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ENERGY COMMISSION**



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Clean Transportation Program

FINAL PROJECT REPORT

Developing a MDHD ZEV Infrastructure Blueprint for the South Coast

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Research and Technology

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PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007) created California's Clean Transportation Program. The statute authorizes the California Energy Commission (CEC) to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies. Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013) reauthorizes the Clean Transportation Program through January 1, 2024, and specifies that the CEC allocate up to \$20 million per year (or up to 20 percent of each fiscal year's funds) in funding for hydrogen station development until at least 100 stations are operational.

The Clean Transportation Program has an annual budget of about \$100 million and provides financial support for projects that:

- Reduce California's use and dependence on petroleum transportation fuels and increase the use of alternative and renewable fuels and advanced vehicle technologies.
- Produce sustainable alternative and renewable low-carbon fuels in California.
- Expand alternative fueling infrastructure and fueling stations.
- Improve the efficiency, performance and market viability of alternative light-, medium-, and heavy-duty vehicle technologies.
- Expand the alternative fueling infrastructure available to existing fleets, public transit, and transportation corridors.
- Establish workforce-training programs and conduct public outreach on the benefits of alternative transportation fuels and vehicle technologies.

To be eligible for funding under the Clean Transportation Program, a project must be consistent with the CEC's annual Clean Transportation Program Investment Plan Update. The CEC issued Grant Funding Opportunity GFO 20-601 to accelerate the deployment of MDHD ZEVs and ZEV infrastructure with a holistic and futuristic view of transportation planning. In response to GFO 20-601, the recipient submitted an application which was proposed for funding in the CEC's notice of proposed awards April 8, 2021 and the agreement was executed as ARV-21-027 on October 4, 2021.

ABSTRACT

This report uses data from multiple sources to conduct modeling and analysis to estimate the number of future Medium- and Heavy-Duty Zero Emission Vehicles (MDHD ZEVs) deployed in the South Coast Air Quality Management District (SCAQMD) territory and their respective power and fuel requirements. Projections of future MDHD ZEV deployments in the region are estimated based on EMFAC model vehicle inventory, the current California Air Resources Board (CARB) Scoping Plan, and relevant ZEV mandates. The numbers of projected MDHD ZEVs operating in the analysis region are approximately 2,900 in the year 2025, approximately 56,000 in 2030, and approximately 129,000 in 2040. The estimated electric energy and hydrogen fuel requirements are approximately 165 MWh and 5,000 kg, respectively for the year 2025, and 8,000 MWh and 165,000 kg for 2040. The number of future MDHD electric charging stations and hydrogen fueling stations are estimated based on the amount of total fuel and electric energy needed and daily dispensing capacity limits per station. The approximate combined numbers of stations required are on the order of up to 45 stations by year 2025, on the order of 150 by 2030, and on the order of 400 by 2040. The required station numbers will vary significantly depending on a number of parameters, including MDHD ZEV deployment timelines, number of private versus shared facilities, and individual station capacities and specifications. This report also provides a map of the South Coast region, with a relative preference rating of areas for the placement of future MDHD hydrogen fueling and electric charging stations. The candidate area analysis considers existing transportation infrastructure, current MDHD vehicle driving patterns and truck stops, electric grid infrastructure, projected MDHD ZEV fuel/energy requirements, and zoning information. In addition, the report evaluates the anticipated benefits associated with MDHD ZEV deployment in the region, including reductions of GHG, criteria pollutant, and air toxics emissions, qualitative health impacts, and jobs created by investments.

Keywords: MDHD ZEVs, ZEV infrastructure, BEV, FCEV, Blueprint

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TABLE OF CONTENTS

Acknowledgements	i
Preface.....	ii
Abstract	iii
Table of Contents.....	v
List of Figures.....	vii
List of Tables	viii
Executive Summary.....	1
CHAPTER 1: Introduction	5
Project Overview	5
Analysis Methodology	6
CHAPTER 2: MDHD Vehicle and Fleet Analysis	8
Present MDHD ZEV Population	8
MDHD ZEV Population Projections	9
MDHD Vehicle Transportation Model.....	10
CHAPTER 3: Electricity and Fuel Resource Analysis	12
Electricity Resources.....	12
Electric Utilities.....	12
Electric Grid Infrastructure	13
Hydrogen Fuel Resources	15
Current Hydrogen Production Capacity.....	15
Renewable Hydrogen Generation Potential.....	16
CHAPTER 4: Infrastructure Design Basis.....	18
MDHD ZEV Hydrogen Fueling and BEV Charging Standards	18
BEV Charging Standards	18
Hydrogen Fueling Standards	18
Existing MDHD BEV Charging and Hydrogen Fueling Stations.....	18
MDHD ZEV Technical Specifications.....	19
Estimated Hydrogen Fuel and Electric Energy Use	21
CHAPTER 5: Benefit Analysis	23
Methodology	23
GHG Emissions Reduction	23
Criteria Air Pollutant Emissions.....	24
Health Benefits to Local and Disadvantaged Communities.....	26
Job Creation	29
CHAPTER 6: Blueprint	30
Design Basis	30
MDHD ZEV Deployment Projections.....	30
MDHD ZEV Technical Specifications.....	31

Fuel and Energy Requirements.....	31
MDHD Vehicle Transportation Model.....	32
Methodology and Analysis Results	33
A forecast of preferred areas in the region, for placement of future MDHD BEV charging stations and hydrogen fueling stations, is developed using transportation and land designation data obtained from the SCAG transportation model, electric grid infrastructure data obtained from CEC, and transportation infrastructure data.	34
Candidate MDHD BEV Charging and Hydrogen Fueling Stations	35
MDHD ZEV Stations Specifications and Proposed Locations	35
MDHD ZEV Stations Costs and Deployment Timelines	36
MDHD ZEV Maintenance and Service Requirements.....	39
CHAPTER 7: Summary and Conclusions.....	41
Project Overview	41
Summary of Results	41
MDHD Vehicle and Fleet Analysis.....	41
Electricity and Fuel Resource Analysis.....	42
Infrastructure Design Basis	43
Benefit Analysis.....	43
Conclusions and Recommendations.....	44
Glossary	46
Acronyms	49
REFERENCES	51
APPENDIX A: VMT Estimates for SCAQMD (2025, 2030, 2040).....	53
APPENDIX B: EMFAC Vehicle Inventory Definitions.....	55

LIST OF FIGURES

	Page
Figure 1: SCAQMD Jurisdiction Map (SCAQMD, 2023).....	6
Figure 2: Analysis Flow Chart.....	7
Figure 3: MDHD Vehicle Traffic Data	11
Figure 4: Electricity Serving Entities within South Coast AQMD Region	12
Figure 5: Electric Grid Transmission Lines and Substations within the SCAQMD Territory	14
Figure 6: Electric Power Plants within the SCAQMD Territory	15
Figure 7: Existing Hydrogen Generation within the SCAQMD Territory	16
Figure 8: Solar Supply Curves for the SCAQMD Territory	17
Figure 9: Projected Number of MDHD BEV Charging and Hydrogen Fueling Stations in the SCAQMD Territory	22
Figure 10: Estimated MDHD Transportation GHG Emissions for the SCAQMD Territory	23
Figure 11: Estimated MDHD Transportation PM _{2.5} Emissions for the SCAQMD Territory	24
Figure 12: Estimated MDHD Transportation PM ₁₀ Emissions for the SCAQMD Territory	24
Figure 13: Estimated MDHD Transportation SO _x Emissions for the SCAQMD Territory	25
Figure 14: Estimated MDHD Transportation CO Emissions for the SCAQMD Territory.....	25
Figure 15: Estimated MDHD Transportation NO _x Emissions for the SCAQMD Territory.....	26
Figure 16: CalEnviroScreen 4 - Score Percentile	27
Figure 17: CalEnviroScreen 4 - Pollution Percentile.....	27
Figure 18: CalEnviroScreen 4 – Diesel PM Percentile	28
Figure 19: CalEnviroScreen 4 – PM _{2.5} Percentile.....	28
Figure 20: CalEnviroScreen 4 – Ozone Percentile	29
Figure 21: SCAG Land Use Designation Data.....	33
Figure 22: Heat Map for Charging/Fueling Station Area Preference	34
Figure 23: Potential Candidate Sites for MDHD ZEV Stations.....	35
Figure 24: MDHD Hydrogen Fueling Station Deployment Timeline.....	38
Figure 25: MDHD BEV Charging Station Deployment Timeline.....	39
Figure 26: MDHD ZEV Population Projections for the SCAQMD Territory	42

LIST OF TABLES

Page

Table 1: MDHD Vehicle Classification.....	6
Table 2: MDHD ZEV Population in the Four Counties in SCAQMD Region by End of 2022 based on DMV Data (CEC, 2023)	8
Table 3: HVIP Voucher requests for the SCAQMD region as of March 1, 2023 (HVIP, 2023).....	8
Table 4: 2020 Power Content Label for Southern California Edison.....	12
Table 5: Existing Hydrogen Generation in Southern California.....	16
Table 6: MDHD FCEV Technical Specifications.....	19
Table 7: MDHD BEV Technical Specifications	20
Table 8: MDHD ZEV Fuel/Energy Consumption Estimates for the SCAQMD Territory.....	21
Table 9: Number of MDHD BEV Charging and Hydrogen Fueling Stations	31
Table 10: MDHD BEV Charging Station Details	36
Table 11: MDHD Hydrogen Fueling Station Details	36
Table 12: MDHD Hydrogen Fueling Station Cost Estimates	37
Table 13: MDHD BEV Charging Station Cost Estimates	38
Table 14: GHG and Criteria Air Pollutant Emissions Estimates (Tonnes/Day) for the SCAQMD Territory	43
Table A1: MDHD ZEV and Total VMT Estimates for SCAQMD (2025, 2030, 2040).....	53
Table B1: EMFAC MDHD Vehicle Group Designation	55

EXECUTIVE SUMMARY

California's mobile source sector is responsible for a large proportion of air emissions that contribute to nonattainment of National Ambient Air Quality Standards (NAAQS) and climate change, with severe impacts on low-income and disadvantaged communities. The medium- and heavy-duty (MDHD) transportation sector continues to be a significant source of harmful emissions and represents an important opportunity to improve local air quality and combat climate change. Transitioning the MDHD transportation sector to Zero Emission Vehicles (ZEVs) is a core element of the state's strategy to achieve climate and air quality goals, including NAAQS attainment in the South Coast region.

There is a significant need to accelerate the deployment of MDHD ZEV infrastructure in order to support the state's planned transition of the MDHD transportation sector to ZEVs. This need is particularly acute in the South Coast Air Quality Management District (SCAQMD) territory, which includes several disadvantaged communities experiencing some of the worst air pollution in the nation and heavy truck traffic that continues to grow with the logistics industry. The objective of this project (grant number ARV-21-027) is to develop a regional strategy to deploy charging and hydrogen fueling infrastructure for MDHD ZEVs within the SCAQMD territory.

The analysis is conducted using a model that projects the MDHD vehicle population mix by class from 2025 through 2040 using a combination of the EMFAC vehicle population database, the 2022 CARB Scoping Plan, the state's MDHD ZEV transition mandates including the Advanced Clean Trucks and Advanced Clean Fleets rules, and other relevant data. The model also calculates the Vehicle Miles Traveled (VMT) and the greenhouse gas (GHG), criteria pollutant, and air toxic emission reductions for the analysis period. The results are then combined with vehicle route and other data from the Southern California Association of Governments (SCAG) Transportation Model to develop traffic flow maps in ArcGIS. The ArcGIS model incorporates parameters such as freeway on/off ramping, existing truck stops, zoning regulations, etc. and is used to identify candidate areas for the proposed charging and hydrogen fueling stations.

The renewable and non-renewable electricity and hydrogen production resources available within the SCAQMD region to support MDHD ZEV infrastructure were evaluated using data from utilities and other resources. Geospatial assessment of the electric grid infrastructure, including transmission, substations, and existing electric power plant generation capacity were plotted using ArcGIS. The potential for renewable electricity generation within the region through solar PV was also estimated.

A design basis for characteristic MDHD ZEV infrastructure facilities was developed using data from existing and proposed facilities and literature data. Daily hydrogen fuel and electric energy requirements associated with projected deployment rates were estimated based on the VMT, vehicle routes, ZEV efficiencies and other parameters. The results are then used to estimate the number of charging and hydrogen fueling stations needed and associated capacities. Preferred candidate areas for ZEV charging/fueling infrastructure location were identified using a combination of ZEV VMT, number of trips, proximity to nearest electric transmission lines and substations, proximity to nearest highways and on/off ramps, existing truck terminal locations, and zoning information.

The numbers of projected MDHD ZEVs operating in the analysis region are approximately 2,900 in the year 2025, approximately 56,000 in 2030, and approximately 129,000 in 2040.

The estimated daily electric energy and hydrogen fuel requirements are approximately 165 MWh and 5,000 kg, respectively for the year 2025, and 8,000 MWh and 165,000 kg for 2040. The number of future MDHD electric charging stations and hydrogen fueling stations are estimated based on the amount of total fuel and electric energy needed and daily dispensing capacity limits per station. The approximate combined number of stations required are on the order of 45 stations by year 2025, on the order of 150 by 2030, and on the order of 400 by 2040. The required station numbers will vary significantly depending on a number of parameters, including MDHD ZEV deployment timelines, number of private versus shared facilities, and individual station capacities and specifications. The anticipated energy needs and deployment activities will be a considerable challenge and will require coordinated planning, public and private resources and accelerated planning and permitting activities.

The anticipated GHG and criteria air pollutant, and air toxics emissions reduction for the SCAQMD region associated with MDHD ZEV deployment and the number of jobs created were estimated for the analysis period. The planned ZEV transition of the MDHD transportation sector will result in significant GHG and criteria pollutant emission reduction benefits for the region, including in disadvantaged communities.

Based on the analysis and feedback from stakeholders, the following activities are recommended to streamline and accelerate the MDHD transportation sector's transition to ZEVs.

- Coordinated regional planning is critical to meet the anticipated demands. Currently, there is no forum for robust, collaborative, regional planning that includes all stakeholder groups. A consortium of representatives from stakeholders including regulators, utilities, fleet owners and operators, OEMs, vendors and station builders/operators, and communities should be created. Such a consortium can enable improved regional planning, information exchange, optimizing planning and deployment activities and outreach and engagement.
- Developing a publicly available database that details MDHD specific infrastructure parameters and protocols and the characteristics valuable to fleet operators and the trucking industry is necessary. The database development can be led by an academic or non-profit organization active in MDHD sector electrification activities but must include data sharing and collaborative analysis of the technology and policy options and practical challenges.
- Streamlined policies to help accelerate the planning and permitting process are needed. This includes the critical area of improved alignment between state government policies and priorities with county, city and other local jurisdictions' priorities and protocols.
- Deployment activities should be supported through RD&D and novel technological and policy approaches including mobile fueling, microgrids, etc. Continuing and expanding on such recent and planned activities help de-risk and optimize technology choices and configurations.

The methodology and data from this project can serve as a basis to identify future MDHD ZEV infrastructure needs and develop deployment strategies within the SCAQMD territory. MDHD ZEV infrastructure deployments will proceed with a combination of private and public activities which utilize existing incentives and subsidies assisting with early cost inequities. The successes of initial deployments will help shape the evolution of future deployments and transitions. Continued coordination between utilities, regulators, hydrogen suppliers, fleet

owner/operators, and other groups is critical to support the increasing demand created by transitioning the MDHD fleet to battery electric and hydrogen fuel cell drivetrains.

CHAPTER 1:

Introduction

Project Overview

California's mobile source sector is responsible for a large portion of air pollutant emissions that contribute to nonattainment, climate change, and impacts on low-income and disadvantaged communities. According to the California Air Resources Board (CARB), mobile source related emissions contributed 90 percent of smog-forming oxides of nitrogen (NO_x), and 50 percent of carbon dioxide (CO₂) equivalent greenhouse gases (GHG) emissions, as well as 90 percent of diesel particulate matter (PM). Diesel particulate matter is responsible for the majority of the cancer burden in disproportionately impacted communities, which are frequently located near high-volume roadways, intermodal sites (such as rail yards and ports), and distribution centers. The medium/heavy-duty (MDHD) transportation sector continues to be a significant source of harmful pollutant emissions and represents an opportunity to further improve local air quality and assist in combating climate change.

California's South Coast Air Quality Management District (SCAQMD) region (i.e., the Inland Empire and much of the greater Los Angeles region), and the San Joaquin Valley are the two regions that will have the most difficulty achieving attainment due to a number of factors, discussed in details in the SCAQMD's Air Quality Management Plan (SCAQMD, 2022). Some of these factors are beyond each region's control and require best efforts from local, state and federal partners. Increased control of NO_x will be required for ozone and particulate matter (PM_{2.5}) attainment. Because mobile sources are responsible for the large majority of the emissions inventory in these two regions, the state's regulation of mobile sources is driven by the emission reduction needs in the South Coast Air Basin and the San Joaquin Valley. Heavy duty (HD) diesel trucks are the largest source of NO_x emissions in the South Coast Air District. Moreover, NO_x emission from these trucks is more than three and a half times that from the 200 highest emitting stationary sources (i.e., refineries, power plants and the rest of the Regional Clean Air Incentive Market (RECLAIM) program). Attainment of federal ozone standards is not feasible without rapidly addressing emissions from these vehicles.

Transitioning the MDHD transportation sector to Zero Emission Vehicles (ZEVs) that use low or zero carbon electricity and hydrogen is critical to achieving state's climate and air quality goals, including attainment of National Ambient Air Quality Standards (NAAQS) for criteria pollutants in the South Coast region. These objectives are being pursued through a number of initiatives, including the Advanced Clean Trucks (ACT) and Advanced Clean Fleets (ACF) programs. A major component of the transition is planning, building, and deploying the charging and hydrogen fueling stations and associated infrastructure for the vehicles. This is a significant challenge due to a number of factors including capacity limitations of the electric grid, demand growth, associated costs, and land use limitations.

This project is aimed at developing a strategy to design, build, and deploy charging and hydrogen fueling infrastructure for MDHD battery electric vehicles (BEVs) and fuel cell electric vehicles (FCEVs) within California's South Coast AQMD territory. A map of the SCAQMD territory, which includes large areas of Los Angeles, Riverside and San Bernardino counties, including the Coachella Valley and all of Orange County, is shown in Figure 1 (SCAQMD, 2023).

Figure 1: SCAQMD Jurisdiction Map (SCAQMD, 2023)



Source: University of California, Riverside

The US Federal Highway Administration (FHWA) defines medium-duty vehicles as those with a gross vehicle weight rating (GVWR) between 10,000 and 26,000 lbs, and heavy-duty vehicles as those with a GVWR above 26,000 lbs, as shown in Table 1. The same class and duty definitions are used in this report.

