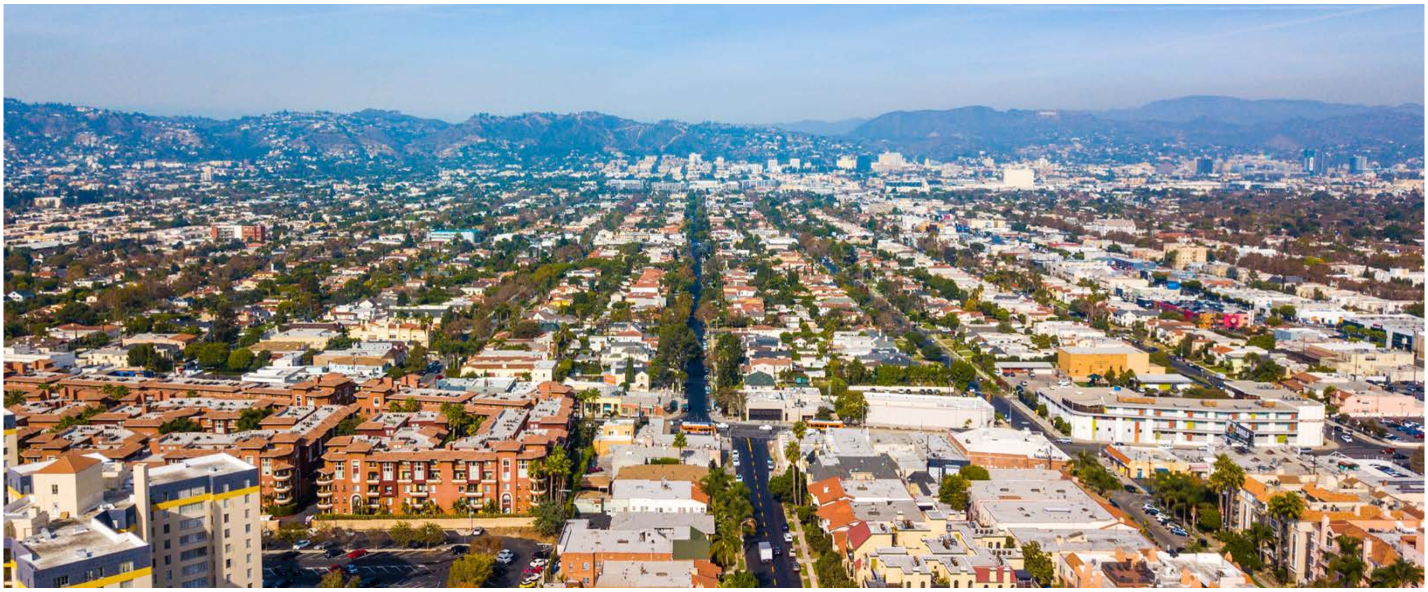
LA100 EQUITY STRATEGIES



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

LA DWP

NREL Transforming ENERGY

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LA DWP

NREL Transforming ENERGY

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

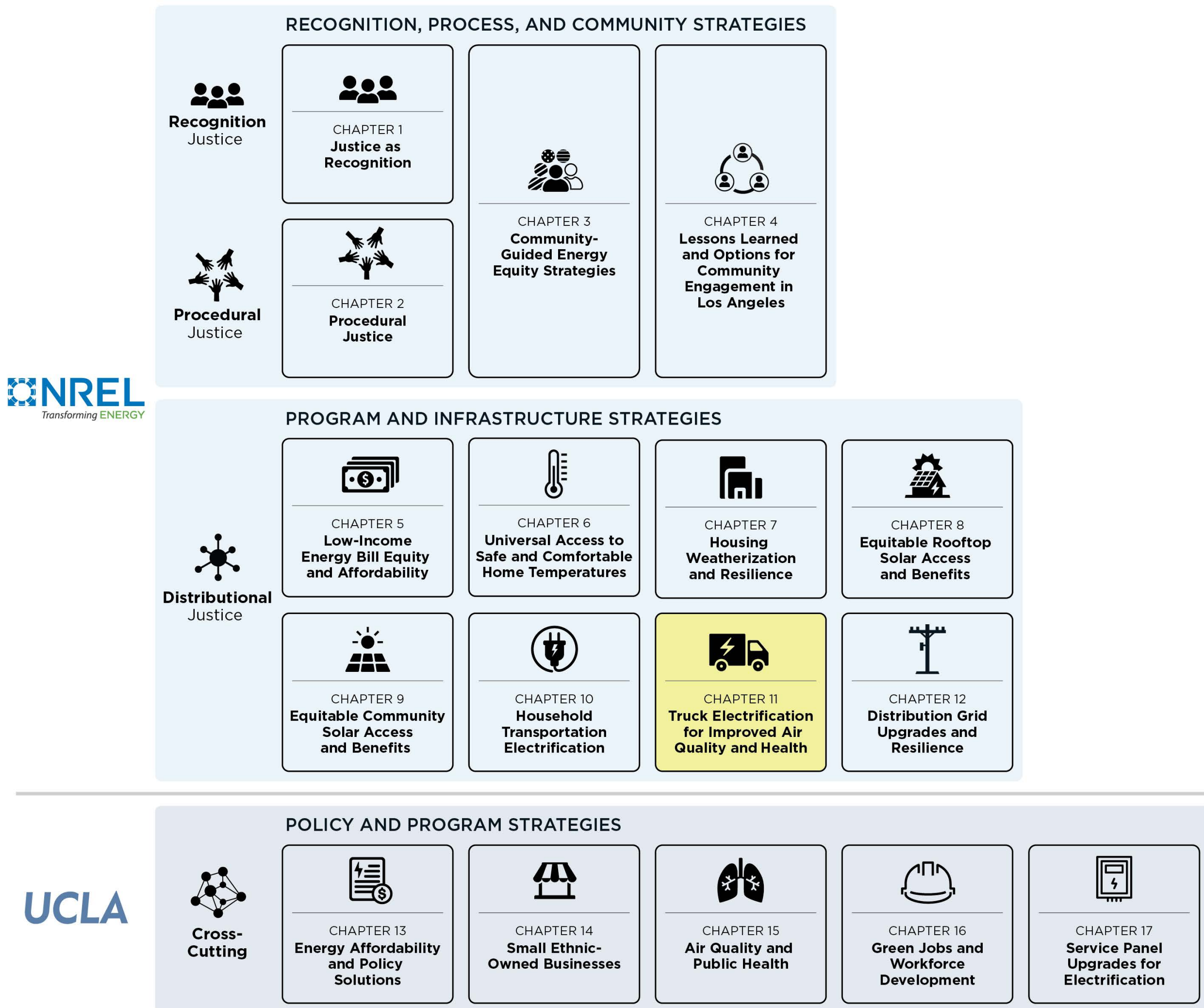
LA100 Equity Strategies employs a unique mixed-methodological approach utilizing three distinct—but connected—research efforts. Through these efforts, NREL and UCLA developed a range of strategy options for increasing equity in LA's transition to 100% clean energy.

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

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]

[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.

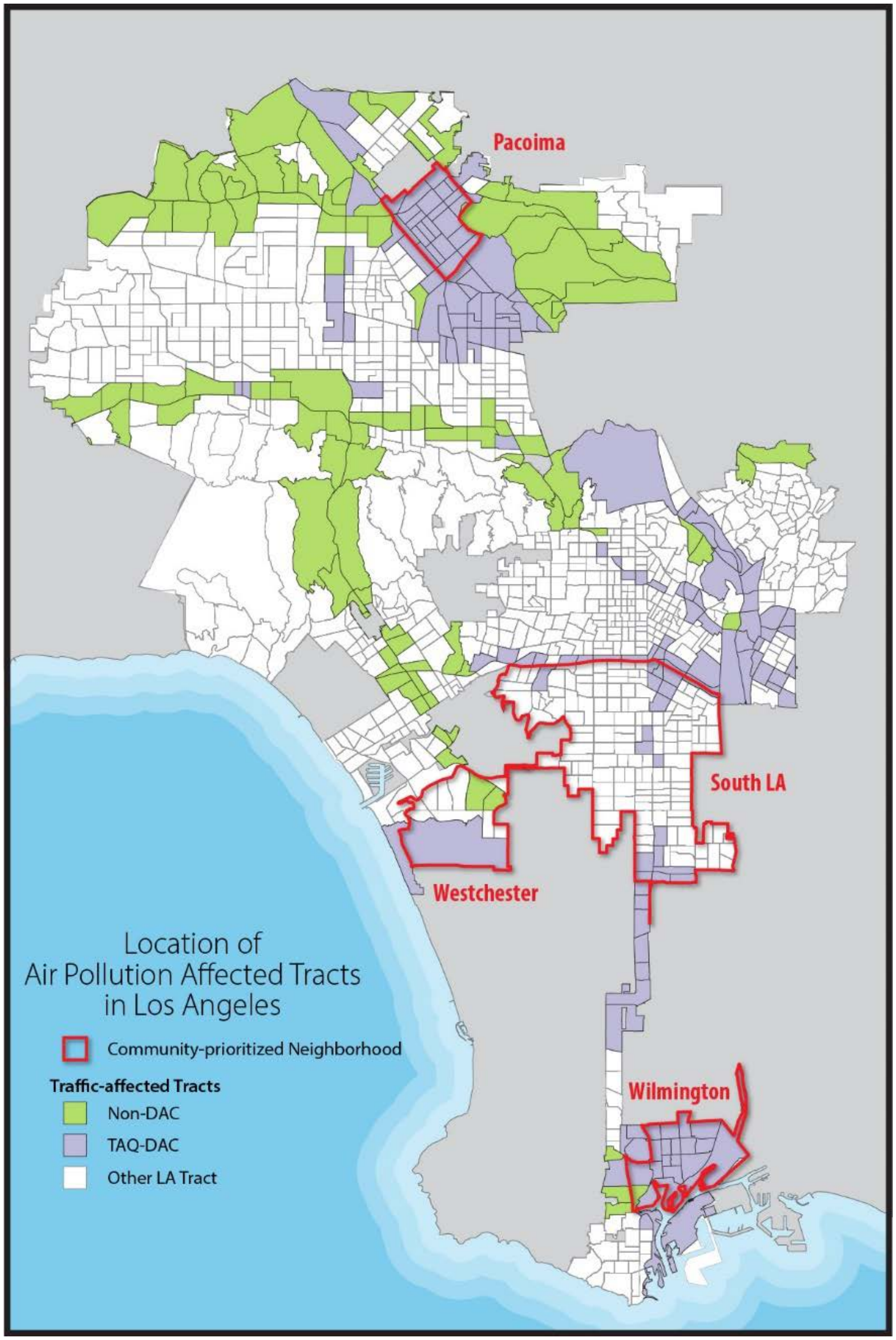

Figure ES-1. Location of traffic air pollution-affected tracts in Los Angeles

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.

