Medium- and Heavy-Duty Electric Vehicle Adoption and Infrastructure Assessment

Introduction/Executive Summary

The California Electric Transportation Coalition (CalETC) and Guidehouse prepared an assessment of the market adoption of and charging infrastructure needs to meet California's landmark medium- and heavy-duty (MHD) electric vehicle (EV) regulations. The adoption forecast for MHD vehicles extends from 2020 to 2050 and is focused on the census tract level for MHD on- and off-road vehicles. The adoption forecast is based on existing MHD EV projections, information related to current MHD regulatory rulemakings in California, and market intelligence. The adoption forecast was used to estimate the charging infrastructure needs for MHD EVs, including the approximate locations and site configurations of MHD EV charging infrastructure. At this time, there is insufficient data to accurately estimate the utility- and customer-side costs associated with MHD charging infrastructure.

Key conclusions of this assessment are:

- Very little charging infrastructure support for MHD EVs exists today. The charging infrastructure additions needed to support the transition of the MHD market to EVs require immediate attention.
- The challenges in building out adequate MHD charging infrastructure are not insurmountable, but they will require a coordinated effort by the public and private sectors to ensure the economic and environmental benefits of transitioning to a fully zero-emission fleet benefits all Californians.
- Planned and thoughtful development of charging infrastructure, including site configurations that are co-located to support a variety of vehicle and equipment needs across all segments of MHD EV, trucks, vans, buses and equipment, will be essential to ensure adequate access to charging infrastructure and successful market launch and growth.
- Successful market acceleration for MHD EVs will require adequate and reliable public incentives until such time as the value proposition for individuals or fleets purchasing MHD EVs is equal to or greater than the cost of these technologies.
- Battery costs and electricity fuel costs relative to gasoline and diesel costs are key drivers in the market adoption of MHD EVs.
- Consumer awareness and acceptance of MHD EVs is a critical component of market adoption.
- Policy makers and state agencies should support a comprehensive study of infrastructure costs, installation complexities, and economic jobs implications for MHD EVs as a top priority.

Modeling Methodology Overview

Guidehouse's EV adoption model is based on multidimensional inputs to forecast vehicle penetration. The model includes MHD battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) that are owned by both individuals and fleets in California. The model leveraged VAST Suite[1] to forecast geographic penetration and dispersion of electric vehicles. The inputs for the EV adoption analysis were based at the census tract level, including vehicle registration by fuel type and zip code, expected fuel costs for gasoline/diesel and electricity rates, battery costs, vehicle availability and

[1] Guidehouse's Vehicle Analytics Simulation Tool™ (VAST) Suite uses proprietary datasets to provide market transparency that informs client lifecycle consulting needs, such as electric vehicle (EV) charging station location optimization analysis to develop an EV charging infrastructure plan.

efficiency, vehicle miles traveled (VMT) incentives, BEV range and PHEV battery utilization, and demographic data, e.g. population, income, units in housing structure, vehicle ownership, household counts, and educational attainment. The model's key outputs for the EV adoption analysis are the number of EV sales, the EV population in a given year, location, powertrain, and vehicle class.

The inputs to model the infrastructure charging needs for the forecasted MHD EVs include a siting objective function, charging site distance threshold, charger-to-vehicle ratios[2], VMT, existing charging infrastructure, and annual average daily traffic. The outputs of the charging needs modeling include site location at the census tract level, use case including public market, private depot, etc., charging level (Level 2 or DCFC), average weighted kW by use case, technology, and year, and the number of ports for each site. The model used a hybrid approach to allocate EV charging site locations by combining an approach that would meet the demand with the minimum number of sites and an approach that allocates sites efficiently to meet the points of highest demand. The approach to minimize facilities flags optimal sites for ensuring complete coverage in areas with low availability of charging infrastructure, such as rural areas, while the target market share best simulates the behavior of all agents in the market, so it is the best for forecasting future loads. The hybrid approach allowed the model to cover the entire state and provide a census tract level charging forecast.

The forecast for transport refrigeration units (TRUs) leveraged state-wide TRU population and TCO data from CARB[3] to forecast the adoption of electric TRUs (eTRUs).[4] The census tract level adoption forecast used County Business Patterns (CBP) dataset from the US Census Bureau to disaggregate statewide forecast to census tract level by number of employees per tract. The annual energy consumption and site configurations for eTRUs were projected by using the CARB data and the census tract level forecast.

