Los Angeles County
Metropolitan Transportation Authority

CLEAN TRUCK TECHNOLOGY COMPARATIVE REPORT 4

Fueling and Charging Infrastructure: Estimated Energy and Infrastructure Needs, and Costs

METRO GOODS MOVEMENT PLANNING



Metro

MAY 2022

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Nomenclature

ACF	Advanced Clean Fleets
ACT	Advanced Clean Trucks
BET	Battery Electric Truck
BEV	Battery-Electric Vehicle
bph-hr	brake horsepower-hour
CAIRP	California Registered International Registration Plan
CARB	California Air Resources Board
CNG	Compressed natural gas
dge	Diesel gallon equivalent
DPM	Diesel Particulate Matter
EMFAC	EMission FACtor
EPA	Environmental Protection Agency
EVSE	Electric Vehicle Service Equipment
FCET	Fuel Cell Electric Truck
FCEV	Fuel Cell Electric Vehicle
gCO2e/MJ	Grams of carbon dioxide equivalent per megajoule
GHG	Greenhouse Gas
GO-BIZ	Governer's Office of Business and Economic Development
HDV	Heavy-duty vehicle
LCFS	Low Carbon Fuel Standard
LDV	Light-duty vehicle
LNG	Liquified natural gas
MHD	Medium- and heavy-duty
NH3	Ammonia

NOx	Nitrogen oxides
NREL	National Renewable Energy Laboratory
NZE	Near-Zero Emission
PM	Particulate matter
RD	Renewable diesel
RH2	Renewable hydrogen
RMP	Rocky Mountain Power
RNG	Renewable natural Gas
SMR	Steam-methane reforming
SO2	Sulfur dioxide
ULSD	Ultra-low sulfur diesel
VMT	Vehicle Miles Traveled
VOC	Volatile organic compounds
WTW	Well-to-Wheel
ZE	Zero-Emission
ZEV	Zero-emission vehicle

1 Introduction

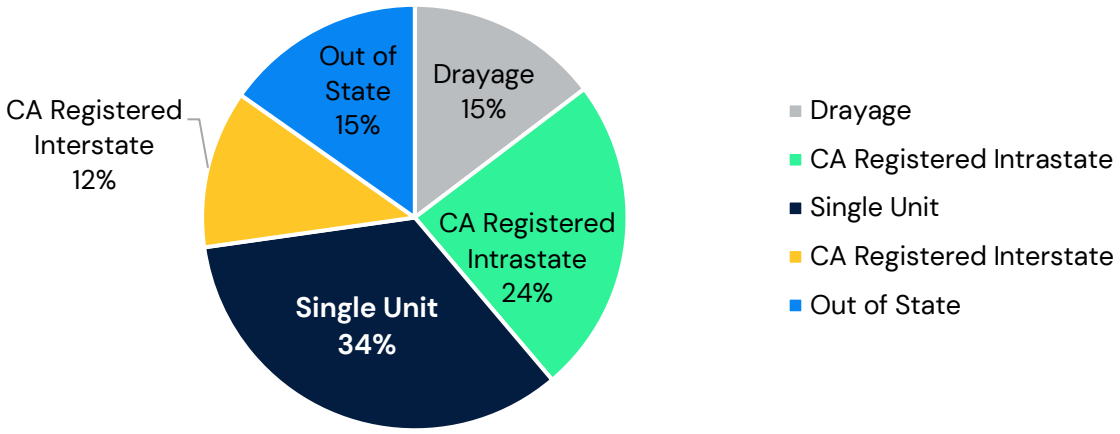
The composition of the Los Angeles (L.A.) County's heavy-duty truck fleet is expected to change substantially over the next two decades in response to climate-focused regulations. Report 3: Technology Mix for Meeting Public Health and Climate Goals determined the technology mix of the Class 8 truck fleet to meet local public health, regional air quality, and climate goals. This report will take the fleet modeling outputs from Report 3 and estimate the number and type of charging and fueling stations needed to sufficiently serve the new Class 8 technology mix in L.A. County. Of particular importance is the zero-emission vehicle technologies, including battery electric and hydrogen fuel cell electric trucks. The projected deployment of Class 8 battery electric truck (BET) and hydrogen fuel cell electric trucks (FCET) needed to comply with current and upcoming emission standards presents unique charging and fueling challenges. This report seeks to understand the fueling and charging needs of L.A. County's changing heavy-duty truck fleet as well as the associated costs.

This report starts by describing the current state of fueling infrastructure technology for diesel, natural gas, electric vehicle supply equipment (EVSE), and hydrogen. Next, the technology mix outputs are used to model the projected energy and fueling needs of the changing fleet, which is then used to determine the number of charging and fueling stations necessary to accommodate the increase in these Class 8 truck powertrains. The final section of this report presents cost projections based on the number and type of charging and fueling stations. Infrastructure costs are presented for each fuel type as well as the total infrastructure costs across all fuels collectively.

2 Vehicle Technology Mix Summary

The current Class 8 truck mix in L.A. County, as was discussed in Report 1: Baseline Conditions, consists of five categories including trucks registered in California - Single Unit, CAIRP Interstate, CAIRP Intrastate, and Drayage trucks - as well as trucks registered Out of State and operating within Los Angeles County. Single unit and intrastate trucks make up over half of the Class 8 trucks in L.A. County, while the remaining three vehicle categories make up the rest (Figure 1). These vehicle categories, which operate under different duty cycles depending on their function, are an important consideration when assessing the future technology mix for the immediate- (1-3 years). short- (4-6 years), medium- (7-9 years), and long-term (10+ years) timeframes.

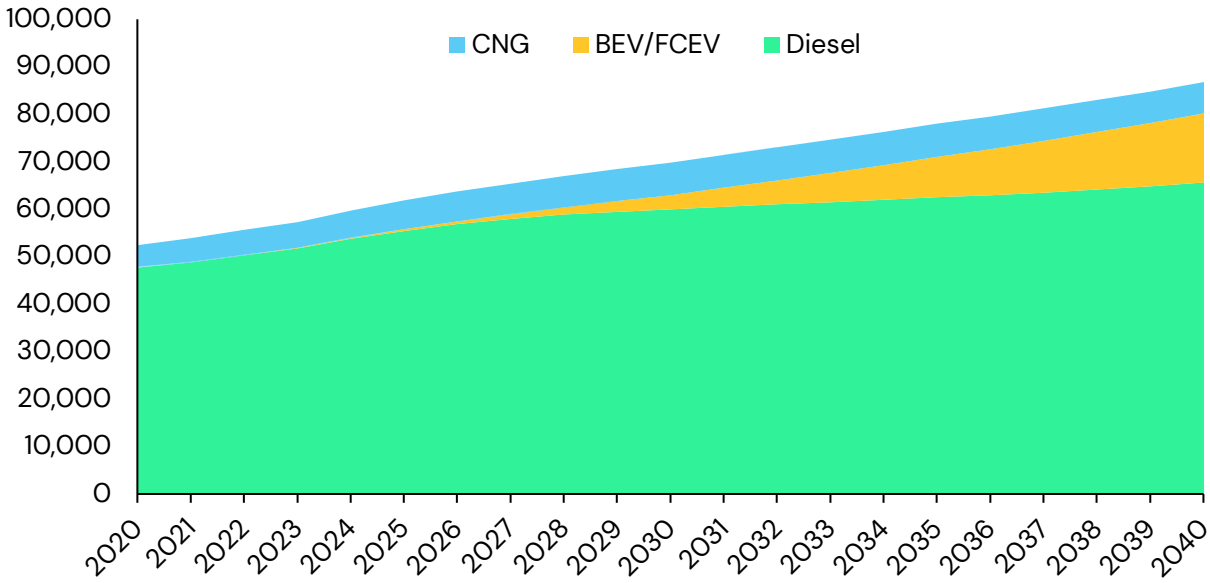
Figure 1 - Class 8 Trucks by Vehicle Category, Los Angeles County



In Report 3, the Class 8 technology mix, or the number of trucks by fuel type, was projected to 2040. To conduct this technology forecast, a baseline was developed based on the California Air Resources Board's (CARB) Emission FACtors (EMFAC) 2021 model. EMFAC2021 reflects relevant heavy-duty

policies including CARB's Advanced Clean Trucks (ACT) regulation[1], CARB's Heavy-Duty Omnibus regulation[2], United States Environmental Protection Agency's and the National Highway Traffic Safety Administration's Phase 1 and Phase 2 greenhouse gas (GHG) standards[3], and CARB's Truck and Bus regulation[4]. It is important to note, however, that, of these policies, the ACT is the only one that impacts the Class 8 truck technology mix. Figure 2 shows the baseline population of all Class 8 trucks by fuel type.

Figure 2 - Population of All Class 8 Trucks - Baseline Scenario

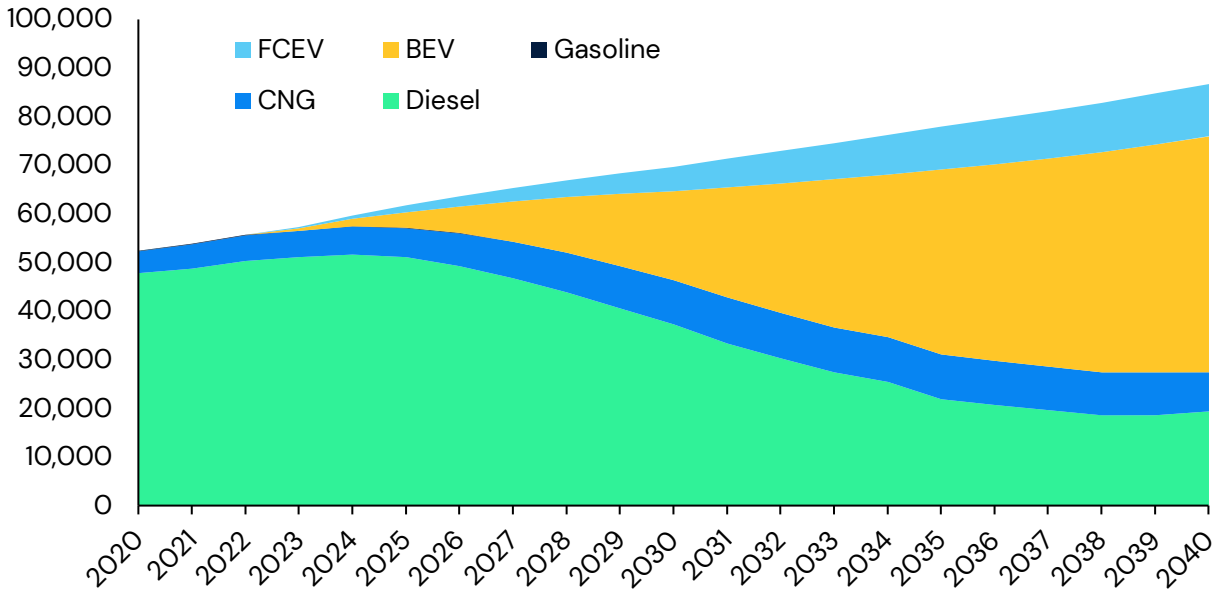


California's Advanced Clean Fleets (ACF) regulation sets heavy-duty ZEV adoption targets for fleets that operate in California. This project used targets set forth in the ACF to forecast the Class 8 truck vehicle mix through 2040 (Figure 3). Please see Report 3 (Technology Mix for Meeting Public Health and Climate Goals) for more information on how the ACF was used to develop the forecasted technology mix in Figure 3. This projected technology mix gradually replaces Class 8 diesel trucks through 2028; however, by 2030 and through 2040, the share of Class 8 BETs increases more rapidly. The share of FCET trucks is projected to increase moderately, while the share of compressed natural gas (CNG) trucks remains relatively stable through 2040.

