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Developing a Medium and Heavy-Duty ZEV Infrastructure Blueprint for the South Coast

Blueprint Report

UCR College of Engineering- Center for Environmental Research & Technology

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PREFACE

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% of smog-forming oxides of nitrogen (NO_X), and 50% of carbon dioxide (CO_2) equivalent greenhouse gases (GHG) emissions, as well as 90% 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 (MHD) 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.

Transitioning the MHD 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 and Advanced Clean Fleets programs. A major component of the transition is planning, building, and deploying the charging and 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 MHD battery electric vehicles (BEVs) and fuel cell electric vehicles (FCEVs) within California's South Coast AQMD territory. This report uses data from multiple sources to conduct modeling and analysis to estimate the number of future MHD ZEVs deployed in the South Coast Air Quality Management District (SCAQMD) territory and their respective power and fuel requirements. Projections of future MHD ZEV deployments in the region are estimated based on EMFAC model vehicle inventory, the current CARB Scoping Plan, and relevant ZEV mandates. The number of projected MHD ZEVs operating in the analysis region, the estimated electric energy and hydrogen fuel requirements for those vehicles, and the anticipated number of future MHD electric charging stations and hydrogen fueling stations are estimated through 2040. In addition, the report evaluates the anticipated benefits associated with MHD ZEV deployment in the region, including reductions of GHG, criteria pollutant, and air toxics emissions, qualitative health impacts, and jobs created by investments.

For more information about the Fuels and Transportation Division, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

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

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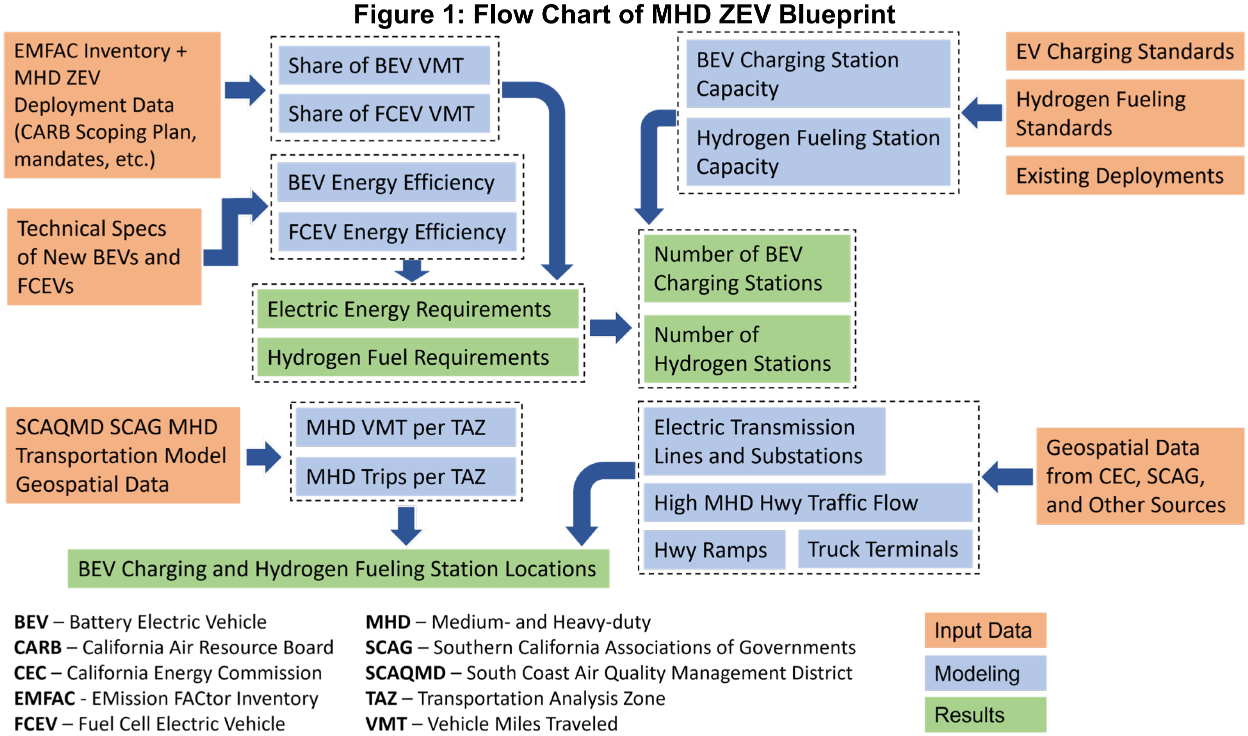
CHAPTER 1: MHD ZEV Deployment Analysis

1.1 Design Basis

The methodology used by the project team to develop the medium- and heavy-duty (MHD) zero emission vehicle (ZEV) infrastructure blueprint is depicted by the flow chart in Figure 1. The team utilizes prior analysis methodology (Raju et al., 2021), to estimate future daily vehicle miles traveled (VMT) by MHD 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 MHD 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 (SCAQMD). 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 MHD 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 MHD ZEV charging and fueling infrastructure locations.

Figure 1: Flow Chart of MHD ZEV Blueprint



Source: University of California, Riverside

As shown in Table 1, the US Federal Highway Administration 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. The same class and duty definitions are used by this blueprint.

Table 1: MHD Vehicle Classification

Vehicle Class	Gross Vehicle Weight Rating	GVWR Category
Class 3	10,000 - 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

1.2 MHD ZEV Deployment Projections

The number of deployed MHD 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 MHD vehicles. A summary is shown in Table 2 (CEC, 2023a).

Table 2: Total MHD ZEV Population by end of 2022

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: California Energy Commission

Estimates of daily VMTs of MHD 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 3. Definitions for the vehicle categories are provided in Table A1 in Appendix A. 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 MHD 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% below 1990 levels by 2030 and to 80% 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% sales of ZEVs by 2030 for T7 and 50% sales of ZEV by 2030 for T6 have been adopted.
- Advanced Clean Fleets (ACF)
  - Increase of MHD 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.
- ARB 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 MHD ZEVs are comprised of 80% BEVs and 20% FCEVs unless specified otherwise.

Table 3: MHD ZEV VMT Estimates for SCAQMD (2025, 2030, 2040)

Vehicle Category	BEV VMTs			FCEV VMTs		
Year	2025	2030	2040	2025	2030	2040
All Other Buses	72,962	162,428	225,555	37,292	45,119	56,389
MH	603	74,242	99,313	152	12,374	21,590
Motor Coach	617	25,824	94,585	155	5,165	11,823
PTO	952	8,121	28,325	240	225	15,107
SBUS	1,008	82,239	151,216	254	8,224	37,804
UBUS	301	0	0	264	0	0
T6 Ag	1	21	11	0	5	3
T6 CAIRP heavy	556	21,014	53,475	140	4,670	12,834
T6 CAIRP small	78	2,943	7,492	20	654	1,798
T6 instate construction heavy	1,470	50,848	107,028	370	11,299	25,687
T6 instate construction small	3,810	131,525	276,287	959	29,228	66,309
T6 instate heavy	13,890	538,924	1,411,722	3,498	119,761	338,813
T6 instate small	19,099	728,934	1,867,168	4,809	161,985	448,120
T6 OOS heavy	319	12,045	30,649	80	2,677	7,356
T6 OOS small	45	1,700	4,330	11	378	1,039
T6 Public	500	17,858	42,759	126	3,968	10,262
T6 utility	142	5,210	12,721	36	1,158	3,053
T7 Ag	0	4	2	0	1	1
T7 CAIRP	2,298	143,275	327,862	575	19,103	109,287
T7 CAIRP construction	213	12,175	23,064	53	1,623	7,688
T7 NNOOS	2,801	174,651	399,657	700	23,287	133,219
T7 NOOS	903	56,296	128,826	226	7,506	42,942
T7 POLA	2,073	153,824	436,185	518	20,510	145,395
T7 Public	166	9,970	21,821	42	1,329	7,274
T7 Single	966	61,345	142,650	242	8,179	47,550
T7 single construction	528	30,203	57,217	132	4,027	19,072
T7 SWCV	65	2,265	1,613	16	302	538
T7 tractor	2,838	172,501	385,621	709	23,000	128,540
T7 tractor construction	435	24,915	47,199	109	3,322	15,733
T7 utility	14	842	1,852	3	112	617

Source: University of California, Riverside

1.3 MHD ZEV Fueling and Charging Standards

1.3.1 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/drayage 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.