Table 1: MDHD Vehicle Classification

Vehicle Class	Gross Vehicle Weight Rating	GVWR Category
Class 3	10,001 - 14,000 lbs	Medium Duty
Class 4	14,001 - 16,000 lbs	Medium Duty
Class 5	16,001 - 19,500 lbs	Medium Duty
Class 6	19,501 - 26,000 lbs	Medium Duty
Class 7	26,001 - 33,000 lbs	Heavy Duty
Class 8	> 33,001 lbs	Heavy Duty

Source: US Federal Highway Administration

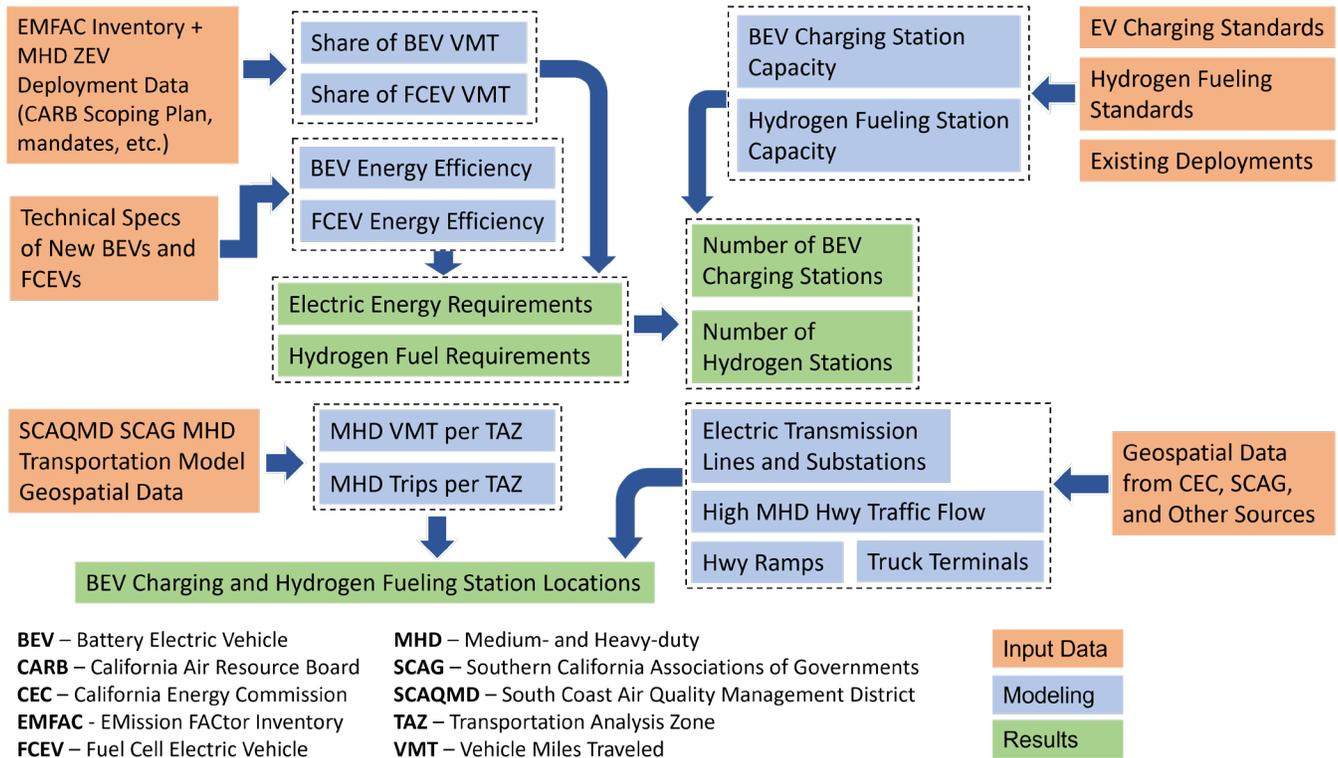
Analysis Methodology

The methodology used by the project team to develop the MDHD ZEV infrastructure blueprint is depicted by the flow chart in Figure 2. The team utilizes prior analysis methodology (Raju et al., 2021), to estimate future daily vehicle miles traveled (VMT) by MDHD ZEVs (BEVs and FCEVs), based on the EMFAC model vehicle inventory, the current California Air Resources Board (CARB) Scoping Plan, and relevant ZEV mandates.

The team has identified technical specifications of recently released MDHD BEVs and FCEVs to project fuel/energy efficiency and to estimate the daily total electric energy and hydrogen fuel needs within the SCAQMD region. Furthermore, the team has identified relevant BEV charging and hydrogen fueling standards to estimate the number of necessary BEV charging and hydrogen fueling stations and their associated daily dispensing capacity parameters. To select

desirable candidate areas for charging and hydrogen fueling infrastructure locations, the project team is using MDHD origin-destination and traffic flow geospatial data from the Southern California Association of Governments (SCAG) and electrical infrastructure geospatial data from the California Energy Commission (CEC). Land use designation geospatial data from SCAG are also utilized in refining the selection of desirable areas for future MDHD ZEV charging and fueling infrastructure locations.

Figure 2: Analysis Flow Chart



Source: *University of California, Riverside*

A detailed account of current MDHD ZEV population and projections of future ZEV deployments for the region are presented in Chapter 2. The SCAG MDHD truck transportation model and its use in this report are discussed in Chapter 2. The existing electric energy, hydrogen resources and infrastructure, and potential for renewable hydrogen generation are discussed in Chapter 3. The design basis used by the project and analysis of electric energy and hydrogen fuel requirements are discussed in Chapter 4. The benefits of MDHD ZEV deployment in the region, including GHG and criteria pollutant emissions reductions, and anticipated health and jobs benefits are discussed in Chapter 5. The blueprint developed by this project, along with specifications for candidate BEV charging and FCEV fueling stations is discussed in Chapter 6. Project summary, conclusions, and recommendations are included in Chapter 7.

CHAPTER 2: MDHD Vehicle and Fleet Analysis

Present MDHD ZEV Population

The number of deployed MDHD ZEVs within the four counties (Los Angeles, Orange, Riverside, San Bernardino) included in SCAQMD territory, as of the end of 2022, is compiled by the California Energy Commission (CEC) based on the Department of Motor Vehicles (DMV) registration of MDHD vehicles. A summary is shown in Table 2 (CEC, 2023).

Table 2: MDHD ZEV Population in the Four Counties in SCAQMD Region by End of 2022 based on DMV Data (CEC, 2023)

Class	Drive Type	Vehicle Type	Number of Vehicles
4	Electric	Bus	37
4	Electric	Truck	10
6	Electric	Bus	28
6	Electric	Delivery Van	26
6	Hydrogen	Bus	28
6, 7, 8	Electric	Bus	5
6, 7, 8	Electric	Truck	15
7	Electric	Bus	89
7	Electric	Truck	15
8	Electric	Bus	346
8	Electric	Truck	78
8	Hydrogen	Bus	39

Source: *University of California, Riverside*

Another source of MDHD ZEV population estimates is the California Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP). The HVIP data set includes a list of voucher requests for eligible MDHD ZEV purchases in California. Table 3 lists the number of voucher requests for SCAQMD region as of March 1, 2023 (HVIP, 2023). The differences in number of vehicles in Tables 2 and 3 indicate that only a portion of the issued vouchers have been redeemed.

Table 3: HVIP Voucher requests for the SCAQMD region as of March 1, 2023 (HVIP, 2023)

Drive Type	Vehicle Type by Vocational Use	Number of Vouchers
ePTO	Utility Truck	125
BEV	NA	112
BEV	Bus - Heavy Duty/Transit	509
BEV	Bus - Medium Duty	217
BEV	Bus - School	364
BEV	Panel/ Step/ Cargo Van	558
BEV	Refuse	24
BEV	Truck - Box	386

BEV	Truck - Straight	1
BEV	Truck - Tractor	1151
BEV	Utility Truck	10
FCEV	NA	1
FCEV	Bus - Heavy Duty/Transit	55
FCEV	Truck - Tractor	87

Source: *University of California, Riverside*

MDHD ZEV Population Projections

Estimates of daily VMTs of MDHD BEVs and FCEVs within the SCAQMD area have been calculated for the years 2025, 2030, and 2040 using analysis methodology reported earlier and updated data (Raju et al., 2021). The estimates are summarized in Table A1 in Appendix A. Definitions for the vehicle categories are provided in Table B1 in Appendix B. The vehicle population projections are estimated using the base vehicle inventory from the EMFAC model, which is updated using a combination of current and proposed state regulations, data from publicly available literature, and feedback from stakeholders. The vehicle populations are based on the MDHD population projections in the Reference Scenario of the CARB Scoping Plan (CARB, 2022). The CARB vehicle population projections are further updated to account for rules and regulations adopted since then. The projections include the anticipated impacts of SB 350, California’s Clean Energy and Pollution Reduction Act that established clean energy goals including statewide GHG reduction 40 percent below 1990 levels by 2030 and to 80 percent below 1990 levels by 2050. The fleet composition also takes into account the expanded HD ZEV Beyond Cleaner Technologies and Fuels Scenario in the 2016 ARB Mobile Source Strategy (CARB, 2016).

The following major updates were made to the Scoping Plan Scenario reflecting ARB rules passed since the last Scoping Plan update.

- Innovative Clean Transit (ICT)
 - All California based transit bus populations except for school buses, are targeted to achieve zero emissions by 2040.
 - School buses are assumed to have specific deployment trends independent of the ICT.
- Zero-Emission Airport Shuttle (ZEAS)
 - All Airport shuttles, part of the other bus (OBUS) category, are targeted to achieve zero emissions by 2035.
- Advanced Clean Trucks (ACT)
 - More aggressive ZE deployment of class 7-8 tractors has been adopted.
 - Targets of 15 percent sales of ZEVs by 2030 for T7 and 50 percent sales of ZEV by 2030 for T6 have been adopted.
- Advanced Clean Fleets (ACF)
 - Increase of MDHD ZEV deployment due to ACF mandate is based on CARB projections (CARB, 2022a).
- Population deployment trends beyond 2030 were created using a combination of the 2019-2030 trends in the Scoping Plan, literature data, stakeholder input, potential

funds availability for vehicle replacement, and projections based on existing documented trends.

- CARB analysis does not always specify the split between BEVs and FCEVs in the ZEV deployment projections. Literature assumptions use a wide range for FCEVs but always indicate that fewer FCEVs are deployed compared to BEVs. Where references do not provide specific details, it is assumed that the MDHD ZEVs are comprised of 80 percent BEVs and 20 percent FCEVs unless specified otherwise.

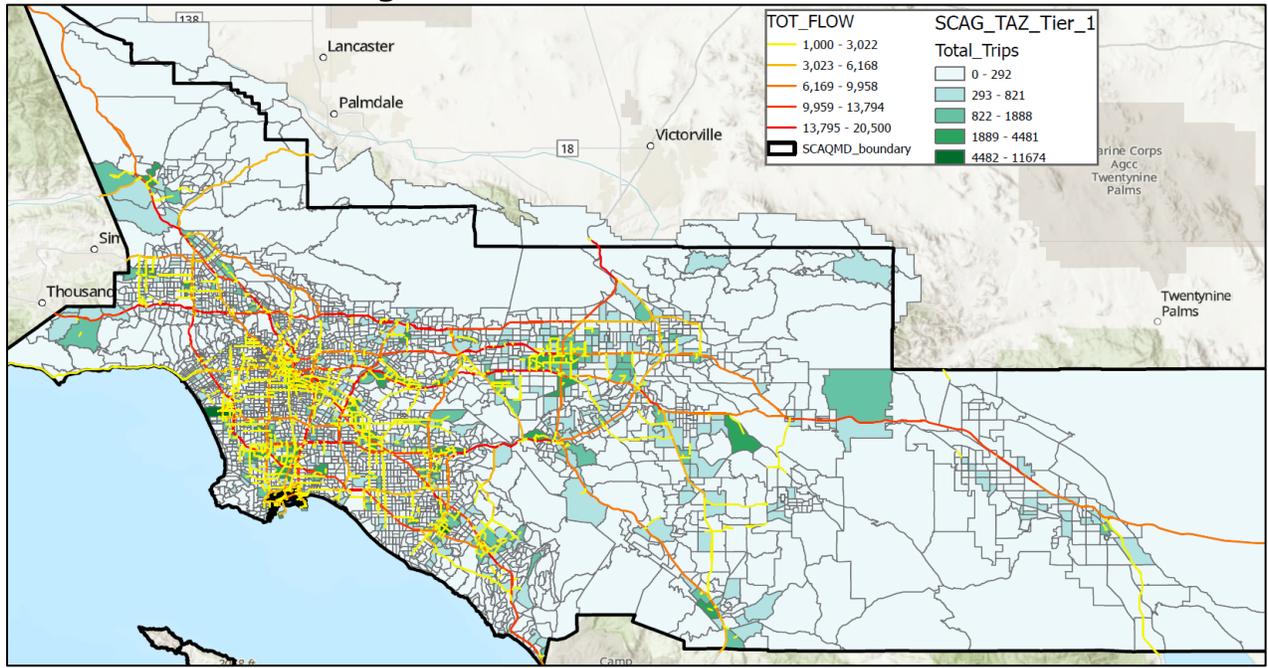
MDHD Vehicle Transportation Model

The analysis of this report utilizes the Southern California Association of Governments Regional Travel Demand model for MDHD vehicle activity (SCAG, 2023a). The SCAG model estimates number of daily trips originating from any transportation analysis zone (TAZ) to all other TAZs. There are 3,558 zones within the SCAQMD region. Figure 3 shows a map with SCAG TAZs in the SCAQMD area, differentiated by shades of green to represent the number of origin-destination trips for each zone. There are several zones, not shown on the map, which are used to indicate trip origins or destinations located outside the SCAG region.

In addition to the number of trips per TAZ, the SCAG model provides daily truck traffic flow on individual segments (links) of the road network system. Link volumes are shown on the map in Figure 3, in colors ranging from yellow to dark red. Daily VMTs for each TAZ are calculated as the product of traffic flow values and road segment lengths.

The study assumes that future ZEVs (BEVs and FCEVs) will be distributed proportionally to existing MDHD vehicle population across the SCAQMD region. Accordingly, the same proportional factor is applied to each TAZ when estimating VMTs and origin-destination trips based on SCAG data. In other words, specific TAZs are not given preference in terms of ZEV deployment. The calculated VMTs and trip values for both BEVs and FCEVs in each TAZ serve to estimate fuel/energy demand, which in turn informs the assignment of ZEV infrastructure preference scores for each zone.

Figure 3: MDHD Vehicle Traffic Data



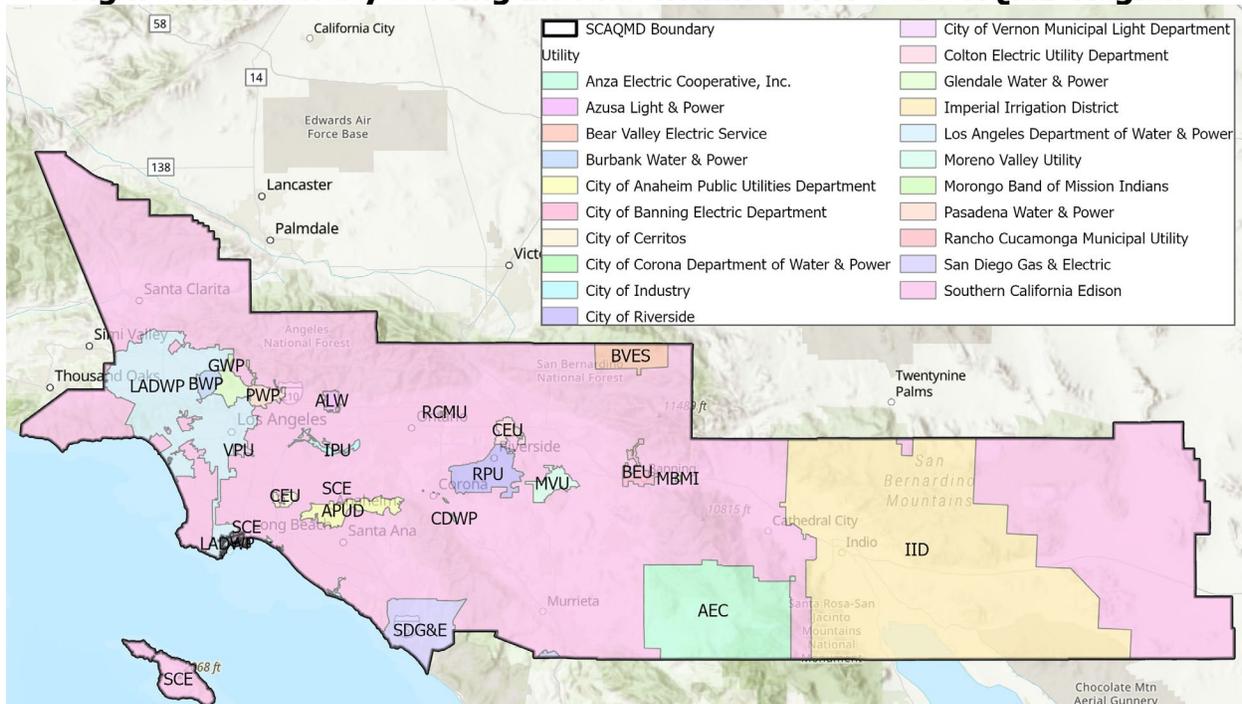
Source: *University of California, Riverside*

CHAPTER 3: Electricity and Fuel Resource Analysis

Electricity Resources Electric Utilities

Electricity service in the South Coast AQMD region is managed by a number of entities, identified in Figure 4 (CEC, 2022). Of those entities, Southern California Edison (SCE) and San Diego Gas and Electric (SDG&E) are investor-owned utilities (IOUs). The remaining entities are predominantly publicly owned utilities (POUs), with the exceptions of Anza Electric Cooperative and the Morongo Band of Mission Indians. Of the POUs, the largest ones are Los Angeles Department of Water and Power (LADWP) and Imperial Irrigation District (IID). As evident from the map in Figure 4, a majority of the region and the overall electric load are served by SCE, LADWP, and IID.

Figure 4: Electricity Serving Entities within South Coast AQMD Region



Source: University of California, Riverside

Table 4 lists the energy resources used in SCE’s electricity mix, according to its Power Content Label for 2020 (CEC, 2021), with 42 percent of the electricity mix originating from unspecified resources due to purchases through open market transactions not traceable to a specific generation source. On the other hand, nearly 43 percent of the electricity mix originates from renewables, of which 30.9 percent are eligible renewables.