Modeling Scenarios and Key Drivers

Table 1 describes the three scenarios for vehicle penetration considered in this effort. All of the scenarios consider the current ZEV mandate, Advanced Clean Truck (ACT) regulation, ACT Fleet regulation, Truck Refrigeration Unit (TRU) regulation, Heavy-duty Diesel Vehicles regulations, and reinstated CAFE standards. Compliance options across the scenarios vary, with the No Incentive and Planned Incentives scenarios achieving compliance via some penalty payments and Regulatory Target scenario achieving compliance via full compliance vehicle sales. Adequate and reliable incentive programs play a key role in market penetration. Other key drivers include battery costs, gasoline and diesel fuel price, consumer awareness and acceptance and California's MHD vehicle regulations.

[2] Charger-to-vehicle ratio assumptions will be co-developed by CalETC and Guidehouse and were based on the best publicly available data (even if LD only) along with substantiated refinements calibrated to Guidehouse's synthetic vehicle load shapes by use case. Charging duty cycles were backchecked to ensure assumptions are operationally realistic.

[3] CARB Technology Assessment: Transport Refrigerators, Page II-9.

[4] This segment includes only electric refrigeration units. Electric trucks are included in other on-road truck segments.

Table 1: Description of Modeling Scenarios

Drivers	Description	No Incentive Scenario	Planned Incentives Scenario	Regulatory Target Scenario
Incentives	Dollar per EV tax incentive ($)	• Any existing and planned California **incentives discontinued**	• California incentive policies **currently existing and planned** (AFDC, Off-Road Vehicle Industry)	• **Additional** "cash on the hood" **incentive** per vehicle covering 50% of incremental cost of EV over ICEV[1]
Battery Costs	Battery pack costs ($ per kWh)	• Guidehouse Insights **higher-bound battery cost** forecast (leading to increased EV operating costs)	• Guidehouse Insights **base battery cost** forecast	• Guidehouse Insights **lower-bound battery cost** forecast (leading to decreased EV operating costs)
Fuel Prices	Gasoline and diesel prices ($ per gallon)	• 25% **lower gasoline and diesel prices** vs. base (leading to decreased operating ICEV costs)	• AAA California average **base** assumption, adjusted for inflation	• 75% **higher gasoline and diesel prices** vs. base (leading to increased operating ICEV costs)
Consumer Awareness and Acceptance	Marketing and outreach influencing customer familiarity (i.e., public awareness / acceptance), prerequisite for adoption	• One-third **lower consumer awareness and acceptance** vs. base (leading to decreased EV adoption)	• Guidehouse Insights **base** assumption, calibrated to California's historical consumer awareness metrics	• One-third **higher consumer awareness and acceptance** vs. base (leading to increased EV adoption)[1]
Regulations	Policies regulating ICEVs and EVs	• **Penalties** paid **in lieu of adoption** per ZEV, ACT, ACT Fleet, and TRU rules	• **Penalties** paid **in lieu of adoption** per ZEV, ACT, ACT Fleet, and TRU rules	• **Adoption** consistent with ZEV, ACT, ACT Fleet, TRU, and Heavy-Duty Diesel Vehicles rules, and reinstated CAFE standards

The forecast shows that under the planned incentives scenario, on-road MHD EVs will have 12% market share by 2040, with 6.9% BEV and 4.7% PHEV; 12% market share equates to about 41,000 EV truck sales in 2040. Most of these sales are approximately 14,000 class 2a trucks, 7,000 class 7-8 trucks, 5,000 class 3 trucks, and 4,000 TRUs.

Under the planned incentive scenario, in 2040, there will be over 456,000 on-road MHD EVs, which would account for 6% penetration of the total on-road truck population; 3.7% would be BEVs and 2.1% would be PHEVs. Most of these vehicles are 213,000 class 2a trucks, 73,000 TRUs, 50,000 class 7-8 trucks, and 37,000 class 2b trucks. Although the highest quantity of the EV population will be made up of class 2a trucks, this will only account for 4% of the class 2a market segment because by 2040 there will be nearly 5 million class 2a trucks on the road in California. Class 2b will also be at 4% of its market segment, while class 3, class 4-5, and class 7-8 will reach 7% of their market segments. Class 6 and specialty on-road vehicles will reach 8% of their market segment, school busses will reach 16%, transit busses will reach 24%, and TRUs will reach 27%.