1.3.2 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.

1.3.3 Existing MHD 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 MHD 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.

1.4 MHD ZEV Technical Specifications

The team has identified vehicle technical specifications for MHD 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 B1 in Appendix B 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 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 B2 in Appendix B lists technical specifications for selected MHD 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.

1.5 Fuel and Energy Requirements

1.5.1 Estimated Hydrogen Fuel and Electric Energy Use

Table 4 presents estimated daily requirements for hydrogen fuel and electric energy for MHD ZEVs within the SCAQMD area, projected for the years 2025, 2030, and 2040. The VMT values, obtained from Table 3, 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% for 2030 and again increased by 10% for 2040, assuming technology development and efficiency improvements. The analysis assumes 8% 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% for 2030 and by 10% for 2040.

Table 4: MHD 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: South Coast Air Quality Management District

Table 5 lists the estimates of the required number of BEV charging and hydrogen fueling stations, serving MHD ZEVs within the SCAQMD region in 2025, 2030, and 2040. The estimates are based on hydrogen fuel and electric energy requirements in Table 4. 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 are likely needed initially to support early adopters of MHD ZEVs, resulting in higher station to vehicle ratios.

As evident from Table 3, in the year 2025 large portion of MHD 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 5: Number of Public MHD BEV Charging and Hydrogen Fueling Stations

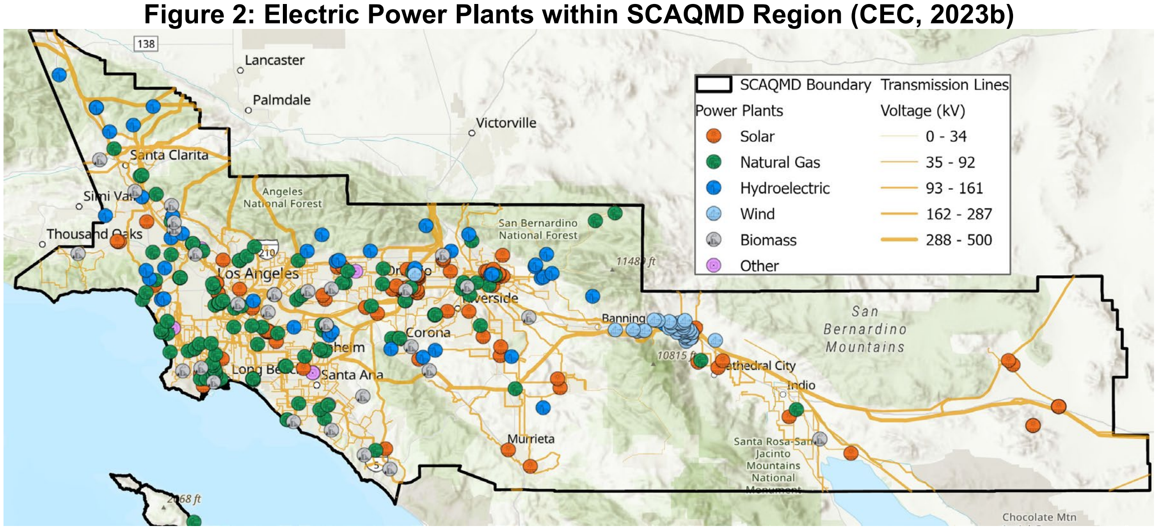
Year	2025		2030		2040	
Station Type	EV	Hydrogen	EV	Hydrogen	EV	Hydrogen
Number	up to 30	up to 15	105	52	224	165

Source: University of California, Riverside

1.5.2 Current Electricity Production

Figure 2 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.

Figure 2: Electric Power Plants within SCAQMD Region (CEC, 2023b)

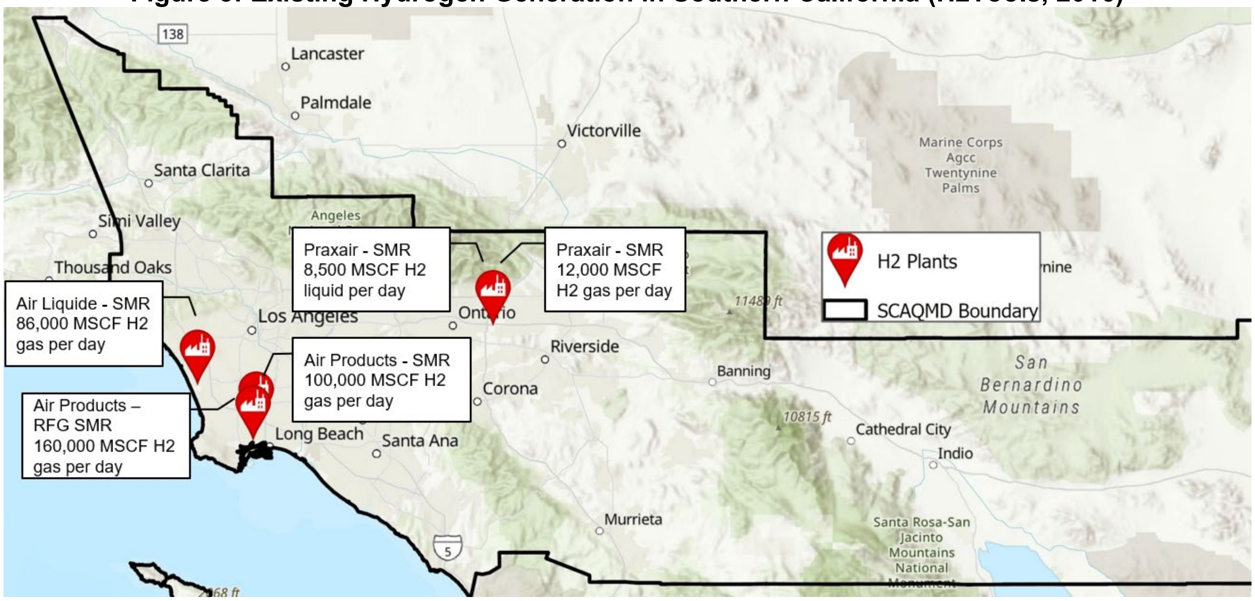


Source: California Energy Commission

1.5.3 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 3. 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 2 shows daily production capacities in 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 3: Existing Hydrogen Generation in Southern California (H2Tools, 2016)