For a comprehensive discussion of the vehicle technology mix, see Report 3: Technology Mix for Meeting Public Health and Climate Goals.

[1] Advanced Clean Trucks | California Air Resources Board
[2] Heavy-Duty Omnibus Regulation | California Air Resources Board
[3] Final Rule for Phase 1 Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles | US EPA
[4] Truck and Bus Regulation | California Air Resources Board

Figure 3 – Population of all Class 8 Trucks – ACF Scenario

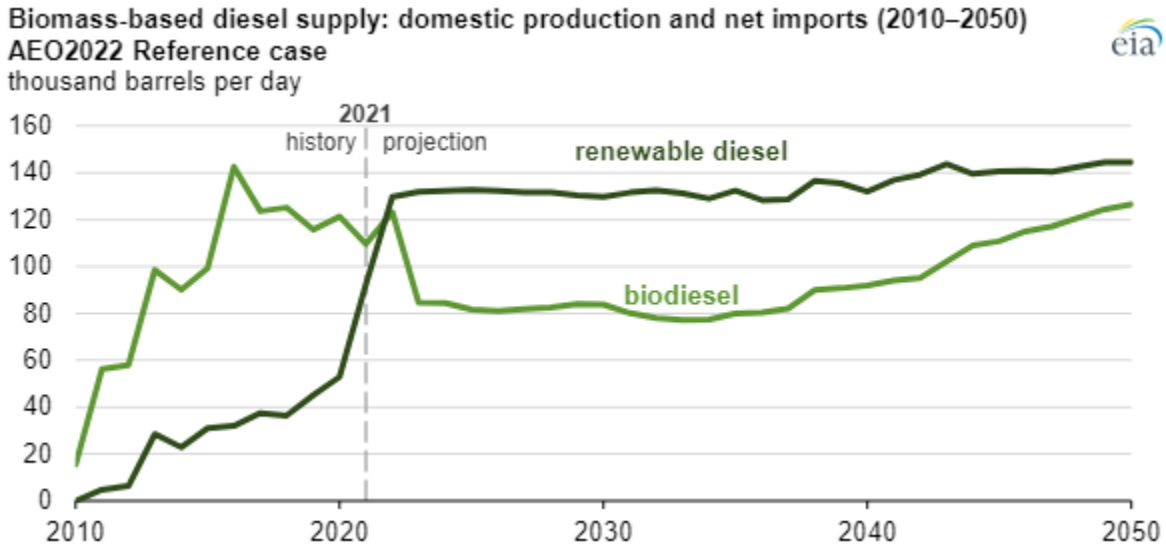


3 Overview of Infrastructure Technologies, Options, and Suitability for Various Use Cases

3.1 Diesel

Heavy-duty vehicles have long been fueled by diesel fuel due to their operational reliability and maturity in the market as well as the availability of diesel fueling infrastructure. However, as consequences to climate and public health became more apparent and urgent, the transportation industry is seeking to develop incrementally more sustainable forms of diesel. Renewable diesel (RD) is identical to conventional diesel but is produced predominately from fats/oils and fermentation of sugar. Although RD has a higher cetane rating, which means it burns more completely, due to aftertreatment technologies and PM filters in Class 8 trucks, renewable diesel produces the same tailpipe emissions as conventional diesel. It is estimated that RD produces up to 85 percent fewer lifecycle emissions depending on the feedstock and facility compared to conventional diesel.[5] Production of renewable diesel in the United States has seen a considerable rise since 2010 and is expected to surpass biodiesel and then remain relatively stable through 2050, according to EIA's Annual Energy Outlook 2022 (Figure 4). Importantly, RD and biodiesel are not the same fuel. RD is a diesel fuel produced from nonpetroleum renewable resources which is not a mono-alkyl ester and is regulated as a motor vehicle fuel or fuel additive under 40 Code of Federal Regulations part 79. Biodiesel, on the other hand, is a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats that is 99-100 percent biodiesel by volume, and it is produced via process called transesterification. Often, RD is considered a 'drop-in fuel', referring to its ability to be used in existing diesel engines, storage tanks, and other equipment without modification; biodiesel does not have the same capability.

Figure 4 - Current and Projected U.S. Renewable Diesel Production[6]

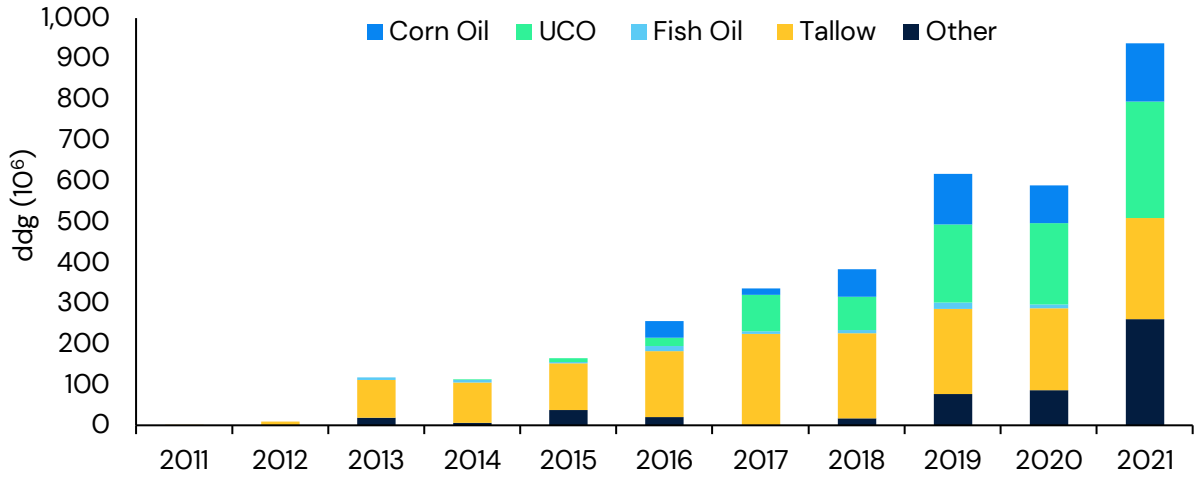


California RD production has followed a similar trajectory, with a steep increase since 2012. The highest levels of recent RD production occurred in 2021 at nearly 1 billion diesel gallon equivalent (dge) in 2021,

[5] Oregon DEQ. (n.d.). Renewable Diesel 101. Retrieved from https://www.oregon.gov/deq/FilterDocs/cfpdieselfaq.pdf
[6] EIA. (2022, March 24). EIA projects U.S. renewable diesel supply to surpass biodiesel in AEO2022. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=51778

as reported by CARBs Low Carbon Fuel Standard program. Used cooking oil (UCO), animal tallow, corn oil, and other materials were used as feedstocks to produce RD in 2021.

Figure 5 - California Renewable Diesel Total Volume by Feedstock[7]



In 2013, CARB adopted voluntary low nitrogen oxide (low NOx) emission standards for on-road heavy-duty engines to prepare the industry for future emission reduction mandates. This includes three standards: 0.02 grams of NOx per brake horsepower-hour (g/bph-hr), 0.05 g/bhp-hr, and 0.10 g/bhp-hr. While the voluntary program is open for diesel engine certification, the only engines that are certified as of February 2022 are natural gas or propane engines[8].

3.2 Natural Gas

Like diesel, alternatives to conventional natural gas are also available for use. Renewable natural gas (RNG), also referred to as biomethane, is a pipeline-quality gas that can be used interchangeably with conventional natural gas. RNG is produced through the decomposition of organic matter, most commonly through the collection of bio-gas from landfills, wastewater treatment plants, and livestock fertilizer. Increasingly, RNG – which can be converted into liquified natural gas (LNG) and compressed natural gas (CNG) – is used as a replacement fuel in natural gas vehicles, including heavy-duty trucks. In order to use RNG in vehicles, the biogas undergoes purification that removes water, carbon dioxide, hydrogen sulfide, and other trace elements. The upgrading process increases the methane content and produces a suitable transportation fuel.[9]

RNG is considered an advanced biofuel under the Federal Renewable Fuel Standard (RFS) program and is also a suitable fuel in California's LCFS program. Both programs – with the RFS acting as a floor for the biofuel market and the LCFS encouraging industry advancements – have helped to bring increasing volumes of RNG to market. According to CARB, the total volume of RNG tracked in the LCFS program for 2021 was over 50 million dge, primarily made using landfill gas as a feedstock.

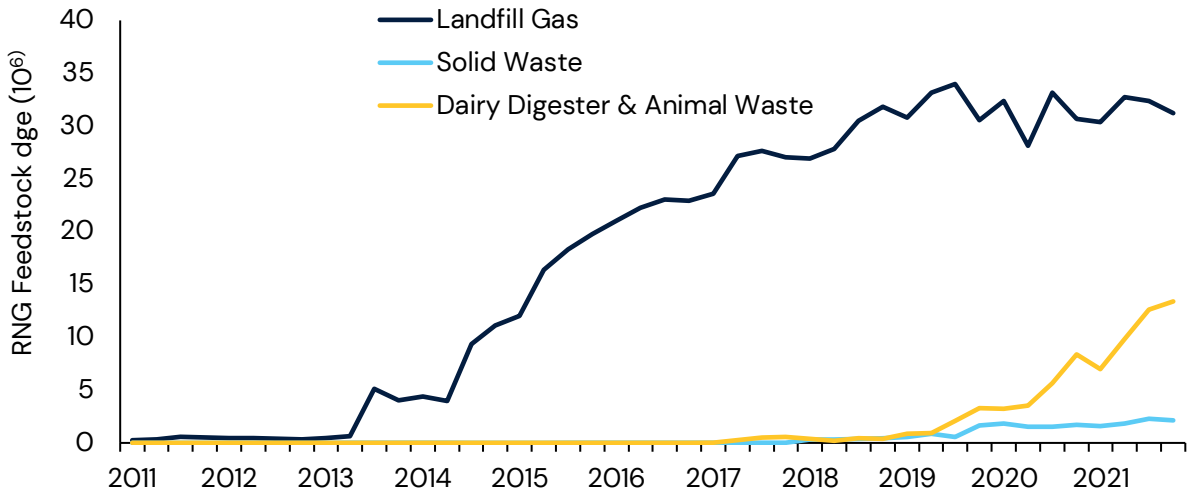
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[7] CARB. (2022, April 30). LCFS Quarterly Data Spreadsheet. Retrieved from https://ww2.arb.ca.gov/sites/default/files/2022-05/quarterlysummary_043022.xlsx

[8] https://ww2.arb.ca.gov/sites/default/files/2022-03/Optional%20Low%20NOx%20Certified%20Heavy-Duty%20Engines-as%20of%2002242022-1_0.pdf

[9] AFDC. (n.d.). Renewable Natural Gas Production. Retrieved from https://afdc.energy.gov/fuels/natural_gas_renewable.html#:~:text=Renewable%20natural%20gas%20%28RNG%29%20is%20a%20pipeline-quality%20gas,matter%29%20that%20has%20been%20processed%20to%20purity%20stand

Figure 6 – California RNG Total Volume by Feedstock[10]



As discussed in Section 3.1, low NOx engines are another emissions reduction technology which run on natural gas. As of February 2022, CARB has certified over 40 low NOx heavy-duty engines that run on natural gas.[11]

3.3 Battery Electric

Class 8 BETs will require a range of charging options to accommodate the diversity of trucking operations. As a simple example, trucks that operate solely in California and those that operate across state borders will travel different distances daily and annually; charging needs for trucks that stay within California will also vary greatly depending on their duty-cycle.

