West Coast Clean Transit Corridor Initiative

Interstate 5 Corridor Background Research Technical Memorandum

California, Oregon, Washington

March

2020

Contents

Appendices

Tables

Figures

Abbreviations and Acronyms

AC	alternating current
AFLEET	Alternative Fuel Life Cycle Environmental and Economic Transportation Tool
BEV	battery electric vehicle
CARB	California Air Resources Board
CCS	Combined Charging Standards
CHAdeMO	Charge de Move
DC	direct current
ETTF	E-Truck Task Force
EV	electric vehicle
EVSE	electric vehicle supply equipment
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model
HD	heavy-duty
HVIP	Hybrid and Zero-emission Truck and Bus Voucher Incentive Project
I 5	Interstate 5
IEA	International Energy Agency
kW	kilowatt
kWh	kilowatt hour
LD	light-duty
MD	medium-duty
MW	megawatt
NCPA	Northern California Power Agency
OEM	original equipment manufacturer
PHEV	plug-in hybrid electric vehicle
SAE	Society of Automotive Engineers
SCPPA	Southern California Public Power Authority
SEPA	Smart Electric Power Alliance
TCO	total cost of ownership
V	voltage
VMT	vehicle miles traveled
ZEV	zero-emission vehicle

Definitions

Area	A region defined by the rate of urbanization and industrialization. These areas are separated between urban/metro and rural.
AC charging	An alternating current (AC) power connection to the electric vehicle's on-board charging module, which converts the AC power to direct current (DC) power. The DC power is then supplied to the vehicle's battery system.
Charger	An electric fuel dispenser device that can have one or more ports for charging an electric vehicle. Some chargers consist of a power box and a dispenser as two separate items.
Charging equipment	Three levels of electric vehicle charging equipment are available: AC Level 1 charging, AC Level 2 charging, and fast charging. Charging equipment is classified by the rate at which the batteries are charged. Level 1 and Level 2 chargers are typically used for passenger vehicles at home or at work while the vehicle sits idle. Fast chargers as public infrastructure are needed for electric trucks because Level 1 and Level 2 chargers cannot replenish the energy required to operate these vehicles fast enough.
Charging site	A property upon which a number of electric vehicle chargers and associated electric equipment, designated spaces, lighting, and other amenities are installed to accommodate electric vehicles and their drivers.
DC fast charging	A DC power connection from a DC charger directly to the electric vehicle's battery system. DC fast charging substantially increases the charging speed, compared with AC charging.
Electric vehicle	A vehicle with a motor powered by electricity. Electric vehicles are also referred to as zero-emission vehicles because they do not emit air pollutants associated with vehicles powered by internal combustion engines. In this report, unless stated otherwise, electric vehicle means a battery electric vehicle as opposed to a fuel-cell electric vehicle.
Heavy-duty (HD) truck	Heavy-duty trucks include long-haul tractor-trailer trucks and transit buses. They are generally considered to be in the Class 7 or Class 8 weight category.
Kilowatt (kW)	A watt is a unit of power, and power is the rate at which energy is produced or consumed. One kilowatt equals 1,000 watts, and it is used to describe energy consumption at the household level. For example, a dishwasher uses approximately 1.2 kilowatts.
Kilowatt hour (kWh)	A kilowatt hour is 1,000 watt-hours, and it is a unit used to measure the amount of power used over a period of time. For example, a refrigerator uses approximately 540 watts and it runs about 8 hours each day, meaning

	it uses approximately 4 kilowatt-hours per day.
Light-duty (LD) vehicle	A light-duty vehicle is a passenger vehicle, in the Class 1 or Class 2 weight category.
Location	In this report, the vicinity in which an electric vehicle charging site would be best positioned.
Medium-duty (MD) truck	Medium-duty trucks include cargo vans, delivery trucks, and shuttle buses. They are generally considered to be in the Class 3 through Class 6 weight categories.
Megawatt (MW)	One megawatt equals 1,000 kilowatts, and it is used to describe energy consumption at the level of cities and generating plants. Wind turbines typically generate around 2 to 3 megawatts of power each.
Port	Connector device or cable that is part of a charger and is used to connect to an electric vehicle when it needs to be charged.
Total cost of ownership (TCO)	The cost of purchasing, operating, and maintaining an electric vehicle over the time it is owned. Calculating the TCO should take into account any applicable governmental subsidies and/or incentives for encouraging the use of electric vehicles.