[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.

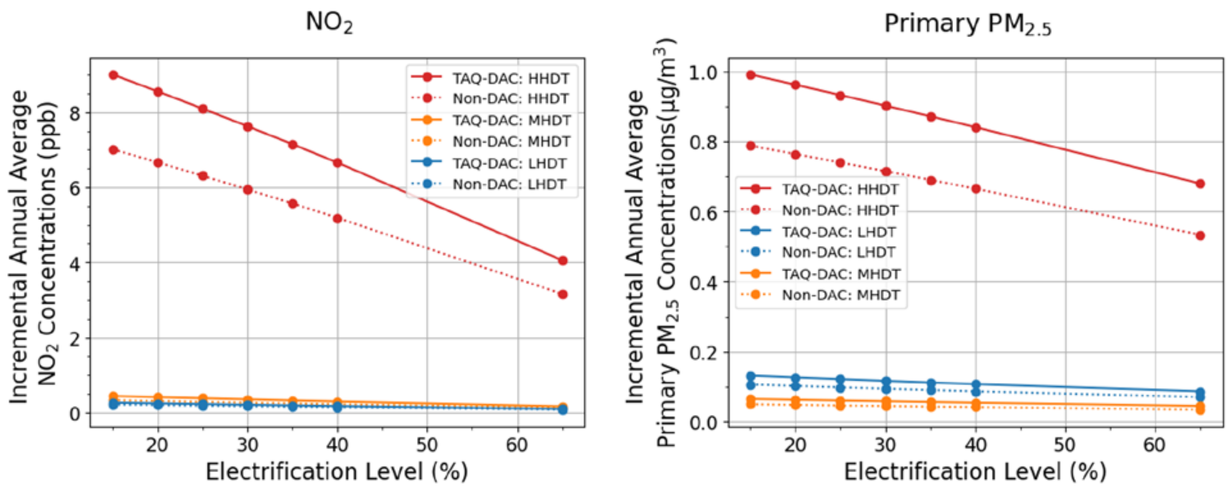

Figure ES-22. Incremental annual-average truck-related near-road NO_2 concentration (in parts per billion [ppb], left panel) and primary $PM_{2.5}$ (µg/m^3, right panel) by heavy-duty truck classification and electrification level in Los Angeles (2035)

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%).

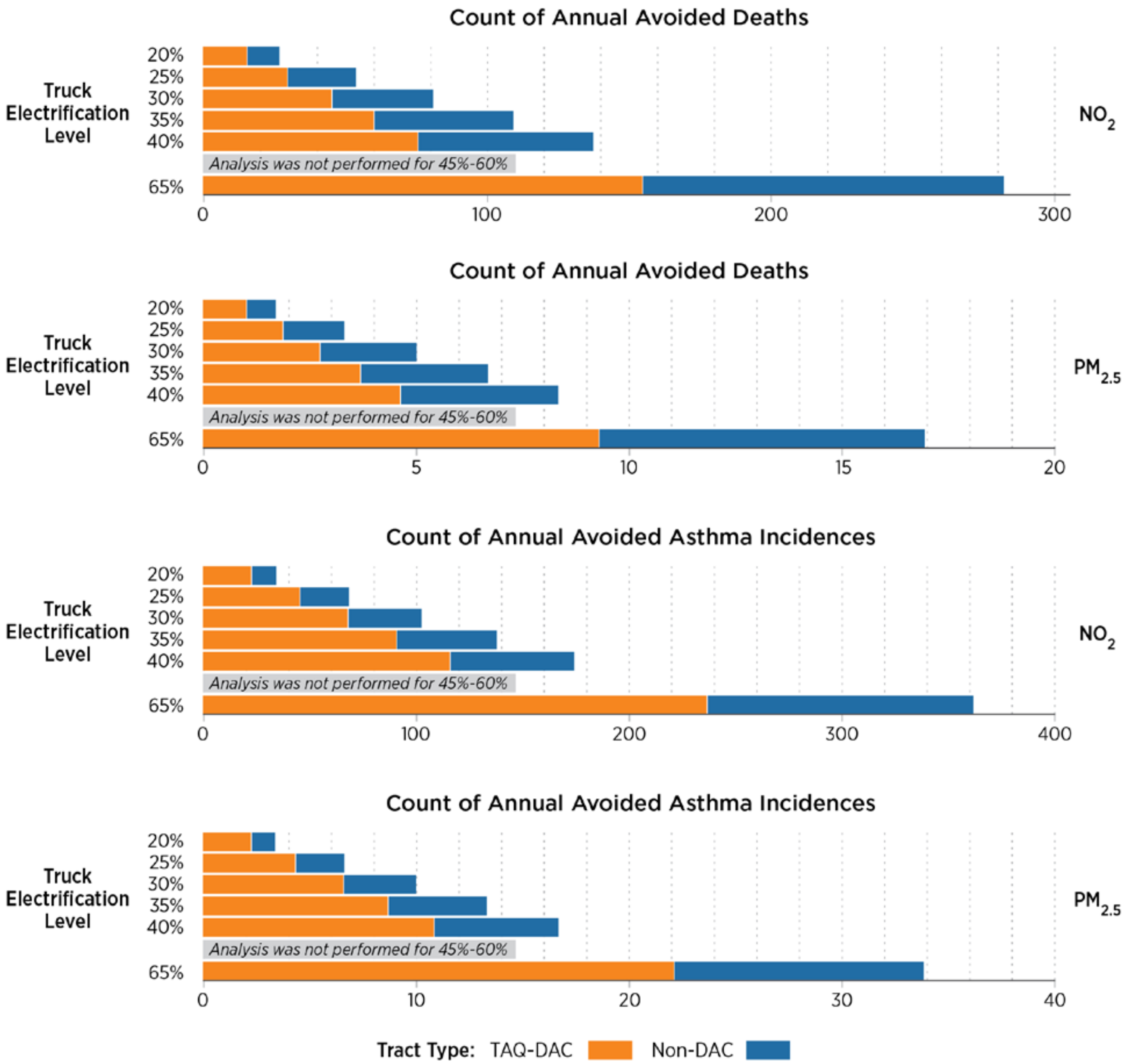

Figure ES-3. Premature deaths and asthma-related health benefits accrued by TAQ-DACs and non-DACs by heavy-duty truck electrification level relative to 15% electrification baseline (2035)

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

[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.

Table of Contents

List of Figures

List of Tables

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 $\mu g/m^3$ 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 $\mu g/m^3$ 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).

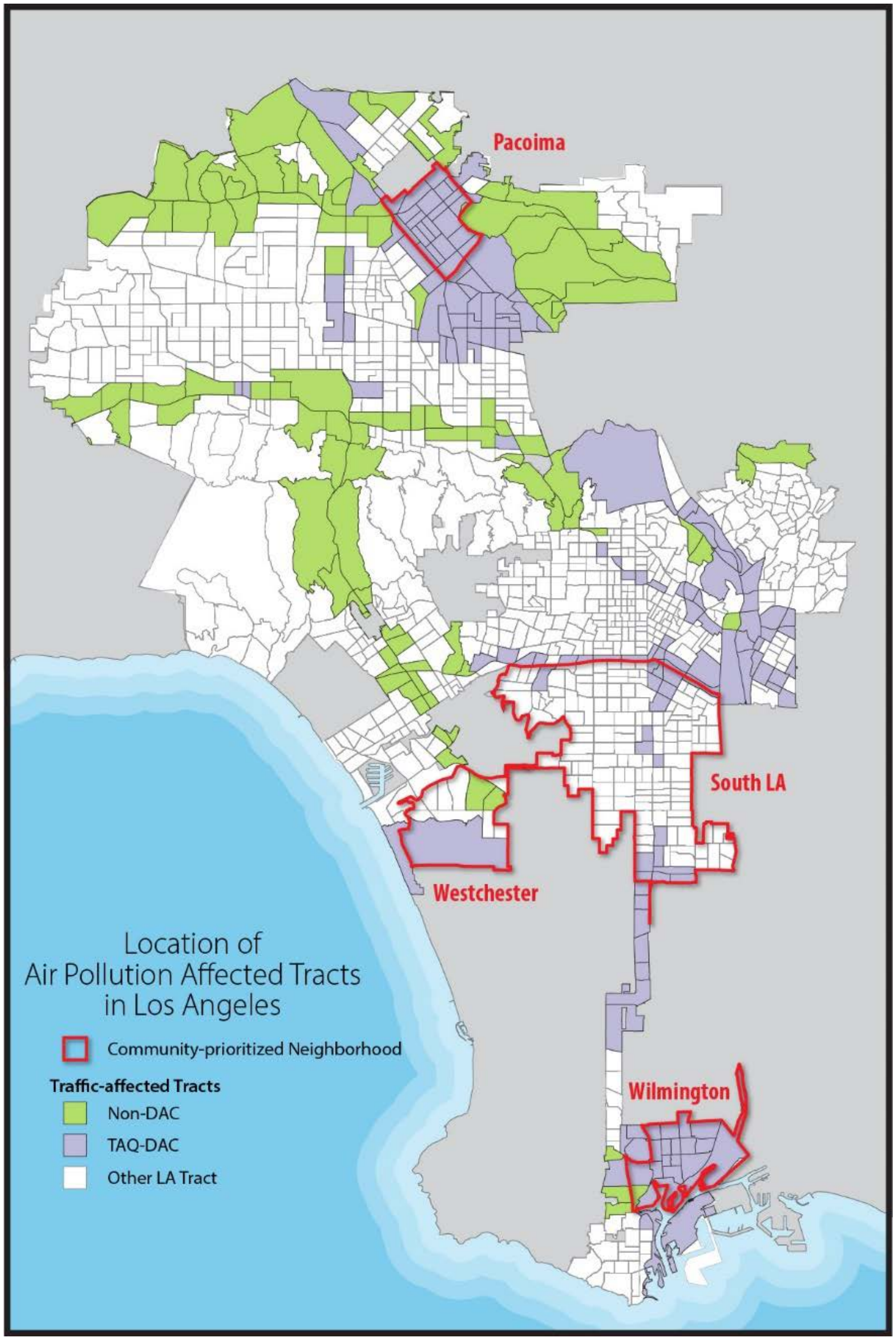

Figure 1. Location of traffic air pollution-affected tracts in Los Angeles

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.

