeles (American Community Survey 2015–2019).

The top 40% of census tracts with zero-vehicle ownership households (> 12.0%) were flagged as priority tracts for multimodal equity analyses.

TAZ = transportation analysis zone.

Detailed Scenario Settings

In the Base scenario, for DAC residents who do not have access to privately owned cars, they only have access to walking, biking, transit, and taxi/transportation network companies. The rest of DAC residents who have their own vehicles have an additional travel option (i.e., driving). The level of service for these modes is either obtained from observed data or assumed with a reference from a similar existing service, as follows:

- **Driving:** The Google Maps API was used to query the needed travel time between DACs and their destinations. An average driving cost of $0.66/mile is used in the analysis, which covers the gas, insurance, and maintenance.
- **Transit:** The Google Maps API was used to query the availability of transit as well as the travel time, access time (i.e., the walking time needed to reach a transit station), and egress

time (i.e., the walking time needed to reach the final destination from a transit station). If the Google Maps API returned transit fare information, it was adopted; if not, $1.75 per trip ride was used to represent the transit fare.

- Taxi/transportation network companies have the same travel time as driving privately owned vehicles. The cost is calculated as distance × $1.00/mile + time × $0.50/minute.
- The cost of nonmotorized travel modes (i.e., walking and biking) is 0, and their travel time is queried from the Google Maps API.

In Equity scenario 1, where shared EV programs are provided to DACs, all residents in the Base scenario (including those with access to private cars and those without) have shared EV as an additional available travel option to choose from. The travel time of using shared EV programs is the same as driving personal vehicles, but shared EV programs require users to pick up and drop off the vehicles at stations; therefore, 5 minutes of access and egress time (total of 10 minutes) was added to the total travel time that a shared EV program requires. The rate used in this study adopts parameters similar to an existing EV-sharing program in the LA region (i.e., BlueLA) which uses $0.15 per minute plus tax as a community rate.[15] Features of other alternative travel modes (e.g., transit and taxis) are the same as the Base scenario.

In Equity scenario 2, where shared micromobility programs are provided to DACs, all residents in the Base scenario (including both those with access to private cars and those without) have shared micromobility as an additional available travel option to choose from. The travel time of using shared micromobility is calculated from the biking option. E-bikes/e-scooters are typically 1.3 times faster than using a traditional bike in urban areas, so the travel time needed to use shared micromobility is calculated proportionally. Additionally, depending on whether the shared micromobility service is docked or dockless, users need to either walk to a station or to the nearest vehicles. Therefore, an average of two minutes of time to access a micromobility vehicle was added to the total travel time of using shared micromobility. The rate of this newly added travel option in the study adopts a rate similar to existing EV-sharing program in the LA region (i.e., MetroBike) with $1.75 per 30 minutes and a minimum fare of $1.75.[16] Features of other alternative travel modes (e.g., transit and taxis) are the same as the Base scenario.

In Equity scenario 3, where transit services are improved, all residents in the Base scenario (including both those with access to private cars and those without) have access to better transit services in terms of: (1) adding transit services with a minimum speed of 20 mph if no existing transit service connects DACs and their destinations; (2) reducing the transit travel time to be 20% faster than the current transit service, which can be achieved by implementing dedicated bus lanes; and (3) reducing access time to be the lower value between the current level or 5 minutes, which can be achieved by on-demand bus services. The cost of transit remains the same as in the Base scenario. Features of other alternative travel modes (e.g., transit and taxis) are the same as the Base scenario.

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[15] blinkmobility.com/rental-rates

[16] https://bikeshare.metro.net/signup/#/

Mode Choice Model

The mode choice model was used to capture LA residents' mode choice preference, or which mode to choose when facing multiple available travel mode options. The mode choice model was estimated based on the trips made in the Southern California region from the National Household Travel Survey (NHTS): California Add-On (U.S. DOT Federal Highway Administration 2017) data set. The data set includes 51,263 trips made by individuals, with driving, walking, transit, bike, and taxi making up more than 99% of travel modes (Figure A-8).

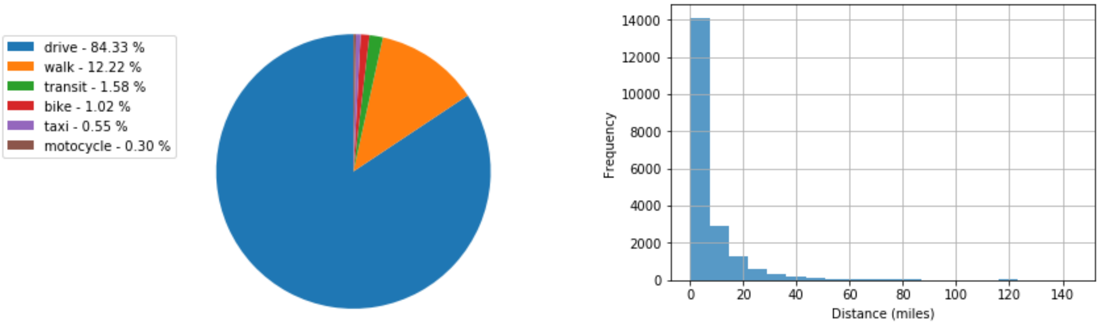


Figure A-8. Observed mode share in Southern California region (left) and travel distance histogram (right) (2017)

Source: 2017 National Household Travel Survey California Add-On, U.S. DOT Federal Highway Administration

A multinomial logit model was used to describe the mode choice preference. The utility of choosing each travel option is shown in Equations 1 through 6, and Equation 7 shows the probability of choosing a certain travel option.

$$V_{transit} = ASC_{transit} + \beta_{time} ivtt_{transit} + \beta_{cost} cost_{transit} + \beta_{egr} egr_{time} + \beta_{acc} acc_{time} \quad (1)$$

$$V_{drive} = ASC_{drive} + \beta_{time} ivtt_{drive} + \beta_{cost} cost_{drive} \quad (2)$$

$$V_{walk} = ASC_{walk} + \beta_{time} ivtt_{walk} \quad (3)$$

$$V_{bike} = ASC_{bike} + \beta_{time} ivtt_{bike} \quad (4)$$

$$V_{taxi} = ASC_{taxi} + \beta_{time} ivtt_{taxi} + \beta_{cost} cost_{taxi} \quad (5)$$

$$ASC_{drive} = 0 \quad (6)$$

$$P_i = \frac{\exp(V_i)}{\sum_{j=1}^{J} \exp(V_j)} \quad (7)$$

The data used to estimate the mode choice model were queried from the Google Maps API, in the same way as described in the scenario settings. A multinomial logit was estimated from the collected data with existing travel modes (i.e., driving, walking, transit, biking, and taxi). Motorcycle trips were removed from the data set as their mode share was too small. The R package Apollo was used to estimate the model, and the generated mode choice model is shown in Table A-3. The model has a good representation with an adjusted Rho-square of 0.73. The signs and magnitudes of estimated coefficients are also behaviorally reasonable.

Table A-3. Estimated Mode Choice Model

Variable	Estimates	Standard Error	T Value
ASC_taxi	-3.9	0.14	-27.64
ASC_transit	-1.2	0.11	-11.27
ASC_bike	-3.0	0.06	-54.01
ASC_walk	0.27	0.04	6.68
ASC_car	0	—	—
Travel time	-0.08	0.002	-43.46
Travel cost	-0.12	0.01	-11.22
Access time	-0.07	0.007	-9.83
Egress time	-0.05	0.007	-6.45

LL (start) = -25297.2

LL (final) = -6813.44

Adjusted Rho-Square = 0.7303

AIC = 13642.87

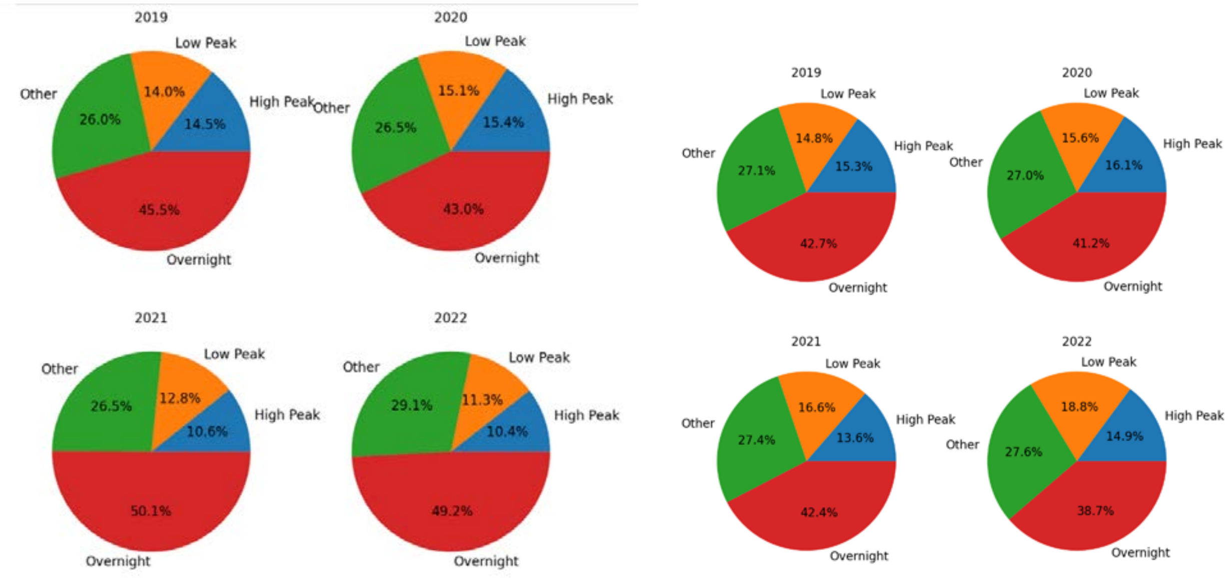
BIC = 13705.01

An incremental logit model for newly added travel modes (i.e., e-bikes and shared EVs) in the Equity scenarios uses the relative preference between existing modes and newly added modes from other studies, where such preferences are observed from real-world data. We used the relative mode choice preference among travel modes in the literature for the Equity scenario analysis.

Historic EV Charging Data

To better understand charging behavior and the extent to which it may impact peak electricity demand as vehicle electrification increases, NREL conducted analysis on LADWP-provided data on charging patterns at 35 charging stations. Stations analyzed included residential, commercial, and BlueLA EV car share. Findings include:

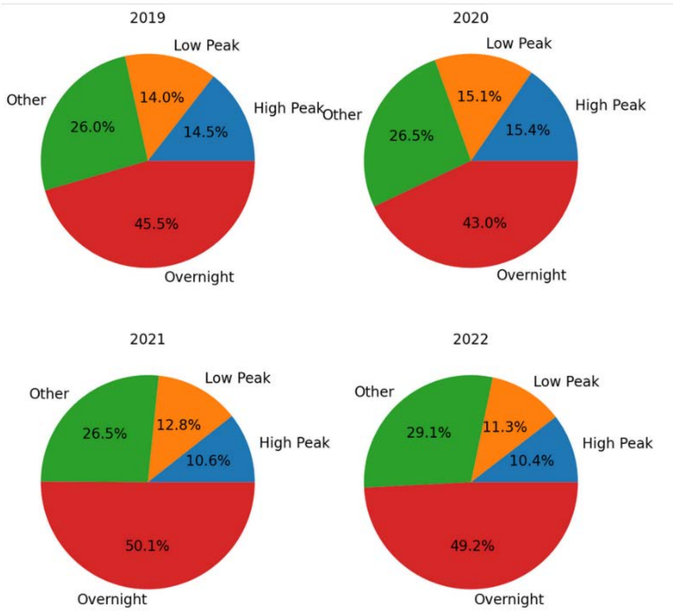
- Residential charging occurs more consistently overnight and at non-peak times when electricity rates are generally lower:
    - About 40% of sampled commercial charging consistently occurred overnight, versus >70% of residential.
    - Residential charging occurred during peak times an average of 26% of the time compared to commercial at 31% of the time.
    - Apartments had the lowest peak charging times of commercial chargers analyzed (22% versus 78%).
- BlueLA car share sites used approximately 50% overnight charging and 26% peak demand charging times.



Residential (n=22)

Commercial (n=13)

Figure A-9. Charging times by peak period and year for LADWP customers who received an EV charging infrastructure rebate for installation of a time-of-use sub-meter, for residential customers (left) and commercial customers (right)



EV Car Share Sites (n=8)

Figure A-10. Charging times by peak period and year for time-of-use sub-meters for EV charging at commercial customer sites that host BlueLA EV car sharing vehicles

Multimodal

This section shows the detailed modeling results, including the impacts of the multimodal strategies on travel time, travel cost, and opportunities reached across neighborhoods.

Newly added travel options can reduce DACs' expenditure on daily travel in most cases. As shown in Figure A-11, transit service with a fixed fare, on average, reduces DAC residents' expenditure on travel the most. Newly added travel options do not always help DAC residents save costs. Depending on the location and travel demand patterns of a neighborhood, travel options can bring zero reductions, or even an increase in travel-related expenditures.

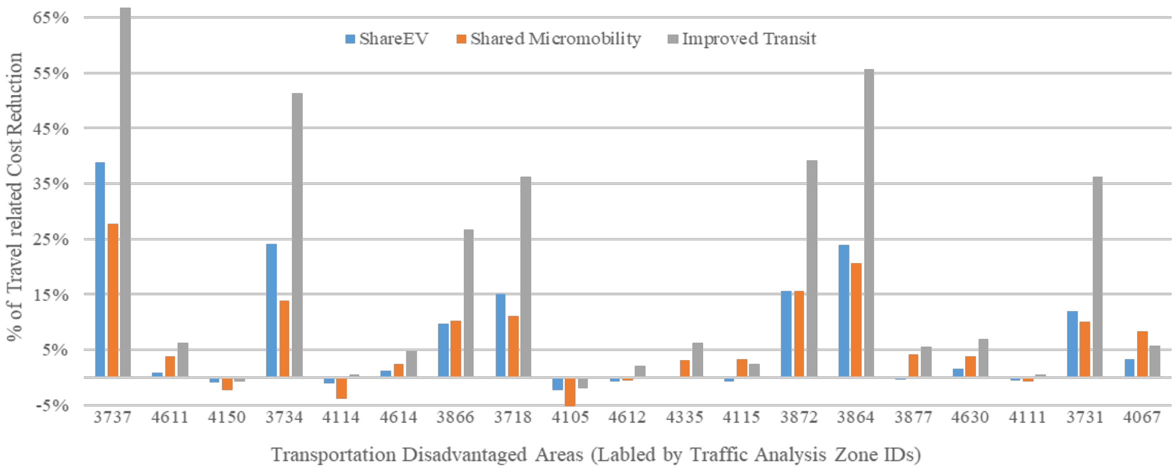


Figure A-11. Percentages of travel cost reduction from newly added travel options (where positive values are cost reductions and negative values are cost increases)

Providing new travel options to DACs can help reduce time spent on transportation. As shown in Figure A-12, on average, improved transit reduces travel time the most, with the highest time saving reaching 30%.

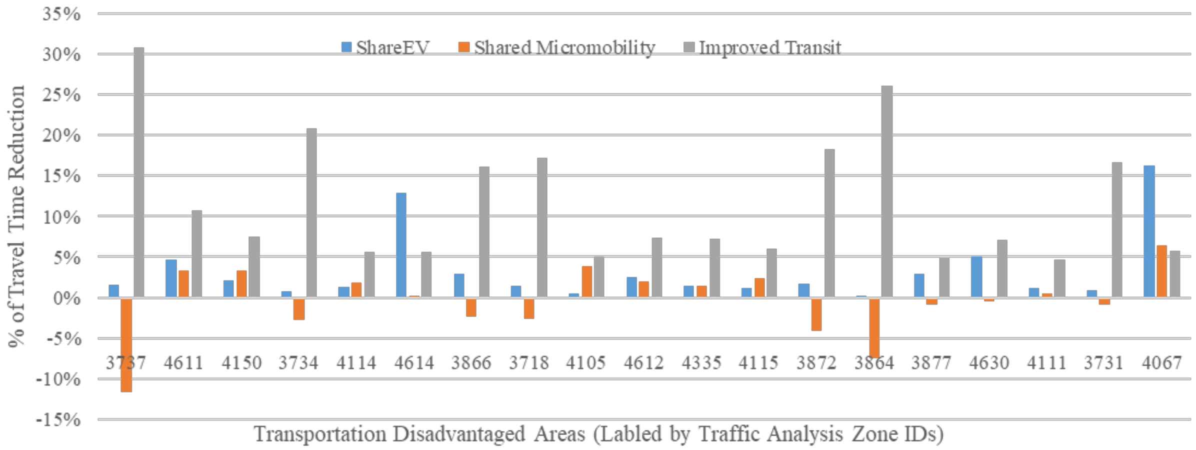


Figure A-12. Percentage of travel time reduction from newly added travel options relative to the baseline (where positive values are a reduction in travel time and negative values are an increase in travel time)

Newly provided travel options can help DAC residents reach more destinations. As shown in Figure A-13, improved transit on average has the highest increase in destinations that can be reached, ranging between 0.33% and 20%.

Figure A-13. Percentage of change in accessible opportunities relative to the baseline

Assumptions in Multimodal Modeling

- 2017 NHTS data-based mode choice model preference still applies to future year scenarios.
- The Google Maps API-queried traffic conditions represent the average conditions in the analyzed scenarios.
- In the Equity scenarios, the provided multimodal services (e.g., shared EV program and shared e-bikes) are sufficient to DAC residents (i.e., service is always available when a DAC resident needs to access the service). Modeling the exact number of vehicles needed and the specific locations of service (i.e., shared EV or e-bike station) is out of the scope of this analysis.
- From CSTDM data, each traffic analysis zone could have up to 7,000 destinations per day. We only take the destinations with more than 30 trips per day for analysis. This resulted in 60% of total demand included in final modeling.
- The analysis does not consider the variation of demand and traffic conditions within a day.
- The travel demand data, the number of trips traveling between origins and destinations by sociodemographic category or DAC metric, is not available. Therefore, we disaggregated the travel demand by the proportion that is transportation disadvantaged to identify the travel demand of the targeted DAC population. For example, if 80% of the population in a census tract do not own vehicles (i.e., are zero-vehicle households), then we estimated that 80% of the travel demand originating from the subject census tract is generated by those zero-vehicle households (which in our analysis are considered transportation disadvantaged).

- The added new services are not expected to change the traffic conditions (e.g., creating more congestion). Although this study did not estimate the exact number of vehicles needed for shared EV programs or buses needed to achieve the improved transit service, based on existing studies of the relationship between number of vehicles and speed in the traffic flow fundamental diagram, the typical number of vehicles deployed through similar new services is not expected to significantly affect traffic conditions. Additionally, the new services are only expected to be implemented in a limited area, and the usage of those services would be spread across different times of day.

Modeling Mode Shift Implications

The multimodal modeling work described above covered about 60% of trips in the 2020 CSTDM dataset that originate within the city of LA, down selecting for origin-destination pairs that account for 70% of trips and then data cleaning that whittled that down to 59.3% of all trips. Using just those results for approximately 60% of trips, the metrics presented in the Denver E-Bike sidebar were estimated, including:

- Up to 6.8% reduction in total VMT/year
- Up to 294,000 tons reduced in CO_2e/year.
- Up to 186 GWh/year reduction in electricity demand compared to EV trips

To better estimate the implications of mode shift to e-bikes for vehicle miles traveled (VMT), carbon dioxide equivalent emissions, and electricity demand, the mode shift potential of all trips less than or equal to 35 miles (99.1% of trips in the dataset) needed to be modeled. To do this, a simple linear regression was generated from the modeled trips (Figure A-14), using trip distance and the VMT reduced by e-bike trips per total miles traveled (TMT). This VMT reduction metric was generated by dividing the modeled shift of VMT to e-bikes by the TMT, including transit, driving, biking, and walking.

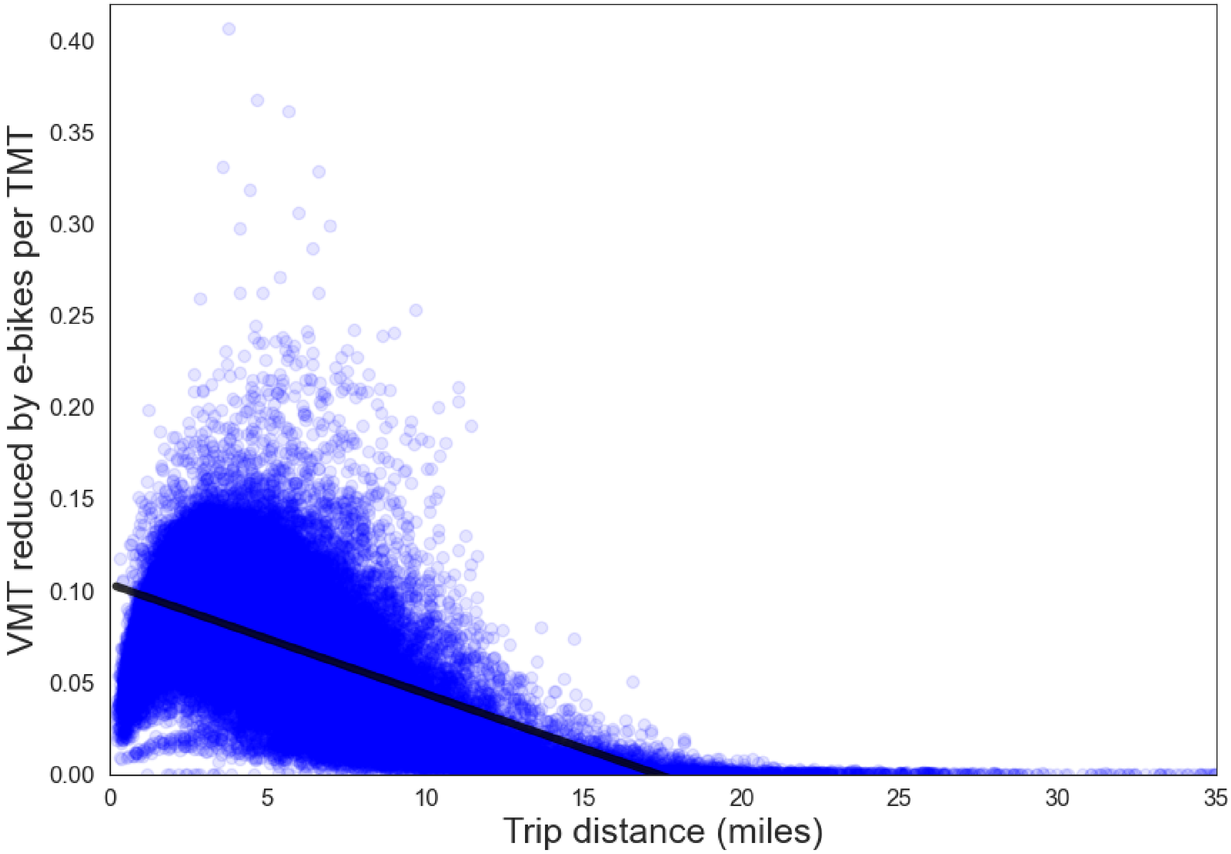


Figure A-14. Regression of trips whose mode shift potential was modeled, to estimate mode shift potential of unmodeled trips.

Filling in the mode shift potential of these disproportionately longer trips shifted the e-bike impact metrics to the ones shown in the callout box:

- Up to 4.7% reduction in total VMT/year
- Up to 316,000 tons reduced in CO_2e/year.
- Up to 187 GWh/year reduction in electricity demand compared to EV trips

A.2 Data Sources and Assumptions

NREL used multiple data sets relevant to EV rebates, residential EV charging infrastructure rebates, public charging stations usage, and commercial EV charging infrastructure rebates, as described in Table A-4.

Table A-4. Summary of Transportation Modeling Data Sources

Data	Source	Description	Resolution	Vintage
Existing EV ownership	Experian (proprietary and licensed to NREL)	Vehicle registration data, including EVs	Zip code	2021 (Q4)
Existing EV charging infrastructure	Alternative Fuels Data Center Station Locator	Location of public and private EV charging stations, both current and planned	Point location	Current
Historical energy price	Bureau of Labor Statistics	Electricity and gas prices	Metropolitan level	2016–2021
California Statewide Travel Demand Model	Caltrans	Travel demand data in California (historical and projection)	State level	2015, 2020, 2030, 2040
Building type data	NREL LA ResStock model	Building type information	City level	2017
Mode shift and VMT reduction targets	City of Los Angeles, Los Angeles County, Metro	Mode shift or VMT reduction targets or projections based on: LA Metro Traffic Reduction Study, Mobility Plan 2035, Transportation Demand Management Ordinance and Guidelines, Metro Strategic Plan (Vision 2028), California Environmental Quality Act Vehicle Miles Traveled (VMT) reduction requirements, Sustainable City pLAn, and the LA Green New Deal Targets and Annual Reports	Variable	Variable
National Household Travel Survey - California Add-On	NREL Transportation Secure Data Center	Historical travel demand data in California	Point location	2017
Vehicle consumer choice and stock	NREL Automotive Deployment Options Projection Tool (ADOPT)	ADOPT is a vehicle consumer choice and stock model.	ZIP code	Variable
EV charging infrastructure	NREL Electric Vehicle Infrastructure Projection Tool (EVI-Pro)	EVI-Pro estimates how much charging infrastructure is needed to meet given charging demand in a given area.	State level	Variable

Data	Source	Description	Resolution	Vintage
EV penetration	NREL Electric Vehicle Infrastructure for Equity Model (EVI-Equity)	EVI-Equity evaluates questions related to equitable EV charging and EV ownership.	2021	
LADWP EV and EV charging infrastructure data	LADWP	Load profiles for EV charging for customers who have received EV charging infrastructure rebate for time-of-use sub-meter (residential and commercial) Load profiles for EV charging infrastructure owned by LADWP or other city agencies Vehicle information provided in applications for EV charging infrastructure rebates (used vehicle only).	Variable	Variable; typically one year
Disadvantaged communities (DACs)	California Senate Bill 535	DACs are identified as tracts designated disadvantaged by California Senate Bill 535.	Census tract	2021
Zero-vehicle households	American Community Survey	Vehicles available by housing unit	Census tract	2015–2019
Transit quality	U.S. Environmental Protection Agency Smart Location Database	Field D5de: Proportional Accessibility of Regional Destinations (expressed as a ratio of total metropolitan statistical area accessibility)	Census tract	2020

Modeling and Analysis Limitations

EV/ EV charging infrastructure modeling and analysis do not account for dynamic relationships (potential feed-back loops) between EV adoption and EV charging infrastructure deployment or the overall cost of public EV charging infrastructure stations (e.g., real estate, equipment, maintenance). EV adoption can possibly induce EV charging infrastructure deployment, or vice versa. However, in this task, citywide EV adoption is inherited from (or set by) the previous round of modeling for the initial LA100 study (Cochran and Denholm 2021), and the focus is on the distribution of EVs across the city to achieve a certain level of equitable access to EVs. Based on the distribution of EVs as such, the distribution of EV charging infrastructure is determined for different levels of equitable access. Similar to the LA100 study, this task is mostly scenario-based analysis, but with a particular focus on equity. In addition, this task does not incorporate the overall cost of charging stations when determining the location or distribution of EV charging infrastructure. The cost or economics of charging stations may affect the decision around location, but this task is more interested in equity, rather than accurate or precise siting analysis of charging stations.

In addition to the assumptions listed in Section A.2, multimodal modeling analysis has one more data assumption. The CSTDM demand matrix, predicted by Caltrans for all scenarios, is adopted to represent the travel demand of DACs. The CSTDM travel demand data are generated through a transportation planning process that comprehensively considers population, demographic characteristics, land use, road network characteristics, transit service, and other important influencing factors. Therefore, data represent the demand pattern in the planned scenarios. The travel demand associated with DACs describes the number of trips originating from or arriving at DACs. However, it is likely that a subset includes trips that are not made by DAC residents, as the data set may contain the through traffic or the traffic that comes from other areas to DACs for activities but includes travel by individuals who do not reside in DACs. However, to improve the transportation services to DACs and life quality of DAC residents, the enhancement of the general access to/from DAC regions will improve DAC residents' overall access to opportunities.

A.3 Additional Output Metrics Added and Capabilities Enabled

EV/ EV Charging Infrastructure: Higher Resolution, More Dimensions

Compared to the LA100 study (Cochran and Denholm 2021), the more integrated and bottom-up approaches (using ADOPT, EVI-Pro, and EVI-Equity) for LA100 Equity Strategies enable us to characterize EV adoption as well as EV charging infrastructure deployment by location (census block group or tract), household income, race, ethnicity, and other metrics. In addition, we can now show the impact of various incentives (federal, state, and local) on equitable EV adoption and examine scenarios or strategies that could help achieve more equitable EV adoption. Similarly, one of the new output metrics is the degree of affordability for owning EVs, accounting for household income and expenditures, EV capital cost, and charging cost. For various equitable EV charging infrastructure distribution configurations, we can investigate who is benefiting from that EV charging infrastructure, which was not addressed in the original LA100 study.

Multimodal Transportation: Beyond Privately Owned Vehicles

Additional output metrics about travel modes other than privately owned vehicles are included, such as transportation energy-related expenditures of using non-driving modes, peoples' usage of non-driving modes, and the potential electricity demand of providing multimodal transportation services to DACs.

Multimodal transportation-related output metrics provide a broader picture of the transportation mobility status of DACs. Improving transportation services to currently disadvantaged communities requires collaborative efforts from multiple city agencies in addition to LADWP. The City and County of Los Angeles also have goals and pathways identified for achieving more equitable transportation services. Adding multimodal transportation-related output metrics could not only help LADWP better align its efforts with other city agencies but will provide a picture of the electricity impact of these efforts.

Enabling Equity Strategy Analysis

These synergistic modeling pathways address two primary concerns expressed by Steering Committee members: namely, the barrier of EV affordability and the relevance of multiple modes of transportation to the target DAC or overburdened and underserved populations. The focus on multimodal transportation is relevant for multiple reasons, including both the reality that EVs are financially inaccessible, even for many households that own personal vehicles, and that many households in Los Angeles cannot or choose not to own a personal vehicle.

The modeling framework described here provide equity strategies for EV and EV charging infrastructure access and expand the s transportation conversation to include all households, not just those that own vehicles. The metrics provided (as summarized in Table 3) will enable evaluation of policies and practices and prioritization of investments with respect to transportation equity impacts.

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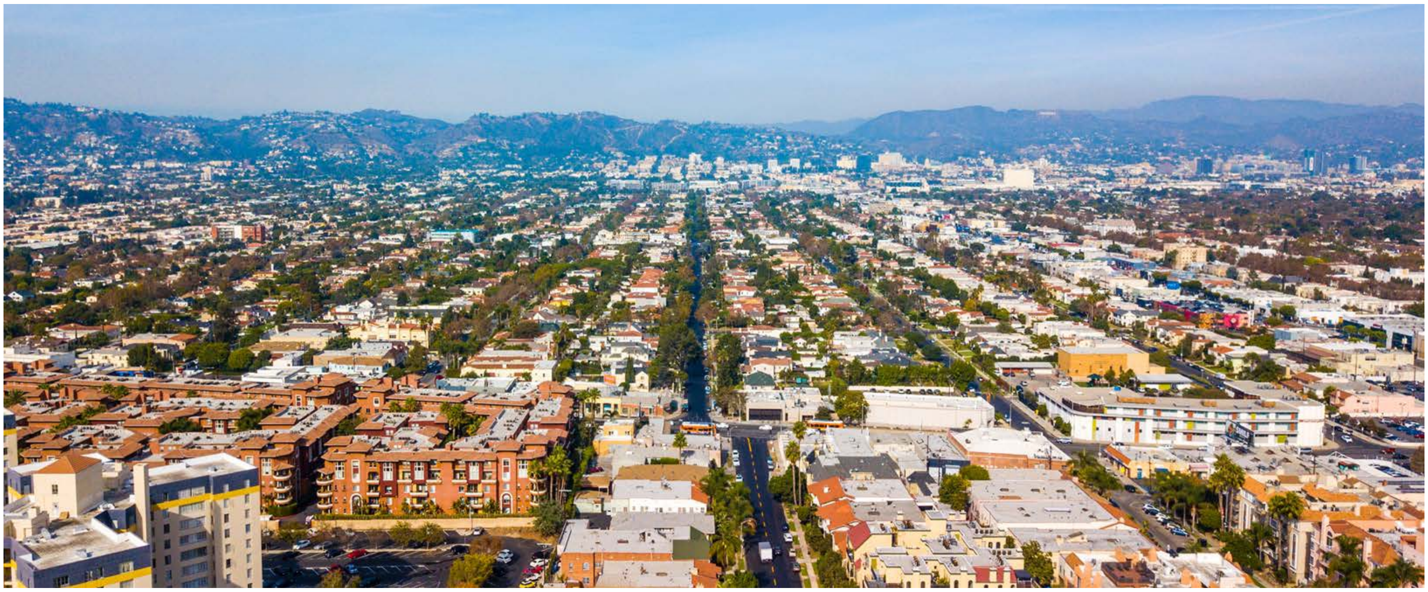

Chapter 11: Truck Electrification for Improved Air Quality and Health

FINAL REPORT: LA100 Equity Strategies

Vikram Ravi, Yun Li, Garvin Heath, Isaias Marroquin, Megan Day, and Julien Walzberg

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November 2023

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Preface

The Los Angeles 100% Renewable Energy Study, or LA100, revealed that although all communities in Los Angeles will share in the air quality and public health benefits of the clean energy transition, increasing equity in participation and outcomes will require intentionally designed policies and programs. The LA100 Equity Strategies project was specifically designed to help Los Angeles identify pathways to such policies and programs in the form of equity strategies. The project aimed to do this by incorporating research and analysis to chart a course toward specific, community-prioritized, and equitable outcomes from the clean energy transition outlined in the LA100 study.

The Project Partners

The Los Angeles Department of Water and Power (LADWP), the National Renewable Energy Laboratory (NREL), and the University of California Los Angeles (UCLA) partnered on the LA100 Equity Strategies project to develop strategies for engaging communities, funding equitable technology and infrastructure investments, expanding existing programs, and designing new programs and policies to improve equity by incorporating what community members themselves know is needed to achieve a more equitable energy future.

The Project Approach

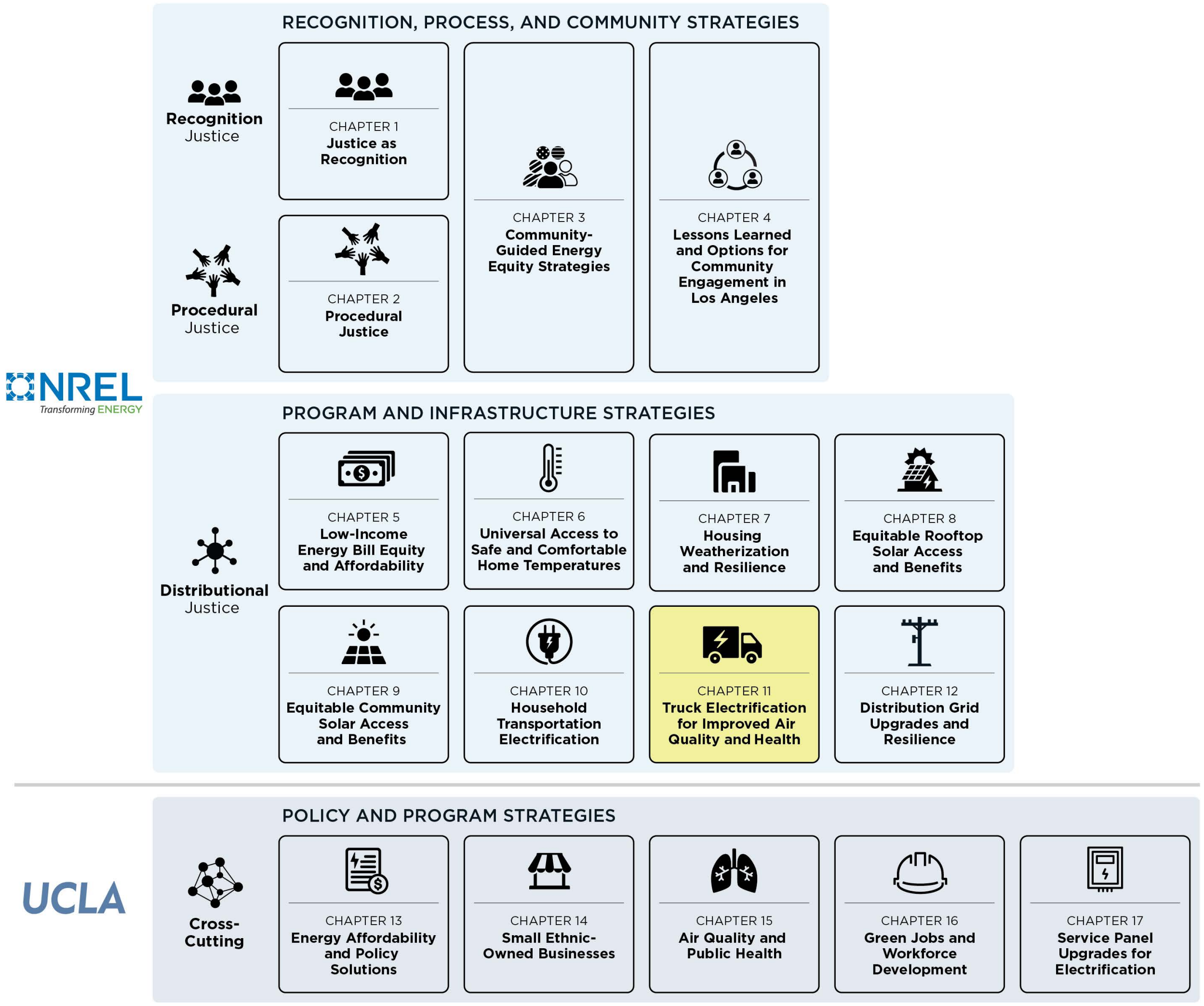
LA100 Equity Strategies employs a unique mixed-methodological approach utilizing three distinct—but connected—research efforts. Through these efforts, NREL and UCLA developed a range of strategy options for increasing equity in LA's transition to 100% clean energy.

A Project Summary

To get a high-level overview of the project, you can dive into the executive summary, interactive data visualizations, and more on the LA100 Equity Strategies website at maps.nrel.gov/la100/equity-strategies.

The Full Report

NREL's final full report for the LA100 Equity Strategies project encompasses seventeen chapters. The first twelve chapters, authored by NREL, are organized around the three tenets of justice. Chapters 1–4 address recognition and procedural justice, while Chapters 5–12 address distributional justice. The final five chapters, authored by UCLA, provide crosscutting policy and program strategies. Each chapter provides data, methods, insights, and strategies to help LADWP make data-driven, community-informed decisions for equitable investments and program development.



NREL Chapters

Chapter 1: Justice as Recognition

Chapter 2: Procedural Justice

Chapter 3: Community-Guided Energy Equity Strategies

Chapter 4: Lessons Learned and Options for Community Engagement in Los Angeles

Chapter 5: Low-Income Energy Bill Equity and Affordability

Chapter 6: Universal Access to Safe and Comfortable Home Temperatures

Chapter 7: Housing Weatherization and Resilience

Chapter 8: Equitable Rooftop Solar Access and Benefits

Chapter 9: Equitable Community Solar Access and Benefits

Chapter 10: Household Transportation Electrification

Chapter 11: Truck Electrification for Improved Air Quality and Health

Chapter 12: Distribution Grid Upgrades for Equitable Resilience and Solar, Storage, and Electric Vehicle Access

UCLA Chapters

Chapter 13: Energy Affordability and Policy Solutions Analysis

Chapter 14: Small Ethnic-Owned Businesses Study

Chapter 15: Air Quality and Public Health

Chapter 16: Green Jobs Workforce Development

Chapter 17: Service Panel Upgrade Needs for Future Residential Electrification

List of Abbreviations and Acronyms

ABM	activity-based travel demand model
ACF	Advanced Clean Fleets
ACT	Advanced Clean Trucks
AMI	acute myocardial infarctions
BenMAP	Environmental Benefits Mapping and Analysis Program
BenMAPR	an R implementation of the Benefits Mapping Program
BEV	battery electric vehicle
CARB	California Air Resources Board
CRF	concentration-response functions
DAC	disadvantaged community
EIR	Environmental Impact Report
EMFAC	Emission FACtor
EPA	U.S. Environmental Protection Agency
ePTO	electric power take-off
ER	emergency room
EV	electric vehicle
FCV	fuel cell vehicle
GVWR	gross vehicle weight rating
GWh	gigawatt-hours
HHDT	Heavy heavy-duty trucks
HRRR	High-Resolution Rapid Refresh
HV	hybrid vehicle
HVIP	Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project
IRA	Inflation Reduction Act of 2022
kV	kilovolt
kW	kilowatt
LADOT	Los Angeles Department of Transportation
LADWP	Los Angeles Department of Water and Power
LAMP	Landside Access Modernization Project
LAWA	Los Angeles World Airports
LAX	Los Angeles International Airport
lbs	pounds
LDA	light-duty automobile (passenger car)
LHDT	light heavy-duty trucks
META	Mobile Emissions Toolkit for Analysis
MHDT	medium heavy-duty trucks
MSS	Mobile Source Strategy
NG	natural gas
NLCD	National Land Cover Database
NO_x	oxides of nitrogen
NOAA	National Oceanic and Atmospheric Administration
NREL	National Renewable Energy Laboratory
PM	particulate matter
POLA	Port of Los Angeles

POLB	Port of Long Beach
ppb	parts per billion
RTMA	Real-Time Mesoscale Analysis
SB	California Senate Bill
SCAB	South Coast Air Basin
SCAG	Southern California Association of Governments
SCAQMD	South Coast Air Quality Management District
SCR	selective catalytic reduction
SLTRP	Strategic Long Term Resource Plan
SoCAB	Southern California Air Basin
TAQ-DAC	traffic air quality disadvantaged community
UCLA	University of California Los Angeles
VMT	vehicle miles traveled
WRF-Chem	Weather Research and Forecasting model coupled with Chemistry
ZEV	zero-emission vehicle

Executive Summary

The LA100 Equity Strategies project integrates community guidance with robust research, modeling, and analysis to identify strategy options that can increase equitable outcomes in Los Angeles' clean energy transition. This report focuses on truck electrification as a means to improve air quality and health in traffic and air quality disadvantaged communities. It also identifies potential strategies to more equitably distribute air quality benefits from electrification of trucks, defined here as heavy-duty vehicles over 8,500 pounds (lbs) gross vehicle weight.[1,2]

Specifically, NREL analyzed 1) baseline air pollutant emissions, 2) emissions reductions associated with incremental increases in electrification of three types of heavy-duty trucks in 2035, and 3) resultant changes to air pollutant concentrations for selected census tracts along major roadways in disadvantaged and non-disadvantaged communities for comparison.[3] In addition, NREL analyzed the impact of estimated pollutant concentrations on several health effects and the distribution of those health effects by disadvantaged community status.[4] NREL's analysis is complemented by a University of California Los Angeles (UCLA) analysis of air quality benefits from transportation electrification, which included light-duty vehicles (Chapter 15) and evaluated regional air-quality changes across Los Angeles.

Research was guided by input from the community engagement process, and associated equity strategies are presented in alignment with that guidance.

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[1] There are also light-duty trucks (<6,000 lbs) as well as medium-duty trucks (5,751–8,500 lbs). In this analysis, we only consider heavy-duty trucks because of their outsized impact on air pollution compared to the other two vehicle classes. Hereafter, when "truck" is used, it refers to heavy-duty trucks. The definition of heavy-duty trucks varies by agency. In this report we use the California Air Resources Board EMFAC2021 model definition, which aligns with the definition used by Southern California Area Governments. The heavy-duty truck category is divided into three subcategories: light heavy-duty trucks (LHDT) (8,501–14,000 lbs in gross vehicle weight, Classes 2b–3), medium heavy-duty trucks (MHDT) (14,001–33,000 lbs, Classes 4-7), and heavy heavy-duty trucks (HHDT) (≥33,001 lbs, Class 8). All three are considered in this analysis. See Appendix A.1 for a detailed description of the classifications.

[2] Other types of zero-emissions trucks are not modeled here. This analysis focuses on battery electric trucks to best reflect the LA100 Early No Biofuels scenario with high electrification.

[3] Electrification can lead to a shift in emissions from the vehicle to a power plant. The City of Los Angeles has decided to achieve 100% renewable energy for its power plants by 2035, which is the year of our analysis. Thus, we expect much lower net emissions from electrified vehicles in that year. As tall stacks dilute concentrations resulting from emitted air pollutants, power plant emissions should not significantly affect the near-road, ground-level concentrations estimated in this analysis. Impacts of net emissions are not considered in this research but could be in future research.

[4] DAC is defined herein by the California Senate Bill (SB) 535 designation (2022).

Community Guidance

Guidance from the LA100 Equity Strategies Steering Committee, listening sessions with community-based organizations and community members, and community meetings included the following:

- Ensure investments are made in communities that have had the most pollution burden.
- Reduce pollution from traffic.
- Incentivize local goods movement to be cleaner and powered by green power.
- Work with companies to upgrade fleets to electric vehicles for clean air overall and for low-income delivery workers.
- Focus on cleaning up pollution from the Port of Los Angeles (POLA) (e.g., freight traffic) (Wilmington neighborhood), Los Angeles International Airport (Westchester), South Los Angeles, and Pacoima.

Wilmington, LA Harbor Resident:

"Since I have been here, three generations, half of my family, has died from cancer. As young as 34 years old. From breast cancer, lung cancer, liver cancer, kidney cancer. With people that don't even drink or smoke … I know that the refineries have an issue. The contaminants from the trucks and the containers, from the brakes. They have a black soot in our community. And in that black soot, who knows what that's giving us? … And you wake up in the morning, your car is full of that stuff. You wipe your car down and your rag is black. Or it's inside your house."

Distributional Equity Baseline

Approximately one-half of census tracts in Los Angeles are disadvantaged communities (DACs), which are defined as tracts scoring greater than 75 in a composite of 21 pollution burden-based and population characteristic-based indicators within CalEnviroScreen Version 4.0 and adjusted by California Senate Bill (SB) 535. NREL sought to identify census tracts whose air quality is most greatly impacted by traffic through developing a CalEnviroScreen-based framework using a subset of its indicators. NREL's analysis found that two CalEnviroScreen indicators—traffic impacts and diesel particulate matter (PM)—best identify tracts whose air quality is most impacted by traffic; we name this subscore, "traffic air quality disadvantaged communities" (TAQ-DACs).

A map of the TAQ-DACs used in this study is shown in Figure ES-1. Our analysis reveals that 58% of DACs have percentile scores >75 for either traffic impacts or diesel PM, and 32% of DAC tracts have a composite percentile score >75 for both indicators. Because by design, 25% of census tracts statewide are DACs, DACs in Los Angeles have a disproportionately high representation among California's most traffic-affected tracts.[5]

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[5] NREL conducted a statistical analysis of equity in the distribution of Los Angeles Department of Water and Power (LADWP) charging rebates. The LADWP Commercial New Charger program (also known as Charge Up LA!) has offered up to a $125,000 rebate for installed chargers servicing medium- and heavy-duty electric vehicles (EVs) (Class 3–8). As only 14 such rebates have been approved to-date, the sample size is too small for analysis of equitable distribution of rebates. LADWP offers a $4,000 rebate for commercial light-duty vehicle Level 2 chargers and an additional $1,000 for chargers installed in DACs. NREL analysis of the $63.7 million distributed for 987 Level 2 commercial charging rebates between 2013 and 2021 found that incentives were disproportionately distributed to non-disadvantaged, non-Hispanic, mostly renter, and wealthier neighborhoods.

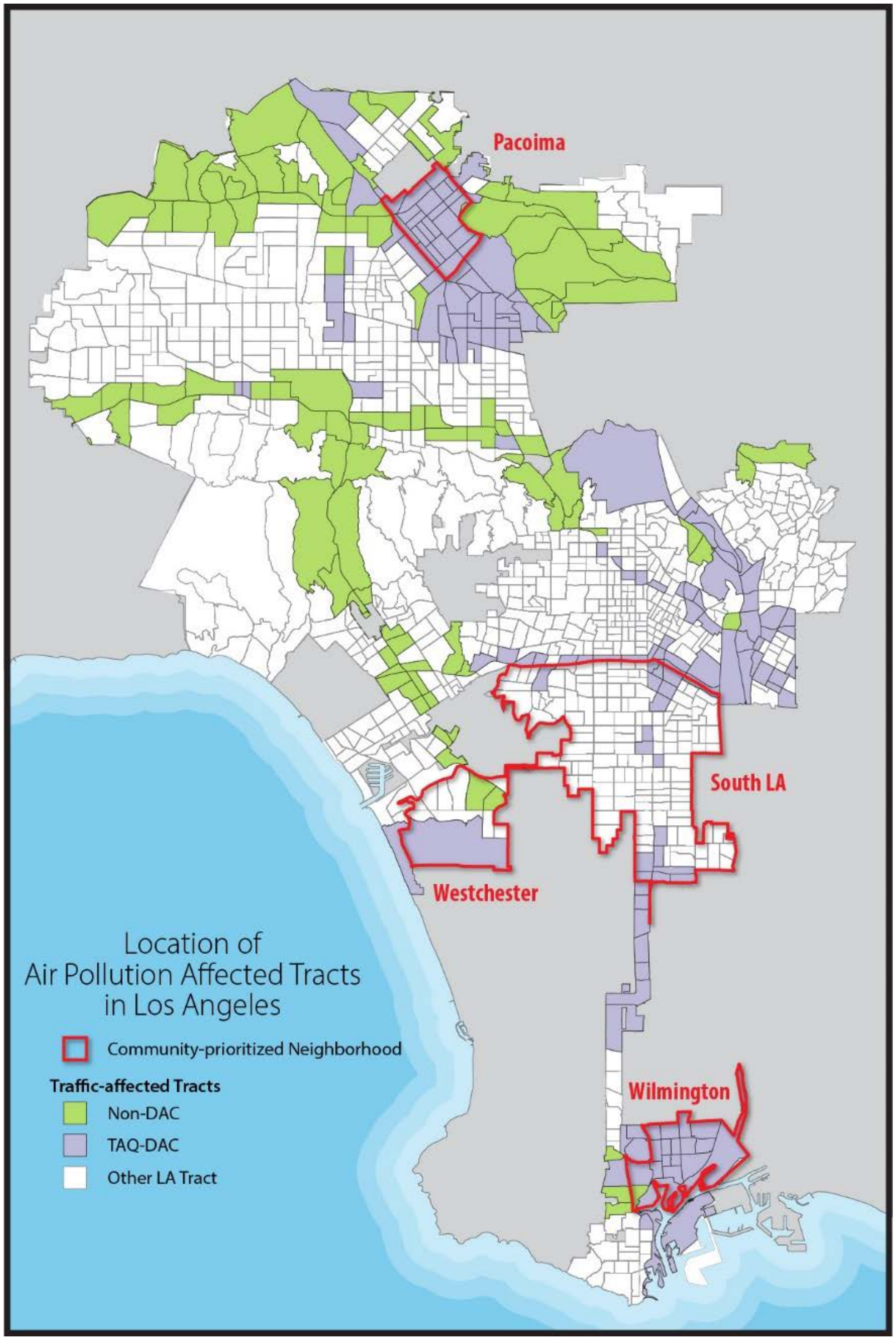

Figure ES-1. Location of traffic air pollution-affected tracts in Los Angeles

Traffic-affected non-DACs are shaded in green and traffic air quality affected DACs (TAQ-DACs) are shown in purple. Community-prioritized neighborhoods are outlined in red and annotated.

Key Findings

NREL analyzed baseline air pollutant emissions, emissions reductions associated with incremental increases in electrification of each heavy-duty truck category in 2035, and resultant changes to air pollutant concentrations for selected census tracts along major roadways in TAQ-DACs and non-DAC locations in Los Angeles for comparison.[6] In addition, NREL calculated the impact of estimated pollutant concentrations on several health effects that could be experienced by those living near major roadways and the distribution of those health effects by DAC status. Key takeaways include:

- Although heavy-duty trucks account for only 5% of registered vehicles in Los Angeles, they account for 51% of emissions of nitrogen oxides (NO_x) from on-road transportation sources.
- Heavy heavy-duty trucks contribute more than 90% of the truck-related NO_2 and 80% of primary $PM_{2.5}$ incremental near-road pollutant concentrations (5× the other heavy-duty truck categories).
- Heavy-duty truck-related near-road air pollutant concentrations of NO_2 and primary $PM_{2.5}$ in 2035 decrease linearly with an increasing fraction of heavy-duty trucks being electrified (Figure ES-2); for every incremental increase in the fraction of LA-registered trucks electrified analyzed, there is a consistent benefit in terms of pollutant concentration reduction.
- The air quality benefits that can be achieved by electrifying heavy-duty trucks vary by where such trucks are more prevalent on Los Angeles' roadways. The largest pollutant concentration reductions from heavy-duty truck electrification occur in census tracts located closest to freeways, including Interstate Highways 5, 10, 110, and 405, and U.S. Highway 101.
- TAQ-DACs benefit approximately 25% more from heavy-duty truck electrification in terms of NO_2 and $PM_{2.5}$ near-road concentration than non-DACs, as seen in the difference in slopes between the TAQ-DAC and non-DAC lines in Figure ES-2. This is because DACs, and especially TAQ-DACs, are more likely to be near major roadways in Los Angeles than non-DACs and thus would see greater benefit from emission reductions on the same roadways.

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[6] Electrification can lead to a shift in emissions from the vehicle to a power plant. The City of Los Angeles has decided to achieve 100% renewable energy for its power plants by 2035, which is the year of our analysis. Thus, we expect much lower net emissions from electrified vehicles in that year. As tall stacks dilute concentrations resulting from emitted air pollutants, power plant emissions should not significantly affect the near-road, ground-level concentrations estimated in this analysis. Impacts of net emissions are not considered in this research but could be in future research.

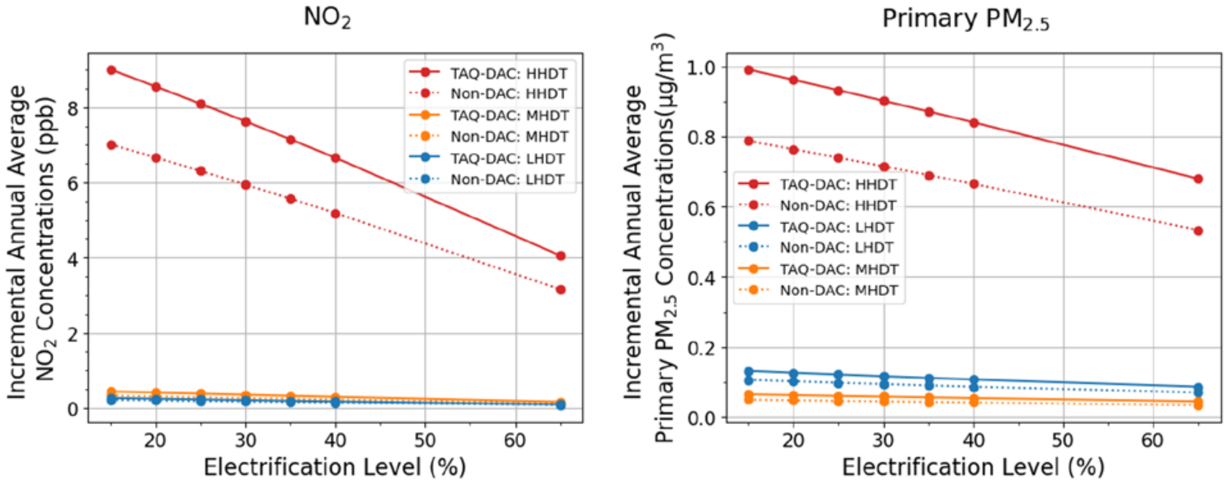

Figure ES-22. Incremental annual-average truck-related near-road NO_2 concentration (in parts per billion [ppb], left panel) and primary $PM_{2.5}$ (µg/m^3, right panel) by heavy-duty truck classification and electrification level in Los Angeles (2035)

HHDT = heavy heavy-duty vehicles, MHDT = medium heavy-duty vehicles, LHDT = light heavy-duty vehicles

Truck electrification equity metrics include:

- Exposure to poor air quality from traffic
- Disadvantaged community status
- Premature deaths and asthma-related health impacts from exposure to heavy duty truck emissions.

- Electrification of heavy-duty trucks could yield significant health benefits, including avoided premature deaths, hospital admissions and emergency room visits from cardiovascular and respiratory disease, asthma incidences, and acute myocardial infarctions (commonly known as heart attacks). Similar to the results for pollutant concentrations, TAQ-DACs benefit more than non-DACs for each increment of additional truck electrification fraction across most health endpoints assessed. For example, increasing electrification by 2035 from the baseline of 15% to 65% of heavy-duty trucks results in greater reduction in premature deaths in TAQ-DACs than in non-DACs (55% and 45% avoidance, respectively) (Figure ES-3). Similarly, avoided incidences of asthma in children are also accrued more by residents of TAQ-DACs (60%–65%, depending on electrification level) compared to the non-DACs (35%–40%).