To meet the needs of the dynamic Class 8 vehicle market, innovations in charger technology are needed. While Level 2 chargers are more suitable for light- and medium-duty EVs, direct current fast chargers (DCFC) are more likely to be needed for Class 8 trucks. DCFCs can currently operate at power levels between roughly 20 kilowatts (kW) and 360 kW and offer a faster charge than Level 2 chargers. For example, a 150 kW and 350 kW DCFC can charge an electric truck in 1.2 hours and 0.5 hour, respectively, assuming a battery capacity of 175 kilowatt-hours (kWh). A more recent development within the industry is megawatt (MW) charging technology, which has the potential to significantly reduce charging dwell times. Leading the development of a Megawatt Charging System (MCS) is the member-based Charging Interface Initiative (CharIN). The MCS is designed to provide a maximum of 3.75 MW of charging power (Figure 7). It is expected that CharIN will publish the final MCS standard in 2024.[12]

[10] CARB. (2022, April 30). LCFS Quarterly Data Spreadsheet. Retrieved from https://ww2.arb.ca.gov/sites/default/files/2022-05/quarterlysummary_043022.xlsx

[11] https://ww2.arb.ca.gov/sites/default/files/2022-03/Optional%20Low%20NOx%20Certified%20Heavy-Duty%20Engines-as%20of%2002242022-1_0.pdf

[12] Inside EVs. (2022, June 15). CharIN Officially Launches The Megawatt Charging System (MCS). Retrieved from https://insideevs.com/news/592360/megawatt-charging-system-mcs-launch/

Figure 7 - The Megawatt Charging System (MCS) Connector



Connector standardization is also important to the success of heavy-duty EVSE development. While interoperability in charging infrastructure is improving over time, there remains a lack of standardization for charger connectors. Importantly, interoperability goes beyond connector standards; it also includes the software and communications connections between EVSE and charging networks. Table 1 shows existing and upcoming charging connector standards relevant to heavy-duty electric vehicles.

Table 1 - Existing and Upcoming Charging Connector Standards[13]

Diagram	Connector Standard	Maximum Output Power	Application Notes
	SAE J1772	19.2 kW AC	Used for Level 1 and Level 2 charging in North America. Commonly found on home, workplace, and public chargers.
	CCS[14]	450 kW DC	Used for DC fast charging most vehicle models in North America. Generally installed at public charging stations.[15]
	CHAdeMO	400 kW DC	Used for DC fast charging select vehicles models in North America. Generally installed at public charging stations.

[13] California Energy Commission. (2021, July). Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment Analyzing Charging Needs to Support ZEVs in 2030. Retrieved from https://efiling.energy.ca.gov/getdocument.aspx?tn=238853

[14] North American CCS standard is referred to as Type 1, CCS 2.0 is typically found in Europe.

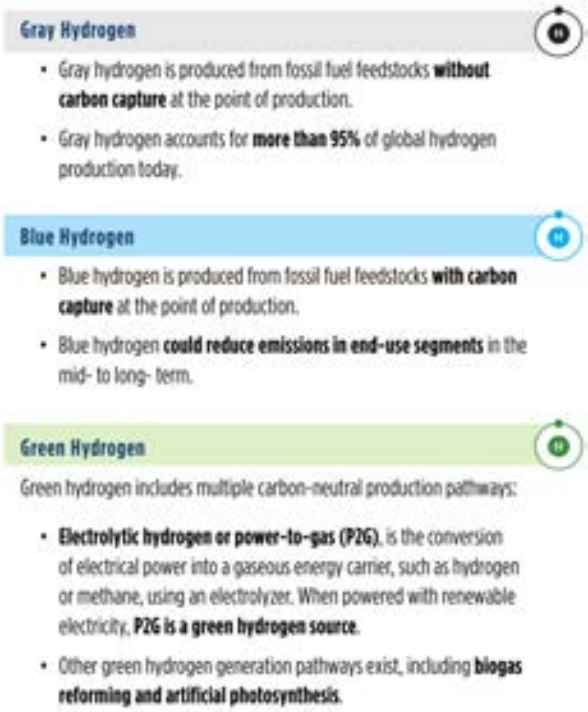
[15] Incentive funding provided by the federal government via the National EV Infrastructure (NEVI) Formula Program is contingent upon certain requirements including that the chargers must include at least four 150kW plugs with CCS ports. This requirement, however, is only to receive federal funding through the NEVI program. Entities can deploy CHAdeMO charger ports, but they will not qualify for federal NEVI funding. See NEVI funding guidelines here: https://www.fhwa.dot.gov/environment/alternative_fuel_corridors/nominations/90d_nevi_formula_program_guidance.pdf

	Tesla	22 kW AC 250 kW DC	Used for both AC and DC fast charging for Tesla models only.
	SAE J2954	22 kW light-duty, 200 kW MD/HD	Wireless power transfer. The standard for MD/HD vehicles is under development.
	SAE J3068	133 kW to 166 kW DC	Developed for three-phase charging, which the SAE J1772 and J1772 combo could only accommodate single-phase charging.
	SAE J3105	>1 MW	Automated connection device to charge MD/HD vehicles. Variants include pantograph “up” or “down” and pin-and-socket. LA Metro has already deployed this technology on the G/Orange Line,
	CharIN Megawatt Charging System	4 MW	Conductive MW-level charging for MD/HD road vehicles, ships and planes. The technical specification is expected in 2024.

3.4 Hydrogen

There are three types of hydrogen that are referred to by color and represent the type of energy used to produce the hydrogen fuel: gray hydrogen, blue hydrogen, and green hydrogen. Gray hydrogen is produced using fossil fuels, typically natural gas. Blue hydrogen is also produced from fossil fuel feedstocks, with the addition of carbon capture. Green hydrogen is produced using a zero-emission or carbon-neutral energy source such as wind, solar, and biomass (Figure 8).[16]

Figure 8 - Types of Hydrogen



In the U.S. and California, steam-methane reforming (SMR) is the most common hydrogen production method due to the abundance and low cost of natural gas. The process uses high-temperature steam to heat methane and produce hydrogen, with carbon-monoxide and carbon-dioxide as by-products.[17]

Renewable hydrogen (RH_2), which is also referred to as green hydrogen, is produced by splitting water into hydrogen and oxygen using renewable electricity or organic material (biomass). This process produces hydrogen and oxygen, whereby the hydrogen is collected and used in various end uses including as a transportation fuel. The oxygen is typically released as a by-product unless there is a local need for it. Renewable hydrogen can be produced using two technologies: electrolysis and anaerobic digestion, but thermochemical processes are currently in the commercial prototype phase. RH_2 technology options are summarized in

[16] CEC. (n.d.). Hydrogen Fact Sheet. Retrieved from https://www.energy.ca.gov/sites/default/files/2021-06/CEC_Hydrogen_Fact_Sheet_June_2021_ADA.pdf
[17] U.S. DOE. (n.d.). Hydrogen Production: Natural Gas Reforming. Retrieved from https://www.energy.gov/eere/fuelcells/hydrogen-production-natural-gas-reforming

Table 2.

Table 2 - Renewable Hydrogen Production Technology Summary[18]

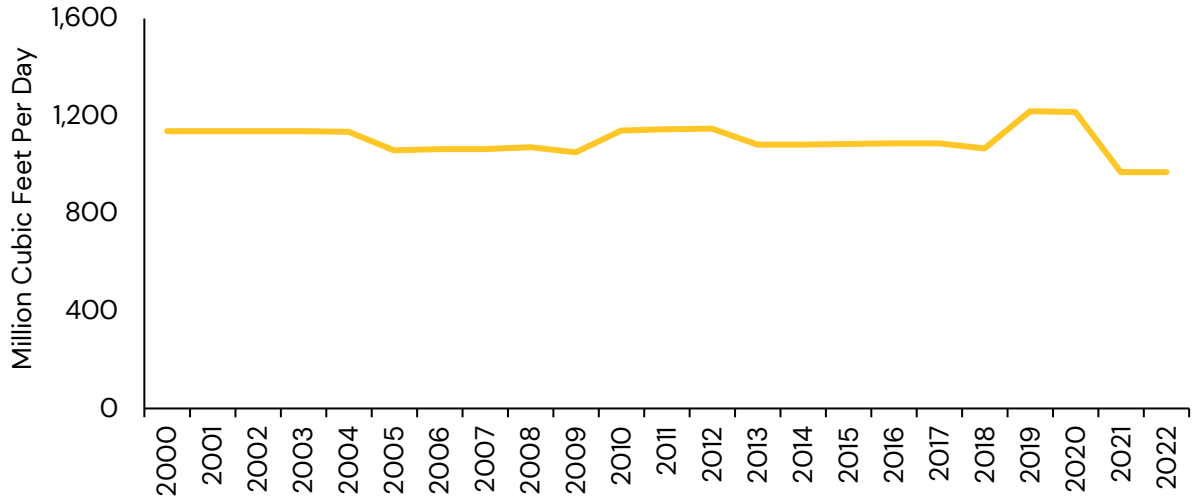
Technology Group	Subgroups	Description	Deployment Status
Electrolysis	• Alkaline • Polymer Electrolyte Membrane (PEM) • Solid Oxide	Uses applied voltage to drive a catalyzed electrochemical reaction completed via an electrolyte to evolve hydrogen and oxygen	Commercial
Anaerobic Digestion	• High vs. low solids • Batch vs. continuous	Decomposition of organic material via anaerobic reaction to form methane, CO_2 and minor constituents	Commercial
Thermochemical	• Gasification (several types) • Pyrolysis • Hydrothermal	Use of heat and/or pressure to extract volatile material from biomass producing syngas (mostly hydrogen and carbon monoxide) which is further reacted and purified to hydrogen or methane	Commercial Prototype