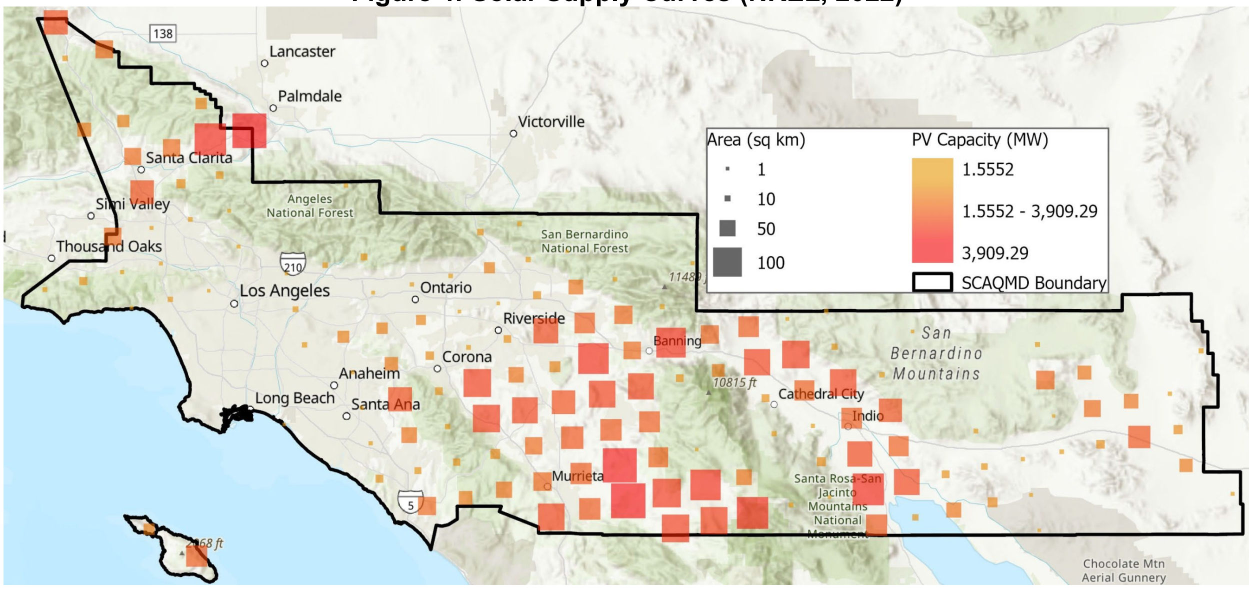
Source: Hydrogen Tools

1.5.4 Renewable Energy 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 MHD 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 4 presents an analysis from NREL (2022) on the potential for renewable solar energy production in the SCAQMD region. The analysis takes into account several factors, including land availability, capacity factors, and proximity to transmission systems.

Figure 4: Solar Supply Curves (NREL, 2022)



Source: National Renewable Energy Laboratory

CHAPTER 2: Station Location Evaluation

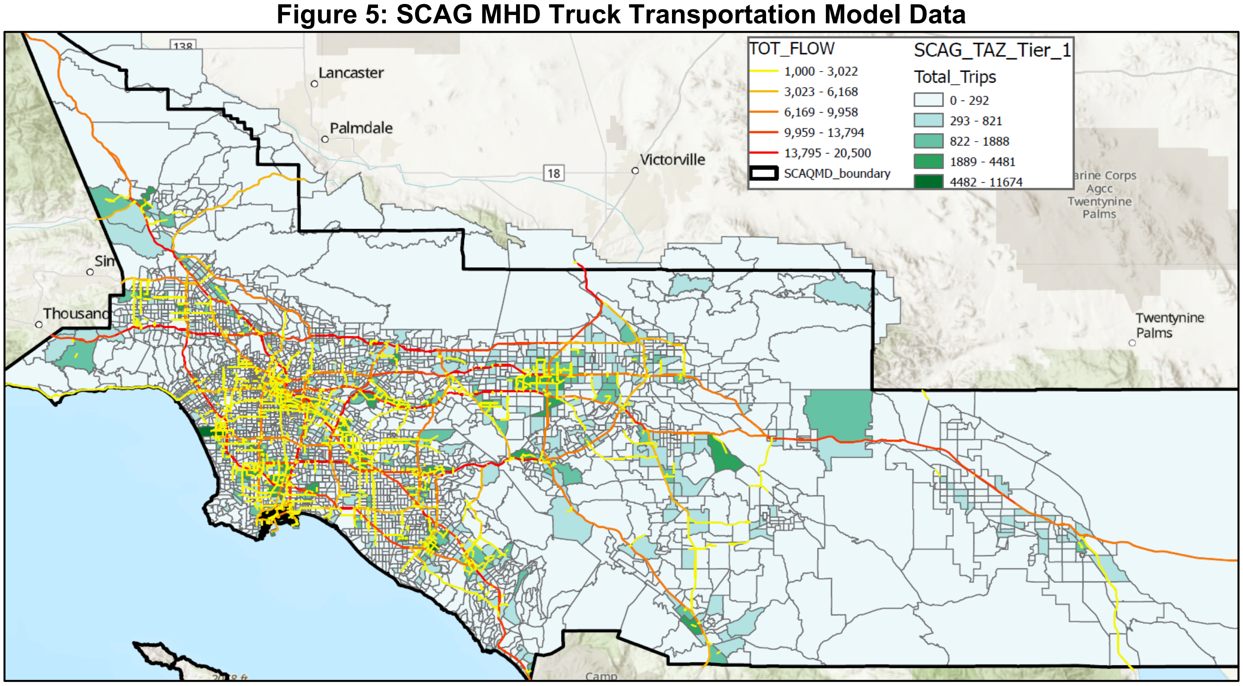
2.1 Traffic Analysis

To identify potential candidate locations 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 5 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 5, 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 FCETs) will be evenly distributed 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.

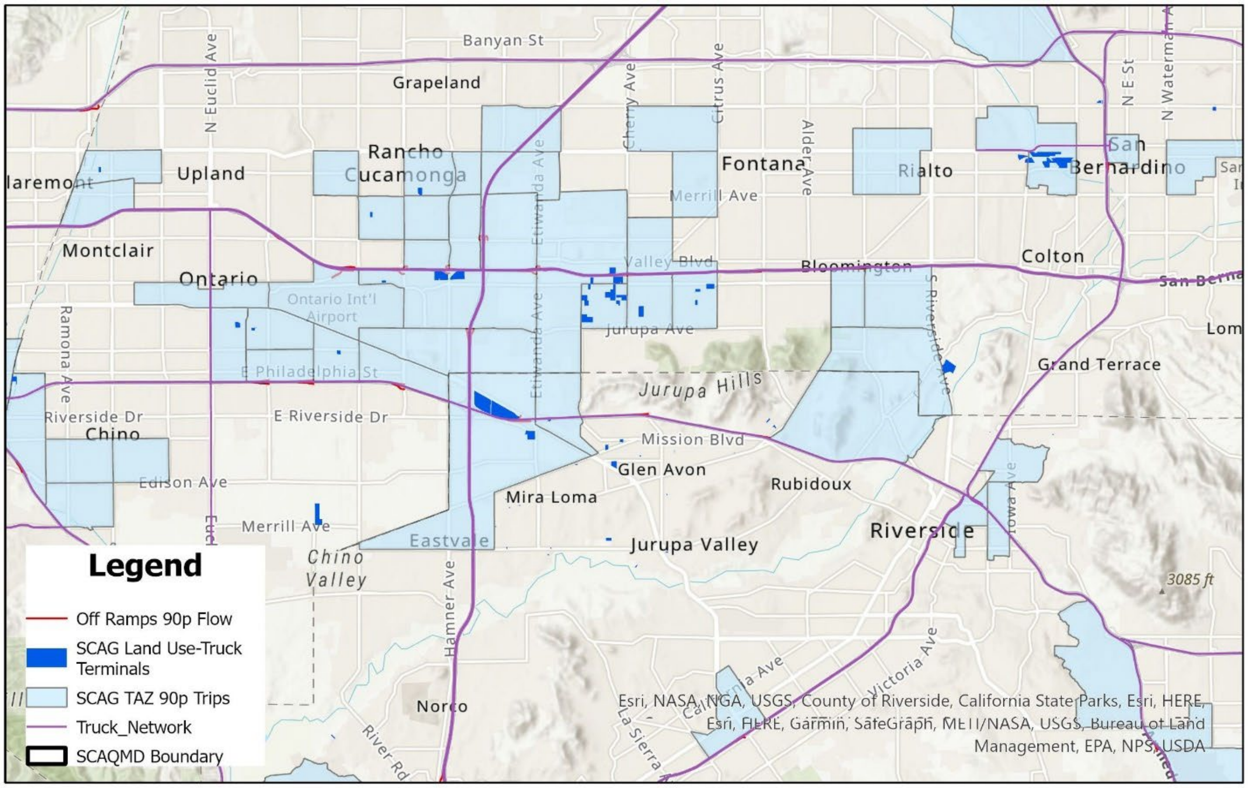
Figure 5: SCAG MHD Truck Transportation Model Data



Source: Southern California Association of Governments

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 6 shows a map of an area within Riverside County, with truck terminals shown in dark blue.