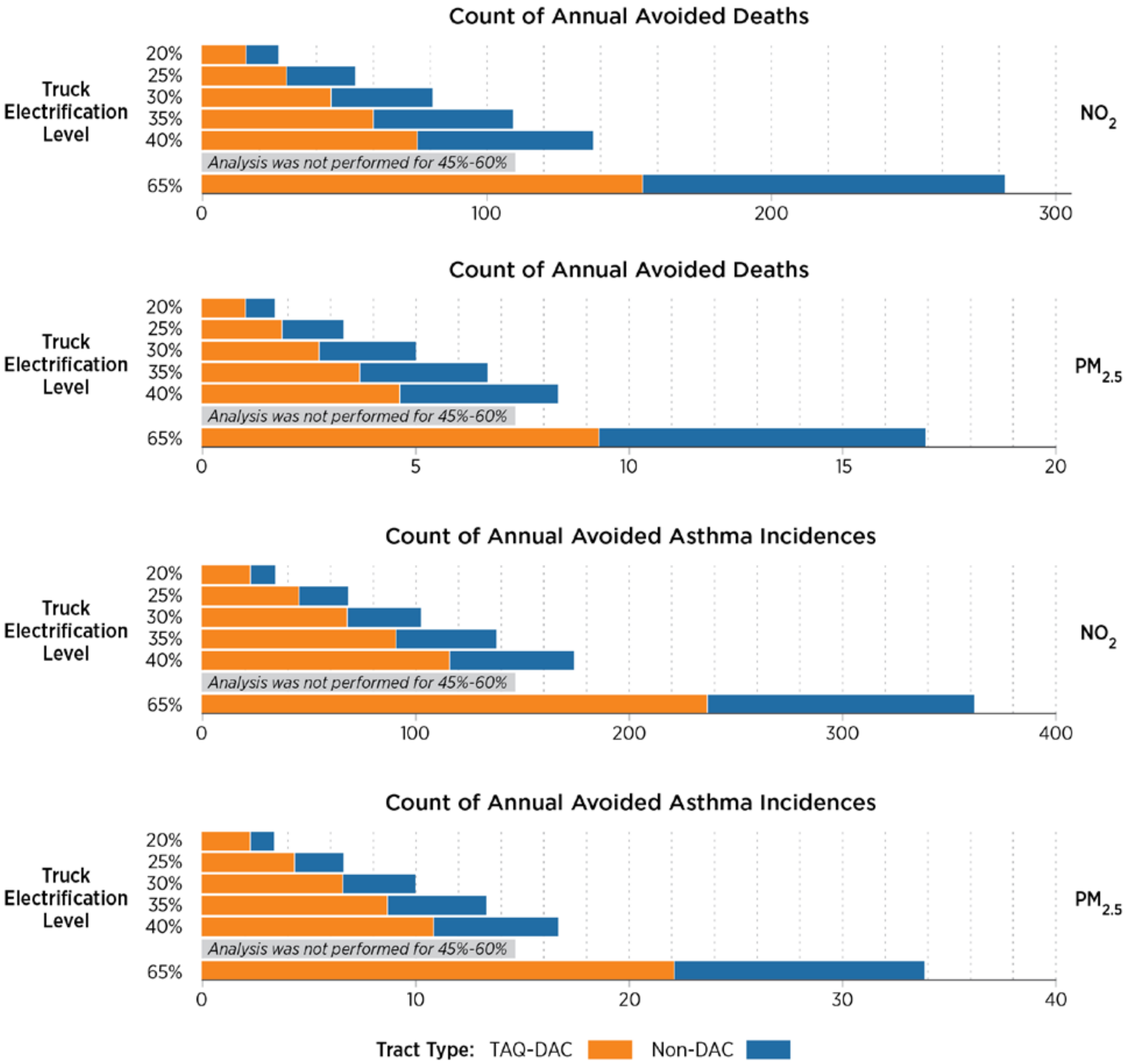

Figure ES-3. Premature deaths and asthma-related health benefits accrued by TAQ-DACs and non-DACs by heavy-duty truck electrification level relative to 15% electrification baseline (2035)

Avoided deaths are for people 25 years and older. Avoided asthma incidences are for children aged 17 years and younger. For both health endpoints, more benefits are accrued by residents living in TAQ-DACs compared to non-DACs.

Equity Strategies

Modeling, analysis, and community engagement identified the following strategy options for decision makers to achieve more-equitable outcomes in Los Angeles' transition to clean energy associated with electrification of heavy-duty trucks. Elaboration of these strategies is found in Section 3 (page 23).

Pursue electrification of LA-registered heavy-duty trucks (>8,500 lbs), and within that, prioritize heavy heavy-duty trucks (>33,000 lbs, HHDT) like fire trucks, dump trucks, fuel trucks, and heavy semi tractors to achieve the highest and most equitable air quality and health improvements.

Lead by example.

- Establish goals, a timeline, and a budget for electrification of LADWP's heavy-duty truck fleet in alignment with Charge Up LA! and California Air Resources Board's (CARB's) Advanced Clean Fleets targets.
    - Establish a carve-out target for electrification of the HHDT fleet.
- Consider adding a contractual provision requiring electrification of heavy-duty vehicle fleets over time by companies contracting with LADWP.

Establish citywide heavy-duty truck electrification goals.

- Establish a 2035 Charge Up LA! heavy-duty truck electrification goal (in addition to the existing 2025 and 2030 goals) aligned with the CARB Mobile Source Strategy and associated Advanced Clean Fleets regulation. Advanced Clean Fleets projects a roughly 40% heavy-duty electrified truck fleet by 2035. NREL analysis indicates this translates to a 2035 electric truck population of 28,000 in Los Angeles.
- Add an HHDT electrification goal as a share of the Charge Up LA! heavy-duty truck electrification goals.
- Establish citywide charging infrastructure targets aligned with truck electrification goals:[7]
    - 1,900–3,300 truck chargers by 2025
    - 5,400–9,600 truck chargers by 2030
    - 14,000–24,000 truck chargers by 2035.

Establish heavy-duty electric truck purchase incentives to achieve truck electrification goals.

- Promote and budget for scaling and potentially increasing the Charge Up LA! medium- and heavy-duty EV charging station rebate.[8]
- Establish a heavy-duty electric truck purchase incentive.

Collaborate on City of Los Angeles and other fleet electrification planning.

- Collaborate with city agencies to support electrification of city-owned HHDT fleets (e.g., fire trucks, dump trucks, fuel trucks) and development of necessary charging infrastructure.
- Locate incentivized charging infrastructure by working with city and regional agencies (e.g., Los Angeles Department of Transportation and Southern California Area Governments) to understand where HHDTs would ideally be charged, especially those servicing the POLA, the Port of Long

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[7] Heavy-duty truck charging would likely be connected to the higher-capacity 34.5-kilovolt (kV) portion of the distribution grid in Los Angeles, rather than the 4.8-kV distribution system that serves most smaller and residential loads (up to ~500 kilowatts [kW]). NREL conducted an equity analysis of upgrades and resilience for the 4.8-kV system that connects to most residents (Chapter 12), but did not analyze the 34.5-kV distribution system. Adding substantial heavy-duty vehicle charging loads may contribute to a need to upgrade the 34.5-kV distribution grid and, in combination with increasing electrification of vehicles and residential and commercial buildings, may be a catalyst for conversion of the 4.8-kV distribution system to a higher voltage as has been done in most U.S. cities.

[8] As of May 2023, LADWP offered a rebate of between $10,000 and $125,000 per charging station depending on charger type and size (Los Angeles Department of Water and Power 2022a).

Beach, and Los Angeles International Airport. Considerations can include available space, need for public or private fleet charging stations, planning for distribution grid upgrades, etc.

NREL modeling indicates achieving 2035 truck electrification goals could increase electricity demand by up to 2,800 gigawatt-hours (GWh) per year. If appropriate incentives and programs are designed and implemented, this level of increased demand could potentially help to increase flexible loads (NRDC 2021) and decrease rates (Los Angeles Department of Water and Power 2022b), but these outcomes would need to be studied further for verification.

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1 Introduction

Exposure to near-road traffic-related air pollutants has direct and inequitable health impacts that can be mitigated by vehicle electrification (HEI 2022). Traffic-related air pollutants include a complex mixture of gaseous pollutants such as oxides of nitrogen (NO and NO_2, named collectively NO_x); volatile organic compounds, polycyclic aromatic hydrocarbons, and carbon monoxide; and particle pollutants such as fine particulate matter ($PM_{2.5}$), ultrafine particles ($PM_{1.0}$), and elemental or black carbon (HEI 2022).

Traffic-related emissions can be a significant contributor to elevated concentrations of NO_x and $PM_{2.5}$ in communities close to or immediately downwind of roadways, and thus can lead to increases in health burdens associated with air pollutants for these communities. A recent study analyzing data from near-road monitoring sites (within a 50-meter distance from roadway)[9] found that the multiyear, national-average increment of additional daily concentration from vehicles traveling on roadways is +6.9 parts per billion (ppb) and +1.0 µg/m^3 for NO_2 and $PM_{2.5}$, respectively, (Gantt, Owen, and Watkins 2021), indicating higher air pollution-related health burden in communities near roadways.[10] Although there are no near-road monitors for $PM_{2.5}$ or NO_2 in Los Angeles, near-road increments in some nearby Southern California sites are even higher than these national averages (e.g., Riverside has NO_2 increments of approximately +10 ppb) (Gantt, Owen, and Watkins 2021; Mukherjee et al. 2020).

This analysis builds on the LA100 study (Cochran and Denholm 2021), which—with regard to transportation sources—focused on the benefits from electrification of light-duty vehicles (primarily passenger cars) operating on city roads as well as some categories of heavy-duty and off-road vehicles operating at the POLA and the Port of Long Beach (POLB). One gap identified in the LA100 analysis was electrification of heavy-duty vehicles.[11] Here, we focus on vehicles designated as heavy-duty trucks,[12] which can be classified into three different gross vehicle weight rating-based categories (California Air Resources Board 2021a):

- Light heavy-duty trucks (LHDT): 8,501 lbs–14,000 lbs (vehicle weight Class 2b–3)
- Medium heavy-duty trucks (MHDT): 14,001 lbs–33,000 lbs (vehicle weight Class 4–7)
- Heavy heavy-duty trucks (HHDT): ≥33,001 lbs (vehicle weight Class 8).

We collectively call these three categories “trucks” for brevity.[13]

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[9] These monitoring sites were established as part of the U.S. Environmental Protection Agency’s (EPA’s) 2010 National Ambient Air Quality Standard review for NO_2.

[10] For reference, the national ambient air quality standard for NO_2 is 53 ppb on an annual basis, and is 12 µg/m^3 for $PM_{2.5}$ (https://www.epa.gov/criteria-air-pollutants/naaqs-table).

[11] “Vehicles” means cars and trucks but is effectively synonymous with trucks when used in the context of heavy-duty since only trucks are in those weight classes.

[12] Note that buses are not included in this analysis despite them belonging to the class of heavy-duty vehicles because travel demand data were not available for them from the source used to support our analysis (Southern California Area Governments).

[13] While federal and state agencies, such as the Federal Highway Administration and California Air Resources Board (CARB), divide trucks into additional gross vehicle weight rating-based categories (Figure A-1, in Appendix A.1), we chose to group these vehicles into three truck categories based on availability of projected future vehicle activity data.

Trucks are only a small fraction of the total vehicle population, yet they generate more than 50% of vehicular emissions of NO_x in the portion of Los Angeles County that is within the South Coast Air Quality Management District (see Section 2.1, page 9). Potential truck emissions reduction strategies include mode shifting (e.g., to rail), improved logistics, and fleet conversion to several zero-emission vehicle types. We focus on vehicle electrification because of this strategy's nexus to the mission of LADWP. Furthermore, while other zero-emission vehicles such as fuel cell vehicles are emerging, they represent a small fraction of vehicles projected by CARB to meet air quality regulations (California Air Resources Board 2021b). Thus, only battery electric vehicles (BEVs) are considered in this analysis. Truck electrification is expected to yield significant air quality and health benefits, a hypothesis we test in our analysis.

We conduct a parametric sensitivity analysis wherein the electrified fraction of the on-road vehicle fleet of each of the three heavy-duty truck categories is varied incrementally from the electrification level required to meet the currently enforced California statewide policy (low) to a theoretical upper bound that goes far beyond current and proposed policies (high). Impacts on near-road air quality and health are studied at each electrification increment independently for each of the three truck categories. Although such an analysis could be conducted for the whole city, the focus of this analysis is on a subset of city tracts whose air quality is most affected by traffic sources. We classify these tracts into two categories: traffic air quality disadvantaged communities (TAQ-DACs, as defined in this chapter's executive summary) and selected non-DAC tracts. A map of the tracts (TAQ-DACs and non-DACs) analyzed is shown in Figure 1. We conduct this analysis for 2035, which is the year in which the city aims to achieve its goals of a clean, 100% carbon-free grid aligned with the LA100 Early & No Biofuels scenario (Cochran and Denholm 2021).

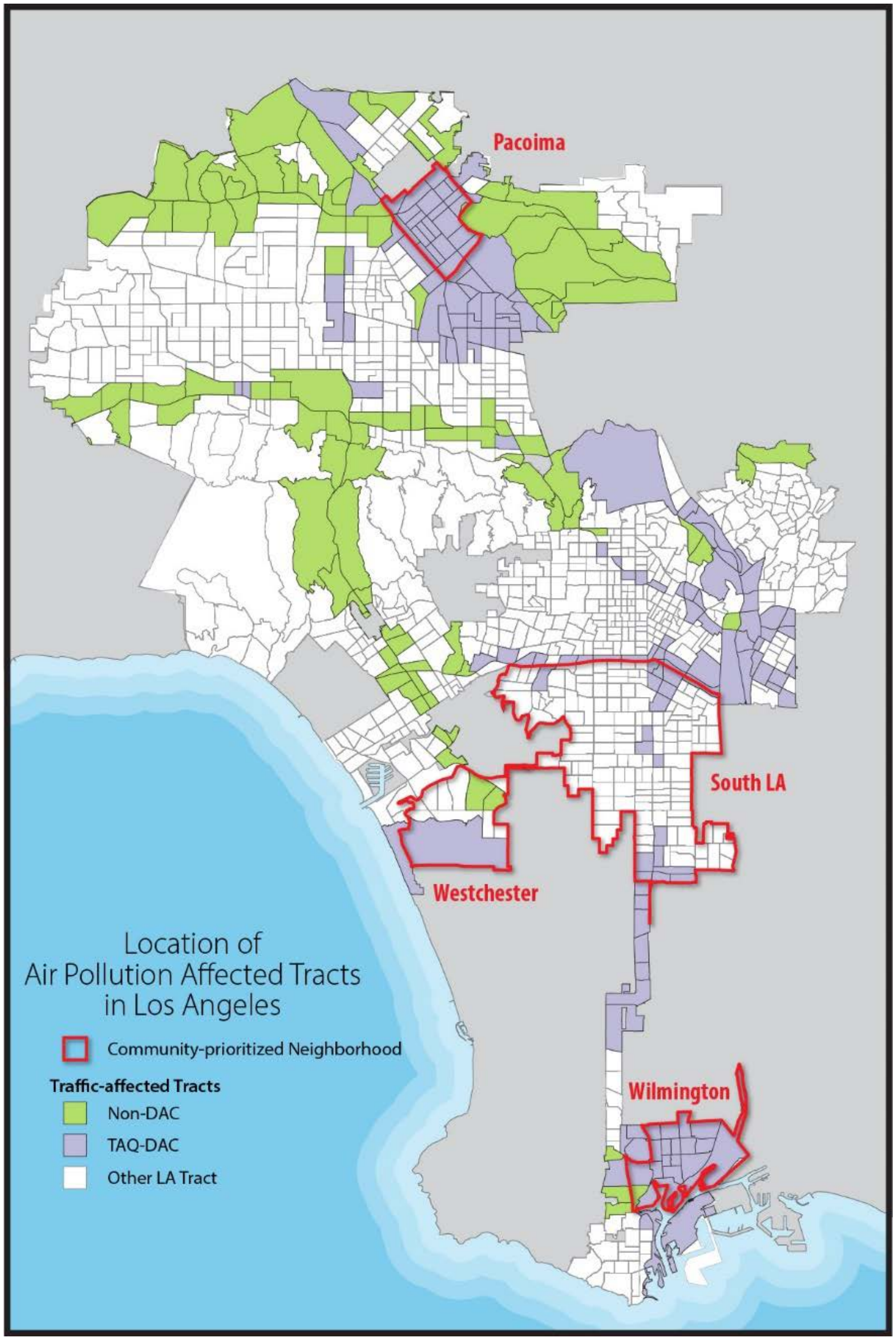

Figure 1. Location of traffic air pollution-affected tracts in Los Angeles

Traffic-affected non-DACs are shaded in green and traffic air quality affected DACs (TAQ-DACs) are shown in purple. Community-prioritized neighborhoods are outlined in red and annotated.

1.1 Modeling and Analysis Approach

This section describes the electrification adoption scenarios selected for this analysis, associated vehicle activity and pollutant emissions, and how we model changes in pollutant concentration in the near-road environment and health benefits at the census tract level. The overall workflow of this analysis is shown in Figure 2.

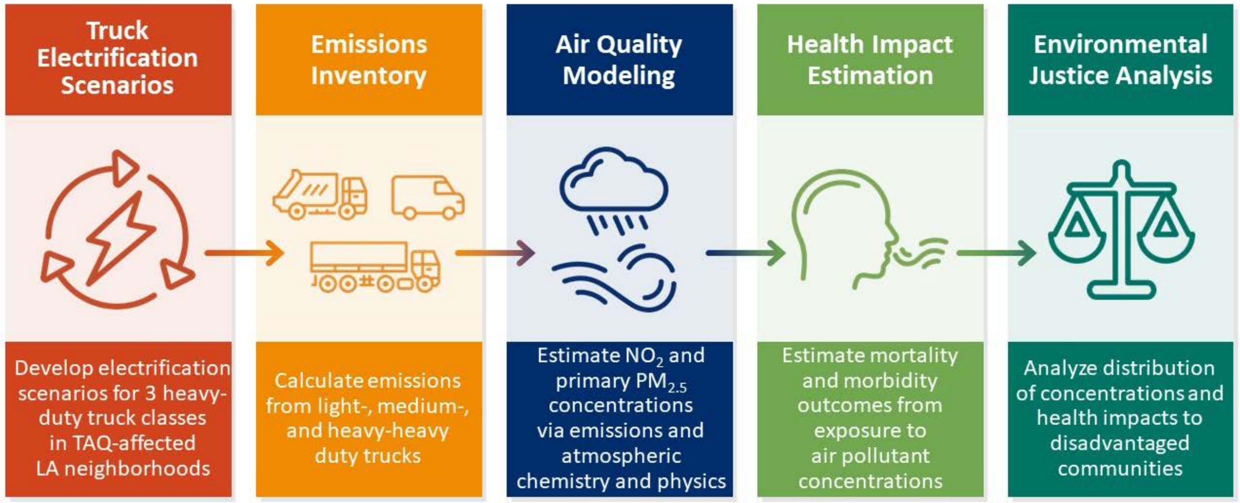

Figure 2. Air quality, health, and environmental justice impact analysis workflow informing equity strategy development

1.1.1 Electrification Scenarios

To investigate how near-road air pollution changes with increasing electrification of trucks registered in the City of Los Angeles, we use a parametric sensitivity analysis. We incrementally vary the electrified fraction of each of the three categories of trucks on major roadways in Los Angeles in 2035 from 15% to 65%, including 20%, 25%, 30%, 35%, and 40% electrification levels, and then estimate the change to air pollutant emissions and resultant concentration for each truck category and electrification level. The analysis is performed for all selected TAQ-DAC and non-DAC census tracts, as well as four community-prioritized neighborhoods: Pacoima, Wilmington, Westchester, and South LA.

Figure 3 annotates the electrification levels tested. The lower bound (15%) reflects compliance with CARB's Advanced Clean Trucks (ACT) regulation (California Air Resources Board 2023b), which was granted a Clean Air Act waiver from the U.S. Environmental Protection Agency (EPA) in March 2023 to allow it to go into effect (Davenport 2023). The regulation requires an increasing percentage of Class 2b–8 truck sales in California from 2024 to 2035. Zero-emission truck sales must reach 55%, 75%, and 40% of sales for Class 2b–3 trucks, Class 4–8 straight trucks, and Class 7 and 8 truck tractors, respectively, in 2035.[14]

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[14] The projection of future fleets composition in the EMFAC2021 model reflects the Advanced Clean Trucks (ACT) regulation; thus, we obtained the fraction of zero-emission trucks in the total registered truck fleets in 2035 from the EMFAC2021 model.

The middle point (40%) in the range of electrification levels tested is consistent with CARB's 2020 Mobile Source Strategy (MSS) (California Air Resources Board 2021b). This Strategy includes the now CARB-approved Advanced Clean Fleets (ACF) regulation[15] (California Air Resources Board 2023a) as well as an assumed accelerated turnover of MHDT and HHDT to meet the 2031 and 2037 South Coast Air Basin and San Joaquin Valley Air Basin ozone goals and the State of California's longer-term (2045 and 2050) climate targets. This regulation, if enacted as CARB approved it in April 2023, would require 100% zero-emission Class 2b–8 truck sales starting in 2036 in California.[16] CARB maintains an online tool called the DRAFT Mobile Emissions Toolkit for Analysis (META) (California Air Resources Board 2023d) that can translate a fraction of zero-emission truck purchases/sales to a fraction of total registered vehicles, which we use to estimate the truck electrification levels in 2035. Although the ACT and ACF regulations allow any zero-emission technology, for the purposes of our analysis, we assume 100% of the mandates would be met with electrified trucks.

The upper bound of the tested electrification levels (65%) assumes 100% zero-emission Class 2b–8 truck purchases starting in 2024 along with the accelerated turnover of MHDT and HHDT assumptions contained in the 2020 MSS. This information is used as input to CARB's META tool to estimate the fraction (i.e., 65%) of total registered trucks that are electrified in 2035. Note that this upper bound is highly unlikely given the current status of the zero-emission truck market, charging infrastructure, and other factors, but it is included in this analysis as a theoretically maximum benefit level.

A detailed description of the two CARB benchmark regulations and the conversion from zero-emission truck sales/purchase to zero-emission truck population using CARB's META tool is included in Appendix A.2.

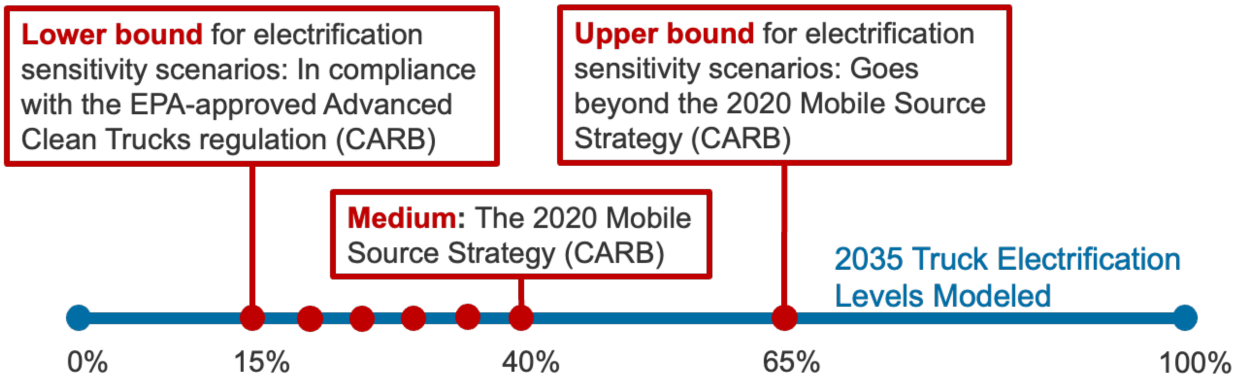

Figure 3. Analyzed 2035 truck electrification levels in the City of Los Angeles and associated CARB-approved regulations

We also analyze the near-road impacts of the two University of California Los Angeles (UCLA)-designed truck electrification scenarios: the Equity scenario and the Equity Mobile Source Strategy scenario (referred to as the "UCLA Equity" and the "UCLA MSS" scenarios in this

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[15] To be enforceable, the EPA must approve the Advanced Clean Fleets regulation.

[16] Some truck vocational categories, such as drayage trucks and delivery trucks, are required to reach 100% zero-emission truck purchases before 2035 in the Advanced Clean Fleets regulation.

report). The near-road air quality impact analysis of these two scenarios is discussed in Appendix A.10, and the results of the regional air quality impact analysis of these two scenarios can be found in UCLA's Chapter 14. Because UCLA's scenarios test vehicle electrification levels contained within the range tested here, their results are consistent with the sensitivity analysis results.

1.1.2 Emission Inventory Development

An emission inventory that quantifies when, where, and how much of a pollutant is emitted is the main input to an air quality model. For the three heavy-duty truck categories, emissions are quantified as follows:

$$Emission_{h,v,l} = \sum_{s,f} VMT_{h,v,l,f} \times EF_{h,v,s,f}$$

where emissions for the pollutant of interest (NO_x or $PM_{2.5}$) are calculated for each hour (*h*) of the year, for each vehicle type (*v*), and for each link (*l*), which is a linearized road segment usually a few hundred meters or less in length.

Roads considered in our analysis include most roads in the Southern California Association of Governments (SCAG) database, including freeways, major and minor arterials, major and minor collectors, and ramps (SCAG 2020).[17] We also include traffic on local roads to the extent these roads are included in the SCAG database. Areas where this distinction could be important are within large facilities like the Ports of Los Angeles and Long Beach and Los Angeles International Airport (LAX). Geospatial representation of the roads within these facilities is sparse (i.e., not all roads are included in the SCAG database). However, at these facilities, roadway emissions may be dwarfed by emissions from other sources, as detailed in the appendix (Figures A-7 and A-8 in the appendix). Communities downwind of these facilities are also exposed to these non-road emissions, which are not modeled in this study.

Vehicle miles traveled (VMT) for each hour, vehicle type, and link are based on link-level activity data from travel demand modeling conducted by SCAG (2020). VMT by fuel type (*f*) are based on projected VMT in CARB's Emission FACtor model (EMFAC) for 2035, with appropriate adjustments made for assumed electrification level for each truck category. Likewise, the emission factor, which varies by vehicle category, speed (*s*), and fuel type, is also estimated from EMFAC. Note that the fleet electrification levels described in Section 1.1.1 (page 4) are converted to corresponding changes in VMT for the inventory development. Additional information on the statistical analysis of the SCAG VMT data and the development of emission factors using the EMFAC model is included in Appendix A.3.

In this analysis, we focus on NO_x emissions from running exhaust; other processes, including engine start and idling, are not considered. From CARB's EMFAC2021 (v1.0.2), within the Los Angeles South Coast subarea's on-road emissions, start emissions contribute 4%–17% while idling emissions contribute 2%–11% to total NO_x tailpipe exhaust emissions from the three

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[17] SCAG data also include some road geometries that represent connectors of traffic analysis zone centroids and are not real roads, and thus were not included here.

categories of heavy-duty trucks (Figure A-5 in Appendix A.3). The exclusion of these processes could represent an important gap to address with future research because community-identified neighborhoods with poor air quality—for instance surrounding the ports—may have a large proportion of NO_x emissions from trucks waiting to enter, depart, and drop off or pickup cargo. Similarly, $PM_{2.5}$ emissions from running exhaust, tire wear, and brake wear are included; road dust emissions are not considered.

1.1.3 Near-Road Air Quality Modeling

The focus of this analysis is near-road communities, which experience disproportionately high pollutant concentrations, specifically NO_x, and directly emitted (so-called, "primary") $PM_{2.5}$. Here, a research-grade line-source air quality model called R-LINE (Snyder et al. 2013) is used to predict $PM_{2.5}$ and NO_2 concentrations caused by the analyzed truck emissions (often referred to as "incremental" concentrations because they are additional to concentrations caused by other sources). R-LINE is based on a steady-state Gaussian formulation and is designed to simulate ground-level, line-type source emissions (e.g., mobile sources along roadways) by numerically integrating emissions from points along a line.[18] The most recent version of R-LINE is implemented as part of AERMOD, an EPA-approved, peer-reviewed, regulatory model that is freely available (Cimorelli et al. 2005; Perry et al. 2005). A simplified, Tier-2 NO_x chemistry option is used in R-LINE, which accounts for conversion of directly emitted NO to NO_2. The modeling and analysis domain covers the selected TAQ-DAC and non-DAC tracts, and the community-prioritized neighborhoods within Los Angeles, as shown in Figure 1, at a spatial resolution of 100 meters × 100 meters. The meteorological input data to air quality modeling are described in Appendix A.4.

R-LINE has been shown to overpredict concentrations of NO_2 and $PM_{2.5}$ under low-wind (i.e., stable) conditions that typically occur during nighttime (Zhai et al. 2016; Pandey, Venkatram, and Arunachalam 2023; Pandey and Sharan 2019; Chang et al. 2023). We applied feasible approaches to mitigate this bias but believe that some remains. We find that annual-average concentration *changes* modeled by R-LINE are similar to those modeled by UCLA's Weather Research and Forecasting model coupled with Chemistry (WRF-Chem) model, a state-of-the-science model. Because our analysis focuses on benefits due to *changes* in concentrations (corresponding to a change in electrification level), use of R-LINE for this analysis is deemed reasonable and allows us to test more scenarios than can be done using a more detailed but computationally complex model like WRF-Chem. Further information about changes we made to the default version of R-LINE, as well as results of model evaluation, are included in Appendix A.4.

1.1.4 Health Impacts Modeling and Environmental Justice Analysis

Both $PM_{2.5}$ and NO_2 traffic air pollutants cause health issues including asthma, cardiovascular disease, respiratory disease, and premature mortality (HEI 2022). We model health benefits that could accrue to city residents as a result of emissions reductions from electrifying trucks in selected TAQ-DAC and non-DAC tracts using a methodology similar to that used in the LA100

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[18] Although the model includes algorithms for simulating the near-source effects of complex roadway configurations (e.g., noise and vegetative barriers, and depressed roadways), we consider all roadways to be flat (i.e., have no surrounding vertical complexities).

study (Heath et al. 2021). The basis of our analysis relies on the EPA's Environmental Benefits Mapping and Analysis Program (BenMAP) model (Sacks et al. 2018), with updated health effect estimates identified in the most recent meta-analysis conducted by a Health Effects Institute panel (HEI 2022). Details of specific mortality and morbidity health endpoints analyzed are provided in Appendix A.5. Environmental justice analysis is conducted for the TAQ-DAC and non-DAC tracts using methods developed in the LA100 study (Hettinger et al. 2021).

2 Modeling and Analysis Results

This section presents air pollutant emissions and concentration reductions under the tested electrification levels as well as public health benefits associated with these reductions in air pollutant concentrations. Environmental justice implications of concentration reductions and public health benefits are also discussed. Finally, this section reports estimates of electric truck population-associated increase in electricity demand and charging infrastructure in Los Angeles for 2035. Results caveats, as well as suggestion of future research directions for improvements to this chapter's research are included in Appendix A.12.

2.1 Current NO_x and Primary $PM_{2.5}$ Emissions from Heavy-Duty Trucks

Figure 4 shows the current contribution of heavy-duty trucks to the on-road motor vehicle fleet and on-road air pollutant emissions in Los Angeles based on EMFAC2021 (California Air Resources Board 2022). Although heavy-duty trucks account for only 5% of registered vehicles in Los Angeles, they account for 51% of emissions of nitrogen oxides (NO_x) from on-road transportation sources and 32% of primary $PM_{2.5}$ emissions. Of the three heavy-duty truck categories, HHDT has the smallest fleet population but the highest NO_x and primary $PM_{2.5}$ emissions because of its high emission factors of running exhaust NO_x and brake wear $PM_{2.5}$. Based on emission factors from EMFAC2021, a diesel HHDT emits 50× more NO_x and 7× more brake wear $PM_{2.5}$ than a gasoline passenger vehicle per mile traveled.

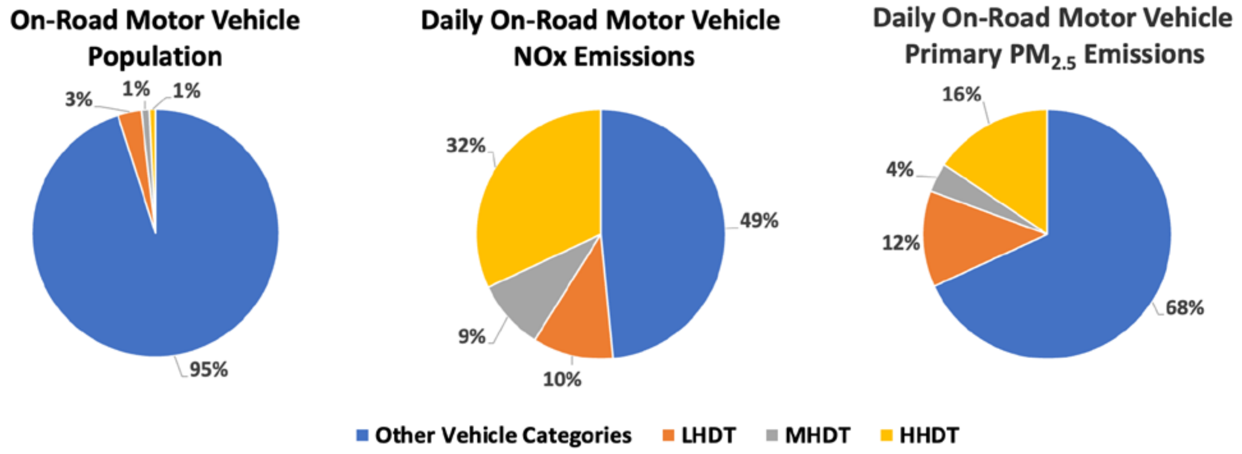

Figure 4. Fractional distribution of 2022 on-road motor vehicles registered in Los Angeles, and daily on-road motor vehicle NO_x and primary $PM_{2.5}$ emissions

The figure is based on data from the EMFAC2021 model for Los Angeles (South Coast subarea) for 2022. Heavy-duty trucks are categorized as LHDT, MHDT, and HHDT. All other on-road vehicle categories are aggregated into "Other Vehicle Categories."

2.2 City-Wide Heavy-Duty Truck NO_x and Primary $PM_{2.5}$ Emissions by Electrification Level in 2035

Figure 5 shows changes in citywide emissions of NO_x and primary $PM_{2.5}$ from heavy-duty trucks on selected roads as a function of the level of electrification for each truck category's on-road fleet. NO_x emissions from HHDTs are approximately 8–10× the combined emissions from

LHDTs and MHDTs at each electrification level. $PM_{2.5}$ emissions, which include emissions from running exhaust, tire wear, and brake wear (the difference in braking systems for combustion versus electric engines with regenerative brakes is accounted for), are also dominated by HHDTs, and decrease linearly with increasing vehicle electrification, although at a slower rate than NO_x emissions. $PM_{2.5}$ emissions decrease more slowly than NO_x because even when exhaust emissions are eliminated in switching to electric drive trains, tire wear and brake wear $PM_{2.5}$ emissions do not decrease as significantly because electric vehicles (EVs) still have tires and brakes. Details on the emissions from different $PM_{2.5}$ processes are included in Appendix A.6 (Figure A-5).

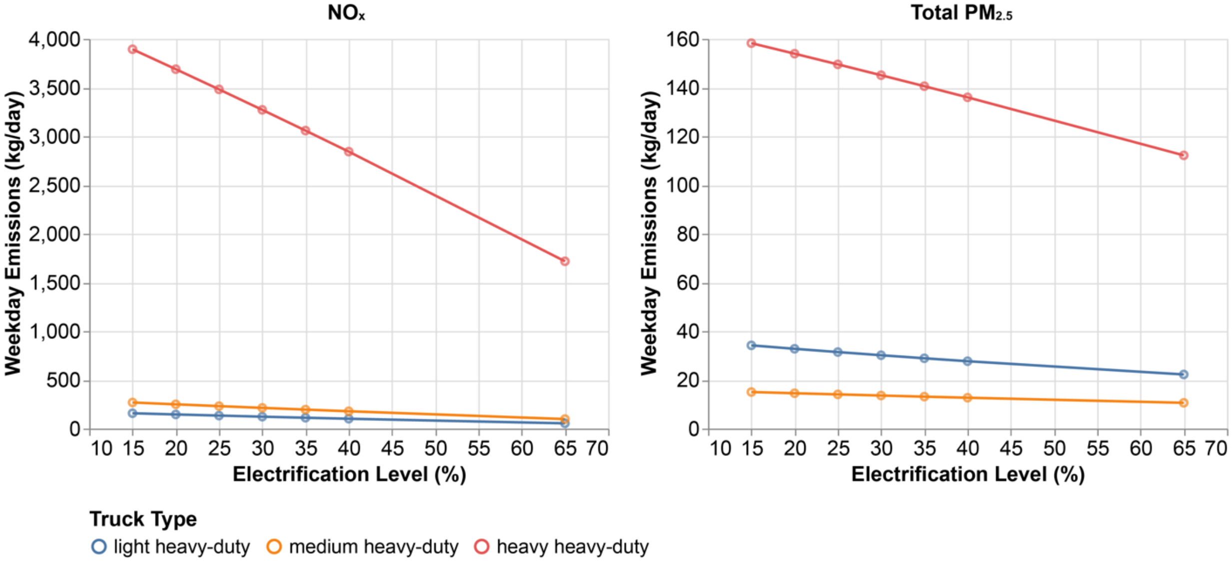

Figure 5. Projected daily emissions of NO_x and total primary $PM_{2.5}$ from each heavy-duty truck category for a typical weekday in Los Angeles in 2035 as a function of on-road fleet electrification level from 15% to 65%

NO_x emissions shown here are those from running exhaust, and (total) $PM_{2.5}$ emissions include emissions from running exhaust, tire wear, and brake wear.

2.3 Truck-Related Near-Road NO_2 and Primary $PM_{2.5}$ Concentrations by Electrification Level in 2035

Figure 6 shows LHDT-, MHDT-, and HHDT-induced near-road NO_2 and primary $PM_{2.5}$ concentrations averaged across selected TAQ-DACs and non-DACs under tested electrification levels. (Note that the modeled NO_2 and primary $PM_{2.5}$ concentrations are likely being overestimated by AERMOD.) There are linear reductions in both NO_2 and primary $PM_{2.5}$ near-road concentrations with increasing electrification for both TAQ-DAC and non-DAC tracts. Of the three heavy-duty truck categories, HHDT dominates truck-related NO_2 (>90%) and primary $PM_{2.5}$ (>80%) incremental concentration under every electrification level, as well as reductions in truck-related NO_2 (>90%) and primary $PM_{2.5}$ (>80%) concentration moving from low to high electrification levels.

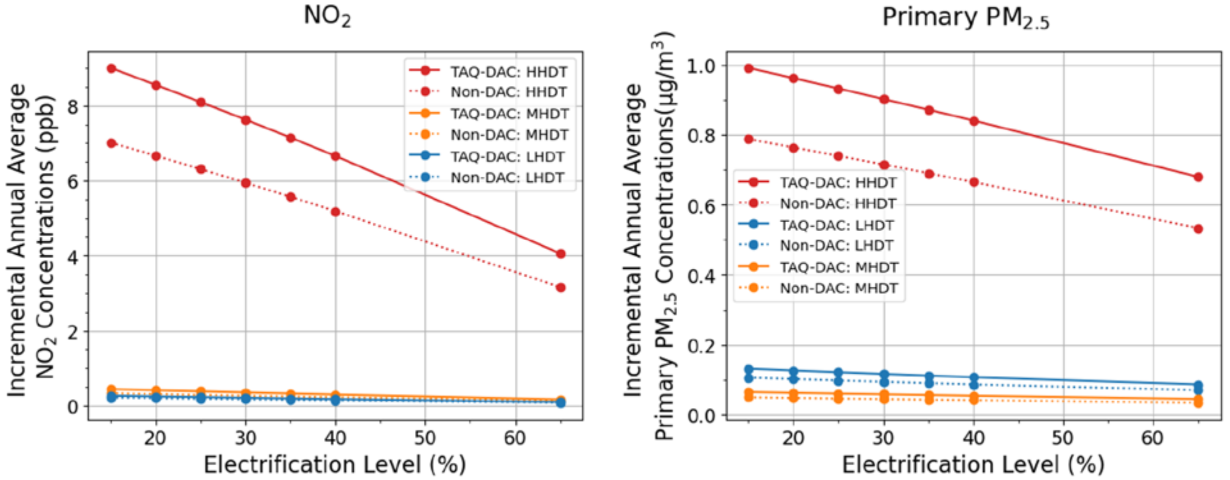

Figure 6. Incremental annual-average truck-related near-road NO_2 concentrations (ppb, left panel) and near-road primary $PM_{2.5}$ concentrations ($\mu g/m^3$, right panel) at tested electrification levels

The incremental near-road pollutant concentrations are shown separately for TAQ-DACs (solid lines) and non-DACs (dotted lines) by truck categories (LHDT in blue, MHDT in orange, and HHDT in red).

Table 1 reports the sensitivity (i.e., the slopes of lines in Figure 6) of changes in near-road NO_2 and primary $PM_{2.5}$ concentrations to increases in electrification levels. Since the change in concentration of both pollutants is linear with respect to electrification level, the table can be used to estimate reductions in near-road NO_2 and primary $PM_{2.5}$ concentrations from different truck electrification levels that are not modeled in this report. As shown in the table, with a 1% increase in HHDT electrification, on average, TAQ-DAC tracts can benefit from a 0.099 ppb and 0.0062 $\mu g/m^3$ decrease in near-road NO_2 and $PM_{2.5}$ concentrations, respectively, which is 28% and 22% more than non-DAC tracts. Benefits of near-road NO_2 ($PM_{2.5}$) concentration reductions from a 1% increase in both LHDT and MHDT electrification are 10× (5×) smaller than with HHDT. This applies to both TAQ-DACs and non-DACs.

Table 1. Reduction in Annual-Average Near-Road NO_2 and Primary $PM_{2.5}$ Concentrations Achieved With 1% Increase in Electrification of On-Road Trucks in TAQ-DACs and Non-DACs

	Near-Road NO_2 (ppb)			**Near-Road Primary $PM_{2.5}$ ($\mu g/m^3$)**		
Tract Category	**LHDT**	**MHDT**	**HHDT**	**LHDT**	**MHDT**	**HHDT**
TAQ-DAC	0.0034	0.0055	0.099	0.0009	0.0004	0.0062
Non-DAC	0.0028	0.0041	0.077	0.0007	0.0003	0.0051
	Increased Benefits for TAQ-DAC versus non-DAC					
(TAQ-DAC – Non-DAC) / Non-DAC	21%	34%	28%	28%	33%	22%

Air quality benefits that can be achieved by electrifying heavy-duty trucks are spatially heterogeneous (Figure 7). National Renewable Energy Laboratory (NREL) modeling indicates near-road pollutant concentration reductions in tracts closest to freeways—including Interstate

Highways 5, 10, 110, and 405, and U.S. Highway 101—are larger than those in tracts near arterial roads and those near LAX and the POLA. The largest tract-level reduction in near-road annual-average NO_2 concentrations (22.2 ppb) is observed in the Boyle Heights neighborhood near I-5 (Golden State Freeway). The largest tract-level reduction in annual-average near-road primary $PM_{2.5}$ concentrations (1.6 µg/m^3) is observed in the Pacoima neighborhood near I-5.

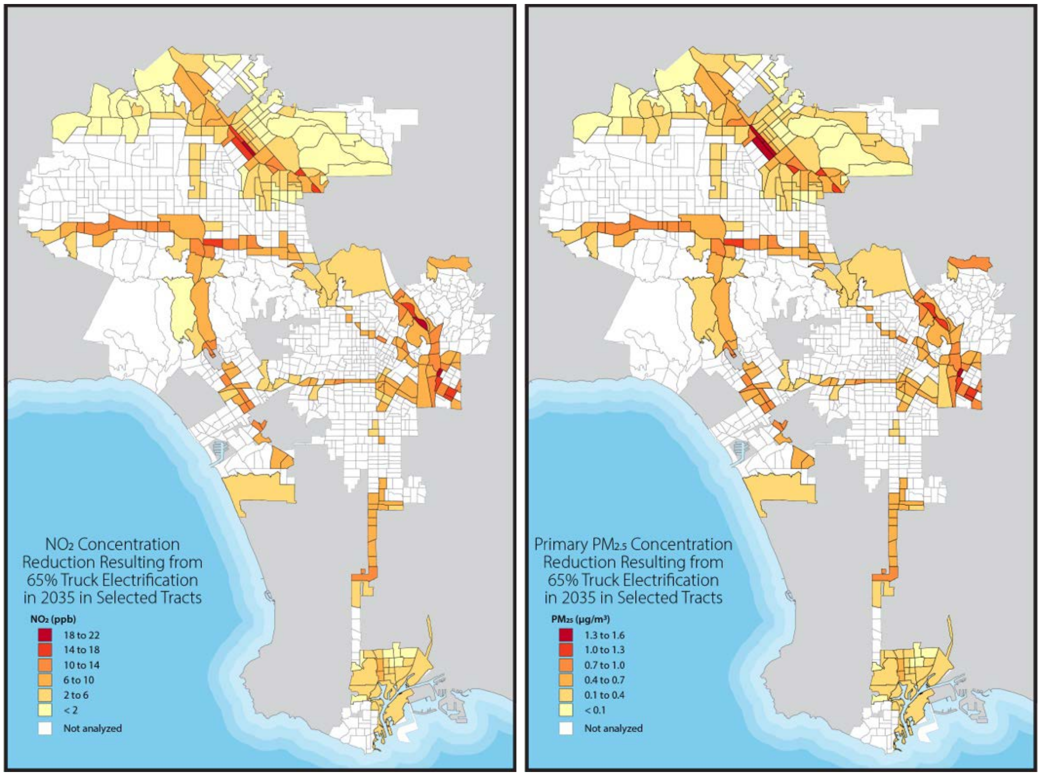

Figure 7. Spatial pattern of reductions in 2035 near-road truck-related NO_2 concentrations (ppb, left panel) and primary $PM_{2.5}$ (µg/m^3, right panel) from the 15% electrification scenario compared to the 65% electrification scenario

Comparisons between the 15% and 65% electrification levels are shown for the maximum reductions in truck-related NO_2 and $PM_{2.5}$ concentrations tested in this report. The spatial patterns are similar for other comparisons between different electrification levels but at smaller delta values.

2.4 Heavy-Duty Truck Electrification Public Health Benefits by Electrification Level in 2035

Electrification of heavy-duty trucks can provide health benefits such as avoided hospital admissions, emergency room visits, asthma exacerbation, as well as avoiding premature deaths by reducing exposure to $PM_{2.5}$ and NO_2. The health benefits of truck electrification are reported here as annual benefits, which means they accrue every year with the same electrification levels, and thus will accumulate significantly over long periods of time. In addition, this analysis focuses on census tracts near major roadways, and health benefits estimates are specific to those tracts. Benefits also accrue to residents of neighborhoods living further away from the selected major roadways. In this regard, benefits quantified in this analysis underestimate citywide benefits. The further from major roadways (especially freeways), the lower the near-road concentration improvement from truck electrification; thus, benefits do not increase linearly with increasing aerial extent of air quality modeling domain. As the air quality model used in this analysis is known to overpredict air pollutant concentrations, especially the concentration of NO_2, any overprediction of NO_2 concentration will lead to a commensurate overestimation of health benefits. Although the degree of overestimation is unknown, and thus the magnitude of health benefits associated with NO_2 concentration reduction are not accurate, the percentage change to NO_2 concentration and associate health effects from incremental increases in truck electrification should be more reliable.

Avoided deaths from five discrete electrification levels of the truck population relative to the base electrification level (15%) are shown in Figure 8. About 27 premature deaths per year could be avoided from lower $PM_{2.5}$ concentration, and several hundred deaths per year from lower NO_2 concentration in the 65% electrification scenario relative to the 15% scenario. In almost all scenarios, slightly greater benefits are accrued by TAQ-DACs, with about 53% to 54% of the avoided deaths in TAQ disadvantaged communities in the case of $PM_{2.5}$ and NO_2, respectively.

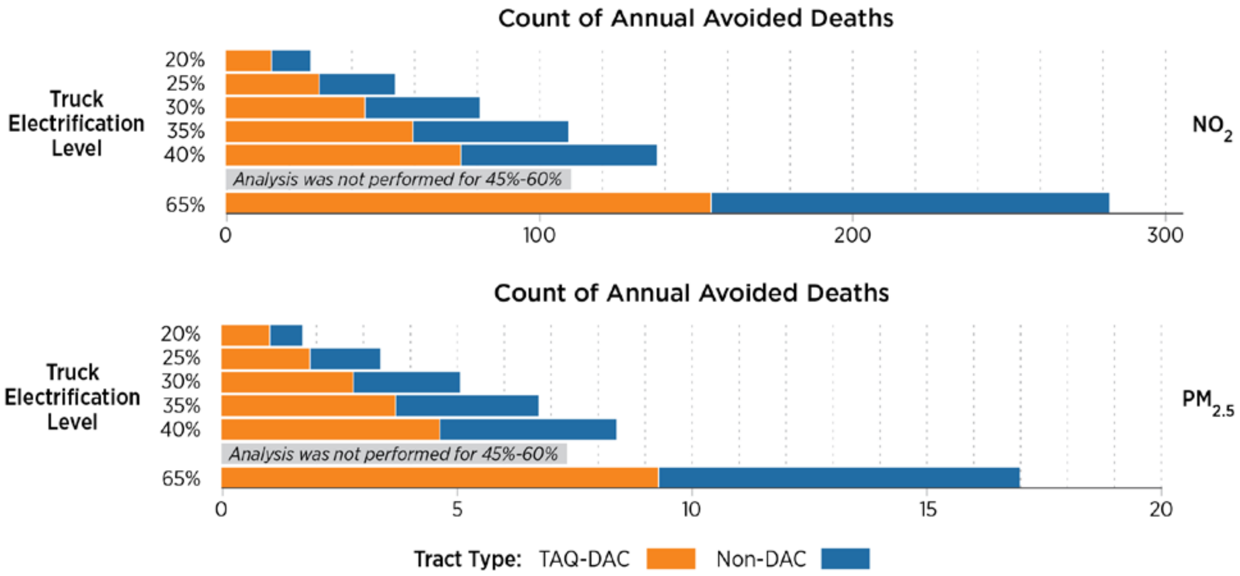

Figure 8. Annual avoided premature deaths from heavy-duty truck electrification for NO_2 and $PM_{2.5}$ by electrification level relative to 15% electrification baseline (2035)

Avoided exposure to NO_2 is the cause of most avoided deaths (top) with primary $PM_{2.5}$-related avoided deaths (bottom) being a relatively smaller fraction. TAQ-DACs accrue slightly higher benefits compared to the modeled non-DACs in this analysis. The reported avoided deaths are for age 25 and over.

The morbidity-related health benefits shown in Figure 9 are additional to avoided mortality (death). Our analysis suggests that large benefits could accrue by both TAQ-DACs and non-DACs from electrification of heavy-duty trucks. Annual cardiovascular and respiratory disease-related hospital admissions for population aged 65 years and older (top row, Figure 9) decrease because of a reduction in exposure to $PM_{2.5}$, and the benefits are almost equally distributed between the TAQ-DACs and non-DACs analyzed.[19] Quantified NO_2 and $PM_{2.5}$-related benefits for asthma and acute myocardial infarctions (AMIs) are also shown in Figure 9 (bottom row). Reduction in ambient NO_2 concentration due to truck electrification is likely to reduce asthma incidences in children (aged 0–17 years) by several hundred per year in high electrification scenarios. A decrease in primary $PM_{2.5}$ concentration is likely to provide additional benefits by avoiding asthma incidences, although not as large as from NO_2. Asthma avoidances could be higher in TAQ-DACs, which accrue about 60%–65% of the benefits. Heart attacks (AMI) cases (for population aged 65 years and over) also decrease from electrification with avoided cases slightly greater in TAQ-DACs (55%) than in non-DACs (45%).

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[19] No NO_2 benefits were quantified for cardiovascular and respiratory disease-related hospital admissions because of a lack of health impact functions for these diseases from exposure to NO_2.

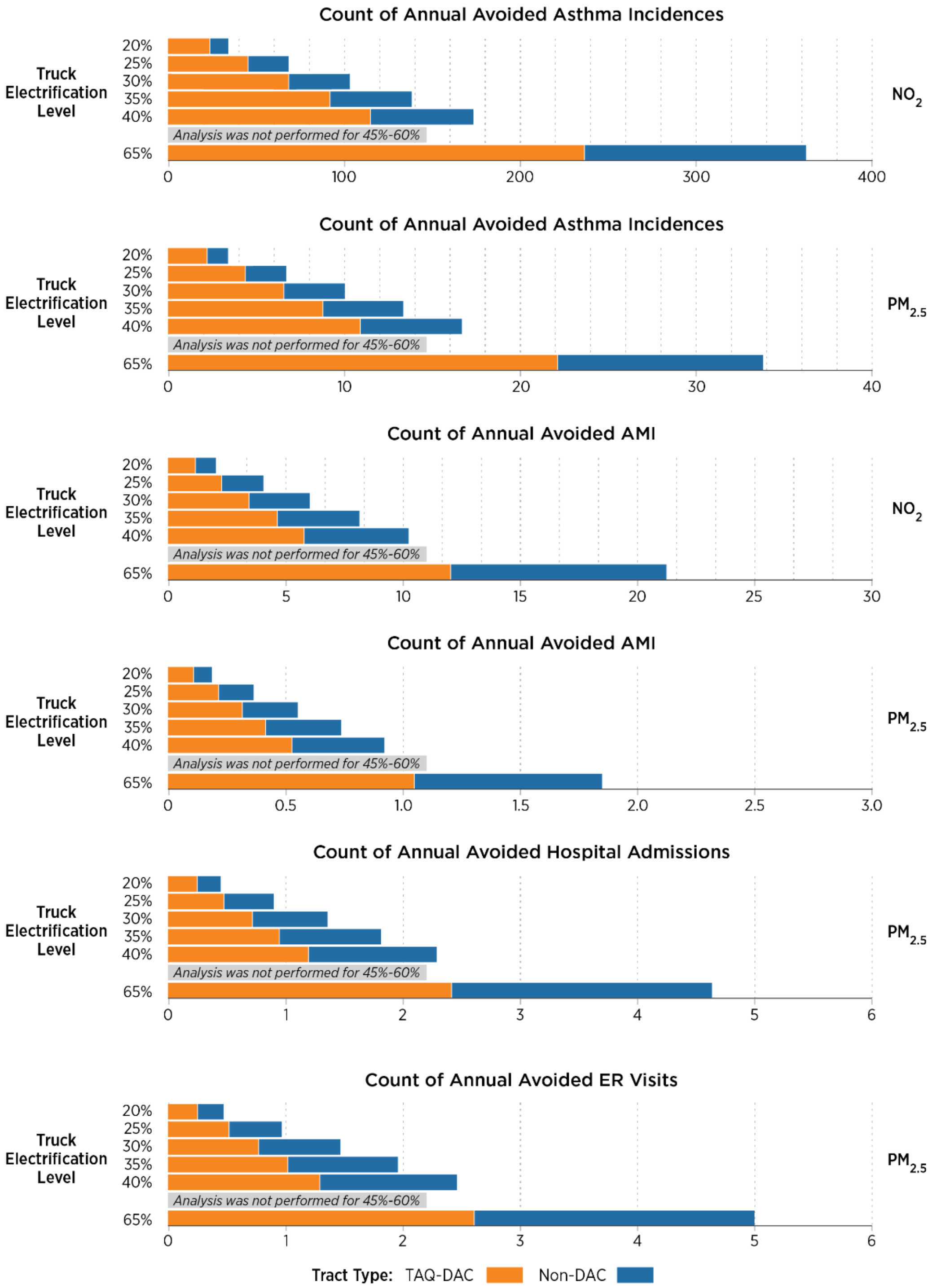


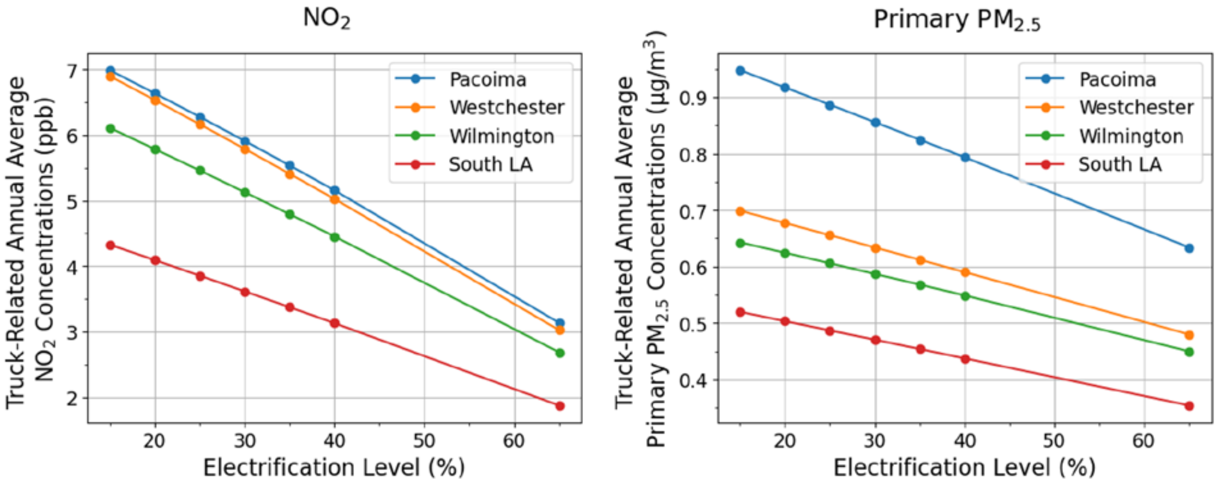
Figure 9. Annual morbidity-related health benefits from heavy-duty truck electrification by electrification level relative to 15% electrification baseline (2035)

The top four panels display incidences of asthma and acute myocardial infarction (AMI, aka heart attack) caused by both NO_2 and $PM_{2.5}$ avoided due to truck electrification. Avoided hospital admissions and emergency room (ER) visits in the bottom two panels include combined outcomes for cardiovascular and respiratory diseases and are only quantified for $PM_{2.5}$ because of lack of relevant health impact functions for NO_2. Reported avoided asthma incidences are for children (age 0–17), AMIs are for age 18 and over, and hospital admissions and ER visits are for people age 65+.