Table 4: 2020 Power Content Label for Southern California Edison

Energy Resources	SCE Power Mix	Green 50 percent Option	Green 100 percent Option	2020 CA Power Mix

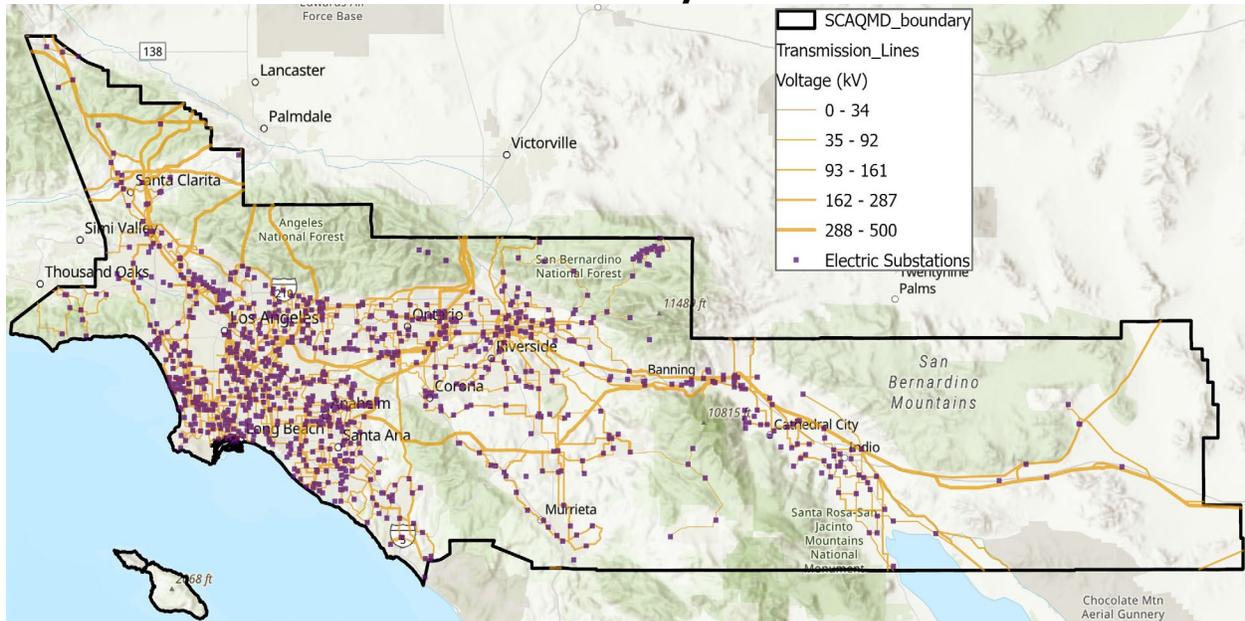
Eligible Renewable	30.9 percent	65.4 percent	100.0 percent	33.1 percent
Biomass & Biowaste	0.1 percent	0.1 percent	0.0 percent	2.5 percent
Geothermal	5.5 percent	2.8 percent	0.0 percent	4.9 percent
Eligible Hydroelectric	0.8 percent	0.4 percent	0.0 percent	1.4 percent
Solar	15.1 percent	57.6 percent	100.0 percent	13.2 percent
Wind	9.4 percent	4.7 percent	0.0 percent	11.1 percent
Coal	0.0 percent	0.0 percent	0.0 percent	2.7 percent
Large Hydroelectric	3.3 percent	1.6 percent	0.0 percent	12.2 percent
Natural Gas	15.2 percent	7.6 percent	0.0 percent	37.1 percent
Nuclear	8.4 percent	4.2 percent	0.0 percent	9.3 percent
Other	0.3 percent	0.2 percent	0.0 percent	0.2 percent
Unspecified Sources of Power	42.0 percent	21.0 percent	0.0 percent	5.4 percent
Total	100 percent	100.0 percent	100.0 percent	100.0 percent

Source: Southern California Edison

Electric Grid Infrastructure

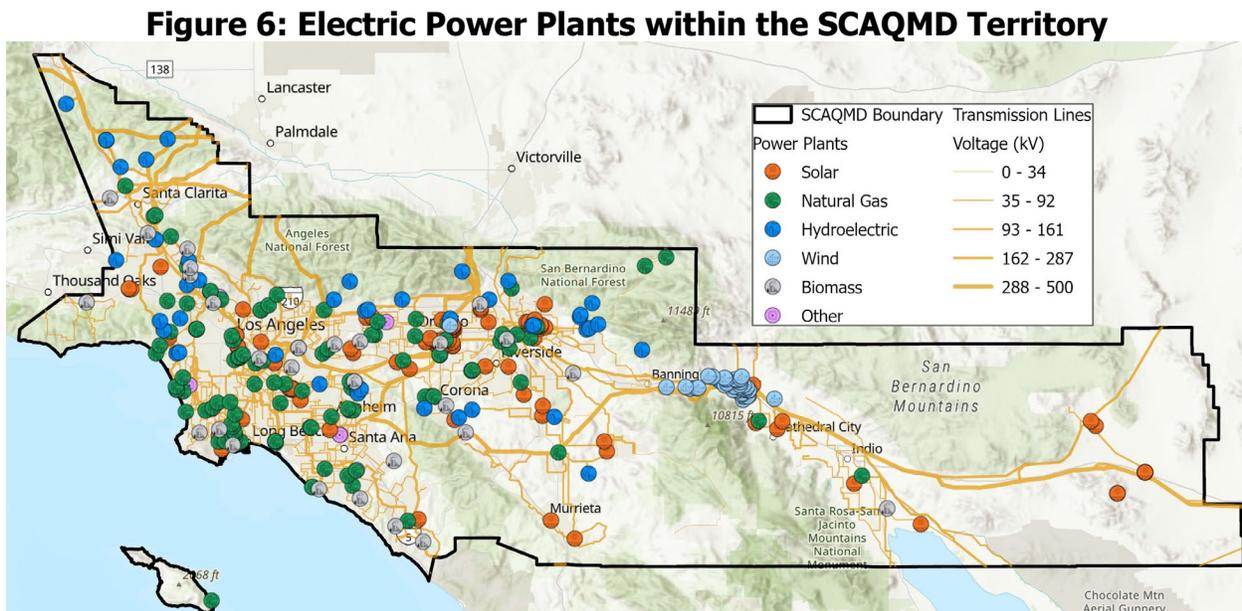
Figure 5 presents a high-level overview of the electric grid system in the SCAQMD region (CEC, 2022). It consists of the transmission lines providing electric power at various voltage potentials to the many electric substations in region, which in turn provide power at lower voltage potential on the distribution circuit networks (not shown in Figure 5).

Figure 5: Electric Grid Transmission Lines and Substations within the SCAQMD Territory



Source: *University of California, Riverside*

Figure 6 shows a map with the locations of electric power generation plants within the SCAQMD region, categorized by the type of energy source used to produce electricity (CEC, 2022).



Source: *University of California, Riverside*

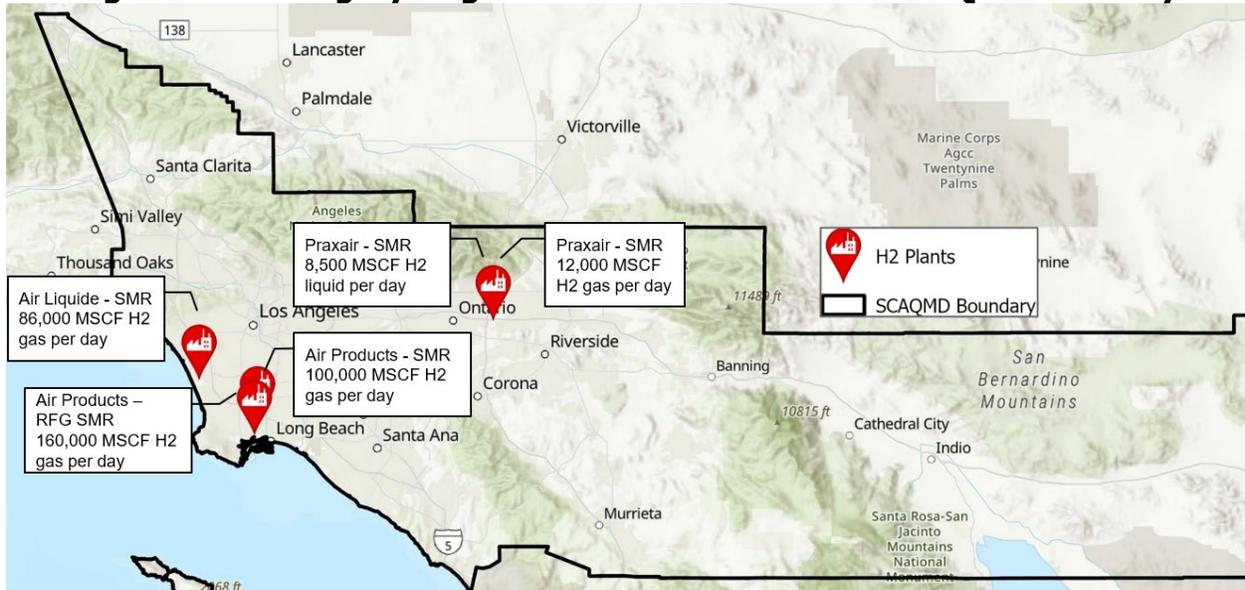
The two IOUs in the region (SCE and SDG&E) provide interactive data maps of their respective distribution circuit systems, which are updated frequently with information including new electric load integration capacity and solar PV generation integration capacity. These data are of particular interest to this project, as they could identify suitable areas for installations of MDHD BEV charging stations or electrolytic hydrogen production facilities, without the need for costly distribution system assessments and upgrades including new distribution lines, transformers, etc. Furthermore, the data can identify suitable areas with available capacity for interconnection of large solar PV generating facilities, whose renewable power output can be used to power neighboring BEV charging stations or hydrogen production facilities.

Hydrogen Fuel Resources

Current Hydrogen Production Capacity

The existing hydrogen production in Southern California is limited to a few producers and locations, as shown on the map in Figure 7 (H2Tools, 2016). Major producers are Air Products and Air Liquide, located in the cities of Carson, Wilmington and El Segundo. They produce gaseous hydrogen through methane steam reforming (MSR) of fossil natural gas, to meet demands of oil refining and other industries. Table 5 shows daily production capacities in 2016 (H2Tools, 2016). There are only two hydrogen pipelines in the region, both relatively short: a 2-mile-long pipeline located in the city of Ontario and operated by Praxair and a 12-mile pipeline which crosses the borders of the cities of Carson, Los Angeles, and Long Beach, operated by Air Products.

Figure 7: Existing Hydrogen Generation within the SCAQMD Territory



Source: University of California, Riverside

Table 5: Existing Hydrogen Generation in Southern California

Producer	City	H2 Process	Product	Industry	Capacity (MSCF/day)	Capacity (kg/day)
Praxair	Ontario	SMR	H2 Liquid	Multiple	8,500	20,483
Praxair	Ontario	SMR	H2 Gas	Multiple	12,000	28,917
Air Liquide	El Segundo	SMR	H2 Gas	Oil Refining	86,000	207,240
Air Products	Wilmington	SMR	H2 Gas	Oil Refining	160,000	385,562
Air Products	Carson	SMR	H2 Gas	Oil Refining	100,000	240,976

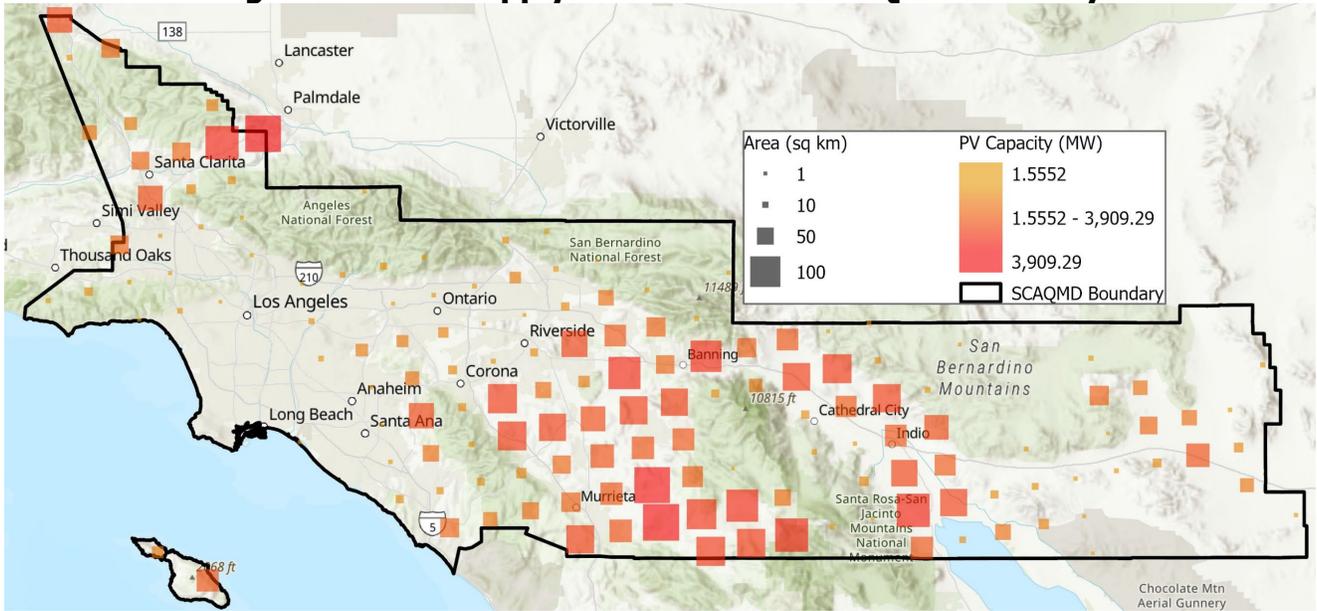
Source: University of California, Riverside

Renewable Hydrogen Generation Potential

With the limited overall production of hydrogen in the region, which is already utilized by various industries, it is evident that significant new hydrogen production capacity would be required to support the medium and heavy-duty ZEV infrastructure. Furthermore, the necessary additional hydrogen production facilities would need to utilize renewable energy sources in order to meet state goals of carbon neutrality. With that in mind, the two best candidates are electrolytic hydrogen production using solar or wind energy, and hydrogen produced using biomass or biogas.

Figure 8 shows an analysis, obtained from NREL (NREL, 2022), on potential renewable energy production from solar for the SCAQMD region, based on various factors including land availability, capacity factor, and proximity to transmission system.

Figure 8: Solar Supply Curves for the SCAQMD Territory



Source: *University of California, Riverside*

CHAPTER 4:

Infrastructure Design Basis

MDHD ZEV Hydrogen Fueling and BEV Charging Standards

BEV Charging Standards

With respect to BEV charging there are existing Society of Automotive Engineers (SAE) standards that are continually updated and several new evolving standards. For medium-duty (MD) BEVs, advanced versions of the SAE J3068 standard can offer 3 phase 480V AC at 120A, with a maximum power output of 100kW. For MD and HD vehicles SAE J1772-CCS-2 offers 1,000V DC at up to 500A for a maximum DC charge rate of 500kW. The SAE J3105 enables overhead DC charging at up to 600kW rate for port/drays trucks. The presently developed SAE J3271 MCS can provide 1,000V DC at 1,000A for a charge rate of 1MW. Future amendments of the standard are expected to facilitate 1,250V at 3,000A (3.75MW) charging for HD BEVs with higher voltage battery pack vehicles.

Currently being standardized as SAE J3400, the North American Charging Standard (NACS), also referred to as the Tesla charging standard, can provide a charging rate of 250kW with 500V DC at 500A, or 500kW with 1,000V DC at 500A.

Hydrogen Fueling Standards

The standards relevant to hydrogen fueling of FCEVs are SAE J2600 (pertaining to fueling coupling), SAE J2601 (hydrogen fueling of LDVs at 350 and 700 bar), SAE J2601-2 (hydrogen fueling of HDVs at 350 bar) and SAE J2601-3 (hydrogen fueling of industrial vehicles). The SAE J2719 standard pertains to hydrogen gas quality, while SAE J2799 relates to FCEV to station communication. Under the SAE J2601-2 normal fueling option, current fueling rates for FCEVs with tank capacities ranging from 2 to over 10 kg can achieve 3.6 kg/min at a pressure of 350 bar. Future SAE J2601-2 fast fueling option of the standard aims at increasing this rate to 7.2 kg/min. On the other hand, fueling rates of 3.6 kg/min at 700 bar pressure can be achieved under SAE J2601 for FCEVs with tank capacities from 2 to 30+ kg. Future revisions of the standard aim to increase the fueling rate to 8 kg/min, and eventually to a rate of 10 kg/min.

Existing MDHD BEV Charging and Hydrogen Fueling Stations

One of the largest public BEV charging stations for commercial HD BEVs was deployed in 2023 at the Port of Long Beach. The station, constructed by WattEV, features 13 dual-cord CCS 360kW ports, capable of charging 26 trucks concurrently at 180kW per truck, comprising a total power demand of nearly 5MW (WattEV, 2023).

The majority of MDHD BEV truck owners/operators own and use behind-the-gate BEV charging. Some examples include Dependable Supply Chain Services, TEC Equipment, NFI Industries, etc. The Orange County Transportation Authority (OCTA) has deployed one of the largest HD hydrogen fueling stations in the country, featuring 18,000-gal (4,536 kg) liquid hydrogen storage capacity to fuel their newly acquired New Flyer FCEV buses at 350 bar pressure (OCTA, 2023). The station is capable of refueling 40 to 50 buses per day, with 37.5 kg of hydrogen per bus. SunLine Transit Agency also owns and operates a behind-the-gate hydrogen fueling station located in Thousand Palms. There are three HD truck hydrogen

fueling stations within the SCAQMD region, owned and operated by Shell, located in Ontario, Wilmington, and the Port of Long Beach.

MDHD ZEV Technical Specifications

The team has identified vehicle technical specifications for MDHD ZEVs that have either been announced or released on the market. The list of vehicles selected is not exhaustive but includes samples of each vehicle type and class to be used for this analysis. The data was obtained from the Zero-Emission Technology Inventory (ZETI) (DriveToZero, 2023). Table 6 lists technical parameters for hydrogen FCEVs, including type, make, model, class, tank capacity, power, range, and fueling time where available. Notably, at present, only class 8 FCEV vehicles have been released or announced. Fuel efficiency of various class 8 HD FCEVs is between 5 to 9 mi/kg, with the exception of refuse trucks, where significant energy is used for pick-up and dumping.

Table 7 lists technical specifications for selected MDHD BEVs, including vehicle type, maker, model, class, energy storage capacity, range, power, and charging capacity. Electric energy efficiency for most HD vehicles (class 7 and 8) falls between 0.3 to 0.7 mi/kWh range, while MD vehicle energy consumption is between 0.7 to 1.4 mi/kWh.