Hydrogen production capacity in California has remained relatively stable in the past two decades (Figure 9). There are, however, signs that the industry will increase capacity in order to meet the demands of hydrogen FCETs. Recently, the Governor's Office of Business and Economic Development (GO-Biz) announced its intention of creating a renewable hydrogen hub in the State. The Governor's Office revised the May 2022 budget to include direct investments in renewable hydrogen production.[19]

[18] CEC. (2020, June 3). Roadmap for the Deployment and Buildout of Renewable Hydrogen Production Plants in California. Retrieved from https://www.energy.ca.gov/publications/2020/roadmap-deployment-and-buildout-renewable-hydrogen-production-plants-california

[19] GO-BIZ. (2022, May 18). Press Release: California Formally Announces Intention to Create a Renewable Hydrogen Hub. Retrieved from https://business.ca.gov/california-formally-announces-intention-to-create-a-renewable-hydrogen-hub/

Figure 9 - California Refinery Hydrogen Production Capacity as of January 2022[20]



In addition, to considerations for how hydrogen is produced, one must also consider how hydrogen is delivered to the end user. Current hydrogen delivery systems include gaseous hydrogen delivery, liquid hydrogen delivery, and on-site hydrogen production and storage. Gaseous hydrogen delivery entails compressing hydrogen prior to transport, which is then delivered by truck or pipeline to the customer. Liquid hydrogen delivery converts hydrogen to liquid form where it must be cooled to below -423 degrees Fahrenheit using a process called cryogenic liquefaction. It is then transported as a liquid in super-insulated, cryogenic tanker trucks to its end destination. Before dispensing the hydrogen, it is vaporized to a high-pressure gaseous product. One of the advantages of this delivery pathway is that can be more economical than trucking gaseous hydrogen over long distances. Hydrogen may also be produced on-site using several processes, including the methods discussed in

[20] U.S. EIA. (2022, June 21). California Refinery Hydrogen Production Capacity as of January 1. Retrieved from https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=8_NA_8PH_SCA_6&f=A

Table 2. On-site production can reduce transportation and distribution costs but increase production costs due to the high capital costs of constructing production facilities. On-site production can be particularly suitable for more remote locations where regular delivery of hydrogen is not feasible, with one example being fuel cell electric buses deployed at Sunline Transit in the Coachella Valley. Figure 10 depicts the three types of hydrogen delivery pathways.

Figure 10 - Hydrogen Delivery Pathways[21]



[21] California Fuel Cell Partnership. (n.d.). Costs and Financing. Retrieved from https://h2stationmaps.com/costs-and-financing

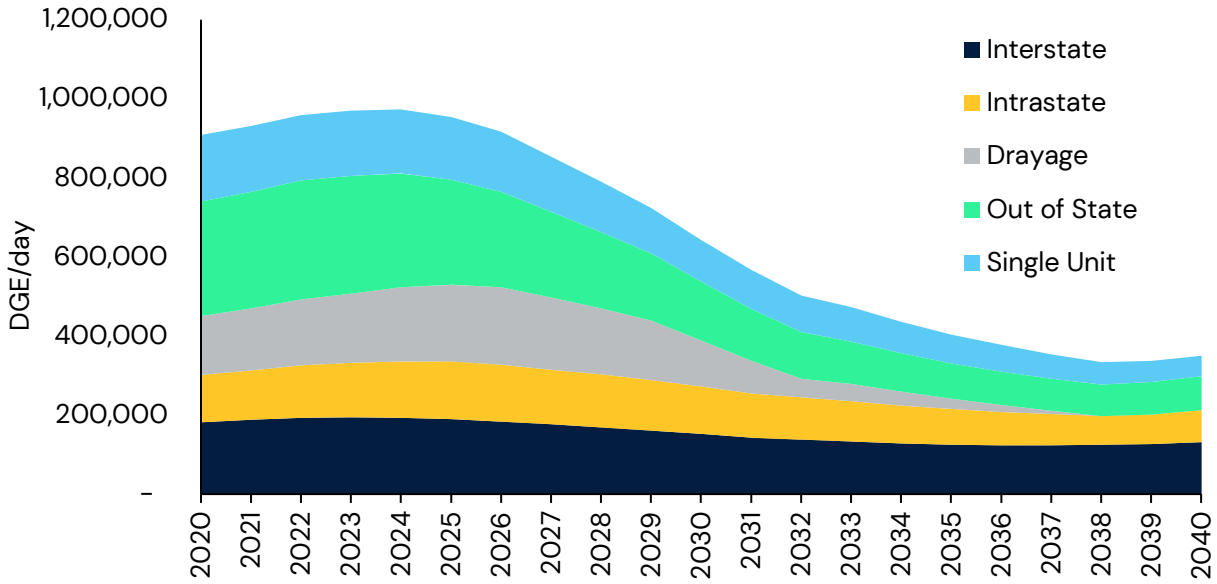
4 Estimated Energy and Fueling Needs

This section will discuss the methodology for estimating the projected energy and fuel consumption needs for LA County's Class 8 truck population by technology type. As discussed in Report 3, the population of Class 8 trucks is expected to transition from being fueled almost entirely by diesel to a mix of conventional and low NOx diesel, ultra-low NOx CNG, battery electric, and hydrogen. Please refer to Report 3 for more details on the projections of truck populations by technology type.

4.1 Diesel

Diesel fuel consumption is expected to increase moderately through 2024 where daily aggregate consumption is roughly 970,000 gallons per day. Beginning in 2025 diesel fuel consumption is expected to progressively decline through 2040 to 350,000 gallons per day (Figure 11).

Figure 11 - Estimated Class 8 Diesel Consumption in L.A. County

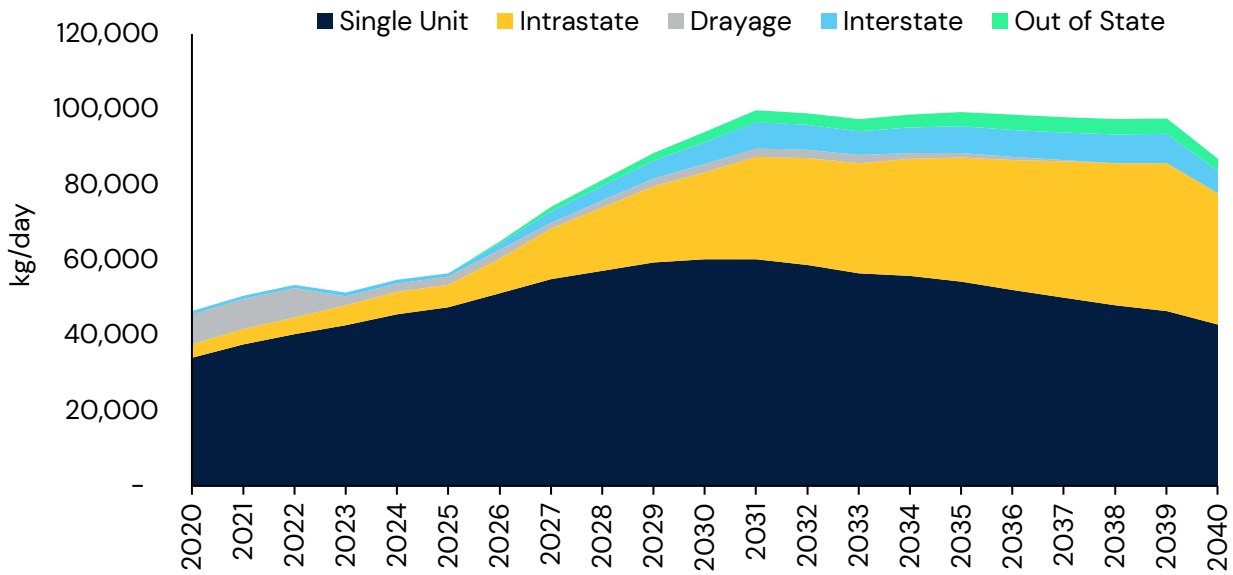


4.2 Natural Gas

The natural gas consumption for Class 8, heavy-duty, natural gas trucks was calculated by using EMFAC2021 natural gas consumption outputs for each vehicle category population. Total natural gas consumption and vehicle population by truck category was assessed to understand the average daily natural gas used per vehicle per day. Next, using the technology mix projections from Report 3, the natural gas consumption per year for each vehicle category was estimated.

This analysis indicated that natural gas Class 8 trucks are expected to increase and replace a large number of diesel trucks, particularly during the next decade. As such, natural gas consumption from Class 8 trucks is also estimated to increase. Single unit and California-registered intrastate trucks are expected to comprise the majority of future natural gas consumption. California-registered interstate and Out of State trucks are expected to remain at low levels of natural gas consumption, while natural gas drayage trucks are expected to completely phase out by 2035 due to ACF requirements in which all non-ZEV trucks will be removed from the CARB Drayage Truck Registry in 2035. Figure 12 shows the estimated natural gas consumption from Class 8 natural gas vehicles (NGV) over the timeframe of this analysis.

Figure 12 – Estimated Class 8 NGV Natural Gas Consumption in L.A. County

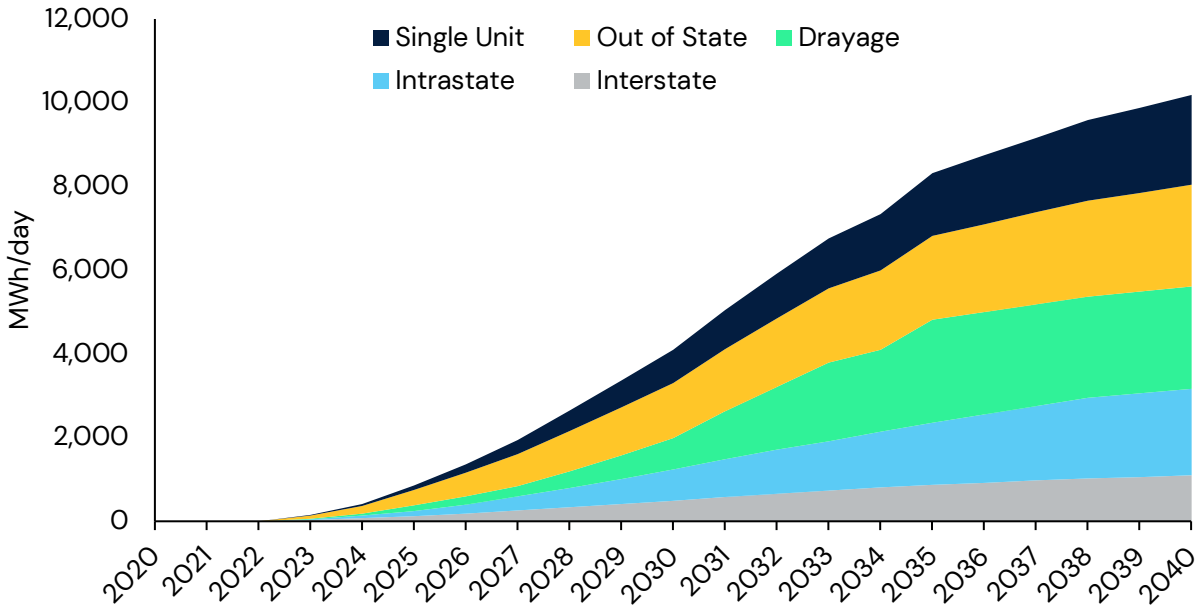


4.3 Electricity

The electricity consumption for Class 8, heavy-duty, battery electric trucks was calculated by using EMFAC2021 electricity consumption outputs for each truck category population. Total electricity consumption and vehicle population by truck category was assessed to understand the average daily kilowatt-hour per vehicle for each vehicle category. Then, using the technology mix projections from Report 3, the electricity consumption per year for each truck category was estimated.