2.5 Truck-Related Pollutant Concentrations and Health Impacts in Community-Prioritized Neighborhoods in 2035

In addition to the TAQ-DACs and non-DACs selected throughout the city, we analyzed 2035 near-road air pollutant (NO_2 and primary $PM_{2.5}$) concentration changes and associated public health benefits in four neighborhoods prioritized by the community: Pacoima, South LA, Westchester, and Wilmington, under varying electrification levels (Figure 10). The comparison of pollutant concentrations at those four neighborhoods with the concentrations at the selected TAQ-DACs and non-DACs are included in Appendix A.8. The neighborhoods were identified as having air quality or truck traffic challenges based on guidance from the LA100 Equity Strategies Steering Committee, listening sessions with community-based organizations and community members, and community meetings.

Consistent with the results shown for the selected TAQ-DACs and non-DACs, near-road NO_2 and primary $PM_{2.5}$ concentrations at the four selected LA neighborhoods decrease linearly with increased electrification levels. When comparing the 65% electrification level to the 15% electrification level, near-road NO_2 and primary $PM_{2.5}$ concentrations decrease by 55%–57% and 30%–32%, respectively.



(a) (b)

Figure 10. Average annual truck-related near-road NO_2 concentrations (a) and primary $PM_{2.5}$ concentrations (b) in community-prioritized neighborhoods by electrification level

Truck-related NO_2 and primary $PM_{2.5}$ concentrations are summed for the three heavy-duty truck categories: LHDT, MHDT, and HHDT.

Among the neighborhoods analyzed, Pacoima shows the highest truck-related near-road NO_2 and primary $PM_{2.5}$ concentrations under every electrification level because some census tracts within Pacoima are close to I-5, which has a high volume of truck traffic. Conversely, South LA has the lowest truck-related near-road NO_2 and $PM_{2.5}$ among the four community-identified neighborhoods, likely because most of the tracts are not close to major freeways with high truck volume and thus trucks are not the dominant air pollutant source in the area. Westchester, the neighborhood adjacent to LAX, and Wilmington, the neighborhood in between the POLA and POLB, also show lower truck-related near-road NO_2 and primary $PM_{2.5}$ concentrations than Pacoima (and the average among selected TAQ-DACs and non-DACs shown in Figure A-9).[20]

Avoided premature deaths are shown in Figure 11 for the four neighborhoods prioritized by the community. Neighborhood results include all tracts that are part of each neighborhood, independent of whether these tracts are classified as TAQ-DACs or non-DACs. Our analysis shows that in South LA, a region comprising 28 neighborhoods, the 65% truck electrification level could help avoid approximately 75 premature deaths, mostly from avoided exposure to NO_2.[21] In other neighborhoods, reduction in exposure to NO_2 also drives the health results shown in Figure 11. $PM_{2.5}$ exposure accounts for only 5–6% of avoided deaths in these four neighborhoods. Results for additional health endpoints (cardiovascular and respiratory hospital admissions, asthma incidences, and heart attacks) are included in Appendix A.8 (Table A-6).

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[20] Heavy-duty trucks operating in POLA/POLB and LAX are small portions of total air pollutant emissions from these facilities. Residents living in Wilmington and Westchester will experience air quality from all sources within those facilities, not just the heavy-duty trucks modeled here. Consequently, electrification of trucks operating in those neighborhoods will not reduce overall air pollution as much as in neighborhoods whose main source of air pollutants are major roads. More information about sources of air pollutants within POLA/POLB and LAX is in Appendix A.7. Further information about how we estimated truck emissions within POLA/POLB and LAX is in the "Emission Inventory Development" section.

[21] While the formal geographic boundary of South LA includes areas outside the City of Los Angeles, results included here are only for the portion of South LA within the city.

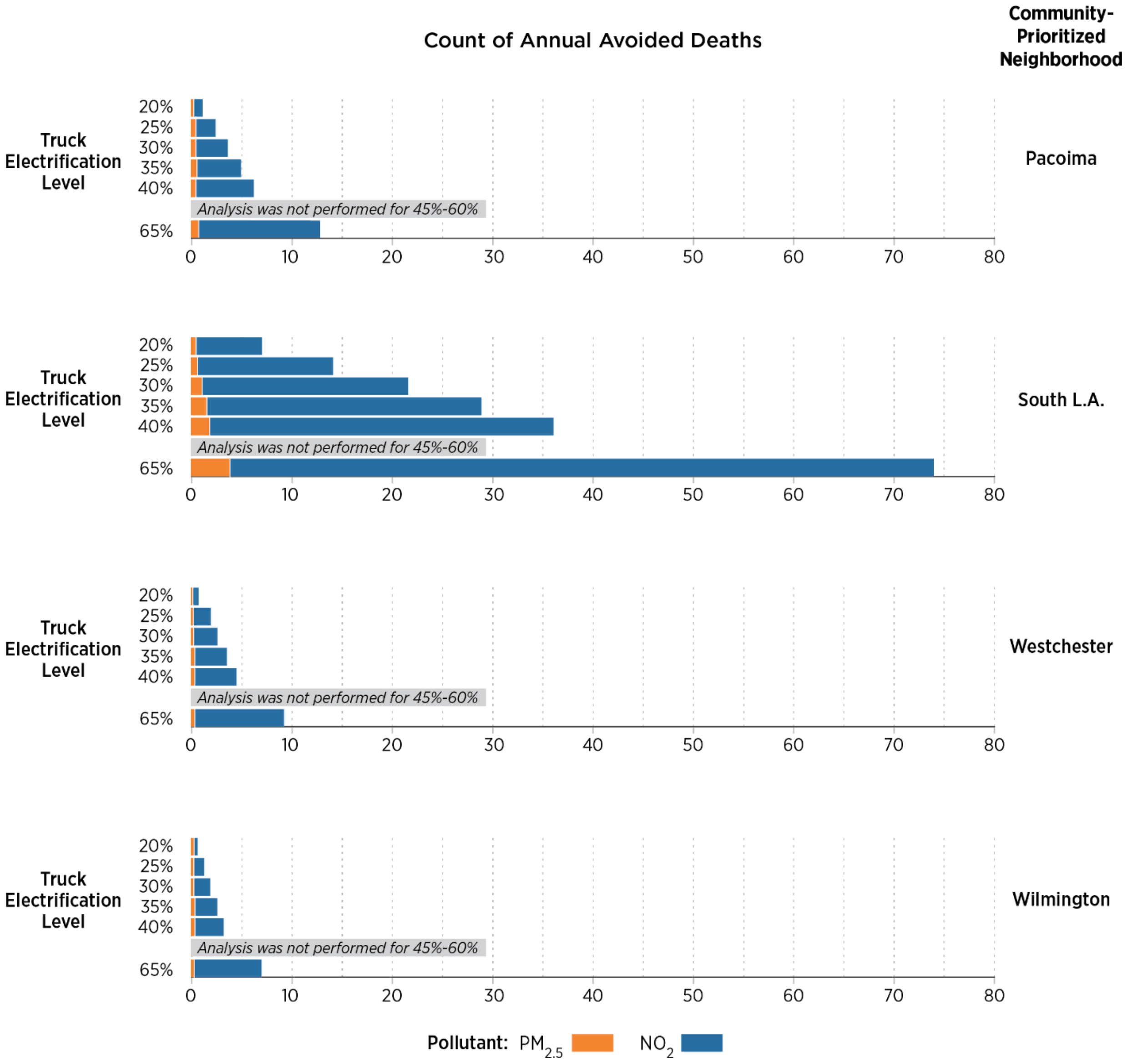

Figure 11. Annual avoided premature deaths from heavy-duty truck electrification for near-road NO_2 and $PM_{2.5}$ by electrification level relative to a 15% electrification level in community-prioritized neighborhoods

Reported avoided deaths are for people aged 25 years and over. Modeled health benefits in South LA are large because a much larger population is exposed in South LA than in other neighborhoods.

2.6 Electric Truck Population, Increased Electricity Demand, and Charging Infrastructure

To enable estimation of pollutant concentration reduction associated with LADWP's Charge Up LA! program goals (stated in terms of number of electrified trucks), we translate targeted electrification goals into the electrified fraction of on-road heavy-duty truck fleet based on a projection of registered heavy-duty truck population in Los Angeles (Table 2). We also estimate the number of electrified trucks associated with each fraction of the heavy-duty truck fleet electrified we test in our scenarios based on the projected citywide truck population. In each case, we then estimate the associated increased electricity demand and the number of chargers required to support that number of electrified trucks. This information is provided to help LADWP consider adjustments to the Charge Up LA! goals in light of CARB's ACT regulation (EPA-approved) and Advanced Clean Fleets regulation (CARB-approved, pending the EPA's approval) for 2035. It can also help inform decision and design of a potential charger-based goal to support the number of electrified vehicles already in Charge Up LA! program goals or in state mandates. Estimated increased electrical demand for each level of electrified vehicles can help with supply side planning.[22] According to LADWP's 2022 Strategic Long Term Resource Planning report (Los Angeles Department of Water and Power 2022b), LADWP supplied 21,000 GWh of electricity in fiscal year 2020–2021; thus, the highest electrification level (i.e., 65%) of trucks modeled in this report will increase current electricity supply by 3%–13%.

Figure 12 relates the current Charge Up LA! Program goals to current and proposed CARB regulations.

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[22] We have not included an estimation of the increased hourly charging load profiles in this report due to lack of information on various factors affecting load profiles, such as electric truck design, truck charging behaviors, and truck charging infrastructure. Future work on truck charging load modeling is needed to understand the impact of increasing truck electrification on maximum hourly electricity load.

Table 2. Near-Road Incremental Concentration Reductions, Electricity Demand, Charging Needs, and Costs Associated with Heavy-Duty Truck (Class 3–8, Excluding Buses) Electrification Levels and Related City and State Goals and Mandates (2035)[a]

Gray-shaded cells indicate the input with which all others are calculated.

Electrification Level	Percentage of LA-Registered Heavy-Duty Trucks Electrified in 2035 (excluding buses)	Number of Electrified Heavy-Duty Trucks (excluding buses)[b]	Percentage Reduction in Incremental Near-Road NO_2 Concentration from Heavy-Duty Trucks in TAQ-DACs[d]	Percentage Reduction in Incremental Near-Road $PM_{2.5}$ Concentration from Heavy-Duty Trucks in TAQ-DACs[d,e]	Estimated Increased Demand (GWh/year)[g]	Estimated Number of Chargers Needed[h]	Estimated Maximum Charger Rebate Program Cost (million $)[i]
Charge Up LA! electrification level (assuming 2025 target met in 2035)	5%	3,800[c]	4.7%[e]	2.9%[f]	55–230	1,900–3,300	240–410
EPA-approved ACT regulation, 2035 mandate	15%	10,000	14%	8.6%	140–640	5,000–8,700	620–1,100
Charge Up LA! electrification level (assuming 2030 target met in 2035)	16%	11,000[c]	15%	9.2%	160–690	5,400–9,600	680–1,200
Additional electrification level tested	20%	14,000	19%	11%	200–860	6,800–12,000	850–1,500
Additional electrification level tested	25%	17,000	24%	14%	240–1,100	8,300–15,000	1,000–1,900
Additional electrification level tested	30%	21,000	28%	17%	300–1,300	10,000–18,000	1,200–2,200
Additional electrification level tested	35%	24,000	33%	20%	350–1,500	12,000–21,000	1,500–2,600
CARB-approved Advanced Clean Fleets regulation, 2035 goal	40%	28,000	38%	23%	400–1,700	14,000–24,000	1,800–3,000
Additional electrification level tested	65%	45,000	61%	37%	650–2,800	22,000–39,000	2,800–4,900

[a] The number of electrified trucks in 2035, percentage reductions in NO_2 and $PM_{2.5}$ concentrations, estimated increased demand, number of chargers needed, and charger rebate program cost in this table are based on calculations for Class 3–8 truck categories only because SCAG models trucks and buses separately and we focus on trucks in this report. However, Class 3–8 vehicles also include buses which are likewise eligible for the Charge Up LA! program. Another version of this table (excluding the columns on the percentage reductions in NO_2 and $PM_{2.5}$ concentrations) that includes buses (all Class 3–8 vehicle categories) is provided in Appendix A.9.

[b] The number of electric trucks registered in Los Angeles is calculated as the total number of trucks registered in Los Angeles (2035) multiplied by the percentage of truck fleet electrified by 2035. The total number of trucks registered in Los Angeles (2035) is estimated to be 6.5% of the total number of trucks registered in California (2035) based on CARB's EMFAC2021 model. The ratio of LA-registered versus CA-registered trucks (6.5%) is provided by the LADWP Electric Transportation Programs office and is calculated based on California Department of Motor Vehicles registration data in recent years.

[c] Values shown in these two cells represent the population of electric Class 3–8 *trucks only* in the Charge Up LA! 2025 and 2030 targets (if were met in 2035) from NREL's estimation based on the EMFAC2021 fleets population data projected to 2035. The original Charge Up LA! target is 4,000 electric Class 3–8 in 2025 and 12,000 in 2030 including trucks and buses. Note that the electrification levels shown on Figure 12 are also for electric Class 3–8 vehicles, which include both trucks and buses.

[d] The percentage reductions in NO_2 and $PM_{2.5}$ concentrations are based on reductions from a baseline of 0% electric trucks out of all registered trucks in 2035. The NO_2 and $PM_{2.5}$ concentrations in a 0% electrification level are extrapolated from our tested electrification bounds based on linear regression. In addition, NO_2 and $PM_{2.5}$ concentrations induced by Class 3–8 are calculated as the sum of pollutant concentrations from MHDT, HHDT, and the fraction of pollutant concentrations from Class 3 trucks in the LHDT category estimated from the EMFAC2021 model (California Air Resources Board 2022).

[e] $PM_{2.5}$ concentration does not decrease to the same extent as the fraction of vehicles electrified because even when the $PM_{2.5}$ from running exhaust is eliminated with an electrified vehicle, $PM_{2.5}$ emitted from brakes and tires is not.

[f] These results are extrapolated from our tested electrification bounds based on linear regression.

[g] The lower bound of the range is estimated based on the energy demand for an electric heavy-duty truck per year from the CARB META tool (California Air Resources Board 2023d). The upper bound is estimated based on the estimate assumed for the 2021 California Load Serving Entities study (Guidehouse 2021). GWh = gigawatt hours.

[h] The lower bound of the range is estimated based on the number of chargers needed per electric heavy-duty truck from the International Council on Clean Transportation (Bernard et al. 2022). The upper bound is estimated based on the Assembly Bill (AB) 2127 Electric Vehicle Charging Infrastructure Assessment (California Energy Commission 2021).

[i] This estimation is based on LADWP's Charge Up LA! Program (Los Angeles Department of Water and Power 2022a). Per this program, "Charging station rebates to charge medium- and heavy-duty EVs of up to $125,000 per charging station depending on power output," which we assume to be $125,000 in all cases.

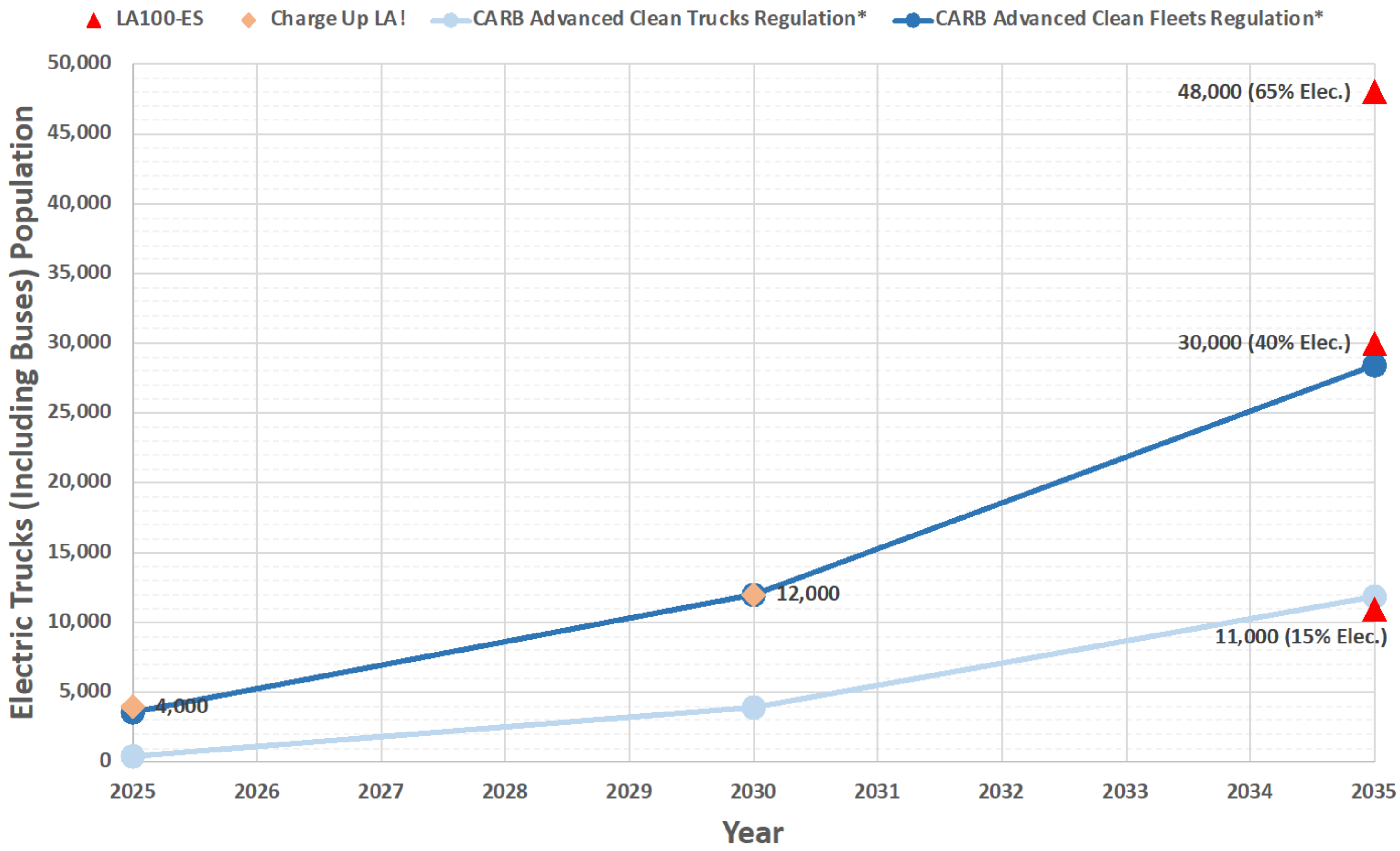

Figure 12. Heavy-duty truck (including buses) electrification levels (2025–2035) including Charge Up LA! goals, NREL-application of LA share of CARB state-level regulations, and LA100 Equity Strategies (LA100-ES) analyzed electrification levels

* The CARB ACT regulation line also accounts for CARB's Innovative Clean Transit regulation, which targets electrifying bus fleets. The CARB Advanced Clean Fleets Regulation line also includes the Innovative Clean Transit regulation and MSS assumptions about accelerated turnover of MHDT and HHDT.

The Advanced Clean Trucks regulation received approval from the EPA in March 2023 and is currently being enforced. The number of electrified trucks (including buses) shown for the ACT regulation also accounts for additional electric bus adoption required by CARB's Innovative Clean Transit regulation. In general, ACT aligns or goes beyond the April 2023 proposed "Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles – Phase 3" and "Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles" vehicle pollution standards by the EPA (USEPA 2023c, 2023d). (See discussion in Appendix A.2.) CARB approved the Advanced Clean Fleets regulation in April 2023, and it is now pending approval from the EPA. The number of electrified trucks (including buses) shown for the ACF regulation also includes the additional zero-emission trucks (including both trucks and buses) adoption assumptions in CARB's Mobile Source Strategy, which includes the Innovative Clean Transit regulation targeting bus fleets and CARB's accelerated turnover assumptions of MHDT and HHDT to meet the near-term South Coast Air Basin and San Joaquin Valley Ozone goals as well as the State of California's longer-term climate targets

3 Equity Strategies Discussion

Modeling, analysis, and community engagement identified the following strategy options for achieving more-equitable outcomes in the distribution of benefits and burdens in Los Angeles' transition to clean energy associated with electrification of heavy-duty trucks.

NREL modeling indicates achieving 2035 truck electrification goals could increase electricity demand by up to 2,800 GWh per year. If appropriate incentives and programs are designed and implemented, this level of increased demand could potentially help to increase flexible loads (NRDC 2021) and decrease rates (Los Angeles Department of Water and Power 2022b) [23], but these outcomes would need to be studied further for verification.

- To gain the greatest air quality benefits from truck electrification, prioritize HHDTs within LADWP's Charge Up LA! Program. This could be accomplished by either or both of the following:
    - Create a carve-out target within the overall program targets. For every percent of heavy-duty trucks electrified, 80%–90% of NO_2 and $PM_{2.5}$ concentration reductions near major roadways in Los Angeles come from HHDTs (Figure 6), and DACs disproportionately benefit from electrification of these vehicles, which can justify a greater than pro rata carve-out target.
    - Increase the incentive level for HHDTs. Review of the experience of other State of California, as well as non-California state and federal programs, could help to define such an incentive level.
- Currently, the Charge Up LA! program sets a target for electrified vehicles but does not provide incentive funding to support the achievement of this target. To aid the achievement of current program targets for electrified vehicles, consider creating incentives. Such an incentive program could be structured either:
    - With LADWP providing incentive funding; or
    - By leveraging existing state and federal funding. We cataloged funding sources for which LA truck owners could qualify (see Appendix A.11 "State and Federal Funding"); or
    - A combination of funding sources. For instance, LADWP could provide a top-up level of funding to further incentivize electrified HHDT, to stack on top of the funding available from other state and federal sources. However, any such top-up program would need to be coordinated with the primary funding source to ensure allowability of the recipient to receive funding from both sources.
- Increase the ambition of the Charge Up LA! program in terms of number of chargers; estimates are provided in Table 2. For heavy-duty trucks, many will be on similar duty cycles, and thus the number of chargers will need to be close to the number of electrified trucks, a level of charging infrastructure not currently envisioned by Charge Up LA! program goals.[24]

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[23] From August 12, 2022, SLTRP Advisory Group presentation.

[24] Heavy duty truck charging would likely be connected to the higher-capacity 34.5-kV portion of the distribution grid in Los Angeles, rather than the 4.8-kV distribution system that serves most smaller and residential loads (up to ~500 kW). NREL conducted an equity analysis of upgrades and resilience for the 4.8-kV system that connects to most residents (Chapter 12) but did not analyze the 34.5-kV distribution system. Adding substantial heavy-duty vehicle charging loads may contribute to a need to upgrade the 34.5-kV distribution grid and, in combination with increasing electrification of vehicles and residential and commercial buildings, may be a catalyst for conversion of the 4.8-kV distribution system to a higher voltage as has been done in most U.S. cities.

- Establish goals, a timeline, and a budget for electrification of LADWP's heavy-duty truck fleet in alignment with Charge Up LA! and California Air Resources Board's (CARB) Advanced Clean Fleets targets. Set LADWP fleet electrification targets in proportion to their share of total truck registrations in Los Angeles; setting a higher goal could signal LADWP leadership.
    - Electrification may not be possible for some vehicles in LADWP's fleet because of the need to use conventionally powered vehicles during critical infrastructure emergencies,[25] to mutually aid jurisdictions with less electric charging infrastructure, etc. In such cases, consider voluntarily complying with the CARB Truck and Bus Regulation (California Air Resources Board 2023e), for instance, by retrofitting diesel-powered trucks to add diesel particulate filters and selective catalytic reduction (SCR). This step can demonstrate leadership, ensure proportional contribution of LADWP to its own Charge Up LA! program goals, and, most importantly, provide air quality and equity benefits to the residents of Los Angeles. Consider starting such voluntary compliance with vehicles of model year 2009 or earlier, since older vehicles are more polluting and do not comply with CARB's 2010 diesel engine emission standards.[26, 27]
    - Establish a carve-out target for electrification of HHDT fleet as per strategy described above.
    - Consider adding a contractual provision requiring electrification of heavy-duty vehicle fleets by companies contracting with LADWP per schedule and proportion consistent with the Charge Up LA! program goals.
- Collaborate with city agencies to support electrification of city-owned HHDT fleet (e.g., fire trucks, dump trucks, fuel trucks) and charging infrastructure.
- Revisit LADWP's Charge Up LA! program goals of 4,000 Class 3–8 trucks (including buses) electrified by 2025 and 12,000 by 2030 to consider additional State of California policies and desired air pollutant concentration goals.
    - Add a goal aligned with the CARB MSS (and its associated Advanced Clean Fleets regulation) of approximately 28,000 electrified Class 3–8 trucks in Los Angeles by 2035. (The equivalent number of Class 3–8 trucks plus buses is 30,000.)
    - Consider a goal higher than those associated with mandates based on achieving a desired air pollutant concentration reduction level (Table 2).

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[25] The CARB Truck and Bus Regulation provides an exemption from emissions compliance for vehicles defined as an authorized emergency vehicle per Vehicle Code Section 165 or licensed by the California Highway Patrol as emergency vehicles (California Air Resources Board 2023f).

[26] Model year 2010 is when CARB's Truck and Bus Regulation came into force, requiring diesel-powered vehicles above 14,000 lbs (MHDT & HHDT) operating in California to have 2010 or newer model year engines by 2023 (California Air Resources Board 2023e). All new diesel engines beginning in 2010 were required to be equipped with diesel particulate filters and SCR to reduce NO_x, and PM emissions by 90% or more (The International Council On Clean Transportation 2021).

[27] Based on analysis of data provided by LADWP for their existing vehicle fleet of 4,714 active vehicles, 15% are fueled by diesel (of which 98% are heavy-duty) and 80% are fueled by unleaded gasoline. Among the 4,714 active vehicles, 3,947 of them fall in vehicle weight Class 2b–8 and 2,320 are in Class 3–8. Although only 13% of the LADWP fleet is composed of HHDTs, over 73% of HHDTs are fueled by diesel, which is the highest-emitting fuel type. HHDTs also have the highest average annual mileage of vehicle categories in the fleet. Furthermore, 31% of the currently operating vehicles are model year 2009 or older, with 49% of the HHDT fleet being model year 2009 or earlier.

- Locate incentivized charging infrastructure by working with city and regional agencies (e.g., Los Angeles Department of Transportation and Southern California Area Governments) to understand where HHDTs would ideally be charged, especially those servicing the POLA, the POLB, and LAX. Considerations can include available space, need for public or private fleet charging stations, and planning for distribution grid upgrades.

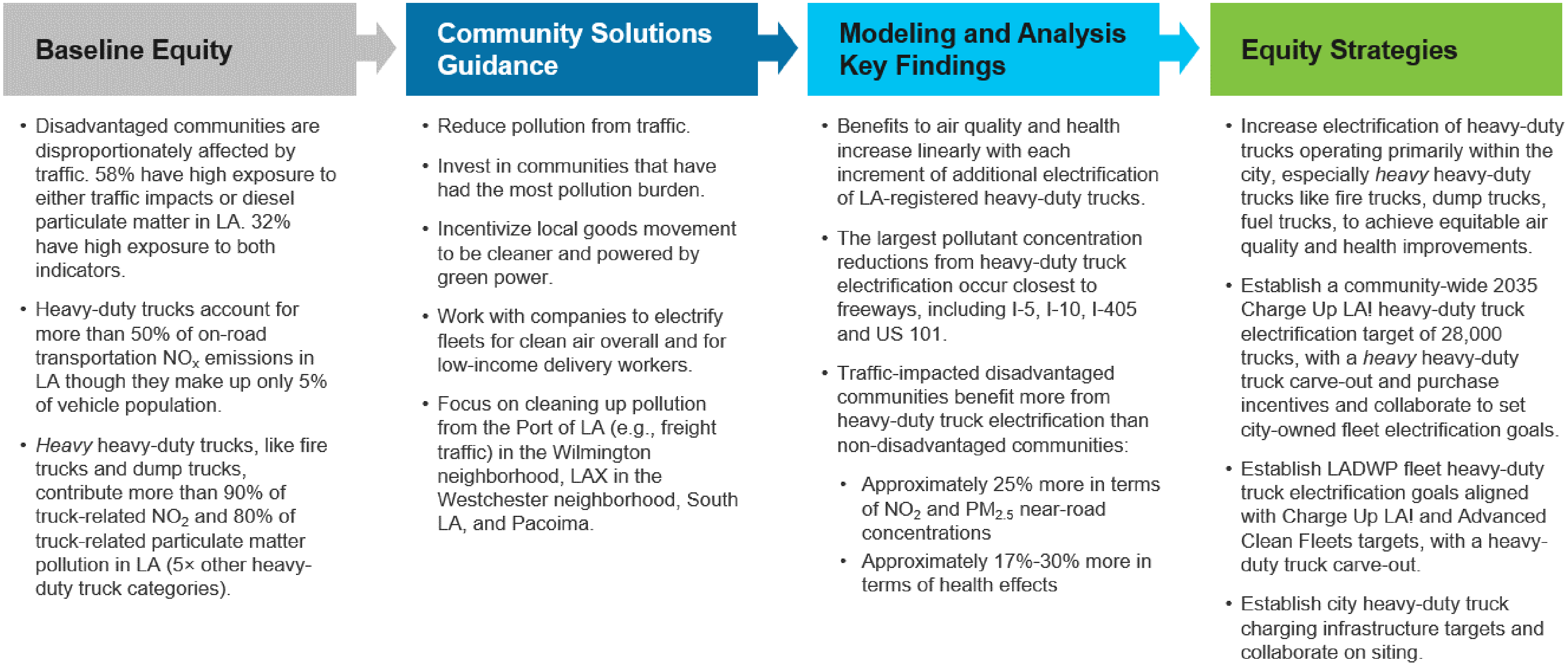
Table 3. Equity Strategy Options: Benefit, Cost, Timeline, Responsible Party, and Evaluation Metrics

Equity Strategy	Benefit/Impact	Cost	Timeline	Responsible Party	Evaluation Metrics
Establish goals, a timeline, and a budget for electrification of LADWP's heavy-duty truck fleet (Class 2b-8), with a heavy heavy-duty truck carve-out.	Electrification of heavy heavy-duty trucks reduces air pollution emissions 5× more than electrification of other truck types, leading to proportionally greater improvements in health outcomes	Dependent on fleet goal, purchase price, and operation and maintenance cost differentials[a]	2024–2035	LADWP	• 6% of heavy-duty truck fleet electrified by 2025 is 240 LADWP Class 2b–8 trucks, aligned with Charge Up LA! • 18% of heavy-duty truck fleet electrified by 2030 is 710 LADWP Class 2b–8 trucks, aligned with Charge Up LA! • 40% of heavy-duty truck fleet electrified by 2035 is 1,580 LADWP Class 2b–8 trucks, and aligns with Advanced Clean Fleets target[b]
Establish a city-wide 2035 Charge Up LA! heavy-duty truck electrification goal, with a heavy heavy-duty truck carve-out. Collaborate with city agencies to support electrification of city-owned HHDT fleet. Establish a heavy-duty electric truck purchase incentive.	38% and 23% reduction in incremental near-road NO_2 and $PM_{2.5}$ concentrations from heavy-duty trucks in TAQ-DACs	Cost can't be determined if LADWP decides to add funds, but could be $0 if leveraging federal and state funds	2024–2035	LADWP in coordination with city agencies such as LADOT, Fire Department, Public Works, General Services, POLA, LAX	28,000 electric heavy-duty trucks in Los Angeles in 2035 (40% of heavy-duty trucks) aligns with Advanced Clean Fleets target

Equity Strategy	Benefit/Impact	Cost	Timeline	Responsible Party	Evaluation Metrics
Establish citywide charging infrastructure targets aligned with truck electrification goals. Collaborate with city and other agencies on charging infrastructure siting with a focus on trucks servicing the ports and airport.	400–1,700 GWh demand increase/year	$10,000– $125,000 per Class 3–8 truck charger rebate, $11.7 to $250 million/year	2024–2035	LADWP in coordination with LADOT, Southern California Area Governments, POLA, LAX	Number of truck chargers • 1,900–3,300 by 2025 • 5,400–9,600 by 2030 • 14,000–24,000 by 2035

[a] Emergency designated vehicles are exempt from the CARB Advanced Clean Fleets mandate. For those vehicles where electrifying is not feasible for emergency preparedness reasons, other air quality interventions can be considered like emissions controls or additional community truck electrification can be supported.

[b] The equivalent number of electric trucks for Classes 3-8 (which are the classes included in the Charge Up LA! program) is 140 by 2025, 420 by 2030, and 930 by 2035. LADWP-owned vehicles are discussed in Footnote 27.



Baseline Equity

- Disadvantaged communities are disproportionately affected by traffic. 58% have high exposure to either traffic impacts or diesel particulate matter in LA. 32% have high exposure to both indicators.
- Heavy-duty trucks account for more than 50% of on-road transportation NO_x emissions in LA though they make up only 5% of vehicle population.
- *Heavy* heavy-duty trucks, like fire trucks and dump trucks, contribute more than 90% of truck-related NO_2 and 80% of truck-related particulate matter pollution in LA (5× other heavy-duty truck categories).

Community Solutions Guidance

- Reduce pollution from traffic.
- Invest in communities that have had the most pollution burden.
- Incentivize local goods movement to be cleaner and powered by green power.
- Work with companies to electrify fleets for clean air overall and for low-income delivery workers.
- Focus on cleaning up pollution from the Port of LA (e.g., freight traffic) in the Wilmington neighborhood, LAX in the Westchester neighborhood, South LA, and Pacoima.

Modeling and Analysis Key Findings

- Benefits to air quality and health increase linearly with each increment of additional electrification of LA-registered heavy-duty trucks.
- The largest pollutant concentration reductions from heavy-duty truck electrification occur closest to freeways, including I-5, I-10, I-405 and US 101.
- Traffic-impacted disadvantaged communities benefit more from heavy-duty truck electrification than non-disadvantaged communities:
  - Approximately 25% more in terms of NO_2 and $PM_{2.5}$ near-road concentrations
  - Approximately 17%-30% more in terms of health effects

Equity Strategies

- Increase electrification of heavy-duty trucks operating primarily within the city, especially *heavy* heavy-duty trucks like fire trucks, dump trucks, fuel trucks, to achieve equitable air quality and health improvements.
- Establish a community-wide 2035 Charge Up LA! heavy-duty truck electrification target of 28,000 trucks, with a *heavy* heavy-duty truck carve-out and purchase incentives and collaborate to set city-owned fleet electrification goals.
- Establish LADWP fleet heavy-duty truck electrification goals aligned with Charge Up LA! and Advanced Clean Fleets targets, with a heavy-duty truck carve-out.
- Establish city heavy-duty truck charging infrastructure targets and collaborate on siting.

Figure 13. Synthesis of baseline equity conditions, community solutions guidance, and modeling and analysis key findings into equity strategies

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Appendix. Transportation and Air Quality Modeling Methodology, Detailed Results, Further Resources, Limitations and Future Research

A.1 Vehicle Classes and Types

In this analysis, we focus on heavy-duty trucks based on gross vehicle weight rating (GVWR)-based classification as shown in Figure A-1. The LA100 study focused on passenger cars (vehicles classified as "LDA" in EMFAC), and this analysis complements the LA100 study by considering heavy-duty trucks.

In this analysis, the vehicle types are grouped into three broad GVWR-based categories based on definitions used by the EMFAC2021 model (California Air Resources Board 2021a):

- Light heavy-duty trucks (LHDT, Class 2b–3, GVWR 8,501 lbs–14,000 lbs)
- Medium heavy-duty trucks (MHDT, Class 4–7, GVWR 14,001 lbs–33,000 lbs)
- Heavy heavy-duty trucks (HHDT, Class 8, GVWR ≥33,001 lbs).

Class 2 can be divided into Class 2a (GVWR 6,001 lbs–8,500 lbs; not in this figure) and Class 2b (GVWP 8,501 lbs–10,000 lbs; in this figure). Class 2b belongs to the LHDT category, and Class 2a belongs to the medium-duty vehicle category, which is out of the scope of this study. In addition, the definition of heavy-duty vehicle used here aligns with that used in the EMFAC2021 model. The Federal Highway Administration defines medium- and heavy-duty vehicles differently than the EMFAC model and their comparison is shown in Table A-1.

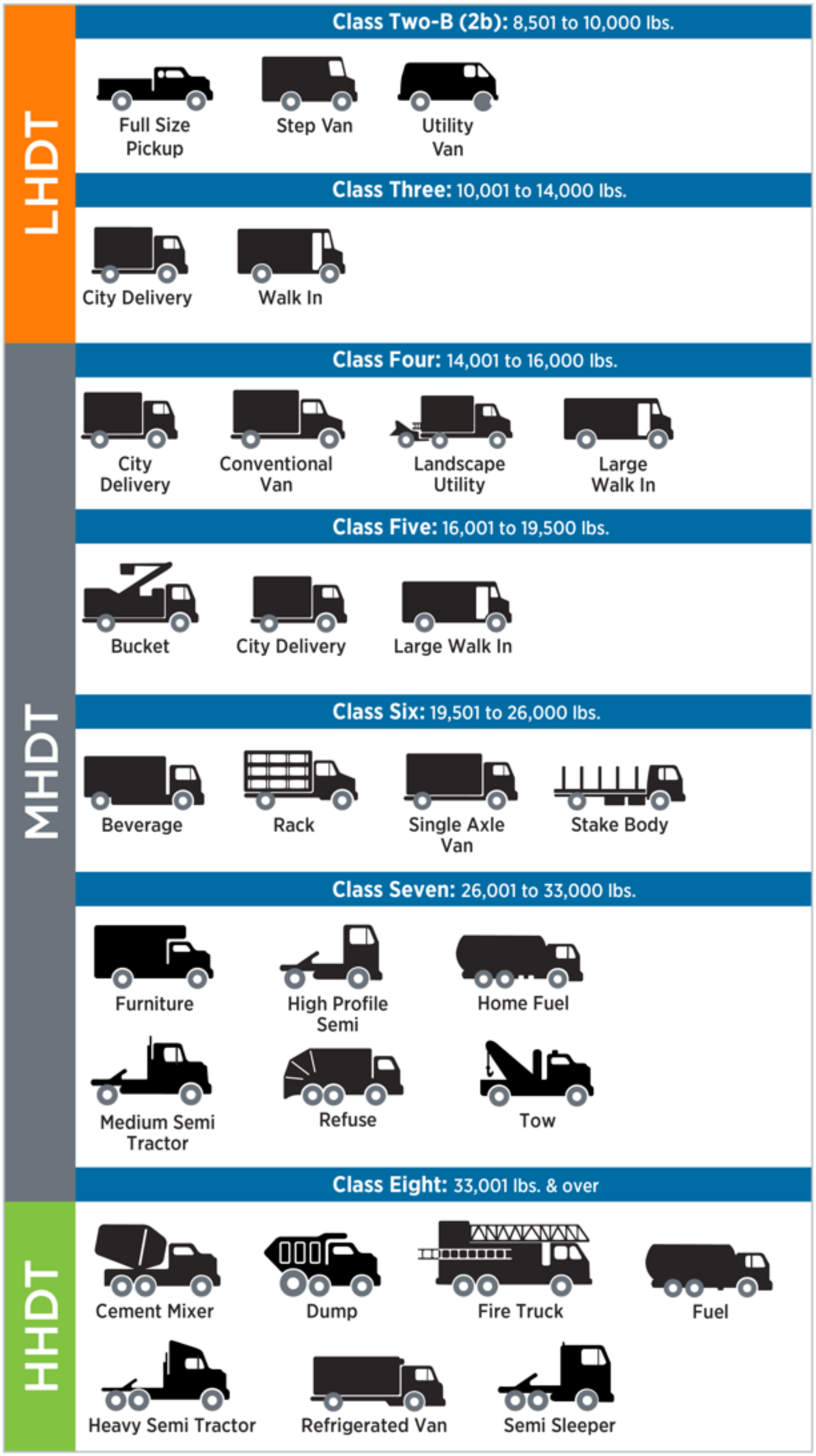

Figure A-1. Classification of trucks by weight class based on GVWR as used by the Federal Highway Administration

The figure is modified from “Types of Vehicles by Weight Class,” U.S. DOE Alternative Fuels Data Center, https://afdc.energy.gov/data/10381. The vehicle types are based on definitions from the EMFAC2021 model.

Table A-1. Vehicle Weight Class and Types Used by Different Agencies[a]

Vehicle Weight Class Based on GVWR (lbs)	Vehicle Types Used by the Federal Highway Administration	Vehicle Types Used by the California Air Resources Board in EMFAC[b] (and in this chapter)
Class 1: <6,000	Light Duty	Light Duty
Class 2a: 6,001–8,500		Medium Duty
Class 2b: 8,501–10,000		Light Heavy Duty
Class 3: 10,001–14,000	Medium Duty	
Class 4: 14,001–16,000		Medium Heavy Duty
Class 5: 16,001–19,500		
Class 6: 19,501–26,000		
Class 7: 26,001–33,000	Heavy Duty	
Class 8: >33,001		Heavy Heavy Duty

[a] Charge Up LA! considers vehicle weight Class 3 to Class 8 as a single group for medium- and heavy-duty vehicles which are eligible for commercial charging station rebates.

[b] The GVWR range classified as medium-duty vehicles in the EMFAC2021 model is 5,751–8,500 lbs (California Air Resources Board 2021a). To align with the GVWR range used by the vehicle weight classes, the medium-duty vehicle is approximated to Class 2a.

A.2 Statewide and Nationwide Zero-Emission-Truck-Related Regulations, and the Conversion from Zero-Emission Truck Sales/Purchase to Zero-Emission Truck in Total Fleet Population

Advanced Clean Trucks (ACT) Regulation

The California statewide ACT regulation, which was approved by CARB in 2021 and by the EPA in 2023, aims to accelerate the transition to zero-emission trucks in weight Class 2b to 8 (GVWR 8,501 lbs and above) from 2024 to 2035 (California Air Resources Board 2023b). Table A-2 summarizes the manufacturer zero-emission sales percentage requirements from 2024 to 2035.

Table A-2. Manufacturer Zero-Emission Truck Sales Percentage Required in the ACT Regulation from 2024 to 2035

Model Year	Class 2b–3	Class 4–8 Vocational	Class 7–8 Tractors
2024	5%	9%	5%
2025	7%	11%	7%
2026	10%	13%	10%
2027	15%	20%	15%

Model Year	Class 2b–3	Class 4–8 Vocational	Class 7–8 Tractors
2028	20%	30%	20%
2029	25%	40%	25%
2030	30%	50%	30%
2031	35%	55%	35%
2032	40%	60%	40%
2033	45%	65%	40%
2034	50%	70%	40%
2035 and beyond	55%	75%	40%

Advanced Clean Fleets (ACF) Regulation

The California statewide Advanced Clean Fleets (ACF) regulation, which was approved by CARB in 2023 (pending approval from the EPA), works together with the ACT regulation and aims to further accelerate the transition to zero-emission trucks in weight Class 2b to Class 8 (GVWR 8,501 lbs and above) (California Air Resources Board 2023a). The ACF regulation requires that manufacturers only sell zero-emission trucks starting 2036. In addition, the ACF regulation accelerates the electrification of the following fleet categories[28]:

- Drayage fleets: 100% of the new drayage trucks to be registered in the CARB Online System (for reporting drayage trucks related information) should be zero-emission beginning 2024. All drayage trucks entering seaports and intermodal railyards would be required to be zero-emission by 2035.
- High priority and federal fleets: 100% of the new purchases are zero-emission beginning 2024.
- State and local agencies fleets: 50% of the new purchases are zero-emission beginning in 2024 and 100% of the new purchases are zero-emission by 2027.

Note that the ACF regulation does not have a schedule for the fraction of zero-emission truck new sale/purchase by year so far, thus we adopted scheduling assumptions from the default MSS scenario when converting to the fraction of the total truck fleet that are electrified in 2035. We deem this a reasonable approximation because the original proposed ACF regulation is part of the 2020 MSS report released in 2021 (California Air Resources Board 2021b). Table A-3 summarizes the zero-emission purchase percentage requirements from 2024 to 2035 in the default MSS scenario. In addition to the increasing fractions of new purchases that are required to be zero-emission, the default MSS scenario assumes accelerated turnover of older internal combustion engine trucks to meet the near-term South Coast Air Basin and San Joaquin Valley Ozone goals and the state's longer-term climate targets.

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[28] This is a generic summary of the requirements in the ACF requirements. Please refer to the CARB's ACF website (https://ww2.arb.ca.gov/our-work/programs/advanced-clean-fleets) for detailed description of the regulation.

Table A-3. Zero-Emission Truck Purchases Percentage in Default MSS Scenario (2024–2035)

Model Year	Class 2b–3	Class 4–8 Vocational	Class 7–8 Tractors	Utility / Public / Refuse / Bus	Delivery / Drayage
2024	5%	9%	5%	25%	100%
2025	7%	11%	7%	25%	100%
2026	10%	13%	10%	50%	100%
2027	15%	20%	15%	50%	100%
2028	20%	30%	20%	50%	100%
2029	25%	40%	25%	100%	100%
2030	30%	50%	30%	100%	100%
2031	44%	60%	44%	100%	100%
2032	58%	70%	58%	100%	100%
2033	72%	80%	72%	100%	100%
2034	86%	90%	86%	100%	100%
2035 and beyond	100%	100%	100%	100%	100%

Vehicle Emission Standards Proposed by the Biden Administration and EPA

In April 2023, the Biden administration and the EPA-proposed pollution standards for greenhouse gas and criteria air pollutant emissions of light- and medium-duty vehicles as well as heavy-duty trucks (USEPA 2023c). In addition to manufacturers achieving such performance-based standards through a wide range of available emission control technologies, the proposed standards are also projected to accelerate the number of EVs sold and adopted. Table A-4 summarizes the requirements on new zero-emission truck sales in the proposed rules from 2027 to 2032 (with some simplifications to align with the truck categories in ACT and ACF). In general, the requirements on Class 2b–3 trucks in the new proposed rules are slightly higher than the ACT requirements and the requirements on Class 4–8 trucks are lower than the ACT requirements.

Table A-4. Biden Administration and EPA-Proposed Zero-Emission Truck Sales Percentage (2027–2032)

Model Year	Class 2b–3	Class 4–8 Vocational[a]	Class 7–8 Tractors[a]	Bus[a]	Refuse Hauler
2027	17%	22%	10%	30%	15%
2028	20%	28%	12%	33%	19%
2029	28%	34%	15%	35%	22%
2030	34%	39%	20%	38%	26%
2031	43%	45%	30%	40%	29%
2032	46%	57%	34%	45%	36%

[a] The new proposed rules further separate the categories in these columns into several subcategories when setting targets. The numbers shown in these columns are based on the *maximum* targets among the several subcategories within each category listed here.

A.3 Additional Information on Emission Inventory Development

Meteorological Data Used for Developing Emission Factors

Truck-related emission factors are dependent on meteorology conditions including ambient temperature and relative humidity. The source of meteorological data used in our analysis for developing emission factors is the gridMET data[29] for calculating representative temperature and relative humidity profiles for the city, which is divided into three different regions based on k-means clustering of the gridMET data for the city, an example of which is shown in Figure A-2 (Abatzoglou 2013). The k-means clustering is conducted using the monthly average of daily minimum and maximum temperature and relative humidity data for all gridMET grid cells in Los Angeles. Diurnal profiles developed using this method are used as an input to the EMFAC model for estimating emission factors (which also vary by vehicle category, speed, and fuel type). Diurnal profiles for a month from each quarter is used to represent other months: January (representative for February and March), April (for May and June), July (for August and September), and October (for November and December).

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[29] "gridMET," Climatology Lab, https://www.climatologylab.org/gridmet.html, accessed 02/2023.

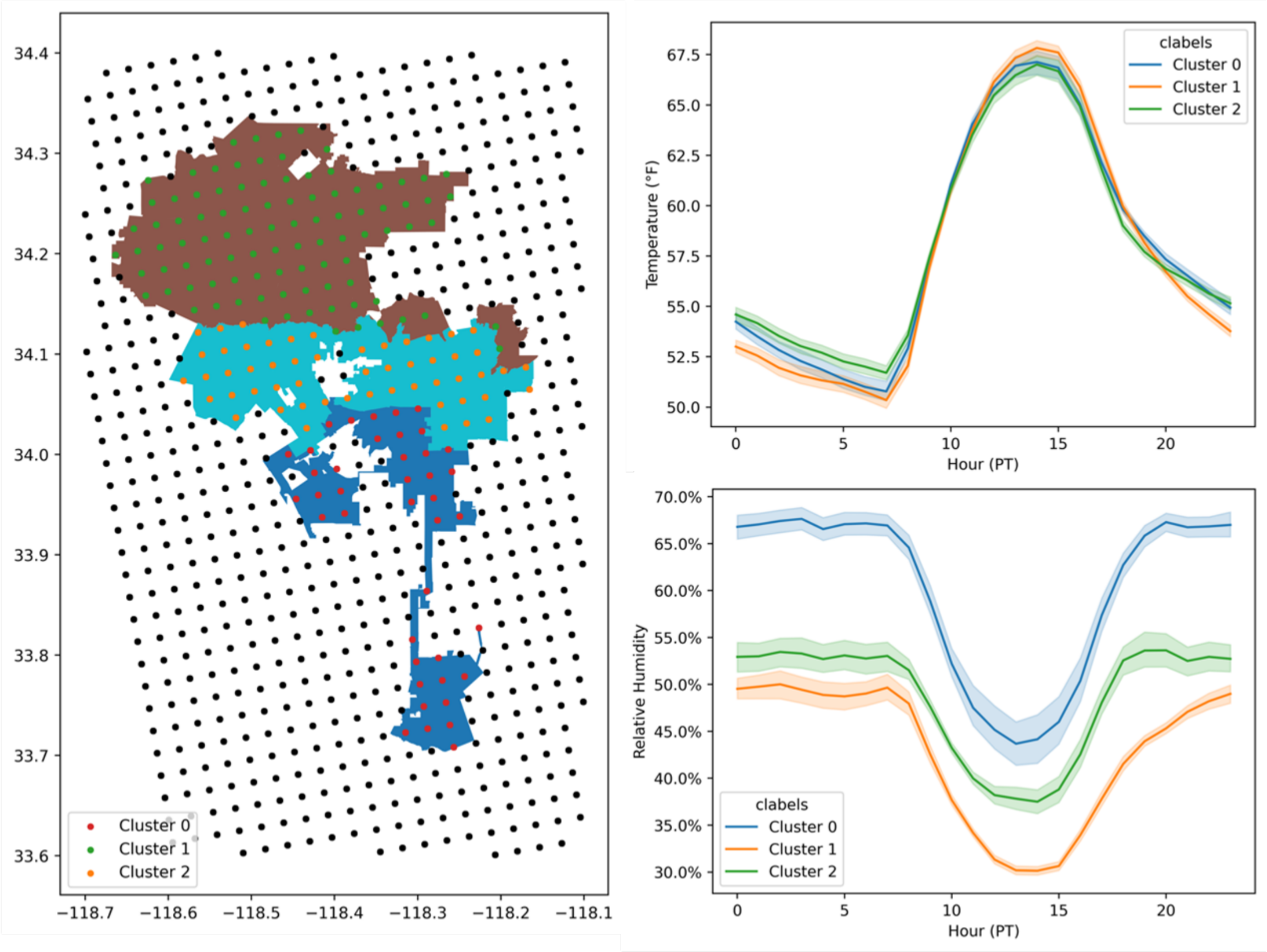

Figure A-2. Los Angeles temperature and relative humidity clusters for an example month (January)

The city is divided into three clusters based on gridded minimum and maximum data of temperature and relative humidity from the gridMET data. Shaded areas represent 95% confidence intervals.

Activity Data from the SCAG Database

SCAG forecasts travel behavior in six counties that form the South Coast—Imperial, Los Angeles, Orange, Riverside, San Bernardino, and Ventura—and the cities within this region. This is done using a software program called the Regional Transportation Model, an activity-based travel demand model (ABM). The SCAG ABM provides travel demand forecast for base and future years (including 2035) for light-duty and medium-duty vehicles as well as three different truck types, the benefits from electrification of which are analyzed in this report. It also models the traffic for five periods for a typical weekday: morning peak hours (called a.m. peak period in the SCAG report), midday period, evening peak rush hours (PM peak period), evening period, and night period. The hours represented by these periods are shown in Figure A-3. Weekends are dealt with similarly based on VMT scaling profile developed using data from California Department of Transportation Performance Measurement (PeMS) [30] data set.

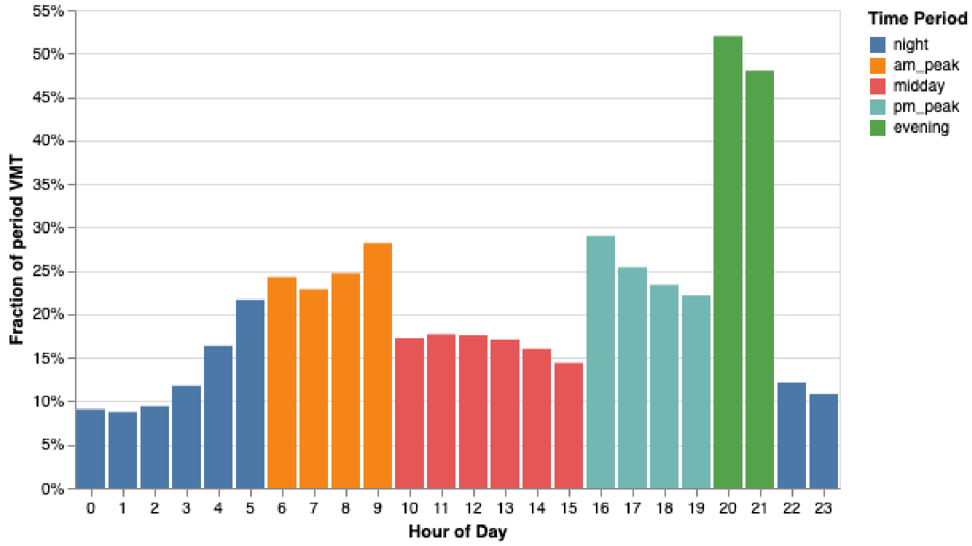

Figure A-3. SCAG VMT allocation by hour and time period

Emissions, especially those of NO_x, can also depend on the speed of the vehicle. Though posted speed limits are one possible source of speed data, they are often not very useful for an urban area like Los Angeles where traffic during specific hours of the day can be affected by factors such as congestion. We use simulated speed from the SCAG data to calculate emissions. Note that the simulated speed can be different from posted speed limits; a comparison of the simulated speed and posted speed limits in Los Angeles for different periods is shown in Figure A-4.

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[30] Caltrans Performance Measurement System (PeMS), https://pems.dot.ca.gov, accessed March 2023.