Table 6: MDHD FCEV Technical Specifications

Vehicle Type	Maker	Model	Class	H2 Storage Capacity (kg)	Peak Power (kW)	Range (miles)	Refueling time (min)
HD Bus	ENC	AXESS 40' FC	8	50	NA	260	NA
HD Bus	New Flyer	Xcelsior 40'	8	37.5	160	350	6-10 min
HD Bus	New Flyer	Xcelsior 60'	8	60	320	350	12-20 min
HD Truck	Toyota	Beta	8	40	500	300	NA
HD Truck	Nikola	Tre	8	70	575	500	20 min
HD Truck	Hyzon	HYHD8-200	8	50	450	350	15 min
Refuse	Hyzon	Refuse	8	NA	360	125	NA

Source: *University of California, Riverside*

Table 7: MDHD BEV Technical Specifications

Vehicle Type	Maker	Model	Class	Storage Capacity (kWh)	Range (miles)	Peak Power (kW)	Charging capacity (kW)
MD Bus	Micro Bird	D Series 24'	4	88	100	NA	50
MD Bus	Optimal EV	VMC Optimal S1	4	113	125	280	60
MD Bus	Lightning Motors	F-550	5	128	100	180	80
MD Truck	Kenworth	K270E	6	282	200	282	NA
MD Truck	SEA	Ford F-650	6	138	200		NA
MD Bus	Lion Electric	LionM 26'	6	160	150	160	80
MD Bus	Motiv	EPIC-F53 29'	6	127	105	230	60
HD Truck	Kenworth	K370E	7	282	200	282	NA
HD Truck	SEA	Ford F-750	7	138	170	NA	NA
HD Bus	BYD	K7M 30'	7	215	158	180	150
HD School Bus	Thomas	C2 Jouley	7	226	138	217	90
HD Truck	Nikola	Tre	8	733	330	797	350
HD Truck	BYD	8TT	8	422	167	350	NA
HD Truck	Kenworth	T680E	8	396	150	493	150
HD Truck	Peterbilt	570EV	8	400	150	493	150
HD Truck	Tesla	Semi	8	1,000	500	NA	1,000
HD Truck	Volvo	VNR Electric	8	565	275	NA	250
HD Truck	Lion	Lion8	8	252	170	350	NA
HD Truck	Lion	Lion8T	8	653	260	500	NA
HD Bus	New Flyer	Xcelsior 40'	8	525	251	160	150
HD Bus	New Flyer	Xcelsior 60'	8	525	153	320	150
HD Bus	BYD	K8M 35'	8	391	196	300	150
HD Bus	BYD	K11M 60'	8	578	193	360	200
HD Bus	Green Power	EV350 40'	8	400	212	350	150
HD Bus	Motor Coach	J450	8	544	240	260	150
HD Bus	Proterra	ZX5 Max 40'	8	675	297	239	340
Refuse	BYD	8R	8	295	56	316	240

Refuse	Lion Electric	8P ASL	8	336	170	350	NA
Refuse	Peterbilt	520	8	396	80	400	NA
HD School Bus	Navistar	CE Series	8	315	200	225	150

Source: University of California, Riverside

Estimated Hydrogen Fuel and Electric Energy Use

Table 8 presents estimated daily requirements for hydrogen fuel and electric energy for medium-duty and heavy-duty zero-emission vehicles (MDHD ZEVs) within the SCAQMD area, projected for the years 2025, 2030, and 2040. The VMT values, obtained from Table 4, are grouped by duty type (MD and HD). An average energy efficiency of 0.95 and 0.45 mi/kWh is used for MD and HD BEVs, respectively, for 2025. These efficiency values are increased by 10 percent for 2030 and again increased by 10 percent for 2040, assuming technology development and efficiency improvements. The analysis assumes 8 percent electric energy losses during BEV charging. For 2025, an average energy efficiency of 7 mi/kg hydrogen is used for HD FCEVs. The average fuel efficiency for MD FCEVs is estimated at 10 mi/kg, as no actual MD FCEVs specifications are currently available. The hydrogen fuel efficiency values were increased by 10 percent for 2030 and by 10 percent for 2040.

Table 8: MDHD ZEV Fuel/Energy Consumption Estimates for the SCAQMD Territory

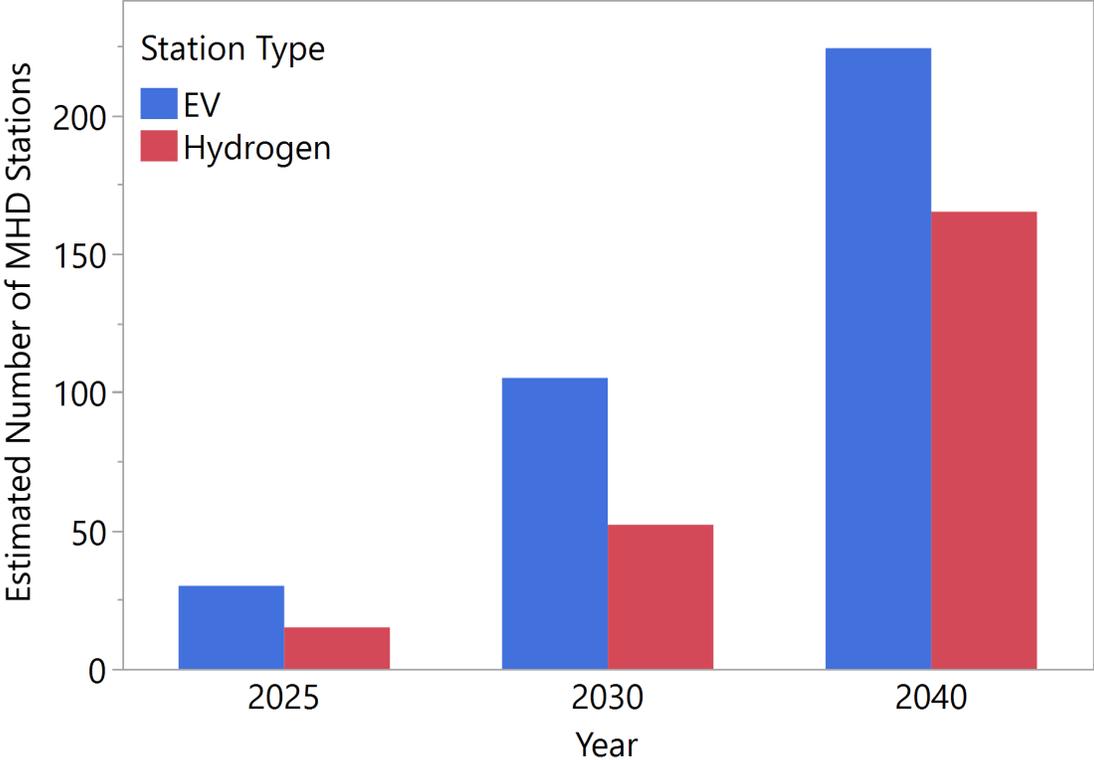
Year	ZEV Type	Duty Type	VMT	Vehicle Population	Fuel/Energy	Unit
2025	BEV	MD	116,053	1,961	131,934	kWh
2025	BEV	HD	13,601	111	32,643	kWh
2025	FCEV	MD	48,142	813	4,814	kg
2025	FCEV	HD	3,589	28	513	kg
2030	BEV	MD	1,863,873	39,948	1,926,300	kWh
2030	BEV	HD	842,267	6,654	1,837,674	kWh
2030	FCEV	MD	406,888	8,250	36,990	kg
2030	FCEV	HD	112,303	888	14,585	kg
2040	BEV	MD	4,412,636	88,637	4,145,843	kWh
2040	BEV	HD	1,973,570	14,272	3,914,518	kWh
2040	FCEV	MD	1,057,986	20,997	87,437	kg
2040	FCEV	HD	657,857	4,757	77,669	kg

Source: University of California, Riverside

Figure 9 shows the estimates of the required number of BEV charging and hydrogen fueling stations, serving MDHD ZEVs within the SCAQMD region in 2025, 2030, and 2040. The estimates are based on hydrogen fuel and electric energy requirements in Table 8, assuming hydrogen station capacity of 2,000 kg/day, BEV station capacity of 3MW (72,000 kWh/day), and average capacity utilization of 50 percent. The project team has updated the baseline energy use based estimates for 2025 using existing and planned deployment efforts and stakeholder input. Significant deployment of public stations is likely needed initially to support early adopters of MDHD ZEVs, resulting in higher station to vehicle ratios. In addition to the public ZEV infrastructure detailed in Figure 9 many private (behind-the-gate) ZEV infrastructure deployments will likely support large private fleets.

As evident from Table A1, in the year 2025 large portion of MDHD ZEVs consists of transit buses, in accordance with the Innovative Clean Transit rule. As many of these ZEV transit buses will operate within cities located all over the SCAQMD region, we assume most transit agencies will require behind-the-gate hydrogen fueling or charging for their ZEV fleets.

Figure 9: Projected Number of MDHD BEV Charging and Hydrogen Fueling Stations in the SCAQMD Territory



Source: University of California, Riverside

CHAPTER 5:

Benefit Analysis

Methodology

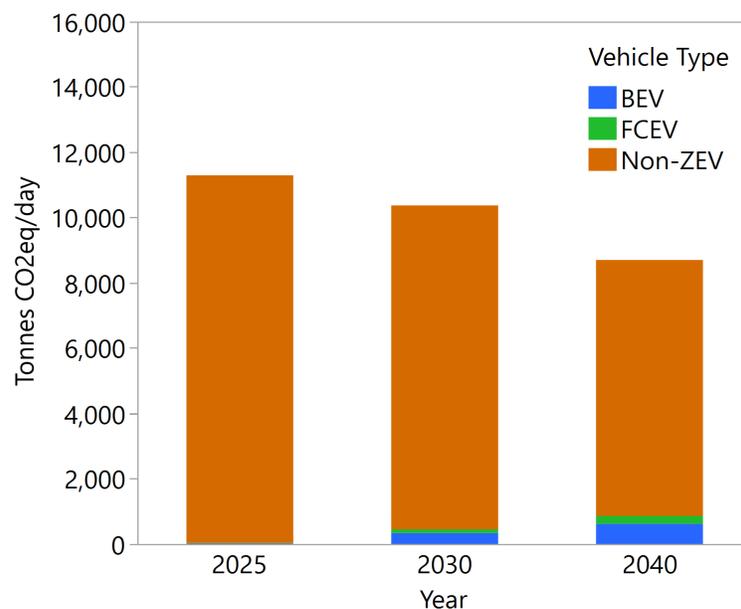
The estimated reduction of greenhouse gas and criteria air pollutant emissions is based on estimated MDHD ZEV VMTs deployed within the SCAQMD in the years 2025, 2030, and 2040, listed in Table 8. The GHG emission reductions were calculated by conducting a Life Cycle Assessment (LCA) using the CA-GREET 3.0 model. The tailpipe criteria pollutant and air toxics emissions were calculated using a combination of the EMFAC model and updated real world emission factors estimated and reported by UC Riverside (Raju et al., 2021).

GHG emissions include carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). Combined, they are reported as 100-year global warming potential (GWP) and measured in tonnes of CO_{2eq} (CO₂ equivalent). CO₂ has a 100-year GWP multiplier factor of 1x, CH₄ factor of 28x, and N₂O factor of 273x. Criteria air pollutant emissions include carbon monoxide (CO), nitrogen oxides (NO_x), sulfur oxides (SO_x), particulate matter (PM) with particle diameter of 10 µm or less (PM₁₀), and particulate matter with particle diameter of 2.5 µm or less (PM_{2.5}).

GHG Emissions Reduction

Estimated life cycle GHG emissions from the MDHD transportation sector for the SCAQMD region are shown in Figure 10. The GHG in tonnes of CO_{2eq} per day are estimated for 2025, 2030, and 2040. While the GHG emissions reductions from 2025 to 2030 are fairly small, they reach 23 percent in 2040. To place these numbers in perspective, it is necessary to consider the impact these reductions have on the overall GHG emissions in the state. For example, the 2020 CARB GHG emissions inventory shows that the transportation sector was responsible for 37 percent of total GHG emissions in the state, while HD vehicles contributed to 24 percent of transportation GHG emissions (CARB, 2022b).

Figure 10: Estimated MDHD Transportation GHG Emissions for the SCAQMD Territory



Criteria Air Pollutant Emissions

Figure 11 shows estimated tailpipe emissions of MDHD vehicle PM_{2.5} for 2025, 2030, and 2040, within the SCAQMD region, measured in tonnes per day. Figure 12 shows emission estimates for PM₁₀ for 2025, 2030, and 2040. Since the PM_{2.5} and PM₁₀ emissions reported here originate from vehicle exhaust, the majority can be considered diesel PM. MDHD ZEV deployment is the primary contributor to the reductions of PM emissions from 2025 to 2040.

Figure 11: Estimated MDHD Transportation PM_{2.5} Emissions for the SCAQMD Territory

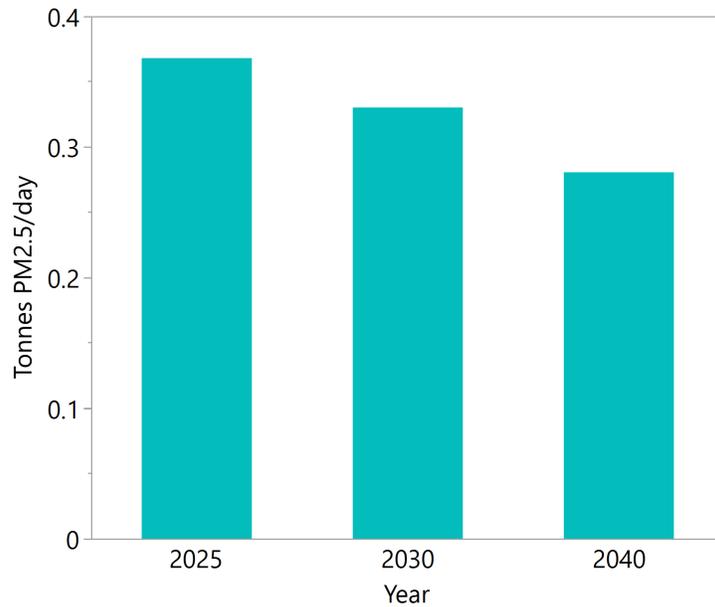
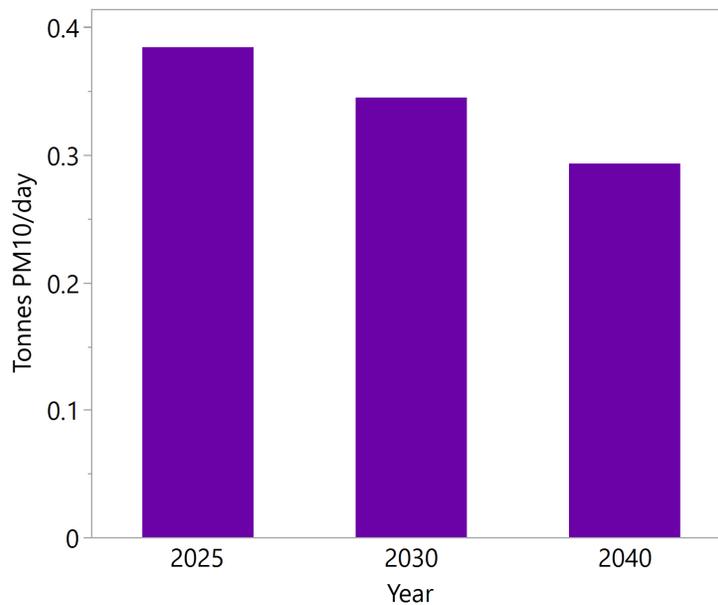


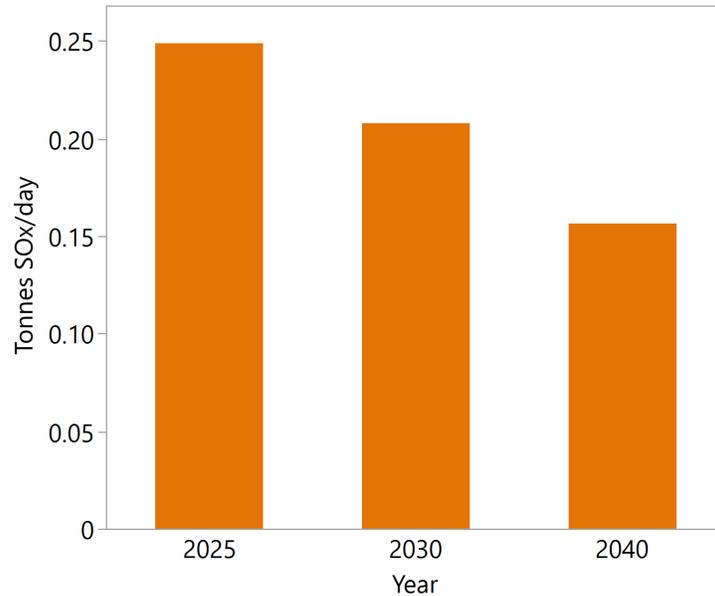
Figure 12: Estimated MDHD Transportation PM₁₀ Emissions for the SCAQMD Territory



Source: University of California, Riverside

Figure 13 shows estimated MDHD vehicle SO_x emissions within the SCAQMD region, for the years 2025, 2030, and 2040, in tonnes per day.

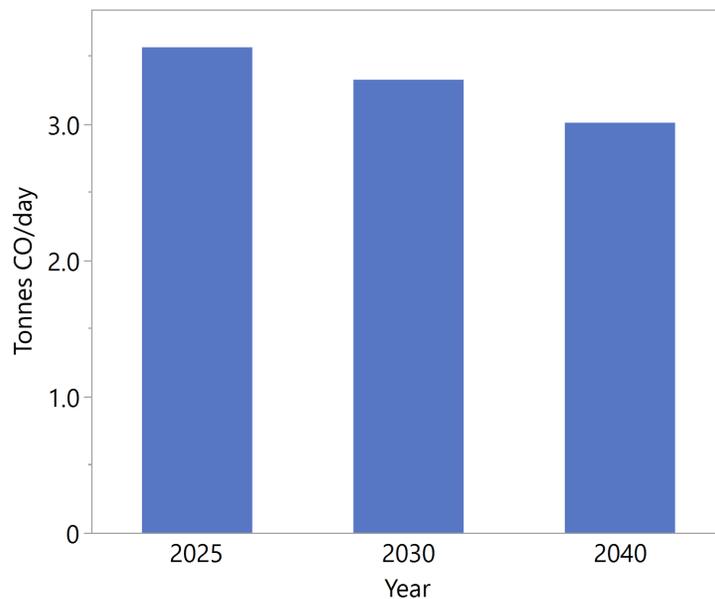
Figure 13: Estimated MDHD Transportation SO_x Emissions for the SCAQMD Territory



Source: University of California, Riverside

The bar chart in Figure 14 shows estimated CO emissions of MDHD vehicles within the SCAQMD region, for the years 2025, 2030, and 2040, in tonnes per day.

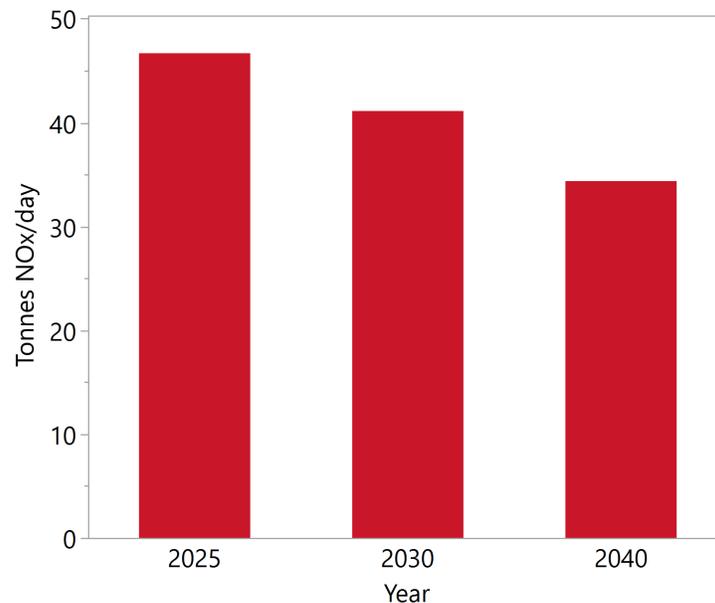
Figure 14: Estimated MDHD Transportation CO Emissions for the SCAQMD Territory



Source: University of California, Riverside

The bar chart in Figure 15 represents estimated MDHD vehicle NO_x emissions within the SCAQMD region in 2025, 2030, and 2040, in tonnes per day.