The results of this analysis showed that electricity consumption for Class 8 BETs is expected to increase by four orders of magnitude (~1 to ~10,000 MWh/day) from 2020 to 2040 under the ACF scenario. See Report 3: Technology Mix for Meeting Public Health and Climate Goals to see in detail how the ACF impacts vehicle population by fuel type, and how that impacts energy demand. The share of electricity consumption across the five vehicle category is projected to be relatively similar, with Interstate vehicles having the lowest consumption and Drayage trucks having the highest consumption. Figure 13 shows the estimated electricity consumption from Class 8 BETs over the timeframe of this analysis.

Figure 13 – Estimated Class 8 BET Electricity Consumption in L.A. County

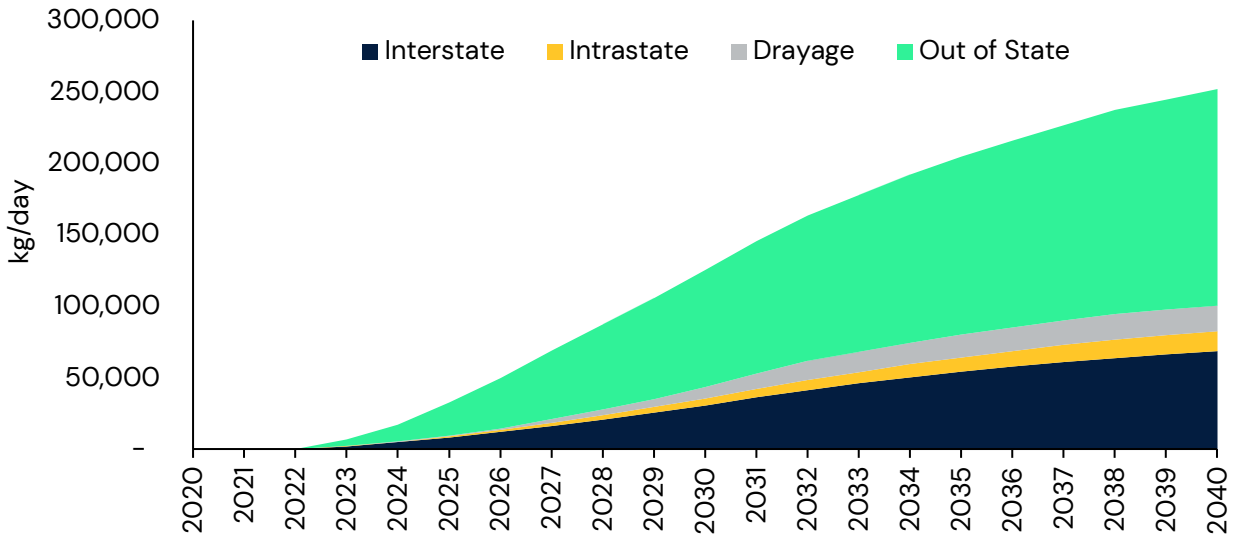


4.4 Hydrogen

The methodology to estimate hydrogen fuel consumption utilized the projected hydrogen truck population and the energy economy ratios (EER) gathered from the Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies (GREET) 2021 model. An EER of 1.36 was assumed for line-haul trucks and is lower than CARB's LCFC EER which assumes a 1.9 EER for all heavy-duty vehicle duty-cycles. The EER was used to calculate the amount of hydrogen needed per truck compared to their diesel truck counterparts. For example, if a diesel tractor is consuming 10 gallons per vehicle per day, then a hydrogen truck uses 7.35 diesel gallon equivalent (dge) of hydrogen per vehicle per day. The average daily hydrogen fuel consumption was multiplied by the annual hydrogen truck population per Report 3 to estimate annual hydrogen consumption.

The results of this analysis indicated that class 8 heavy-duty FCET hydrogen consumption is expected to increase significantly from 2020 to 2040 under the ACF scenario. When comparing projected hydrogen consumption across the five vehicle categories, Out of State trucks are expected to consume the majority of hydrogen, followed by Interstate trucks. These assumptions are based on the fact that these vehicle categories are long-haul trucks which are expected to have the best business case for hydrogen FCET technology. As discussed in Report 3, it is assumed that Single Unit trucks will not adopt FCETs and instead will transition to BET and natural gas technologies due to their shorter daily VMT. Figure 14 shows the estimated hydrogen consumption from Class 8 FCETs over the timeframe of this analysis.

Figure 14 - Estimated Class 8 FCET Hydrogen Consumption in L.A. County



5 Projected Charging and Fueling Infrastructure Needs

This section will discuss the projected charging and fueling infrastructure needs for the transitioning heavy-duty truck fleet within L.A. County using estimates from the previous section. To understand the incremental infrastructure needs based on LA County's transitioning fleet, infrastructure estimates are evaluated over the immediate , short- , medium- , and long-term timeframes.

5.1 Diesel

Diesel is a well-established transportation fuel and has ample infrastructure within LA County. For this reason, and because the demand for diesel fuel is expected to decline significantly, it is assumed that no additional fueling infrastructure will be required. Therefore, this Section 0 will focus on projected fueling and charging needs for natural gas, electric, and hydrogen infrastructure.

5.2 Natural Gas

The technology mix and vehicle population projections in Report 3 estimate that a small portion of trucks in LA County will run on natural gas through 2040, primarily Single Unit and California-registered Intrastate trucks. Notably, natural gas trucks are not expected to be adopted by drayage fleets, largely due to the ACF regulation and other zero emissions incentive programs.

The majority of Class 8 trucks deployed throughout the timeframe of this study are expected to be ZEVs, therefore, we do not expect there to be a substantial demand for natural gas other than from Single-Unit and Intrastate trucks. To develop a sense of what additional fueling capacity may be needed to accommodate increases in the natural gas truck population, the project team conducted an analysis that assumes any increase in natural gas demand will require proportional increases in fueling infrastructure. Importantly, the resources and data referenced for this analysis did not indicate whether or not existing natural gas fueling infrastructure in L.A. County is already at maximum capacity, or if existing stations can be used to meet increased fueling demand. This is an important distinction that should be explored more deeply. To be conservative, the project team assumed that all existing natural gas stations are at maximum capacity, requiring new stations to meet increased demand. Therefore, this should be considered a high scenario for infrastructure demand; it is likely that at least some existing stations have capacity to spare for meeting increased demand.

According to the U.S. Department of Energy's (U.S. DOE) Alternative Fuel Data Center, approximately 82 CNG and LNG stations exist in L.A. County with about 65% of them being private stations. While the project team reviewed data available on whether each station is capable of serving HDTs, such information was not reliably available for enough stations to make a full assessment. Therefore, it should be assumed that at least some of these existing stations may be designed for light- or medium-duty vehicles.

As shown previously in Section 4.2, natural gas consumption in L.A. County is currently between 40,000 and 60,000 kilograms per day (kg/day) but is expected to grow to roughly 100,000 kg/day by 2030. Using this information along with projections from Report 3 for how the natural gas truck fleet is expected to increase, it is estimated that 61 additional refueling stations may be required to meet the peak of natural gas demand in 2035. Because it is assumed that the natural gas truck fleet will decline from 2035 through 2040, the number of additional natural gas stations then decreases. Table 3 show estimates for the cumulative number of additional natural gas refueling stations that may be required to meet projected additions in demand, assuming increases in the quantity of stations required increases proportionally with demand.

Table 3 – Additional Natural Gas Refueling Stations Estimated to be Required, Cumulative

Station Type	2025	2030	2035	2040
Private	7	38	40	27
Public	4	20	21	15
Total	11	58	61	41

To reiterate, this analysis should be considered as a conservatively high estimate for the reasons stated above.

To analyze this from a different angle, the project team also used the projected daily natural gas fuel demand from Section 4.2 and estimated the total number of CNG fueling stations that may be needed under various station throughput scenarios. Table 4 shows the results. These results show the total estimated demand for fueling stations, not the additional stations needed beyond what already exists.

Table 4 Estimated Total Cumulative Number of CNG Stations Required to Meet Projected Demand

			Estimated Number of Stations Required by Station Throughput Scenario			
Year	Estimated Daily Fuel Demand (kg)	Estimated Daily Fuel Demand (gge)	500 GGE/Day Station	1,000 GGE/Day Station	1,500 GGE/Day Station	2,000 GGE/Day Station
2020	46,312	18,039	36	18	12	9
2025	56,466	21,994	44	22	15	11
2030	93,883	36,569	73	37	24	18
2035	99,240	38,655	77	39	26	19
2040	86,806	33,812	68	34	23	17

This analysis indicates that between 19 and 77 stations in total may be needed across LA County to meet the projected demand for natural gas refueling, depending on the throughput of the station. As there are currently 82 CNG and LNG stations in LA County, it is expected that these will likely serve a significant portion of demand, however approximately 65% of those stations are private so some public natural gas fueling infrastructure development may be necessary in the future, however to what extent is currently not known.

5.3 Battery Electric

The electric truck fleet is expected to see the largest increase among any other truck technology in the next two decades. A methodology was developed to estimate the number of charging ports required commensurate with the increase in electricity demand from Class 8 electric trucks. The following section describes the assumptions applied to this analysis followed by the estimated number and type of charging ports necessary to meet the demand.

The first step of this analysis was to assume the fleet size distribution of the set of future electric trucks in L.A. County. It is assumed that each vehicle category, with the exception of Out of State trucks, will exhibit the same fleet distribution as is provided by CARB's fleet database, that is, the number of fleets which contain certain quantities of trucks (e.g., X fleets contain 10-20 trucks). Using electric truck population data outlined in Report 3, the fleet characteristics were established (see Appendix 7.1 BET Fleet Distribution for the projected fleet distribution for each vehicle category). It should be noted that CARB's fleet database only provides fleet size information for trucks that are registered in California and does not provide data on Out of State trucks.

This analysis assumes three types of charging access options for electric trucks: Private, Public (Opportunity/Fast), and Public (Overnight). Table 5 provides a summary of each type.