Under the planned incentive scenario, the off-road EV sales are expected to reach 78% penetration and account for 273,000 vehicle sales. Most of these sales, 258,000, will be forklifts. The other sales will be 9,000 airport ground support equipment and 6,000 seaport cargo handling equipment. By 2040, airport ground support equipment will have 91% market penetration in its segment, while seaport cargo handling equipment and other forklifts will have 74% and 78% respectively. The highest expected penetration for airport ground support equipment and other forklifts is due to relatively high EV population to date and wider vehicle availability.

Under the regulatory target scenario, the number of on-road MHD EVs in 2040 would increase from approximately 456,000 in the planned incentive scenario to 1.06 million, a 132% increase. Under the no incentive scenario, the population of EVs would decrease by 27% to 332,000. Off-road MHD EVs have much less variation between the scenarios, with the regulatory target scenario increasing by 15%

from 273,000 to 315,000 for the planned incentive scenario and the no incentive scenario would decrease by 14% to 234,000.

For all scenarios, the on-road MHD EV adoption is expected to be spread across the major metropolitan areas, the ports, and the Central Valley, with the highest adoption occurring in Los Angles, Sacramento, and the San Francisco Bay Area.

EV Charging Needs and Site Configuration Output

Guidehouse estimated the number of charging ports needed per 1,000 vehicles and from that analyzed the needed site build out to ensure adequate access to charging infrastructure across the various scenarios. Both public and private charging infrastructure needs were considered as the charging infrastructure needs varies widely across vehicle segments.

Public hub site locations were determined based on highway annual average daily traffic (AADT) and sized as small, medium, or large based on highway traffic demand at each location. The private depot locations and sizes were determined based on where vehicles were registered. Private charging is expected to fulfill most charging needs for all uses, driven by convenience and customer preference. Level 2 charging is expected to continue to play a key role for class 2 vehicles, however, DCFC will be key for class 3 and above, as well as off-road segments. Heavy-duty segments, such as class 7-8 trucks, are expected to rely primarily on DCFC.

Table 2: Port Count Per 1,000 MHD Vehicles, Planned Incentives Scenario, 2040

	Charging Port Count Needed per 1,000 Vehicles[1], Planned Incentives Scenario, 2040			
Vehicle Segment	**DCFC Private Depot**	**Level 2 Private Depot**	**DCFC Public Hub**	**Level 2 Public Hub**
Class 2a Vehicles	5	610	3	20
Class 2b Vehicles	5	610	3	20
Class 3 Trucks	270	250	60	30
Class 4-5 Trucks	270	250	60	30
Class 6 Trucks	280	250	60	30
Class 7-8 Trucks	870	0	110	30
School Buses	120	650	0	0
Transit Buses	730	15	0	0
On-Road Specialty Vehicles	560	130	80	30
In-State TRUs	0	870	110	30
Airport Ground Support Equipment	500	270	0	0
Seaport Cargo Handling Equipment	500	270	0	0
Other Forklifts	0	770	0	0

(1) Charging Port Count stacks across site type, e.g., 1,000 Class 2a Vehicles require 5 DCFC at Private Depot + 610 Level 2 at Private Depot + 3 DCFC at Public Hub + 20 Level 2 at Public Hub sites in total.

For each vehicle segment Guidehouse estimated the average port count per site for small, medium, and large site sizes assuming stacking across vehicle segments and technologies, i.e. ports for multiple vehicle segments are expected to be co-located. Due to the charging infrastructure variation across vehicle segments, the number of sites that must be electrified sufficiently to support MHD vehicles varies dramatically, e.g. by 2040 2b trucks will require tens of thousands of sites to be electrified in support of these trucks although the port count per site is one or less but Class 6 trucks require 300 or less sites be electrified, with 1-5 ports each, and only exceed this number of sites needed in the cases where 3 or less trucks are owned by an individual or small contractor. All these site configurations by vehicle segment are provided in the full report. The two examples here are shown in Table 3 and 4 below.