Figure 15: Estimated MDHD Transportation NO_x Emissions for the SCAQMD Territory



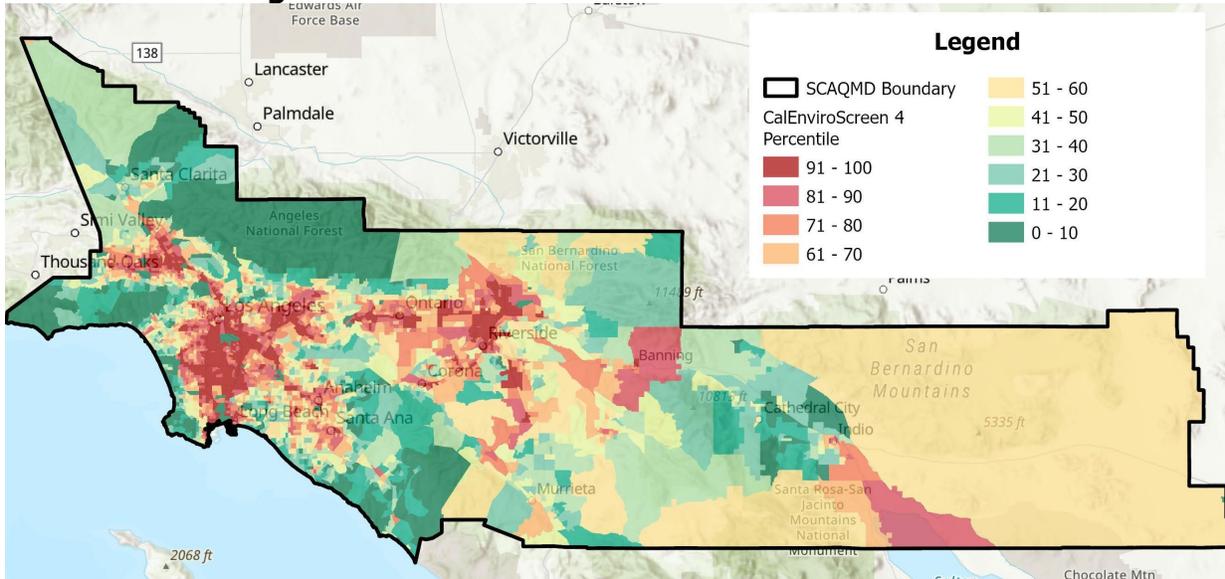
Source: *University of California, Riverside*

Health Benefits to Local and Disadvantaged Communities

According to CARB, mobile source related emissions contributed to 90 percent of smog-forming NO_x and 90 percent of diesel particulate matter. Diesel particulate matter is responsible for the majority of the cancer burden in disproportionately impacted communities, which are frequently located near high-volume roadways, intermodal sites (such as rail yards and ports), and distribution centers.

The CalEnviroScreen tool uses environmental, health, and socioeconomic data to estimate and map impacts of pollution on communities in California, and to identify where people are especially vulnerable to pollution impacts. Communities scoring in the 90th percentile on the CalEnviroScreen 4.0 are considered disadvantaged communities. Figure 16 shows the latest CalEnviroScreen 4.0 state score ranking for tracts within the SCAQMD region. It is evident that many communities within the greater Los Angeles, including the Inland Empire and Orange County, have a score in the top 10 percent for the state. The Figure shows the overall score. However, this report only evaluates the air pollution impacts of MDHD ZEV deployment in the region. The air pollution scores are shown in Figures 17 through 20.

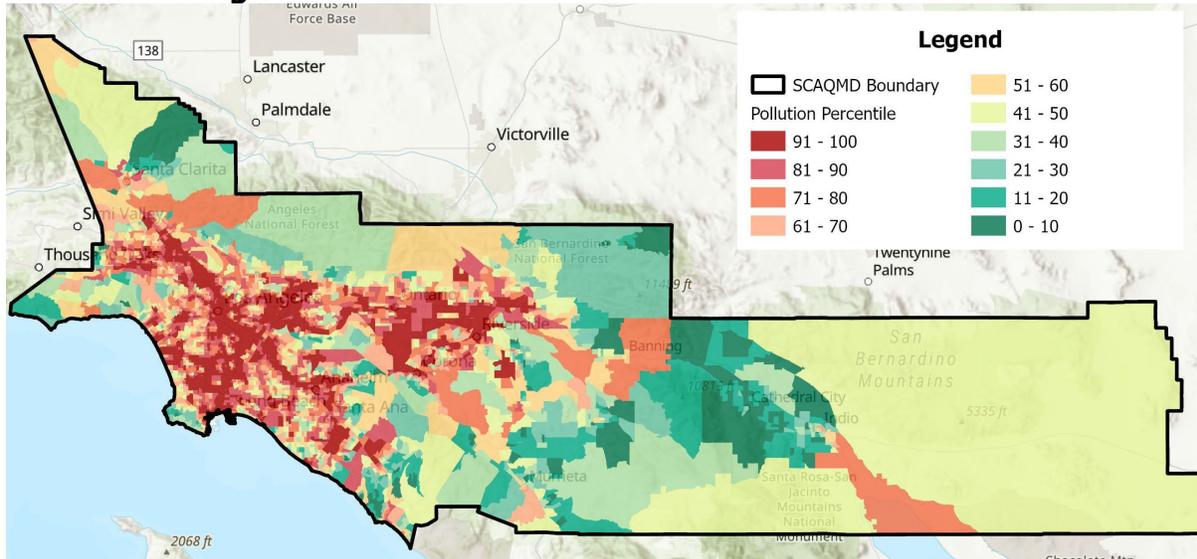
Figure 16: CalEnviroScreen 4 - Score Percentile



Source: University of California, Riverside

Figure 17 maps the CalEnviroScreen 4.0 pollution ranking for the tracts within the SCAQMD region. Significant number of communities within the greater Los Angeles area score in the 90th percentile for pollution in the state.

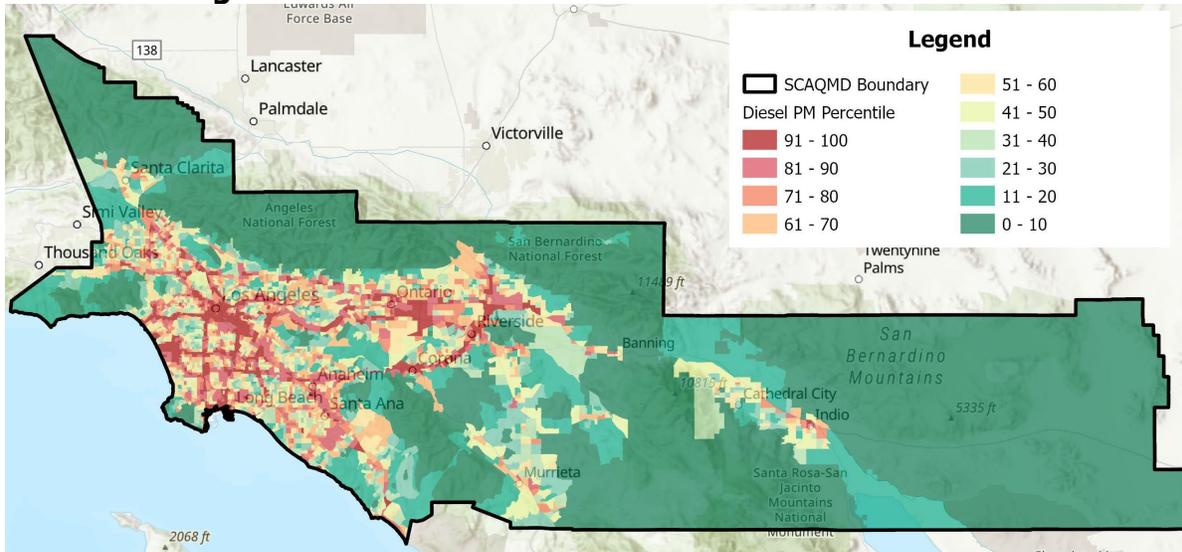
Figure 17: CalEnviroScreen 4 - Pollution Percentile



Source: University of California, Riverside

Figure 18 shows the CalEnviroScreen 4.0 diesel PM state ranking for the tracts within the SCAQMD region. Since the majority of diesel PM is emitted by mobile sources, the most impacted communities are those located within the major transportation routes. Diesel PM is the pollution metric having a significant health toll that is directly related to transportation emissions, specifically diesel powered MDHD vehicles. Reducing transportation related PM emissions would directly reduce diesel PM in the air.

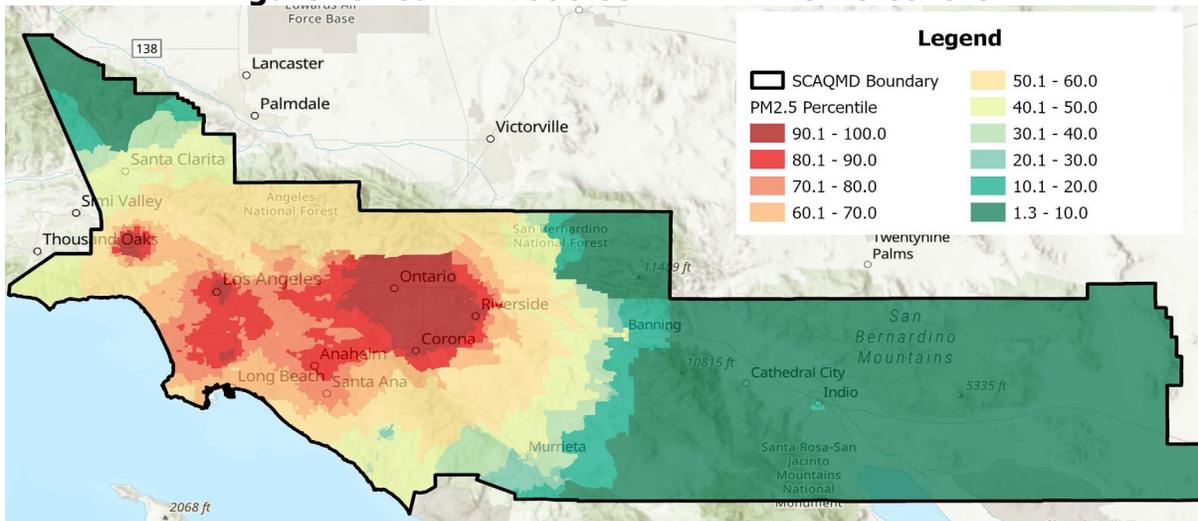
Figure 18: CalEnviroScreen 4 – Diesel PM Percentile



Source: University of California, Riverside

The map in Figure 19 shows CalEnviroScreen 4.0 PM_{2.5} ranking for the tracts within the SCAQMD region. The communities most impacted, scoring in the 90th percentile, include the majority of the Inland Empire, from Corona to Riverside and Ontario. As discussed in the previous section on criteria air pollutant emissions reduction, MDHD vehicles contribute to PM_{2.5} emissions, and reduction in transportation related PM_{2.5} emissions would result in overall reduction of ambient PM_{2.5}.

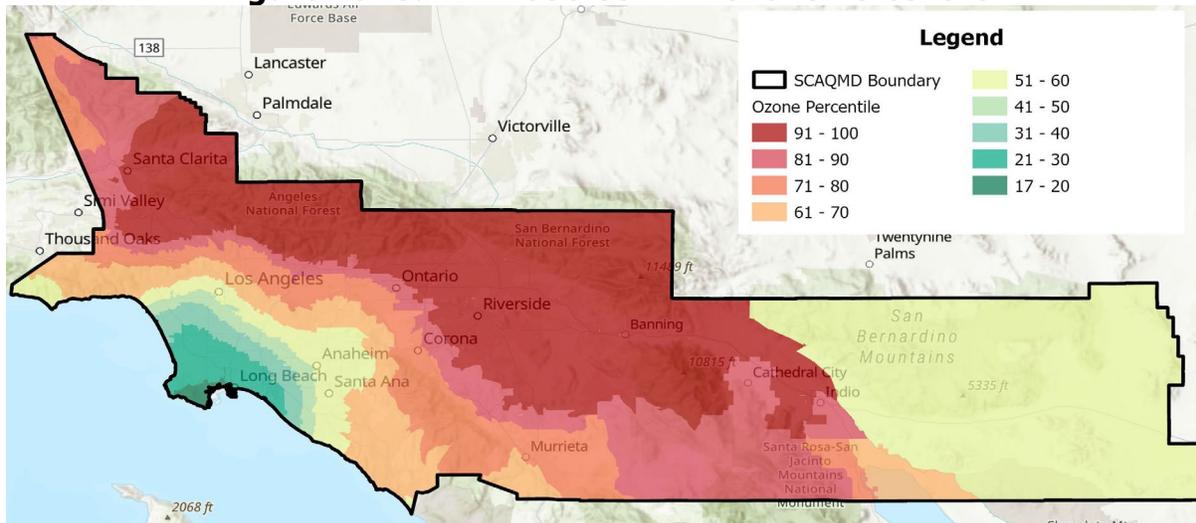
Figure 19: CalEnviroScreen 4 – PM_{2.5} Percentile



Source: University of California, Riverside

Figure 20 shows a map of CalEnviroScreen 4.0 ozone ranking for the tracts within the SCAQMD region. Large portion of the region in the North West scores in 90th percentile for the state. NO_x is a precursor of ozone, which has serious health impacts.

Figure 20: CalEnviroScreen 4 – Ozone Percentile



Source: *University of California, Riverside*

Job Creation

Analysis by the CARB for the ACT and ACF regulations include economic impacts analysis (CARB, 2019; CARB, 2022a). The macroeconomic analysis by CARB shows that while the ACT regulation is expected to result in a net addition of 7,442 jobs to the State's economy, the ACF regulation is expected to have a negative impact on jobs after 2026. However, this analysis includes jobs across all sectors, incorporating current tax and revenue mechanisms that support some public sector offices. The investments related to manufacturing and deploying MDHD ZEVs, building the associated infrastructure, providing the electricity and hydrogen, along with conducting operations and maintenance will result in a significant number of new jobs across the region. The vehicle population analysis conducted as part of this project indicates that there will be approximately 129,000 MDHD ZEVs deployed by 2040 in the SCAQMD territory. Economics of MDHD ZEVs and infrastructure are difficult to predict and analyze, particularly because the industry is undergoing rapid evolution and many real costs are not publicly available. The project team used literature data to evaluate the investment necessary to deploy the associated infrastructure (ICCT, 2019; ICCT, 2023). The 'Job Co-benefit Modeling Tool' developed by the CARB to evaluate the impact of California Climate Investments projects was then used to estimate the number of jobs created by the investments (CARB, 2023). Based on the estimated investment necessary to develop the infrastructure, a total of 250 jobs will be created by 2025, while 4,296 and 9,550 jobs will be created by 2030 and 2040 respectively for the analysis region. Of these, the estimated direct jobs for the years 2025, 2030, and 2040 are 107, 1,835, and 4,080, respectively, with the rest being jobs indirectly supported by the investments. However, it should be noted that this analysis does not differentiate between temporary and permanent jobs and does not incorporate all employment sectors and does not include the jobs eliminated by the deployment of these technologies. Also, it should be noted that it is likely that a majority of these jobs will be outside of the SCAQMD territory and may even be outside of California. Therefore, the net number of permanent jobs created within the analysis region are likely to be significantly lower. The project team recommends a focused and deeper analysis to evaluate all aspects of the economic impacts associated with the projected MDHD ZEV infrastructure deployment.

CHAPTER 6:

Blueprint

Design Basis

The methodology used by the project team to develop the MDHD ZEV infrastructure blueprint design basis is described in Chapter 1 and detailed by Figure 2. The team utilizes prior analysis methodology (Raju et al., 2021), to estimate future daily vehicle miles traveled (VMT) by MDHD ZEVs (BEVs and FCEVs), based on the EMFAC model vehicle inventory, the current California Air Resources Board (CARB) Scoping Plan, and relevant ZEV mandates.

The team has identified technical specifications of recently released MDHD BEVs and FCEVs to project fuel/energy efficiency and to estimate the daily total electric energy and hydrogen fuel needs within the South Coast Air Quality Management District. Battery charging and hydrogen fueling standards utilized in the blueprint analysis along with SCAG trip modeling is described in earlier Chapters. As shown in Table 1, the US Federal Highway Administration defines medium-duty vehicles as those with a gross vehicle weight rating between 10,000 and 26,000 lbs, and heavy-duty vehicles as those with a GVWR above 26,000 lbs.

MDHD ZEV Deployment Projections

The methodology to determine the number of deployed MDHD ZEVs within the four counties included in the SCAQMD region is described in Chapter 2. Based on the analysis conducted by this project and prior work by the authors, estimates of daily VMTs by MDHD BEVs and FCEVs within the SCAQMD area have been prepared for the years 2025, 2030, and 2040. The estimates are summarized in Table A1 in Appendix A. Definitions for the vehicle categories are provided in Table B1 in Appendix B. The vehicle population projections are estimated using the base vehicle inventory from the EMFAC model, which is updated through a combination of current and proposed state regulations, data from publicly available literature, and feedback from stakeholders.

The design basis for MDHD fueling and charging standards is detailed in Chapter 4. Charging capacities range from SAE J3068 standard with a maximum power output of 100kW to SAE J1772-CCS-2 for a maximum charge DC rate of 500kW. The presently developed SAE J3271 provides a charge rate of 1MW with future amendments of the standard expected to reach 3.75MW charging for HD BEVs with higher voltage battery pack vehicles. Additional standards include SAE J3400, the North American Charging Standard (NACS), providing charging rates up to 500kW.

Hydrogen fueling standards described in Chapter 4 include: SAE J2600, SAE J2601, SAE J2601-2, and SAE J2601-3. Under the SAE J2601-2 normal fueling option, current fueling rates for FCEVs can achieve 3.6 kg/min with future SAE J2601-2 fast fueling option increasing this rate to 7.2 kg/min. Future revisions of SAE J2601 aim to increase the fueling rate to 8 kg/min, and eventually to a rate of 10 kg/min.

Utilizing a combination of published specifications and real-world high capacity deployments the team has estimated station refueling capacities utilized within the blueprint design basis. The Port of Long Beach station features 13 dual-cord CCS 360kW, capable of charging 26 trucks concurrently at 180kW per truck, comprising a total power demand of nearly 5MW (WattEV, 2023). While the majority of MDHD BEV truck charging is currently performed by

private or behind-the-gate BEV chargers. The Orange County Transportation Authority (OCTA) station is capable of refueling 40 to 50 buses per day, with 37.5 kg of hydrogen per bus. SunLine Transit Agency also owns and operates behind-the-gate hydrogen fueling station located in Thousand Palms. There are three HD truck hydrogen fueling stations within the SCAQMD region, owned and operated by Shell, each located in Ontario, Wilmington, and the Port of Long Beach.