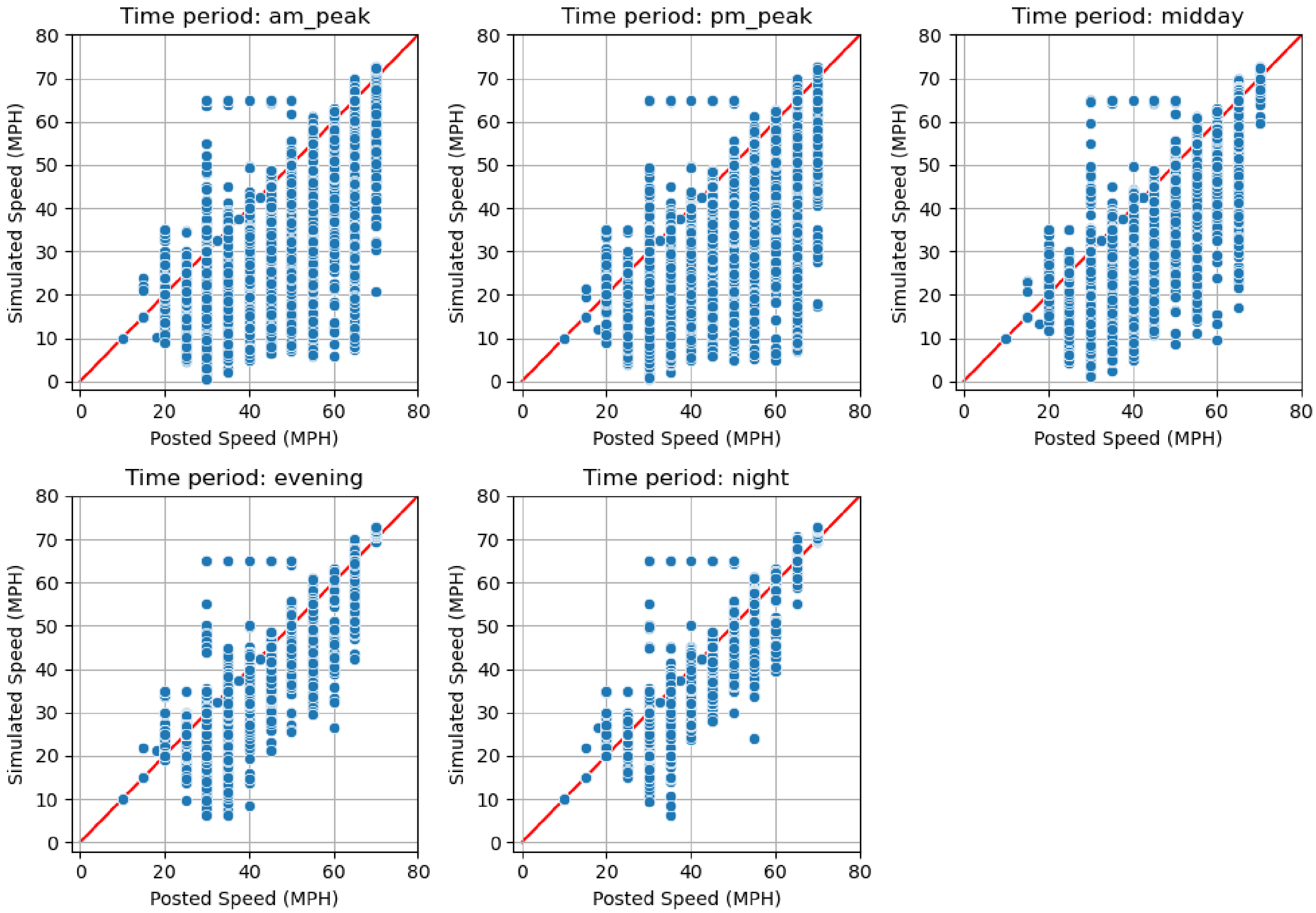

Figure A-4. Posted vs. simulated speed limit comparison for Los Angeles

In emissions modeling, link-level simulated speeds are used. Simulated speeds are calculated from SCAG data for each link and period. Note that simulated speeds are closer to posted speed limits during normal hours (e.g., during evening or night hours) and lower than posted speed limits during peak congestion hours.

Emission Processes Excluded from Emission Inventory Development

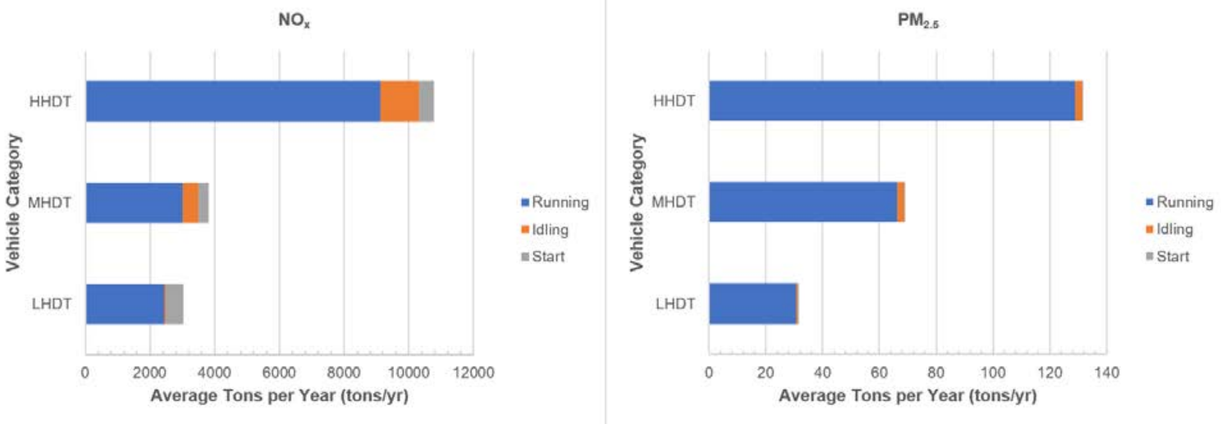

Figure A-5. Annual-average total NO_x and $PM_{2.5}$ exhaust tailpipe emissions by truck type and emissions process (running exhaust, idling and engine start) in Los Angeles South Coast subregion

Using EMFAC2021 (v1.0.2) the inventory for on-road emissions for the Los Angeles South Coast subarea, considering annual emissions from calendar year 2017 to 2022 of LHDT1 (GVWR 8,501 lbs–10,000 lbs), LHDT2 (GVWR 10,001 lbs–14,000 lbs), MHDT, and HHDT (EMFAC2007 Categories), the contribution of running, idling, and start emissions processes to total exhaust tailpipe emissions was calculated for both NO_x and $PM_{2.5}$. Vehicle categories LHDT1 and LHDT2 are powered by gasoline and diesel fuel while MHDT and HHDT fuels consisted of gasoline, diesel, and natural gas. For every individual vehicle category and calendar year, the on-road emissions were summed across the different fuel types, and the average was taken across every calendar year. This applies to both NO_x and $PM_{2.5}$ and separated by emission process. The LHDT1 and LHDT2 vehicle categories were collapsed to a single classification (LHDT). For total NO_x exhaust tailpipe emissions: running exhaust emissions contributed 81%, 79%, and 84%; start exhaust emissions contributed 17%, 8%, and 4%; and idling exhaust emissions contributed 2%,13%, and 11% for LHDT, MHDT, and HHDT, respectively. For total $PM_{2.5}$ exhaust tailpipe emissions; running exhaust emissions contributed 97%, 96%, and 98% while idling exhaust emissions contributed 2%, 4%, and 2% for LHDT, MHDT, and HHDT, respectively. Compared to NO_x, start exhaust emissions did not contribute a significant amount to the total $PM_{2.5}$ exhaust tailpipe emissions for any vehicle category.

A.4 Additional Information on Air Quality Modeling

Meteorological Input Data to Air Quality Modeling

Meteorological variables required for running R-LINE are obtained by running the AERMOD’s meteorological preprocessor, which is called AERMET. Required meteorology input data for AERMET is obtained from the real-time mesoscale analysis (RTMA), which is an analysis product prepared by the National Center for Environmental Prediction, and they are obtained from the National Oceanic and Atmospheric Administration’s (NOAA’s) Big Data Program, which is hosted by the Amazon Web Service[31] for 2022 (Pondeca et al. 2011), which is the meteorological year used in this analysis. RTMA is a high spatial (2.5 km) and high temporal (hourly) resolution analysis system for near-surface weather conditions. AERMET also requires upper-air meteorological data, which is obtained from the NOAA Earth System Research Laboratories Radiosonde Database for the San Diego site (WBAN ID: 03190), which is the nearest, suitable upper-air site (Schwartz and Govett 1992). Finally, the required surface input data (i.e., surface roughness length, albedo, and Bowen ratio) to AERMET are generated using the surface preprocessor called AERSURFACE with the land cover data from the 2016 National Land Cover Database (NLCD) (Dewitz 2019). The AERSURFACE-calculated surface roughness lengths are substituted with the data from the High-Resolution Rapid Refresh dataset for better representation of the surface roughness in Los Angeles (Dowell et al. 2022).

AERMOD Model Setups and Evaluation

To address the overprediction of NO_2 and $PM_{2.5}$ concentrations under low-wind (i.e., stable) conditions that typically occur during nighttime, we increased the minimum value of the lateral turbulent wind component, and the minimum value of wind speed to 1 m/s (Zhai et al. 2016; Chang et al. 2023), which helped reduce modeled nighttime NO_2 and $PM_{2.5}$ concentrations but likely the overprediction issue remains. We have not included discussion on statistical evaluation of the model performance for two reasons. First, there are no near-road monitors for $PM_{2.5}$ or NO_2 in the City of Los Angeles or source-apportionment analysis of the air pollutant concentrations that are induced only by heavy-duty trucks. Second, our modeling year is 2035 with projected truck traffic and emissions. We believe that overprediction remains given comparisons between our modeling results and the air quality observations located near freeways.

A.5 Health Data and Concentration-Response Functions Used in This Analysis

Our health analysis uses a python version of BenMAPR, an R implementation of the Benefits Mapping Program (BenMAP) that was developed by the EPA, in which additional concentration-response functions (CRFs) have been implemented based on the most recent traffic-related air pollution health effects meta-analysis conducted by the Health Effects Institute (HEI 2022; Buonocore et al. 2023). A generic version of health impact calculation takes the following form:

$$\Delta H = \left(1 - e^{-\beta \Delta C}\right) * R * P$$

Where ΔH is a change in health outcomes (i.e., avoided or additional cases) corresponding to a change in pollutant concentration denoted by ΔC. R is the baseline rate of health outcome, and P is the age-specific population exposed to changes in pollutant concentration. Our python version on BenMAP, called BenMAPpy, uses population data by age group at census block group level based on the U.S. Census Bureau's population American Community Survey's data. Baseline rate (R) for mortality and morbidity were same as implemented in BenMAPR which are based on county mortality rate data from the U.S. Centers for Disease Control Wide-ranging Online

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[31] "NOAA Real-Time Mesoscale Analysis (RTMA) / Unrestricted Mesoscale Analysis (URMA)," https://registry.opendata.aws/noaa-rtma, accessed January 2023.

Data for Epidemiological Research (U.S. CDC WONDER) dataset and morbidity rates from the Healthcare Cost and Utilization Project as available in BenMAP, details of which are provided in a recent study (Buonocore et al. 2023). Additional details on CRFs used in this analysis are provided in Table A-5.

Table A-5. Details on Concentration Response Used in BenMAPpy for Specific Pollutants and Age Groups

Health Endpoint	Pollutant	Effect Estimate	Age Group	Source
Mortality	$PM_{2.5}$	0.0059	25 years and above	HEI (2022)
Mortality	NO_2	0.0039	25 years and above	HEI (2022)
Cardiovascular hospital admissions	$PM_{2.5}$	0.00094	65 years and above	Levy et al. (2012); Zanobetti et al. (2009)
Respiratory hospital admissions	$PM_{2.5}$	0.0011	65 years and above	Levy et al. (2012); Zanobetti et al. (2009)
Cardiovascular ER visits	$PM_{2.5}$	0.00094	65 years and above	Levy et al. (2012); Zanobetti et al. (2009)
Respiratory ER visits	$PM_{2.5}$	0.0011	65 years and above	Levy et al. (2012); Zanobetti et al. (2009)
Asthma incidences	$PM_{2.5}$	varies	17 years and below. Effect estimate varies by several age groups for children.	Khreis et al. (2017)
Asthma incidences	NO_2	varies	17 years and below. Effect estimate varies by several age groups for children.	Khreis et al. (2017)
Acute myocardial infarctions (AMI)	$PM_{2.5}$	0.0025	18 years and above	Mustafić et al. (2012)
AMI	NO_2	0.0011	18 years and above	Mustafić et al. (2012)

A.6 Modeled Emissions Estimates

Figure A-6 shows modeled weekday particulate matter $PM_{2.5}$ emissions in 2035 by truck type and the three emissions processes (running exhaust $PM_{2.5}$, brake wear $PM_{2.5}$, tire wear $PM_{2.5}$) under multiple electrification levels.

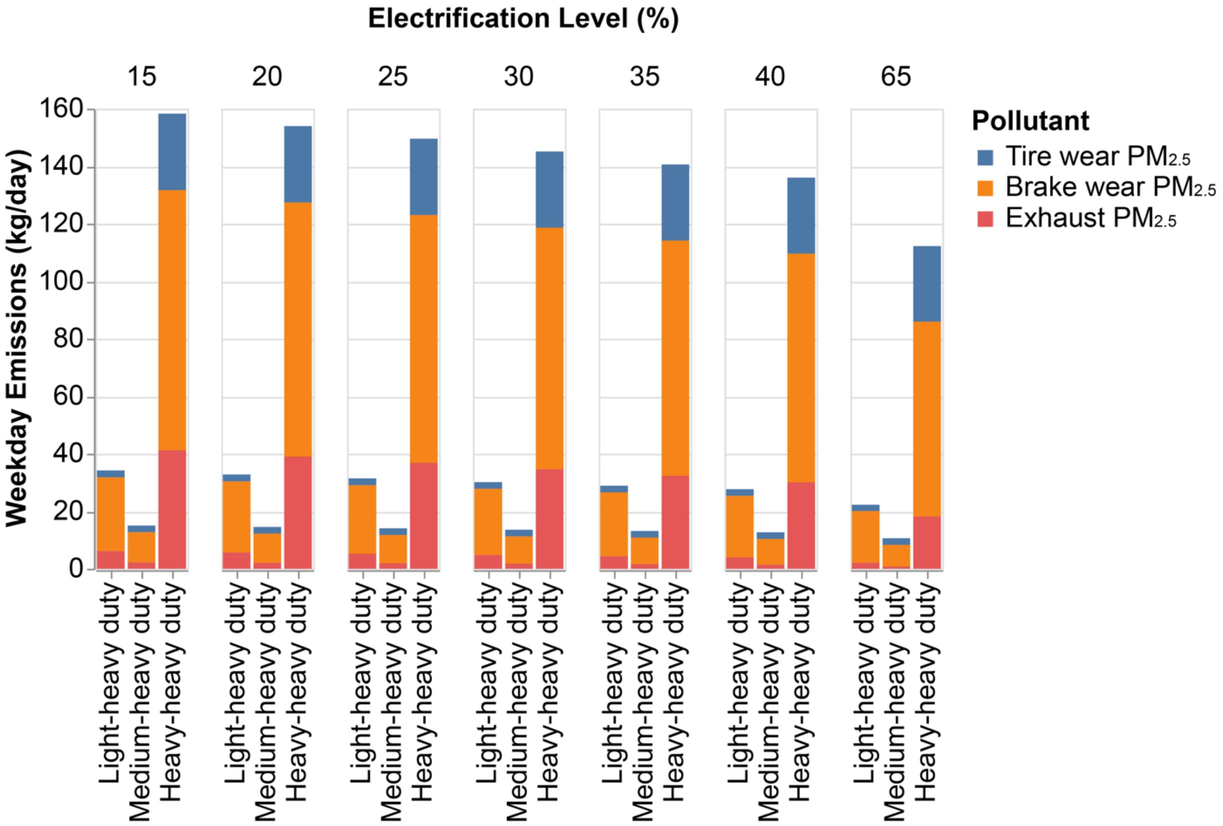

Figure A-6. Modeled weekday $PM_{2.5}$ emissions in 2035 by truck type and the three emissions processes (running exhaust $PM_{2.5}$ (exhaust), brake wear $PM_{2.5}$, tire wear $PM_{2.5}$) under multiple electrification levels

A.7 Air Pollutant Emissions at the Ports of Los Angeles and Long Beach, and at LAX

Westchester and Wilmington, the two neighborhoods close to the ports and LAX respectively, do not show up as "hot spots" for air pollution concentration and associated reductions in this analysis. This is likely a result of a modeling artefact rather than a reflection of low concentrations in these neighborhoods, which residents have reported as a significant issue. On the one hand, heavy-duty truck activities within the ports' and LAX's boundaries were simplified in our analysis (see Section 1.1.2, page 6). On the other hand, our analysis of on-road heavy-duty truck emissions accounts for only a small fraction of the total emissions in those areas. Many different emission sources within both LAX and the ports were not included in our analysis and yet are part of the lived experience of residents of Westchester and Wilmington neighborhoods.

The POLA's and POLB's Inventory of Air Emissions 2021 (Starcrest Consulting Group LLC 2022b) (Starcrest Consulting Group LLC 2022a) show that the heavy-duty trucks operating within the POLA's and POLB's terminals and facilities that we model in this chapter account for just 3% and 0%, respectively, of the total NO_x and $PM_{2.5}$ emissions from all activities within the ports (Figure A-7). Likewise, LAX's Air Quality Improvement Measures of LAX 2017 emissions inventory (Los Angeles World Airports 2019) shows that heavy-duty trucks operating within LAX's roadways and parking lots account for 1% and 4% of the total NO_x and $PM_{2.5}$ emissions that originate from the sum of all activities within the airport (Figure A-8). Larger sources at these facilities include oceangoing vessels, which account for 75%–80% and 72-79% of NO_x and $PM_{2.5}$ emissions at the ports, and aircraft, which account for 94% and 83% of NO_x and $PM_{2.5}$ emissions at LAX, respectively.

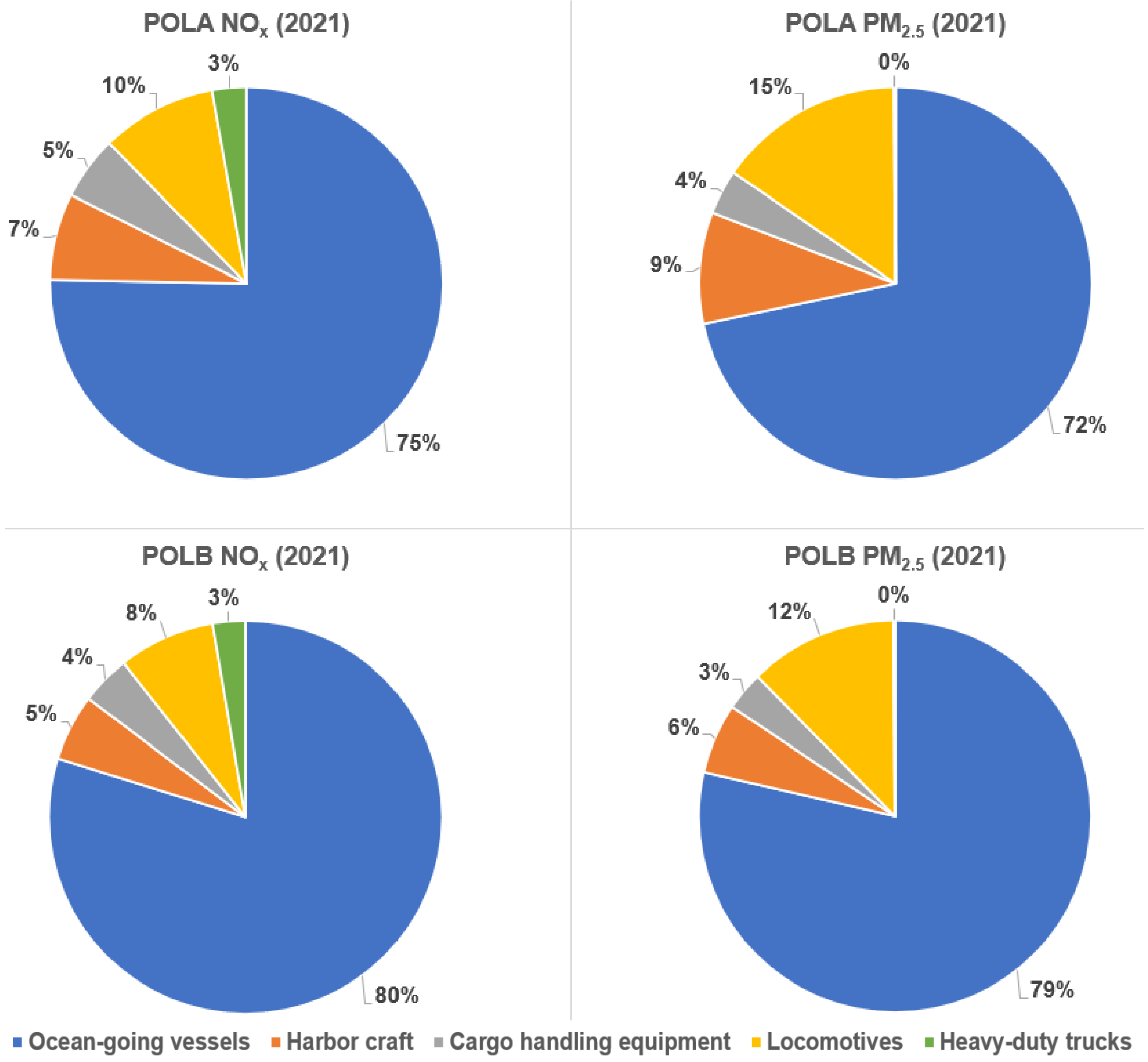

Figure A-7. Total NO_x and $PM_{2.5}$ emissions within POLA and POLB boundaries (2021)

NO_x and $PM_{2.5}$ emissions that originate within the ports were obtained from the Port of Los Angeles Inventory of Air Emissions 2021 and POLB Air Emissions Inventory 2021. Sources of emission include oceangoing vessels, harbor craft, cargo handling equipment, locomotives, and heavy-duty trucks servicing the ports. Heavy-duty truck emissions include on-terminal operations which consist of trucks waiting for terminal entry, transiting the terminal to drop off and/or pickup cargo, and departing the terminal. Data of truck activity within the ports' terminals and facilities which includes average times (gate in, loading/unloading, gate out), distances, and speeds was obtained from terminal personnel. Speed-specific composite emission factors for diesel and natural gas to account for idling and driving of heavy-duty trucks on the ports were obtained from CARB's on-road vehicle emissions model EMFAC2021 based on estimates of VMT, average speeds, and model year information specific to the ports. On-road heavy-duty trucks emissions which consist of travel on public roads within the Southern California Air Basin (SoCAB), from the port to the cargo truck's first rest stop within SoCAB or up to the SoCAB boundary, whichever is reached first, are excluded. Note that over 96% of VMT by heavy-duty trucks for both ports fall within this category. On-terminal heavy-duty trucks fueled by natural gas and more commonly diesel reflect idling and running emissions for both NO_x and $PM_{2.5}$ while brake and tire wear emissions for $PM_{2.5}$ from diesel fueled trucks are not included. Total NO_x ($PM_{2.5}$) in tons per year for POLA and POLB are 7,909 (163) and 6,998 (155), respectively.

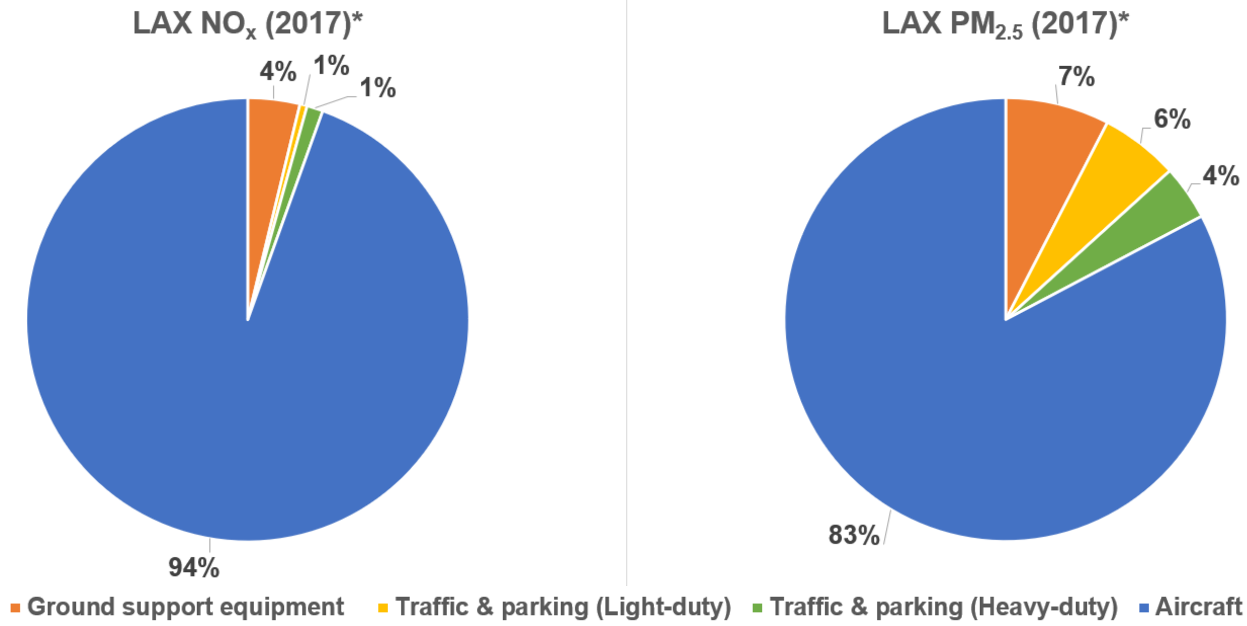

Figure A-8. Total NO_x and $PM_{2.5}$ emissions within the LAX boundary (2017)*

* Emissions from the Ground support equipment and the Traffic & parking categories are for 2017. Emissions from the Aircraft category are for 2018.

NO_x and $PM_{2.5}$ emissions that originate within the airport were obtained from the Los Angeles World Airports (LAWA) LAX Air Quality Improvement Measures 2017, 2023, and 2031 Emissions Inventories. This applies to ground support equipment and traffic and parking of light-duty vehicles and heavy-duty trucks. Traffic and parking emissions include trip segments traveled on airport roadways and in airport parking lots. Emission factors for both pollutants and relevant vehicles classes were obtained from EMFAC2017 emissions inventories for the South Coast Air Basin (SCAB) portions of Los Angeles County for the calendar year 2017 by utilizing daily total pollutant emissions and VMT data outputs. Actual travel distances of vehicles relevant to 2017 LAX traffic and parking activity were calculated using multiple sources such as the 2017 LAX Landside Access Modernization Project (LAMP) Environmental Impact Report (EIR), annual Trip General Reports published by LAWA for 2015 and 2017, the 2013 LAX Specific Plan Amendment Study EIR, and Google Earth Pro. The light-duty category of Traffic and parking includes total emissions from LDA, LDT1, and LDT2s while the heavy-duty category includes total emissions from LHDT1, LHDT2, MHDT, and HHDTs as defined by EMFAC. $PM_{2.5}$ Traffic and parking emissions include exhaust, tire wear, and brake wear. Emissions from regional, airport-related trips to/from LAX on public roads and highways and paved road dust were excluded from this inventory. Note that over 95% of VMT by light- and heavy-duty vehicles falls within this regional category of Traffic and parking emissions. *Aircraft emissions were obtained from South Coast Air Quality Management District's (SCAQMD's) Revised Draft 2022 AQMP Aircraft Emissions Inventory report (South Coast AQMD 2021) for the calendar year 2018 due to the LAWA emissions inventory lacking such emissions data. Total NO_x ($PM_{2.5}$) in tons per year for LAX are 4,875 (56).

A.8 Additional Results: Air Quality Modeling and Health Impacts in Community-Prioritized Neighborhoods

Figure A-9 presents the incremental annual-average truck-related NO_2 and primary $PM_{2.5}$ concentrations in the 15% and 65% electrification levels for the TAQ-DAC and non-DAC comparison and for the four community-prioritized neighborhoods. (Recall that high truck traffic volume is a major criterion for selecting TAQ-DACs and non-DACs.) Interestingly, both NO_2 and primary $PM_{2.5}$ near-road concentrations within the selected neighborhoods are comparable or lower than the averaged concentrations at non-DACs, which are all lower than the average concentrations within TAQ-DACs. Health benefits for several health endpoints accrued in each of these neighborhoods are detailed in Table A-6.

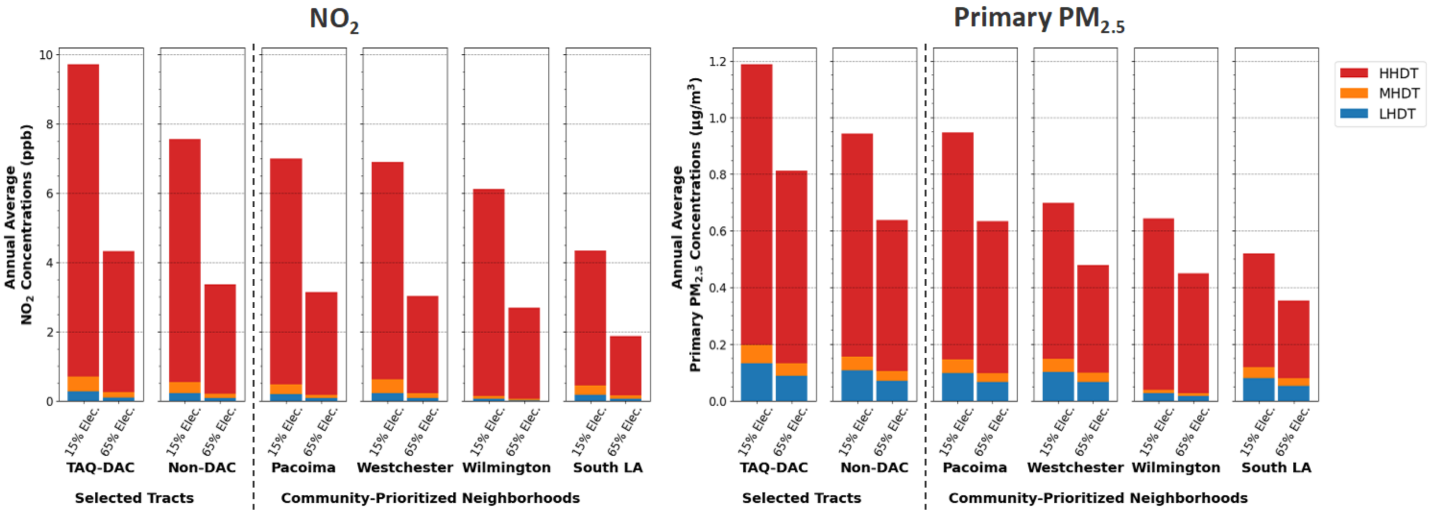

Figure A-9. Incremental 2035 annual-average truck-related near-road NO_2 concentrations (ppb, left) and primary $PM_{2.5}$ concentrations (µg/m^3, right) at 15% and 65% electrification levels

Results are shown in stacked bars for three truck categories, LHDT, MHDT and HHDT, and by selected tracts and community-prioritized neighborhoods.

Table A-6. Estimated Health Benefits by Electrification Level Relative to 15% Electrification in Community-Prioritized Neighborhoods

AMI = acute myocardial infarctions, ER visits = emergency room visits

Neighborhood	Health Endpoint	Quantified Health Benefits (number) at Each Electrification Level Relative to 15% Electrification					
		20%	25%	30%	35%	40%	65%
Pacoima	AMI NO_2	0.087	0.18	0.27	0.36	0.45	0.95
	AMI $PM_{2.5}$	0.009	0.018	0.027	0.036	0.046	0.093
	Cardiovascular ER Visits $PM_{2.5}$	0.012	0.025	0.037	0.049	0.062	0.13
	Cardiovascular Hospital Admissions $PM_{2.5}$	0.010	0.019	0.029	0.039	0.049	0.099
	Premature Deaths NO_2	1.1	2.3	3.5	4.7	5.9	12
	Premature Deaths $PM_{2.5}$	0.08	0.16	0.24	0.32	0.40	0.82
	Respiratory ER Visits $PM_{2.5}$	0.009	0.018	0.027	0.036	0.045	0.092
	Respiratory Hospital Admissions $PM_{2.5}$	0.010	0.020	0.030	0.040	0.051	0.10
South LA	AMI NO_2	0.54	1.1	1.6	2.2	2.8	5.7
	AMI $PM_{2.5}$	0.046	0.092	0.14	0.18	0.23	0.46
	Cardiovascular ER Visits $PM_{2.5}$	0.050	0.10	0.15	0.20	0.25	0.51
	Cardiovascular Hospital Admissions $PM_{2.5}$	0.040	0.079	0.12	0.16	0.20	0.40
	Premature Deaths NO_2	6.8	14	21	27	34	70
	Premature Deaths $PM_{2.5}$	0.38	0.77	1.2	1.5	1.9	3.9
	Respiratory ER Visits $PM_{2.5}$	0.037	0.073	0.11	0.15	0.18	0.37
	Respiratory Hospital Admissions $PM_{2.5}$	0.041	0.082	0.12	0.16	0.21	0.41
Westchester	AMI NO_2	0.062	0.12	0.19	0.25	0.32	0.66
	AMI $PM_{2.5}$	0.005	0.009	0.014	0.019	0.023	0.047
	Cardiovascular ER Visits $PM_{2.5}$	0.007	0.014	0.021	0.028	0.035	0.072
	Cardiovascular Hospital Admissions $PM_{2.5}$	0.006	0.011	0.017	0.022	0.028	0.056
	Premature Deaths NO_2	0.86	1.72	2.6	3.5	4.4	8.9
	Premature Deaths $PM_{2.5}$	0.043	0.086	0.13	0.17	0.22	0.44

Neighborhood	Health Endpoint	Quantified Health Benefits (number) at Each Electrification Level Relative to 15% Electrification					
		20%	**25%**	**30%**	**35%**	**40%**	**65%**
	Respiratory ER Visits $PM_{2.5}$	0.005	0.010	0.015	0.021	0.026	0.052
	Respiratory Hospital Admissions $PM_{2.5}$	0.006	0.011	0.017	0.023	0.029	0.058
Wilmington	AMI NO_2	0.050	0.10	0.15	0.20	0.26	0.53
	AMI $PM_{2.5}$	0.004	0.007	0.011	0.015	0.019	0.039
	Cardiovascular ER Visits $PM_{2.5}$	0.005	0.010	0.016	0.021	0.026	0.054
	Cardiovascular Hospital Admissions $PM_{2.5}$	0.004	0.008	0.012	0.017	0.021	0.043
	Premature Deaths NO_2	0.65	1.3	2.0	2.6	3.3	6.8
	Premature Deaths $PM_{2.5}$	0.032	0.065	0.097	0.13	0.16	0.34
	Respiratory ER Visits $PM_{2.5}$	0.004	0.008	0.011	0.015	0.019	0.039
	Respiratory Hospital Admissions $PM_{2.5}$	0.004	0.008	0.013	0.017	0.022	0.044

A.9 Additional Results: Increased Electricity and Charging Infrastructure Demand

Table A-7 shows the estimated increases in electricity demand and number of chargers needed to support the different levels of electrification. Note that this table differs from Table 2 in that the number of electrified trucks in 2035, estimated increased demand, estimated number of chargers needed and estimated maximum charger rebate program cost are calculated only for trucks in Table 2, and for trucks and buses in Table A-7.

Table A-7. Estimated Electricity and Charger Demand Increase by On-Road Heavy-Duty Truck Fleet (Including Buses) Electrification Level

This is a supplementary version of Table 2, which includes analysis on all Class 3–8 vehicles (both trucks and buses). Gray-shaded cells indicate the input with which all others are calculated.

	Percentage of LA-Registered Heavy-Duty Trucks Electrified in 2035, Including Buses	Number of Electrified Heavy-Duty Trucks, Including Buses)	Estimated Increased Demand (GWh/year)	Estimated Number of Chargers Needed	Estimated Maximum Charger Rebate Program Cost (million U.S. dollars)[i]
Charge Up LA! electrification level (assuming 2025 target met in 2035)	5%	4,000	56–250	2,000–3,500	250–440
EPA-approved ACT regulation, 2035 mandate	15%	11,000	150–690	5,400–9,600	680–1,200
Charge Up LA! electrification level (assuming 2030 target met in 2035)	16%	12,000	170–740	5,900–10,000	740–1,200
Additional electrification level tested	20%	15,000	210–920	7,300–13,000	910–1,600
Additional electrification level tested	25%	18,000	250–1,100	8,800–16,000	1,100–2,000
Additional electrification level tested	30%	22,000	310–1,600	11,000–19,000	1,400–2,400
Additional electrification level tested	35%	26,000	360–1,600	13,000–23,000	1,600–2,900
CARB-approved Advanced Clean Fleets regulation, 2035 goal	40%	30,000	420–1,800	15,000–26,000	1,900–3,200
Additional electrification level tested	65%	48,000	670–3,000	23,000–42,000	2,900–5,200

A.10 Air Pollutant Emissions, Concentrations, and Public Health Results from Modeling UCLA-Developed Scenarios

NREL's university collaborators, the University of California Los Angeles, studied the air quality and public health impact of electrifying multiple sources (i.e., all on-road and off-road transportation sources) using a regional meteorology and air quality model in Los Angeles. Here, we adopted the electrification assumptions on heavy-duty trucks in the UCLA-tested scenarios and modeled the near-road air quality impacts of adopting electric trucks in these scenarios and the associated public health impact. The description of the UCLA-tested scenarios is summarized in Table A-8.

Table A-8. UCLA-Tested Heavy-Duty Truck Electrification Scenario Names and Assumptions (2035)

Scenario Name in This Chapter (NREL)	Scenario Name in Chapter 14 (UCLA)	Assumptions on the Electrification of Heavy-Duty Trucks		
		LHDT	MHDT	HHDT
UCLA Equity	2035 Equity	15%	19%	19%
UCLA MSS	2035 MSS	22%	39%	39%

Figure A-10 presents the incremental annual-average truck-related NO_2 and primary $PM_{2.5}$ concentrations in the UCLA Equity and the UCLA MSS scenarios for the TAQ-DAC and non-DAC comparison and for the four community-prioritized neighborhoods. All regions of focus show 21%–22% reductions in annual-average truck-related NO_2 concentrations and 11%–12% reductions in primary $PM_{2.5}$ concentrations from UCLA Equity to UCLA MSS. Similar to the results shown for the parametric tests in the main content, HHDT dominant the absolute NO_2 and $PM_{2.5}$ concentrations in both scenarios and the reductions in concentrations from UCLA Equity to UCLA MSS. Corresponding health benefits accrued in the two UCLA scenarios are shown in Table A-9.

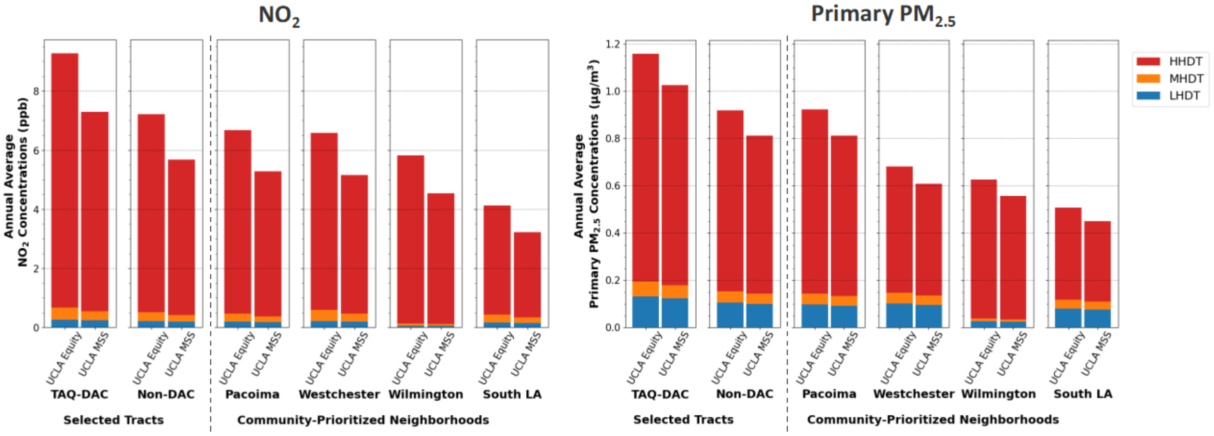

Figure A-10. Incremental annual-average truck-related NO_2 concentrations (ppb, left panel) and (b) primary $PM_{2.5}$ concentrations (µg/m^3, right panel) in UCLA-tested scenarios

Results are shown in stacked bars for three truck categories, LHDT, MHDT and HHDT, and by selected tracts and community-prioritized neighborhoods.

Table A-9. Annual Health Benefits Accrued by TAQ-DACs and non-DACs for UCLA Scenarios (2035)

ER Visits = emergency room visits, AMI = acute myocardial infarctions

Health Endpoint	UCLA Equity		UCLA MSS	
	TAQ-DAC	Non-DAC	TAQ-DAC	Non-DAC
Premature Deaths NO_2	13	11	70	58
Premature Deaths $PM_{2.5}$	0.73	0.6	4.0	3.3
Cardiovascular ER Visits $PM_{2.5}$	0.12	0.11	0.65	0.6
Cardiovascular Hospital Admissions $PM_{2.5}$	0.09	0.09	0.51	0.47
Respiratory ER Visits $PM_{2.5}$	0.09	0.08	0.47	0.43
Respiratory Hospital Admissions $PM_{2.5}$	0.1	0.09	0.53	0.49
AMI NO_2	0.98	0.76	5.36	4.13
AMI $PM_{2.5}$	0.08	0.06	0.45	0.35

A.11 State and Federal Funding and Other Relevant Resources

Many California and federal funding programs support electrification of trucks and deployment of supporting charging infrastructure. Table A-10 summarizes these programs. Section 3 (page 23) describes how these programs could be used by LADWP.

Table A-10. California and Federal Truck Electrification Funding Sources

Program Name and Agency Owner	Eligible Recipients	Funded Vehicle Types and Technologies	Incentive Amount Available per Vehicle or Infrastructure	Process to Receive Funding	Caveats and Additional Requirements
CARB's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) (California HVIP 2023)	California-based public, private, and nonprofit organizations and businesses.	Trucks and buses with GVWR over 5,000 lbs and drivetrain technology of ePTO, HV, NG, ZEV-BEV, and ZEV-FCV drivetrain technologies. Charging and fueling infrastructure for ZEV-BEVs and ZEV-FCVs. Funded from California Climate Investments Cap-and-Trade auction proceeds.	$2,000–$348,000 for vehicles, depending on vehicle class, drivetrain technology, and fleet size. $1,976–$1,800,000 for infrastructure, depending on the drivetrain served. Voucher amounts depend on whether vehicles or infrastructure operate within DACs. More than 50% of voucher incentives received by the City of Los Angeles to date are in DACs.	Voucher applications are available on a first-come, first-served basis. Incentive is applied at point of sale and administered by participating dealerships or original equipment manufacturers. The seller is reimbursed by HVIP after eligible vehicles and infrastructure are purchased and delivered to the customer. The seller must redeem the voucher amount from HVIP within 18 months.	As of 2023, purchasers are entitled to an annual maximum of 30 vouchers but can apply for an additional quantity equivalent to the number of vouchers redeemed by the seller within the same year of submission. Vehicles domiciled in a disadvantaged and/or low-income community can receive an additional 15% rebate on top of base incentives. This applies to purchasers or leases made by public or private small fleets of 10 or fewer trucks/buses. There is a $50 million revenue cap for private fleets, but public entities like LADWP are exempt. Fleets of 10 or fewer vehicles can stack other state funding programs with HVIP if the other program allows, such as the CARB Truck Loan Assistance Program.

Program Name and Agency Owner	Eligible Recipients	Funded Vehicle Types and Technologies	Incentive Amount Available per Vehicle or Infrastructure	Process to Receive Funding	Caveats and Additional Requirements
CARB's Carl Moyer Memorial Air Quality Standards Attainment Program (Carl Moyer Program) (South Coast AQMD 2023a) (South Coast AQMD 2023b) (California Air Resources Board 2023c)	California-based private and public businesses and entities.	On-road heavy-duty trucks and buses with GVWR over 14,000 lbs, transit, solid waste collection, public agency and utility, and emergency vehicles with electric, alternative fuel, or cleaner diesel technologies. Mobile off-road equipment with propulsion engines over 25 horsepower (construction and farm, stationary agricultural, cargo handling, ground support, marine vessels, shore power, locomotives, lawn and garden, light-duty vehicles) with cleaner-emission-certified engine, verified-diesel emission control strategy, or zero-emission power systems. Charging and fueling infrastructure for near-zero (alternative fuel) and zero-emission (battery) heavy-duty vehicles and equipment.	Grants based on incremental cost and cost-effectiveness (except infrastructure) to reduce NO_x, reactive organic gases, or PM with limit of $34,000 per "weighted ton" of emissions reduced for vehicles, engines, and equipment brought up to current emission standards and $522,000 per "weighted ton" of emissions reduced for vehicles and equipment brought beyond current emission standards (e.g., zero-emission or cleanest certified optional standard). Projects are evaluated by location within a disadvantaged or low-income community and may be prioritized, regardless of cost-effectiveness, in the South Coast AQMD. Over 50% of SCAQMD's Carl Moyer Program funds are targeted for disadvantaged or low-income communities.	Funds are distributed through the local air districts (e.g., SCAQMD) who must be contacted for applications and updated information on available funding and types of projects they consider eligible. Funded by SB 1107 and AB 923 (vehicle registration fees) with $60 million annual-average available statewide.	In the South Coast AQMD, projects must operate at least 75% of the time within its boundaries. The Carl Moyer Program is especially applicable to owners of heavy-duty fleets that are exempt from current regulations, an example of which is CARB's exemption of emergency vehicles under their ACF regulation. It could be an option for LADWP to voluntarily clean up older fleet vehicles to meet criteria beyond current regulatory requirements.

Program Name and Agency Owner	Eligible Recipients	Funded Vehicle Types and Technologies	Incentive Amount Available per Vehicle or Infrastructure	Process to Receive Funding	Caveats and Additional Requirements
Inflation Reduction Act of 2022 (IRA) Alternative Fuel Vehicle Refueling Property Credit (SEC. 13404) (30C) - (Otis 2023) (AndreTaxCo PLLC 2023) (Congress 2022)	US-based businesses and individual taxpayers and tax-exempt entities.	Electric and hydrogen fuel cell vehicle charging stations. “Alternative fuel” or “qualified clean-fuel” vehicle refueling property/infrastructure must comply with one of the following: • 85% by volume of one or more of the following: ethanol, natural gas, compressed natural gas, liquified natural gas, liquified petroleum gas, or hydrogen • Any mixture that consists of two or more of the following: biodiesel, diesel fuel, or kerosene and at least 20% by volume of biodiesel • Electricity.	Up to 30% per fueling/charging station with a $100,000 maximum limit (or 6% if prevailing wage and apprenticeship requirements are not met). The smaller of the two options (30% or $100,000) is generally applied. This is available through December 31, 2032.	Incentive is claimed through end of year tax forms.	EV charging stations must be bidirectional, meaning it can charge the battery of an EV as well as discharge electricity from the battery to an external electric load such as the grid. Infrastructure must be located in an eligible census tract which meets the criteria of a “low-income community,” or it must be located outside of an “urban area.”

Program Name and Agency Owner	Eligible Recipients	Funded Vehicle Types and Technologies	Incentive Amount Available per Vehicle or Infrastructure	Process to Receive Funding	Caveats and Additional Requirements
IRA Clean Vehicle Credit (SEC. 13401) (30D) / Qualified Commercial Clean Vehicle Credit (SEC. 13403) (30D) - (IRS 2023b) (IRS 2023a) (Office of the Law Revision Counsel 2023) (Congress 2022)	US-based businesses and individual taxpayers and tax-exempt entities.	Plug-in electric vehicles with at least 7 kWh of battery capacity if the GVWR is less than 14,000 lbs (LHDT) or 15 kWh if the GVWR is 14,000 lbs or above (MHDT, LHDT). Fuel cell motor vehicles with at least one cell that produces electricity on board by combining oxygen with hydrogen fuel (LHDT, MHDT, HHDT).	Up to $7,500 for plug-in electric vehicles under 14,000 lbs GVWR but as of April 18, 2023, it must meet either the critical minerals requirement for $3,750 or the battery components requirement for $3,750. Up to $40,000 for plug-in electric vehicles at 14,000 lbs GVWR or above. Up to $40,000 for fuel cell motor vehicles, $4,000 if GVWR <8,500 lbs, $10,000 if GVWR >8,500 lbs and <14,000 lbs, $20,000 if GVWR >14,000 lbs and <26,000 lbs, and $40,000 if GVWR >26,000 lbs. This credit is available through December 31, 2032.	IRS Form 8936 must be filed to claim the credit for qualified vehicles under 14,000 lbs GVWR while the form to claim the credit for vehicles at 14,000 lbs GVWR or above is still being finalized. One credit is allowed per vehicle and there is no limit on the quantity of credits one can claim, but the credits are nonrefundable which means one cannot get back more on the credit(s) than they owe in taxes.	The vehicle must be bought new and placed in service in 2023 or after and made by a qualified manufacturer (except for FCV). Incremental cost is the additional amount paid for a qualified vehicle relative to the price of a comparable vehicle powered by gasoline or diesel. Vehicles at 14,000 lbs GVWR or above must be subject to a depreciation allowance except for vehicles placed in service by a tax-exempt entity and not subject to a lease.

Program Name and Agency Owner	Eligible Recipients	Funded Vehicle Types and Technologies	Incentive Amount Available per Vehicle or Infrastructure	Process to Receive Funding	Caveats and Additional Requirements
IRA Clean Heavy-Duty Vehicles Program (SEC. 60101) - (USEPA 2023a) (Congress 2022)	A state, municipality, Indian tribe, and nonprofit school transportation association	Class 6 and 7 zero-emission heavy-duty vehicles, which includes electric or fuel cell delivery trucks, refuse trucks, utility trucks, school buses, and day cab tractors as well as infrastructure to charge, fuel, or maintain such zero-emission vehicles	A total of $1 billion to distribute through grants and rebates is available until September 30, 2031 (or until exhausted), within which, $400 million is appropriated for nonattainment areas of any air pollutant. Eligible recipients and contractors that provide rebates may be awarded up to 100% of costs related to the following: • The incremental cost for replacing a non-zero-emission vehicle with a zero-emission vehicle • Purchasing, installing, operating, and maintaining charging/ fueling/ maintenance infrastructure • Workforce development and training to support charging/fueling/ maintenance/operation • Planning and technical activities to support adoption and deployment.	Applications will be submitted to the EPA. There are no details on this process at this time.	A zero-emission vehicle corresponds to a vehicle with a drivetrain that produces zero exhaust emissions of both air pollutants and greenhouse gases under any operational mode or condition such as a BEV or FCV. An eligible contractor is a contractor with the ability to sell, lease, license, or contract as well as arrange financing for zero-emission vehicles or infrastructure for charging/ fueling/ maintaining such vehicles to eligible recipients. Eligible recipients can be individuals or entities. Air pollutants refer to criteria air pollutants as defined by the EPA (carbon monoxide, particulate matter, ground-level ozone, nitrogen dioxide, sulfur dioxide, and lead) as well as precursors of such (if applicable).

Program Name and Agency Owner	**Eligible Recipients**	**Funded Vehicle Types and Technologies**	**Incentive Amount Available per Vehicle or Infrastructure**	**Process to Receive Funding**	**Caveats and Additional Requirements**
IRA Clean Ports Program (SEC. 60102) - (USEPA 2023b) (Congress 2022)	A port authority; state, regional, local, or Tribal agency with jurisdiction over a port authority/ port; air pollution control agency; and a private entity that applies for a grant jointly with an entity described above and either owns, operates, or uses the facilities, equipment, and other technologies of a port.	Zero-emission port equipment and technology related but not limited to port facilities, electric or fuel cell cargo handling equipment, and transportation which includes electric or fuel cell drayage trucks, harbor craft, and locomotives as well as oceangoing vessels.	A total of $3 billion to distribute through grants and rebates is available until September 30, 2027 (or until exhausted), within which $750 million is appropriated for nonattainment areas of any air pollutant. Amounts awarded to eligible recipients per port equipment or technology unit are not specified but available to support their purchase or installation of zero-emission port equipment and technology, conduct planning or permitting for such purchase or installation, and develop qualified climate action plans.	Eligible recipients must submit an application to the EPA. There are no details on this process at this time.	Funds awarded must be used by recipients to purchase or install zero-emission port equipment or technology at the location of the port(s) or to directly serve the port(s) involved. Zero-emission port equipment or technology refers to human-operated equipment or human-maintained technology that produces zero emissions of both air pollutants and greenhouse gases or captures all the emissions of such pollutants and gases from oceangoing vessels at birth. Air pollutants refer to criteria air pollutants as defined by the EPA (carbon monoxide, particulate matter, ground-level ozone, nitrogen dioxide, sulfur dioxide, and lead) as well as precursors of such (if applicable).

ePTO = electric power take-off, HV = hybrid vehicle, NG = Natural Gas, ZEV = zero-emission vehicle, BEV = battery electric vehicle, and FCV = fuel cell vehicle (hydrogen).

See (California Air Resources Board 2017) for clarification on how "weighted ton" is calculated, the results of which are then used to determine eligible grant amounts.

Several State and Federal websites (summarized in a list format below) provide additional funding sources, tools, and resources to help stakeholders make the transition to cleaner fleets.

- **EPA SmartWay** Heavy-Duty Truck Electrification Resources (USEPA 2022) provides links to:
    - *Grant, loan, and incentive programs* that fund commercial BEVs and charging stations to help fleet owners of conventionally fueled diesel and gas trucks make the switch to electrically powered drivetrains
    - *Calculators* that estimate the total cost of owning commercial BEVs and cost comparisons relative to owning conventionally fueled commercial vehicles
    - *Publications* that highlight the technology and market readiness of commercial BEVs
    - *Informative resources* that focus on the charging infrastructure including the impacts on the electric grid, utility demand charges, and associated steps for selection, installation, and maintenance of such; and *organizations* that study transportation electrification.
- US DOE EERE Alternative Fuels Data Center
    - **Federal Laws and Incentives** (USDOE 2023a)
        - Lists up-to-date federal and state laws and incentives related to alternative fuel vehicles and infrastructure. The database can be filtered by federal or state jurisdiction, vehicle/infrastructure fuel technology, incentive/regulation type (e.g., grant, tax incentive, air quality/emissions, building code, etc.), and end-use type (e.g., commercial or government entity, alternative fuel producer or purchaser, and multiunit dwelling). The data are downloadable and provides a brief description, including point of contact information or link to source, of the requirements under laws and regulations as well as the offerings and eligible criteria under state and utility/private incentive programs.
    - **Publications** (USDOE 2023b)
        - Lists publications related to alternative fuel vehicles and infrastructure. Hundreds of publications in the form of reports, conference papers and proceedings, journal articles and abstracts, brochures and fact sheets, books and chapters, presentations, technology bulletins, and newsletters can be explored by entering a keyword or selecting a category with respect to the vehicle/infrastructure fuel technology of interest. Outputs can be sorted by relevance, title, author, date, or publication type and clicked on to read a brief summary of the publication or access a link to the pdf. Below is a partial list of relevant publications that could be of interest to LADWP which were obtained by selecting the “electricity” category:
            - “A Framework to Analyze the Requirements of a Multiport Megawatt-Level Charging Station for Heavy-Duty Electric Vehicles” (Mishra et al. 2022).
            - “Charting the Course for Early Truck Electrification” (Lund et al. 2022).
            - “Impacts of Increasing Electrification on State Fleet Operations and Charging Demand” (Booth et al. 2022).

    - "A meta-study of purchase costs for zero-emission trucks" (Sharpe and Basma 2022).
    - "Heavy-duty truck electrification and the impacts of depot charging on electricity distribution systems" (Borlaug et al. 2021).

- CALSTART and California Climate Investments Funding Finder tool (CALSTART and California Climate Investments 2023)
    - *Offers a search engine that helps stakeholders of light-, medium-, and heavy-duty fleets find California state programs that incentivize alternative fuel vehicles and infrastructure*. The tool allows filtering for programs via criteria such as zip code or county, vehicle/infrastructure fuel technology, vehicle vocation type, infrastructure eligibility, private/public fleet, scrappage requirement, vehicle weight classification, eligibility for combination with HVIP or EnergIIZE, whether it is first-come, first-served, and whether there is an equity component to it. The outputs provide a brief description of the program as well as the relevant organization(s) involved, how much funding is available (cumulative and per project), contact information, website link, and what components of the criteria described above are applicable for funding.

A.12 Limitations and Future Analysis

The modeling and analysis presented in this report are based on available data and the current state of knowledge. The scope for improvement of the analysis includes:

- **Sequencing of Electrification of Different Truck Vocations:** There are many different vocations of heavy-duty trucks, and each will have differing electrification potential and charging needs. Some may offer more cost-effective opportunities for electrification, charging cycles more amenable to existing distribution system capacity, etc. These differences could be investigated to propose a strategic sequencing of electrification of certain vocations, for instance within LADWP's and other city agency fleets.
- **Buses:** Our analysis also did not consider buses because they are not included in the SCAG travel demand database. Yet, buses (city transit buses, school buses and tour buses) are heavy-duty vehicles and qualify for the Charge Up LA! program incentives and goals. Furthermore, the LA100 study assumed that all school and urban transit buses would be electrified by 2030 (Hale et al. 2021). If true, the electrification of these fleets would contribute approximately 1,237 school buses, 1,693 LA Metro and 403 LA DOT buses (total = 3,333) toward the Charge Up LA! program goal of 12,000 by 2030. In addition, electrification of these buses will contribute to air pollutant emission reduction, both when driving and also at the 16 depots of the three bus fleets in terms of start and idling emissions. Future work could consider the benefits to air pollutant concentrations, health, and equity of the electrification of these fleets.
- **Effects on LADWP Power Plants and SLTRP:** Different electrification levels of heavy-duty trucks will result in varying increases in electricity demand and charging load. The results of this study and any strategies pursued can inform the next Strategic Long Term Resource Plan (SLTRP), specifically the Expected Load Forecast of future years (Los Angeles Department of Water and Power 2022b). If any load increase due to heavy-duty vehicle electrification is met through city-owned hydrogen combusting power plants in 2035, flexible charging (which is potentially an option for the analyzed heavy-duty vehicles) can be used to minimize impacts from power plant operations by choosing to operate the plants when NO_x emissions from hydrogen combustion would result in least exposure to those emissions.