This page is intentionally left blank.

1. Introduction

This technical memorandum was prepared in support of the West Coast Clean Transit Corridor Initiative, which presents an initial strategy for transportation electrification infrastructure along Interstate 5 (I-5) in California, Oregon, and Washington for medium-duty (MD) and heavy-duty (HD) trucks. The study investigated the wide range of commercial electric vehicle (EV) use cases and their charging technology solutions across multiple vehicle classes. The final report—West Coast Clean Transit Corridor Initiative, Interstate 5 Corridor, Final Report—provides a final set of recommendations on charging infrastructure locations along I-5 from southern California to northern Washington and describes the impact that MD and HD zero-emission trucks would have on the electric grid.

This technical memorandum provides the background research that supports the findings and recommendations of the final report. The following bullets provide an overview of the technical memorandum:

- **Chapter 1** introduces the reader to the West Coast Clean Transit Corridor Initiative and provides an orientation to the topics covered in subsequent chapters.
- **Chapter 2** discusses pertinent research related to EV technology and how some electric utilities have already invested in electric truck charging.
- **Chapter 3** summarizes the survey results conducted with major stakeholders in the electric truck arena: fleet operators, electric truck manufacturers, and charger providers.
- **Chapter 4** provides an overview of the truck market, including:
    - existing markets for both conventional and electric trucks
    - electric truck market trends
- **Chapter 5** discusses the electric truck charger market, including current and future charging technologies.
- **Chapter 6** describes existing and planned electric truck charging infrastructure programs and includes feedback from charger providers and electric utilities regarding the needed infrastructure upgrades.
- **Chapter 7** lists the references used in the preparation of this technical memorandum.

2. Overview of Electric Vehicle Technology and Investment

This chapter discusses the current state of the EV industry. It also identifies several barriers and challenges facing the industry, and offers some solutions to continue advancing the deployment of electric MD/HD trucks.

Current State of Electric Vehicle Technology

The section describes the current state of EV technology. Further information is available in Chapter 4, Truck Market Overview, and in Chapter 5, Electric Truck Charger Market Overview.

Numerous demonstrations and studies have shown that for certain uses, current EV technology has an overall positive return on investment over the vehicle's lifetime. Anticipated future reductions in the costs of producing EVs will increase the appeal of MD/HD EVs. However, a complete replacement of internal combustion engines soon is unlikely. The International Energy Agency (IEA) estimates that with existing and committed policies, the total number of electric and hybrid EVs on the road in 2030 will be around 125 million, or 16 percent of the global market—and most of these EVs will be light-duty (LD) (IEA 2018). This falls short of the IEA's goal of 228 million EVs to meet its EV30@30 goal of a 30 percent market share for EVs by 2030. More incentives and education about the benefits of EVs are needed to advance the global EV market.

MD trucks are often excellent candidates for battery electric technologies because they operate from a fixed start/end location, travel a predictable daily distance, and maintain a low average speed and drive time (North American Council for Freight Efficiency 2019). Similarly, some stop-and-go HD truck applications are good candidates for electrification today. Of all HD trucks, buses are the most likely candidates for the early adoption of electrification. Government support for public transit agencies, short routes, frequent stops, and the opportunity to charge overnight when costs are usually lowest have helped propel the electric bus market forward. China leads the world in terms of the number of electric buses deployed, but increasingly cities in the European Union and North America are deploying electric buses, too. Although electric buses still face some technology challenges such as power draw from auxiliary heating and air conditioning systems or wheelchair lifts, they are a proven technology available at increasingly affordable prices. Other low-speed, frequently idle duty-cycle vehicles such as port yard tractors, drayage trucks that transport freight short distances, delivery vans, and delivery trucks are best suited to realize the greatest efficiency gains from electrification. Battery range limitations, battery costs, and energy recovery advantages associated with regenerative braking mean that electrification is more likely to happen for slower-speed, shorter-range vehicles first in the MD/HD market (California Air Resources Board [CARB] 2018a).

HD trucks and buses accounted for 10 percent of the 3.2 trillion vehicle miles driven in 2016. In 2017, over 12 million HD trucks were registered in the US (Davis and Boundy 2019). Although they account for only 5 percent of the vehicles on US roads, HD vehicles contribute a disproportionately high 23 percent of all transportation emissions. Reducing future energy demand and emissions requires systemic improvements to vehicle efficiency and increased use of cleaner technology zero-emission vehicles (ZEVs) (US Environmental Protection Agency 2017).