MDHD ZEV Technical Specifications

The team has identified vehicle technical specifications relevant to this analysis, for ZEVs that have either been announced or released on the market. The list of vehicles selected is not exhaustive, but includes samples of each vehicle type and class to be used for this analysis. The data was obtained from the Zero-Emission Technology Inventory (ZETI) (DriveToZero, 2023). Table 6 in Chapter 4 lists technical parameters for hydrogen FCEVs, including type, maker, model, class, tank capacity, power, range, and fueling time where available. Notably, at present, only class 8 FCEVs have been released or announced. Fuel efficiency of various class 8 HD FCEVs is between 5 to 9 mi/kg, with the exception of refuse trucks, where significant energy is used for pick-up and dumping.

Table 7 in Chapter 4 lists technical specifications for selected MDHD BEVs, including vehicle type, maker, model, class, energy storage capacity, range, power, and charging capacity. Electric energy efficiency for most HD vehicles (class 7 and 8) falls between 0.3 to 0.7 mi/kWh range, while MD vehicle energy consumption is between 0.7 to 1.4 mi/kWh.

Fuel and Energy Requirements

Table 8 in Chapter 4 presents estimated daily requirements for hydrogen fuel and electric energy for medium-duty and heavy-duty zero-emission vehicles (MDHD ZEVs). The VMT values, obtained from Table 8, are grouped by duty type (MD and HD). For 2025, an average energy efficiency of 7 mi/kg hydrogen is used for HD FCEVs. The hydrogen fuel efficiency values were increased by 10 percent for 2030 and by 10 percent for 2040.

Table 9 lists the estimates of the required number of BEV charging and hydrogen fueling stations, serving MDHD ZEVs within the SCAQMD region in 2025, 2030, and 2040. The estimates are based on hydrogen fuel and electric energy requirements in Table 8.

As evident from Table 4 (Chapter 2), in the year 2025 large portion of MDHD ZEVs consists of transit buses operating within cities located all over the SCAQMD region, and it is assumed that most transit agencies will require behind-the-gate fueling or charging for their ZEV fleets.

Table 9: Number of MDHD BEV Charging and Hydrogen Fueling Stations

Year	2025		2030		2040	
	EV	Hydrogen	EV	Hydrogen	EV	Hydrogen
Number	up to 30	up to 15	105	52	224	165

Source: University of California, Riverside

Figure 6 in Chapter 4 details a map with the locations of electric power generation plants within the SCAQMD region, categorized by the type of energy source used to produce electricity.

Existing hydrogen production in Southern California is limited to a few producers and locations, as shown on the map in Figure 7 (Chapter 3). There are only two hydrogen pipelines in the region, both relatively short: a 2-mile-long pipeline located in the city of Ontario and operated by Praxair and a 12-mile pipeline which crosses the borders of the cities of Carson, Los Angeles, and Long Beach, operated by Air Products.

Figure 8 in Chapter 4 presents an analysis of the potential for renewable solar energy production in the SCAQMD region. The fuel and energy analysis considered several factors, including hydrogen production, renewables, and energy production and transmission systems.

MDHD Vehicle Transportation Model

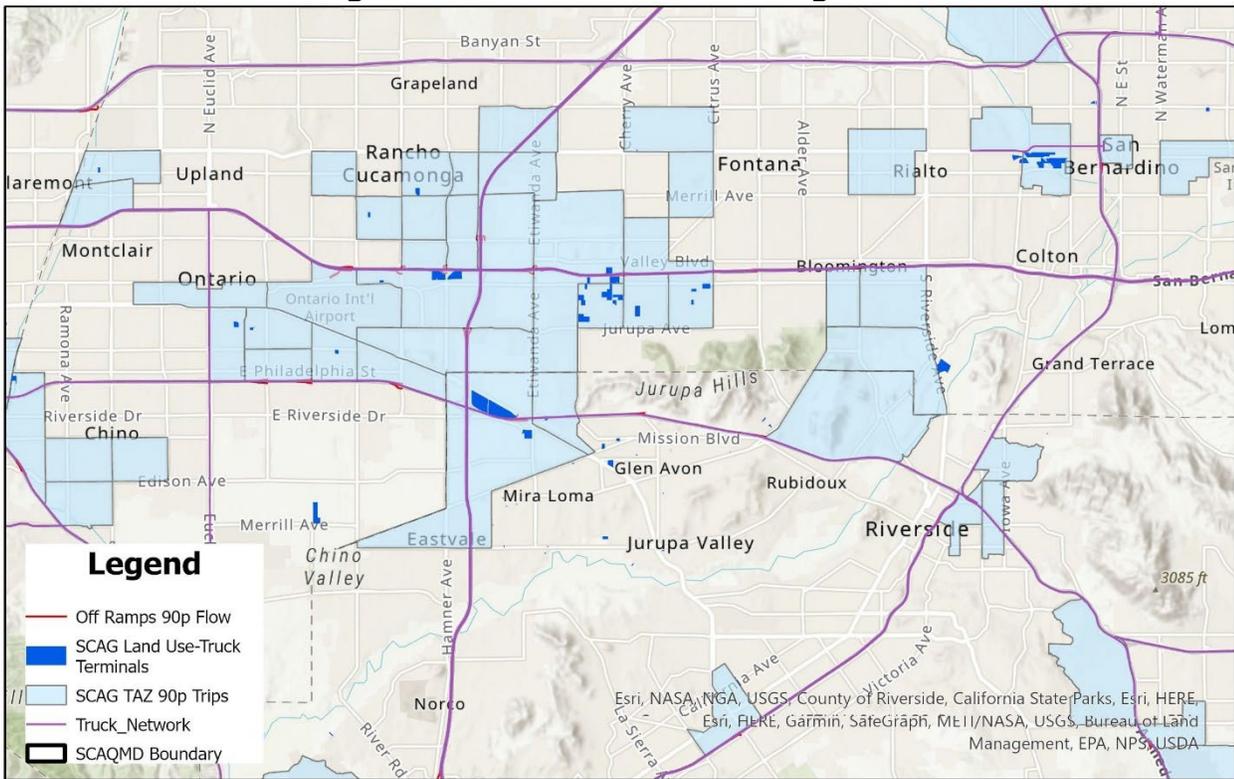
To identify potential candidate areas for ZEV infrastructure with high energy/fuel demand, the team is utilizing the SCAG truck transportation model (SCAG, 2023a). The SCAG model estimates number of daily trips originating from any transportation analysis zone (TAZ) to all other TAZs. There are 3,558 zones within the SCAQMD region. Figure 3 in Chapter 2 shows a map with SCAG TAZs in the SCAQMD area, differentiated by shades of green to represent the number of origin-destination trips for each zone. There are several zones, not shown on the map, which are used to indicate trip origins or destinations located outside the SCAG region.

In addition to the number of trips per TAZ, the SCAG model provides daily truck traffic flow on individual segments (links) of the road network system. Link volumes are shown on the map in Figure 3, in colors ranging from yellow to dark red. Daily VMTs for each TAZ are calculated as the product of traffic flow values and road segment lengths.

The study assumes that future ZEVs (BEVs and FCEVs) will be distributed proportionately to existing MDHD vehicles across the SCAQMD region. Accordingly, the same proportional factor is applied to each TAZ when estimating VMTs and origin-destination trips based on SCAG data. In other words, no TAZ is given preference in terms of ZEV deployment. The calculated VMTs and trip values for both BEVs and FCEVs in each TAZ serve to estimate fuel/energy demand, which in turn informs the assignment of ZEV infrastructure preference scores for each zone.

In addition to the SCAG truck transportation model data the team is using SCAG land use designation data, which includes vacant land and truck terminals (SCAG, 2023a). Figure 21 shows a map of an area within Riverside County, with truck terminals shown in dark blue.

Figure 21: SCAG Land Use Designation Data



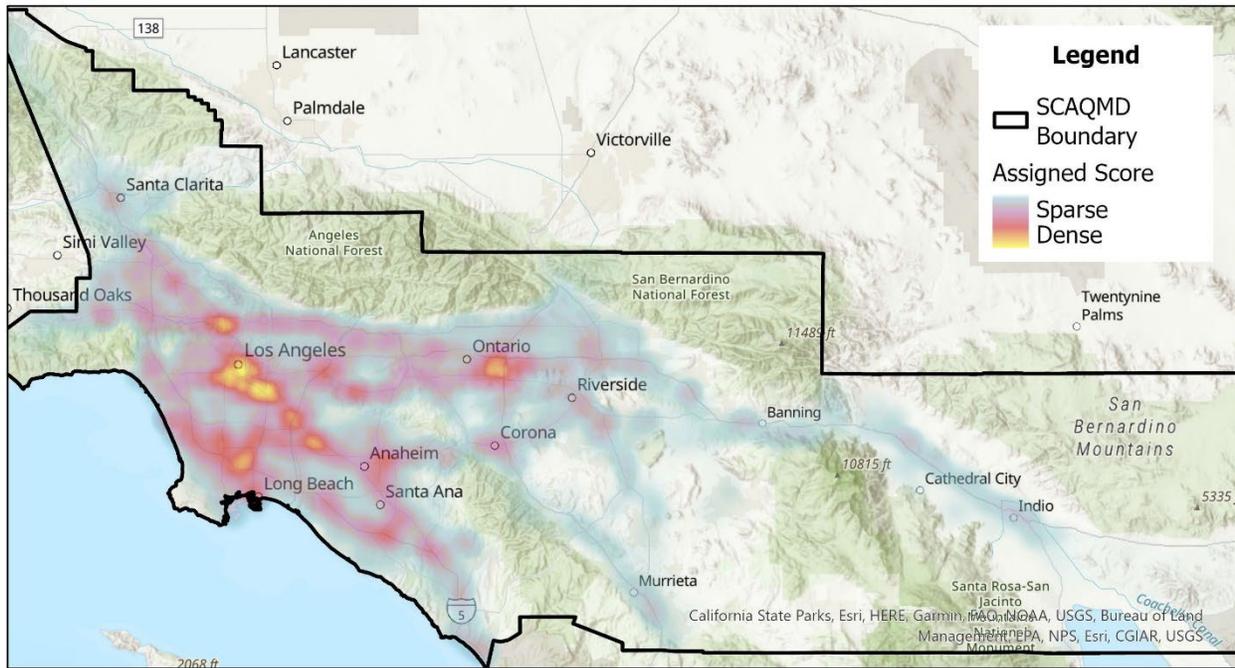
Source: *University of California, Riverside*

In addition to truck terminals, Figure 21 depicts highway on/off ramps and TAZs in the 90th percentile for traffic flow and origin-destination trips, respectively, within a section of the Inland Empire in the SCAQMD region.

Methodology and Analysis Results

The analysis approach consists of dividing the SCAG TAZs within the SCAQMD territory to squares with surface areas of 1 sq. mile. Each square takes the values of VMTs and origin-destination trips of the TAZ within which it is contained, where both parameters are normalized by the surface area of each TAZ. Furthermore, distances for the center of each square to the nearest highway, highway on/off ramp, electrical transmission line, and electrical substation are calculated in ArcGIS software. GIS data for electrical infrastructure was obtained from CEC (CEC, 2022). In addition, surface area of truck terminals within each square is calculated. The values for all these parameters are normalized to a range of 0 to 1, and then added with equal weight of 1, to generate a score for each square, representing preferences for locating ZEV infrastructure. Figure 22 shows a heat map generated using the data, where the score value for each square is assigned to the square's center point to generate the resulting heat map. The highest intensity areas have high MDHD vehicle activity coupled with increased potential for electrical grid connection. This map shows which areas within the SCAQMD region are high priority candidates for future MDHD vehicle charging and hydrogen fueling infrastructure. Specific locations will be dependent upon zoning, current land use, permitting, ordinances, local regulations, and other parameters.

Figure 22: Heat Map for Charging/Fueling Station Area Preference



Source: *University of California, Riverside*

The blueprint presented in this report provides an analysis of the infrastructure requirements to support existing and future MDHD ZEVs within the SCAQMD territory. Data on deployed MDHD ZEVs in the region is obtained from the CEC, while projections of future MDHD ZEV deployments in the region are developed using a combination of the EMFAC vehicle population database, the 2022 CARB Scoping Plan, the state’s MDHD ZEV transition mandates including the Advanced Clean Trucks and Advanced Clean Fleets rules, and other relevant data. The numbers of projected MDHD ZEVs operating in the analysis region are approximately 2,900 in the year 2025, approximately 56,000 in 2030, and approximately 129,000 in 2040.

Corresponding daily vehicle miles travelled by MDHD BEVs and FCEVs are estimated for the years 2025, 2030, and 2040. These numbers are then used in conjunction with current and projected ZEV energy efficiency specifications to calculate the amount of hydrogen fuel and electric energy needed daily to support future MDHD ZEV population in the region. The estimated daily electric energy and hydrogen fuel requirements are approximately 165 MWh and 5,000 kg, respectively for the year 2025, and 8,000 MWh and 165,000 kg for 2040.

The number of future MDHD BEV charging stations and hydrogen fueling stations is estimated based on the amount of total fuel and electric energy needed and daily dispensing capacity limits per station. The approximate combined number of stations required are on the order of 45 stations by year 2025, on the order of 150 by 2030, and on the order of 400 by 2040. The required station numbers will vary significantly depending on a number of parameters, including MDHD ZEV deployment timelines, number of private versus shared facilities, and individual station capacities and specifications.

A forecast of preferred areas in the region, for placement of future MDHD BEV charging stations and hydrogen fueling stations, is developed using transportation and land designation data obtained from the SCAG transportation model, electric grid infrastructure data obtained from CEC, and transportation infrastructure data.

Candidate MDHD BEV Charging and Hydrogen Fueling Stations MDHD ZEV Stations Specifications and Proposed Locations

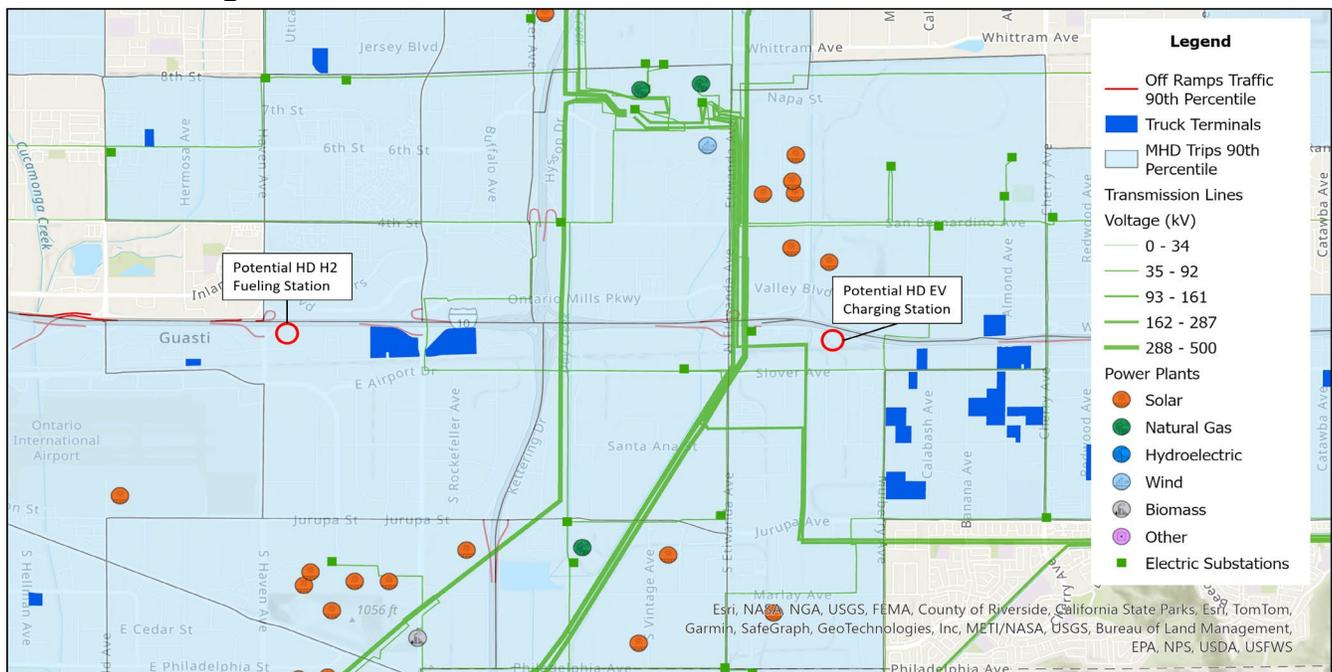
The candidate locations for a MDHD BEV charging station and a hydrogen fueling station are shown on the map in Figure 23. Both are located near the intersection of Interstate 10 and Interstate 15, which is one of the hot spots on the heat map in Figure 22. Additional details regarding the site locations and station specifications for MDHD BEV charging station and hydrogen fueling stations are provided in Table 10 and Table 11, respectively.

As evident from Figure 23, both station locations fall within an area made of transportation analysis zones (marked by light blue color) with the top 10 percent of number of MDHD vehicle trips in the SCAQMD region. A significant number of nearby on/off ramps (indicated by red lines) are characterized as having top 10 percent of the MDHD vehicle traffic flow in the SCAQMD area. Furthermore, a significant number of truck terminals (marked by dark blue color) are located within the area. The proposed site for MDHD BEV charging station is located near an electrical substation (green square) and transmission lines (green colored lines). Number of solar PV generators with capacity greater than 1 MW are shown in the area on the map in Figure 23.

The proposed sites for station location are vacant parcels of land in commercial or industrial zones, as indicated in Tables 10 and 11. The proposed electric power of 3 MW for the BEV station is assumed to be supplied by the electric grid, operated by SCE. The proposed BEV station is equipped with 12 CCS-2 charging ports, capable of charging 12 BEV trucks concurrently at 250 kW. The BEV charging station can serve up to 72 BEV trucks per day.

Hydrogen fuel is delivered to proposed hydrogen station in liquid form by truck. The station can store up to 5000 kg of liquid hydrogen onsite. The station is equipped with two dispensers capable of dispensing hydrogen gas at 350 or 700 bar pressures. The hydrogen fueling station can serve up to a 100 FCEV trucks per day.