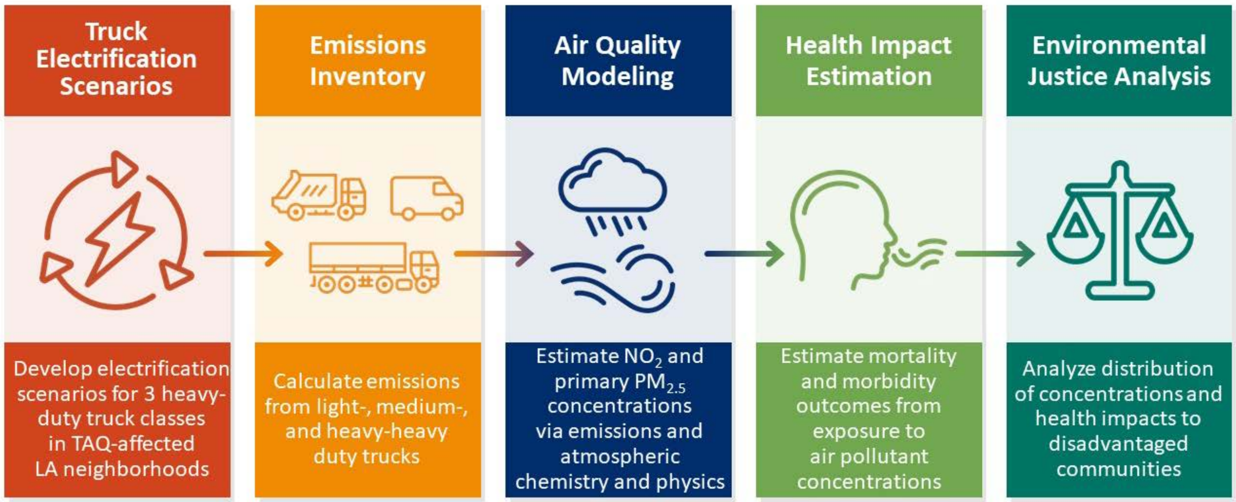

Figure 2. Air quality, health, and environmental justice impact analysis workflow informing equity strategy development

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]

[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.

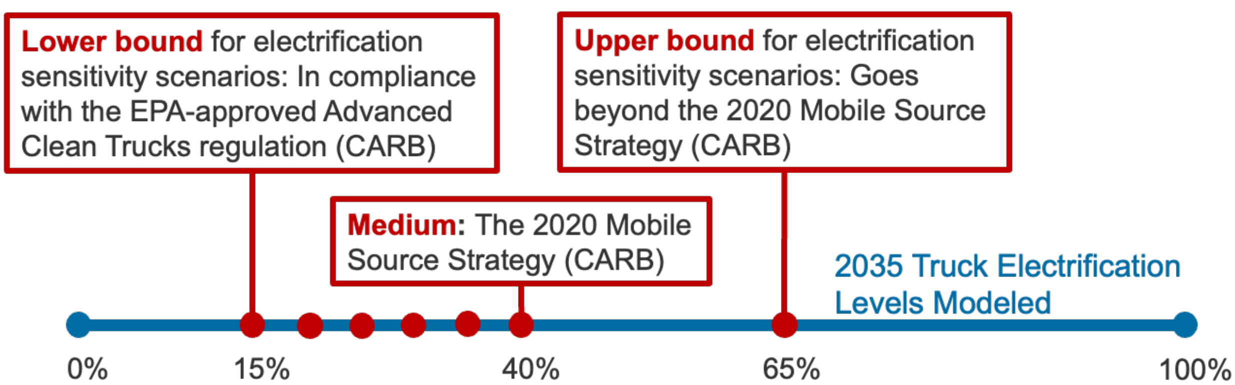

Figure 3. Analyzed 2035 truck electrification levels in the City of Los Angeles and associated CARB-approved regulations

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

[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

[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

[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.

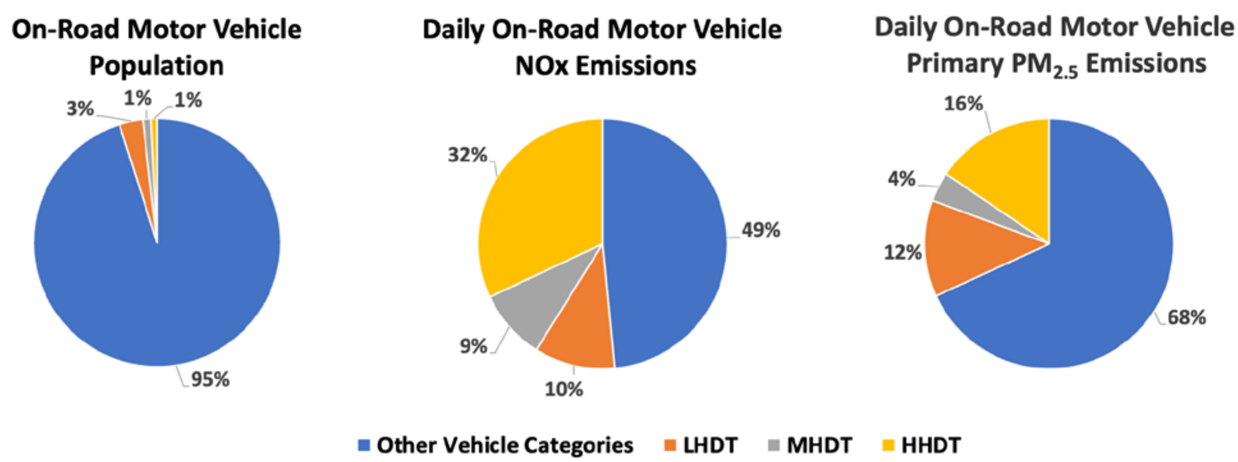

Figure 4. Fractional distribution of 2022 on-road motor vehicles registered in Los Angeles, and daily on-road motor vehicle NO_x and primary $PM_{2.5}$ emissions

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).

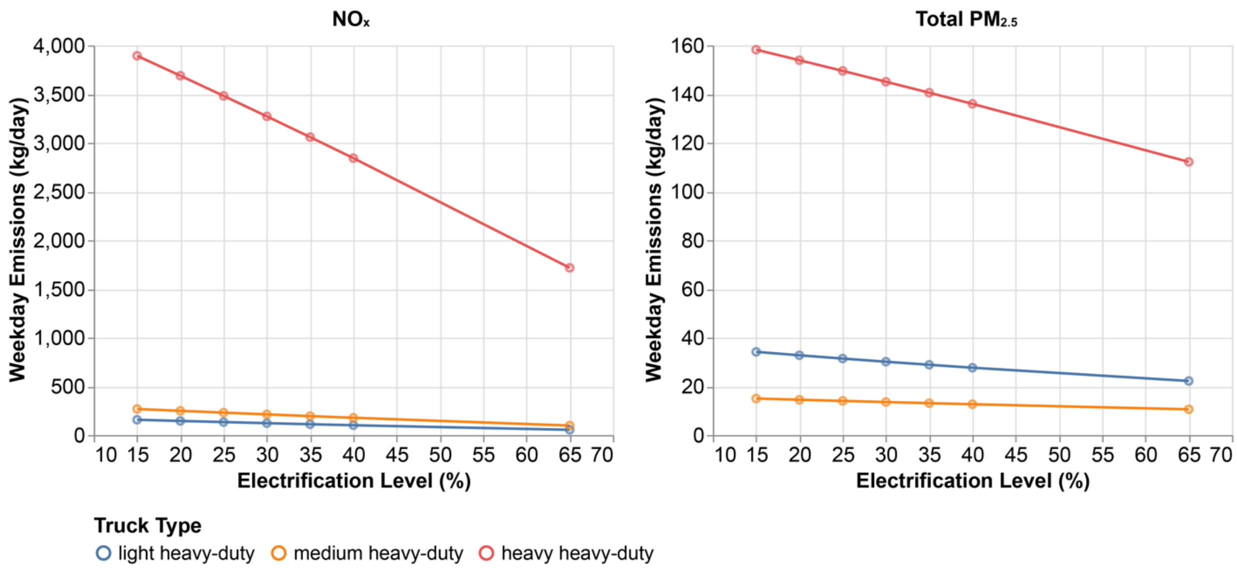

Figure 5. Projected daily emissions of NO_x and total primary $PM_{2.5}$ from each heavy-duty truck category for a typical weekday in Los Angeles in 2035 as a function of on-road fleet electrification level from 15% to 65%

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.

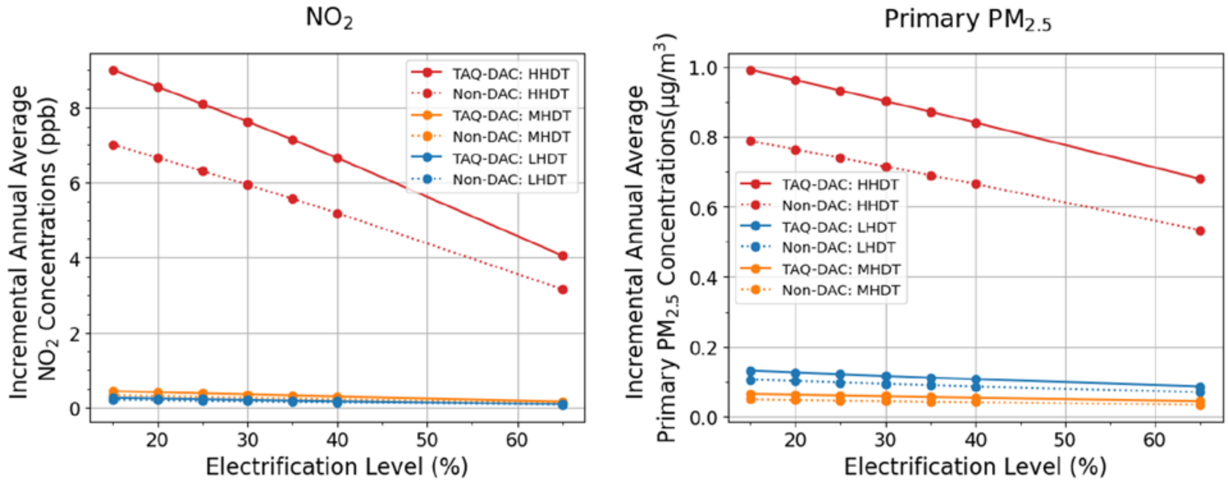

Figure 6. Incremental annual-average truck-related near-road NO_2 concentrations (ppb, left panel) and near-road primary $PM_{2.5}$ concentrations (µg/m^3, right panel) at tested electrification levels

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 µg/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 $PM_{2.5}$ (µg/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.