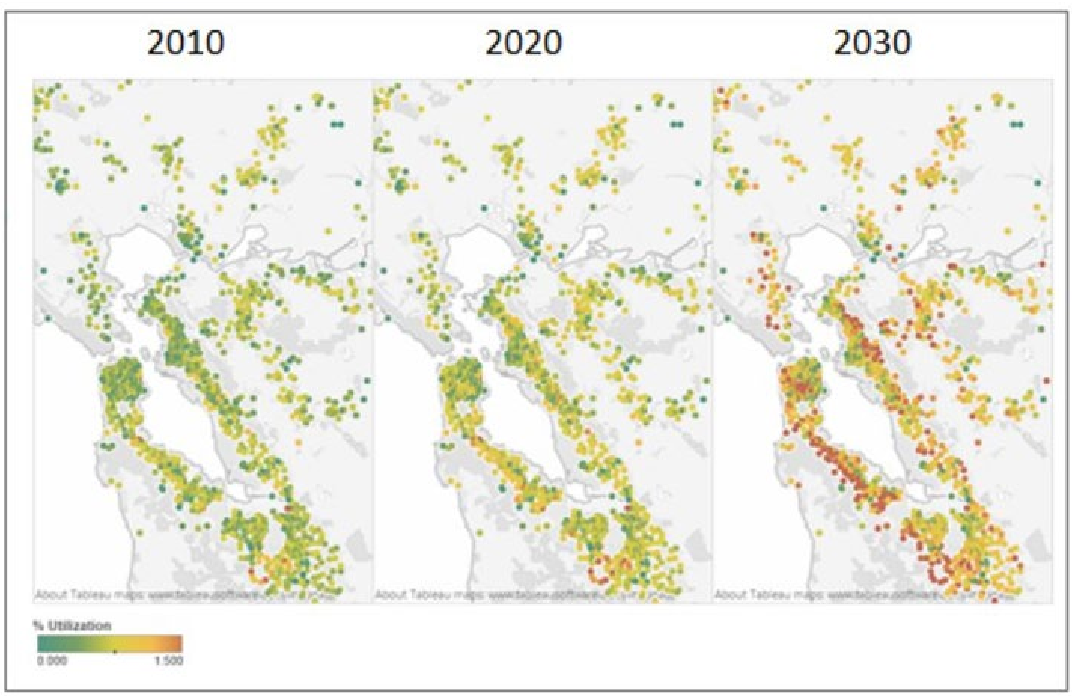
Electric trucks have lagged buses as a developing electric technology—as of 2018, electric trucks were primarily deployed only in demonstration and trial projects. IEA estimated a 1 to 3 percent market share of all-electric trucks by 2030, depending on how aggressive government policies push for the adoption of EVs. In contrast, IEA estimated a 15 to 35 percent market share for electric buses in 2030 (IEA 2018). This difference is largely attributable to the fact that battery technologies do not yet have the capacity to provide ranges equivalent to those offered by conventional trucks. Although production has not yet become fully commercialized, truck makers such as Volvo, Daimler, Mack, Paccar, and Navistar continue developing and testing zero-emission trucks that can compete with the performance of conventional models (see Table 6 in Chapter 4, Truck Market Overview, for a list of models of electric trucks available today and under development).

Electric Utility Investment in Truck and Bus Charging

Infrastructure Deployment

Electric utilities have an important role to play in furthering infrastructure deployment, in terms of upgrades to the electrical grid and the installation of charging sites to satisfy increasing demand. The California Transportation Electrification Assessment study developed by Energy and Environmental Economics, Inc., forecast how plug-in EVs would affect the distribution system. Figure 1 shows the percentage utilization for each of the interconnections within the distribution grid in the San Francisco area (green and yellow indicate utilization below 100 percent, and red represents utilization close to 150 percent or more). Even under the "most likely adoption" scenario, which is the most conservative, EVs will add enough demand to exceed current grid capacity in some areas by 2030—requiring distribution system upgrades.