Figure 6: SCAG Land Designation Data



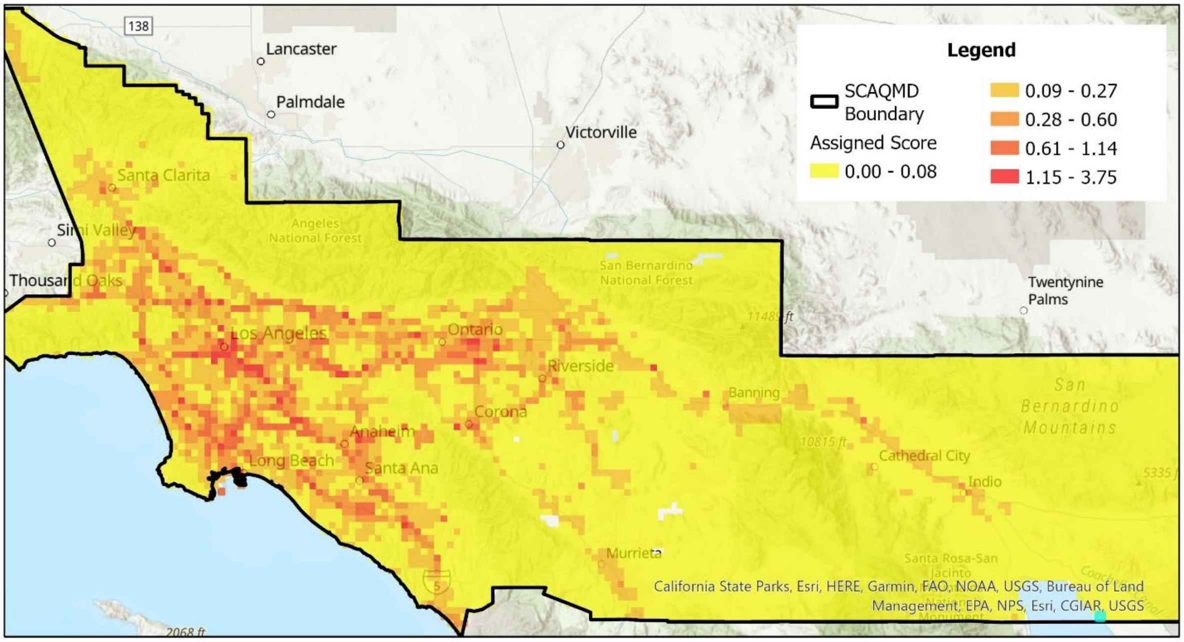
Source: University of California, Riverside

In addition to truck terminals, Figure 6 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.

2.2 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, as shown in Figure 6. 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, 2023b). 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 7 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 MHD 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 MHD vehicle charging and hydrogen fueling infrastructure. Specific locations will be dependent upon zoning, current land use, permitting, ordinances, local regulations, and other parameters.

Figure 7: Charging/Fueling Station Location Preference



Source: University of California, Riverside

CHAPTER 3: Benefit Analysis

3.1 Methodology

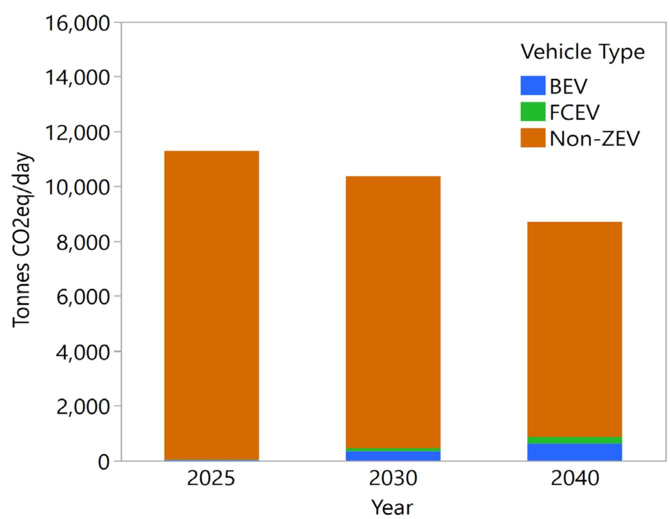
The estimated reduction of greenhouse gas and criteria air pollutant emissions is based on estimated MHD ZEV VMTs deployed within the SCAQMD in the years 2025, 2030, and 2040 listed in Table 3. The GHG emission reductions were calculated by conducting a Life Cycle Assessment (LCA) using the CA-GREET 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).

The 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 CO2eq (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 (NOX), sulfur oxides (SOX), particulate matter (PM) with particle diameter of 10 μm or less (PM10), and particulate matter with particle diameter of 2.5 μm or less (PM2.5).

3.2 GHG Emissions Reduction

Estimated life cycle GHG emissions from the MHD transportation sector for the SCAQMD region are shown in Figure 8. The GHG in tonnes of CO2eq per day are estimated for 2025, 2030, and 2040. While the GHG emissions reductions from 2025 to 2030 are fairly small, they reach 23% 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 transportation sector was responsible for 37% of total GHG emissions in the state, while HD vehicles contributed to 24% of transportation GHG emissions (CARB, 2022b).