- **Sources within POLA, POLB and LAX:** The roads and roadway emissions sources analyzed here are based on SCAG data and do not include sources[32] operating within the boundaries of large facilities such as the POLA, POLB, and LAX including emissions processes from trucks that are not analyzed here, e.g., emissions during idling and hoteling.) See Section 2.5 (page 16) and Appendix A.7 (page 47) for further information about sources within these facilities. To the extent that sources operating within these facilities qualify for the Charge Up LA! program or for other sources of funding that could support their electrification (e.g., for drayage trucks), benefits of electrification for these communities will be underestimated in this study. Future work could be more comprehensive in quantifying the benefits of truck electrification by considering such vehicles.
- **Cumulative Benefits:** It is important to note that the health benefits of truck electrification are reported here as annual benefits, which means that they should accrue every year experiencing the same electrification level, and thus will accumulate significantly over long periods of time. Cumulative benefits could be quantified.
- **Benefits to Residents Living Farther from Major Roads:** This analysis focuses on census tracts located near major roadways within Los Angeles, and thus the health benefits estimates are specific to just the impact of those major roadways on the selected tracts. Additional benefits should accrue to residents of neighborhoods living further away from the selected major roadways as well as from the effects of trucks driving on non-major roads. In this regard, benefits quantified in this analysis underestimate citywide benefits, although the further from major roadways (especially freeways) the lower the near-road concentration improvement from truck electrification, thus benefits do not increase linearly with increasing aerial extent of air quality modeling domain. Future research could extend the modeling domain to quantify citywide benefits of truck electrification.
- **Idling Emissions:** The current analysis focuses on only on-road emissions of NO_x and $PM_{2.5}$ from running exhaust (i.e., the exhaust emitted when vehicles are moving), as well as from brake wear and tire wear for $PM_{2.5}$. However, there are likely areas in the city (e.g., areas downwind of the ports and LAX) where other processes such as idling exhaust and exhaust from engine starts as well as from auxiliary power units from heavy-duty trucks could be significant (See the Section “Emissions Inventory Development” and Appendix A.3 “Additional Information on Emission Inventory Development” for more information about processes contributing to total exhaust tailpipe emissions). Vehicle electrification will decrease these emissions and thus provide greater benefits to nearby communities than shown in this analysis, which could be investigated and quantified in follow-on analysis.
- **Out-of-State Registered Vehicles:** Because of the presence of two major ports (POLA and POLB), there is significant movement of trucks that are registered out of state on city roads. Our analysis does not consider them—we used the total number of all three heavy-duty truck categories that are registered in the city as a proxy of the total number of all three heavy-duty truck categories that are running on roads within the city. Further analysis could focus on developing a better representation of the impacts of all trucks running on roads within the city, including out-of-state registered vehicles for a more accurate quantification of the air quality and health benefits from electrifying trucks.
- **Accounting for Power Plant Emissions:** Electrification can lead to a shift in emissions from the vehicle to a power plant. The City of Los Angeles has decided to achieve 100% clean energy for its power plants by 2035, which is the year of our analysis. Thus, we expect much lower net emissions from electrified vehicles in that year compared to today. Furthermore, tall stacks dilute concentrations

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[32] Sources operating solely within a facilities boundaries are known as non-road mobile sources; by contrast, on-road mobile sources operate on public roads.

resulting from emitted air pollutants, and thus will not significantly affect near-road, ground-level concentrations as estimated in this analysis. Impacts of net emissions are not considered in this research but could be in future research.

- **Addressing NO_x Overestimation:** The air quality model used in this analysis is known to overpredict air pollutant concentrations, especially the concentration of NO_2. Any overprediction of NO_2 concentration will lead to a commensurate overestimation of health benefits associated with NO_2 concentration reductions from truck electrification analyzed here. Although the degree of overestimation is unknown (it is impossible to validate a prediction of future concentrations), and thus the magnitude of health benefits associated with NO_2 concentration reduction are not accurate, the percentage change to NO_2 concentration and associate health effects from incremental increases in truck electrification should be more reliable. Further improvements to the air quality model settings and specifications could help to reduce NO_2 concentration overestimation further and commensurately achieve more accurate health impact estimates.
- **Tire and Resuspended Dust Emissions:** Emissions from tire wear and resuspension of dust are a function of vehicle weight. Electric trucks, because of their batteries, can weigh more than their conventional, fossil-fuel counterparts. However, due to insufficient data on how tire wear emissions change when switching from combustion to electric trucks, we assume emissions from electric trucks remain the same as those of conventional, fossil-fuel vehicles. Similarly, dust emissions from resuspension can also depend on vehicle weight. Both sources of emissions could be analyzed in future work.
- **Non-Battery Electric ZEVs:** Electrification scenarios modeled here consider all EVs to be fully battery electric, not plug-in hybrid or fuel cell vehicles. Benefits associated with other zero emissions vehicle options can differ from those presented here because of differences in emissions processed (e.g., regenerative braking-related brake wear emission reductions may not be realized in other options). Load estimation presented here can also be different based on the specific technology (or a mix of technologies) adopted. These additional assessments could be considered in future work.

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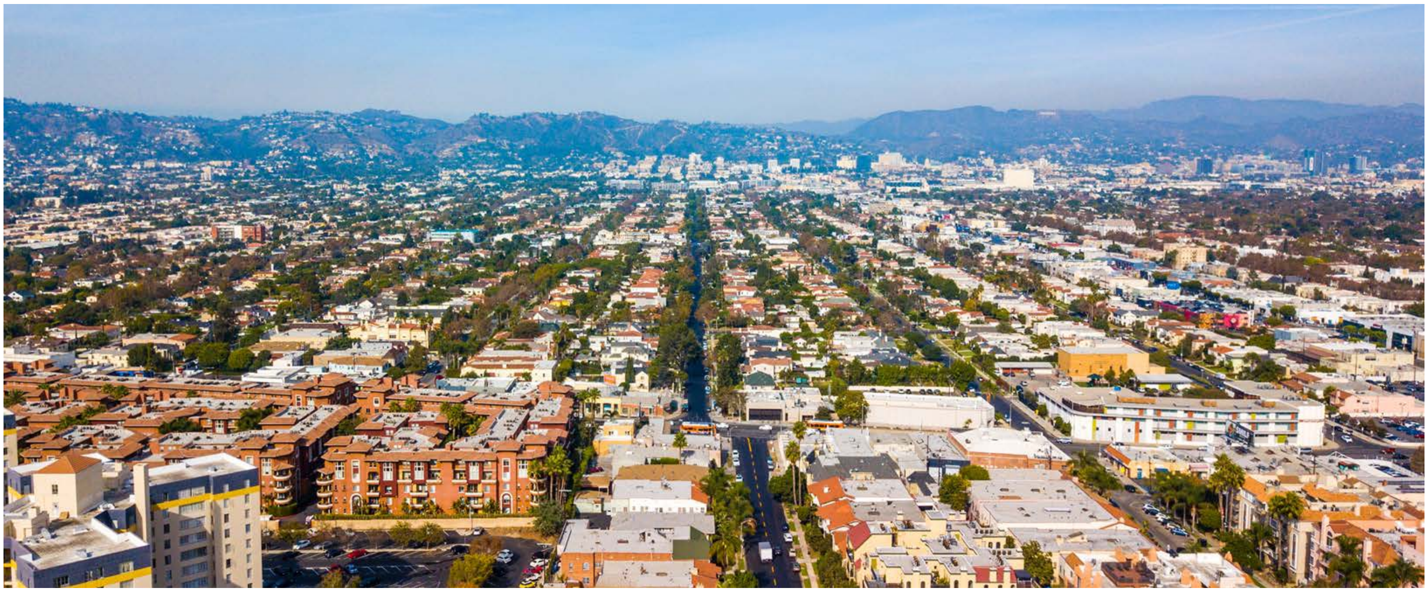
LA100 EQUITY STRATEGIES



Chapter 12. Distribution Grid Upgrades for Equitable Resilience and Solar, Storage, and Electric Vehicle Access

FINAL REPORT: LA100 Equity Strategies

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LA100 EQUITY STRATEGIES

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Preface

The Los Angeles 100% Renewable Energy Study, or LA100, revealed that although all communities in Los Angeles will share in the air quality and public health benefits of the clean energy transition, increasing equity in participation and outcomes will require intentionally designed policies and programs. The LA100 Equity Strategies project was specifically designed to help Los Angeles identify pathways to such policies and programs in the form of equity strategies. The project aimed to do this by incorporating research and analysis to chart a course toward specific, community-prioritized, and equitable outcomes from the clean energy transition outlined in the LA100 study.

The Project Partners

The Los Angeles Department of Water and Power (LADWP), the National Renewable Energy Laboratory (NREL), and the University of California Los Angeles (UCLA) partnered on the LA100 Equity Strategies project to develop strategies for engaging communities, funding equitable technology and infrastructure investments, expanding existing programs, and designing new programs and policies to improve equity by incorporating what community members themselves know is needed to achieve a more equitable energy future.

The Project Approach

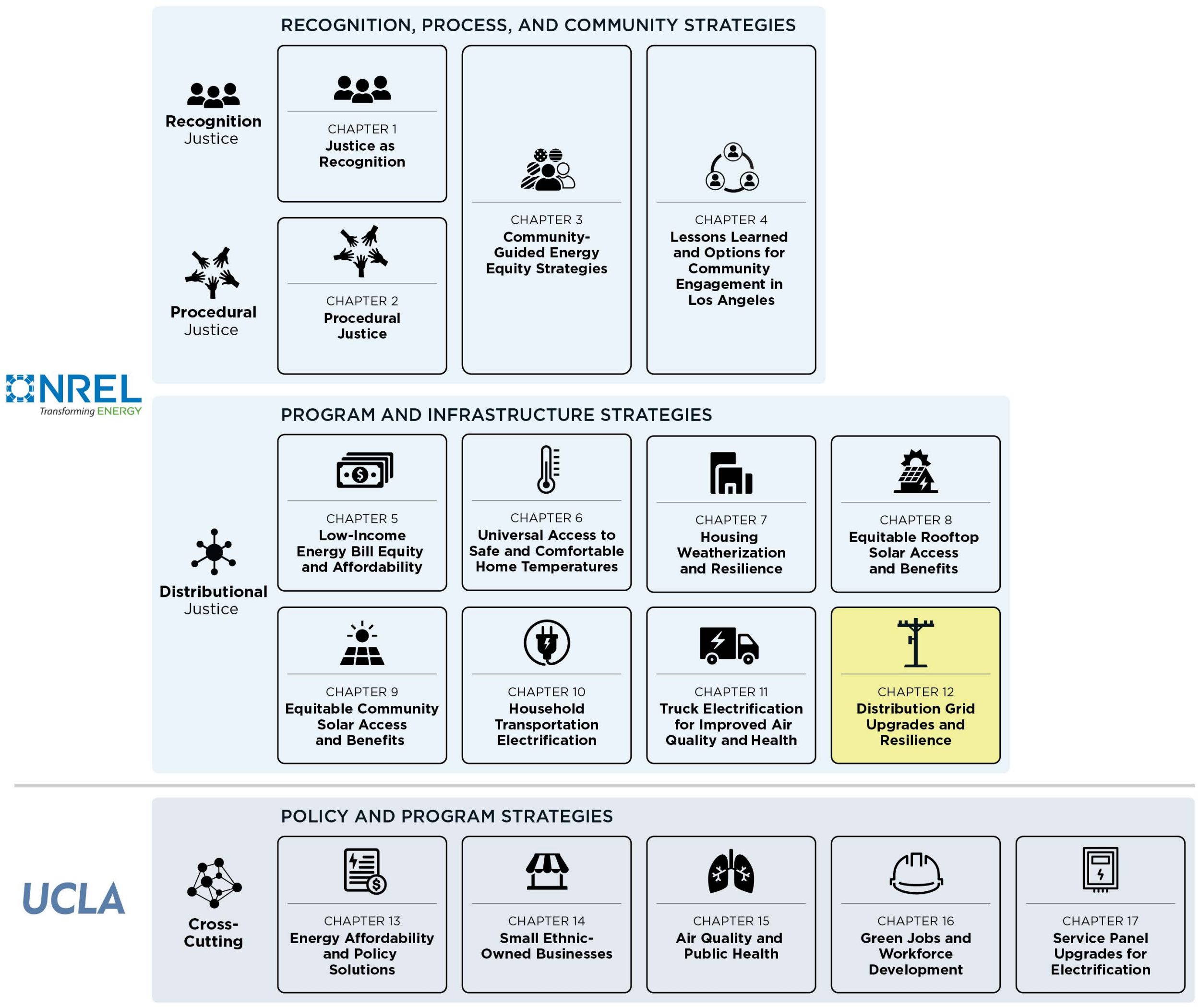
LA100 Equity Strategies employs a unique mixed-methodological approach utilizing three distinct—but connected—research efforts. Through these efforts, NREL and UCLA developed a range of strategy options for increasing equity in LA's transition to 100% clean energy.

A Project Summary

To get a high-level overview of the project, you can dive into the executive summary, interactive data visualizations, and more on the LA100 Equity Strategies website at maps.nrel.gov/la100/equity-strategies.

The Full Report

NREL's final full report for the LA100 Equity Strategies project encompasses seventeen chapters. The first twelve chapters, authored by NREL, are organized around the three tenets of justice. Chapters 1–4 address recognition and procedural justice, while Chapters 5–12 address distributional justice. The final five chapters, authored by UCLA, provide crosscutting policy and program strategies. Each chapter provides data, methods, insights, and strategies to help LADWP make data-driven, community-informed decisions for equitable investments and program development.



NREL Chapters

Chapter 1: Justice as Recognition

Chapter 2: Procedural Justice

Chapter 3: Community-Guided Energy Equity Strategies

Chapter 4: Lessons Learned and Options for Community Engagement in Los Angeles

Chapter 5: Low-Income Energy Bill Equity and Affordability

Chapter 6: Universal Access to Safe and Comfortable Home Temperatures

Chapter 7: Housing Weatherization and Resilience

Chapter 8: Equitable Rooftop Solar Access and Benefits

Chapter 9: Equitable Community Solar Access and Benefits

Chapter 10: Household Transportation Electrification

Chapter 11: Truck Electrification for Improved Air Quality and Health

Chapter 12: Distribution Grid Upgrades for Equitable Resilience and Solar, Storage, and Electric Vehicle Access

UCLA Chapters

Chapter 13: Energy Affordability and Policy Solutions Analysis

Chapter 14: Small Ethnic-Owned Businesses Study

Chapter 15: Air Quality and Public Health

Chapter 16: Green Jobs Workforce Development

Chapter 17: Service Panel Upgrade Needs for Future Residential Electrification

List of Abbreviations and Acronyms

A	amp, a unit of electric current
DAC	disadvantaged community
DER	distributed energy resource
dGen	Distributed Generation Market Demand model
DISCO	Distribution Integration Solution Cost Options model
EMF	electromagnetic fields
ERAD	Equity and Resiliency Analysis for Distribution model
EV	electric vehicle
HVAC	heating, ventilation, and air conditioning
kV	kilovolt, a unit of electric potential
kW	kilowatt, a unit of electric power
LADWP	Los Angeles Department of Water and Power
LMI	low and moderate income
NREL	National Renewable Energy Laboratory
PUMA	Public Use Microdata Area
PV	photovoltaics
SAIDI	system average interruption duration index
SAIFI	system average interruption frequency index
SCADA	supervisory control and data acquisition
V	volt, a unit of electric potential

Executive Summary

The LA100 Equity Strategies project integrates community guidance with robust research, modeling, and analysis to identify strategy options that can increase equitable outcomes in Los Angeles' clean energy transition. As Los Angeles transitions toward clean energy, existing distribution grid infrastructure will need to be updated and expanded to support reliable service during routine operations, enable interconnection with distributed energy resources and electrified loads, and provide access to energy-related services during disasters. This chapter focuses on equity in distribution grid upgrades, reliability, and resilience in Los Angeles.

Specifically, NREL performed grid upgrade and resilience analyses using a detailed model of the distribution grid and income-differentiated household load profiles, electric vehicle (EV) adoption patterns, distributed solar adoption, and grid reliability to explore two key questions to inform how the City of Los Angeles can ensure a resilient and reliable distribution grid for all communities during the clean energy transition:

- Where can distribution system upgrades can be prioritized to enable equitable access to, and adoption of, clean energy technologies?
- How can Los Angeles provide equitable, resilient access to electricity-related services (e.g., health care, food) during disaster events like earthquakes and flooding?

The electric distribution system is the "last mile" of the grid, linking the multistate bulk power system with customers; new loads, including EVs; and distributed energy resources, such as customer and community solar and storage. This analysis focuses on the 4.8-kilovolt (kV) system, including service transformers that represent the utility-side of the grid connection for most residential customers. Chapter 17 looks at the customer-side of the grid connection with a focus on electric panel upgrade needs. The transition toward clean energy can put additional stress on the distribution system from distributed energy resources and electrification—especially EVs and increased use of electricity for heating, cooling, cooking, and hot water. This stress, measured here as the number of equipment overloads and voltage violations, correlates strongly to grid reliability and therefore is used as a proxy for understanding additional upgrades needed and to help ensure equitable access to electrification and distributed energy resources. NREL also conducted community resilience analysis to examine customer-level access to both electricity and a larger range of services, such as hospitals and grocery stores during a disaster. This analysis explicitly considers equity to understand differences in current resilience and resilience strategies to effectively improve critical services access for all Angelenos.

Research was guided by input from the community engagement process, and associated equity strategies are presented in alignment with that guidance.

Community Guidance

Guidance from the LA100 Equity Strategies Steering Committee, listening sessions with community members co-hosted with community-based organizations, and community meetings included the following:

> **South LA Resident:**
>
> "I need to find someone with an upgrade of electric because…we have blockage [outages] all the time when somebody hits a [utility] post and the electricity go off and it cause problem in my home now that I cannot wash [clothes] and watch a TV at the same time. My electric goes off…they have these accidents, these people hit these posts [utility poles], then your electric's out for two hours or so, and it messes up your appliance…your appliance be off and…it's a mess."

- Invest in infrastructure capacity for all Angelenos by understanding that barriers to accessing clean, energy efficient technologies arise from multiple intersecting sociodemographic factors. For example, consider the citywide infrastructure and investments needed to ensure new clean technologies, such as EVs, will be available for all Angelenos to access and use.
- Redress historical and ongoing neighborhood neglect: outdated infrastructure needs remediation and attention to safety and health concerns.
- Develop strategies to upgrade the grid and electrical capacity (i.e., panels) of existing housing stock in Los Angeles without further burdening low- and moderate-income communities, particularly in historically disenfranchised neighborhoods.
- Guarantee access to safe and comfortable shelter during disaster events, such as heat waves and fires, particularly when access to cooling and grid reliability in participants' homes is compromised. Community members often stated that they relied on spaces outside their homes to provide a safe and comfortable environment.
- Provide safety upgrades to residential electrical infrastructure in disadvantaged communities (DACs). In buildings with older electrical systems, outages have additional impacts, such as causing safety risks and negatively affecting home appliances.

Distributional Equity Baseline

An analysis of distributional equity in electric power distribution systems infrastructure reliability found that DACs and mostly Hispanic communities experience more *frequent* power interruptions than non-disadvantaged, mostly non-Hispanic communities. No statistically significant difference was found in the *duration* of power interruptions across communities (Figure ES-1).

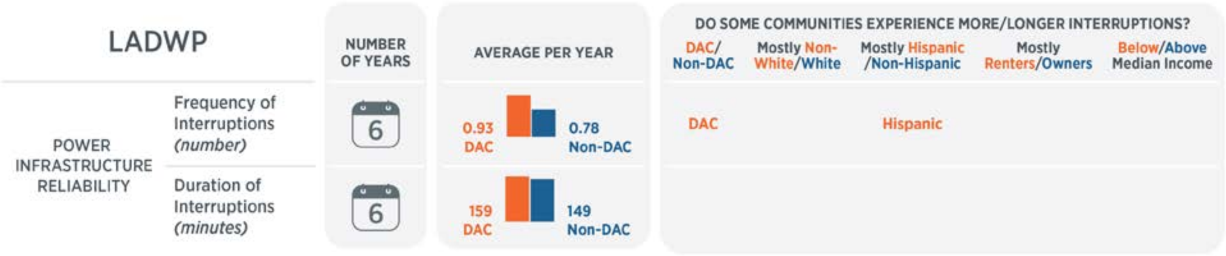


Figure ES-1. Statistical analysis of LADWP customer electric outage metrics (2015–2020)

In addition, DACs are less than one-half as likely to have underground distribution lines compared to non-DAC areas (12.6% versus 26.7% of lines undergrounded). Underground lines offer reliability, aesthetic, and other benefits.

Key Findings

- Grid reliability challenges are unequally distributed and disproportionately impact DACs. Modeled levels of grid stress—overloads and voltage challenges that provide a forward-looking proxy for lower reliability—are an average of 14% higher in regions of the city with significant DAC representation.[1] This is expected to worsen to 25% by 2035. (Figure ES-2).
- Grid stress represents a key challenge to supporting significantly higher loads from electrification and widespread integration of distributed solar and storage. To overcome these challenges, substantial increases in distribution capacity are needed.

Distribution grid equity metrics include:

- Risk of power outages and grid stress (overloads and voltage challenges) by disadvantaged community status and neighborhood.
- Ability for low- and middle-income (LMI) customers to install electrified appliances, EVs, solar, storage, and other technologies without grid or service transformer limitations.
- Access to critical services during disasters by disadvantaged community status and neighborhood.

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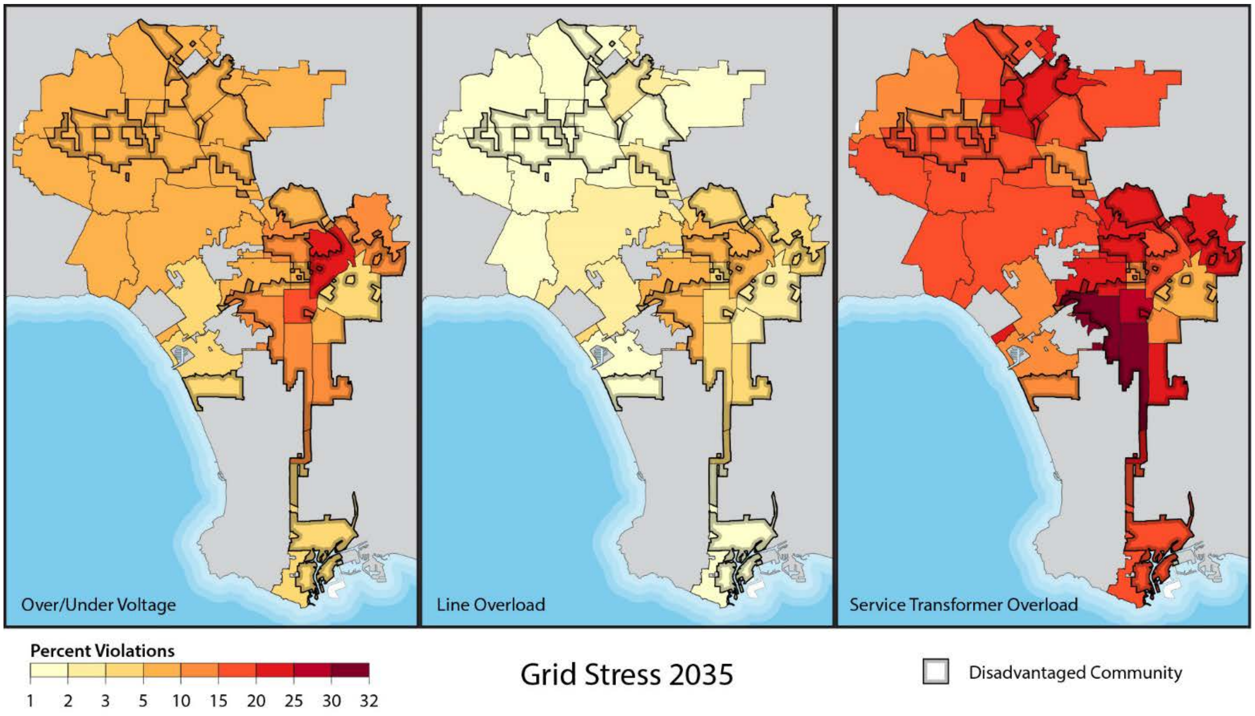
[1] Specifically for census Public Use Microdata Areas (PUMAs) where 75% or more of the representative neighborhoods are classified as DACs versus those with fewer DACs.



(a) (b) (c)

Figure ES-2. Grid stress level estimates for 2035-Equity case showing (a) over/under voltages, (b) line overloads, and (c) service transformer overloads

The level of grid stress is significantly higher in 2035 than in 2019

- Grid limitations could limit the success of other clean energy equity programs. In some cases, service transformer or grid upgrade costs may be borne by the customer, creating an additional barrier to adoption for customers, especially those with lower incomes. In other cases, required grid upgrades may be delayed, which could in turn delay other programs that seek to increase electrification, solar, and storage.
- Access to critical services—grocery, hospitals, emergency shelters, convenience stores, and banking—varies considerably among neighborhoods, even without disaster events. Although DACs have generally lower access to services such as groceries, hospitals, and convenience stores, they generally have higher access to emergency shelters and banking. These trends continue during disasters. Both DAC and non-DAC neighborhoods see significant reductions in service access during simulated disaster events, though the impacts vary considerably by service and neighborhood, resulting in some neighborhoods having very low service access. Residential electricity access is also reduced for most DAC and all modeled non-DAC neighborhoods during disaster events (Figure ES-3).
- Implementing resilience strategies such as microgrids that use future solar and storage resources already estimated to be installed and adding backup power (e.g. additional solar + storage) to 50% of critical infrastructure can significantly improve service access during disasters. If targeted for communities with initially lower resilience, such approaches could help provide more equitable service access during disaster events (Figure ES-3).

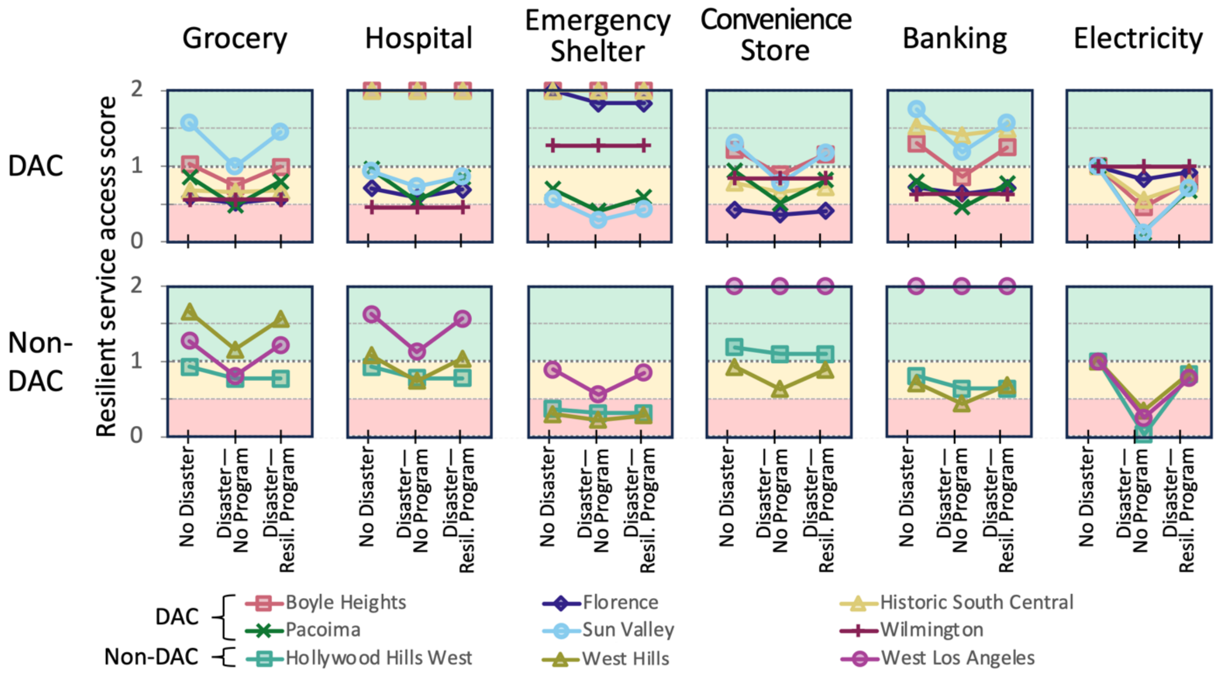


Figure ES-3. Modeled community-level resilient service access score for six critical services for residents of nine neighborhoods before and during disaster events in 2035

For each neighborhood-service combination, three access levels are shown as a series of points: No disaster, during a disaster with no resilience program, and during a disaster with a resilience program that combines microgrids using solar + storage already estimated to be installed and backup power at 50% of critical service facilities.

Resilience scores on the y-axis are normalized by median system-wide access for each critical service relative to normal operations (no-disaster event scenario). Values in the top green bands are at or above the system-wide no-disaster level (≥1), those in the yellow band have reduced service access between 50% and 100% of the system-wide no-disaster average, and those in the bottom red band are below 50% for the system-wide no-disaster average.

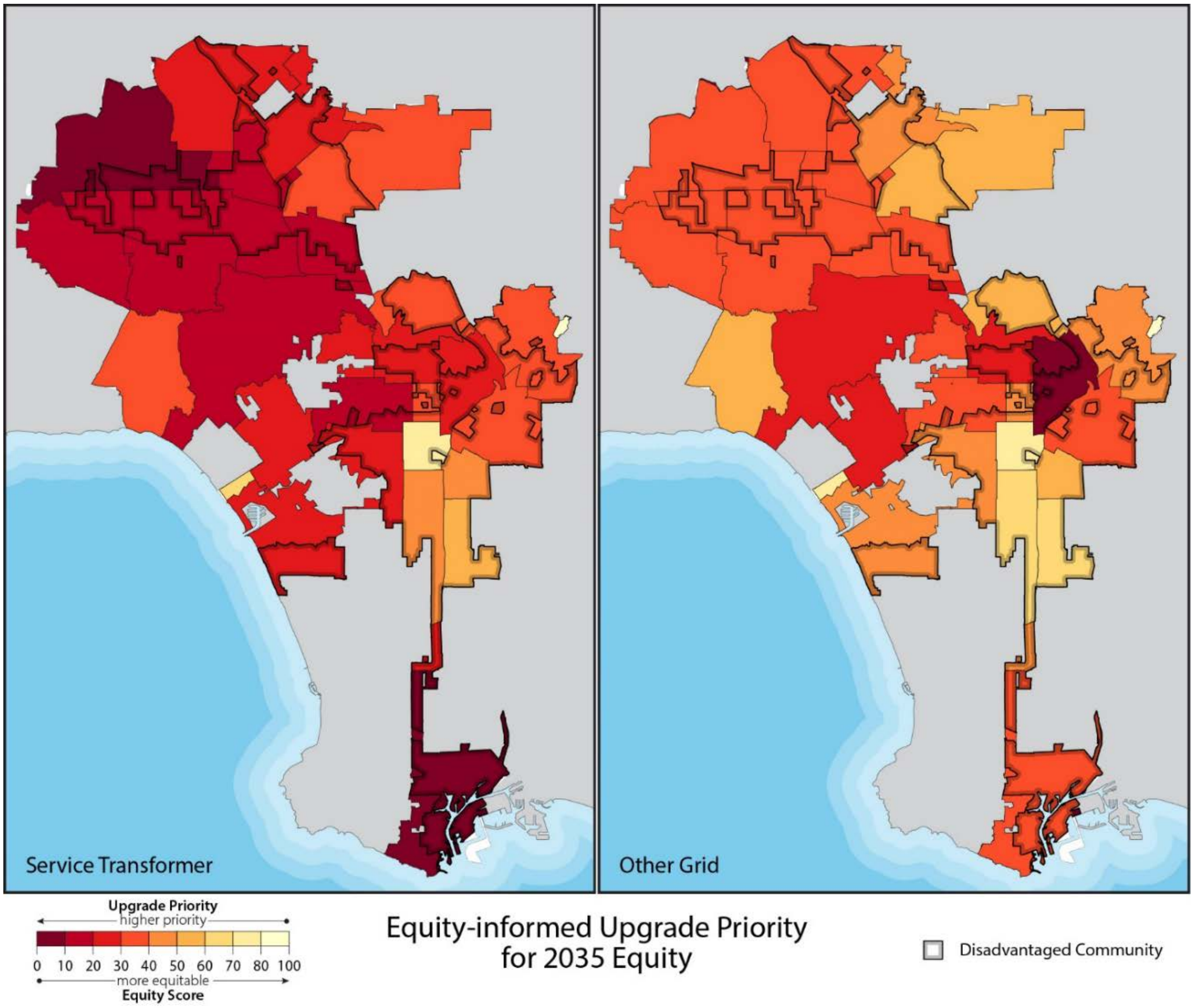
Equity Strategies

Modeling, analysis, and community engagement identified the following strategies for achieving more equitable outcomes in the distribution of benefits and burdens for distribution grid reliability and resilience in LA's transition to clean energy.

- Incorporate equity as a priority when planning grid infrastructure investments. For instance, incorporating sociodemographic data—including income and race—and DAC status into other grid evaluation metrics can highlight areas of inequity to correct. And, upgrade priority can be boosted for regions with larger differences in grid stress or other indicators between DAC and non-DAC neighborhoods. Figure ES-4 shows an example of this approach highlighting a prioritization that combines grid stress with grid (in)equity.
- Upsize transformer capacity by a factor of 2–3+ when replacing service transformers to cover not only traditional growth trends but also higher load increases and high-capacity services needed with electrification. This is especially important for customers with existing 60-amp (A)–100 A service projected to need to grow to 150 A–200 A. This can help prevent grid connections from being a barrier to equitable technology adoption and can also avoid the need to replace transformers again

before end of life, as might happen if ongoing transformer replacements do not fully consider these future higher load levels.

- Coordinate grid upgrade programs with other programs—such as those aimed at increasing equity in cooling, EVs, home electrification, and electric panel upgrades—so that the grid does not create a barrier for deployment. For example, this could include programs that cover any service transformer upgrade costs for low- to moderate-income customers, along with programs to support additional grid upgrades that might also be needed.
- Consider increased investment in underground distribution lines in non-flood-prone portions of DACs.
- Implement community-specific resilience strategies for equitable service access during earthquakes, floods, and other disasters. This includes targeted programs to prioritize resilient electricity upgrades, including on-site backup power (such as solar + storage), for critical emergency services in neighborhoods with traditionally low non-disaster service access. Additional programs could target backup power, such as solar and storage, for mobility-impaired low- to moderate-income community members.
- Collaborate with community-based organizations for preparedness, education, and support programs (Chapter 3). Efforts that work in collaboration with trusted community-based organizations could prove more effective for preparedness, particularly in DAC neighborhoods.



(a) (b)

Figure ES-4. Equity-informed upgrade priorities for (a) service transformer and (b) other grid components for the 2035 equity scenario at the Public Use Microdata Area level across the in-basin LADWP grid

Higher scores are lower priority because they indicate a combination of lower grid stress and/or higher equity.

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1 Introduction

As Los Angeles transitions toward clean energy, existing and aging distribution grid infrastructure will need to be updated and expanded to support routine operations, enable interconnection with distributed energy resources (DERs) and electrified loads, and provide access to energy-related services during disaster events. The objective of the modeling and analysis effort reported here is to inform planning for an equitable[2] and fair distribution grid by exploring three questions:

- How can the City of Los Angeles ensure a resilient and reliable distribution grid for all communities within Los Angeles in the clean energy transition?
- Which distribution system upgrades are required to enable equitable access to, and adoption of, clean energy technologies?
- How can Los Angeles provide equitable access to critical services during disaster events?

1.1 What is the Electric Distribution System? How Does it Look Today?

The electric distribution system is the local part of the grid—the portion within neighborhoods that provides a vital link between the large-scale bulk power system and building loads, distributed solar, distributed storage, and electrified transportation. In addition, the distribution grid provides the key grid link for the DERs that are expected to provide significant in-basin[3] capacity in support of Los Angeles' clean energy goal.

The Los Angeles Department of Water and Power (LADWP) electric distribution system contains two utility voltage levels: (1) the larger 34.5-kilovolt (kV) subtransmission circuits that serve the dual purpose of connecting the transmission system to local distribution substations and directly serving larger customers (generally >500 kilowatts (kW)) and (2) the 4.8-kV local distribution system to service smaller loads. Because most residential customers (both single-family and multifamily customers) are connected to the 4.8-kV system, this analysis primarily considers the 4.8-kV system. In addition, residential customers have a secondary or service voltage, which is typically in the 120-volt (V)–480-V range, that is not captured in detail in this analysis, but Chapter 17 considers the customer portion of this low-voltage system.

As seen in Figure 1, the current system has reliability equity challenges, including a higher system average interruption frequency index (SAIFI) in DACs and predominantly Hispanic neighborhoods. Specifically, DACs and mostly Hispanic communities experience more *frequent* power interruptions than non-disadvantaged, mostly non-Hispanic communities. No statistically

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[2] Energy equity or justice "refers to the goal of achieving equity in both the social and economic participation in the energy system, while also remediating social, economic, and health burdens on those historically harmed by the energy system." (Baker, DeVar, and Prakash 2019, p9).

[3] In this report, "in-basin" refers to the Los Angeles Basin.

significant difference was found in the *duration* of power interruptions across communities. In addition, DACs are less than one-half as likely to have underground distribution lines compared to non-DAC areas (12.6% versus 26.7% of lines undergrounded), as seen in Figure 2.

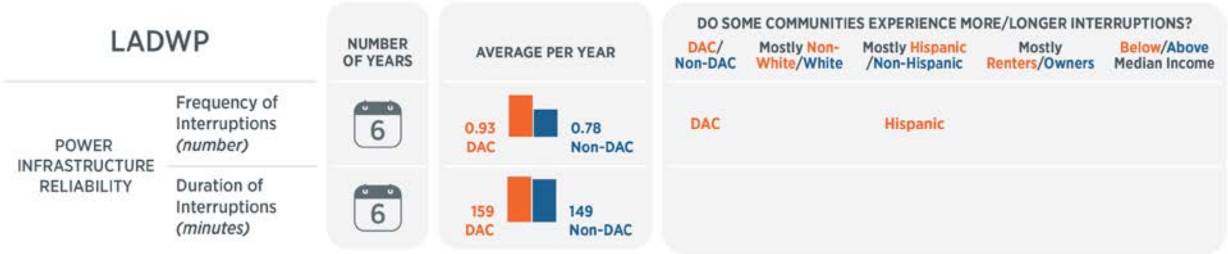

Figure 1. Statistical analysis of LADWP customer electric outage metrics (2015–2020)

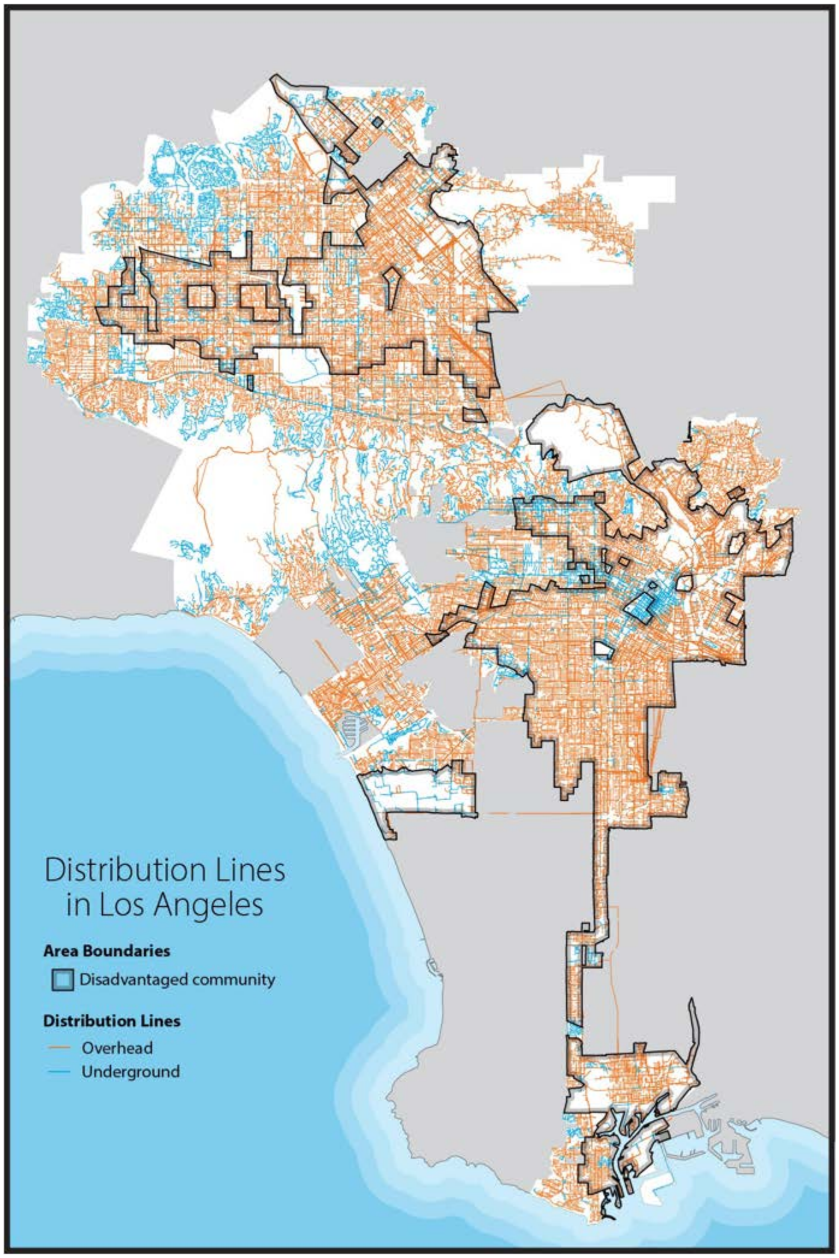

Figure 2: Underground and overhead distribution lines in Los Angeles

LADWP is already undertaking a multiyear effort to address a backlog of aging equipment maintenance through the Power Supply Reliability Program[4] and other programs, although these programs do not directly consider equity and may only partially address electrification and DER needs. With climate-related disaster events expected to become more common with climate change, it is also critical to consider the resilience of the distribution grid and related services during emergencies. Currently, LADWP is prioritizing electricity hardening options such as on-site storage for a range of city facilities for both emergency services and to provide resilience

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[4] "Power System Reliability Program," LADWP, http://prp.ladwp.com/.

hubs to offer shelter and other services to residents. However, this program does not explicitly consider equity or other services beyond municipal services.

1.2 Barriers to Equitable Interactions With the Distribution Grid

The wide range of barriers to participating in the clean energy transition that disadvantaged community (DAC) members might face can be thought of as a series of closed doors (Figure 3). For example, consider installing rooftop solar. Potential barriers may include the high up-front cost of solar, low roof structural integrity, inadequate home electric panel or internal wiring, and challenges with the grid itself. This analysis focuses on the grid itself, and other challenges—or doors—are covered in other chapters.[5] We divide the grid upgrade analysis into two elements: (1) the connection from homes to the grid with a focus on potential overloading of the service transformers, as in some situations customers might be expected to pay for some of or all service transformer upgrade costs and (2) the larger distribution grid itself, where upgrade costs are typically covered by the utility.

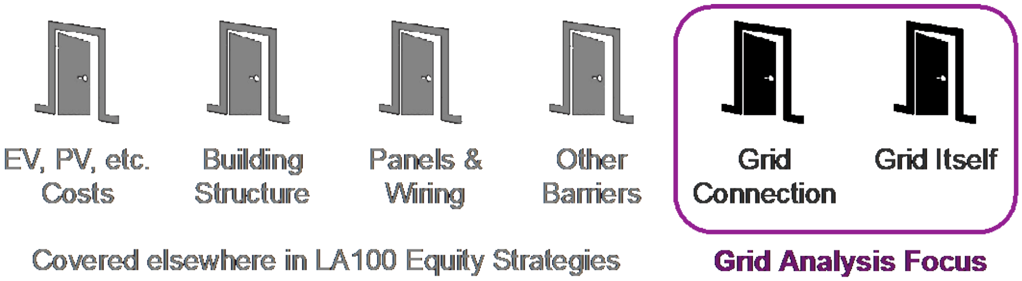

Figure 3. The barriers for a DAC member participating in the clean energy transition may be visualized as a series of closed doors

This chapter considers ways to open the doors associated with the two grid-related elements. Other chapters address other barriers.

1.3 Resilient Access to Electricity and More During Disaster Events

Access to electricity-related services during disaster events such as earthquakes or flooding is a significant additional challenge for DACs. This analysis explores options for improving community energy resilience during disaster events. Our modeling considers more than just whether customers can keep their lights on by also looking at customer-level access to a range of critical services during disaster events.

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[5] Specifically, the chapters on electricity rates and affordability (Chapter 5), solar adoption (Chapter 8), and electric service panel upgrades (Chapter 17) explore these other barriers in detail.

2 Summary of Community Guidance

As described in detail in Chapter 1 and Chapter 2, the LA100 Equity Strategies project team conducted extensive community engagement to identify community guidance on needs, priorities, and equity strategies from the local perspective. Employing qualitative methodology to code and categorize community-grounded data, this approach was applied to reveal the findings most relevant to distribution grid reliability and resilience. The following list summarizes this community guidance:[6]

- *Invest in infrastructural capacity—from building-scale to urban-scale, that lowers barriers to accessing and using clean energy efficient technologies*: Invest in infrastructural capacity for all Angelenos by understanding that barriers to accessing clean, energy efficient technologies arise from multiple intersecting sociodemographic and built-environment factors. For example, consider that distribution grid infrastructure and service transformer investments will be needed to ensure new clean technologies such as electric vehicles (EVs) will be available for all Angelenos to access and use. This includes investing in public infrastructure and making upgrades to single-family and multifamily homes.
- *Upgrade and maintain aging infrastructure for safety and efficiency*: Redress historical and ongoing neighborhood neglect by remediating outdated infrastructure. A few engaged residents were particularly concerned with safety and health dangers related to transmission lines in their community in South LA.[7]
- *Develop affordable strategies for grid and home electrical capacity upgrades that do not further burden low- or moderate-income Angelenos*: Develop strategies to upgrade the grid and electrical capacity (i.e., panels) of existing housing stock in Los Angeles without further burdening low- or moderate-income communities, particularly, as one resident noted, "neighborhoods that have been disenfranchised historically and are now expected to get up to speed to be part of the energy revolution." Another resident specifically mentioned the older housing stock in South LA (Leimert Park), which is from the late 1920s, and noted that most houses still have old electrical panels that would require upgrades to use any of the new energy efficient technologies being proposed.[8]
- *Support the development and maintenance of publicly accessible resilience spaces for safe and comfortable shelter during disaster events*: Residents often stated that in disaster events such as heat waves and fires, when access to cooling and grid reliability in their homes is compromised, they rely on spaces outside their homes to provide a safe and comfortable environment. These spaces include offices and employment locations, shopping malls, coffee shops, parks, and libraries (when they are open and accessible).
- *Invest in local capacity building and knowledge sharing about safe, efficient practices Angelenos use in their homes during extreme weather*: Provide the educational tools needed to foster and value local expertise by developing a space for Angelenos to share community knowledge and practices.

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[6] Additional quotes from engaged residents, can be found in Section A.7 in the appendix.

[7] The potential health risks of living near transmission lines have been the subject of intense debate. Reports from a wide range of credible sources "have all concluded that insufficient scientific evidence exists to warrant the adoption of specific health-based EMF [electromagnetic field] mitigation measures" (PG&E 2006), such as those from transmission lines.

[8] This assessment is supported by the panel upgrade needs estimated in Chapter 17.

- *Prioritize upgrading critical electrical infrastructure in neighborhoods with older housing stock to prevent local blackouts and their negative effects*: In buildings with older electrical systems, outages have additional impacts such as negatively affecting home appliances. In relation to outages, two reasons for local blackouts in participants homes were identified:
    - **Rain:** One resident commented on a series of outages she experienced during two days of continuous rainfall.
    - **Infrastructural Accidents and Electrical Capacity:** Another resident commented on a need for an upgraded electrical system in her neighborhood and in her home because of accidents where neighborhood electrical posts have been hit and her house has experienced a 2-hour power outage.

3 Modeling and Analysis Approach

The grid upgrade and resilience analyses build on a detailed electrical engineering model of the distribution grid and National Renewable Energy Laboratory (NREL)-modeled, Los Angeles-specific, income-differentiated household load profiles, EV adoption patterns and charging profiles, and distributed solar adoption and production.[9] Scenario details can be found in Section A.2 of the appendix. For the distribution grid analysis, the baseline (2019) estimates are scaled to match LADWP historical load patterns as described in Section A.1 of the appendix.

Infrastructure upgrade analysis provides insight into the variation across Public Use Microdata Areas (PUMAs) of grid impacts and costs needed to mitigate grid stress introduced by changing loads and equitable adoption of and access to solar, storage, and EVs. These impacts are analyzed for DACs and non-DACs to understand any differences. This analysis informs PUMA-level prioritization for infrastructure upgrade investments to ensure equitable access to reliable power.

The second part of this analysis considers equitable access to electricity and social services during resilience events, such as earthquakes and flooding. The analysis reported here includes income, DAC status, and other equity metrics to evaluate access to critical services during such events, compute aggregated community energy resilience scores, and assess which resilience strategies are most effective at boosting critical services access.

3.1 Modeling Approach Background

Both analyses use distribution grid feeder[10] models from the original LA100 study (Palmintier et al. 2021) as a starting point. The forecasted electricity consumption, EV and distributed solar and storage adoption and use, along with their time-series demand and generation profiles are estimated at the census-tract scale for representative customers. As described in Section A.1 of the appendix, a multistep process is then used to map these parameters to corresponding feeders and then customer locations.

This analysis considers two scenarios: a 2019 baseline and a 2035 equity scenario. The 2019 baseline scenario represents the present state of the system, and corresponding analyses and metrics assess the health of the present grid and existing inequities. The 2035 equity scenario uses projections of load changes due to electrification and adoption of DER technologies to look at equity-centric impacts on the distribution grid. To ensure the spatial load patterns better reflect on-the-ground conditions, the 2019 forecasted loads are scaled to match 2019 supervisory control and data acquisition (SCADA) data from LADWP at the feeder level. The same scaling multipliers are also applied for 2035. Section A.2 of the appendix includes additional scenario details and load and DER assumptions.

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[9] See Chapters 6, 7, 8, and 10 for methodologies and modeling details.

[10] Here, each feeder is the "last mile" portion of the distribution grid that connects dozens to hundreds of customers to a distributing substation. This report considers only the 4.8kV system, which connects to smaller loads (up to about 500kW) and therefore includes most housing in the city.

3.2 Equitable Distribution Grid Upgrade Priorities and Grid Upgrade Analysis Methodology

This analysis combines forward-looking reliability analysis and demographic data to help inform planning strategies to achieve an equitable distribution grid. As described in this section, this assessment uses projected grid stress as a proxy for reliability under a combination of increased load from electrification and equitable adoption and use of DERs.

A combination of increasing load, aging equipment, and large amounts of DERs can impact the reliability of the distribution system, potentially leading to outages. Past reliability performance is typically measured with metrics like system average interruption duration index (SAIDI) and SAIFI, but future reliability is difficult to predict, in part because it requires significant amounts of failure rate and condition data that are not available. Therefore, this work considers *grid stress* as a proxy for reliability prediction. Specifically, we define grid stress as line and transformer overloading along with out-of-range equipment voltages, because these elements tend to be strongly correlated with equipment failure and outages on the grid. These grid stress elements can be simulated for both current and future systems using physics-based distribution power flow analysis, which is commonly used for engineering analysis.

To run physics-based power flow analysis and determine grid stress, distribution feeders across the in-basin LADWP service territory are modeled in OpenDSS. Power flow simulations are then run using OpenDSS/PyDSS, with automation provided by the Distribution Integration Solution Cost Options (DISCO)[11] tool (Horowitz et al. 2019; Wang et al. 2022). Using DISCO upgrade analysis, the feeder-level grid stress, infrastructure upgrades, and costs to alleviate grid stress are determined for the 2019 baseline scenario and the 2035 equity scenario. Figure 4 summarizes this workflow for conducting equitable distribution grid upgrade analysis.

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[11] https://github.com/NREL/disco

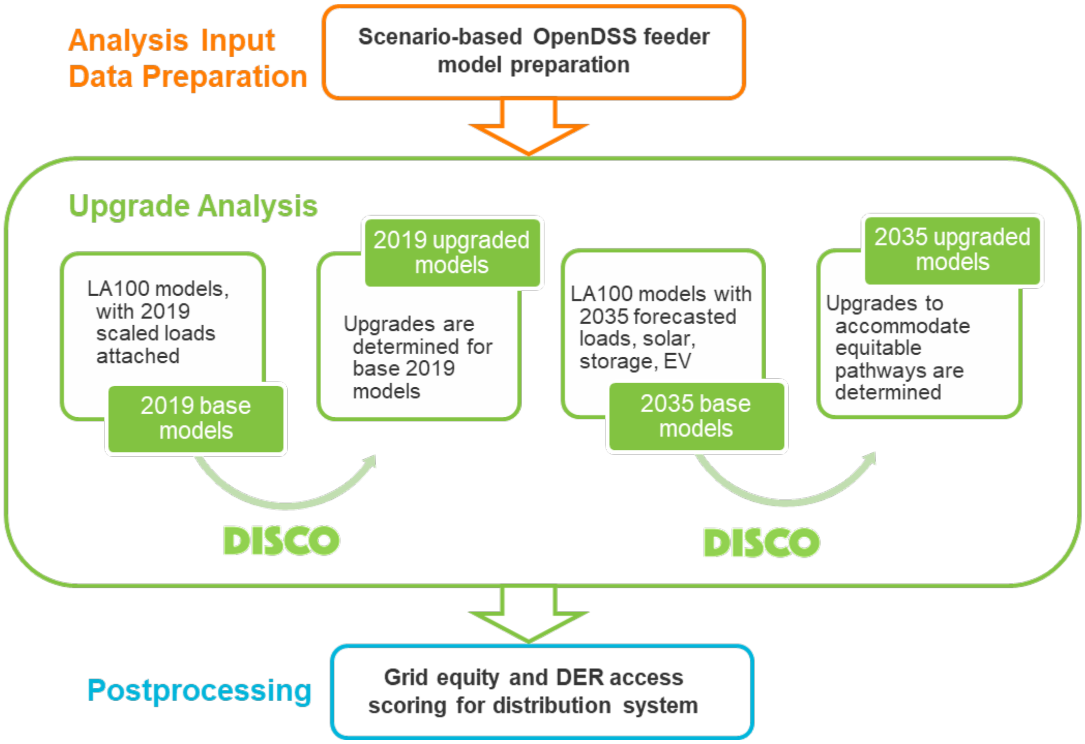

Figure 4. Equitable distribution grid upgrade analysis workflow

The first level of translation from the feeder-level analysis involves computing the *grid stress score* for individual census tracts, which is a combination of undervoltages, overvoltages, service transformer overloads, and line overloads. This is performed by first mapping feeder-level results to the census tract so they can be combined with demographic data available at that resolution. A high grid stress score implies high limits imposed by the grid. When analyzing the scenarios for 2035, a *DER adoption score* for each census tract is also estimated to capture the level of DER adoption in each census tract, for individual technologies like EV, solar, and storage. As seen in Figure 5, the grid stress score and the DER adoption score can be combined to arrive at a census-tract level *DER access score*.