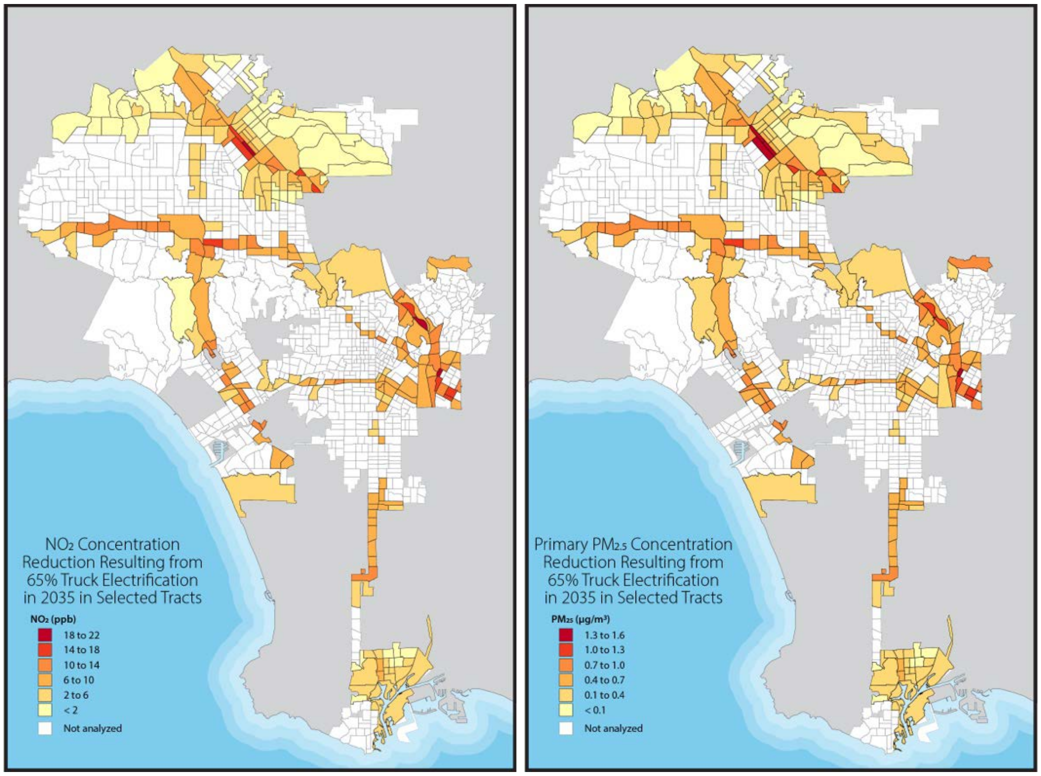

Figure 7. Spatial pattern of reductions in 2035 near-road truck-related NO_2 concentrations (ppb, left panel) and primary $PM_{2.5}$ (µg/m^3, right panel) from the 15% electrification scenario compared to the 65% electrification scenario

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.

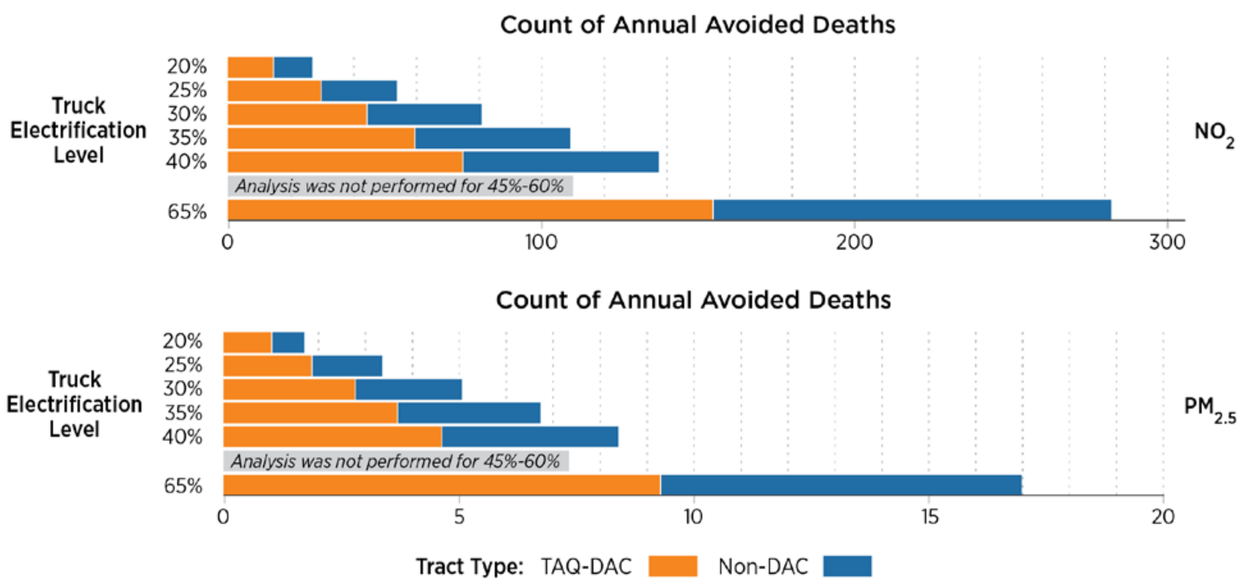

Figure 8. Annual avoided premature deaths from heavy-duty truck electrification for NO_2 and $PM_{2.5}$ by electrification level relative to 15% electrification baseline (2035)

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%).

[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.

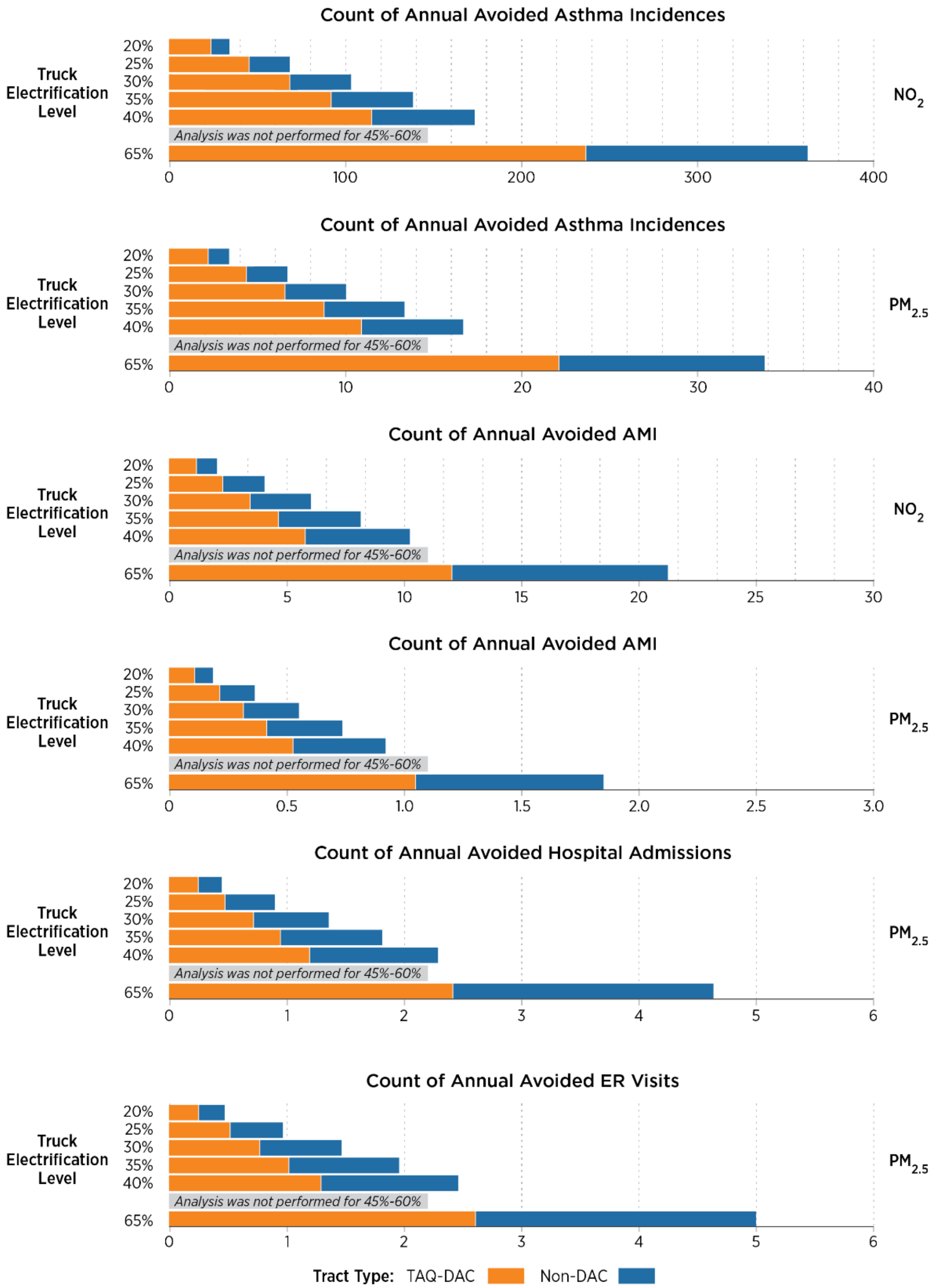

Figure 9. Annual morbidity-related health benefits from heavy-duty truck electrification by electrification level relative to 15% electrification baseline (2035)

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.