Figure 23: Potential Candidate Sites for MDHD ZEV Stations



Source: University of California, Riverside

Table 10: MDHD BEV Charging Station Details

County	San Bernardino
City	Fontana
Parcel #	023806230
Size (Acres)	19
Land Use	Vacant
Zoning	Industrial
Electricity supply	Grid connected
Charging ports	12
Charging Standard	CCS-2
Max charge rate (MW)	0.35
Trucks per day	72
SCE Grid power (MW)	3
Battery Storage	Optional

Source: *University of California, Riverside*

Table 11: MDHD Hydrogen Fueling Station Details

County	San Bernardino
City	Ontario
Parcel #	021021260
Size (Acres)	7
Land Use	Vacant
Zoning	Commercial
Hydrogen supply	Truck delivery
Liq. Hydrogen Storage (kg)	5000
Dispensers	2
Fuel Pressure	350/700 bar
Dispensing rate (kg/h)	320
Trucks per day	100
SCE Grid power (MW)	0.15

Source: *University of California, Riverside*

MDHD ZEV Stations Costs and Deployment Timelines

The estimated costs for building and operating the proposed MDHD hydrogen fueling station are listed in Table 12, which include capital costs and operation and maintenance costs. The capital costs are based on DOE reported costs for hydrogen fueling station with liquid hydrogen storage, with a daily dispensing hydrogen capacity of 1,400 to 1,620 kg (DOE, 2021). We are using the lower bound for capital costs, which is \$1,200 per kg of hydrogen dispensed daily, since the proposed hydrogen station has a daily dispensing capacity of 5,000 kg. The annual operation and maintenance costs estimates are based on CARB's Hydrogen Station Network Self-Sufficiency Analysis report (CARB, 2021). The estimates include fixed costs and variable electricity costs. Costs of liquid hydrogen procurement, sales taxes, and

credit card fees are not included in the estimate. We assumed 355 operational days per year with 10 maintenance days.

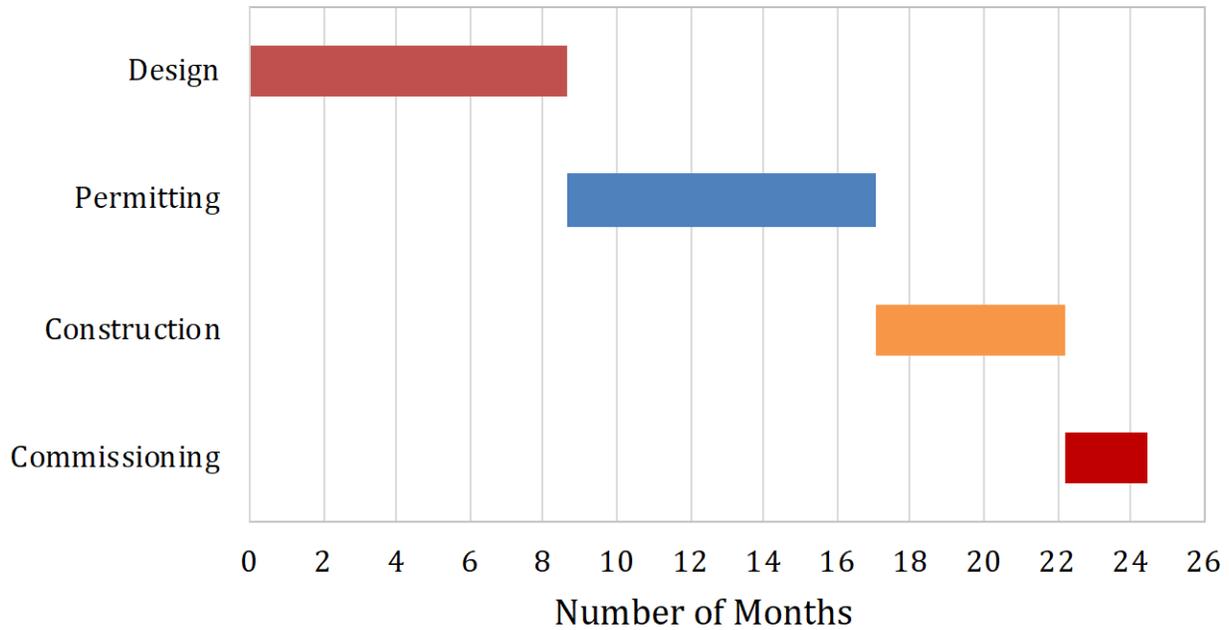
Table 12: MDHD Hydrogen Fueling Station Cost Estimates

Capital Cost Estimate	
Total Capital Cost - \$6,000,000	
Annual Maintenance and Operation Costs Estimate	
Internet	\$2,300
Fixed Electricity	\$2,100
Permits	\$3,700
Hydrogen Quality Tests	\$5,400
Insurance	\$7,200
Property Tax	1 percent of Capital Cost
Rent	\$48,000
Fixed Labor	3 percent of Capital Expense
Variable Electricity	\$0.54 per kg H ₂ Dispensed
Total Annual Maintenance and Operation Costs	\$1,267,200

Source: University of California, Riverside

The estimated timeline of the proposed MDHD hydrogen fueling system design, permitting, construction, and commissioning activities is show in Figure 24. These are based on the average timelines of actual hydrogen station projects (NREL, 2023).

Figure 24: MDHD Hydrogen Fueling Station Deployment Timeline



Source: *University of California, Riverside*

The total installation costs of the MDHD BEV charging station are influenced greatly by the electric grid connection requirements. The maximum power demand of the proposed BEV charging station and available load integration capacity at the proposed project site determine electrical interconnection requirements. Since the total power demand of the proposed BEV charging station is 3.5 MW, we consider three different scenarios: 1) Scenario 1 assumes the available load integration capacity on the circuit is sufficient and no distribution upgrades are required; 2) Scenario 2 includes some distribution feeder upgrades; 3) Scenario 3 includes substation upgrades in addition to feeder upgrades.

Table 13 lists total capital costs under the three different scenarios. The equipment and installation costs per charging port are based on the lower bound estimate for 350 kW fast DC charger (Borlaug et al., 2021). Site improvement for unpaved land per acre and power supply and interconnection costs are based on Port of Long Beach BEV charging assessment report (Moilanen et al., 2021). The total capital cost under Scenario 1 is \$4,288,000. Scenario 2 includes total capital cost under Scenario 1 plus additional electrical distribution feeder upgrade cost ranging from \$2M to \$12M (Borlaug et al., 2021). Scenario 3 adds to the total costs of Scenario 2 an additional cost for electric substation upgrades estimated at \$3M to \$5M (Borlaug et al., 2021).

Figure 25 shows the timeline for deployment of the proposed MDHD BEV charging station under the three different scenarios. We use the average values reported by Borlaug et al., 2021.

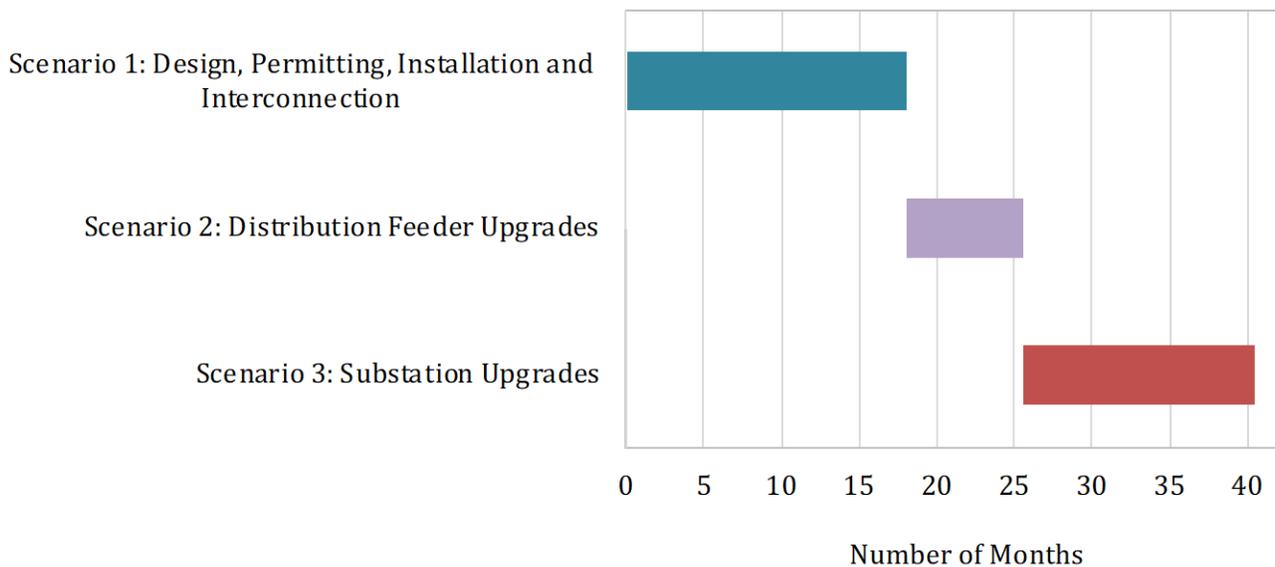
Table 13: MDHD BEV Charging Station Cost Estimates

Capital Cost Estimate Scenario 1	
Chargers (\$128,000 per charging port)	\$1,536,000
Charger Installation (\$26,000 per charging port)	\$312,000

Site Improvements (\$275,000 per acre)	\$1,100,000
Power Supply and Interconnection	\$340,000
Project Management	\$1,000,000
Scenario 1 - Total Capital Cost	\$4,288,000
Capital Cost Estimate Scenario 2	
Scenario 1 - Total Capital Cost	\$4,288,000
Feeder Upgrades	\$2M to \$12M
Scenario 2 - Total Capital Cost	\$6.3M to \$16.3M
Capital Cost Estimate Scenario 3	
Scenario 2 - Total Capital Cost	\$6.3M to \$16.3M
Substation Upgrades	\$3M to \$5M
Scenario 3 - Total Capital Cost	\$9.3M to \$21.3M

Source: University of California, Riverside

Figure 25: MDHD BEV Charging Station Deployment Timeline



Source: University of California, Riverside

MDHD ZEV Maintenance and Service Requirements

The MDHD ZEV industry acknowledges and recognizes the need for enhanced service and maintenance capabilities associated with future MDHD ZEV deployments. While the ZEV electrical drivetrain reduces much of the maintenance and service associated with IC engines and coupled transmissions much of the traditional service requirements remain with tires, brakes, suspension, axles, bearings, cooling systems, and low voltage systems. The team has considered these common service requirements associated with the proposed fueling and recharging infrastructure. Additionally, the proprietary nature of the ZEV drive systems will require specialty services aligned with manufacturer provided technicians, parts, and facilities. Since the stations proposed by the team are publicly accessible and intended to serve a

multitude of vehicle makes and models the specialty manufacturer services are expected to be obtained at a dealer specified location. Due to these considerations the team is suggesting a fueling and charging facility be independent of ZEV specific service and maintenance facilities that require OEM software and hardware. Only general maintenance and service operations and facilities are being suggested with each deployment.

The earliest MDHD deployments are anticipated to consist of regional operations with local fleets and operators. Many local operators are likely to have their own facility and staff capable of addressing the traditional service and vehicle systems maintenance that is universal across MDHD platforms. These will most commonly consist of tires, brakes, suspension, axles, bearings, and low voltage systems similar to traditional internal combustion engine platforms. ZEV drivetrain related scheduled maintenance and warranty repairs are intended to be completed at manufacturer designated locations.

To support fleets that do not have locally accessible service and maintenance facilities it is being proposed that each proposed MDHD ZEV station has at least one service bay to accommodate MDHD vehicle platforms. The service bay should possess a lift with capacity for Class 8 tractors and associated increased weight from battery packs. The service bay should possess the equipment, tools, capabilities and technicians to service and repair tires, brakes, pneumatics, suspension, axles, fluids, bearings, cooling systems, and low voltage systems. These systems will utilize the traditional components, parts, servicing, and repair methodologies associated with traditional platforms. Special training should be provided on high voltage wiring, batteries, and systems to minimize inadvertent hazards working near ZEV drivetrain components. Vehicle operators and technicians should also be trained to inspect and recognize hazards with worn and loose high voltage cables and connectors. As MDHD ZEV deployments increase over time and the ZEV fleet ages, the need for additional MDHD ZEV maintenance and service facilities will increase.

CHAPTER 7:

Summary and Conclusions

Project Overview

The objective of this project (CEC grant number ARV-21-027) is to develop a regional strategy to deploy charging and refueling infrastructure for medium and heavy-duty battery electric and fuel cell electric vehicles in California's South Coast region. The analysis uses a model developed by the project team that uses the EMFAC vehicle population database combined with the state's MDHD ZEV transition requirements to project the vehicle population mix in the region through 2040. The GHG emission reductions for the MDHD transportation sector were calculated by conducting a Life Cycle Assessment (LCA) using the CA-GREET 3.0 model. The tailpipe criteria pollutant and air toxics emissions were calculated using a combination of the EMFAC model and updated real world emission factors estimated and reported by UC Riverside. Details of the model along with the methodology are available in the literature (Raju et al., 2021). The research team continues to update the vehicle population inventories used in the model using newer versions of EMFAC and other relevant regulations. The team then combines the results of the model projections with vehicle route and other data from the SCAG Transportation Model to develop maps of traffic flows in ArcGIS. The ArcGIS model also incorporates parameters such as freeway on/off ramping, existing truck stops, zoning regulations, etc. and is used to identify candidate areas for the proposed charging and fueling stations. The analysis incorporates available electric grid integration capacity as well.

The sections below provide a summary of the results, conclusions and recommendations on next steps.

Summary of Results

MDHD Vehicle and Fleet Analysis

The project team developed a detailed current inventory of MDHD vehicles by class in the SCAQMD region using existing databases and literature data. The information included data available from the California Energy Commission, Department of Motor Vehicles registered MDHD vehicles, and the California Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project HVIP. These databases identify ongoing MDHD ZEV deployment activities throughout the state. Projections of future MDHD ZEV deployments in the region are estimated based on EMFAC model vehicle inventory, the current California Air Resources Board (CARB) Scoping Plan, and relevant ZEV mandates. The analysis method detailed above focuses on characterizing the current and projected MDHD vehicle population attributes. The fleet information presented in the prior sections encompasses the research, data collection, inventory, and data analysis necessary for conducting a MDHD vehicle and fleet analysis of the South Coast region.

The project team presumes the future MDHD ZEVs will be distributed proportionately compared to the existing MDHD activity throughout the SCAQMD region, allowing current parameters to be representative of the origins, destinations, activity, routes, VMT and goods while accounting for projected growth.

To assist with specific routing and travel patterns in SCAQMD region the team used the Southern California Association of Governments Regional Travel Demand model of medium

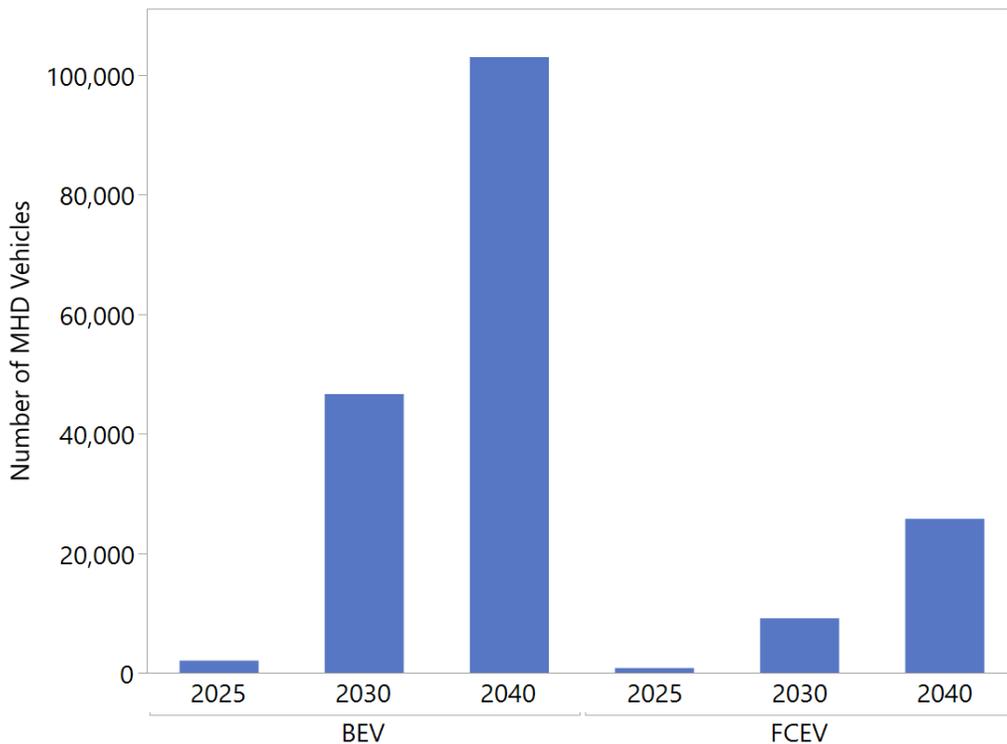
and heavy-duty truck vehicle activity. The SCAG model estimates number of daily trips originating from any transportation analysis zone (TAZ) to all other TAZs. In addition to the number of trips per TAZ, the SCAG model provides daily truck traffic flow on individual segments (links) of the road network system. Daily VMTs for each TAZ are calculated as the product of traffic flow values and road segment lengths.

The key data developed during this Task include:

- An inventory of current and future all MDHD vehicle population and activity details;
- A database of existing ZEV population information and anticipated ZEV deployment through 2040;
- Database of specific vehicle classes, modes, and drive cycles of the current and anticipated ZEV population; and,
- Database of major driving routes, current refueling locations, and other landmarks.

Figure 26 below shows the projected MDHD ZEV populations in the SCAQMD territory for the analysis period.

Figure 26: MDHD ZEV Population Projections for the SCAQMD Territory



Source: *University of California, Riverside*

Electricity and Fuel Resource Analysis

As part of this task, the project team evaluated the renewable and non-renewable electricity and hydrogen production resources available within the SCAQMD region to support medium and heavy-duty ZEV infrastructure. Specific resource assessment activities include:

- Geospatial assessment of the electric grid infrastructure, including transmission, and substations information;
- Geospatial assessment of existing electric power plant generation capacity;

- Assessment of existing hydrogen plant production capacity and pipeline infrastructure; and,
- Assessment of potential for renewable electricity generation by solar PV, based on solar irradiance, land availability and proximity to electric transmission system.

The data generated as part of this task has been used in identifying high priority candidate areas for MDHD ZEV charging and fueling stations within the analysis region.

Infrastructure Design Basis

As part of this task, the team identified and presented methodology, data, data sources, assumptions and modeling results used as the design basis for MDHD ZEV infrastructure deployments within the SCAQMD region. Multiple resources and assumptions were used in estimating daily VMTs for BEVs and FCEVs originating from future MDHD ZEV deployments. Daily hydrogen fuel and electric energy requirements associated with these ZEV deployments were estimated based on ZEV efficiencies and other technical specifications. The results were then used to estimate the anticipated number of ZEV charging and fueling stations (Figure 9) required to support the ZEV deployment projections in the analysis region. Preference for geographic location of future ZEV charging/refueling infrastructure (Figure 22) was evaluated using a model incorporating ZEV VMTs and number of trips, proximity to nearest electric transmission lines and substations, proximity to nearest highways and on/off ramps, and existing truck terminal locations and surface areas.

Benefit Analysis

As part of this task, the team evaluated the anticipated GHG and criteria air pollutant emissions reduction for the SCAQMD region associated with deployment of MDHD BEVs and FCEVs from 2025 through 2040. The GHG emission reductions were calculated using the CA-GREET 3.0 model and the criteria pollutant emission reductions were calculated using a combination of the EMFAC model and updated real world emission factors previously estimated and reported by UC Riverside. The analysis years show a gradually increasing proportion of MDHD ZEVs being deployed with a corresponding reduction in GHG and criteria pollutant emissions. The analysis also summarizes the impact of the MDHD ZEV deployment and associated emission reductions on community health and jobs within the SCAQMD territory.