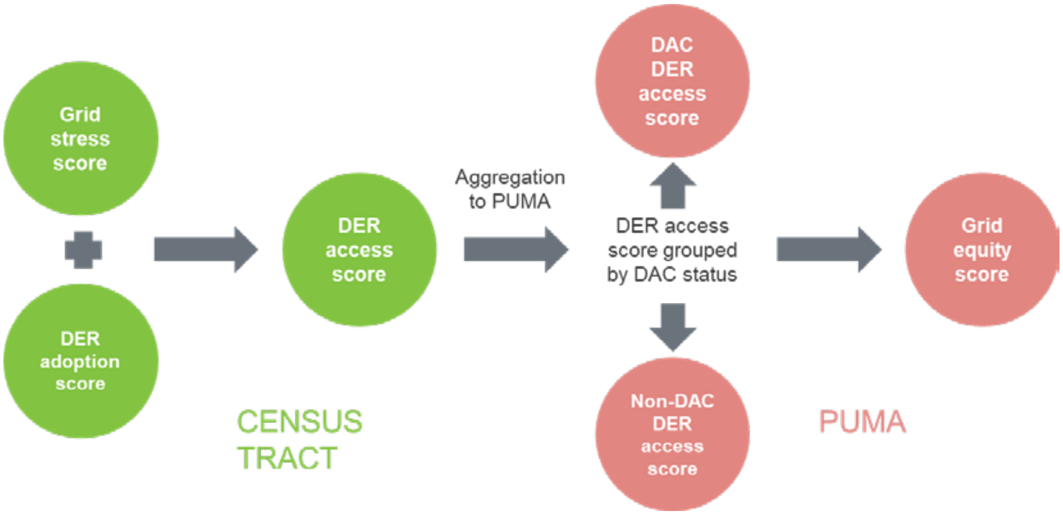

Figure 5. Process to determine a grid equity score for each PUMA in the LADWP service territory by combining the DER adoption and grid stress scores computed at the census-tract level

Traditionally in distribution system planning, grid reliability and costs are used to determine where infrastructure investments are going to be made (i.e., sites with the highest number of violations and poor reliability are prioritized to provide access to reliable power). Therefore, the DER access score represents a traditional, engineering-only assessment of how to prioritize grid investments. In a business-as-usual case, only objectives of reliability and decarbonization are considered. However, this approach does not consider any demographic metrics and does not assess equitable access to DERs.

To perform an equity-focused analysis, the census-tract level DER access score is aggregated by DAC status for each of 30 regions—corresponding to census-defined Public Use Microdata Areas (PUMAs)—in the LADWP territory. Doing so provides the DAC DER access score and non-DAC DER access score by region. The difference between these reflects the inequity within each region. By combining the mean DER access score (technical) and demographic inequity within a region, a combined grid equity score for each region can be computed. This grid equity score captures not only the technical needs but also provides a measure of equity with regard to grid stress and DER adoption for the distribution grid. Regions with a lower grid equity score correspond to those with higher priority for infrastructure investments when planning for the transition toward an equitable distribution grid.

3.3 Equitable Access to Electricity-Enabled Service During Resilience Events

In addition to grid stress during routine operations, we also estimate the equity of access to energy-related services during simulated disaster events for earthquakes and flooding. As described in this section, we use a social burden metric to compare access to a range of services.

3.3.1 Neighborhood Selection

We conduct the resilience analysis for nine neighborhoods in LADWP's in-basin service territory selected for their diversity across several quantitative and qualitative metrics.

Quantitatively, we consider five key metrics: DAC status, SAIFI, SAIDI, median income, and percentage of underground cable length. To ensure diversity, a stratified sampling approach is used by dividing all tracts into three categories for each metric separated by *mean - standard deviation* and *mean + standard deviation*. As a result, all the tracts within +/- one standard deviation of the mean fall into the middle group, and those higher or lower fall into the other two groups respectively. Then, samples are drawn separately for each of the three groups to ensure sufficient coverage of the lower and higher tails of the ranges for these values. Doing so identifies 56 tracts that are then expanded to their corresponding neighborhoods (there are multiple tracts per neighborhood). This results in 65 neighborhoods that include some or all of 252 tracts. We further down selected to nine neighborhoods based on priorities identified in on-the-ground observations, stakeholder listening sessions, and a semiquantitative typology of neighborhood types (Romero-Lankao, Wilson, and Zimny-Schmitt 2022). Doing so results in the selection of the nine neighborhoods for comparative analysis: Boyle Heights, Florence, Historic South Central, Hollywood Hills West, Pacoima, Sun Valley, West Hills, West Los Angeles, and Wilmington. The selected neighborhoods cover 92 census tracts and 167 distribution feeders. Section A.4 in the appendix includes details about the neighborhood selection process and neighborhood data.

3.3.2 Resilience Analysis Methodology

As shown in Figure 6, the resilience analysis first estimates the baseline resilience (i.e., access to critical services) of the selected neighborhoods. Then, various resilience strategies are applied, and resilience is evaluated again to identify the most promising strategies. As described in Section 3.3.3, the resilience scores are based not only on whether electricity can be provided to customers but more importantly on customer access to critical services.

Figure 6. Community energy resilience modeling workflow

The community energy resilience evaluation uses NREL's Equity and Resiliency Analysis for Distribution System tool (ERAD) (Duwadi et al. In Review), which builds a community graph database to capture a simplified, connectivity-only representation of the distribution grid to model whether supply, storage, and control are sufficient to keep loads—critical and otherwise—powered, without conducting power flow analysis. A range of resilience events (represented through probabilistic equipment damage scenarios for earthquakes and flooding) are then applied by taking randomized samples of possible equipment failures for each. These in turn are used to compute customer-level access to critical services, which are then aggregated to compute a community energy resilience score. This process is repeated after various upgrade strategies to identify different patterns of backup generation and microgrids that result in the highest equitable resilience outcomes. In this analysis, upgrade strategies include:

1. **Microgrid**: This strategy adds microgrid controllers to portions of the grid that may be isolated during a disaster, or islands, so they can use future DERs (notably solar and storage) already estimated to be installed[12] within the island to provide power without a connection to the larger grid.
2. **Critical Backup**: This strategy randomly assigns 50% of the critical services to have additional access to generic on-site backup power. In a low-carbon future this could be solar photovoltaics (PV) + storage or more traditional fuel-based backup power that seldom operates.
3. **Microgrid + Backup**: This strategy combines the previous two approaches and tends to provide the highest during-disaster service access.

Section A.4 of the appendix provides additional methodology details.

3.3.3 Equitable Grid Resilience Metrics

In the community energy resilience analysis, we evaluate customer access to a set of six critical services across a range of resilience scenarios. As seen in Figure 7, we measure the level of access each community member has to electricity, as well as a selection of other critical services—hospitals, grocery stores, emergency shelters, banking, and convenience stores—under a set of disaster scenarios. Access is defined as a function of distance to the set of facilities that are operational during the simulated disaster. The access of a household to the critical service is proportional to the inverse of the distance from the house to the nearest facility for that service that still has power. As described in detail in Section A.4 of the appendix, these individual scores are then aggregated across the community and across resilient event scenarios to build the community-scale resilience score.

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[12] For simulations, this focused on customer adopted solar + storage, while additional community-scale storage included in conjunction with community solar (Chapter 9) and/or through LADWP's new Community Energy Storage Program could also contribute and further this strategy. For resilience during disasters where connections to the larger grid may be damaged, however, the presence of storage alone may be insufficient unless these resources include sufficient grid-forming inverters, isolation switches are added, and consideration is given to balancing supply and demand and ensuring island stability. Because the strategy builds on existing distributed generation, we refer to these additional controls as the key enablers of a microgrid.

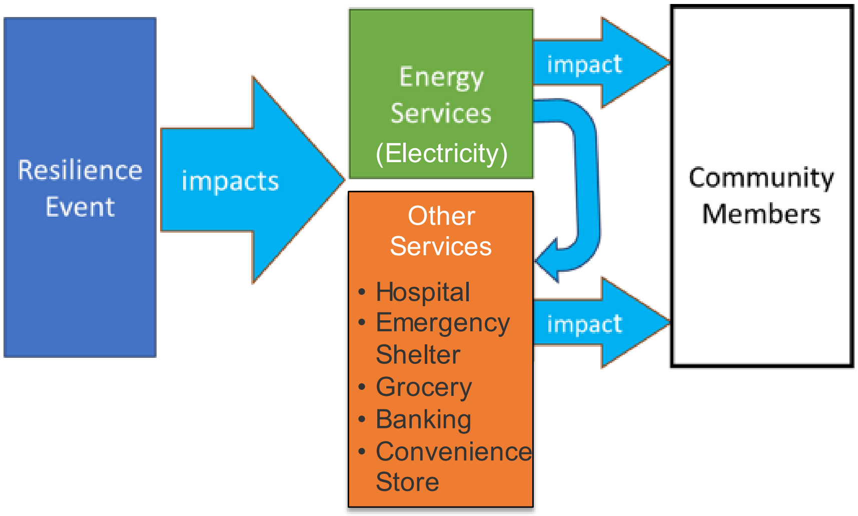

Figure 7. A resilience event can impact both electric service and the power to other critical services

Collectively, the distance-based individual community member access to operational services provides a measure of individual resilience, which is then aggregated to the community level to provide a neighborhood-wide metric.

4 Modeling and Analysis Results

4.1 Distribution Grid Upgrades for Equitable Reliability and Solar, Storage, and EV Access

Equitable distribution grid upgrade prioritization was conducted by PUMA region for feeders across the LADWP in-basin service territory. Results for the baseline 2019 distribution grid show there is already widespread grid stress—voltage stress, line overloads, and transformer overloads—and therefore substantial need for grid upgrades to the current system.

The 2035 high-grid-stress equity scenario expands this analysis using future load and DER estimates from (1) NREL-modeled building load growth including electrification, increased adoption of electric heating and cooling technologies, and general demand increase, (2) NREL-modeled electrified transportation, and (3) NREL-modeled customer adoption of solar and storage. Programs designed to encourage equitable adoption of these technologies are assumed to be in place.[13] As seen in Figure 8, the levels of growth estimated by 2035 result in significant grid stress throughout much of the city. Without any grid changes, the lowest regions' grid stresses in 2035 are roughly close to the highest level of grid stress seen in 2019. The highest regional grid stresses in 2035 are roughly 3×, 11×, and 7× higher than 2019 highs for voltage stress, line upgrades, and service transformer upgrade needs respectively.

Overall, in 2019 DACs experience roughly 1.5× more overloaded service transformers, lines, and voltage violations compared to non-DACs; this result demonstrates inequity in the distribution grid today, and this disparity is amplified in 2035 due to electrification.

Additional results, including maps for 2019, can be found in Section A.5 of the appendix.

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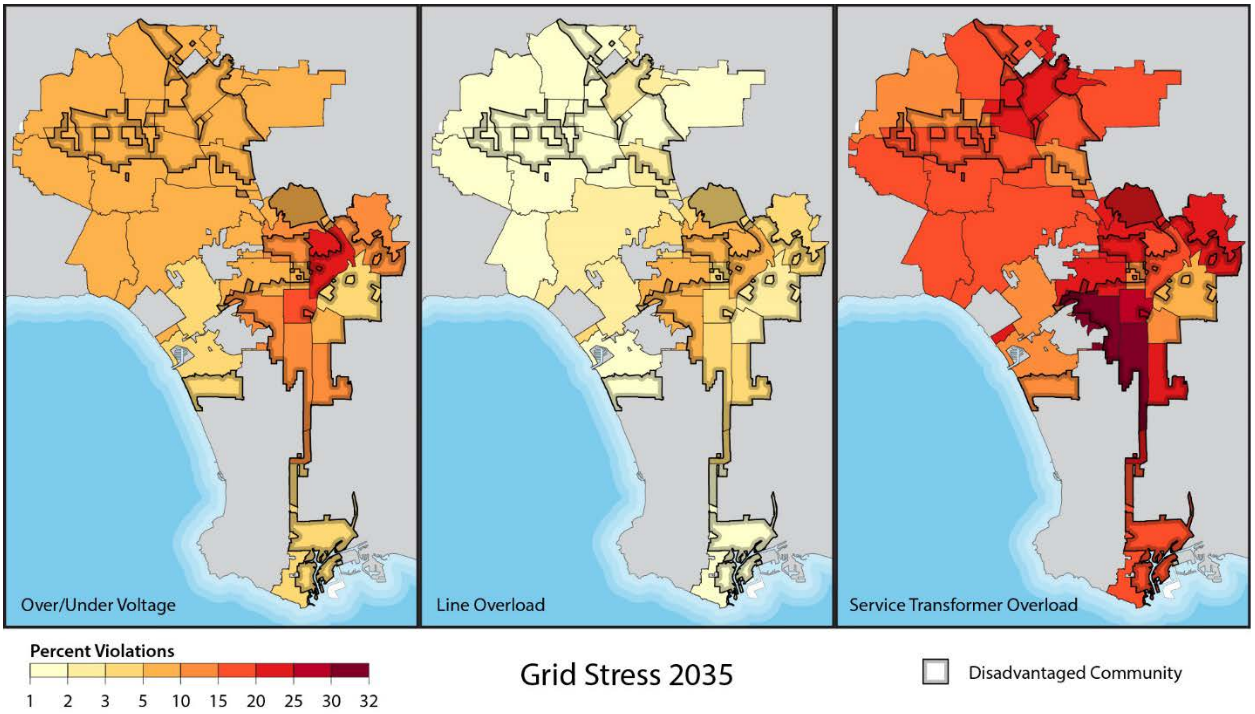
[13] Section A.2 of the appendix describes the specific scenarios from these sources used here.



(a) (b) (c)

Figure 8. Grid stress level estimates for 2035-Equity case showing (a) over/under voltages, (b) line overloads, and (c) service transformer overloads

When grid stress results and DER adoption levels are combined with DAC status as described in Section 3.2, we arrive at the equity-informed upgrade priorities. These priorities are divided between service transformer upgrades and other grid upgrades. In some cases, customers may be expected to pay for their service transformer upgrades while larger grid upgrades are generally covered by LADWP. As a result, these upgrade needs might warrant different approaches or program designs to ensure equitable solutions. LADWP's recently announced Project PowerHouse provides an example of an equity-oriented program that covers the costs of power infrastructure upgrades for 100% affordable housing and permanent supportive housing units.[14]

Figure 9 (page 17) and Figure 10 (page 18) show the prioritization of upgrades based on grid equity for the baseline 2019 grid and for 2035 respectively. These values have been normalized to a zero to 100 scale by year, with zero as the lowest equity and hence highest priority. They show that the service transformer priority patterns differ from other grid upgrades and that these patterns differ over time. The 2019 equity-informed upgrade priority areas primarily reflect areas of deferred upgrades and low DER adoption levels, with some additional priority given to areas facing higher local variation in upgrade need between DAC and non-DAC tracts. These priorities can inform the sequencing of upgrades for the ongoing Power System Reliability Program[15] or

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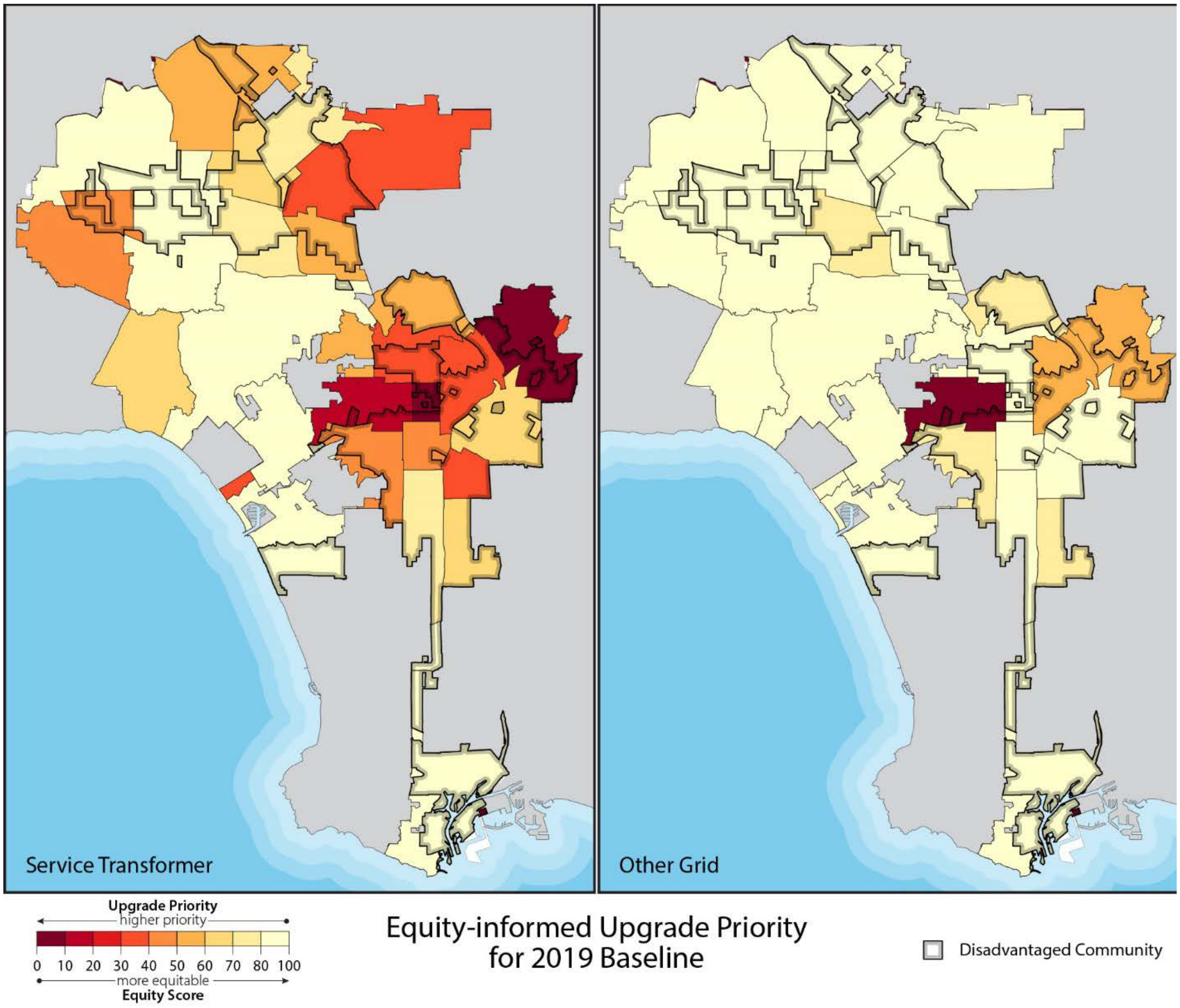
[14] "L.A. Water & Power Commissioners Unanimously Approve New Energy Services Policy Changes to Speed Construction, Lower Costs for 100% Affordable Housing Developments and Permanent Supportive Units," LADWP, March 14, 2023, https://www.ladwpnews.com/l-a-water-power-commissioners-unanimously-approve-new-energy-services-policy-changes-to-speed-construction-lower-costs-for-100-affordable-housing-developments-and-permanent-supportive-units/.

[15] "Power System Reliability Program," LADWP, http://prp.ladwp.com/.

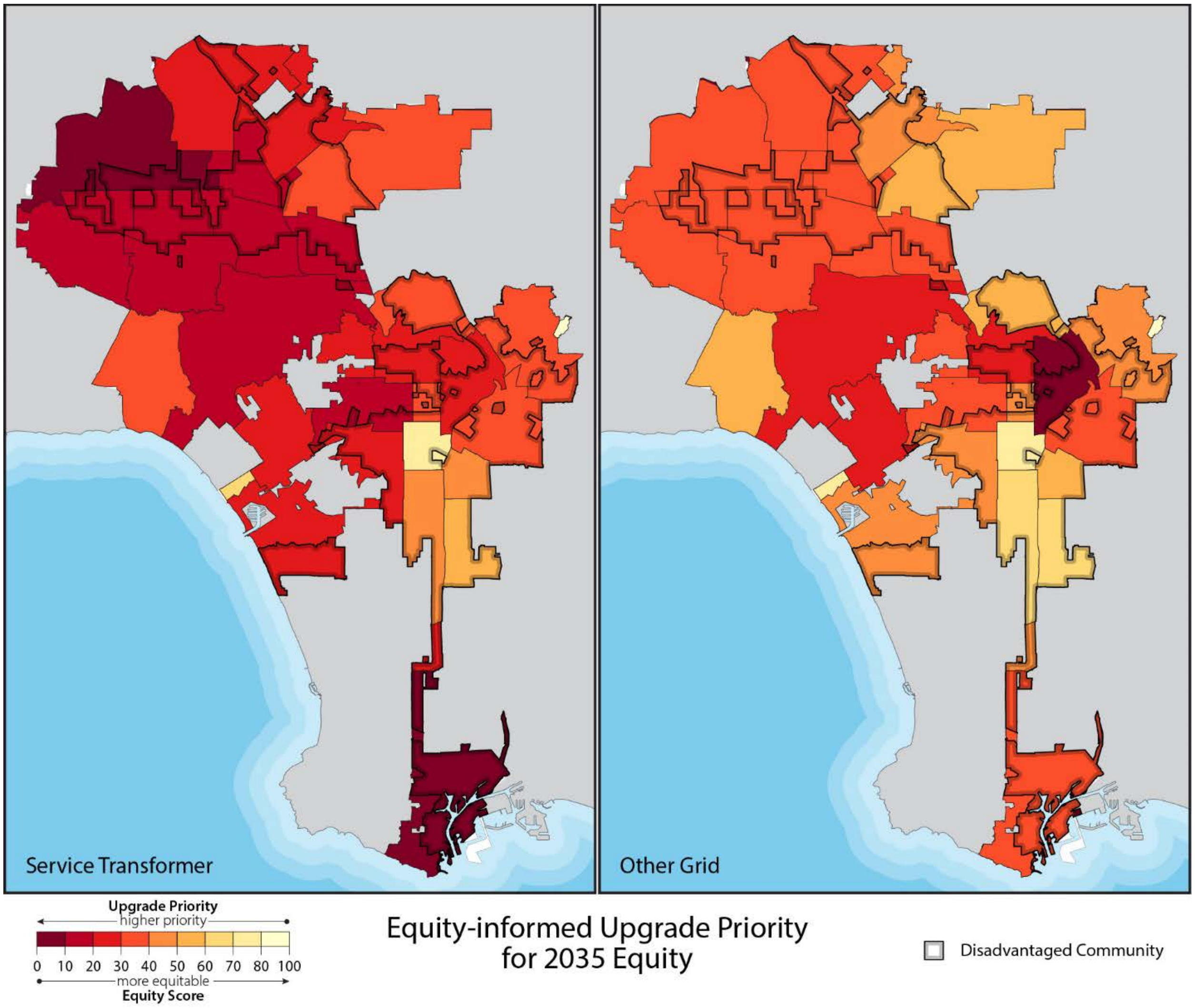
other programs to better support near-term equity. In 2019 (Figure 9), areas with low grid equity scores for service transformers are more uniformly widespread than for other upgrades. For service transformers, upgrade priorities are concentrated from the northeast to northwest of downtown, notably around Koreatown and in the roughly triangular region surrounding Mount Washington from El Sereno to Glassell Park to Eagle Park. These areas seem to combine high inequity in grid stress and DER adoption, and hence greatest need for equitable service transformer upgrades. For other grid upgrades in 2019, the region extending west from Koreatown to the outskirts of Beverly Hills shows the highest priority. Before looking ahead to 2035, it is important to note that these results are normalized for each year from zero (lowest equity, higher priority) to 100 (highest equity, lower priority). In 2019, the overall grid stress is much lower. As a result, the level of stress corresponding to a high priority area in 2019 is actually lower than that found in even lower priority areas in the 2035 scenario.

The 2035 results (Figure 10) reflect significant additional grid needs to support equitable electrification, load growth, and increased DER adoption. Service transformer upgrades are a high priority through much of the city, especially in the far south toward the harbor (including San Pedro, Wilmington, Harbor City, and parts of Harbor Gateway) along with the far northwest (including Northridge, Chatsworth and Porter Ranch). Other grid upgrade needs are somewhat lower priority, but still widespread, with the highest priority northwest of downtown (including portions of Westlake, Pico-Union, Silver Lake, Echo Park, Elysian Park, and Elysian Valley)



(a) (b)

Figure 9. Equity-informed upgrade priority, determined by the normalized grid equity score for (a) service transformer and (b) other grid components for the baseline 2019 in-basin LADWP grid



(a) (b)

Figure 10. Equity-informed upgrade priority for (a) service transformer and (b) other grid components for the 2035 equity scenario at the PUMA level across the in-basin LADWP grid

Demand from electrification and DER growth by 2035 show considerably higher grid stress than for 2019, such that lower priorities in 2035 might correspond to the same scale of investment needed in higher-priority areas for 2019.

In many cases, the upgrades indicated for the baseline system—which are shown for 2019 but are expected to take around a decade to rollout—can help alleviate the need for further upgrades in 2035. However, this is only possible if they are sufficiently oversized to accommodate the expected significant additional growth in load and/or DERs. If such growth is not taken into account, a costly second set of upgrades might be needed to manage the large growth. This speaks to a need to carefully consider the amount of capacity headroom specified for near-term equipment upgrades, particularly for service transformers, and to potentially increase this headroom.

Older buildings and lower-ampacity customers—which tend to be more prevalent in DAC communities (Chapter 17)—may see much higher load growth under equity-oriented programs than customers with newer homes or who already have a larger set of home equipment and correspondingly larger service connections. For example, equity-oriented programs that enable the addition of electrified HVAC (heat pumps), electrified cooking and domestic hot water, and EV chargers in homes that currently have primarily only plug loads and lighting, might see much higher proportional increases from 2019 to 2035 than customers who already have air conditioning and other large electric loads. A current rule of thumb—based on subject matter expert input received during the original LA100 study—is to replace equipment that sees 125% of rated loading with larger equipment such that post-upgrade loading is only 75% of rating. This represents a 1.6× size increase, which would likely be too small for a highly electrified future. A service panel upgrade analysis done as part of the LA100 Equity Strategies project (Chapter 17) suggests that over 50% of DAC customers and over 30% of non-DAC customers have 100A or less service today, often only 60A, but they are estimated to need 150–200A service to accommodate future needs. This implies a 2.0–3.3× capacity increase may be appropriate when sizing replacement transformers, particularly those that currently serve customers with low-amperage service.

4.2 Equitable and Resilient Access to Electricity-Related Services During Disaster Events

We conduct a community energy resilience assessment across nine neighborhoods—six DAC and three non-DAC neighborhoods—from the LADWP in-basin service territory using the approach described in Section 3.3. This selection of neighborhoods covers 167 distribution feeders and 92 census tracts. The selected neighborhoods and demographic data for them are listed in Table A-1 in the appendix.

Figure 11 (page 22) shows the normal, no-emergency-event levels of access to a range of critical services for DAC and non-DAC communities as a radar plot. Each of the spokes of these radar plots captures access to one service. The range for each value is normalized so that 1.0 represents the median, no-event access among all nine neighborhoods studied. These results show that prior to a disaster event, three of six modeled DAC neighborhoods (Wilmington, Pacoima, and Florence) and one of three non-DAC neighborhoods (Hollywood Hills West) have lower access to most services than system-wide median access levels. Although DACs have generally lower access to services such as groceries, hospital, and convenience stores, they generally have higher access to emergency shelter and banking.

Figure 12 (page 23) shows the corresponding results for community-level resilient service access scores during disaster events without any resilience-oriented programs in place.[16] In these results, it is assumed electricity to customers or services is only available if grid substations and distribution equipment are sufficiently intact to provide electricity or if they have generation on-site. At the neighborhood level, these results show that while both DAC and non-DACs see severe reductions in service access during the simulated disaster event scenarios, the impacts are not uniform by service or area. The most uniformly impacted service is electricity, with nearly all areas experiencing significant disruptions. Two DACs (Sun Valley and Pacoima) and two

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[16] Note that in this analysis, PV and storage adopted by customers for economic reasons as captured in Chapter 8 are assumed to be grid-following (as is standard today) and therefore are not available during a disaster unless a microgrid controller is available to provide required coordination.

non-DACs (Hollywood Hills West and West LA) have the lowest remaining electric service, covering less than half their customers.

Among other services, two of six DACs (Pacoima and Sun Valley) and two of three non-DACs (Hollywood Hills West and West Los Angeles) show large decreases in services to levels below 1.0 for three or more services; this result is in part due to their proximity to fault lines or water bodies (see Section A.4 in the appendix for fault locations relative to neighborhoods). Furthermore, even with more modest decreases, the lower pre-disaster service access for Boyle Heights, brings three of its services below 1.0, joining already lower Florence and Wilmington for a total of five of six DACs with low during disaster service access.

Historic South Central and Boyle Heights maintain much of their already high access to emergency shelter and hospital services during disaster events, while West Los Angeles maintains its high access to convenience store and banking services. Although Wilmington experiences some of the lowest overall access to critical services, it has minimal degradation of services during the modeled disasters because Wilmington is farther from the recently active fault zones[17] used in scenarios and has limited flood-prone areas.

Service access during disaster events can be improved through a range of resilience strategies. Here, we consider three:

1. **Microgrid**: Adding microgrid controllers[18] to enable use of existing DERs (including additions estimated in 2035) located on isolated islands of the electric grid that otherwise would be unpowered: In this strategy, critical services would have power if they are part of an island with sufficient generation and a microgrid controller.
2. **Backup:** Implementing a critical infrastructure backup power program that provides 50% of critical service facilities (randomly selected in this analysis) with on-site backup generation (e.g., solar + storage).
3. **Microgrid + Backup:** Implementing a program that combines the first two strategies and enables critical service backup generation to join other DERs in powering islanded microgrids.

Of these three strategies, the third one—the *backup + microgrid* strategy shown in Figure 13 (page 24)—offers the best resilience improvement in both earthquake and flooding event scenarios; however, as seen in Figure 15 and described in Section A.6 in the appendix, in general, enabling microgrid formation through switching and control using existing DERs such as solar and storage is more effective than only providing backup generation units for critical services. Microgrids alone are comparable to site-specific backup for critical services and also support residential electricity. Although the backup + microgrid program makes all nine

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[17] As described in detail in Section A.4 of the appendix, the earthquake scenario results are from four simulated events that occurred close to historically recorded earthquakes with a magnitude of >5.5 from 1965 to 2016 using USGS data. These all happen to fall in the northern part of the city. There are other potentially active fault zones throughout the city include offshore to the southwest that could more severely impact Wilmington and other southern neighborhoods.

[18] Grid-forming modes are included for sufficient inverters, isolation switches, supply/demand balance, and island mode stability.

neighborhoods more energy resilient, the impact of this program on electricity access is largest in non-DAC neighborhoods, where access goes from some of the lowest electricity access scores to some of the highest.

For simplicity, the remainder of this discussion focusses on the backup + microgrid scenario. Figure 13 shows the resilience scores with this program applied for all communities. With this program in place, none of the seven affected neighborhoods fully return to their pre-disaster electricity access levels, although most services are recovered.

A spatial comparison of results for no event, during a disaster with no program, and during a disaster with the backup + microgrid program are shown as maps in Figure 14. In this figure, a combined neighborhood score combines[19] weighted scores across all five critical services and residential electricity. These results show how the northern modeled neighborhoods (Pacoima, West Hills, Sun Valley, and Hollywood Hills West) are generally the hardest hit by the simulated disasters with very low combined neighborhood scores during a disaster without a resilience program (All Hazard map), given their proximity to historical fault lines and flood zones. Service access is notably improved for most of these regions with the backup + microgrid program. The exception is Pacoima, which still has low combined service access even with the program in place. The results for Pacoima do show improvement with the resilience program, but it still has uniformly low disaster-with-program access, largely due to lower pre-disaster (no event) access.

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[19] Using the 2-norm or square root of the sum of the squares

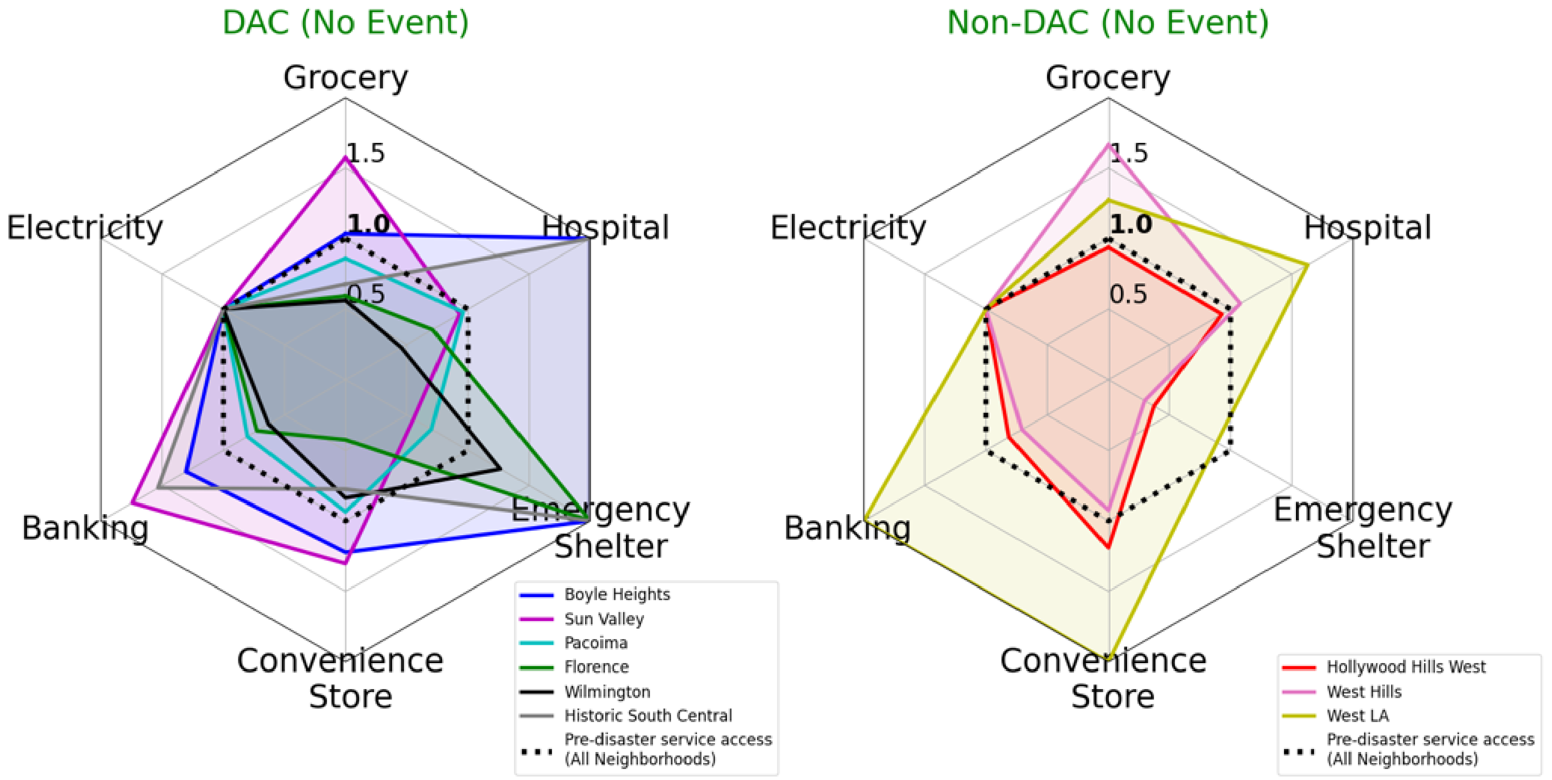


Figure 11. Median DAC and non-DAC normalized 2035 community-level resilient service access scores along six critical service axes during routine grid operations (no event)

These resilience scores are normalized such that the median system-wide access to each service has a score of 1.0 as emphasized by the bold dotted hexagon. Values within this hexagon show lower service access than the system-wide baseline.

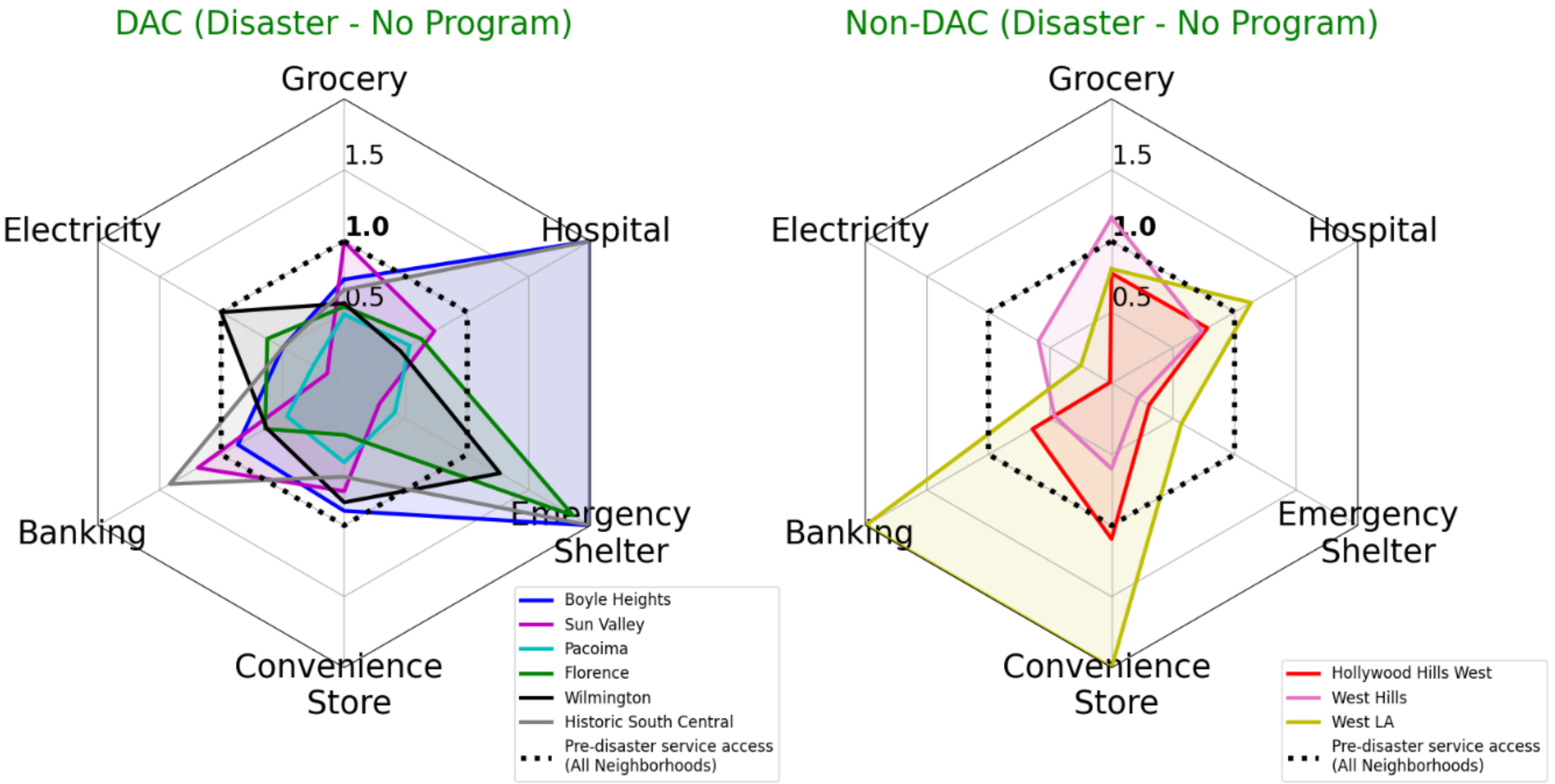


Figure 12. Normalized 2035 post-event community-level resilient service access scores across earthquake and flooding scenarios when there is no resilience-focused program in place.

Resilience scores are normalized along six critical service axes by median system-wide access to critical services in normal operations (no-event scenario). Values within the bold dotted hexagon show lower post-event service access than the system-wide, no-event reference. As described in detail in Section A.4 of the appendix, the earthquake scenario results are from four simulated events located close to historically recorded earthquakes with a magnitude >5.5 from 1965 to 2016 using United States Geological Survey (USGS) data. These all happen to fall in the northern part of the city. There are other potentially active fault zones throughout the city, including offshore to the southwest that could more severely impact Wilmington and other southern neighborhoods.

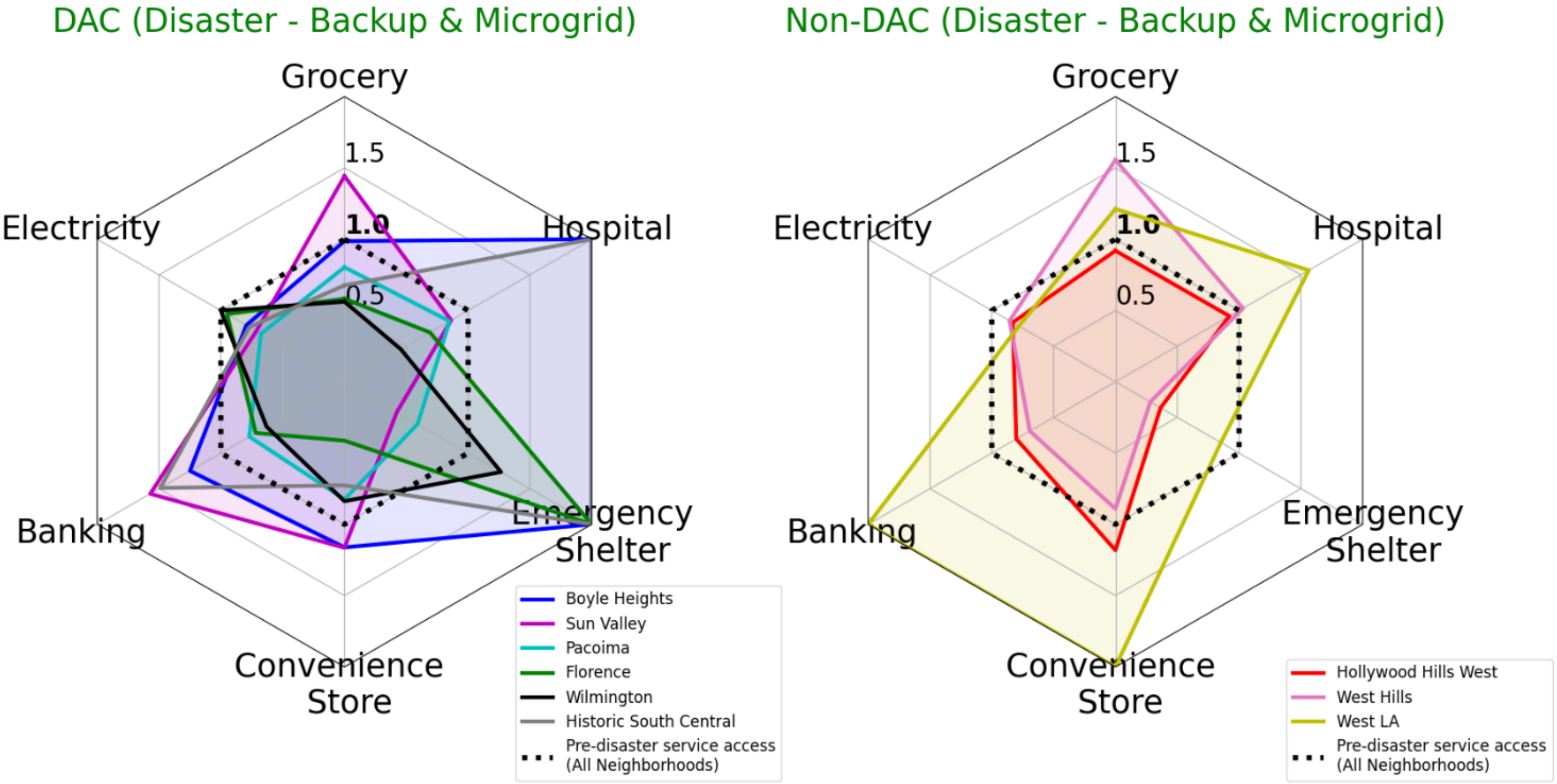
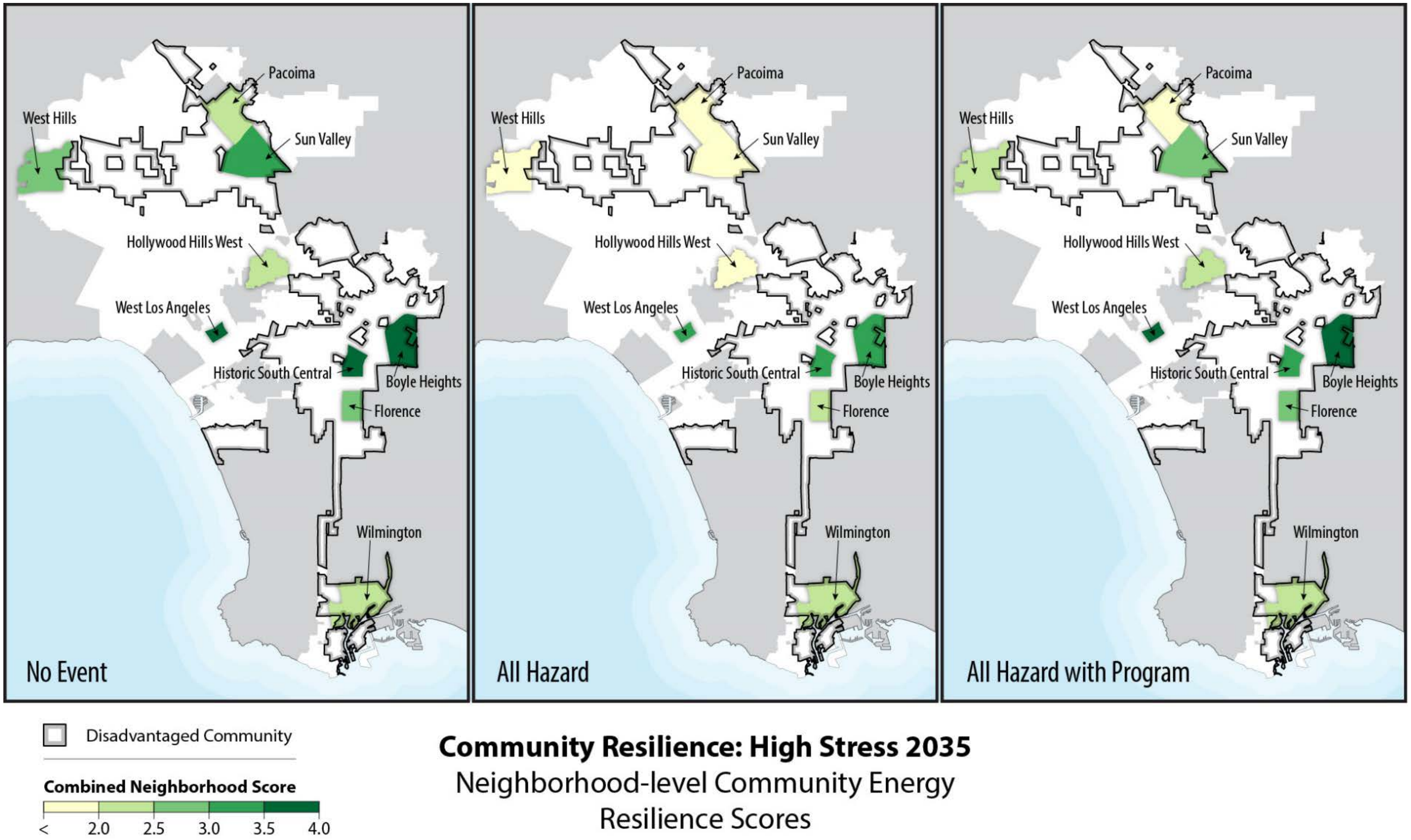


Figure 13. Normalized 2035 post-event community-level resilient service access scores with backup + microgrid and DER resilience strategy

Results show the medians for DAC and non-DAC and cover the same selection of earthquake and flooding events as other post-event results. Resilience scores are normalized along six critical service axes by median system-wide access to critical services in normal operations (no-event scenario); as a result, values within the bold dotted hexagon show lower post-event service access than the system-wide, no-event reference.



Community Resilience: High Stress 2035

Neighborhood-level Community Energy Resilience Scores

Figure 14. 2035 pre- and post-disaster neighborhood aggregate resilience scores with and without the backup + microgrid resilience strategy

Higher scores and darker greens indicate higher multiservice access (better).

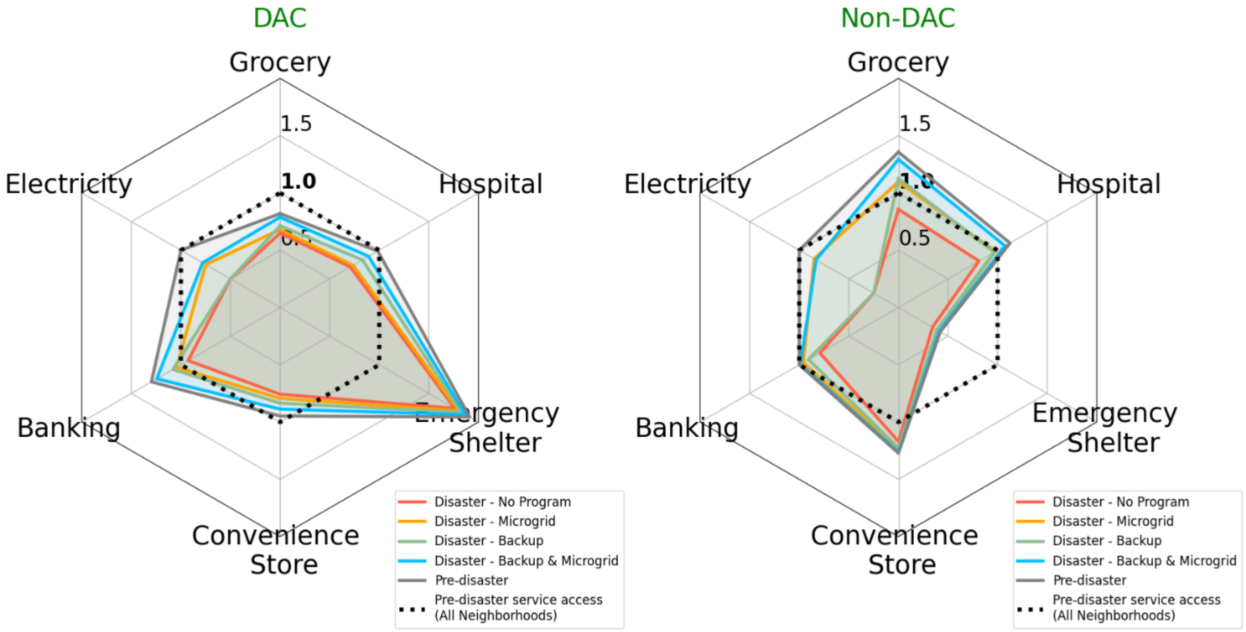


Figure 15. Comparison of resilience strategies for 2035 using normalized pre- and post-disaster-event community-level resilient service access scores across all modeled disaster scenarios

Resilience scores are normalized along six critical service axes by median system-wide access to critical services in normal operations (no-disaster event scenario). Values within the bold dotted hexagon reference show lower post-event service access than the system-wide, no-event reference.

Figure 16 provides a summary of these results by neighborhood and service. Overall, DAC neighborhoods have more access to emergency shelters and banking but less access to groceries, hospitals, and convenience stores in all disaster scenarios (with and without resilience programs). Further, disaster scenarios without resilience programs reduce access to electricity in all neighborhoods. Microgrid programs, using existing distributed generation assets (including those expected to be installed in 2035), increase electricity access though typically not to pre-disaster levels. Backup programs, which consists of providing on-site backup generation to a randomly selected 50% of critical service facilities, provides some improvement to community energy resilience in both DAC and non-DAC neighborhoods by bolstering these services' ability to operate even without grid-supplied electricity. *In combination, both programs see cross benefits. Backup generation located at critical service facilities, if combined with microgrid controls, can also provide additional generation (and storage) to nearby services without backup and can directly support nearby customer electricity. Similarly, the microgrid program can support critical services that do not have on-site backup while also reducing the generation and storage capacity needed at critical service facilities that do have on-site backup.*

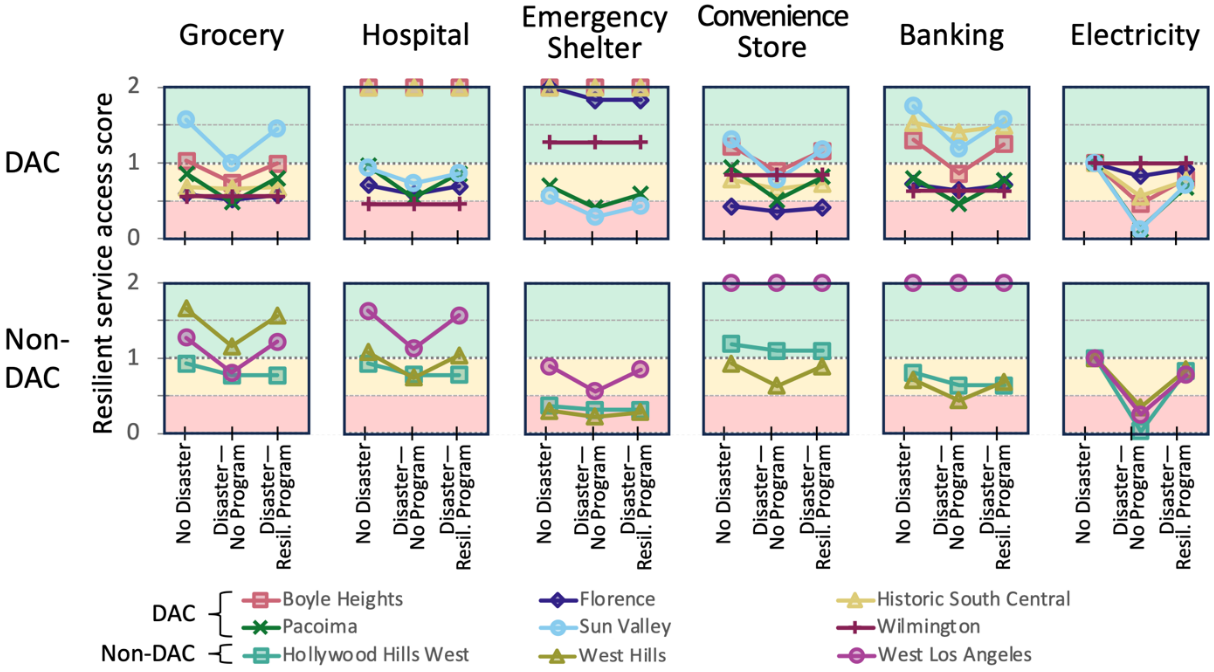


Figure 16. Modeled normalized community-level resilient service access to six critical services for residents of nine neighborhoods before and during disaster events in 2035

For each neighborhood-service combination, three access levels are shown as a series of points: No disaster, during a disaster with no resilience program, and during a disaster with a resilience program that combines microgrids using solar and storage already estimated to be installed and backup power at 50% of critical service facilities.

Resilience scores on the y-axis are normalized by median system-wide access for each critical service relative to normal operations (no-disaster event scenario). Values in the top green bands are at or above the system-wide no-disaster level (≥1), those in the yellow band have reduced service access between 50% and 100% of the system-wide no-disaster average, and those in the bottom red band are below 50% for the system-wide no-disaster average.

To improve pre-disaster access to critical services, community planners can consider increasing relevant service facilities in or near neighborhoods that have the lowest per-service access currently, and the lowest expected access in 2035. This would improve both the day-to-day lives of Angelenos and provide a higher critical service access pre-disaster starting point. For disasters, strategically equipping critical service facilities with on-site backup generation can significantly improve access to services and can be prioritized by the set of critical services that are most likely to have the lowest service access during disasters in each neighborhood. For residential electricity during disasters, the distribution grid can be upgraded with isolation switches and controllers, including grid-forming controllers, to enable microgrid operations. This also provides additional electricity options for critical services.

In addition to the backup and microgrid programs modeled in detail, additional distribution hardening and community or household backup generation kits could be considered based on neighborhood situations. For example, Florence, Historic South Central, and Hollywood Hills West had some of the lowest improvements in service access as a result of the modeled resilience programs during disasters, so might benefit from such alternatives. There may also be differences within neighborhoods due to a combination of demographics and localized disaster effects. In some cases, particularly for low-to-moderate income, mobility-impaired people or those with energy-dependent life-sustaining health needs, individual customer solutions may be needed to enable equitable service access.

Section A.5 of the appendix describes additional results from the community energy resilience analysis, including the distribution of access scores and neighborhood-level figures. Section A.6 of the appendix describes additional results from the community energy resilience analysis, including the distribution of access scores and neighborhood-level figures.