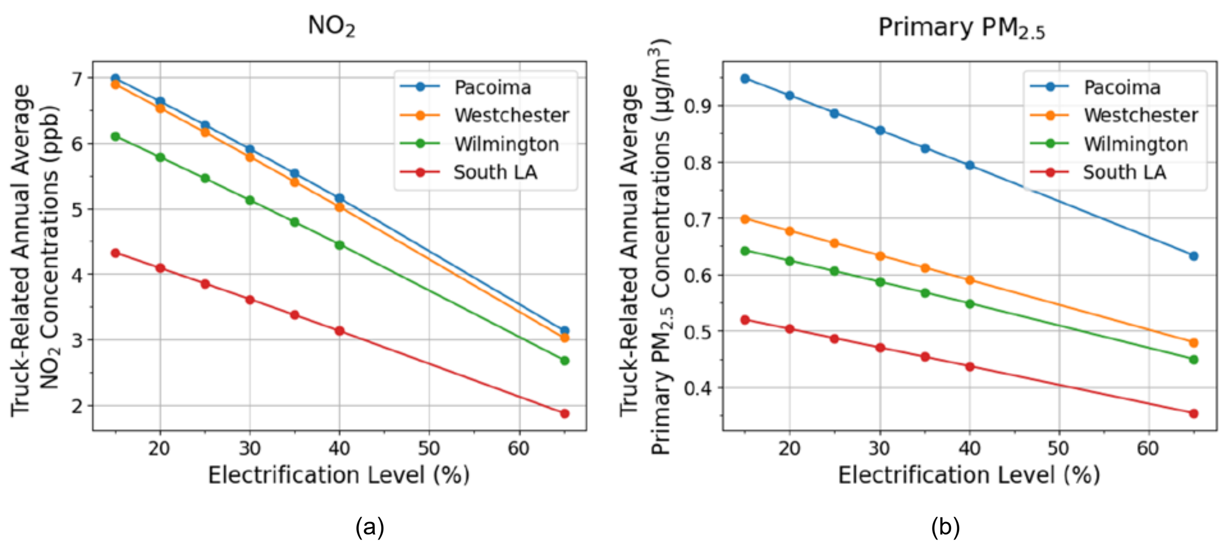

Figure 10. Average annual truck-related near-road NO_2 concentrations (a) and primary $PM_{2.5}$ concentrations (b) in community-prioritized neighborhoods by electrification level

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).

[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.

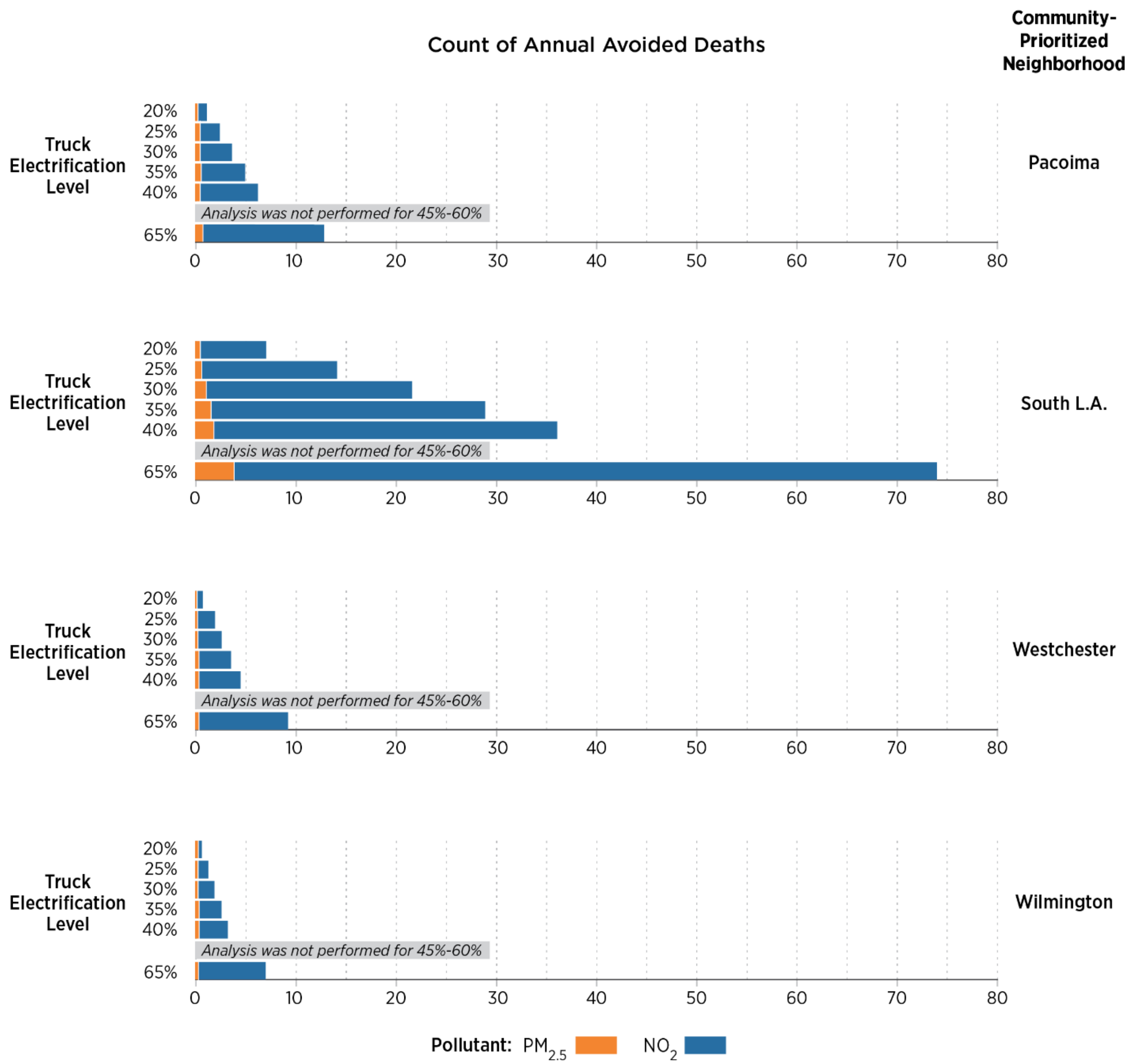

Figure 11. Annual avoided premature deaths from heavy-duty truck electrification for near-road NO_2 and $PM_{2.5}$ by electrification level relative to a 15% electrification level in community-prioritized neighborhoods

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.

[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.

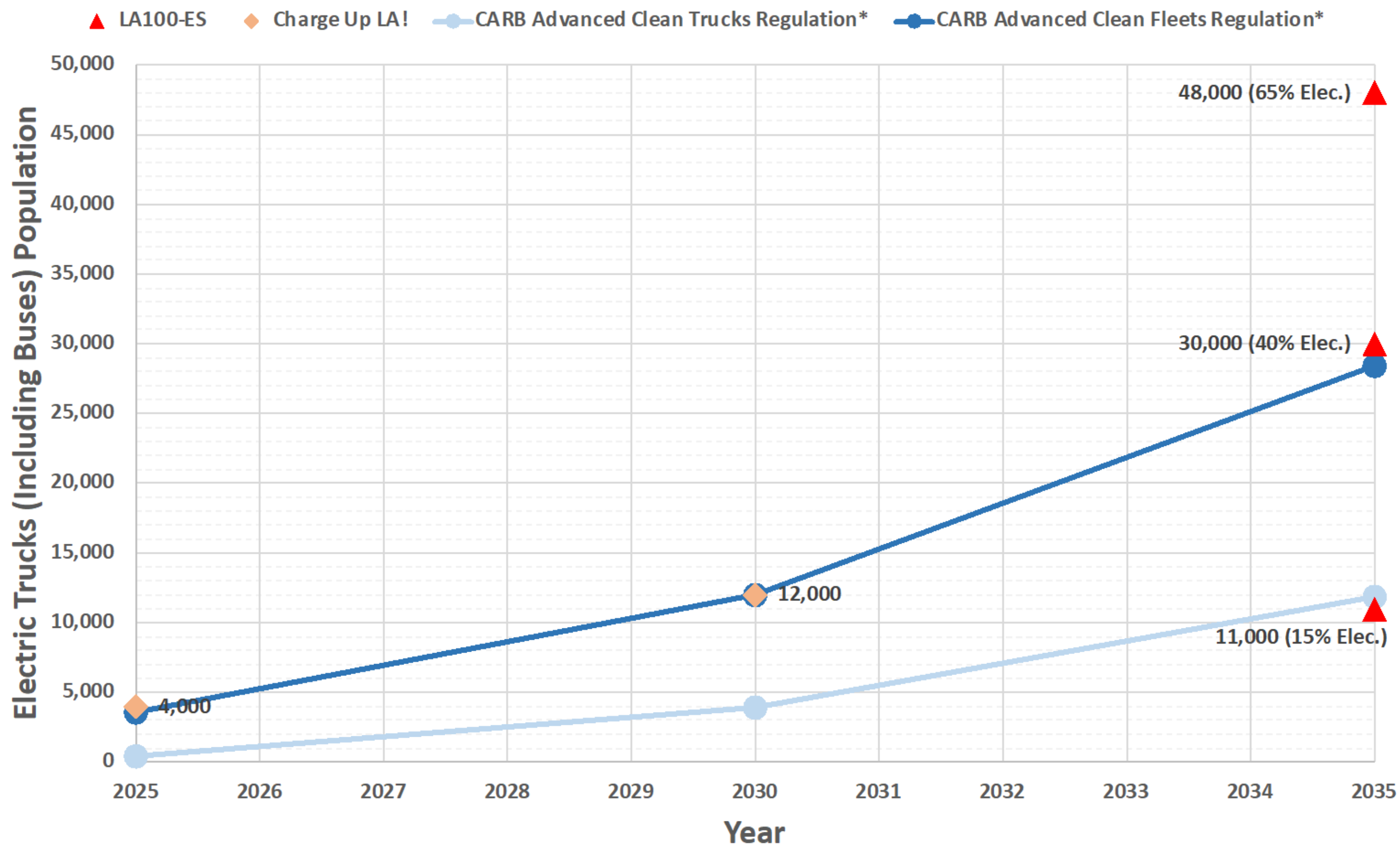

Figure 12. Heavy-duty truck (including buses) electrification levels (2025–2035) including Charge Up LA! goals, NREL-application of LA share of CARB state-level regulations, and LA100 Equity Strategies (LA100-ES) analyzed electrification levels

* 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]

[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.