Table 14: GHG and Criteria Air Pollutant Emissions Estimates (Tonnes/Day) for the SCAQMD Territory

Emissions	Year 2025	2030	2040
NOx	46.68	41.11	34.36
PM2.5	0.37	0.33	0.28
PM10	0.38	0.34	0.29
CO	3.56	3.32	3.01
SOx	0.25	0.21	0.16
GHG	11,289	10,370	8,698

Source: University of California, Riverside

Conclusions and Recommendations

There is a significant need to accelerate the deployment of infrastructure for MDHD ZEVs in order to support the state's planned transition of the MDHD transportation sector. This need is particularly acute in the SCAQMD territory, which includes several disadvantaged communities experiencing some of the worst air pollution in the nation and heavy truck traffic that continues to grow with the logistics industry.

The numbers of projected MDHD ZEVs operating in the analysis region are approximately 2,900 in the year 2025, approximately 56,000 in 2030, and approximately 129,000 in 2040. The estimated daily electric energy and hydrogen fuel requirements are approximately 165 MWh and 5,000 kg, respectively for the year 2025, and 8,000 MWh and 165,000 kg for 2040. The number of future MDHD electric charging stations and hydrogen fueling stations are estimated based on the amount of total fuel and electric energy needed and daily dispensing capacity limits per station. The approximate combined numbers of stations required are on the order of up to 45 stations by year 2025, on the order of 150 by 2030, and on the order of 400 by 2040. The required station numbers will vary significantly depending on a number of parameters, including MDHD ZEV deployment timelines, number of private versus shared facilities, and individual station capacities and specifications.

The anticipated energy needs and deployment timeline for these facilities will be a considerable challenge and will require coordinated planning, public and private resources and accelerated planning and permitting activities. The planned ZEV transition of the MDHD transportation sector will result in significant GHG and criteria pollutant emission reduction benefits for the region, including in disadvantaged communities.

Based on the analysis and feedback from stakeholders, the following activities are recommended to streamline and accelerate the MDHD transportation sector's transition to ZEVs.

- Coordinated regional planning is critical to meet the anticipated demands. Currently, there is no forum for robust, collaborative, regional planning that includes all stakeholder groups. A consortium of representatives from stakeholders including regulators, utilities, fleet owners and operators, OEMs, vendors and station builders/operators, and communities should be created. Such a consortium can enable improved regional planning, information exchange, optimizing planning and deployment activities and outreach and engagement.
- Developing a publicly available database that details MDHD specific infrastructure parameters and protocols and the characteristics valuable to fleet operators and the trucking industry is necessary. The database development can be led by an academic or non-profit organization active in MDHD sector electrification activities but must include data sharing and collaborative analysis of the technology and policy options and practical challenges.
- Streamlined policies to help accelerate the planning and permitting process are needed. This includes the critical area of improved alignment between state government policies and priorities with county, city and other local jurisdictions' priorities and protocols.
- Deployment activities should be supported through RD&D and novel technological and policy approaches including mobile fueling, microgrids, etc. Continuing and expanding on such recent and planned activities help de-risk and optimize technology choices and configurations.

The methodology and data from this project can serve as a basis to identify future MDHD ZEV infrastructure needs and develop deployment strategies within the SCAQMD territory. MDHD ZEV infrastructure deployments will proceed with a combination of private and public activities which utilize existing incentives and subsidies assisting with early cost inequities. The successes of initial deployments will help shape the evolution of future deployments and transitions. Continued coordination between utilities, regulators, hydrogen suppliers, fleet owner/operators, and other groups is critical to support the increasing demand created by transitioning the MDHD fleet to battery electric and hydrogen fuel cell drivetrains.

GLOSSARY

AIR QUALITY STANDARD (AQS) -- The prescribed level of a pollutant in the outside air that should not be exceeded during a specific time period to protect public health. Established by both federal and state governments.

CALIFORNIA AIR RESOURCES BOARD (ARB) -- The "clean air agency" in the government of California, whose main goals include attaining and maintaining healthy air quality; protecting the public from exposure to toxic air contaminants; and providing innovative approaches for complying with air pollution rules and regulations.

CALIFORNIA AMBIENT AIR QUALITY STANDARD (CAAQS) -- A legal limit that specifies the maximum level and time of exposure in the outdoor air for a given air pollutant and which is protective of human health and public welfare. CAAQSs are recommended by the OEHHA and adopted into regulation by the ARB. CAAQSs are the standards which must be met per the requirements of the California Clean Air Act (CCAA).

CALIFORNIA ENERGY COMMISSION - The state's primary energy policy and planning agency. The agency was established by the California Legislature through the Warren-Alquist Act in 1974. It has seven core responsibilities:

- Developing renewable energy
- Transforming transportation
- Increasing energy efficiency
- Investing in energy innovation
- Advancing state energy policy
- Certifying thermal power plants
- Preparing for energy emergencies

CARBON DIOXIDE (CO₂) - A colorless, odorless, non-poisonous gas that is a normal part of the air. Carbon dioxide is exhaled by humans and animals and is absorbed by green growing things and by the sea. CO₂ is the greenhouse gas whose concentration is being most affected directly by human activities. CO₂ also serves as the reference to compare all other greenhouse gases (see carbon dioxide equivalent). The major source of CO₂ emissions is fossil fuel combustion. CO₂ emissions are also a product of forest clearing, biomass burning, and non-energy production processes such as cement production. Atmospheric concentrations of CO₂ have been increasing at a rate of about 0.5% per year and are now about 30% above preindustrial levels. (EPA)

CARBON INTENSITY (CI) -- The amount of carbon by weight emitted per unit of energy consumed. A common measure of carbon intensity is weight of carbon per British thermal unit (Btu) of energy. When there is only one fossil fuel under consideration, the carbon intensity and the emissions coefficient are identical. When there are several fuels, carbon intensity is based on their combined emissions coefficients weighted by their energy consumption levels.

CARBON MONOXIDE (CO) - A colorless, odorless, highly poisonous gas made up of carbon and oxygen molecules formed by the incomplete combustion of carbon or carbonaceous material, including gasoline. It is a major air pollutant on the basis of weight.

ELECTRIC VEHICLE CHARGING STATION (EVSE) -- Infrastructure designed to supply power to EVs. EVSE can charge a wide variety of EVs including BEVs and PHEVs.⁴

ELECTRIC VEHICLES (EV) -- A broad category that includes all vehicles that are fully powered by Electricity or an Electric Motor.

ENVIRONMENTAL TOBACCO SMOKE (ETS) -- Primarily a combination of sidestream smoke from the burning end of a cigarette, pipe or cigar and exhaled mainstream smoke from the smoker. Other components include smoke emitted at the mouthpiece during puff drawing.

FUEL CELL ELECTRIC VEHICLE (FCEV) -- A zero-emission vehicle that runs on compressed hydrogen fed into a fuel cell "stack" that produces electricity to power the vehicle.

GREENHOUSE GAS -- Any gas that absorbs infra-red radiation in the atmosphere. Greenhouse gases include water vapor, carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), halogenated fluorocarbons (HCFCs), ozone (O₃), perfluorinated carbons (PFCs), and hydrofluorocarbons (HFCs). (EPA)

GREENHOUSE GASES, REGULATED EMISSIONS, AND ENERGY USE IN TRANSPORTATION (GREET) -- is a full life-cycle model sponsored by the Argonne National Laboratory (U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy). It fully evaluates energy and emission impacts of advanced and new transportation fuels, the fuel cycle from well to wheel and the vehicle cycle through material recovery and vehicle disposal need to be considered. It allows researchers and analysts to evaluate various vehicle and fuel combinations on a full fuel-cycle/vehicle-cycle basis.

GROSS VEHICLE WEIGHT (GVW) -- The maximum operating weight/mass of a vehicle as specified by the manufacturer including the vehicle's chassis, body, engine, engine fluids, fuel, accessories, driver, passengers and cargo but excluding that of any trailers.

LADWP - The acronym for Los Angeles Department of Water and Power an electric, municipal utility serving the greater Los Angeles, California, region.

NATIONAL RENEWABLE ENERGY LABORATORY (NREL) -- The National Renewable Energy Laboratory (NREL), located in Golden, Colorado, is the United States' primary laboratory for renewable energy and energy efficiency research and development. NREL is the only Federal laboratory dedicated to the research, development, commercialization, and deployment of renewable energy and energy efficiency technologies.

NITROGEN OXIDES (OXIDES OF NITROGEN, NO_x) -- A general term pertaining to compounds of nitric oxide (NO), nitrogen dioxide (NO₂) and other oxides of nitrogen. Nitrogen oxides are typically created during combustion processes and are major contributors to smog formation and acid deposition. NO₂ is a criteria air pollutant and may result in numerous adverse health effects.

PARTICULATE MATTER (PM) -- Unburned fuel particles that form smoke or soot and stick to lung tissue when inhaled. A chief component of exhaust emissions from heavy-duty diesel engines.

PUBLIC OWNED UTILITIES (POUS) -- Non-profit utility providers owned by a community and operated by municipalities, counties, states, public power districts, or other public organizations. Within POUs, residents have a say in decisions and policies about rates, services, generating fuels and the environment.

SDG&E -- The acronym for San Diego Gas & Electric an electric and natural gas utility serving the San Diego, California, region.

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT (SCAQMD) -- the air pollution control agency for all of Orange County and the urban portions of Los Angeles, Riverside and San Bernardino counties. This area of 10,743 square miles is home to over 16.8 million people--about half the population of the whole state of California. It is the second most populated urban area in the United States and one of the smoggiest. Its mission is to clean the air and protect the health of all residents in the South Coast Air District through practical and innovative strategies.

SOUTHERN CALIFORNIA ASSOCIATION OF GOVERNMENTS CLEAN CITIES COALITION (SCAG Clean Cities Coalition) -- SCAG Clean Cities Coalition works with vehicle fleets, fuel providers, community leaders, and other stakeholders to save energy and promote the use of domestic fuels and advanced vehicle technologies in transportation.

SOUTHERN CALIFORNIA EDISON (SCE) -- one of the nation's largest electric utilities, which delivers power to 15 million people in 50,000 square-miles across central, coastal and Southern California, excluding the City of Los Angeles and some other cities.

VEHICLE MILES TRAVELED (VMT) -- The miles traveled by motor vehicles over a specified length of time (e.g., daily, monthly or yearly) or over a specified road or transportation corridor.

ZERO EMISSION (ZE) -- An engine, motor, process, or other energy source, that emits no waste products that pollute the environment or disrupt the climate.

ZERO-EMISSION VEHICLE (ZEV) -- Vehicles which produce no emissions from the on-board source of power (e.g., an electric vehicle).

ACRONYMS

Term	Definition
AAQS	Ambient Air Quality Standards
ACT	Advanced Clean Trucks
ACF	Advanced Clean Fleets
ARB	Air Resources Board
BEV	Battery Electric Vehicle
CAA	Clean Air Act
CCAA	California Clean Air Act
CARB	California Air Resource Board
CEC	California Energy Commission
CE-CERT	College of Engineering - Center for Environmental Research and Technology
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
DMV	Department of Motor Vehicles
EMFAC	EMission FACTor
ePTO	Electric Power Takeoff
FCEV	Fuel Cell Electric Vehicle
FHWA	Federal Highway Administration
GHG	Greenhouse Gas
GREET	Greenhouse gases, Regulated Emissions, and Energy use in Transportation model
GVWR	Gross Vehicle Weight Rating
GWP	Global Warming Potential
HD	Heavy-duty
HVIP	Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project
ICCT	International Council for Clean Transportation
IIP	Imperial Irrigation District
IOU	Investor Owned Utility
LADWP	Los Angeles Department of Water and Power
MD	Medium-duty

MDHD	Medium- and Heavy-duty
MSR	Methane Steam Reforming
N ₂ O	Nitrous Oxide
NACS	North American Charging Standard
NO _x	Nitrogen Oxides
NREL	National Renewable Energy Laboratory
OCTA	Orange County Transportation Authority
PM	Particulate Matter
PM ₁₀	Particulate Matter ≤ 10 μm
PM _{2.5}	Particulate Matter ≤ 2.5 μm
POU	Publicly Owned Utility
RCLAIM	Regional Clean Air Incentive Market
SAE	Society of Automotive Engineers
SCAG	Southern California Association of Governments
SCAQMD	South Coast Air Quality Management District
SCE	Southern California Edison
SDG&E	San Diego Gas and Electric
SIPs	State Implementation Plans
TAZ	Transportation Analysis Zone
US EPA	United States Environmental Protection Agency
VMT	Vehicle Mile Traveled
ZEAS	Zero-Emission Airport Shuttle
ZETI	Zero-Emission Technology Inventory
ZEV	Zero-emission Vehicle

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APPENDIX A: VMT Estimates for SCAQMD (2025, 2030, 2040)

Table A1: MDHD ZEV and Total VMT Estimates for SCAQMD (2025, 2030, 2040)

Vehicle Category	BEV VMT			FCEV VMT			Total VMT		
	Year	2025	2030	2040	2025	2030	2040	2025	2030
All Other Buses	72,962	162,428	225,555	37,292	45,119	56,389	219,362	244,173	281,944
MH	603	74,242	99,313	152	12,374	21,590	127,692	133,926	142,428
Motor Coach	617	25,824	94,585	155	5,165	11,823	130,472	139,752	155,995
PTO	952	8,121	28,325	240	225	15,107	201,539	219,734	249,147
SBUS	1,008	82,239	151,216	254	8,224	37,804	213,319	222,529	249,394
UBUS	301	0	0	264	0	0	776	0	0
T6 Ag	1	21	11	0	5	3	210	124	28
T6 CAIRP heavy	556	21,014	53,475	140	4,670	12,834	117,708	126,360	141,111
T6 CAIRP small	78	2,943	7,492	20	654	1,798	16,461	17,697	19,771
T6 instate construction heavy	1,470	50,848	107,028	370	11,299	25,687	311,087	305,750	282,427
T6 instate construction small	3,810	131,525	276,287	959	29,228	66,309	806,205	790,869	729,067
T6 instate heavy	13,890	538,924	1,411,722	3,498	119,761	338,813	2,939,156	3,240,586	3,725,261
T6 instate small	19,099	728,934	1,867,168	4,809	161,985	448,120	4,041,163	4,383,133	4,927,094
T6 OOS heavy	319	12,045	30,649	80	2,677	7,356	67,468	72,426	80,876
T6 OOS small	45	1,700	4,330	11	378	1,039	9,501	10,223	11,426
T6 Public	500	17,858	42,759	126	3,968	10,262	105,812	107,381	112,832
T6 utility	142	5,210	12,721	36	1,158	3,053	30,097	31,325	33,568
T7 Ag	0	4	2	0	1	1	141	71	14
T7 CAIRP	2,298	143,275	327,862	575	19,103	109,287	2,413,966	2,584,576	2,883,883
T7 CAIRP construction	213	12,175	23,064	53	1,623	7,688	223,456	219,623	202,869
T7 NNOOS	2,801	174,651	399,657	700	23,287	133,219	2,942,695	3,150,576	3,515,389
T7 NOOS	903	56,296	128,826	226	7,506	42,942	948,472	1,015,539	1,133,156
T7 POLA	2,073	153,824	436,185	518	20,510	145,395	2,177,316	2,774,862	3,836,694
T7 Public				42			174,791	179,860	191,940
	166	9,970	21,821		1,329	7,274			

T7 Single	966	61,345	142,650	242	8,179	47,550	1,014,993	1,106,624	1,254,753
T7 single construction	528	30,203	57,217	132	4,027	19,072	554,354	544,844	503,282
T7 SWCV	65	2,265	1,613	16	302	538	67,880	40,852	14,190
T7 tractor	2,838	172,501	385,621	709	23,000	128,540	2,980,895	3,111,788	3,391,930
T7 tractor construction	435	24,915	47,199	109	3,322	15,733	457,294	449,448	415,163
T7 utility	14	842	1,852	3	112	617	14,572	15,181	16,292

Source: *University of California, Riverside*

APPENDIX B:

EMFAC Vehicle Inventory Definitions

Table B1: EMFAC MDHD Vehicle Group Designation

EMFAC Vehicle Group	Vehicle Specifications
T6 Ag	Medium-Heavy Duty Diesel Agriculture Truck
T6 CAIRP heavy	Medium-Heavy Duty Diesel CA International Registration Plan Truck with GVWR>26000 lbs
T6 CAIRP small	Medium-Heavy Duty Diesel CA International Registration Plan Truck with GVWR<=26000 lbs
T6 instate construction heavy	Medium-Heavy Duty Diesel instate construction Truck with GVWR>26000 lbs
T6 instate construction small	Medium-Heavy Duty Diesel instate construction Truck with GVWR<=26000 lbs
T6 instate heavy	Medium-Heavy Duty Diesel instate Truck with GVWR>26000 lbs
T6 instate small	Medium-Heavy Duty Diesel instate Truck with GVWR<=26000 lbs
T6 OOS heavy	Medium-Heavy Duty Diesel Out-of-state Truck with GVWR>26000 lbs
T6 OOS small	Medium-Heavy Duty Diesel Out-of-state Truck with GVWR<=26000 lbs
T6 Public	Medium-Heavy Duty Diesel Public Fleet Truck
T6 utility	Medium-Heavy Duty Diesel Utility Fleet Truck
T6TS	Medium-Heavy Duty Gasoline Truck
T7 Ag	Heavy-Heavy Duty Diesel Agriculture Truck
T7 CAIRP	Heavy-Heavy Duty Diesel CA International Registration Plan Truck
T7 CAIRP construction	Heavy-Heavy Duty Diesel CA International Registration Plan Construction Truck
T7 NNOOS	Heavy-Heavy Duty Diesel Non-Neighboring Out-of-state Truck
T7 NOOS	Heavy-Heavy Duty Diesel Neighboring Out-of-state Truck
T7 other port	Heavy-Heavy Duty Diesel Drayage Truck at Other Facilities
T7 POAK	Heavy-Heavy Duty Diesel Drayage Truck in Bay Area
T7 POLA	Heavy-Heavy Duty Diesel Drayage Truck near South Coast
T7 Public	Heavy-Heavy Duty Diesel Public Fleet Truck
T7 Single	Heavy-Heavy Duty Diesel Single Unit Truck
T7 single construction	Heavy-Heavy Duty Diesel Single Unit Construction Truck

T7 SWCV	Heavy-Heavy Duty Diesel Solid Waste Collection Truck
T7 tractor	Heavy-Heavy Duty Diesel Tractor Truck
T7 tractor construction	Heavy-Heavy Duty Diesel Tractor Construction Truck
T7 utility	Heavy-Heavy Duty Diesel Utility Fleet Truck
T7IS	Heavy-Heavy Duty Gasoline Truck
PTO	Power Take Off
Motor Coach	Motor Coach
SBUS	School Buses
UBUS	Urban Buses
OBUS	Other Buses
All Other Buses	All Other Buses
MH	Motor Homes

Source: *California Air Resources Board*