As electric utilities continue to recognize the net benefit of EV adoption, they may wish to play an active role in supporting the transition to EVs because of the increased power consumption. Limiting the costs to customers may accelerate EV adoption by making them a more appealing option to cost-conscious fleet operators (Hledik and Weiss 2019). Electric utilities have a unique opportunity to identify and support vehicle charging programs now



Source: Energy and Environmental Economics, Inc. (2014)

Figure 1: Forecast Grid Utilization in the San Francisco Region

to receive future benefits. Leveraging their expertise in load management, electric utilities can develop charging programs that will help them prepare for the extra load that EVs will demand from the grid (Gatti 2018). Such programs may set better commercial rates, be scalable, serve communities overburdened by air pollution, leverage multiple funding sources, and incentivize fleet electrification (Houston 2019).

Potential electric utility strategies for expanding charging infrastructure include:

- **Make-ready**: The electric utility invests in infrastructure by upgrading electrical panels, digging trenches, and laying wires, making sites ready for chargers to be installed.
- **End-to-end utility ownership**: The electric utility funds, owns, and operates all infrastructure, including the charger.
- **Incentives**: The electric utility offers incentives, either as full or partial rebates, to the site host for the cost of upgrading infrastructure, purchasing and installing the charger, or both.
- **Financing**: The electric utility pays the up-front costs of electrification and the customer repays the electric utility as a part of its regular electric utility bills.

Several challenges confront the more wide-scale deployment of EV charging infrastructure for MD/HD vehicles. It has long been debated whether public infrastructure should precede wider EV adoption or vice versa. Would more infrastructure induce fleets to deploy EVs or is the infrastructure only useful once EVs are on the roads? Complicating things, different countries currently use different standards. New technologies such as direct current (DC) fast charging sites capable of charging at extremely high powers, overhead pantographs, and inductive charging have complicated efforts to standardize charging infrastructure. China has the most MD/HD EVs deployed of any country, and its preferences for the types and numbers of charging sites needed for its bus fleets may offer guidance for electrification efforts.

As more fleets purchase EVs, governments and private companies are starting to make the necessary investments in public charging infrastructure. The Electrify America project, for example, seeks to deploy 900 highway charging sites set at intervals of 28 to 72 miles apart. As of 2018, there were only 15 truck stop electric charging sites in the three West Coast states: California had six, Oregon had five, and Washington had four. These truck stop sites allow drivers to charge vehicles while taking mandated breaks (Davis and Boundy 2019). Washington and Oregon submitted joint applications for Electrify America funding, focusing on funding further charger deployment in specific high-use or high-density locales, with some consideration for expanding consumer outreach, education, and access to ZEVs among underserved communities (Washington State Department of Transportation 2020). Because there is uncertainty in what the future market will look like, infrastructure planning may involve the potential for future expansion (IEA 2018).

AC versus DC

AC charging is the most common type of EV charging. Most AC chargers at homes, shopping centers, and offices are Level 2 AC chargers. They supply power to the EV's on-board charger, which converts the AC power to DC. These chargers may take four to twelve hours to fully charge an EV.

DC fast charging supplies DC power directly to the EV battery, substantially increasing the charging speed. Most EVs can get an 80 percent charge in about an hour using this technology. DC fast charging is useful for high-mileage and long-distance driving because it allows drivers to charge their EVs during a break, rather than overnight.

Encouraging Electric Vehicle Adoption Through Rates and Infrastructure

Different rate scenarios can substantially influence EV adoption and grid impacts. Rate cases that include time-of-use pricing can help shift EV demand to off-peak hours, maximizing grid efficiency and minimizing the amount of additional capacity necessary to handle EV loads. Under a time-of-use rate case, one study estimated it would cost electric utilities about $150 million in 2015 dollars to upgrade California's energy infrastructure to meet projected demand under a "most likely" scenario for ZEV adoption (Energy and Environmental Economics, Inc. 2014). This represents a significant savings compared with the projected cost of $400 million for upgrades without time-of-use rates causing a shift in charging behavior, as estimated by the same study. Things have measurably changed in the market since this study was completed (for example, the same study predicted cumulative total ZEVs in the US to be under 500,000 in 2017, while the actual number was closer to 760,000). A new assessment would likely provide a more accurate estimate that would likely be higher.