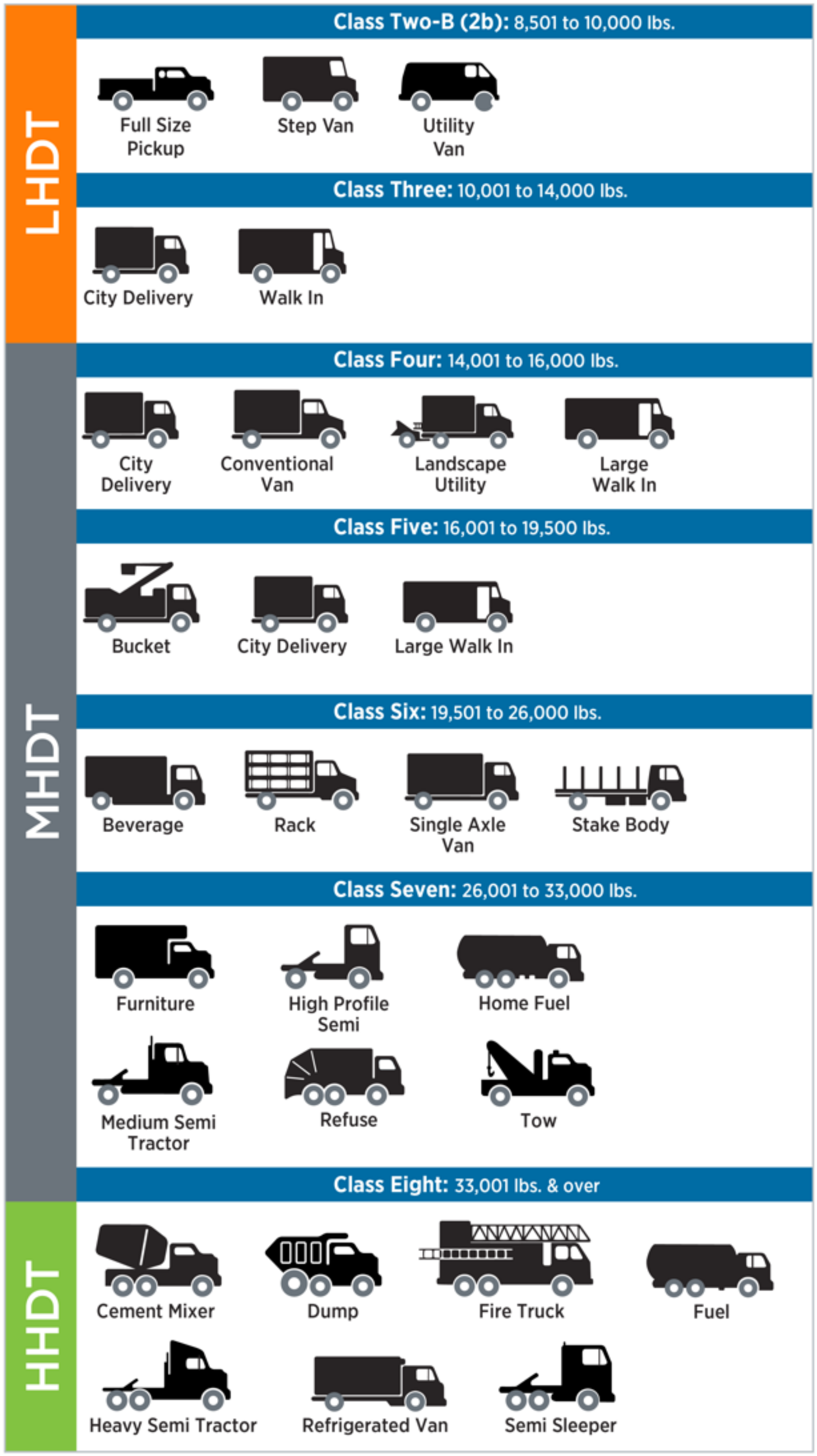

Figure A-1. Classification of trucks by weight class based on GVWR as used by the Federal Highway Administration

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]

<table>
<tr><th>Vehicle Weight Class Based on GVWR (lbs)</th><th>Vehicle Types Used by the Federal Highway Administration</th><th>Vehicle Types Used by the California Air Resources Board in EMFAC[b] (and in this chapter)</th></tr>
<tr><td>Class 1: <6,000</td><td rowspan="3">Light Duty</td><td>Light Duty</td></tr>
<tr><td>Class 2a: 6,001–8,500</td><td>Medium Duty</td></tr>
<tr><td>Class 2b: 8,501–10,000</td><td rowspan="2">Light Heavy Duty</td></tr>
<tr><td>Class 3: 10,001–14,000</td><td rowspan="4">Medium Duty</td></tr>
<tr><td>Class 4: 14,001–16,000</td><td rowspan="3">Medium Heavy Duty</td></tr>
<tr><td>Class 5: 16,001–19,500</td></tr>
<tr><td>Class 6: 19,501–26,000</td></tr>
<tr><td>Class 7: 26,001–33,000</td><td rowspan="2">Heavy Duty</td><td></td></tr>
<tr><td>Class 8: >33,001</td><td>Heavy Heavy Duty</td></tr>
</table>

[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.

[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).

[29] "gridMET," Climatology Lab, https://www.climatologylab.org/gridmet.html, accessed 02/2023.

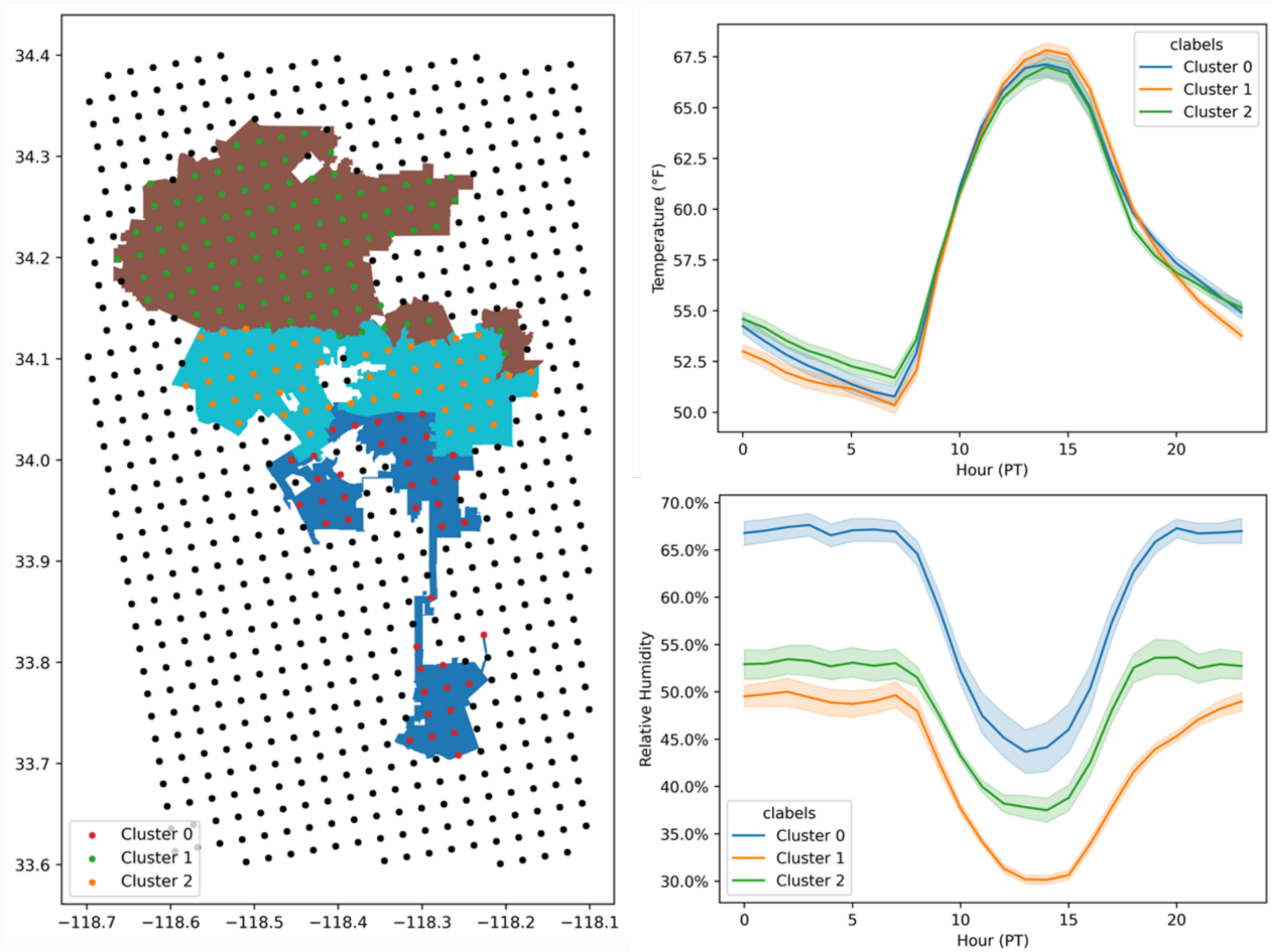

Figure A-2. Los Angeles temperature and relative humidity clusters for an example month (January)

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.

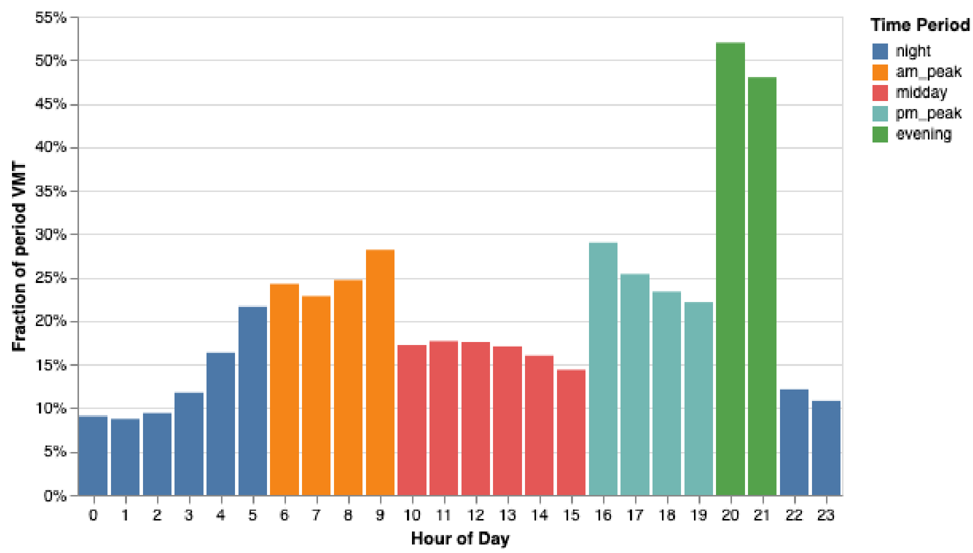

Figure A-3. SCAG VMT allocation by hour and time period

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.