Figure 8: Estimated SCAQMD Region MHD GHG Emissions

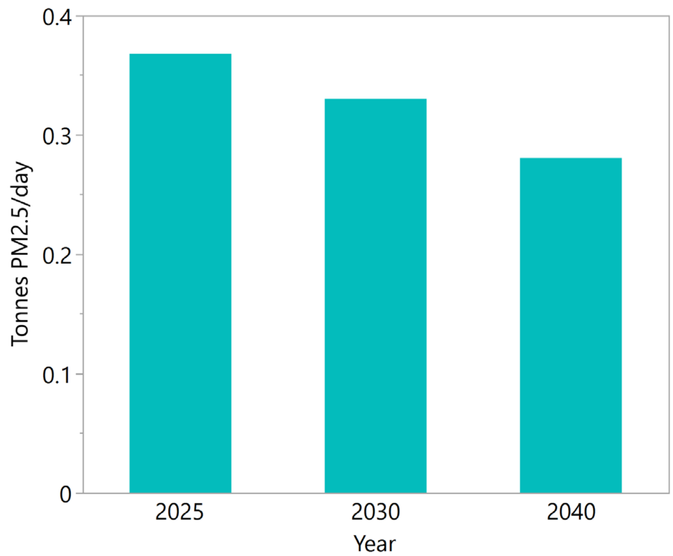


Source: University of California, Riverside

3.3 Criteria Air Pollutant Emissions Reduction

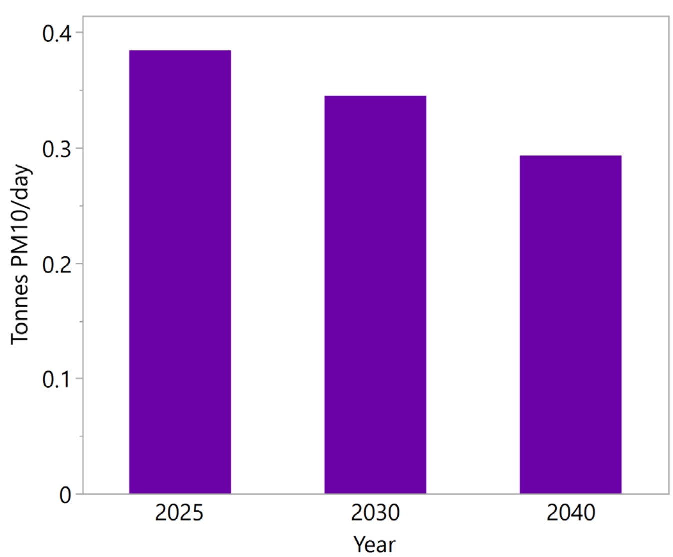
Figure 9 shows estimated tailpipe emissions of MHD vehicle PM2.5 for 2025, 2030, and 2040, within the SCAQMD region, measured in tonnes per day. Figure 10 shows emission estimates for PM10 for 2025, 2030, and 2040. Since the PM2.5 and PM10 emissions reported here originate from vehicle exhaust, the majority can be considered diesel PM. MHD ZEV deployment is the primary contributor to the reductions of PM emissions from 2025 to 2040.

Figure 9: Estimated SCAQMD Region MHD $PM_{2.5}$ Emissions



Source: University of California, Riverside

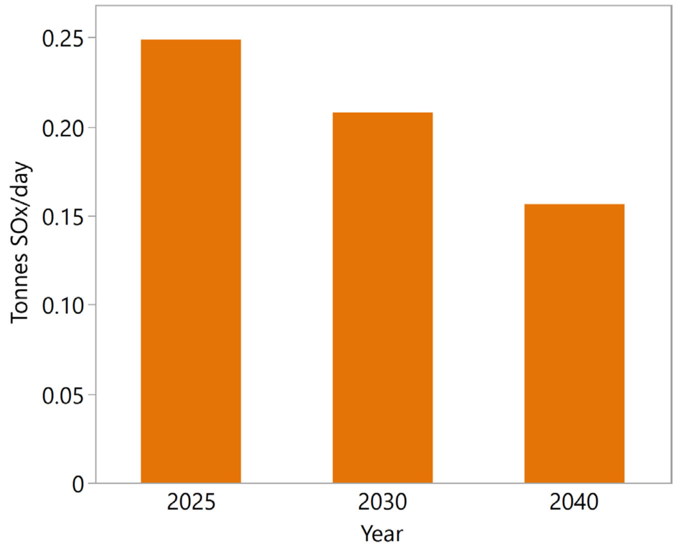
Figure 10: Estimated SCAQMD Region MHD PM_{10} Emissions



Source: University of California, Riverside

Figure 11 shows estimated MHD vehicle SOX emissions within the SCAQMD region, for the years 2025, 2030, and 2040, in tonnes per day.

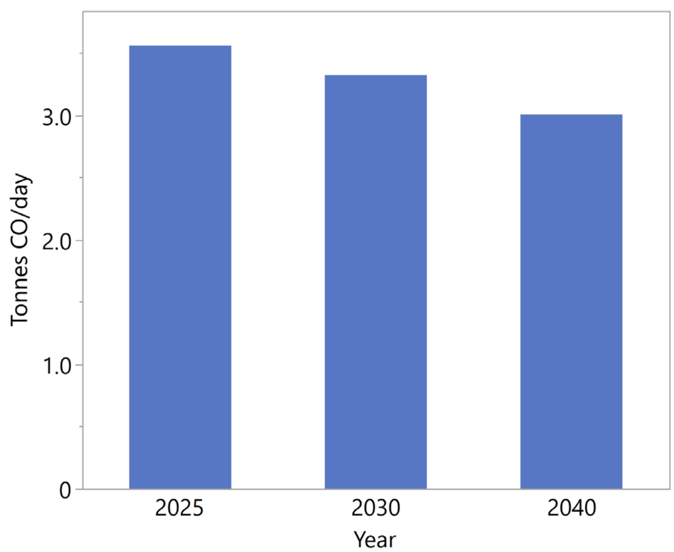
Figure 11: Estimated SCAQMD Region MHD SO_X Emissions



Source: University of California, Riverside

The bar chart in Figure 12 shows estimated CO emissions of MHD vehicle within the SCAQMD region, for the years 2025, 2030, and 2040, in tonnes per day.

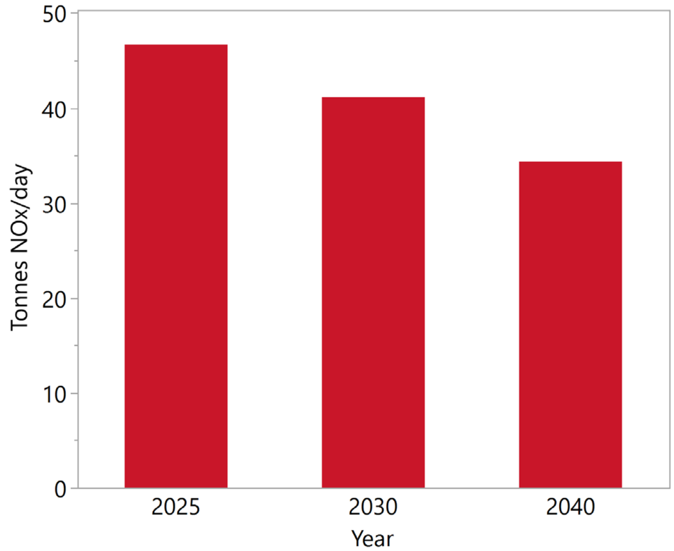
Figure 12: Estimated SCAQMD Region MHD CO Emissions



Source: University of California, Riverside

The bar chart in Figure 13 represents estimated MHD vehicle NOX emissions within the SCAQMD region in 2025, 2030, and 2040, in tonnes per day.

Figure 13: Estimated SCAQMD Region MHD NOx Emissions



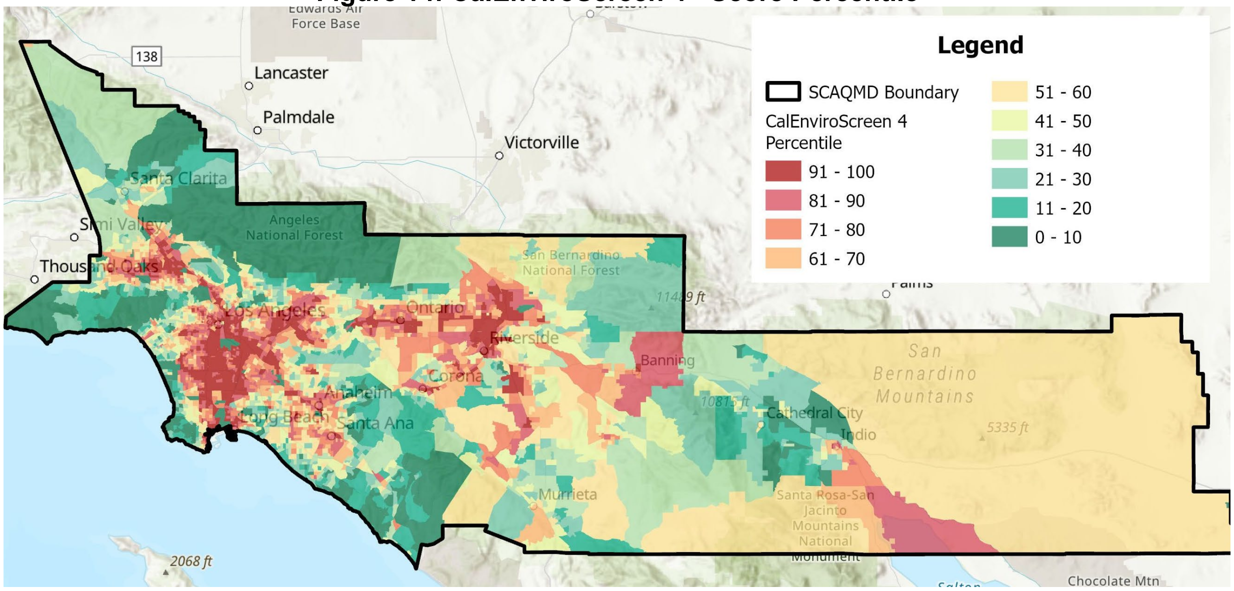
Source: University of California, Riverside