Rate design and site host options offered by an electric utility will influence how and where public DC fast charging sites are deployed (Hledik and Weiss 2019). Because of their different load profiles, DC fast charging sites may require different rate options. Electric utilities may consider how demand charges can determine electric fuel prices and consider strategies to reduce their impact and ensure electric fuel prices are competitive with fossil fuel prices. Allowing customers to experiment with different charging options and find the most efficient system for their situation is helpful. For example, Portland General Electric, Southern California Edison, and Pacific Power proposed limiting demand charges or implementing flat volumetric rates for EV charging. This will help both customers and electric utilities learn more about the energy needs of early adopters. Electric utilities can also help maximize the benefits of EVs by providing more information to customers about their loads and possible ways to reduce costs. Additionally, on-site decision-making support would greatly help fleets, whether provided by the electric utilities or third parties with expertise in this area. Other tools electric utilities can use to encourage infrastructure deployment include:

- Directly managing loads to avoid demand charges.
- Installing energy storage to help manage loads.
- Encouraging infrastructure deployment around known and existing customer bases or at sites with excess grid capacity.
- Placing DC fast charging sites with existing large electricity users so that load increases are incremental.

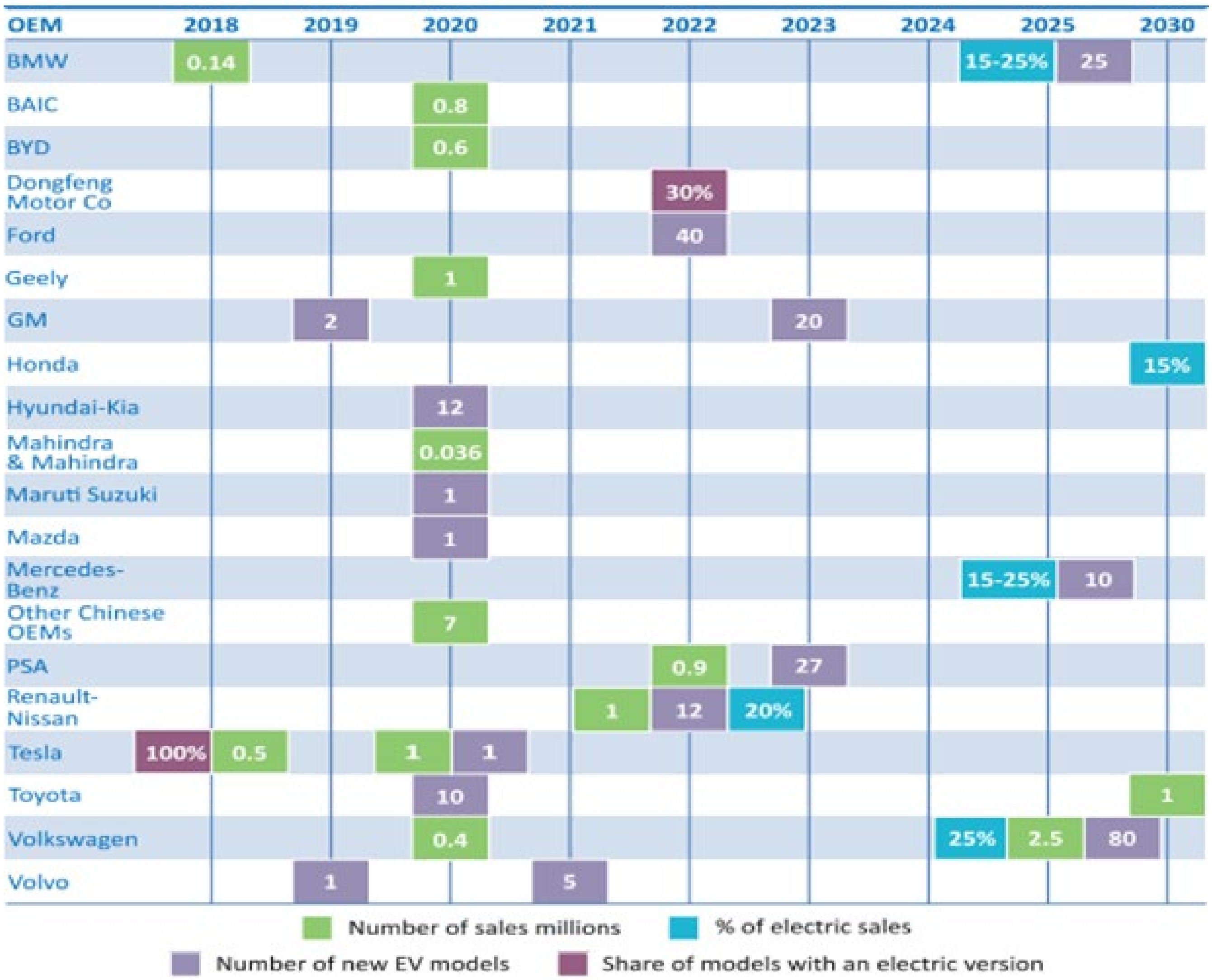
By facilitating the deployment of public electric charging sites, electric utilities can play an important role in reducing initial capital costs for EV fleet conversion and help realize the benefits of electric transportation sooner (Hledik and Weiss 2019).