5 Equity Strategies Discussion

Modeling results demonstrate that DACs experience higher grid stress, which could restrict clean energy and technology adoption, access, and use and could also reduce grid reliability. Some neighborhoods—a mix of DACs and non-DACs—also have lower access to critical services during disaster events, suggesting targeted resilience-focused programs may be warranted to provide more equitable access to critical services during disasters. The transition toward clean energy is an opportunity to overcome these disadvantages and provide a more equitable future grid for all Angelenos. Specific strategy options for LADWP and the City of Los Angeles to do so include:

- *Incorporate equity as a priority when planning grid infrastructure investments:* For instance, incorporating sociodemographic data— including income and race—and DAC status into other grid evaluation metrics can highlight areas of inequity to correct. And, upgrade priority can be boosted for regions with larger differences in grid stress or other indicators between DAC and non-DAC neighborhoods. This will also require more neighborhood-scale considerations for load, electrification, and DER trends rather than assuming historical trends of larger load growth and therefore more technology uptake in wealthier neighborhoods will continue. If equity-informed programs succeed in increasing access to electrification, EVs, and DERs for all Angelenos, current approaches to proactively upgrade feeders in anticipation of load growth would need to extend to more DACs to prevent the grid from presenting a barrier to equitable technology access. Incorporating equity metrics into upgrade prioritization, by using metrics such as grid stress (measured in line and transformer overloading and out-of-range equipment voltages), level of anticipated DER adoption, and demographic data (Section 3.2 and Section A.2 in the appendix) is important to overcoming the inequities seen in current and projected grid stress and corresponding reliability (Section 4.1 and Section A.1 in the appendix).
- *Upsize transformer capacity by a factor of 2–3+ when replacing service transformers:* Already, service transformers are sized with some anticipation of future growth when they are replaced due to age, overload, or as part of programs such as the Power System Reliability Program. However, electrification of cooking and water heating and increased adoption of air conditioning, heat pumps, EVs, solar, and storage can all drive a need for significantly larger service transformers. For instance, an historically appropriate 1.6× size increase would likely be too small for a highly electrified future. Instead, 2.0–3.3× capacity increases may be appropriate when sizing replacement transformers, particularly those serving customers with existing low-amp (60–100A) service projected when estimates predict the vast majority of customers will need to grow to 150–200A. Alternatively, in some cases it may be more appropriate to replace a single service transformer with two (or more) units and rework the secondary (low-voltage) connections accordingly. It may also be possible to combine transformer size increases with other grid overhauls such as a feeder transition to 12kV.
- *Coordinate grid upgrade programs with other programs so that the grid does not create a barrier for deployment*. A wide range of programs for the equitable transition to a clean energy future—such as those aimed at increasing equity in cooling, EVs, home electrification, and electric panel upgrades—will require increased capacity on the electric distribution grid overall and for service transformers in particular. As a result, in order for such programs to succeed, they will need to be coordinated with grid and service transformer upgrades. Additionally, integrated program design enables multiple customer-facing and grid upgrade efforts to occur simultaneously and take advantage of synergies such as streamlined customer engagement, application paperwork, and permitting. In particular, programs to reduce or eliminate service transformer upgrade costs for low- and moderate-income

customers may be needed so technical, interconnection cost, and permitting challenges do not impede equitable technology access.

- *Consider increased investment in underground cables in DACs:* Underground cables offer benefits in the form of reliability (Fenrick and Getachew 2012), more visually appealing environments, and higher resilience to most non-flood disaster events, yet are significantly less prevalent in DACs (Figure 2). Outside flood-prone areas and where possible, overhead lines should be considered for replacement with underground lines, particularly during grid capacity upgrades in DACs. And undergrounding efforts should also include upsizing efforts as already described. To reduce the costs associated with undergrounding, such efforts could be combined with other large-scale grid projects such as 12kV transitions, feeder capacity expansion, or concentrated service transformer upgrades.
- *Implement community-specific resilience strategies for equitable service access during disasters:* The community resilience analysis (Section 4.2 and Section A.5 in the appendix) shows neighborhood-level variation to critical energy-requiring service access day-to-day and during disaster events such as earthquakes or floods. Modeling identifies resilience strategies including bosting no-disaster service access, adding backup generation (e.g., additional PV + storage) at critical infrastructure, and using microgrid controls to coordinate existing distributed generation, including customer and community DERs to enable intentional islanding[20] of parts of the distribution grid with grid-forming inverters, and/or corresponding automated switch gear. Such need is further amplified by community guidance (Section 2 and Section A.7 in the appendix). Rather than uniform efforts across the city, achieving equity for all Angelenos requires targeted service and location specific efforts in neighborhoods that currently have low service access and resilience scores.
- *Prioritize resilient electricity options for critical emergency services and at-risk community members within DACs:* During disaster events, providing backup power for critical infrastructure including fire and police departments, healthcare, food, and communication—such as through on-site solar and storage—can increase service access. This is especially critical within neighborhoods such as Pacoima that already have lower service access. Having resilient electricity for emergency services within DACs can create more equitable community resilience. Further, providing resilient electricity options to at-risk community members who may struggle to travel out of the home, such as seniors and those who require electricity for medical equipment such as ventilators or oxygen concentrators, can reduce emergency room visits, morbidity, and mortality (Molinari et al. 2017).
- *Collaborate with community-based organizations for preparedness education and support programs:* Preparation represents a key aspect of successful responses to emergency, disaster, and resilience situations. Yet due to eroded trust, lack of accessible information such as language barriers, and/or other factors, traditional education and support programs from LADWP or the City of Los Angeles may not effectively reach all Angelenos. Efforts that work in collaboration with trusted community-based organizations could prove more effective for preparedness, particularly in DAC neighborhoods. For example, the existing semi-formal network of health promoters or promotores (Center for the Study of Social Policy and First 5 LA 2019) could be provided resilience training and education materials to help share key ideas more widely with community members. Promotores who participated in LA100-ES community engagement activities expressed interest in expanding their knowledge of energy-related technologies and resilience strategies to inform their local networks.

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[20] Intentional islanding is the term for allowing a portion of the distribution grid to operate when not connected to the rest of the grid. This requires switches to isolate from the larger grid and some form of control scheme, such as a microgrid controller and/or grid forming inverters, to balance supply and demand.

Table 1 summarizes the expected benefit and cost (where known) of each strategy, as well as the timeline for implementation (short or long term), the party responsible for implementing the strategy, and metrics for measuring the success of the strategy. Figure 17 and Figure 18 provide a summary of findings, modeling results and equity strategies for distribution grid upgrades and resilience, respectively.

Table 1. Equity Strategy Benefit, Cost, Timeline, Responsible Party, and Metrics for Evaluation

Equity Strategy	Benefit/Impact	Cost	Timeline	Responsible Party	Evaluation Metrics
Incorporate equity as a priority when planning grid infrastructure investments	Reduce grid stress, increase reliability, and prevent the grid from presenting a barrier to clean energy adoption in DACs Increase transparency and ability to monitor progress toward grid equity	Neutral	Start now, keep long term	LADWP	Grid stress (undervoltages, overvoltages, service transformer overloads and line overloads).Reliability (e.g., SAIDI and SAIFI) in DACs versus non-DACs Number of grid evaluation metrics capturing DAC or low-to-moderate income status
Upsize transformer capacity by a factor of 2–3+ when replacing service transformers	Reduce grid barriers to clean energy adoption. Avoid need up upgrade transformers twice	Medium now; cost reduction in long run	Start now, keep long term	LADWP	Average capacity increase for service transformer replacements, including as a function of DAC versus non-DAC, and for customers with <100A service vs. >100A service. Number of repeated replacements to increase capacity of the same service transformer in much less than expected life (e.g. in ≤10 years)
Coordinate grid upgrade programs with other programs so that the grid does not create a barrier for deployment	Ability for other clean energy programs to meet objectives without grid restrictions Reduce cost barriers for low- and moderate-income communities customers and streamline customer engagement, application paperwork, and permitting	Low; may save money overall by enabling other programs to succeed	Start now, keep long term	LADWP	Percent of programs that impact net load that either include distribution grid upgrades or have a complementary distribution grid program. Average service transformer upgrade cost for low- and moderate-income customers who participate in clean energy programs or otherwise adopt EVs, electrification, solar, or storage. Percentage reduction in application and permitting time vs. separate, un-coordinated program participation.

Equity Strategy	Benefit/Impact	Cost	Timeline	Responsible Party	Evaluation Metrics
Consider increased investment in underground cables in DACs	Increase reliability, improve aesthetics, and increase resilience to most disaster events	High	Long term	LADWP	Percentage of circuit-miles that are underground in DAC vs. non-DAC neighborhoods. DAC parity (26.7% to match current non-DAC) means 977 underground miles of the total 3,658 miles of distribution lines in DACs, an increase of 517 miles or 43 miles/year through 2035.)
Implement community-specific resilience strategies for equitable service access during disasters	Increase equity in access to critical services	High	Medium term	LADWP and others	Normalized resilience scores by service and neighborhood. Number of critical services with >0.75 access scores during disaster events by DAC status
Prioritize resilient electricity options for critical emergency services and at-risk community members within DACs	Increase access to critical services and increased community resilience in DACs	High	Start now, keep long term	LADWP	Percentage of facilities for each critical service serving each neighborhood with clean backup power. Percentage of at-risk community members with clean, backup-ready power
Collaborate with community-based organizations for preparedness education and support programs	Increase preparedness in DACs. Overcome trust and information access barriers	Low	Short term	LADWP, community-based organizations	Number of *promotores* trained Number of community members reached

Baseline Equity

- Disadvantaged communities and mostly Hispanic communities experience more frequent power interruptions.
- Customer costs to upgrade utility transformers, when modernizing service size for electrification, integration of solar, storage, EVs, etc., can be a key barrier.
- Disadvantaged community census tracts are less than one-half as likely to have underground distribution lines compared to non-DAC areas (12.6% versus 26.7% of lines undergrounded).

Community Solutions Guidance

- Update aging electric equipment to improve reliability in DAC neighborhoods.
- Support low- and moderate-income households in upgrading their electrical panels and service connections so they can access and use air conditioning, heat pumps, EVs, solar, storage, or upgraded appliances.

Modeling & Analysis Key Findings

- The consequences of poor grid reliability do not impact all communities equally and disproportionally impact DACs.
- Average grid stress is 14% higher in regions of the city with significant DAC fractions today. Without upgrades this is expected to worsen to 25% higher by 2035.
- Service transformer and other grid upgrades are needed to support expected EVs, electrification, solar, and storage.

Equity Strategies

- Incorporate equity as a priority when planning grid infrastructure investments
- Upsize transformer capacity by a factor of 2-3+ when replacing service transformers
- Coordinate grid upgrade programs with other programs so that the grid does not create a barrier for deployment.

Figure 17. Grid upgrade equity strategies

Baseline Equity

- Social burden (effort to access critical services) during disasters is worse in some communities than others.

Community Solutions Guidance

- Guarantee access to safe & comfortable shelter during extreme events.
- Address underlying causes of blackout risks and their negative impacts on home environments.
- Expand outreach and awareness about resources and options in emergencies.
- Prioritize community members with energy-related health needs and seniors in emergency situations.

Modeling & Analysis Key Findings

- Even before disasters, DACs have generally lower access to groceries, hospital, and convenience stores, but generally higher access to emergency shelter and banking.
- Service access is significantly reduced during disasters, though the impacts vary widely. Northern neighborhoods are more impacted due to proximity to active fault-lines and low-lying areas
- Microgrids using expected solar and storage, and backup power at half of critical facilities boosts service access 0-30% depending on neighbohood.

Equity Strategies

- Implement community-specific resilience strategies for equitable service access during disasters
- Prioritize resilient electricity options for critical emergency services and at-risk community members within DACs
- Collaborate with community-based organizations for preparedness education and support programs
- Consider increased investment in underground cables in DACs

Figure 18. Grid resilience equity strategies

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Appendix: Distribution Grid Reliability and Resilience Modeling and Analysis Methodology and Detailed Results

A.1 Methodology Details: Data Preparation

To develop high spatial resolution, bottom-up customer-level load forecasts, as seen in Figure A-1, NREL modeled data at a census-tract resolution and mapped these data first to feeders and then to distribution service transformers. Secondary (low-voltage: 120–480V) line modeling was not included. Instead, all NREL-modeled modeled building loads, EV charging, distributed solar generation, and storage were modeled as being connected directly to the low side of service transformers.

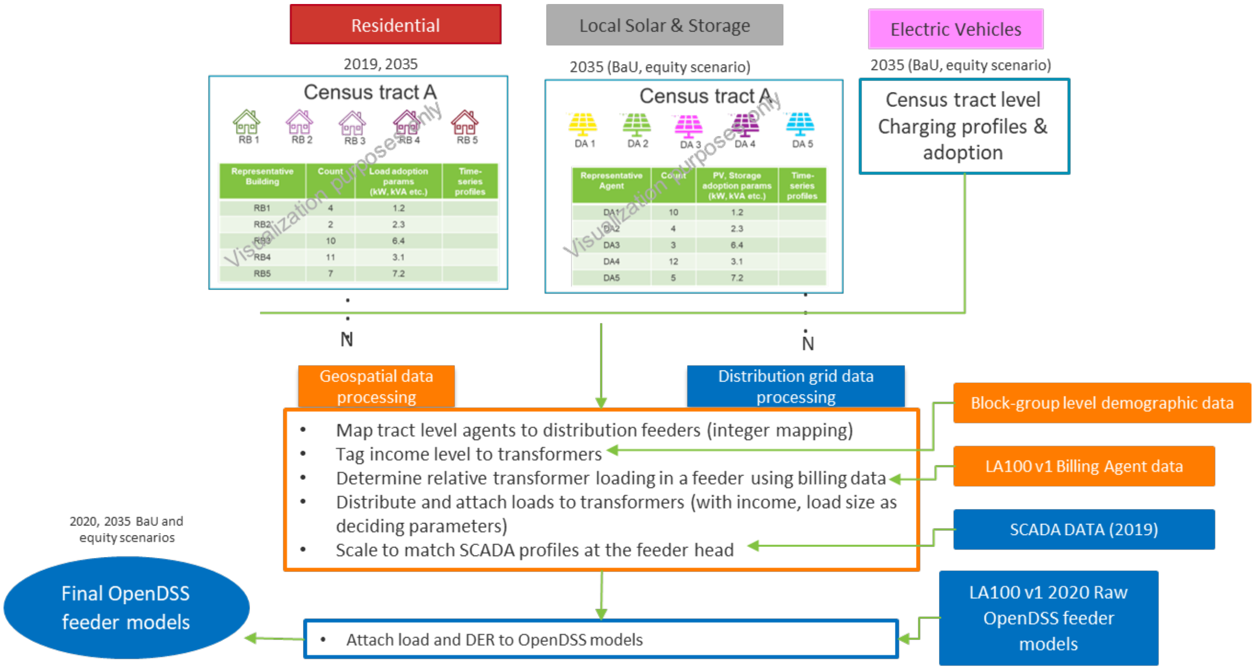

Figure A-1. Simplified schematic of the feeder preparation workflow

NREL-modeled data consisted of agent tables at the tract level, where each agent type corresponds to a row. For example, the building agents represent a unique combination of building type (e.g., single-family detached home), vintage (e.g., 1970s), tenure (e.g., renter occupied), and income level. In addition, each agent type row contains a count of the number of occurrences of that agent type.

NREL modeled approximately 50,000 residential building agents, each with a unique combination of building, building system, and household characteristics and associated energy loads.[21] The distribution grid analysis mapped building agents to census tracts and then to feeders based on spatial proportions, and subsequently mapped to transformers within feeders,

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[21] Distribution gird analysis used the expanded agent list developed by the dGen team to account for additional buildings that appeared in the lidar data but were missing from the detailed building simulation results.

based on income level, transformer capacity, phase count (single-phase versus three-phase), and size of load. Modeled building load time-series data for 2019 was attached to corresponding agents and finally scaled to match 2019 SCADA data. Where feeder-level SCADA data were unavailable, substation transformer bank data were used where available, and where not, neighboring feeder scaling estimates were used instead. We also use SCADA data at the agent level to attach time-series reactive power to this model.

Because the building stock is assumed to be static, the building type to tract and therefore feeder mapping is static, allowing the assignment to be done once and then reused for additional years and scenarios. In addition, the same base weather year (2012) and calendar structure was used for all scenarios. This allowed reusing the feeder-specific load time-series scaling factors developed for 2019 to adjust for spatial differences in 2035. For example, if the modeled 2019 load for a feeder was 10 MW at a given time point, but the corresponding SCADA data were only measured at 6 MW, the scaling factor of 3/5 was applied to both 2019 and 2035 modeled building loads at that point in time. If the 2035 raw modeled building loads at that point were 15 MW, applying the same scaling factor would result in using 9 MW in the 2035 modeling.

Because commercial and industrial loads were not simulated in detail as part of LA100-ES, we reused the commercial and industrial data from the original LA100 project at a feeder level and assigned it proportionally to transformers based on the billing data mapping to the agent commercial load classification in NREL's Distributed Generation Market Demand (dGen) model. These results were then scaled based on a combination of the known fraction of commercial and industrial versus residential annual energy (from billing data) applied to the SCADA data to estimate the non-residential load.

Once the base building load was assigned for all feeders, years, and scenarios, next solar, storage, and EV loads were added. PV adoption is available from the dGen model at the building-agent-type level, making it readily assignable to corresponding loads. The installed solar capacity in 2019 was adjusted to match historical data and adjusted in 2035 using the load max power (not time-series) scale difference between 2019 simulated and 2019 SCADA data at the dGen agent level. The solar time series was translated from capacity to power production based on irradiance data matched to the weather data used in the building simulations. All new solar and storage installations were assumed to use smart inverters consistent with California Rule 21 and IEEE 1547-2018. Specifically, they were modeled as using a combination of Volt-VAR *and* Volt-Watt inverter controls, consistent with LADWP's planned requirements. See Palmintier et al. 2021 Appendix A for specific curves.)

For EVs, detailed charger location, customer assignment, and charge event data were not available. So, we started with the tract-level summary of charging events for both commercial and residential chargers and the tract-level number of residential level-1 and level-2 residential chargers provided by the LA100-ES transportation team. Even this level of data was not available for commercial chargers, so for commercial charging, the maximum number of simultaneous charging events by type (i.e., level-1, 120V AC; level-2, 208–240V AC, or level-3 DC fast charge) was multiplied by a scaling factor to estimate the number of corresponding commercial chargers in the feeder. Chargers were then assigned to service transformers based on transformer phasing, load type, and amount of distributed solar and storage capacity at that transformer. With the charging infrastructure in place, actual EV charging events were then randomly assigned to charging stations for corresponding charger types, customer types, and time periods. This included translating the two typical day (weekend and weekday) time series to match a full 8760 hourly time series by duplicating the weekend day for all Saturdays, Sundays, and widely celebrated national holidays.

Throughout this process, pre- and post-assignment checks were conducted to verify intended behavior (e.g., not having large loads mistakenly assigned to smaller transformers) and to confirm the total demand by type and spatial location was preserved.

With this, the data preparation was complete, and feeder models were ready to run for analysis.

A.2 Methodology Details: Scenario Data Used for Distribution Grid Analyses

The distribution analysis uses 2019 data as a representation of the current system, rather than a more recent year, due to complete data availability—including 2019 SCADA data—and to remove the impacts of the COVID-19 pandemic.

The 2035 grid scenario attempts to capture the highest grid stress across the solar and storage, vehicle electrification, and residential building scenarios. For behind-the-meter PV, this includes the highest PV adoption scenario, which assumes strong programs to enable DER adoption among renters and multifamily building residents (Chapter 8). EV adoption and charging estimates follow the equity scenario adoption patterns for 2035 (Chapter 10). Building loads assume the higher business-as-usual load levels that do not include substantial DAC efficiency deployment. These higher building loads represent additional potential grid stress and are consistent with the load patterns used in the highest behind-the-meter PV adoption scenario (higher energy consumption makes PV adoption more economically attractive).

A.3 Methodology Details: Equitable Distribution Grid Upgrades for Reliability and Solar, Storage, and EV Access and Use

As introduced in Section 3.2, the equitable distribution grid upgrade analysis aims to assess equity in future grid reliability and grid access for adopting DERs, EVs, and other new technologies. This is done by computing current and 2035 grid stress as a proxy for reliability and then estimating distribution system infrastructure upgrade needs and planning strategies to achieve an equitable distribution grid.

In the upgrade cost analysis, distribution grid violations and necessary infrastructure improvements are determined, and associated costs are estimated, to ensure the distribution system does not experience problems such as overloaded equipment or poor voltages. Distribution feeders are modeled using OpenDSS for power flow with automation provided by the DISCO[22] tool. The analysis includes power flow simulations that capture the physics of electricity flowing through wires and other equipment and identification of grid stress in terms of voltage violations and thermal overloads. First, the DISCO analysis is run to estimate stress in the 2019 baseline model year; and then, the analysis is run again to identify impacts of estimated 2035 load and EV and solar and storage deployment. Finally, the grid impacts of both years are

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[22] https://github.com/NREL/disco

postprocessed and evaluated by DAC and non-DAC census tracts. The results are then aggregated to the PUMA level to suggest priorities for infrastructure investments to ensure DACs are not left behind. The analysis uses a total of 580 distribution feeders from throughout the LADWP in-basin service territory with 10+% of distribution feeders in the DAC and non-DAC groups for all in-basin PUMAs (average of 40% feeder coverage across all PUMAs).

A.4 Methodology Details: Equitable and Resilient Access to Electricity-Related Services During Disaster Events

As described in Section 3.3, the equitable resilience analysis looks at individual customer access to critical services during disaster events. This analysis is conducted on the nine neighborhoods described in Section 3.3.1. Table A-1 shows the list of neighborhoods selected for analysis along with the corresponding values of selection metrics. As described in Section 3.3.1, the selection process attempted to find a mix of neighborhoods that represented a wide range of combinations across these metrics.

Table A-1. Summary of Selected Resilience Analysis Neighborhoods and Metrics

Neighborhood	SAIFI (times/ year)	SAIDI (minutes/ year)	Median Annual Income ($)	Percentage Underground Cable Length	DAC Status	Qualitative Energy Access Ranking
Boyle Heights	1.33	144	45,820	14.8	DAC	low
Florence	1.07	126	36,010	6.0	DAC	low
Historic South Central	1.06	156	36,410	17.6	DAC	very low
Hollywood Hills West	1.04	297	128,991	42.3	Non-DAC	very high
Pacoima	0.49	76	63,170	11.9	DAC	middle
Sun Valley	0.74	132	59,230	10.4	DAC	middle
West Hills	1.07	217	103,200	36.5	Non-DAC	high
West Los Angeles	0.85	142	115,200	26.0	Non-DAC	high
Wilmington	1.01	146	58,870	15.0	DAC	very low

Section 3.3.2 describes the equitable resilience analysis process, and Section 3.3.3 provides an overview of the corresponding metrics. This section provides additional details on these metrics.

Community-Member-Level Composite Access-Based Score (CCAS)

We first define a community-member-level composite access-based score that reflects a customer's level of access to critical services, such as energy, health, and food services. Specifically, the score for each customer is combined as a sum of the customer's level of access to each critical service. In its unweighted form used here, the contribution of each critical service facility to the access of a household is proportional to the inverse of the distance from the house to the facility.

To assess neighborhood-level metrics, customer-level scores for various disaster events are aggregated while maintaining visibility of equity metrics and resilience strategy performance (i.e., every neighborhood has a community-member-level composite access-based score). The neighborhood resilience metric is the median of its corresponding community-member-level access-level scores.

Disaster Modeling and Scenario Development Approach

We evaluate earthquake and flooding scenarios to understand the impact on community members' access to critical services and how resilience programs such as microgrids, backup energy sources for critical infrastructure, or a combination of both would improve such access. The Equity and Resiliency Analysis for Distribution (ERAD) tool leverages fragility curves (gathered from multiple scientific journals and conferences as described in (Duwadi et al. In Review) to translate disaster intensity (e.g., earthquake intensity at a given location, water level for flooding) to failure probability for a given distribution system asset type. A fragility curve is a probability distribution that maps the intensity of disaster to damage level or failure probability for a given asset type. Figure A-2 shows an example of a fragility curve for different asset types at different peak ground acceleration magnitudes during an earthquake event.

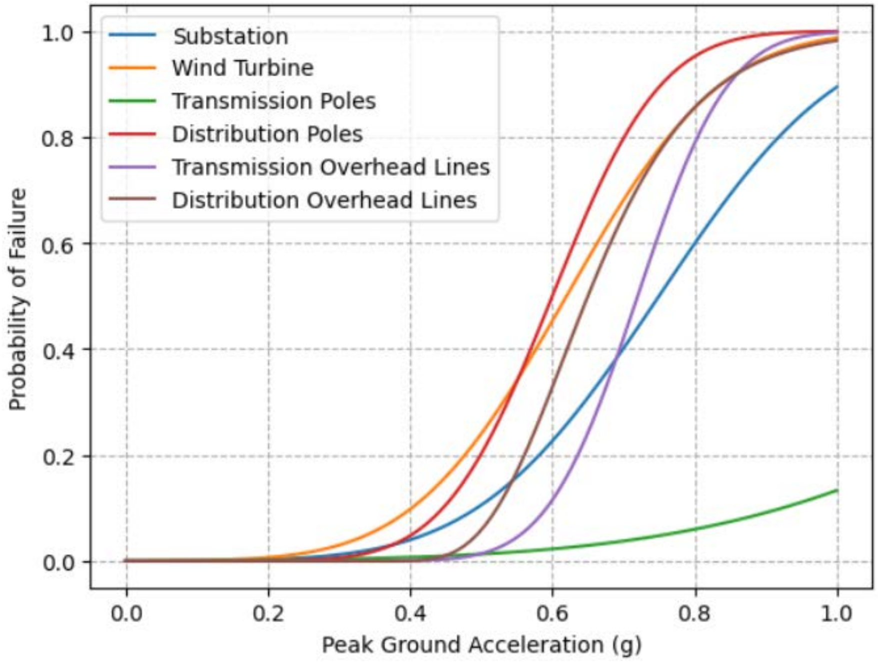

Figure A-2. Fragility curves for different assets under earthquake event

Earthquake Modeling

In developing earthquake scenarios, we carefully select the epicenter location and earthquake magnitude to differentiate impact on assets. All assets would survive in a faraway or very low magnitude earthquake, and all assets would be destroyed in a very high magnitude or nearby earthquake.

We choose four earthquake scenarios for the simulation, each with epicenters on historically active fault lines near our selected neighborhoods and with a magnitude of 6.0 (not big enough to destroy everything but also not small enough that all assets would survive). Figure A-3 (page 43) shows the location of the simulated earthquake epicenters, nearby fault lines and historical earthquake epicenters. The earthquake scenarios are selected based on historically recorded earthquakes with a magnitude >5.5 from 1965 to 2016 using USGS data. As seen in Figure A-3, these all happen to fall in the northern part of the city. There are other potentially active fault zones throughout the city, including offshore to the southwest that could result in different earthquake impacts, particularly for Wilmington and other southern neighborhoods that are far from the selected epicenters. Also, a larger earthquake, even if farther away, could have different impacts.

Each of the selected scenarios is run with 40 Monte Carlo samples to capture a range of outcomes on the probability distributions. For each scenario-sample combination, we simulate all neighborhoods in base case 2019 and high stress 2035 under the following conditions:

1. **Pre-Disaster:** a scenario where critical infrastructure and the distribution grid are operating normally
2. **Earthquake Scenario:** a simulated earthquake scenario where asset impacts are determined by fragility curves and earthquake intensity. This could cause electricity access interruption to customers as well as critical infrastructure.
3. **Post-Earthquake Microgrid Program:** a simulated post-earthquake microgrid program. After an earthquake, multiple islands would be formed that might not have access to electricity from the substation. In this scenario, microgrid controllers are added to each island that has sufficient solar and storage. This solar and storage matches the high estimates for 2035 adoption as described in Section A.2 without any additional resilience-driven installation. A microgrid is considered viable if the sum of generating resource capacity is greater than or equal to sum of total load capacity (100%) multiplied by a load factor of 0.5 and coincidence factor of 0.4. This approach can directly improve community members' electricity access and might also provide electricity to nearby critical services that are also part of the microgrid.
4. **Post-Earthquake Backup Program:** a simulated backup energy source allocation program. Allocating additional backup energy resources (diesel generator, energy storage, etc.) would allow critical infrastructure to provide services, thereby improving community members' access to those services. For backup, we randomly select 50% of critical infrastructure to have a backup energy resource in each sample.
5. **Post-Earthquake Microgrid + Backup Program:** a simulated microgrid + backup program that combines the other two programs. In this program, the additional backup energy resources sited on the premises of a critical service facility can also contribute to a microgrid, if applicable.

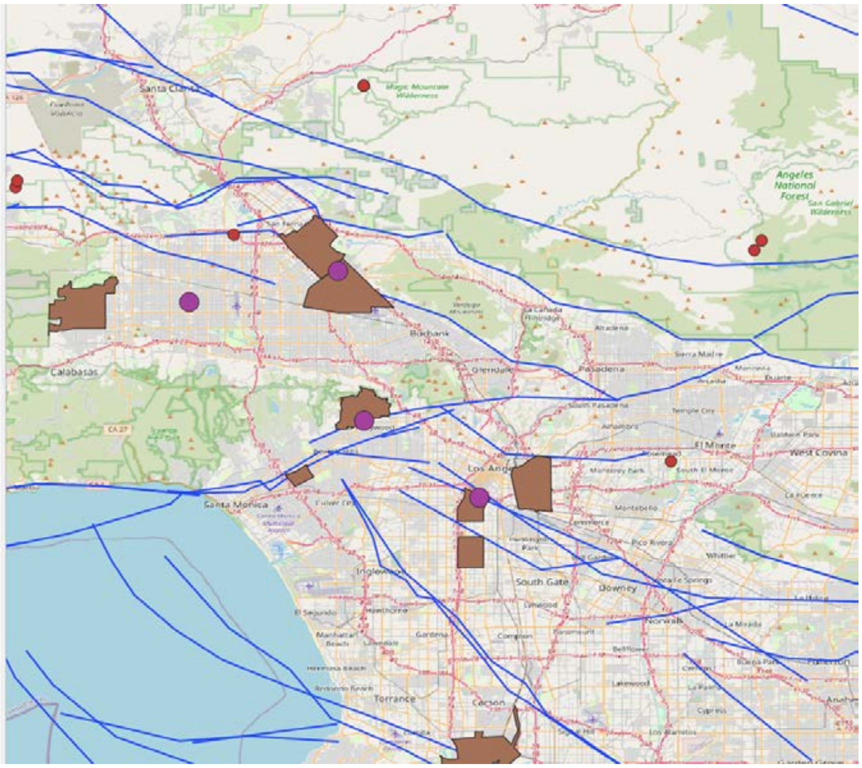

Figure A-3. Earthquake simulation model

Larger, purple dots represent earthquake epicenters used in these simulations. Smaller, red dots show historical earthquake epicenters covering all earthquakes ≥5.5 magnitude from 1965 to 2016 from the United States Geological Survey ("Significant Earthquakes, 1965–2016," USGS, https://www.kaggle.com/datasets/usgs/earthquake-database). There are other potentially active fault zones including offshore to the southwest that could result in different impacts, particularly for southern neighborhoods.

Blue lines represent fault lines from the United States Geological Survey as captured by CalOES GIS Data Management ("Earthquake Faults and Folds in the USA," California Governor's Office of Emergency Services, https://hub.arcgis.com/maps/CalEMA::earthquake-faults-and-folds-in-the-usa/).

Brown polygons are simulated neighborhoods. Base-map OpenStreetMap contributions are used under the Open Database License.

Flooding Modeling

To model the flooding scenario, we use typical historical water level measurements during flooding season: flow (measured in 1,000 cubic feet per second) and level (measured in feet from the ground surface). Figure A-4 shows the physical sensors (green dots) measuring water levels and the flooding polygon considered for the simulation.

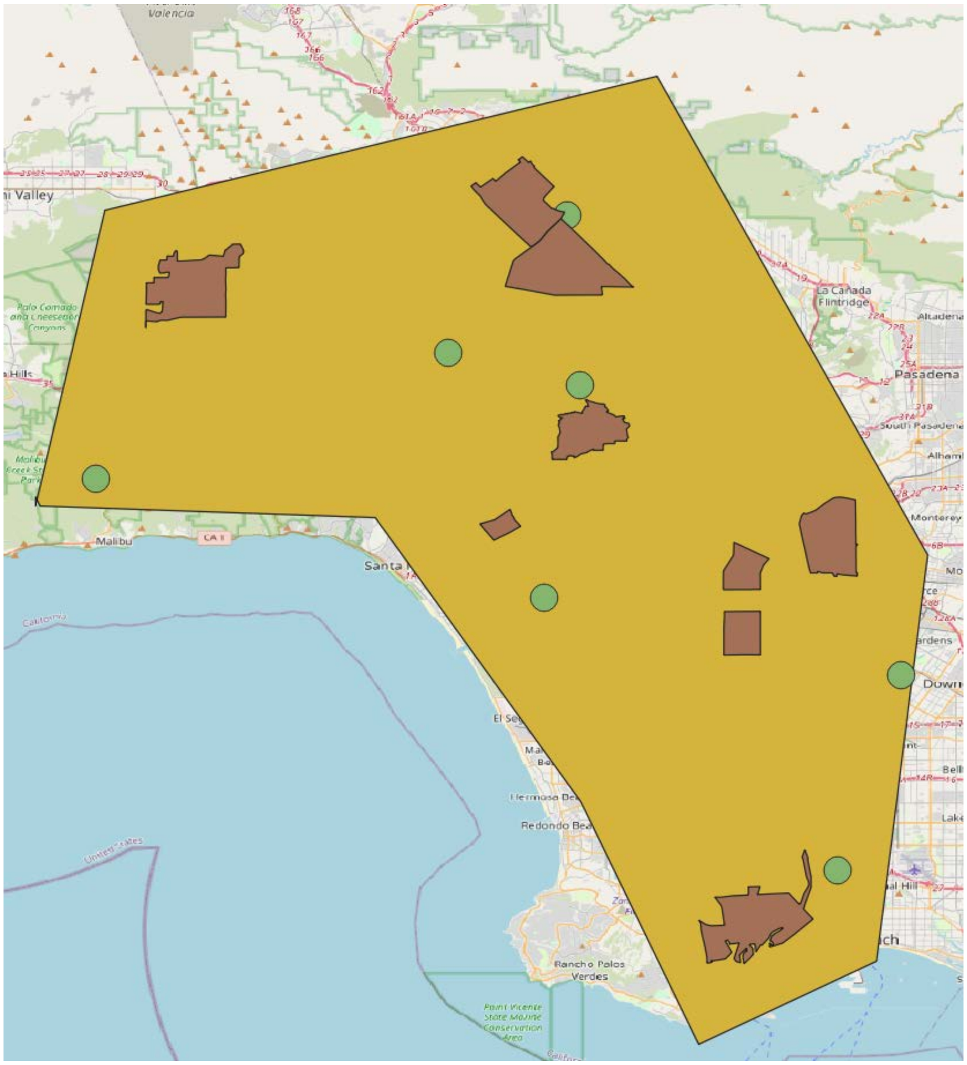

Figure A-4. Flood simulation model

The bigger outer polygon is used as input for flooding modeling. Brown smaller polygons are the neighborhoods simulated. Green dots are physical sensors measuring water levels. Base-map OpenStreetMap contributions are used under the Open Database License.

Each scenario is again run 40× to capture sufficient samples for the probability distribution. As with earthquake modeling, we model pre-disaster flooding, post-flooding microgrid program, post-flooding backup program, and post-flooding microgrid + backup program scenarios for all neighborhoods in base case 2019 and high stress 2035.

Equity-Based Energy Resilience Score and Community Resilience Indicator

Equity is analyzed through the following process:

1. The distribution (e.g., histogram) of community-member-level composite access-based scores disaggregated by DAC status is computed for each group of disaster events (e.g., all earthquake events). Doing so helps analysts understand the strengths and weaknesses of various resilience strategies and the patterns of disparity for resilience.

2. Distributions are then combined across scenario groups using a risk-weighted average that not only accounts for disaster event likelihood but also considers the level of impact. By maintaining the distribution of community-member-level access-based scores and DAC status in this step, we can evaluate the overall performance of resilience strategies in various ways.
3. We then use the median to statistically summarize the community-level resilient service access scores for each service category.
4. Then resilience score distributions are combined by equity group (i.e., DAC status) to arrive at each group's equity-based energy resilience score.
5. The resulting group-level energy resilience scores are normalized across all groups using the community-wide median as a reference.[23] Table A-7 reports the full neighborhood-level resilience results for 2035 high grid-stress case.

Aggregated community energy resilience scores allow evaluation of resilience strategies across the service territory. A good resilience resource allocation solution is one that increases both the equity-based energy resilience score and community resilience indicator values.

While it is critical to keep service access values in a composite resilience metric, we also introduce an aggregate resilience score that can be computed at the customer, neighborhood, or community level. The aggregate resilience score enables a holistic comparison of resilience of different customers, neighborhoods, or communities. This aggregate resilience score is expressed as the Euclidian norm of per-service access scores. Table A-3 shows how demographic groups (DAC and non-DAC) compare in terms of aggregate resilience score and per-service access scores.

Table A-4 shows how neighborhoods' aggregate resilience score and per-service access scores compare during routine situations without a disaster event. It also includes the pre-event coefficient of variation of access to critical services. This is an inverse measure of access equity. The lower the coefficient of variation, the higher the equity of access. Results show that the highest pre-disaster inequity is in access to emergency shelter services, with a coefficient of variation of 0.64. Access to electricity, with a coefficient of variation of 0, is the most equitable in pre-disaster conditions, as only households with grid connections are modeled. This equity indicator can help prioritize resilience investments for both normal operation and disaster conditions.

Table A-5 reports neighborhoods' post-disaster aggregate resilience scores and per-service access scores during a disaster, assuming there is no resilience-oriented program in place. Like in Table A-4, we compute the coefficient of variation as an inequity indicator. Results show that overall access inequity has increased from 0.24 in the pre-disaster conditions to 0.36 in post-

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[23] The reported aggregated scores are normalized for comparison. In most cases, this normalization was based on the population-level median. That is the median of all simulated households from all neighborhoods was set to 1.0, such that values above 1.0 indicated higher service access (better) while those less than 1.0 correspond to lower access (worse). This approach is used for all results with neighborhood-service or finer resolution. For summaries that combine across neighborhoods, such as those by event or program, results are normalized by the median of neighborhood medians.

disaster conditions, which is equivalent to a decrease in equity of access to critical services. The highest post-disaster inequities are in access to electricity, emergency shelter, and hospital services, with a coefficient of variation of 0.80, 0.79, and 0.60 respectively. Access to groceries, with a coefficient of variation of 0.30, is the most equitable in post-disaster conditions.

Table A-6 provides the results during a disaster when the critical backup + microgrid program is applied. The table shows how the post-disaster access inequity decreases from 0.36 to 0.27.

A.5 Additional Results: Equitable Distribution Grid Upgrades for Reliability and Solar, Storage, and EV Access and Use

Figure A-5 and Figure A-6 show the underlying grid stress results at the PUMA level for 2019 and 2035, respectively. In addition, Table A-2 contains the underlying full numeric results for grid stress, equitable grid score and DER access inequity. Here, DER access inequity shows the local variation between DACs and non-DACs within a PUMA. Equitable Grid score is a combination of grid stress results, DER adoption levels, and the local inequity observed in a PUMA.

Table A-2. Complete Numeric Results for Equitable Upgrade Analysis

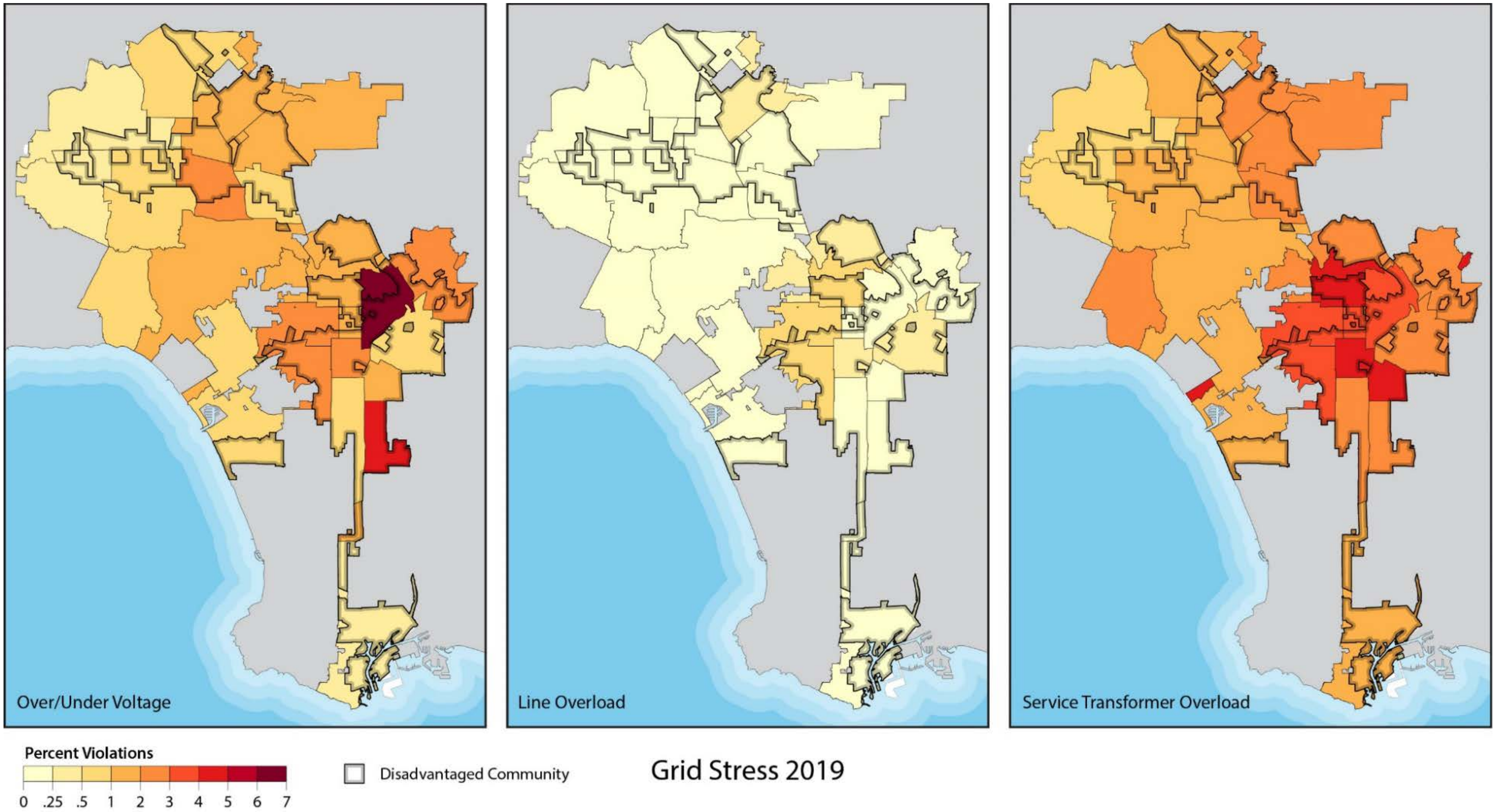
[a] Indicates disadvantaged community.

		Grid Stress (higher=worse)						Equitable Grid Score (higher=more equitable)				DER Access Inequity within a PUMA			
		Service Transformer Overloads (% of transformers)		Over/Under Voltages (% of nodes)		Line Overloads (% of lines)		Service Transformers		Other Grid Upgrades		Service Transformers		Other Grid	
PUMA	**Representative Neighborhoods**	**2019**	**2035**	**2019**	**2035**	**2019**	**2035**	**2019**	**2035**	**2019**	**2035**	**2019**	**2035**	**2019**	**2035**
3705	Chatsworth[a], Northridge, West Hills, Northridge[a], Porter Ranch, North Hills[a], Winnetka[a], Canoga Park[a], Chatsworth Reservoir	0.86	14	0.47	7.2	0.01	1.3	95	0	99	31	0.04	4.4	0.01	1.4
3706	Granada Hills, Mission Hills[a], Sylmar[a], North Hills, Granada Hills[a], Northridge	1.5	17	0.54	8.6	0.01	1.1	51	22	97	34	0.69	0.48	0.11	2.3
3707	Arleta[a], Pacoima[a], Sylmar, Lake View Terrace[a], Hansen Dam	2.4	21	1.6	7.5	0.27	2.1	74	24	92	44	0.04	7.1	0.22	8
3708	Sun Valley[a], Sunland, Valley Glen[a], Lake View Terrace, Tujunga, Shadow Hills, Pacoima[a]	2	18	1.2	7.3	0.03	1.6	37	32	88	50	1	0.59	0.4	0.25
3720	Griffith Park[a], Hollywood Hills[a], Atwater Village[a]	3	21	1.5	6.2	0.42	3.6	58	36	76	54	0.4	0.22	0.7	1
3721	North Hollywood[a], Valley Village, Sun Valley[a], Toluca Lake, Valley Glen[a]	2.3	14	0.83	6.2	0.09	2.3	60	14	95	33	0.4	2.9	0.16	2.1
3722	Valley Glen[a], Sherman Oaks, Van Nuys[a], Valley Village	1.9	18	2.5	7	0	1.2	73	11	72	38	0.25	2.5	0.87	1.3

PUMA	Representative Neighborhoods	Grid Stress (higher=worse)						Equitable Grid Score (higher=more equitable)				DER Access Inequity within a PUMA			
		Service Transformer Overloads (% of transformers)		Over/Under Voltages (% of nodes)		Line Overloads (% of lines)		Service Transformers		Other Grid Upgrades		Service Transformers		Other Grid	
		2019	2035	2019	2035	2019	2035	2019	2035	2019	2035	2019	2035	2019	2035
3723	Panorama City[a], Mission Hills, North Hills[a], Van Nuys[a], Arleta[a], Arleta	1.6	21	1.2	6.6	0	1.5	61	18	94	31	0.61	2.7	0.1	6.4
3724	Tarzana[a], Sepulveda Basin, Encino, Reseda[a], Northridge, Lake Balboa[a], Encino[a], Van Nuys[a], Woodland Hills, North Hills	1.3	17	0.61	8.3	0.03	1.7	89	15	98	36	0.01	2.9	0.04	2.3
3725	Woodland Hills, Winnetka[a], Canoga Park[a], Tarzana, West Hills[a]	0.93	19	0.5	6.6	0.01	1.1	43	13	95	37	1.1	1.7	0.19	1.5
3726	Pacific Palisades	3	18	1	7.6	0.17	1.8	69	34	97	51	0	0	0	0
3727	Beverly Crest, Brentwood, Sherman Oaks, Encino, Bel-Air, Studio City[a], Pacific Palisades, Hollywood Hills, Valley Village, Toluca Lake	1.6	15	1.9	6.3	0.08	2.8	80	19	92	28	0.23	0.62	0.22	2.4
3728	Venice	4.3	24	1.9	8.3	0.13	3	34	67	93	79	0	0	0	0
3729	Century City, Mar Vista, Westwood, Sawtelle, Cheviot Hills, West Los Angeles, Rancho Park, Palms[a], Beverly Crest, Brentwood	1.7	14	0.9	4.9	0.15	2.2	82	22	94	28	0.22	0.08	0.21	2.5
3730	Carthay, Beverly Grove, Pico-Robertson, Mid-Wilshire[a], Mid-City[a], Windsor Square, Hancock Park, Fairfax, Harvard Heights[a], Beverlywood, Koreatown[a], Arlington Heights[a]	3.7	20	2.7	8.4	0.73	6.5	17	14	0	32	0.85	6.8	3.1	7.6
3731	Hollywood, Fairfax, Hollywood Hills West, Beverly Grove, Hollywood Hills	2.8	17	1.1	7.1	0.33	3.8	55	22	95	38	0	0	0	0

		Grid Stress (higher=worse)						Equitable Grid Score (higher=more equitable)				DER Access Inequity within a PUMA			
		Service Transformer Overloads (% of transformers)		Over/Under Voltages (% of nodes)		Line Overloads (% of lines)		Service Transformers		Other Grid Upgrades		Service Transformers		Other Grid	
PUMA	**Representative Neighborhoods**	**2019**	**2035**	**2019**	**2035**	**2019**	**2035**	**2019**	**2035**	**2019**	**2035**	**2019**	**2035**	**2019**	**2035**
3732	East Hollywood[a], Hollywood Hills, Hollywood[a], Los Feliz, Silver Lake, Larchmont, Silver Lake[a], Hancock Park, Los Feliz[a]	4.9	21	1.6	10	0.64	6.4	31	22	83	29	0.15	1.2	0.43	4.7
3733	Pico-Union[a], Koreatown, Koreatown[a], Westlake[a], Harvard Heights[a]	3.92	15	1.5	6.8	0	4.3	9.9	35	90	47	1.4	2.1	0.36	0.38
3734	Pico-Union[a], Westlake[a], Los Feliz, Silver Lake, Westlake, Echo Park[a], Elysian Park[a], Elysian Valley[a]	3.8	19	7	21	0.13	6.4	38	21	54	0	0.2	3.1	0.94	14
3735	Atwater Village[a], El Sereno[a], Highland Park, Eagle Rock, Lincoln Heights[a], Montecito Heights[a], Glassell Park[a], Cypress Park[a], Mount Washington[a]	2.5	24	2.2	13	0.05	4.4	0	36	53	43	1.4	3.4	1.5	6.1
3736	Highland Park	4.3	24	2.2	6.4	0	4.8	37	100	92	100	0	0	0	0
3744	Downtown[a], Chinatown[a], Boyle Heights[a], Lincoln Heights[a], Central-Alameda[a], Historic South-Central[a]	2.4	7.9	0.87	3	0.35	2.2	62	31	97	37	0.57	1.1	0.04	0.13
3745	Historic South-Central[a], Central-Alameda[a], South Park[a]	4.2	14	1.3	7	0	2.7	34	41	95	52	0	0	0	0
3746	Exposition Park[a], Pico-Union[a], Jefferson Park[a], Adams-Normandie[a], Harvard Heights[a], University Park[a], Arlington Heights[a]	4.1	25	2.1	16	0.38	4.9	49	76	92	77	0	0	0	0
3747	Hyde Park[a], West Adams[a], Baldwin Hills/Crenshaw[a], Leimert Park[a], Mid-City[a], Jefferson Park[a], Beverlywood[a], Arlington Heights[a]	3.6	32	2.6	14	0.73	8	41	30	70	48	0.07	0.14	0.81	3.7
3748	Westchester[a], Playa Vista, Del Rey, Venice, Playa del Rey[a]	1.7	15	0.87	3.4	0.04	1.6	86	25	98	44	0	0	0	0

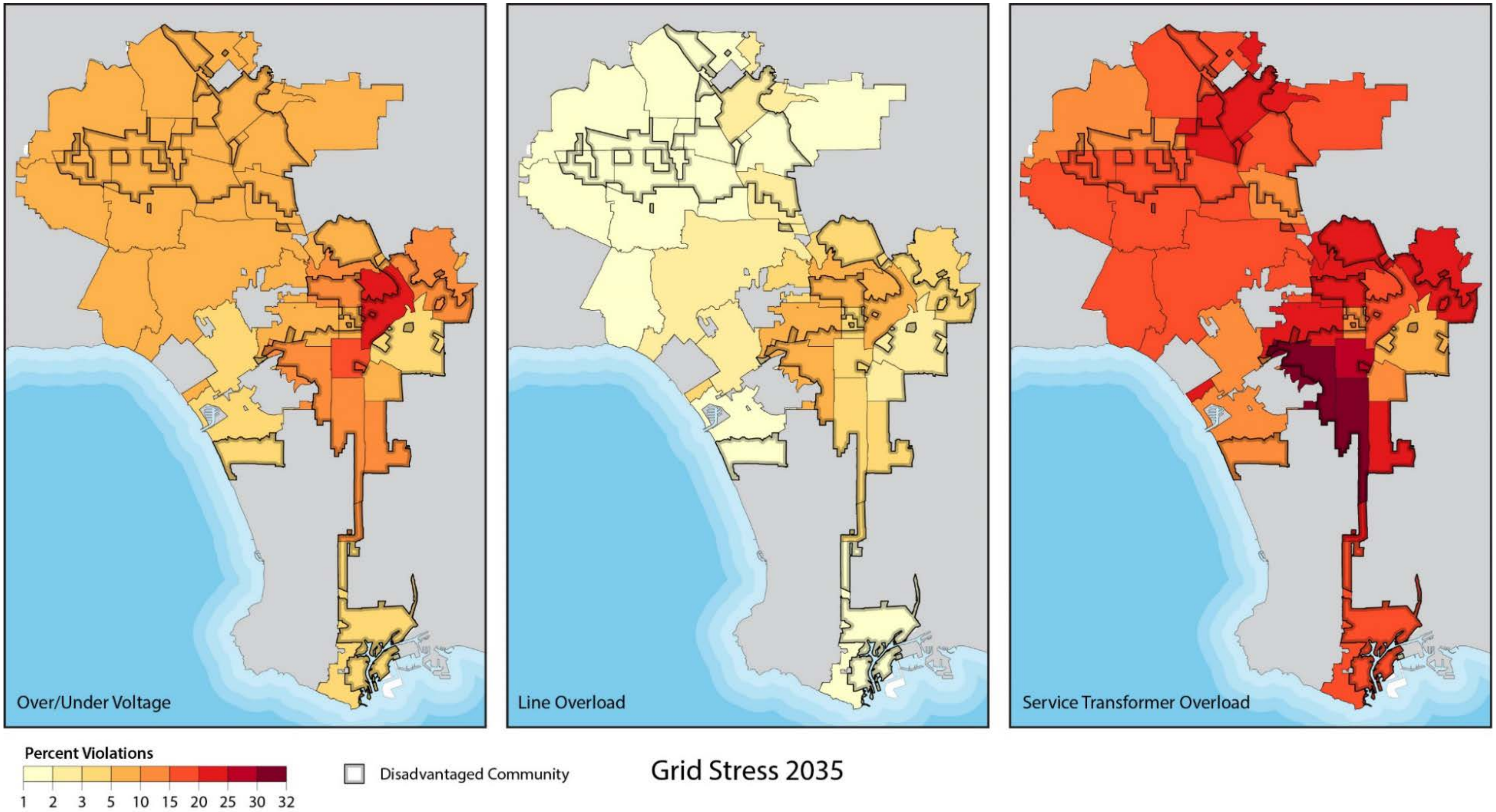
PUMA	Representative Neighborhoods	Grid Stress (higher=worse)						Equitable Grid Score (higher=more equitable)				DER Access Inequity within a PUMA			
		Service Transformer Overloads (% of transformers)		Over/Under Voltages (% of nodes)		Line Overloads (% of lines)		Service Transformers		Other Grid Upgrades		Service Transformers		Other Grid	
		2019	2035	2019	2035	2019	2035	2019	2035	2019	2035	2019	2035	2019	2035
3750	Vermont Square[a], Manchester Square[a], Gramercy Park[a], Vermont Knolls[a], Harvard Park[a], Chesterfield Square[a], Vermont-Slauson[a], Vermont Vista[a], Harbor Gateway[a]	2.1	31	0.94	11	0.03	4.4	74	42	98	67	0	0	0	0
3751	Green Meadows[a], Florence[a], Broadway-Manchester[a], Watts[a]	3	23	4.1	12	0.03	4.3	70	55	79	67	0	0	0	0
3758	Harbor Gateway[a]	1.3	23	1.4	14	0	4.3	98	28	97	45	0	0	0	0
3767	Harbor Gateway[a], Wilmington[a], Harbor City[a], San Pedro[a]	1	16	0.47	4.8	0.03	1.6	100	5.9	100	31.2	0.01	9.8	0.01	9



(a) (b) (c)

Figure A-5. PUMA-level grid stress metrics estimates for current (2019) base case for (a) over/under voltages, (b) line overloads, and (c) service transformer overloads

Note color scale difference compared to 2035.



(a) (b) (c)

Figure A-6. PUMA-level grid stress level estimates for 2035-Equity case for (a) over/under voltages, (b) line overloads, and (c) service transformer overloads

Figure 8 is duplicated for easier comparison with the 2019 results.

The level of grid stress is significantly higher in 2035 than in 2019. Note difference in scale from the 2019 figures.

As can be seen in Figure A-5, in 2019, neighborhoods surrounding South Central see high overloaded transformers, those near Koreatown, Mid-Wilshire experience higher line overloads and those around Northwest Downtown experience higher voltage issues. On average, DACs observe roughly 1.5× more overloaded service transformers and 2× more overloaded lines and 2× more voltage violations, as compared to non-DACs.

Figure A-6 shows the grid stress experienced for the 2035 equity scenario. In 2035, there is a significant overall increase in grid stress. On average, grid stress in service transformers is 8.5× higher than in 2019 and the stress for other parts of the distribution grid is 7.5× higher. In particular, neighborhoods north and west of downtown (stretching from Exposition Park to Silver Lake and Elysian Valley) see the most anticipated 2035 voltage challenges. These areas partially overlap with the estimated regions of the worst line overloads that cover an arc from Hyde Park through Mid-City to Silver Lake and Elysian Valley. Significant service transformer overloads are seen throughout the city, with the highest levels in a rough triangle south and west of downtown stretching from Harbor Gateway to Mid-City to Pico-Union.

A.6 Additional Results: Equitable and Resilient Access to Electricity-Related Services During Disaster Events

Access to Critical Services Post-Disaster and Impact of Resilience Programs

This section provides a breakdown of the equitable resilience results by type of disaster event and neighborhood. It also highlights the effect of mitigation strategies on neighborhood resilience. In general, enabling microgrid formation through switching, control, and using existing DERs such as solar and storage is more effective than only providing backup generation units. But when the backup generation program is combined with the post-disaster microgrid formation strategy, close to pre-disaster levels of access to critical services are restored for all neighborhoods.