Table 5 - Types of Charging Access

Type of Charging Access	Description
Private	Privately-owned EVSE located at fleets' own depots. Nightly charging for 10 hours each night is assumed.
Public (Opportunity/Fast)	Publicly-accessible EVSE meant to provide fast charging. A charging dwell time of 1 hour is assumed.
Public (Overnight)	EVSE provided at lots which give access to certain fleets and owner-operators for overnight charging. Such infrastructure may be necessary for California owner-operators that do not have depots, and for Out of State trucks that dwell overnight. Nightly charging for 10 hours is assumed.

Table 6 shows the other assumptions used in this analysis regarding which truck categories are expected to use each type of charging infrastructure.

Table 6 Assumptions for Charging Infrastructure Demand

	Public (Opportunity/Fast)	Private	Public (Overnight)
Applicable Truck Categories	All trucks assumed to require public opportunity fast charging at some point	50% of trucks in California-registered fleets which have 4-10 vehicles; all trucks in fleets with more than 10 vehicles	50% of trucks in California-registered fleets which have 4-10 vehicles; all trucks in fleets with fewer than 4 vehicles; all Out of State trucks
Truck-to-Port Ratio	6:1	1:1	2:1

Fifty percent of trucks in California-registered fleets which have 4-10 vehicles and all trucks in fleets with fewer than 4 vehicles are assumed to require public overnight charging; it is assumed that these trucks may be owned by fleets that either do not have a depot to house charging infrastructure or that they have limited facilities and space to develop private charging infrastructure. All Out of State trucks are also assumed to require public overnight charging at some time; while these trucks may not dwell in LA County overnight in all cases, we assume that the public overnight charging infrastructure will be available to them when needed. All other California-registered trucks are assumed to rely only

on private charging infrastructure. Additionally, it is assumed that all Class 8 electric trucks may have a need for public fast charging at some point. While all trucks may not use public fast charging regularly, we assume that it will be available to all trucks

The project team also makes some assumptions regarding the number of trucks that a single charger port (also referred to as a plug) can serve. It is assumed that private charging will have a 1:1 truck-to-port ratio, though it is acknowledged that fleets may be able to increase this ratio and not require a dedicated port for each truck. For public overnight charging, a 2:1 ratio is assumed, and for public fast charging a 6:1 ratio is assumed, based on information from the 2021 report prepared for the Port of Long Beach entitled Fueling the Future Fleet: Assessment of Public Truck Charging and Fueling Near the Port of Long Beach.[22]

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https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiUpu6Rplj5AhXeDkQIHVaUANQQFnoECBoQAQ&url=https%3A%2F%2Fpolb.com%2Fdownload%2F379%2Fzero-emissions%2F12744%2Ffinal-polb-charging-study-12-sep-2021.pdf&usg=AOvVaw1k5PGnOe229omQijulgFLU

Table 7 shows the cumulative number of charging ports estimated to be required by truck category, charger access type, and scenario year, with the exception of public fast charging which is shown in a separate table as it is applied to all truck categories combined.

Table 7 - Number of Ports by Truck & Charger Access Type, Cumulative

Truck Category	Scenario Year	Private	Public (Overnight)
Single Unit	2025	478	160
	2030	3,548	1,187
	2035	6,738	2,253
	2040	9,610	3,214
Drayage	2025	302	101
	2030	1,728	578
	2035	5,590	1,869
	2040	5,562	1,860
Intrastate	2025	496	166
	2030	3,263	1,091
	2035	6,511	2,177
	2040	9,042	3,024
Interstate	2025	202	67
	2030	764	256
	2035	1,361	455
	2040	1,722	576
Out of State	2025	-	397
	2030	-	1,402
	2035	-	2,139
	2040	-	2,598
Grand Totals	2025	1,478	891
	2030	9,303	4,514
	2035	20,200	8,893
	2040	25,936	11,272

Under the assumptions stated above, it is estimated that, by 2040, 25,936 privately owned charging ports and 11,272 public overnight charging ports may be required to meet the demand across all Class 8 trucks.

Table 8 shows the cumulative number of public fast charging ports estimated to be required by scenario year. Under the assumptions stated above, it is estimated that, by 2040, 8,080 public fast charging ports may be required to meet the demand across all Class 8 trucks.

Table 8 Number of Public (Opportunity/Fast) Ports by Truck Category, Cumulative

Vehicle Category	Scenario Year	Public (Opportunity/Fast)
All Vehicle Categories Combined	2025	543
	2030	3,055
	2035	6,331
	2040	8,080

To understand the EVSE power output levels necessary for accommodating charging demand, we first identified the battery pack sizes of Class 8 electric trucks on the market today and those planned for launch in the near future. Using the average daily vehicle miles traveled (VMT) from Report 1, BET battery pack data from ICF's EV Model Library[23], and the dwell time assumptions in Table 5, we estimated the EVSE output power level that may be needed for each charging station access type. A full charge is assumed to be from a 20 percent to 80 percent battery state of charge.

Table 9 shows the estimated EVSE output power level for each vehicle category depending on whether a vehicle charges at a public charger, private charger, or a public overnight charging facility.

Table 9 - Estimated EVSE Power Levels (kW) by Vehicle Category and Charger Access Type

Vehicle Categories	Public (Opportunity/Fast)	Private	Public (Overnight)
Out of State Trucks	660	-	70
California-Registered Intrastate	250	25	25
California-Registered Interstate	660	70	70
Drayage Trucks	300	30	30
Single Unit Trucks	140	13.8	13.8

Using the information from Table 9, the cumulative number of EVSE by power level was estimated. Table 10 shows the cumulative number of charging ports estimated to be required by power level and scenario year.

Table 10 - Cumulative Number of Charging Ports Estimated to be Needed for Class 8 Trucks in Los Angeles County, by Power Level and Year

Scenario Year	<19.2 kW	20-30 kW	70-150 kW	250-360 kW	600+ kW	Cumulative Total
2025	638	1,065	799	222	188	2,912
2030	4,735	6,660	3,409	1,388	680	16,873
2035	8,992	16,148	5,829	3,366	1,091	35,426
2040	12,824	19,487	7,569	4,062	1,345	45,286

5.4 Hydrogen Fuel Cell Electric

This section provides estimates for the number of hydrogen fueling stations that may be needed to support Class 8 FCETs across L.A. County based on the estimated demand for hydrogen fuel shown in Section 4.4. As is the case for BET charging infrastructure, the scale and type of hydrogen fueling infrastructure required will vary depending on several variables and assumptions.

Table 11 shows the key assumptions used in the analysis and projections provided within this section. Importantly, as is the case with other fuel types discussed previously, some share of trucks in L.A.

[23] ICF maintains an up-to-date inventory of current and future electric vehicles, including cost, range, and battery size.

County are expected to rely on hydrogen fueling stations that are private access, some will rely on stations that are public access, and others may use both types of stations. The analysis below does not make any assumptions regarding the share of private- versus public-access stations, and instead shows total infrastructure estimates.

Table 11 - Assumptions for Hydrogen Fueling Infrastructure Analysis and Projections

Item	Assumption	Notes and Sources
Average Daily VMT by Truck Category		
CA Interstate	250	Per CARB study on HD Diesel Vehicles[24]
CA Intrastate	150	Per CARB study on HD Diesel Vehicles[24]
CA Drayage	130	Per CARB study on HD Diesel Vehicles[24]
Out of State	250	Per CARB study on HD Diesel Vehicles[24]
Truck Type by Truck Category		
Daycab	CA Intrastate	Assumed to require daycabs due to shorter average daily VMT and expected duty cycle
	CA Drayage	Assumed to require daycabs due to shorter average daily VMT and expected duty cycle
Sleeper	CA Interstate	Assumed to require sleeper cabs due to longer average daily VMT and expected duty cycle
	Out of State	Assumed to require sleeper cabs due to longer average daily VMT and expected duty cycle
Truck Range		
Daycab	500 miles	Reported range for Nikola Tre per Global Drive to Zero ZETI[25]
Sleeper	900 miles	Reported range for Nikola Two per Global Drive to Zero ZETI[25]
Hydrogen Tank Capacity		
Daycab	57 kg	Derived based on 500 mile range and 8.83 miles per kg[25]
Sleeper	98 kg	Derived based on 900 mile range and 9.17 miles per kg[25]

[24] https://ww2.arb.ca.gov/sites/default/files/classic/research/apr/past/13-301.pdf
[25] https://globaldrivetozero.org/tools/zero-emission-technology-inventory/

Item	Assumption	Notes and Sources
Truck Fuel Efficiency		
CA Interstate	8.92 mi/kg	Estimated using CARB EMFAC2021 total truck population and VMT estimates, and assume Energy Economy Ratio (EER)[26] of 1.36
CA Intrastate	8.94 mi/kg	Estimated using CARB EMFAC2021 total truck population and VMT estimates, and assume Energy Economy Ratio (EER) of 1.36
CA Drayage	8.71 mi/kg	Estimated using CARB EMFAC2021 total truck population and VMT estimates, and assume Energy Economy Ratio (EER) of 1.36
Out of State	9.43 mi/kg	Estimated using CARB EMFAC2021 total truck population and VMT estimates, and assume Energy Economy Ratio (EER) of 1.36
Number of Trucks Refueling on a Given Day	All trucks refuel once per day	While daily fueling patterns may vary by truck, we assume each truck refuels once per day.

Table 12 shows the projected number of Class 8 hydrogen FCET trucks expected to operate in L.A. County by truck category and timeframe, as was first described in Report 1 (Baseline Conditions) for this Clean Truck Technology Comparative Project.

Table 12 - Projected Hydrogen FCET Truck Population by Year and Truck Category

Truck Category	Year				
	2020	2025	2030	2035	2040
CA Single Unit	0	0	0	0	0
CA Interstate	0	337	1,276	2,272	2,874
CA Intrastate	0	92	605	1,207	1,677
CA Drayage	1	43	464	907	1,031
Out of State	0	793	2,804	4,277	5,195

Table 13 shows the estimated demand for hydrogen fuel on any given day based on the assumptions above. Out of State trucks are estimated to have the highest hydrogen fuel demand due to their high mileage and high truck population projections compared to other truck categories. California-

[26] The EER is a comparison of the distance traveled by a FCET compared to a conventional diesel truck when using the same amount of energy.

Registered Interstate trucks are second in order of total hydrogen demand, followed by California-Registered Intrastate and California-Registered Drayage trucks.

Table 13 - Estimated Hydrogen Demand on Any Given Day (kg/day)

Truck Category	Year				
	2020	2025	2030	2035	2040
CA Interstate	0	9,446	35,766	63,684	80,557
CA Intrastate	0	1,543	10,149	20,247	28,131
CA Drayage	15	642	6,924	13,535	15,386
Out of State	0	21,033	74,371	113,439	137,788
Total	15	32,664	127,210	210,906	261,862

Table 14 shows the estimated number of hydrogen fueling stations required to meet the demand shown in Table 13 at various station size scenarios. Station size is reported in terms of daily throughput of 1,000 kg through 5,000 kg per day. Naturally, as station throughput increases, the estimated number of required stations decreases. As shown in Table 14, estimates indicate a need for 52 stations to 262 stations in 2040, depending on throughput scenario.