Forecasting Future Demand

This section describes efforts to forecast future demand for EVs. Refer to Chapter 4, Truck Market Overview, for further information.

The expanding EV market is demonstrated by the number of new EVs that manufacturers plan to release in the coming years. EVs of all sizes are likely to become much more important to fleets and consumers as government policies tighten regulations on conventional vehicles to meet air quality and climate goals (CARB 2018c). Figure 2 shows a snapshot of manufacturer announcements related to forthcoming EV models and sales targets.

A few studies have sought to forecast the future market growth of EVs under various policy scenarios. The IEA's Global Electric Vehicle Outlook 2018 estimates EV deployment globally under two scenarios (IEA 2018). The "New Policies Scenario" accounts for policies and measures that governments around the world have either announced or already implemented. The "EV30@30 Scenario" reflects the ambitions of countries that have joined the IEA's Electric Vehicles Initiative, who they pledged to have EVs make up 30 percent of the market for LD vehicles, buses, and trucks, collectively, by 2030 (IEA 2018).



Source: IEA (2018)

Figure 2: Automaker Announcements Related to Forthcoming EV Models or Sales

At a smaller scale, the California Transportation Electrification Assessment Phase 1 report estimates the adoption of ZEVs in California by 2030 under two scenarios (ICF International and Energy and Environmental Economics, Inc. 2014). The "Current Adoption" case is based on anticipated market growth, expected and existing incentive programs, and compliance with existing regulations. The "Aggressive Adoption" case assumes aggressive but feasible new incentive programs or regulations (such incentive programs that would include all possible options for incentivizing EV sales, including government, electric utility, and manufacturer incentives). These scenarios demonstrate that policy has a major role to play in determining the number of ZEVs on the road, underscoring the challenge of predicting future demand to justify the capital costs of infrastructure.

Table 1 lists the total stock of EVs, by category, predicted by each of these studies in 2030.

Table 1: Total Stock of Electric Vehicles in 2030, by Category, as Predicted by Different Studies

Source	Geographic Scope	Classification	Scenario	Baseline Stock	Predicted Stock (2030)
Global Electric Vehicle Outlook (2018)	Global	Light-duty vehicles	New Policies	3 million (2017)	125 million
			EV30@30	3 million (2017)	220 million
		Buses	New Policies	370,000 (2017)	1.5 million
			EV30@30	370,000 (2017)	4.5 million
		Trucks	New Policies	"a few hundred" (2017)	1 million
			EV30@30	"a few hundred" (2017)	2.5 million
California Transportation Electrification Assessment Phase 1 (2014)	California	Light-duty vehicles	Current Adoption	13,600 battery electric vehicles (BEVs) 29,900 plug-in hybrid electric vehicles (PHEVs) (2013)	60,400 BEVs 544,000 PHEVs
			Aggressive Adoption	13,600 BEVs	2.2 million BEVs 4,750,000 PHEVs
		Medium-duty	Current Adoption	500 (2013)	96,500
			Aggressive Adoption	500 (2013)	834,000
		Heavy-duty	Current Adoption	500 (2013)	8,800
			Aggressive Adoption	500 (2013)	65,800

Sources: ICF International and Energy and Environmental Economics, Inc. (2014), IEA (2018)

Challenges and Opportunities

This section describes the barriers and next steps facing transportation electrification efforts. Further information is available in Chapter 4, Truck Market Overview, and in Chapter 5, Electric Truck Charger Market.