3.4 Health Benefits to Local and Disadvantaged Communities

According to CARB, mobile source related emissions contributed to 90% of smog-forming NO_X and 90% 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 14 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% for the state. The Figure shows the overall score. However, this report only evaluates the air pollution impacts of MHD ZEV deployment in the region. The air pollution scores are shown in Figures 15 through 18.

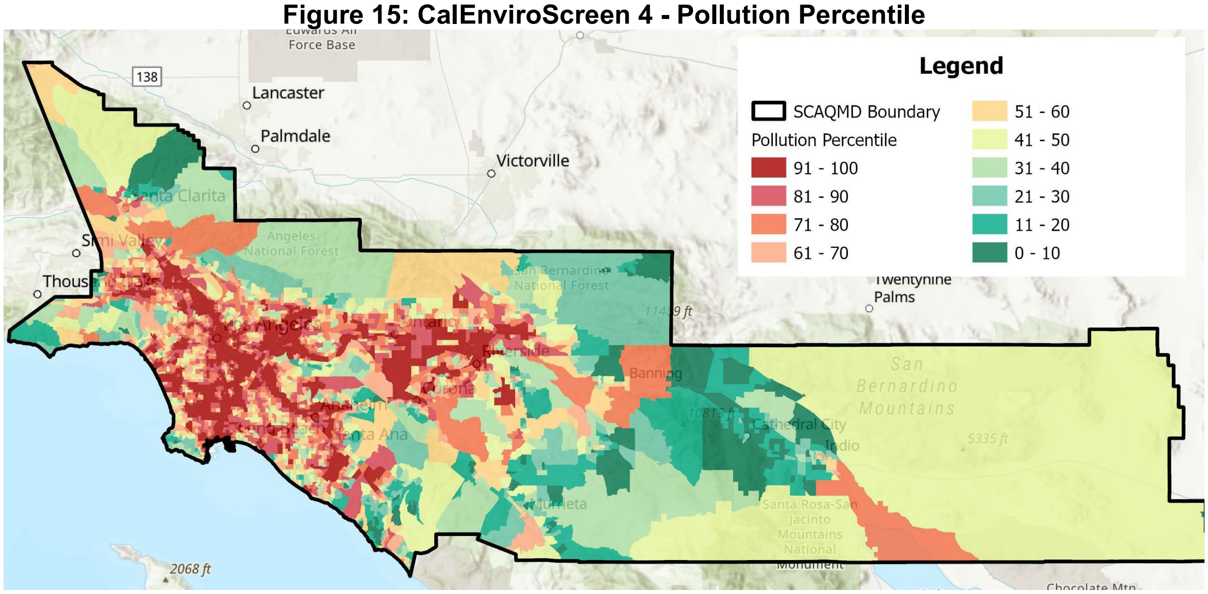
Figure 14: CalEnviroScreen 4 - Score Percentile



Source: CalEnviroScreen

Figure 15 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.

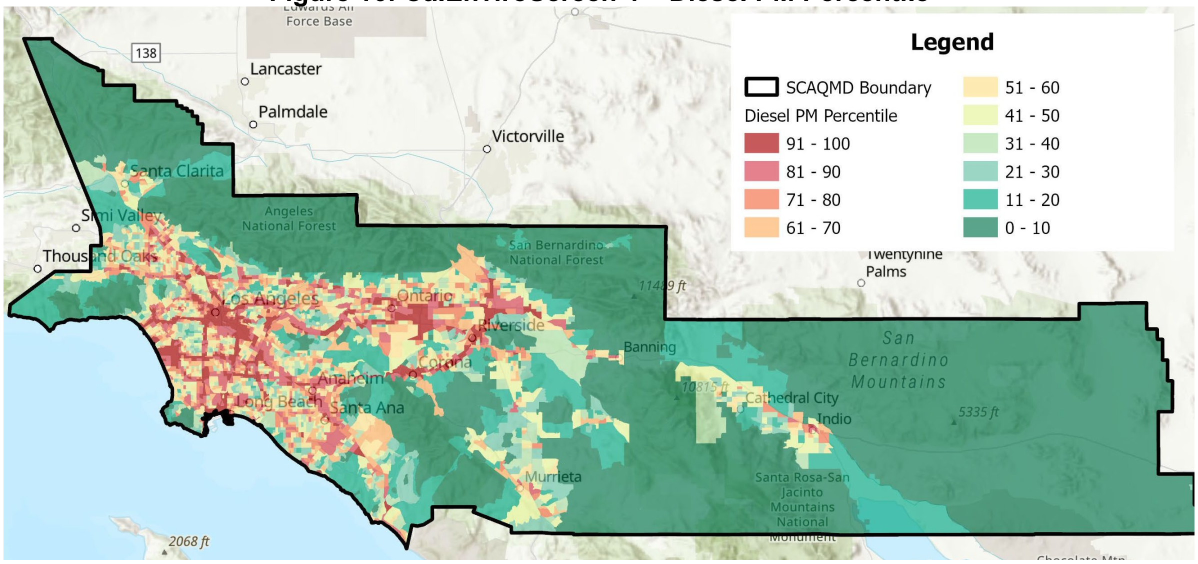
Figure 15: CalEnviroScreen 4 - Pollution Percentile



Source: CalEnviroScreen

Figure 16 shows the CalEnviroScreen 4.0 diesel PM state ranking for the tracts within the SCAQMD region. Since 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 MHD vehicles. Reducing transportation related PM emissions would directly reduce diesel PM in the air.

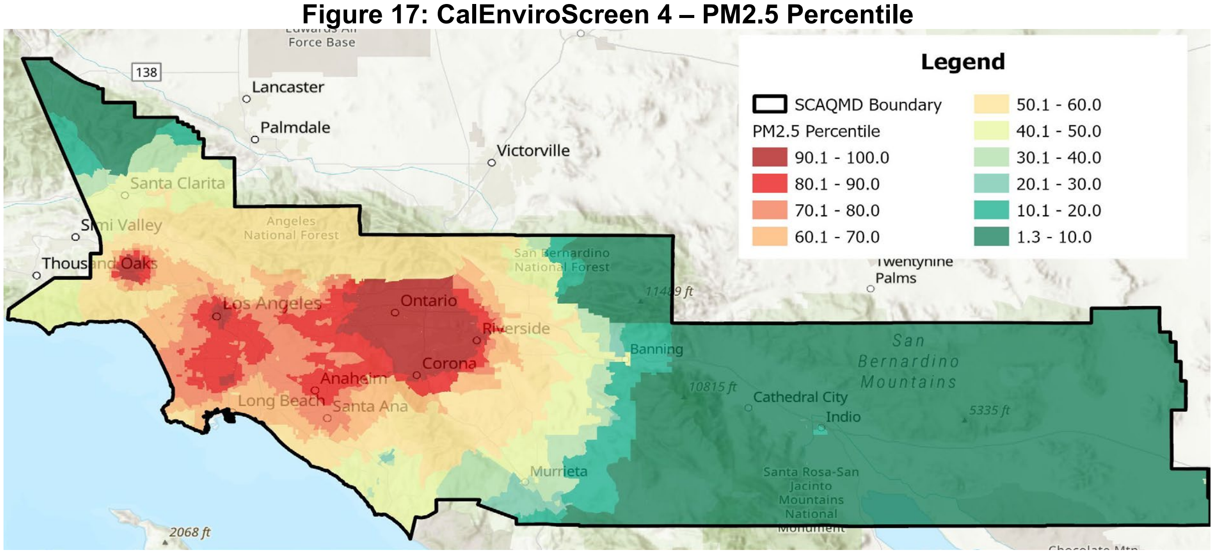
Figure 16: CalEnviroScreen 4 – Diesel PM Percentile