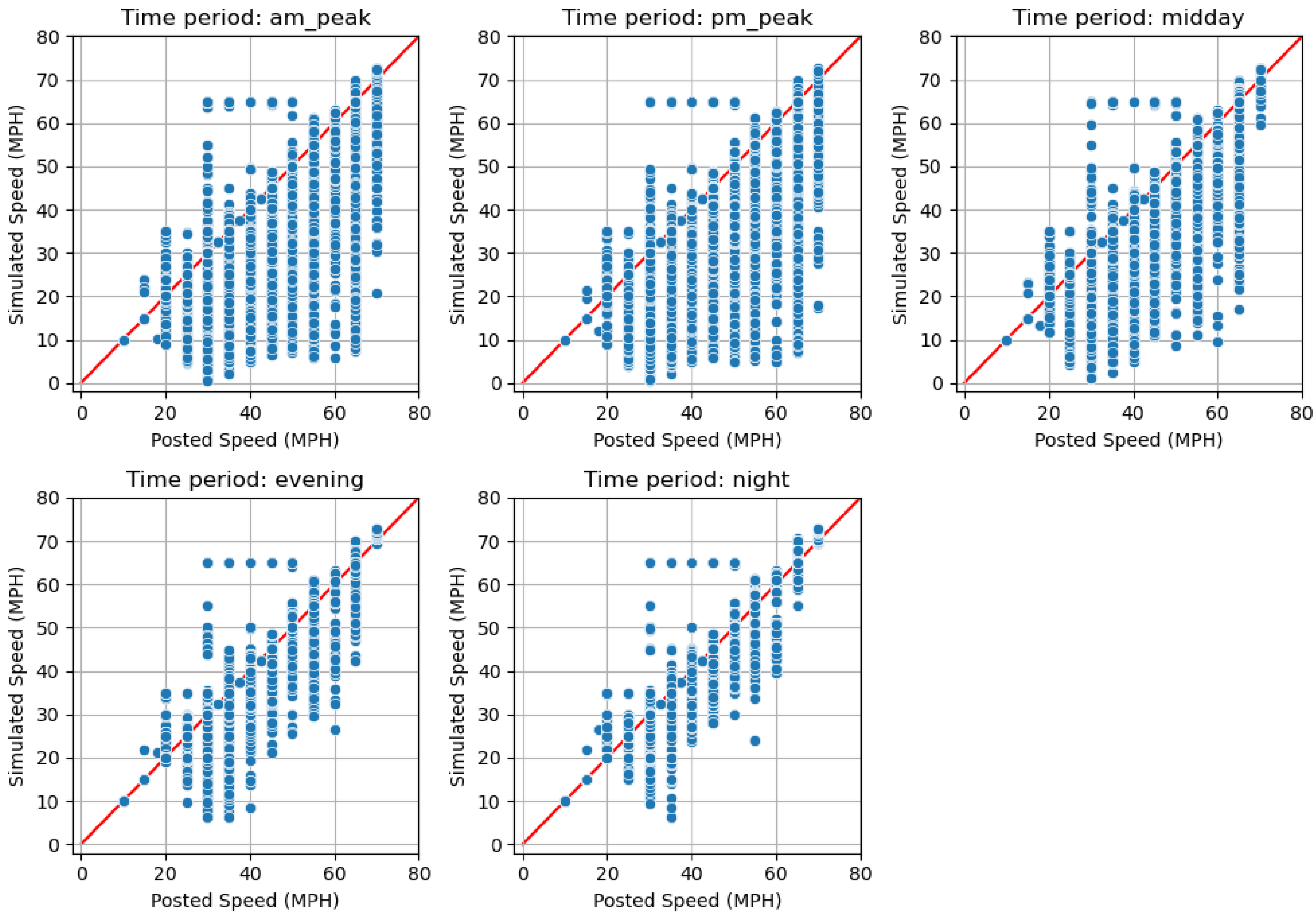

Figure A-4. Posted vs. simulated speed limit comparison for Los Angeles

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

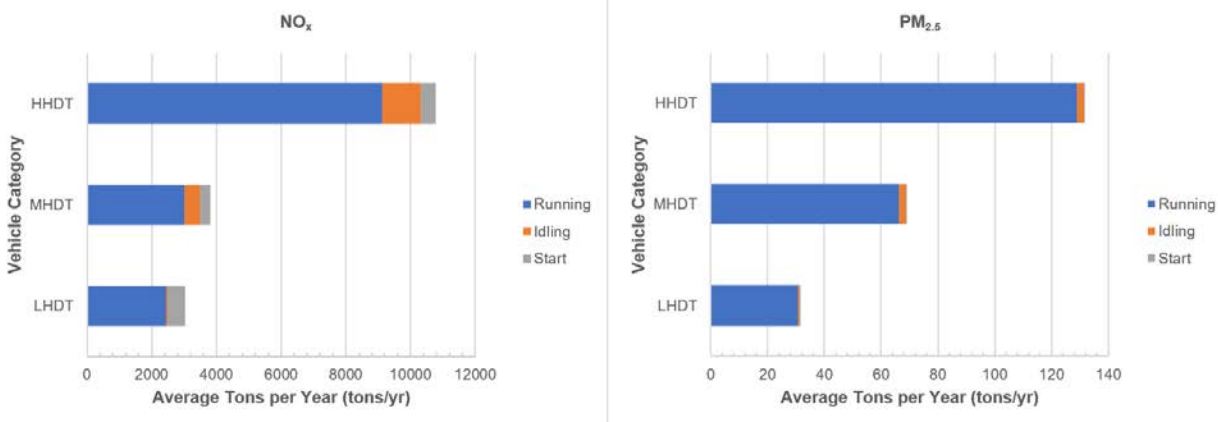

Figure A-5. Annual-average total NO_x and $PM_{2.5}$ exhaust tailpipe emissions by truck type and emissions process (running exhaust, idling and engine start) in Los Angeles South Coast subregion

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

[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.

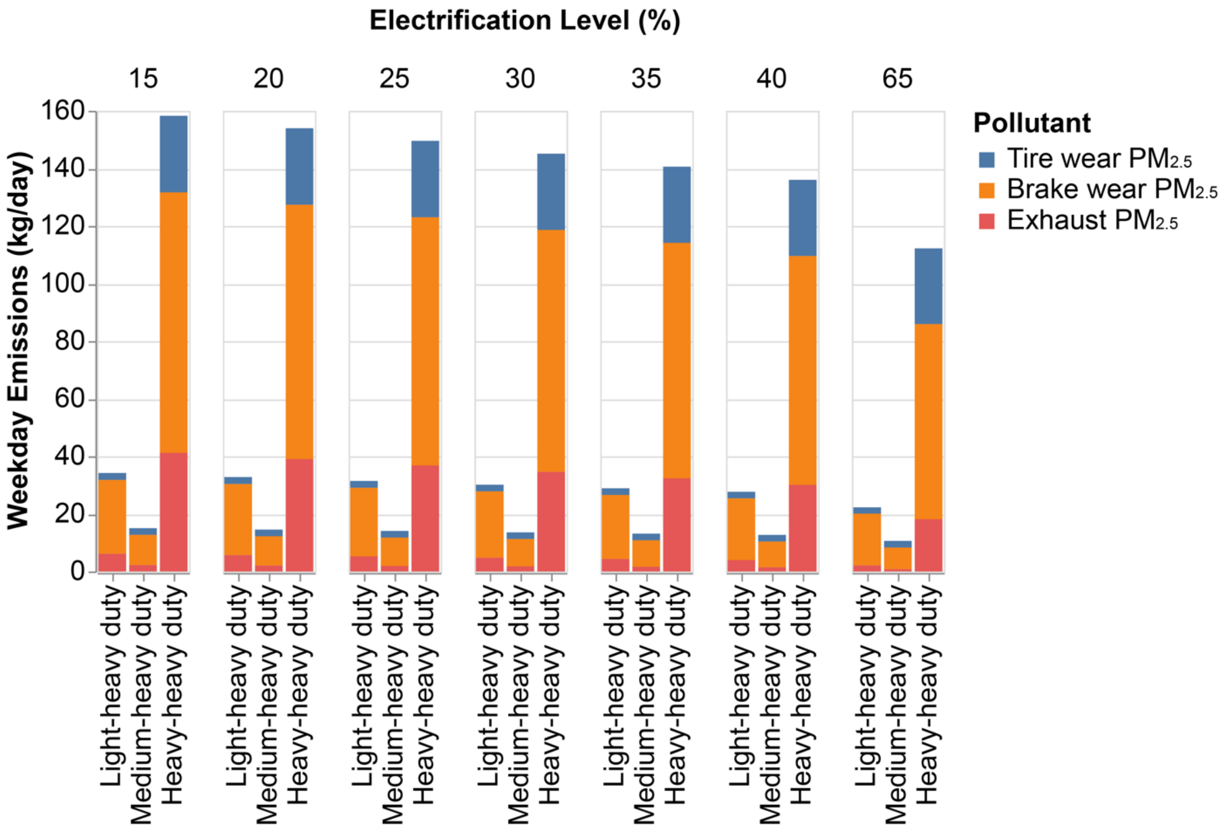

Figure A-6. Modeled weekday $PM_{2.5}$ emissions in 2035 by truck type and the three emissions processes (running exhaust $PM_{2.5}$ (exhaust), brake wear $PM_{2.5}$, tire wear $PM_{2.5}$) under multiple electrification levels

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.