Multiple barriers have stymied EV adoption, including the up-front cost of EVs versus conventional vehicles, lack of charging infrastructure, and lack of awareness about the availability of and best uses for electric technologies (CARB 2018d; CALSTART 2016). The most basic reason that few HD fleets are switching to EVs is that the technology simply is not commercially available (ICF International and Energy and Environmental Economics, Inc. 2014). Although few fleets have committed to switching to fully electric operations, some have expressed a need to better understand how transitioning to EVs will affect their operations. As discussed before, each vehicle use case is different, and some are better suited to electrification than others. When fleets begin to scale up their EV deployment, they must also begin to scale up their electric infrastructure power capacity to accommodate the new vehicles' charging demands. Tools such as a checklist of infrastructure considerations or assistance determining which vehicles best fit a fleet's operational needs would be useful. Additionally, policies that incentivize electric fleet conversion need to continue (CARB 2018d).

Government Incentives, Regulations, and Coordination

Numerous studies agree that subsidies and incentives are still necessary to bring EVs to market. These may, in part, come from electric utilities, but government programs are also likely to play an important role in electrifying our transportation system. Governments can assist in increasing the deployment of battery EVs by offering funding in the form of voucher programs and tax rebates. However, stakeholders have cited a need for better coordination between funding sources. It is currently difficult to understand what funding sources can be combined. Stakeholders have also noted that voucher programs such as California's Hybrid and Zero-emission Truck and Bus Voucher Incentive Project (HVIP) program do not fully cover the incremental cost of purchasing an EV; policies that allow EVs to achieve price parity with diesel vehicles will further promote the technology's adoption (CALSTART 2016).

Education and Knowledge Sharing

Many fleet managers are unaware of the current state of EV technology for MD/HD vehicles. Working groups have called for educational programs and tools to help fleets understand what technologies are available and their anticipated return on investment. A few tools have since been developed to try to meet this need. The Argonne National Laboratory's Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model provides a life cycle comparison of environmental impacts for LD vehicles, but does not provide such information for MD/HD trucks (Argonne National Laboratory 2018). Building on the GREET model, Argonne National Laboratory later developed the Alternative Fuel Life Cycle Environmental and Economic Transportation (AFLEET) Tool, which assists users in measuring the environmental and economic costs and benefits associated with alternative fuel vehicles (Argonne National Laboratory 2017). However, AFLEET does not provide information on specific duty cycles. Recently, CARB developed the Mobile Source Emissions Inventory, an online tool that allows fleets to analyze their on-road emissions and estimate the greenhouse gas reductions and other benefits associated with adopting EVs (CARB 2019e).

Cost of ownership calculations can be complicated by the numerous factors that can influence a given fleet's return on investment. These include vehicle life, market conditions such as the cost of diesel, battery issues such as maintenance and repair, vehicle characteristics such as weight, regulatory issues such as how future policies affect EV adoption, and power issues such as energy sourcing (North American Council for Freight Efficiency 2019).

Electric Vehicle Technology and Investment Conclusions

While the market is slowly moving toward electrification, continued government support will be essential to advance the adoption of clean transportation technologies on a trajectory that meets climate and sustainability goals. Incentives are a key tool for moving the market forward. These include governments supporting the transition of public fleets, point-of-sale and tax rebates, electric utility investments and policies, and availability of public charging infrastructure. Governments can nudge electric utilities toward greater EV penetration by developing policies that advance infrastructure deployment. Increasingly, private companies are becoming involved in deploying charging infrastructure as well, and public-private partnerships represent another financing option for public charging sites. Rebates and tax incentives for employers and businesses that install public or workplace chargers can also speed the adoption of EVs (IEA 2018).

Technology-neutral regulations based on carbon emissions and mandates that suppliers sell a certain number of ZEVs are also important policy tools to move the market toward lower-emission vehicles. This may be especially true in the case of HD vehicles, where the cost benefits of EVs sometimes outweigh the costs of transitioning fleets. Finally, there is a need for a clear and traceable battery supply chain, from resource extraction to end-of-life disposal, to achieve the most socially and environmentally responsible transportation system possible (IEA 2018). This includes the need to identify viable business cases for second-life battery use, such as assessing the feasibility of original equipment manufacturer (OEM) battery leasing programs or developing additional on-site storage (ICF International and Energy and Environmental Economics, Inc. 2014).