Source: CalEnviroScreen

The map in Figure 17 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 region, from Corona to Riverside and Ontario. As discussed in the previous section on criteria air pollutant emissions reduction, MHD vehicles contribute to $PM_{2.5}$ emissions, and reduction in transportation related $PM_{2.5}$ emissions would result in overall reduction of ambient $PM_{2.5}$.

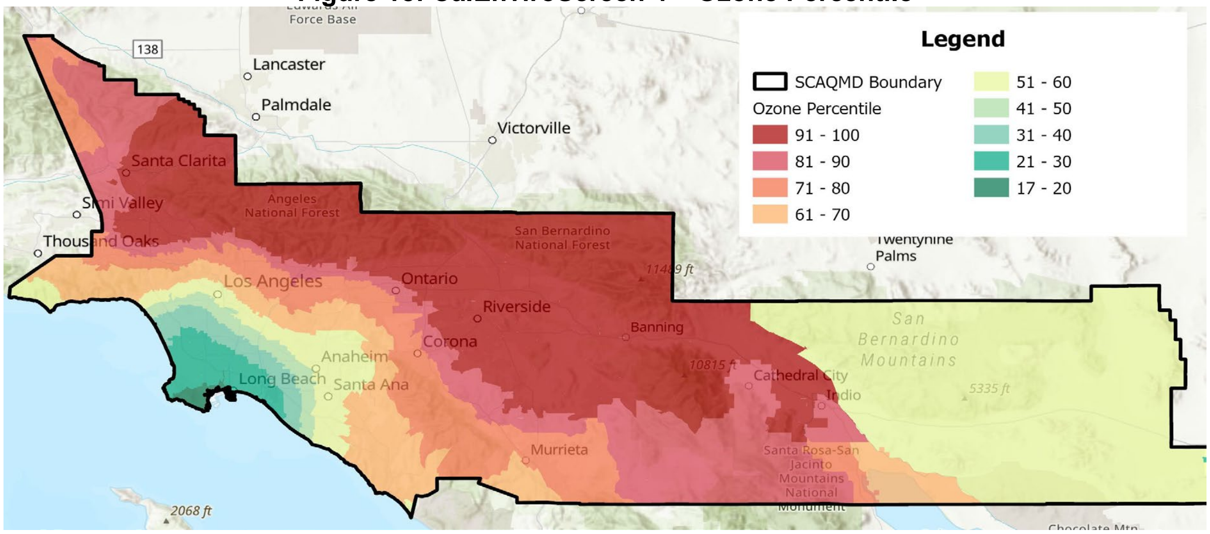
Figure 17: CalEnviroScreen 4 – PM2.5 Percentile



Source: CalEnviroScreen

Figure 18 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. NOx is a precursor of ozone, which has serious health impacts.

Figure 18: CalEnviroScreen 4 – Ozone Percentile



Source: CalEnviroScreen

3.5 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 MHD 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 MHD ZEVs deployed by 2040 in the SCAQMD territory. Economics of MHD 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 impact associated with the projected MHD ZEV infrastructure deployment.

CHAPTER 4: Candidate MHD BEV Charging and Hydrogen Fueling Stations

4.1 MHD ZEV Stations Specifications and Proposed Locations

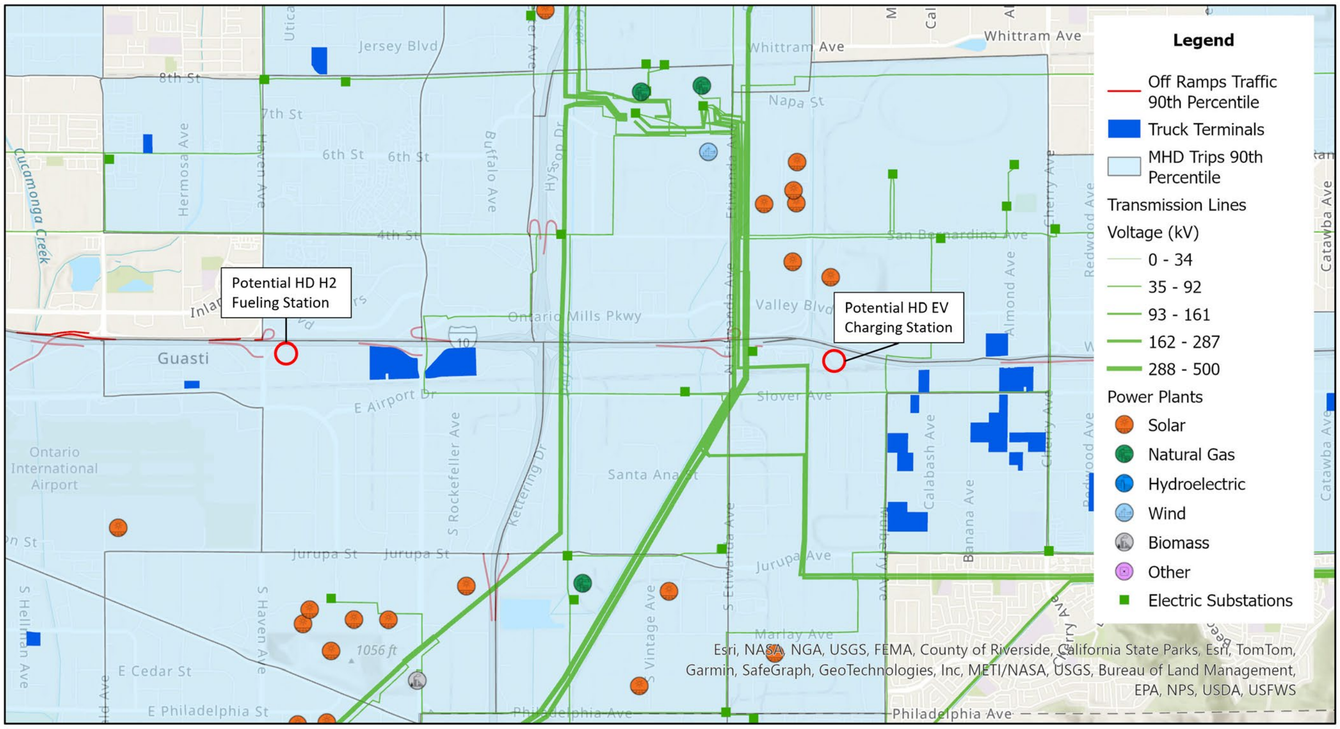
The candidate locations for a MHD BEV charging station and a hydrogen fueling station are shown on the map in Figure 20. Both are located near the intersection of Interstate 10 and Interstate 15, which is one of the hot spots on the heat map in Figure 8. Additional details regarding the site locations and station specifications for MHD BEV charging station and hydrogen fueling stations are provided in Table 6 and Table 7, respectively.

As evident from Figure 19, 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 MHD 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 MHD 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 MHD 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 19.