Table 14 - Estimated Number of Hydrogen Fueling Stations Required Under Various Station Throughput Scenarios

Throughput Capacity in kg/day	Estimated Number of Stations by Year and Scenario				
	2020	2025	2030	2035	2040
1000	0	33	127	211	262
2000	0	16	64	105	131
3000	0	11	42	70	87
4000	0	8	32	53	65
5000	0	7	25	42	52

As stated previously, some share of hydrogen FCETs are likely to rely on private fueling infrastructure instead of public fueling stations. While the exact number of FCETs expected to prefer private infrastructure is unknown, Table 15 below shows an example of how the number of required public fueling stations would decrease as a result. In this example, we assume that 35% of California-Registered Interstate, Intrastate, and Drayage trucks use public stations, along with 100% of Out of State trucks.

Table 15 Example of a Partial Need for Public Infrastructure - Estimated Number of Public Hydrogen Fueling Stations Required (100% of Out of State Trucks and 35% of all other California-Registered Trucks Assumed to Require Public Infrastructure)

Throughput Capacity in kg/day	Estimated Number of Stations by Year and Scenario				
	2020	2025	2030	2035	2040
1000	0	25	93	148	181
2000	0	13	46	74	91
3000	0	8	31	49	60
4000	0	6	23	37	45
5000	0	5	19	30	36

6 Projected Charging and Fueling Infrastructure Costs

This section uses the estimated number of charging and fueling stations for each technology discussed in Section 0 to develop infrastructure cost projections over four timeframes. The timeframes have been grouped into four scenario years to aid in its use going forward; the scenario years include 2025 representing the immediate timeframe, 2030 for the short-term timeframe, 2035 for the medium-term timeframe, and 2040 for the long-term timeframe.

6.1 Infrastructure Costs Analysis Based on Projected Truck Deployments

6.1.1 Natural Gas

Much of the growth in the natural gas market will be due to increasing demand from the transportation sector, and in particular from the medium- and heavy-duty vehicle segments. It is expected that the number of natural gas stations will need to increase within L.A. County to support the growth. A number of factors that influence the cost of a natural gas fueling station including:

- Dispense rate,
- Station design and capacity,
- Location,
- Land acquisition,
- Engineering drawings,
- Equipment, and
- Installation.

In general, there are three types of dispense rates: fast-fill, time-fill, and combination-fill. Fast-fill stations are specially designed, including their compressor and storage capacity, to achieve fill times comparable to those for diesel fueling stations. Time-fill stations instead achieve varying fill times that are typically over several hours, and largely depends on the number of vehicles refueling, the amount of fuel required, and the compressor throughput. Lastly, combination-fill is when a fueling station has the option of time- or fast-fill.

For this analysis, cost data was gathered from a National Renewable Energy Laboratory report that went into detail about the costs associated with CNG vehicle infrastructure. Station costs were given for five different station architectures, but medium and large station costs were found to be most relevant given the size and fueling demands of heavy-duty trucks. Table 16 shows the range of CNG fueling station costs, which include equipment and installation costs.

Table 16 - CNG Infrastructure Cost Assumptions[27]

Station Type	Access	Capacity	Dispense Rate	Low Cost	Average Cost	High Cost
Medium Station	Private	500-800 gge/day	Time-Fill	$550,000	$700,000	$850,000
Large Station	Public	1,500-2,000 gge/day	Fast Fill	$1,200,000	$1,500,000	$1,800,000

Station costs were calculated cumulatively, meaning that each scenario includes the costs from the previous scenario years. It should also be noted that since CNG fueling infrastructure is projected to reach its peak in 2035, infrastructure costs for 2040 are omitted, because no additional infrastructure is expected to be needed. Most of the investment appears to be needed between 2025 and 2030,

[27] U.S. DOE. (2014, September). Costs Associated With Compressed Natural Gas Vehicle Fueling Infrastructure. Retrieved from https://afdc.energy.gov/files/u/publication/cng_infrastructure_costs.pdf

when the CNG population sees a rise and therefore an increase in fueling infrastructure will be necessary. The additional investment to achieve ample infrastructure from 2030 to 2035 is significantly less compared to 2025. Table 17 shows the range of costs for private and public stations for 2025, 2030, and 2035.

Table 17 - CNG Infrastructure Cumulative Costs by Scenario Year and Access Type

Scenario Year	Access and Station Type	Low Cost	Average Cost	High Cost
2025	Private	$3,861,360	$4,914,458	$5,967,556
	Public	$4,212,393	$5,265,491	$6,318,589
2030	Private	$21,048,095	$26,788,484	$32,528,873
	Public	$23,811,986	$29,764,982	$35,717,979
2035	Private	$21,926,383	$27,906,306	$33,886,229
	Public	$24,805,605	$31,007,007	$37,208,408
2040	Private	Non-Applicable		
	Public			

Combining the public and private CNG infrastructure costs from the table above provides a clearer picture of the total investment necessary to achieve ample fueling stations for each scenario year. Table 18 shows these estimates spread out by low, average, and high costs.

Table 18 - Cumulative CNG Infrastructure Costs by Scenario Year

Scenario Year	Low Cost	Average Cost	High Cost
2025	$8,073,753	$10,179,949	$12,286,145
2030	$44,860,080	$56,553,466	$68,246,852
2035	$46,731,989	$58,913,313	$71,094,637
2040	Non-Applicable		

6.1.2 Battery Electric

The primary costs associated with building EVSE include hardware, installation, permitting, and engineering review and drawings. Further capital cost may include costs associated with land acquisition, electric utility distribution grid equipment upgrades, and upgrades to site-level make-ready infrastructure. It should be noted that installation cost reductions can be realized when installing more than one EVSE per site; however, this assumption was not included in this cost analysis for simplicity. The analysis herein only includes the estimated costs of EVSE hardware and installation; it

does not include the costs associated with engineering and design, permitting, utility-side electric grid infrastructure upgrades, or site-level make-ready infrastructure upgrades. Importantly, capital costs for charging infrastructure development is likely to be highly variable from one project to the next. The analysis herein is meant to provide a rough estimate of costs using average unit cost data that is publicly available.

Hardware costs were gathered from a variety of sources, including from EVSE retail websites and several industry reports. Table 19 shows estimates for hardware and installation costs for Level 2 and DCFC stations, and the notes below the table indicate sources of these unit cost estimates.

Table 19 - Estimated Range of EVSE Hardware & Installation Costs

EVSE Type	EVSE Cost Category	Low-Cost Estimate	Medium-Cost Estimate	High-Cost Estimate
Level 2 (3 – 20 kW)	Hardware	$575	$4,000	$8,500
	Installation	$600	$3,000	$12,700
DCFC (20 – 360 kW)	Hardware	$12,500	$50,000	$130,000+[28]
	Installation	$4,000	$21,000	$51,000+

Hardware costs based on:

- EVSE Retail Websites, such as clippercreek.com and smartchargeamerica.com
- A California Electric Transportation Coalition (CalETC) report titled "Comparison of Medium- and Heavy-Duty Technologies in California" prepared by ICF.[29]
- A 2015 Report from the US DOE titled "Costs Associated with Non-Residential EVSE"[30]
- A 2019 Report from the Rocky Mountain Institute titled "Reducing EV Charging Infrastructure Costs"[31]
- A 2019 Report from the International Council on Clean Transportation (ICCT) titled "Estimating Electric Vehicle Charging Infrastructure Costs Across Major U.S. Metropolitan Areas"[32]

Installation costs based on:

- Nicholas, M. (August 2019). Estimating Electric Vehicle Charging Infrastructure Costs Across Major U.S. Metropolitan Areas. The International Council on Clean Transportation[33]

EVSE cost estimates were calculated using the cumulative number of charger ports by power level presented in Section 0, and the estimated range of EVSE costs illustrated above. It is assumed that 19.2 kW charging stations will incur average Level 2 hardware and installation costs; 20kW to 30 kW stations are assumed to incur low-cost DCFC hardware and installation costs; 70 kW to 150 kW stations and 250 kW 360 kW stations will experience medium- and high-costs, respectively. Costs for

[28] Costs above $130,000 exist for DCFC, and Output Power Rating is not the only factor that determines EVSE hardware costs. For example, the FreeWire Boost Charger is a 150 kW charger with 160 kWh of integrated, on-board energy storage, and it is estimated to cost over $210,000. See: https://www.eclipsesolar.ca/store/FreeWire-Boost-Charger-p234250063

[29] ICF. (December 2019).

[30] Smith, M., Castellano, J. (November 2015). *Costs Associated with Non-Residential Electric Vehicle Supply Equipment*. U.S. Department of Energy. https://afdc.energy.gov/files/u/publication/evse_cost_report_2015.pdf

[31] Nelder, C., Rogers, E. (2019). *Reducing EV Charging Infrastructure Costs*. Rocky Mountain Institute. https://rmi.org/insight/reducing-ev-charging-infrastructure-costs/

[32] Nicholas, M. (August 2019). *Estimating Electric Vehicle Charging Infrastructure Costs Across Major U.S. Metropolitan Areas*. The International Council on Clean Transportation. https://theicct.org/sites/default/files/publications/ICCT_EV_Charging_Cost_20190813.pdf

[33] U.S. DOE VTO. (November 2015). Costs Associated with Non-Residential Electric Vehicle Supply Equipment. Retrieved from https://afdc.energy.gov/files/u/publication/evse_cost_report_2015.pdf.

DCFC with output power levels exceeding 360 kW were not readily available as this technology is not commercially available. To account for these high-powered chargers, and given a lack of data, the project team scaled up the high hardware and installation unit cost estimates from the table above and assumed a per-charger hardware cost of $150,000 and a per-charger installation cost of $100,000. Actual costs may vary as this technology is made commercially available in the future.

EVSE costs shown in Table 20 are cumulative, showing the total cost by scenario to expand the charging network for heavy-duty electric trucks.

Table 20 - Cumulative BET Infrastructure Costs (million $)

Scenario Year	<19.2 kW	20-30 kW	70-150 kW	250-360 kW	600+ kW	Total
2025	$4	$18	$57	$40	$47	$166
2030	$33	$110	$242	$251	$170	$806
2035	$63	$266	$414	$609	$273	$1,625
2040	$90	$322	$537	$735	$336	$2,020

Under the assumptions stated above and in previous sections, the estimated total charging infrastructure investment need for both private and public infrastructure will be $166 million in 2025, $806 million in 2030, $1.6 billion in 2035, and $2 billion in 2040, cumulatively. Table 21 shows a breakdown of estimated costs in 2040 by charger output power level and by charger access type. These estimates suggest that approximately 62 percent of the total investment need is by public opportunity/fast chargers, 21% by private chargers, and 16% by public overnight chargers.