Table 3: Site Configurations for Class 2b Vehicles by 2040, Planned Incentive Scenario

Site Type[4]	Site Size	Illustrative Use Case	Average Port Count[1]	Average Rated kW[2]	Total Site Count	Total Rated MW[3]
DCFC Public Hub	Large	Public hub station with 15+ chargers at high-traffic suburban highway exit	<1	164	588	5.0
	Medium	Public hub station with 5-15 chargers along public corridor	<1	164	955	5.4
	Small	Public hub station with <5 chargers on rural highway	<1	164	1,416	5.8
Level 2 Public Hub	Large	Public hub station with 15+ chargers at high-traffic suburban highway exit	<1	12	588	2.6
	Medium	Public hub station with 5-15 chargers along public corridor	<1	12	955	2.8
	Small	Public hub station with <5 chargers on rural highway	<1	12	1,416	2.8
DCFC Private Depot	Large	50+ rental car fleet	<1	174	349	14.9
	Medium	5-10 unit multifamily complex with shared charging	<1	174	1,619	9.5
	Small	3-truck fleet owned by small contractor	<1	173	12,723	8.0
Level 2 Private Depot	Large	50+ delivery van fleet	1	12	885	7.8
	Medium	5-10 unit workplace charging for mid-sized employer	<1	12	5,285	7.4
	Small	Single truck owned by individual contractor	<1	12	79,028	248.0

(1) Average Port Count is stacking across vehicle segments and technologies, i.e., ports for multiple vehicle segments are expected to be co-located, resulting in an actual site having a summed-up port count from all segments served.
(2) Average Rated kW is the average charger rated capacity accounting for charger levels ranging from 3.6 kW to 19.2 kW for Level 2 and from 50 kW to 300 kW for DCFC.
(3) Total Rated MW is the result of Average Port Count x Average Rated kW x Total Site Count, not discounted for any load management, and is therefore different from any grid systemwide coincident / noncoincident peak calculation. See modeling assumptions for further detail.
(4) Class 2a-2b Vehicles are expected to use some Level 1 charging, which would come in addition to the charging needs displayed here.

Table 4: Site Configurations for Class 6 Trucks, Planned Incentive Scenario

Site Type	Site Size	Illustrative Use Case	Average Port Count[1]	Average Rated kW[2]	Total Site Count	Total Rated MW[3]
DCFC Public Hub	Large	Public hub station with 15+ chargers at high-traffic suburban highway exit	7	207	107	164.9
	Medium	Public hub station with 5-15 chargers along public corridor	1	207	174	35.1
	Small	Public hub station with <5 chargers on rural highway	<1	207	258	6.2
Level 2 Public Hub	Large	Public hub station with 15+ chargers at high-traffic suburban highway exit	4	15	107	6.2
	Medium	Public hub station with 5-15 chargers along public corridor	1	15	174	1.3
	Small	Public hub station with <5 chargers on rural highway	<1	15	258	0.2
DCFC Private Depot	Large	10+ rack truck fleet	8	213	24	41.2
	Medium	5-10 rack truck fleet owned by local contractor	5	213	188	209.8
	Small	3-truck fleet owned by small contracting business	1	213	2,600	749.3
Level 2 Private Depot	Large	10+ rack truck fleet	4	15	44	2.6
	Medium	5-10 rack truck fleet owned by local contractor	3	15	337	13.4
	Small	Single truck owned by individual contractor	1	15	4,676	47.8

(1) Average Port Count is stacking across vehicle segments and technologies, i.e., ports for multiple vehicle segments are expected to be co-located, resulting in an actual site having a summed-up port count from all segments served.
(2) Average Rated kW is the average charger rated capacity accounting for charger levels ranging from 9.3 kW to 19.2 kW for Level 2 and from 100 kW to 300 kW for DCFC.
(3) Total Rated MW is the result of Average Port Count x Average Rated kW x Total Site Count, not discounted for any load management, and is therefore different from any grid systemwide coincident / noncoincident peak calculation. See modeling assumptions for further detail.

Conclusions

The number of on-road MHD EVs will need to significantly increase to meet the regulatory target scenario. Meeting this scenario will require a significant increase in planned incentives to reach cost parity for MHD EVs.

There is not enough high quality data to evaluate the costs of infrastructure for MHD EVs, which must be addressed so that stakeholders, state agencies, and elected officials can evaluate the real costs of MHD infrastructure and plan incentive and funding mechanisms accordingly. The forecast shows that heavier vehicles with large batteries will rely primarily on DCFC, which is more costly infrastructure and places more demand on the grid. A strategy to incorporate this increased demand must be established to keep costs at a minimum and provide maximum grid benefits.

Accomplishing this transition is a major challenge but one that California and the EV community welcomes. It will require an “all-hands-on-deck” approach from all public and private entities to work on collaborative and cost-effective solutions. The economic and environmental benefits of building out this infrastructure and fully transitioning MHD trucks and equipment to zero-emission technologies are tremendous and progressive, benefitting all.