The proposed sites for station location are vacant parcels of land in commercial or industrial zones, as indicated in Tables 6 and 7. 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 19: Potential Candidate Sites for MHD ZEV Stations



Source: University of California, Riverside

Table 6: MHD 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 7: MHD Hydrogen Fueling Station Detail

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

4.2 MHD ZEV Stations Costs and Deployment Timelines

The estimated costs for building and operating the proposed MHD hydrogen fueling station are listed in Table 8, 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.

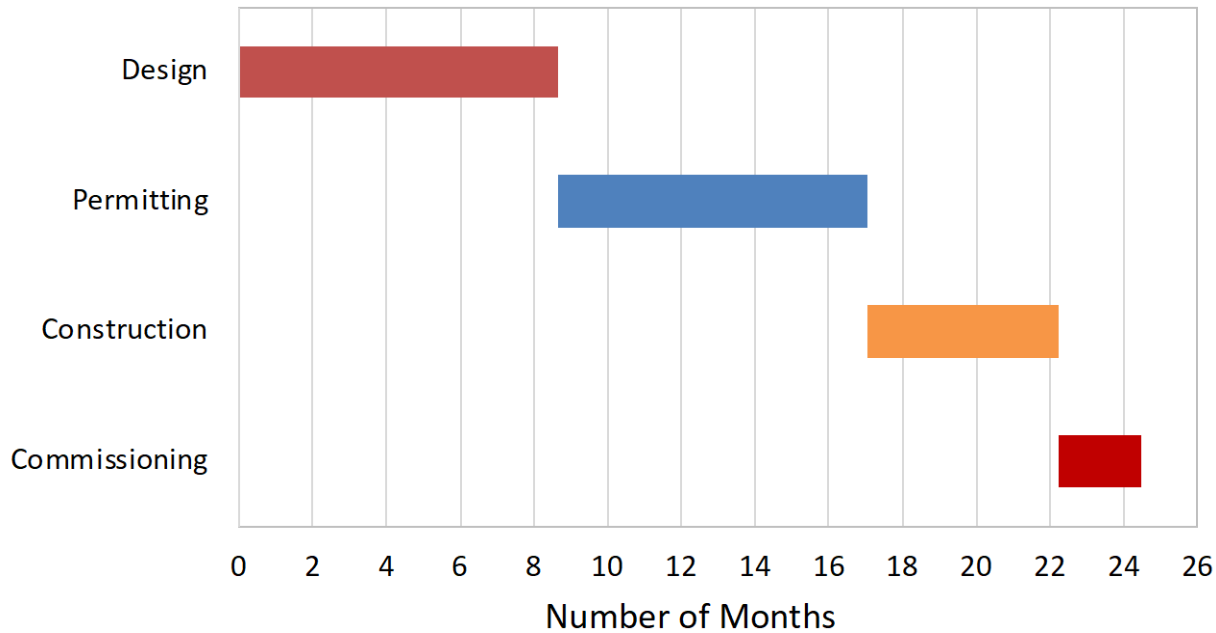
Table 8: MHD Hydrogen Fueling Station Cost Estimates

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% of Capital Cost
Rent	$48,000
Fixed Labor	3% 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 MHD hydrogen fueling system design, permitting, construction, and commissioning activities is show in Figure 20. These are based on the average timelines of actual hydrogen station projects (NREL, 2023).

Figure 20: MHD Hydrogen Fueling Station Deployment Timeline



Source: University of California, Riverside

The total installation costs of the MHD 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 9 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).

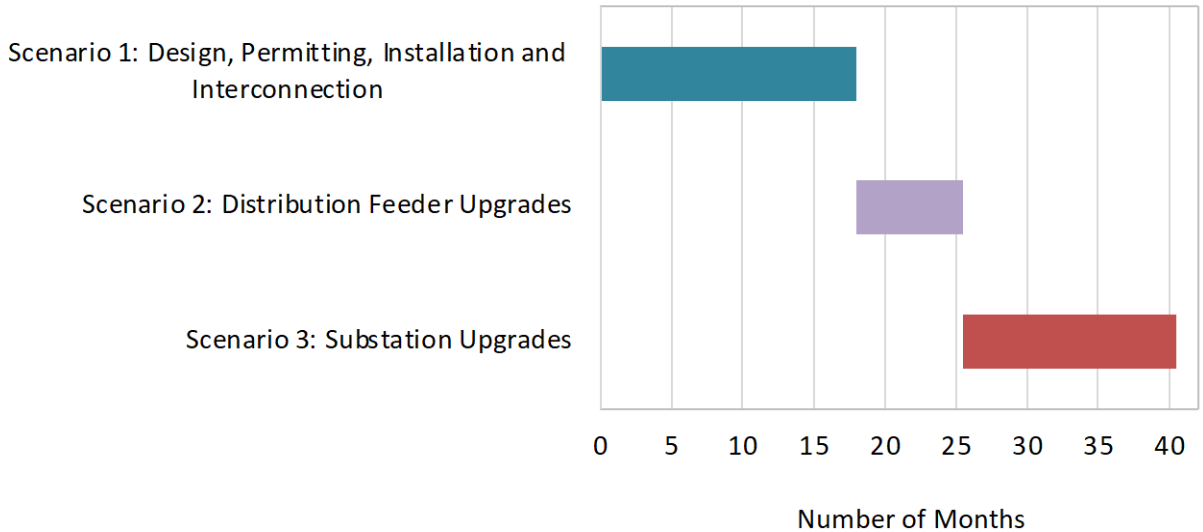
Figure 21 shows the timeline for deployment of the proposed MHD BEV charging station under the three different scenarios. We use the average values reported by Borlaug et al., 2021.

Table 9: MHD 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 21: MHD BEV Charging Station Deployment Timeline



Source: University of California, Riverside

4.3 MHD ZEV Maintenance and Service Requirements

The MHD ZEV industry acknowledges and recognizes the need for enhanced service and maintenance capabilities associated with future MHD 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 MHD 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 MHD 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 MHD ZEV station has at least one service bay to accommodate

MHD 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 MHD ZEV deployments increase over time and the ZEV fleet ages, the need for additional MHD ZEV maintenance and service facilities will increase.

CHAPTER 5: Summary and Conclusions

The blueprint presented in this report offers review and analysis of the requirements for developing an infrastructure to support existing and future MHD ZEVs within the South Coast region. The analysis is conducted using a model that projects the MHD 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 MHD 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 MHD 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 MHD 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 MHD 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 MHD 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 MHD 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 MHD ZEV deployment and the number of jobs created were estimated for the analysis period. The planned ZEV transition of the MHD transportation sector will result in significant GHG and criteria pollutant emission reduction benefits for the region, including in disadvantaged communities.

The methodology and data from this project can serve as a basis to identify future MHD ZEV infrastructure needs and develop deployment strategies within the SCAQMD territory. MHD 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 MHD fleet to battery electric and hydrogen fuel cell drivetrains.

GLOSSARY

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
CAAA	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
FCEV	Fuel Cell Electric Vehicle
GHG	Greenhouse Gas
GVWR	Gross Vehicle Weight Rating
GWP	Global Warming Potential
HD	Heavy-duty
ICCT	International Council for Clean Transportation
MD	Medium-duty
MHD	Medium- and Heavy-duty
MSR	Methane Steam Reforming
N_2O	Nitrous Oxide
NACS	North American Charging Standard

NOx	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
RCLAIM	Regional Clean Air Incentive Market
SAE	Society of Automotive Engineers
SCAG	Southern California Association of Governments
SCAQMD	South Coast Air Quality Management District
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: EMFAC Vehicle Inventory Definitions

Table A1: EMFAC MHD 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

APPENDIX B: MHD ZEV Specifications

Table B1: MHD 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 B2: MHD 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