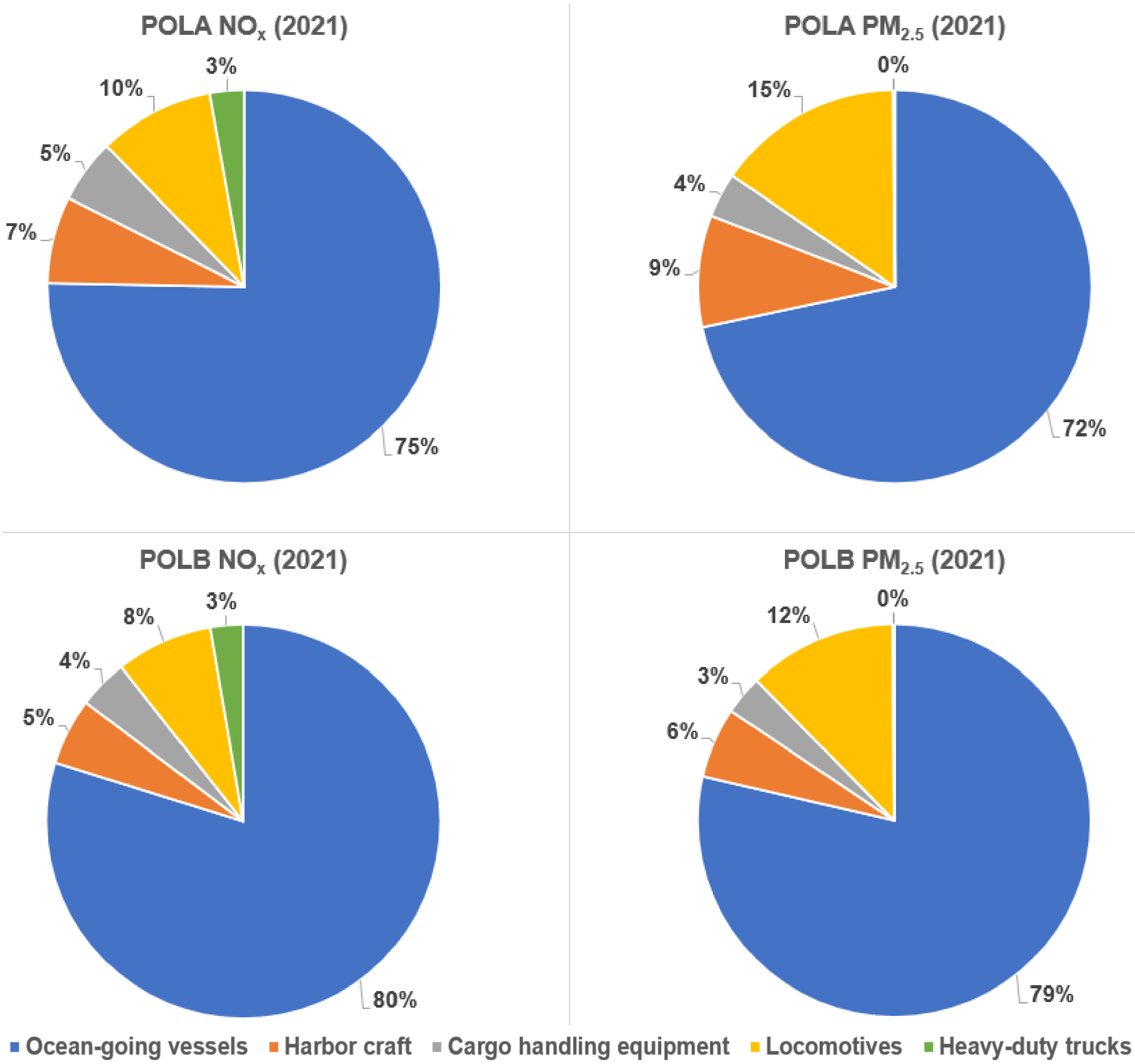

Figure A-7. Total NO_x and $PM_{2.5}$ emissions within POLA and POLB boundaries (2021)

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.

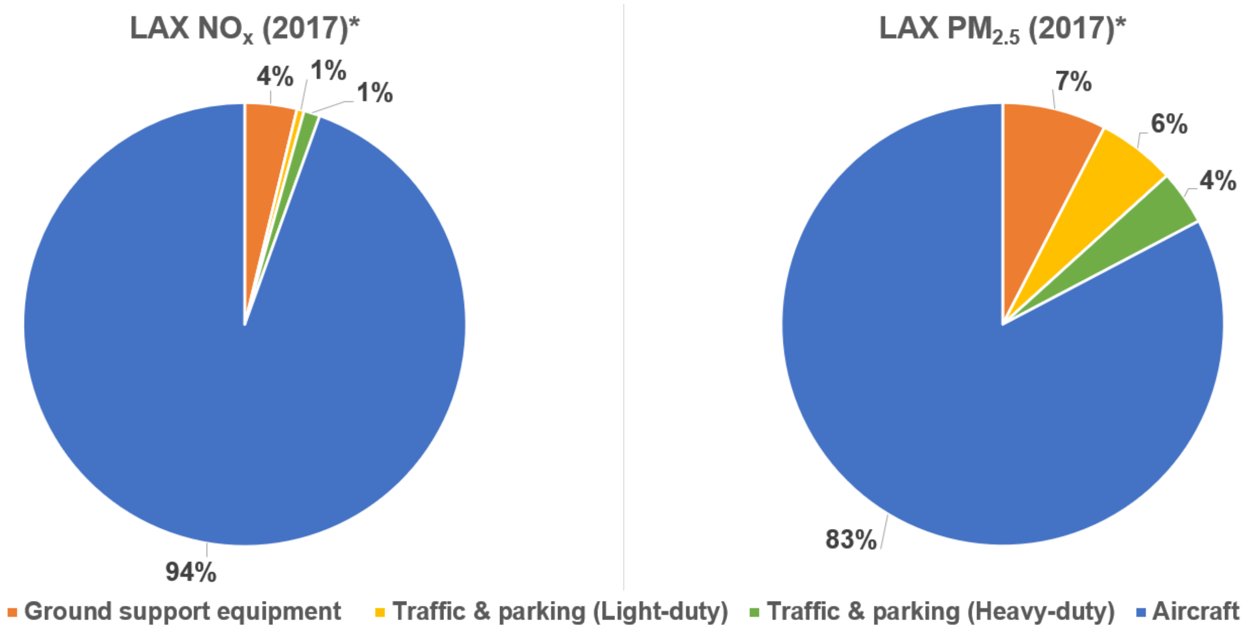

Figure A-8. Total NO_x and $PM_{2.5}$ emissions within the LAX boundary (2017)*

* 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.

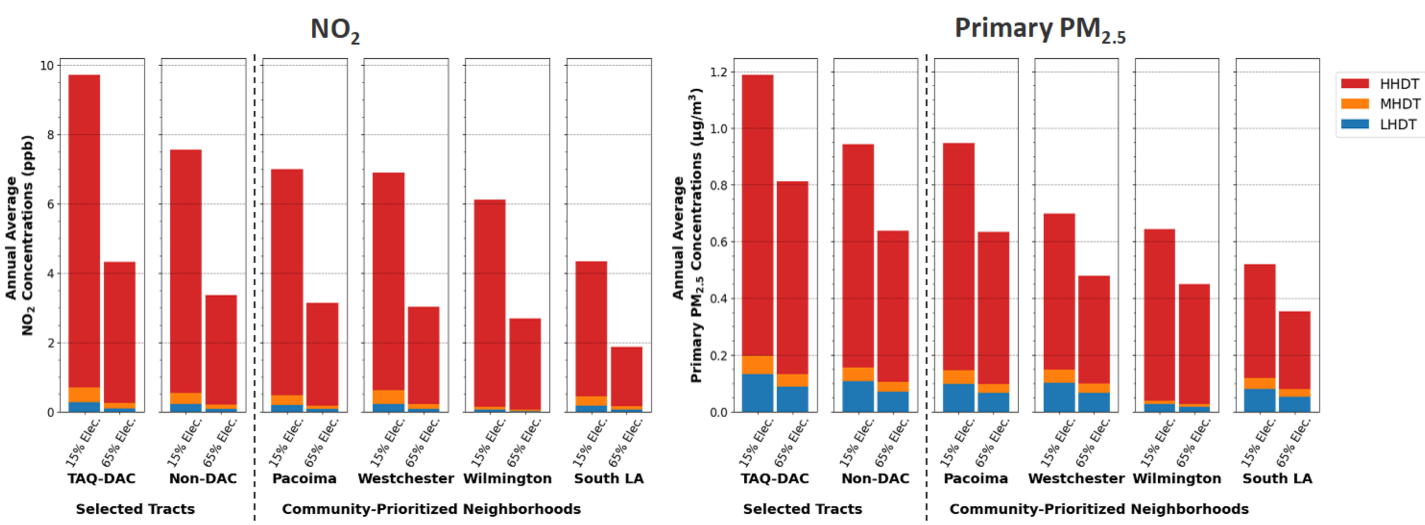

Figure A-9. Incremental 2035 annual-average truck-related near-road NO_2 concentrations (ppb, left) and primary $PM_{2.5}$ concentrations (µg/m^3, right) at 15% and 65% electrification levels

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.

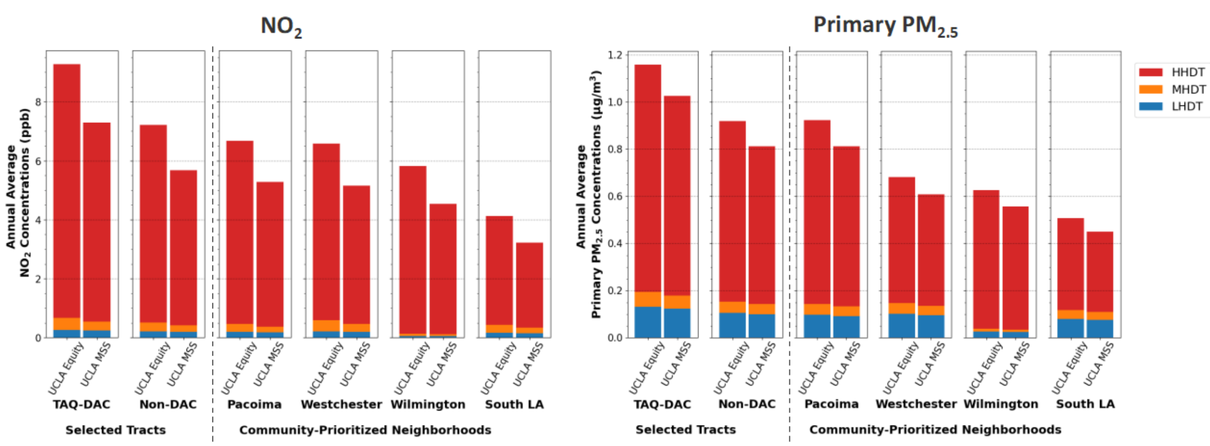

Figure A-10. Incremental annual-average truck-related NO_2 concentrations (ppb, left panel) and (b) primary $PM_{2.5}$ concentrations (μg/m^3, right panel) in UCLA-tested scenarios

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

[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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