Table 21 Estimated BET Charging Infrastructure Costs in 2040 (million $)

Charger Output Power Level	Public (Opportunity/Fast)	Private	Public (Overnight)	Totals
<19.2 kW	$-	$67	$22	**$90**
20-30 kW	$-	$241	$81	**$322**
70-150 kW	$190	$122	$225	**$537**
250-360 kW	$735	$-	$-	**$735**
600+ kW	$336	$-	$-	**$336**
Totals	**$1,261**	**$430**	**$328**	**$2,020**

6.1.3 Hydrogen Fuel Cell Electric

Table 22 shows the estimated number of hydrogen fueling stations required to meet the demand shown in Table 13 in Section 5.4 under various daily station throughput scenarios. As mentioned in previous sections, this table does not make any assumptions for how many stations are private versus

those that are publicly accessible. Instead, it only reports the estimated number of stations based on projected demand for hydrogen across truck categories.

Table 22 – Estimated Number of Hydrogen Fueling Stations Required Under Various Station Throughput Scenarios

Throughput Capacity in kg/day	Estimated Number of Stations by Year and Scenario				
	2020	2025	2030	2035	2040
1000	0	33	127	211	262
2000	0	16	64	105	131
3000	0	11	42	70	87
4000	0	8	32	53	65
5000	0	7	25	42	52

Table *23* shows the estimated capital cost to build the stations shown in Table 22, assuming the per-station capital costs shown in Table 24. These estimates show potential cost reductions through economies of scale; as the daily throughput of the stations increases, the total estimated cost to build the stations decreases. Importantly, stations of various sizes and capacities will be needed throughout Los Angeles County;

Table *23* provides a useful starting point for understanding the potential scale of hydrogen fueling infrastructure costs under various station size scenarios.

Table 23 - Estimated Hydrogen Station Capital Costs Under Various Scenarios

Throughput Capacity in kg	Capital Cost Scenario	Estimated Hydrogen Station Capital Costs (in Millions)				
		2020	2025	2030	2035	2040
1000	**Low**	$0	$165	$635	$1,055	$1,310
2000	**Low**	$0	$80	$320	$525	$655
3000	**Medium**	$0	$83	$315	$525	$653
4000	**High**	$0	$80	$320	$530	$650
5000	**High**	$0	$70	$250	$420	$520

Table 24 - Hydrogen Fueling Station Capital Cost Assumptions

Scenario	Estimated Capital Cost per Station[34]
Low	$5,000,000
Medium	$7,500,000
High	$10,000,000

The per-station capital cost assumptions in Table 24 were based on three sources: the West Coast Collaborative Alternative Fuel Infrastructure Corridor Coalition's Strategic Development Plan, which provides reported station capital cost estimates for proposed stations, a Zero Emission Transit Bus Technology Analysis report by Alameda-Contra Costa Transit District, which provides detailed information on two hydrogen fueling stations the organization has developed for its FCET fuel cell electric buses, and a 2020 document from the US Department of Energy (US DOE) which summarized estimated capital costs for hydrogen fueling stations awarded state funding in California.

[34] Sources: https://westcoastcollaborative.org/files/sector-fuels/wcc-aficc-mhd-infrastructure-development-plan-2020-03-12.pdf; https://www.actransit.org/sites/default/files/2021-06/0604-20%20Report-ZEB%20Perf_FNL_062321.pdf; https://www.hydrogen.energy.gov/pdfs/21002-hydrogen-fueling-station-cost.pdf

7 Appendix

7.1 BET Fleet Distribution

Table 25 - BET Single Unit Fleet Distribution (Number of Fleets with Varying Quantities of Trucks)

	Number of Fleets with Certain Fleet Sizes (Measured by Number of Vehicles within the Fleet)								
Year	1	2	3	4-10	11-20	21-50	51-100	101-1000	>1000
2020	-	-	-	-	-	-	-	-	-
2021	-	-	-	-	-	-	-	-	-
2022	-	-	-	-	-	-	-	-	-
2023	8	6	4	13	6	7	4	9	4
2024	46	32	24	71	36	40	24	50	21
2025	107	74	56	164	83	91	56	117	49
2026	196	135	102	299	151	167	102	213	90
2027	333	230	174	510	256	284	173	362	153
2028	483	333	252	739	372	411	250	525	222
2029	647	446	337	988	497	550	335	703	297
2030	798	550	415	1,219	613	679	413	867	366
2031	941	649	490	1,438	723	801	488	1,023	432
2032	1,074	741	559	1,642	826	914	557	1,168	493
2033	1,210	835	630	1,849	930	1,030	627	1,315	555
2034	1,364	941	711	2,085	1,049	1,161	707	1,483	626
2035	1,515	1,045	789	2,315	1,165	1,289	785	1,647	695
2036	1,657	1,143	863	2,533	1,274	1,410	859	1,801	761
2037	1,799	1,241	937	2,750	1,383	1,531	932	1,955	826
2038	1,942	1,340	1,011	2,968	1,493	1,652	1,006	2,110	891
2039	2,051	1,415	1,068	3,134	1,577	1,745	1,063	2,229	941
2040	2,161	1,491	1,125	3,302	1,661	1,838	1,120	2,348	991

Table 26 - Drayage Fleet Distribution

	Number of Fleets with Certain Fleet Sizes (Measured by Number of Vehicles within the Fleet)								
Year	1	2	3	4-10	11-20	21-50	51-100	101-1000	>1000
2020	1	0	0	1	1	1	0	1	0
2021	1	1	1	2	1	1	1	1	0
2022	1	1	1	2	1	1	1	1	1
2023	9	6	4	13	7	7	4	9	4
2024	26	18	13	39	20	22	13	28	12
2025	52	36	27	79	40	44	27	56	24
2026	79	55	41	121	61	67	41	86	36
2027	178	123	93	273	137	152	92	194	82
2028	268	185	140	410	206	228	139	292	123
2029	368	254	192	563	283	313	191	400	169
2030	563	388	293	860	433	479	292	612	258
2031	755	521	393	1,154	580	642	391	820	346
2032	953	658	496	1,457	733	811	494	1,036	437
2033	979	675	510	1,496	753	833	507	1,064	449
2034	1,036	714	539	1,583	796	881	537	1,126	475
2035	1,099	758	572	1,680	845	935	570	1,195	504
2036	1,143	789	595	1,748	879	973	593	1,243	525
2037	1,192	822	621	1,822	916	1,014	618	1,295	547
2038	1,241	856	646	1,896	954	1,056	643	1,349	569
2039	1,244	858	648	1,901	956	1,058	645	1,352	571
2040	1,250	863	651	1,911	961	1,064	648	1,359	574

Table 27 - California-Registered Intrastate Fleet Distribution

	Number of Fleets with Certain Fleet Sizes (Measured by Number of Vehicles within the Fleet)								
Year	1	2	3	4-10	11-20	21-50	51-100	101-1000	>1000
2020	-	-	-	-	-	-	-	-	-
2021	-	-	-	-	-	-	-	-	-
2022	-	-	-	-	-	-	-	-	-
2023	17	12	9	26	13	15	9	19	8
2024	55	38	28	83	42	46	28	59	25
2025	112	77	58	170	86	95	58	121	51
2026	208	143	108	318	160	177	108	226	95
2027	334	230	174	510	257	284	173	363	153
2028	461	318	240	705	354	392	239	501	212
2029	596	411	310	910	458	507	309	647	273
2030	734	506	382	1,121	564	624	380	797	337
2031	892	616	465	1,364	686	759	462	970	409
2032	1,027	709	535	1,570	790	874	532	1,116	471
2033	1,160	800	604	1,773	892	987	601	1,261	532
2034	1,315	907	685	2,010	1,011	1,119	681	1,429	603
2035	1,464	1,010	762	2,237	1,125	1,246	759	1,591	672
2036	1,606	1,108	836	2,454	1,235	1,366	832	1,745	737
2037	1,751	1,208	912	2,676	1,346	1,490	907	1,903	803
2038	1,894	1,307	987	2,895	1,457	1,612	982	2,059	869
2039	1,963	1,354	1,022	3,000	1,509	1,670	1,017	2,133	901
2040	2,033	1,402	1,059	3,107	1,563	1,730	1,053	2,209	933

Table 28 - California-Registered Interstate Fleet Distribution

	Number of Fleets with Certain Fleet Sizes (Measured by Number of Vehicles within the Fleet)								
Year	1	2	3	4-10	11-20	21-50	51-100	101-1000	>1000
2020	-	-	-	-	-	-	-	-	-
2021	-	-	-	-	-	-	-	-	-
2022	-	-	-	-	-	-	-	-	-
2023	11	7	6	16	8	9	6	12	5
2024	26	18	14	40	20	23	14	29	12
2025	45	31	24	69	35	39	24	49	21
2026	67	46	35	103	52	57	35	73	31
2027	91	63	47	139	70	77	47	99	42
2028	116	80	60	177	89	99	60	126	53
2029	143	99	74	219	110	122	74	155	66
2030	172	119	89	263	132	146	89	187	79
2031	204	141	106	311	157	173	106	221	94
2032	233	161	121	356	179	198	121	253	107
2033	260	179	135	397	200	221	135	282	119
2034	284	196	148	435	219	242	147	309	131
2035	306	211	159	468	235	260	159	333	140
2036	325	224	169	497	250	277	169	354	149
2037	343	237	179	525	264	292	178	373	158
2038	360	248	188	550	277	306	187	391	165
2039	373	258	194	571	287	318	194	406	171
2040	387	267	202	592	298	329	201	421	178

7.2 BET Infrastructure

Table 29 - Three Types of EVSE Accessibility

EVSE Accessibility	Description
Private	Privately-owned charging infrastructure located at fleets' own depots. Nightly charging for 10 hours each night is assumed.
Public (Opportunity/Fast)	Publicly-accessible charging infrastructure meant to provide fast charging. A charging dwell time of 1 hour is assumed.
Public (Overnight)	Charging infrastructure provided at lots which give access to certain fleets and owner-operators for overnight charging. Such infrastructure may be necessary for California owner-operators that do not have depots, and for Out of State trucks that dwell overnight. Nightly charging for 10 hours is assumed.

Table 30 - Battery Size Assumptions

Report Truck Categories	Battery Size (kWh)	Battery Size Assumptions
Out of State Trucks	653	These line haul trucks will require the largest battery capacities
California Registered Intrastate	244	These regional haul trucks will require less battery capacity than Out of State and California Registered Interstate trucks, but probably the same or more as Drayage trucks
California Registered Interstate	653	These line haul trucks will require the largest battery capacities
Drayage Trucks	291	These trucks will require less battery capacity than Out of State trucks and California Registered Interstate trucks but probably similar capacities as CA Registered Intrastate trucks. In some instances, high battery capacities may be needed if the truck drives longer distances and/or makes multiple trips/turns a day.
Single Unit Trucks	138	These trucks will require less battery capacity than the other types of trucks because of their vocational use. In some instances, higher battery capacities may be needed depending on the use case.