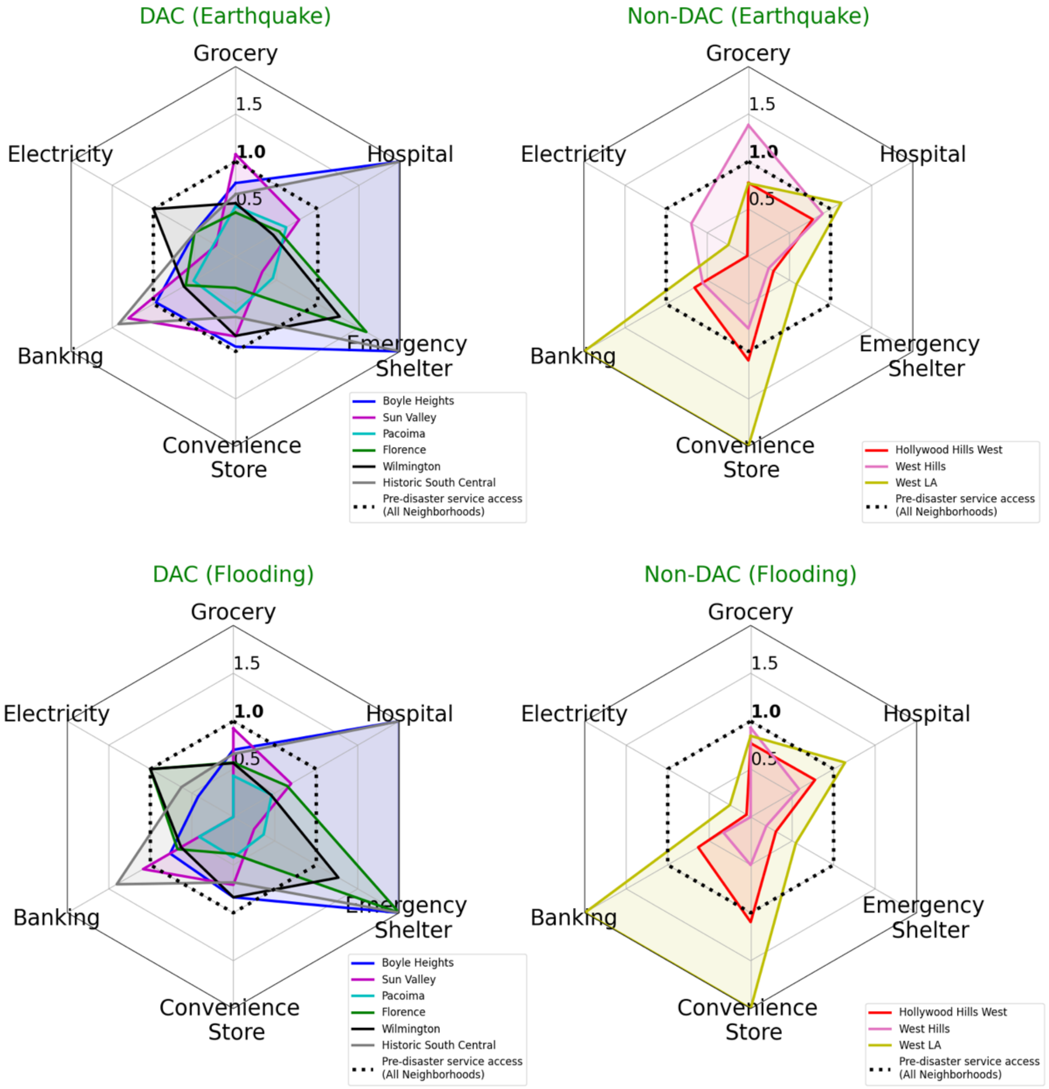


Figure A-7. 2035 post-earthquake and post-flooding (no resilience strategy) equitable access scores

See averages and additional notes in Figure 12.

As seen in Figure A-7, earthquake and flooding events have similar impacts on five of the nine neighborhoods evaluated. In Sun Valley, Pacoima, and West Hills, flooding causes greater reduction in access to electricity. In Florence, the earthquake scenarios cause greater reduction in access to electricity.

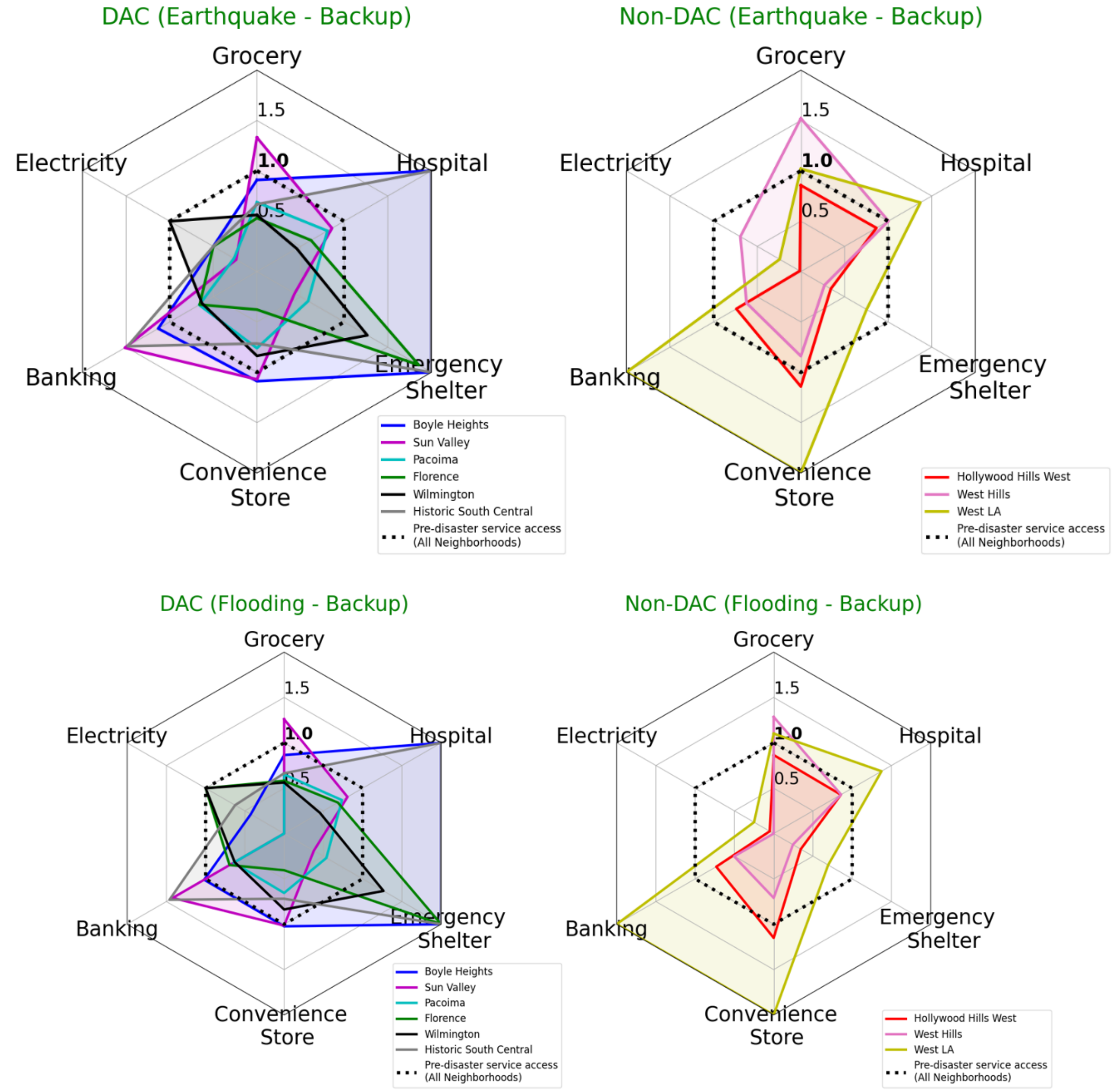


Figure A-8. 2035 Post-event equitable access scores with backup generators added to 50% of critical service facilities

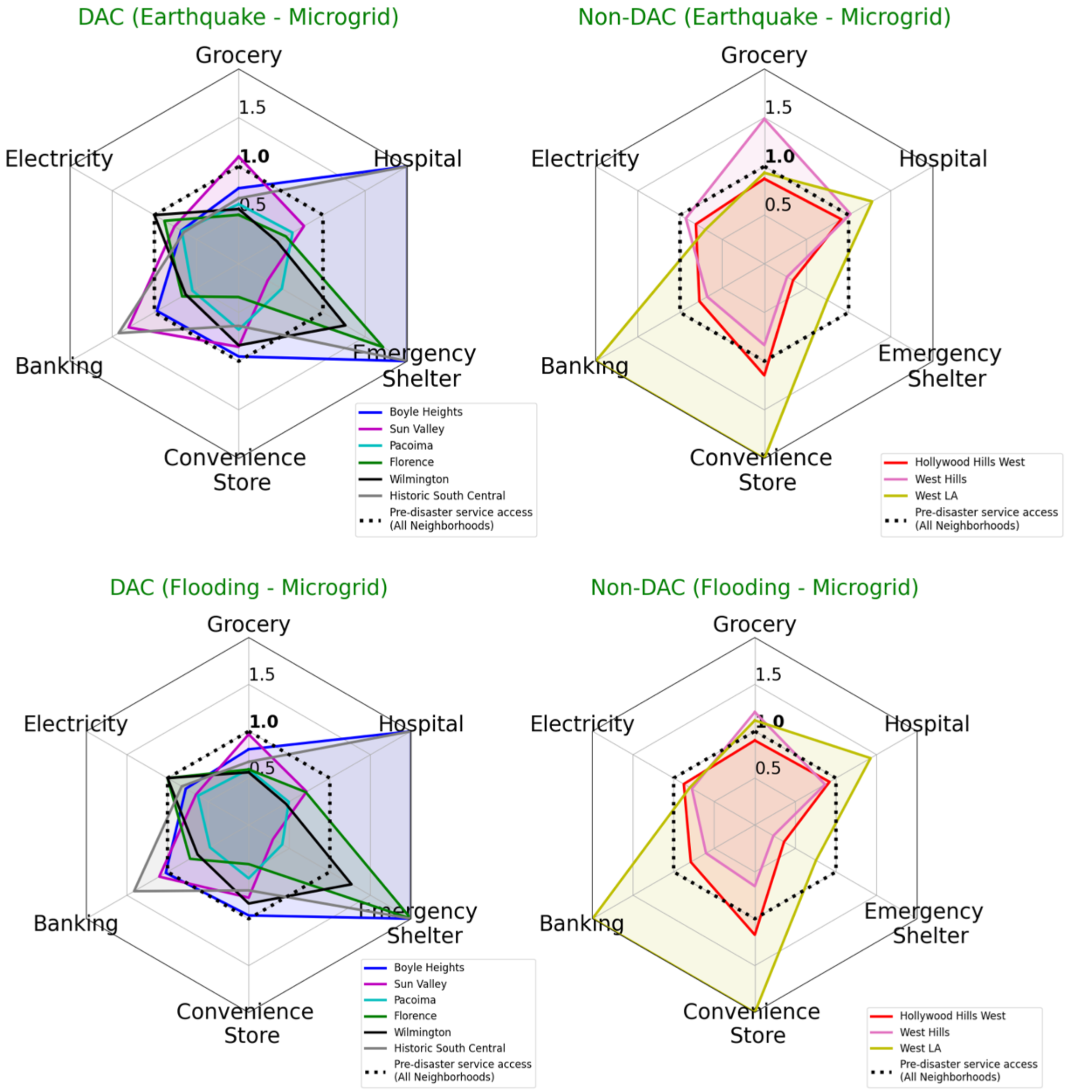


Figure A-9. 2035 Post-event equitable access scores with microgrid controllers added that use estimated existing customer solar + storage installations

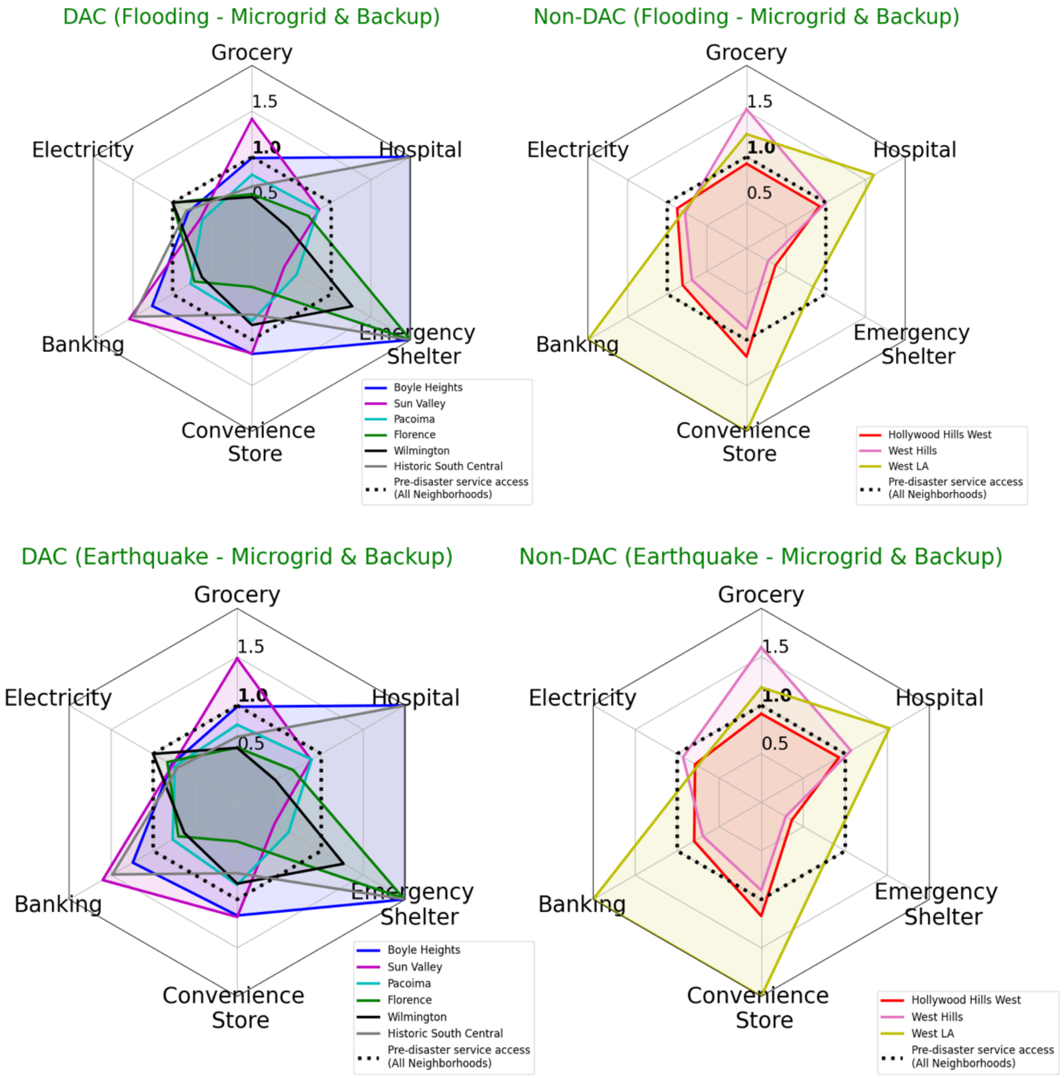


Figure A-10. 2035 post-event equitable access scores with microgrid controllers added that use projected customer solar + storage and new backup generation sited for 50% of critical service facilities

See averages and additional notes in Figure 12.

Figure A-8 through Figure A-10 highlight benefit of the microgrid + backup program that combines the ability of microgrids to support both residential electricity and critical facilities with the further service-only improvement from the critical facility backup program to significantly increase post-disaster access to critical services. Microgrids alone are somewhat less effective for services while backup-only solutions only support services and provide little to no resilience improvement for customer electricity. The results also indicate that microgrid programs tend to be more effective in flooding scenarios than in earthquake events.

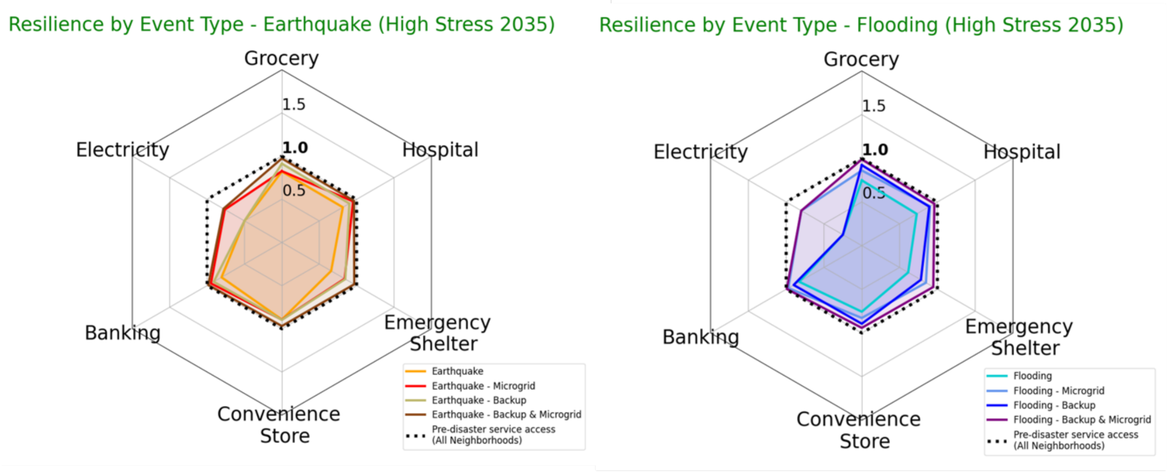


Figure A-11. 2035 post-event equitable access scores by event type and resilience strategy

The microgrid + backup program yields the most post-disaster resilience improvement and is as effective in flooding as in earthquake scenarios (Figure A-11). Neighborhoods generally have less access to electricity during flooding events than during simulated earthquake events.

Distribution of Access to Critical Services Pre-, Post-Disaster and Impact of Resilience Programs

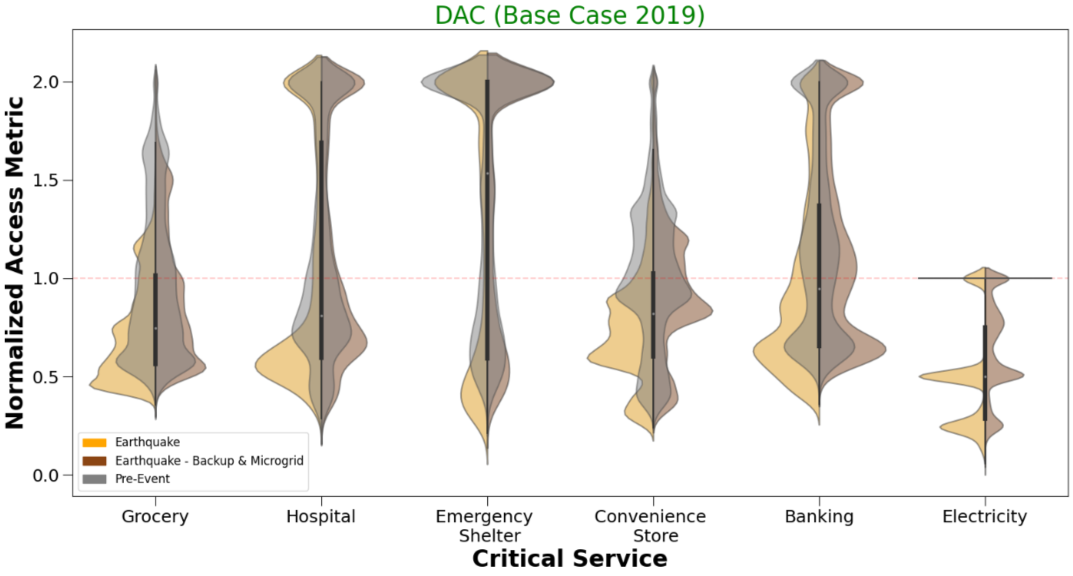
Figure A-12 to Figure A-15 show a series of data-rich overlaid violin plots that illustrate the distribution of access for individual loads in DAC (top) and non-DAC neighborhoods (bottom). Unlike the radar plots above, which collapse these complex distributions into a single number (the median), these figures maintain the details of how individual household's access to services is distributed. For example, wider sections of the violin indicate larger fractions of the population at that access level, while narrower sections indicate few households have that level of access.

The plots display the normalized access for a critical service. The normalized access is scaled such that the median access score for that service across all neighborhoods in the pre-disaster scenario is assigned a value of 1.0. Portions of the distribution >1.0 then represent households with greater than average access, while those <1.0 have lower access for that service. All data are limited to a max access level of 2.0 to prevent outliers from distorting the scale. Any data >2.0 are included at 2.0 in its corresponding distribution; doing so reveals underlying patterns such as whether most households have similar levels of access, whether this access varies widely, and whether it might be multimodal, with one or more groups of households having high access and others cluster having lower access.

Each violin then captures three different conditions for this normalized access for the particular service in that combination of scenario year and DAC status: (1) the No-disaster reference, shown in gray, (2) the during-disaster case with no program, shown in a lighter/brighter color, and (3) the during-disaster case with the backup + microgrid program implemented. The probability distribution for no-disaster reference is plotted symmetrically about the vertical center line, and the two disaster cases are plotted to the left and right of the line for the no-program and backup + microgrid program respectively. The width of the no-disaster violin is exaggerated by 2× so it can be directly compared to the two single-sided disaster violins. As a result, the household distributions of all three cases can readily be compared: left vs. right to see the effectiveness of the microgrid + backup program and each side to the gray no-disaster reference to see how the disaster compares to no-disaster access.

For example, in Figure A-12, the dark yellow distribution (left of the axis) represents access for individuals when a simulated earthquake occurs, and no program is implemented, while the dark brown (right of the access) represents access for individuals when a simulated earthquake occurs and both backup and microgrid programs are implemented. In this case, the gray portion of DAC grocery access is widest around 1.0 showing that a large number of households have the average grocery access among the total studied population with no disaster. The portion of the wider gray section that extends up to around 1.5, shows that many households have higher than average grocery access, while another wider portion around 0.5 shows that another cluster of DAC households have about half the normal access level to groceries. The wider portion of the yellow distribution around 0.7, shows that without a resilience program in place, most of the population shifts from a bit above average to noticeably below average access to groceries during simulated earthquake events; the fact that the bottom of the yellow distribution does not noticeably extend below the lowest gray bulge suggests those with lower access are not significantly impacted further in their grocery access; and the somewhat wider yellow distribution around 0.5 compared to the gray reference shows that more households have fallen to this lower level of grocery access during the simulated earthquake. Looking at the right half of the same stacked violin shows that with the microgrid + backup program in place, the household distribution of access to groceries has been restored to no-disaster levels, as the dark brown distribution closely resembles that of the underlying gray reference. Note that the reference electricity access appears as a gray horizontal line at 1.0 because all households in this study represent LADWP customers who are expected to have electricity in non-disaster times.

All violins approximate the actual distribution as a kernel density, similar to a smoothed histogram, to better estimate the underlying distribution. However, this kernel density can introduce some artifacts to bring the smooth shape back to zero beyond the maximum value of 1.0 (for electricity) or 2.0 (for other services). The individual plotted sample values are the average for each household across the Monte Carlo samples for the corresponding case. For most services, where the underlying metric is distance-based and therefore continuous, this results in smoother results. However, because electric service is modeled as having only two states—on (1.0) or off (0.0)—there are larger "lumps" around 1.0 and 0.0. In some cases, there are also higher electric service distributions at other values such as 0.5 or 0.25, when only some of the Monte Carlo samples result in a loss of electric service.



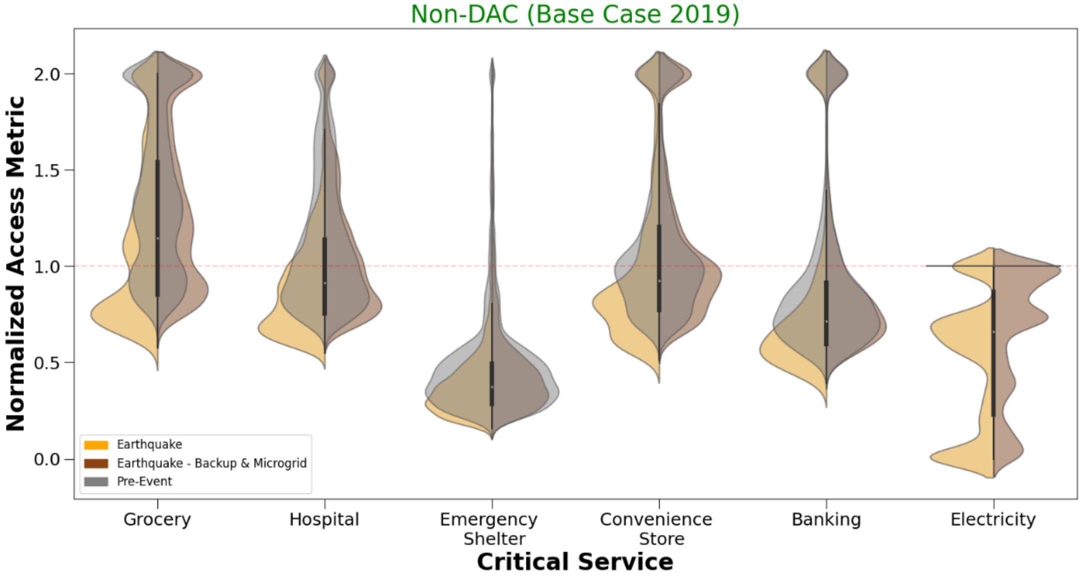
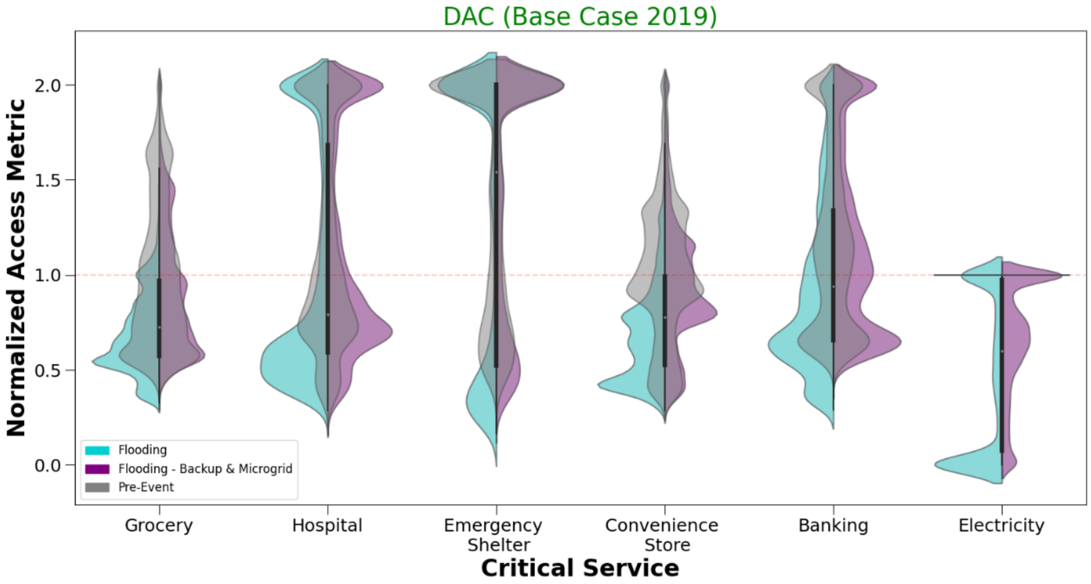


Figure A-12. Distribution of 2019 pre- and post-earthquake equitable access scores and effect of backup + microgrid resilience strategy

The normalized access is scaled such that the median access score for that service across all neighborhoods in the pre-disaster scenario is assigned a value of 1.0. Values >1.0 represent households with greater than average access. The width of the no-disaster violin is exaggerated by 2× so it can be directly compared to the two single-sided disaster violins.



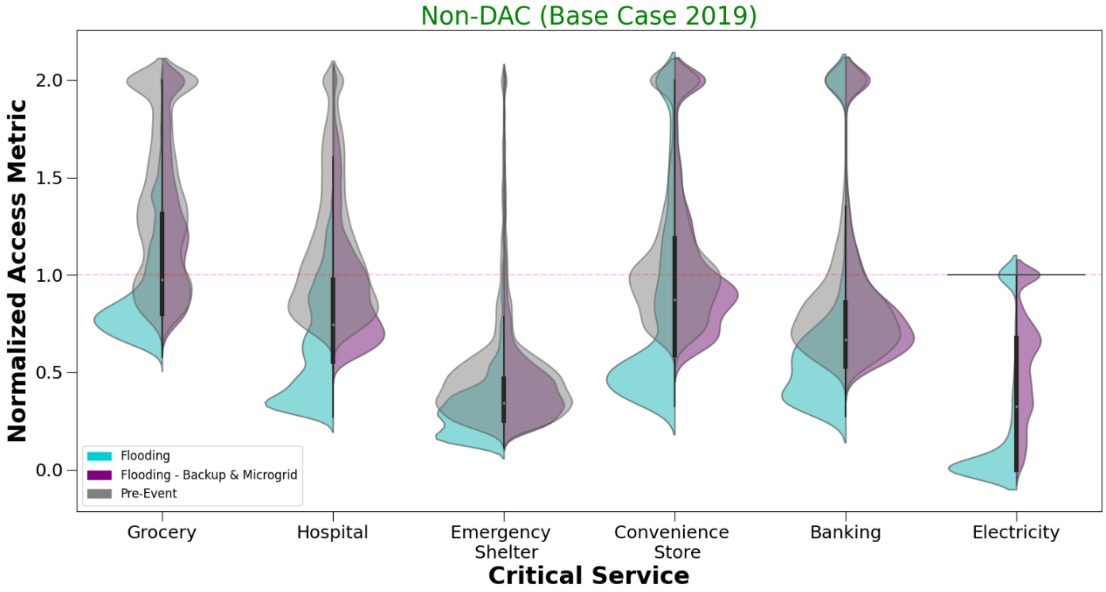
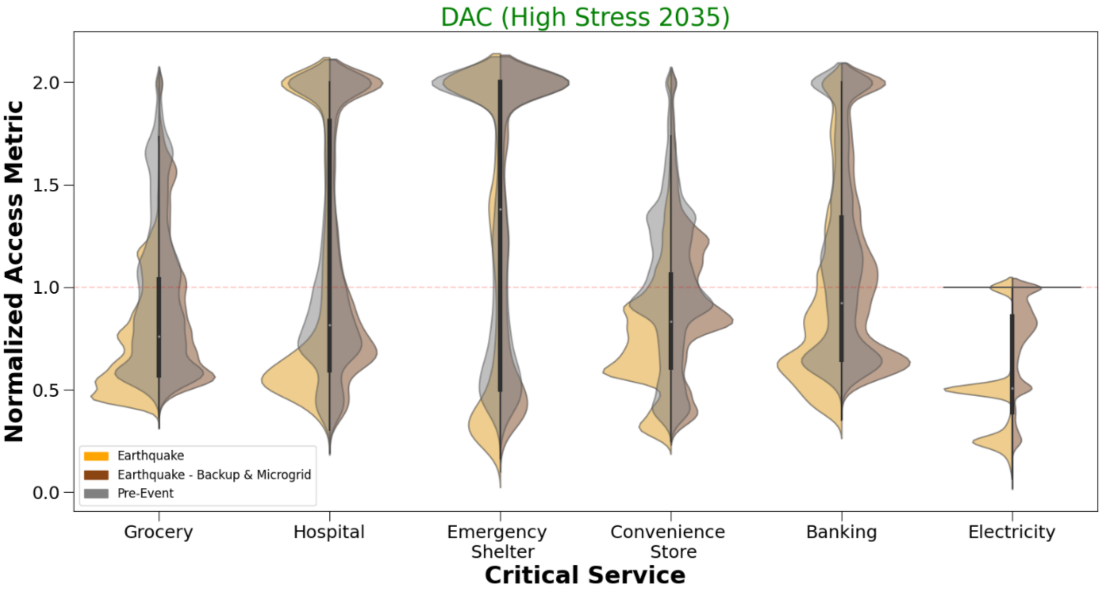


Figure A-13. Distribution of 2019 pre- and post-flooding equitable access scores and effect of backup + microgrid resilience strategy



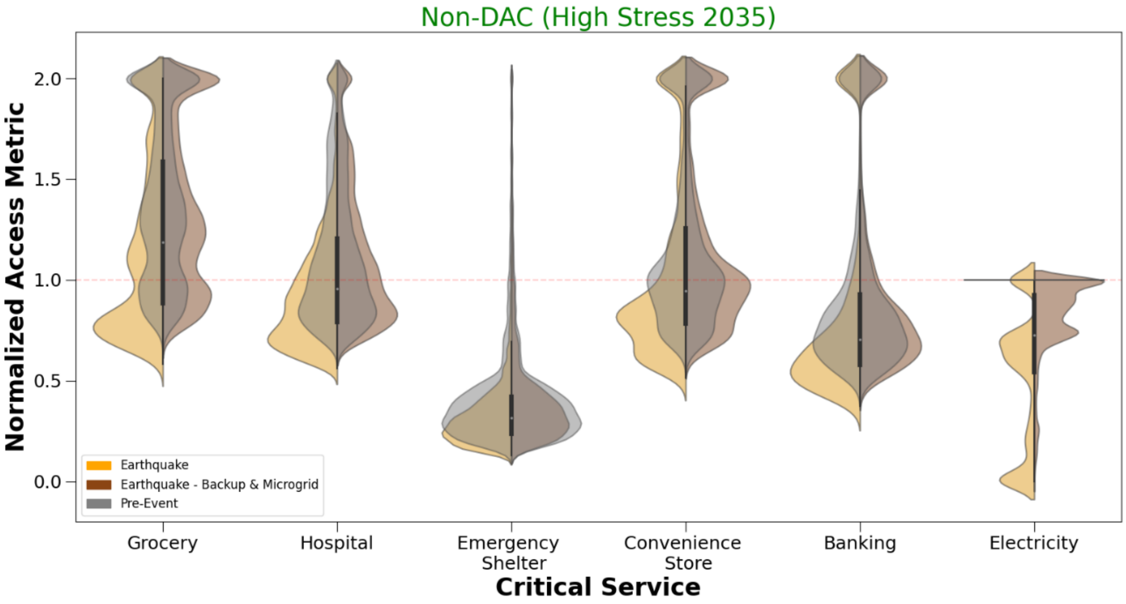
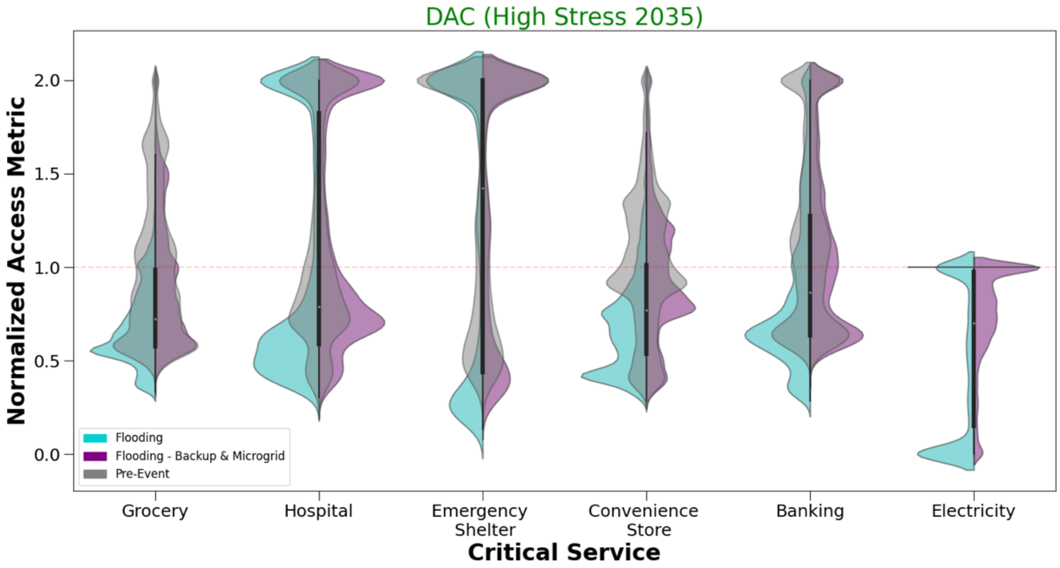


Figure A-14. Distribution of 2035 pre- and post-earthquake equitable access scores and effect of backup + microgrid resilience strategy



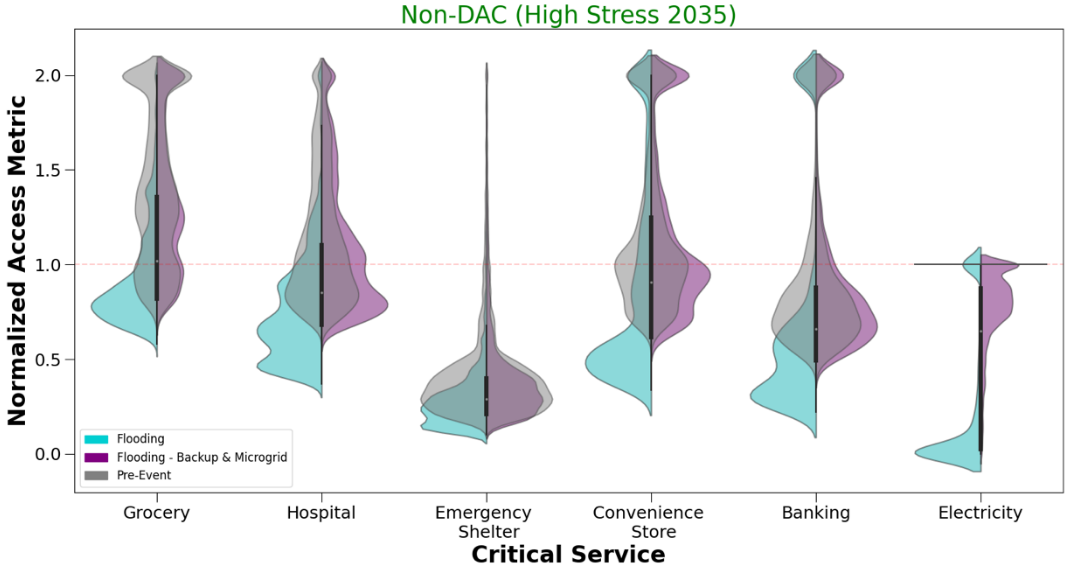


Figure A-15. Distribution of 2035 pre- and post-flooding equitable access scores and effect of backup + microgrid resilience strategy

Equitable Resilience Summary Tables

Table A-3 through Table A-7 provide various summaries of the resilience results. Table A-3 combines across neighborhoods to compare demographic groups. Note that here the use of the Euclidian norm (square root of sum of the squares) to summarize can mask inequities within the demographic groups when one or a few neighborhoods have relative high access scores.

Table A-4 through Table A-6 compare neighborhood results for pre-disaster, disaster without program, and disaster with the microgrid + backup program. Finally, Table A-7, provides complete neighborhood results for all services, events, and program combinations.

As shown throughout this report, community energy resilience is multidimensional. But a single metric is needed to compare resilience among demographic/geographic groups, or resilience by event type. To this end, these tables use the aggregate resilience score, which is the Euclidian norm of per-service access scores, each critical service being an axis of the Euclidian space.

Table A-3. 2035 Aggregate Service Access Scores by Demographic Group and Event Type

Demographic Group	Event	Per-Service Access Score						Aggregate Service Access Score
		Grocery	Emergency Shelter	Convenience Store	Banking	Hospital	Electricity	
DAC	None	0.89	1.52	0.99	1.09	0.97	1.00	2.69
	Earthquake[a]	0.68	1.35	0.73	0.82	0.68	0.50	2.05
	Flooding	0.64	1.41	0.65	0.71	0.66	0.33	1.97
Non-DAC	None	1.34	0.35	1.03	0.79	1.05	1.00	2.39
	Earthquake[a]	1.07	0.29	0.86	0.63	0.88	0.59	1.87
	Flooding	0.84	0.25	0.62	0.50	0.70	0.03	1.38

[a] Earthquake results include four simulated events located close to historically recorded earthquakes from 1965 to 2016, which all happen to fall in the northern part of the city. There are other active fault zones throughout the city and offshore that could more severely impact Wilmington and other southern neighborhoods.

Table A-4. 2035 Pre-Event Aggregate Service Access Scores by Neighborhood

Neighborhood	Per-Service Access Score						Aggregate Service Access Score
	Grocery	Emergency Shelter	Convenience Store	Banking	Hospital	Electricity	
Boyle Heights[a]	1.03	2.00	1.22	1.30	2.00	1	3.64
Florence[a]	0.59	2.00	0.43	0.72	0.71	1	2.56
Historic South Central[a]	0.68	2.00	0.78	1.53	2.00	1	3.52
Hollywood Hills West	0.93	0.37	1.19	0.81	0.93	1	2.22
Pacoima[a]	0.86	0.70	0.94	0.80	0.96	1	2.16
Sun Valley[a]	1.57	0.56	1.30	1.75	0.93	1	3.07
West Hills	1.66	0.30	0.93	0.71	1.08	1	2.53
West Los Angeles	1.27	0.89	2.00	2.00	1.63	1	3.75
Wilmington[a]	0.56	1.27	0.84	0.63	0.46	1	2.06
Coefficient of Variation	**0.40**	**0.64**	**0.41**	**0.45**	**0.47**	**0.00**	**0.24**

[a] DAC neighborhood

Table A-5. 2035 Post-Event (No Program) Aggregate Service Access Scores by Neighborhood

Neighborhood	**Per-Service Access Score**						**Aggregate Service Access Score**
	Grocery	**Emergency Shelter**	**Convenience Store**	**Banking**	**Hospital**	**Electricity**	
Boyle Heights[a]	0.74	2.00	0.89	0.86	2.00	0.46	3.21
Florence[a]	0.52	1.83	0.36	0.64	0.59	0.83	2.28
Historic South Central[a]	0.66	2.00	0.66	1.41	2.00	0.56	3.34
Hollywood Hills West	0.77	0.31	1.10	0.64	0.78	0.03	1.71
Pacoima[a]	0.48	0.41	0.51	0.46	0.54	0.13	1.09
Sun Valley[a]	1.00	0.29	0.78	1.19	0.73	0.12	1.91
West Hills	1.16	0.22	0.63	0.44	0.74	0.35	1.63
West Los Angeles	0.81	0.56	2.00	2.00	1.13	0.25	3.21
Wilmington[a]	0.56	1.27	0.84	0.63	0.46	1.00	2.06
Coefficient of Variation	**0.30**	**0.79**	**0.55**	**0.57**	**0.60**	**0.80**	**0.36**

[a] DAC neighborhood

Table A-6. 2035 Post-Event Aggregate Service Access Scores by Neighborhood with Critical Backup + Microgrid Program

Neighborhood	Per-Service Access Score						Aggregate Service Access Score
	Grocery	**Emergency Shelter**	**Convenience Store**	**Banking**	**Hospital**	**Electricity**	
Boyle Heights[a]	0.99	2.00	1.16	1.25	2.00	0.79	3.54
Florence[a]	0.58	1.83	0.41	0.71	0.69	0.92	2.38
Historic South Central[a]	0.68	2.00	0.73	1.49	2.00	0.77	3.44
Hollywood Hills West	0.77	0.31	1.1	0.64	0.78	0.83	1.90
Pacoima[a]	0.8	0.59	0.82	0.77	0.86	0.68	1.86
Sun Valley[a]	1.45	0.43	1.17	1.57	0.86	0.71	2.71
West Hills	1.56	0.28	0.89	0.69	1.04	0.85	2.36
West Los Angeles	1.22	0.85	2.00	2.00	1.57	0.78	3.64
Wilmington[a]	0.56	1.27	0.84	0.63	0.46	1.00	2.06
Coefficient of Variation	**0.39**	**0.69**	**0.43**	**0.47**	**0.50**	**0.12**	**0.27**

[a] DAC neighborhood

Table A-7. Full Neighborhood-Level Resilience Results for 2035 High Grid-Stress Case

Neighborhood	Service	No Event	No Program			Microgrid			50% Critical Backup			Microgrid + 50% Critical Backup		
			Earthquake[b]	Flood	Disaster Average	Earthquake[b]	Flood	Disaster Average	Earthquake[b]	Flood	Disaster Average	Earthquake[b]	Flood	Disaster Average
Boyle Heights[a]	Electricity	1.00	0.50	0.43	0.46	0.68	0.78	0.73	0.50	0.43	0.46	0.78	0.80	0.79
	Grocery	1.03	0.77	0.70	0.74	0.78	0.81	0.79	0.91	0.87	0.89	0.99	0.99	0.99
	Hospital	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
	Emergency Shelter	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
	Convenience Store	1.22	0.95	0.84	0.89	0.95	0.96	0.96	1.09	1.02	1.06	1.17	1.15	1.16
	Banking	1.30	0.97	0.76	0.86	0.97	1.02	1.00	1.13	1.02	1.08	1.24	1.26	1.25
Florence[a]	Electricity	1.00	0.50	1.00	0.83	0.88	1.00	0.94	0.50	1.00	0.75	0.83	1.00	0.92
	Grocery	0.59	0.46	0.57	0.52	0.50	0.59	0.55	0.53	0.58	0.56	0.57	0.59	0.58
	Hospital	0.71	0.53	0.65	0.59	0.56	0.70	0.63	0.62	0.68	0.65	0.67	0.71	0.69
	Emergency Shelter	2.00	1.59	2.00	1.83	1.71	2.12	1.91	1.86	2.00	1.98	1.98	2.00	2.00
	Convenience Store	0.43	0.33	0.39	0.36	0.34	0.42	0.38	0.38	0.40	0.39	0.40	0.42	0.41
	Banking	0.72	0.61	0.67	0.64	0.67	0.72	0.70	0.66	0.70	0.68	0.70	0.72	0.71
Historic South Central[a]	Electricity	1.00	0.50	0.63	0.56	0.65	0.83	0.74	0.50	0.63	0.56	0.71	0.83	0.77
	Grocery	0.68	0.66	0.66	0.66	0.67	0.67	0.67	0.67	0.66	0.67	0.68	0.68	0.68
	Hospital	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
	Emergency Shelter	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
	Convenience Store	0.78	0.64	0.68	0.66	0.64	0.70	0.67	0.71	0.72	0.72	0.73	0.72	0.73
	Banking	1.53	1.42	1.40	1.41	1.42	1.41	1.42	1.48	1.46	1.47	1.49	1.49	1.49
Hollywood Hills West	Electricity	1.00	0.01	0.05	0.03	0.82	0.88	0.85	0.01	0.05	0.03	0.79	0.88	0.83
	Grocery	0.94	0.78	0.77	0.77	0.87	0.90	0.89	0.86	0.87	0.86	0.91	0.93	0.92
	Hospital	0.93	0.78	0.78	0.78	0.91	0.92	0.92	0.87	0.86	0.86	0.93	0.92	0.92
	Emergency Shelter	0.37	0.31	0.30	0.31	0.34	0.36	0.35	0.34	0.35	0.34	0.36	0.37	0.37

Neighborhood	Service	No Event	No Program			Microgrid			50% Critical Backup			Microgrid + 50% Critical Backup		
			Earthquake[b]	Flood	Disaster Average	Earthquake[b]	Flood	Disaster Average	Earthquake[b]	Flood	Disaster Average	Earthquake[b]	Flood	Disaster Average
	Convenience Store	1.19	1.10	1.10	1.10	1.15	1.17	1.16	1.14	1.15	1.15	1.17	1.18	1.18
	Banking	0.81	0.66	0.63	0.64	0.77	0.79	0.78	0.74	0.73	0.74	0.80	0.81	0.80
Pacoima[a]	Electricity	1.00	0.26	0.00	0.13	0.68	0.63	0.65	0.26	0.00	0.13	0.74	0.63	0.68
	Grocery	0.86	0.53	0.43	0.48	0.61	0.59	0.60	0.69	0.65	0.67	0.80	0.81	0.80
	Hospital	0.96	0.62	0.46	0.54	0.64	0.49	0.57	0.81	0.74	0.77	0.89	0.83	0.86
	Emergency Shelter	0.70	0.45	0.37	0.41	0.51	0.41	0.46	0.59	0.54	0.56	0.61	0.57	0.59
	Convenience Store	0.94	0.59	0.42	0.51	0.68	0.57	0.62	0.76	0.66	0.71	0.85	0.79	0.82
	Banking	0.80	0.51	0.41	0.46	0.55	0.48	0.51	0.66	0.64	0.65	0.77	0.77	0.77
Sun Valley[a]	Electricity	1.00	0.24	0.00	0.12	0.76	0.65	0.71	0.24	0.00	0.12	0.77	0.65	0.71
	Grocery	1.57	1.08	0.92	1.00	1.10	0.97	1.03	1.33	1.26	1.30	1.48	1.41	1.45
	Hospital	0.93	0.77	0.70	0.73	0.77	0.71	0.74	0.86	0.81	0.83	0.88	0.85	0.86
	Emergency Shelter	0.56	0.32	0.25	0.29	0.34	0.30	0.32	0.43	0.38	0.41	0.44	0.41	0.43
	Convenience Store	1.30	0.84	0.71	0.78	0.85	0.78	0.81	1.07	1.01	1.04	1.18	1.15	1.17
	Banking	1.75	1.30	1.09	1.19	1.31	1.10	1.20	1.51	1.42	1.47	1.60	1.55	1.57
West Hills	Electricity	1.00	0.69	0.00	0.35	0.93	0.78	0.85	0.69	0.00	0.35	0.93	0.78	0.85
	Grocery	1.66	1.38	0.93	1.16	1.49	1.20	1.35	1.52	1.29	1.40	1.60	1.52	1.56
	Hospital	1.08	0.90	0.58	0.74	1.02	0.87	0.94	1.00	0.86	0.93	1.07	1.00	1.04
	Emergency Shelter	0.30	0.25	0.19	0.22	0.27	0.23	0.25	0.27	0.25	0.26	0.29	0.27	0.28
	Convenience Store	0.93	0.76	0.50	0.63	0.83	0.65	0.74	0.84	0.71	0.77	0.91	0.88	0.89
	Banking	0.71	0.56	0.33	0.44	0.68	0.60	0.64	0.62	0.50	0.56	0.70	0.69	0.69
West LA	Electricity	1.00	0.24	0.25	0.25	0.70	0.80	0.75	0.24	0.25	0.25	0.76	0.80	0.78
	Grocery	1.27	0.77	0.85	0.81	0.93	1.12	1.02	1.02	1.10	1.06	1.18	1.25	1.22
	Hospital	1.63	1.13	1.14	1.13	1.28	1.43	1.35	1.37	1.37	1.37	1.53	1.61	1.57

Neighborhood	Service	No Event	No Program			Microgrid			50% Critical Backup			Microgrid + 50% Critical Backup		
			Earthquake[b]	Flood	Disaster Average	Earthquake[b]	Flood	Disaster Average	Earthquake[b]	Flood	Disaster Average	Earthquake[b]	Flood	Disaster Average
	Emergency Shelter	0.89	0.59	0.54	0.56	0.75	0.75	0.75	0.75	0.69	0.72	0.86	0.84	0.85
	Convenience Store	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
	Banking	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Wilmington[a]	Electricity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Grocery	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
	Hospital	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
	Emergency Shelter	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.27
	Convenience Store	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
	Banking	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63

[a] DAC neighborhood

[b] Earthquake results include four simulated events located close to historically recorded earthquakes from 1965 to 2016, which all happen to fall in the northern part of the city. There are other active fault zones throughout the city and offshore that could more severely impact Wilmington and other southern neighborhoods.

A.7 Additional Community Member Feedback

This section provides verbatim comments from community members of the listening sessions that are relevant to the equity strategies for the distribution grid.

Invest in Infrastructural Capacity—from Building-Scale to Urban-Scale—that Lowers Barriers to Accessing and Using Clean Energy Efficient Technologies

> I think…most of the problem is with the homes in South LA, you know the electrical is outdated so I hear from a lot of neighbors, they can't even run their computers because now computers are too fast and the electrical can't get out that [current]. So, with all these [new energy efficient technologies]—going with electrical stoves, I'm gonna assume that they're gonna be new—so how is that gonna work? I think a program has to be done to encourage the owners or something to upgrade…like when we did [this transition] with the landscaping…they got a program so if they took out their grass to decrease water, something like that. Because it's just terrible what neighbors go through.—South LA Resident

Upgrade and Maintain Aging Infrastructure for Safety and Efficiency

> I'm thinking about just kind of equity and intentionality and thoughtfulness in infrastructure. And so, what [LA]DWP can do to support a vision of a, of a healthy community, like the last question is, for example, like, I see, at least in my community, we still have things like high tension power lines, right? And so when we are looking at the infrastructure necessary to facilitate renewable energy, we are implementing, creating infrastructure, or even going in and remediating and fixing infrastructure that's outdated in ways that supports the renewable energy efforts but not necessarily at the environmental impact expense disproportionately in inner cities. And to me that's also about public health, when we have public health, adverse health outcomes associated with these types of infrastructure. So just being mindful that, again, we're not adding to that, and that we're going and we're thinking thoughtfully about how this can, these efforts can be combined with going into what high tension power lines or other not optimal infrastructural structures and correcting those and doing something better than what already exists.— South LA Resident

Develop Affordable Strategies for Grid and Home Electrical Capacity Upgrades that Do Not Further Burden Low- and Moderate-Income Angelenos

> I don't have air conditioning…The bills [are too high], but obviously I would like to...I would like to have that in my house because one needs air conditioning, especially now that it has been very hot. I have a little dog—we couldn't go out. Where I used to spend a lot of time was on the beach, but because of the [price of] gas [instead]…I would hang around in the area. I would go to other people's houses [to access air conditioning], sadly, because we didn't qualify for those [cooling] programs.— Pacoima Resident

Support the Development and Maintenance of Publicly Accessible Resilience Spaces for Safe and Comfortable Shelter During Disaster Events

- Oh, [in extreme heat] I just blast the AC [everyone laughs]. I mean I close the door, blast the AC, and think about the electric bill later, because it's so hot I can't sleep. During the day I try to go to a cold spot, like a coffee shop or the parks where there's a lot of trees. There's not much I can do because it's so hot.— East LA Resident
- When it's too hot? Um, well, I come here [Boyle Heights Arts Conservatory and Resilience Hub] because there's really good AC and I work. So, luckily, I have a job where there's AC. But for my puppies I have to make sure the AC is running for them, at home. But I try to maintain and manage what I definitely do is make sure that during the day—I lived in Vegas, for a while, so I can deal with like if there's 116 to 110 on a normal day, on average, so you learn how to manage your AC units so that they don't blow or they don't cause any problems where your electrical bill is crazy. Because the reality is, if it's 105 degrees here you just have to cool your house down to like 95. And it does make a big difference. So you just put your AC to 95 or 85 and it actually works really well. Same thing with my car. I do that, I don't put it all the way down to low because it doesn't really function that way. And then at night you drop it down to at least 10 degrees cooler than…the temperature outside. So that way at least you maintain some type of cool house…and keeping the curtains closed during the day, that really helps, and keeping the doors closed, so that way the puppies don't get exhaustion from heat. And it does, just having your AC controlled…really does work.— East LA Resident

Prioritize Upgrading Critical Electrical Infrastructure in Neighborhoods With Older Housing Stock To Prevent Local Blackouts and Their Negative Effects

> I need to find someone with an upgrade of electric because…we have blockage [outages] all the time when somebody hits a [utility] post and the electricity go off and it cause problem in my home now that I cannot wash [clothes] and watch a TV at the same time. My electric goes off…they have these accidents, these people hit these posts [utility poles], then your electric's out for two hours or so, and it messes up your appliance…your appliance be off, and you know, it's a mess.— South LA Resident

A.8 Data Sources and Assumptions

Table A-8. Summary of Grid Reliability and Resilience Modeling Data Sources

Data	Source	Description	Resolution	Data Year
Electrical distribution grid models	LA100 study (with limited updates)	Existing OpenDSS feeder models will be used, potentially with limited priority updates	Feeder	2018
LADWP power reliability metrics	LADWP	SAIDI/SAIFI additional metrics welcome (e.g., customer-oriented metrics)	Distribution station/census tract	2015–2020
Disadvantaged communities (DACs)	CalEnviroScreen 4.0	DACs are identified as tracts with the highest 25% CalEnviroScreen Scores	Census tract	2021
LADWP electrical infrastructure cost database	LA100 (with limited updates)	Unit costs for electrical equipment to evaluate cost of distribution grid upgrades	Utility-managed components	2020
Electrical loads	NREL residential buildings and transportation modeling	Hourly building loads, EV charging profiles	By building and household type and census tract	2020, 2035
Rooftop solar and storage adoption	NREL local solar and storage modeling	Time-series profiles from agents generated in dGen	Census tract	2020 (existing), 2035
SCADA data	LA100/LADWP	Scales and matches loads placed at the transformer	Feeder / circuit / distribution station / distribution station bank / receiving station	2019 (to avoid COVID anomaly)

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
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UCLA Chapters

Find the LA100 Equity Strategies chapters authored by UCLA at the links below.

Chapter 13: Energy Affordability and Policy Solutions Analysis

Chapter 14: Small Ethnic-Owned Businesses Study

Chapter 15: Air Quality and Public Health

Chapter 16: Green Jobs Workforce Development

Chapter 17: Service Panel Upgrade Needs for Future Residential Electrification