The last 5 years have seen incredible improvements in battery EV technology that popularized LD EVs, brought MD EVs to market, and demonstrated the feasibility of HD EVs in numerous pilot projects. California is a global leader in climate action and transitioning to a clean transportation system, with Oregon and Washington beginning to follow the same path. As these states prepare to lead the rest of the country in deploying zero-emission MD/HD vehicles, they are taking the first steps on a journey toward a clean, healthy, and equitable future.

3. Stakeholder Engagement

This chapter discusses the viewpoints of key stakeholders in the EV arena, proving insight into the challenges and opportunities facing the EV market. The first section of this chapter discusses surveys conducted with three stakeholder groups: fleet operators, electric truck manufacturers, and charger providers. The second section summarizes input gathered through an industry task force and working group, with members who represent government agencies, EV manufacturers, battery suppliers, equipment providers, electric utilities, and end users. The final section provides the survey results of electric utility companies.

Stakeholder Surveys

To augment the information obtained through the background research discussed in the preceding chapter, surveys were developed and administered to three stakeholder groups: fleets, OEMs (electric truck manufacturers), and electric vehicle supply equipment (EVSE) providers (charger providers). This survey effort was meant to obtain additional information and perspectives on MD/HD EV charging infrastructure development from each stakeholder group. It took a qualitative approach to gathering information, given the relatively small numbers of respondents. The survey results provide a more textured, case-specific understanding of the views and experiences of the stakeholder groups. Each survey was tailored to obtain specific information from each group. This chapter summarizes the information gathered from the stakeholder groups, placing an emphasis on key feedback received through the surveys.

Fleet Operators. The fleet survey was directed toward fleets that use MD/HD vehicles, and it captured the following information:

- fleet composition by vehicle type, vehicle class/weight, geography, etc.
- duty cycles: rural versus urban versus suburban transportation, miles traveled per day, hours of operation with breaks, charging patterns
- vocational segment: long-haul, drayage, regional HD distribution, and MD delivery
- ownership model: fleet owner, licensed motor carrier, or independent owner-operator
- trends among fleets: growth potential of fleets, existing MD/HD ZEVs, and plans for growth
- suggested charging infrastructure locations

Original Equipment Manufacturers. The OEM survey was directed toward OEMs that manufacture MD/HD vehicles, and it captured the following information:

- conventional truck sales: most recent three years and forecast sales
- MD/HD ZEV sales: most recent three years and forecast sales
- MD/HD ZEV product availability and development: models commercially developed, announced to the public, and intended for future years
- preferences regarding MD/HD truck chargers: standards, charging rates, modes of charging
- barriers to market adoption of MD/HD ZEVs: infrastructure, charging standards, service and support, business case, customer appetite, regulations

Electric Vehicle Supply Equipment Provider. The EVSE provider survey was directed toward EVSE hardware and software suppliers, and it captured the following information:

- charging standards: known charging standards and preferences
- identification of barriers
- recommendations for policies and regulations supportive of MD/HD EV charging infrastructure development
- infrastructure development best practices
- software to enable demand management and load balancing

The results of these surveys support the West Coast Clean Transit Corridor Initiative effort by capturing the perspectives of these groups regarding developing MD/HD EV charging infrastructure on the West Coast. The remainder of this section summarizes the results of each survey; however, all information collected from the OEM and EVSE surveys is in Appendix A, Stakeholder Surveys Supporting Documentation.

Fleet Operator Survey

Survey Methods

The purpose of the fleet survey was to obtain information from MD and HD truck fleets in California, Oregon, and Washington regarding their views, plans, and needs surrounding EV charging infrastructure development. The survey asked fleets a number of questions on several topics, including, but not limited to, the following:

- Current fleet operations and make up (number of vehicles by type, size, and fuel type)
- Current duty cycle of fleet vehicles (miles per day, hours per day, type of terrain)
- Vehicle refueling frequency and charging frequency for existing EVs
- Expectations of fleet size changes in the next three to five years
- Plans to acquire MD/HD EVs in the next three to five years (if so, how many, by type and size)
- Where MD/HD EV charging infrastructure is needed in California, Oregon, and Washington
- Perceptions on barriers to MD/HD EV infrastructure development, support needed, and plans for future scale of infrastructure

The fleet survey used a combination of the following methods: targeted emails, snowball sampling, and study partner referrals. First, the researchers sent an invitation to take the survey to 130 contacts obtained through study team suggestions, which represented about 60 separate fleets. Next, the researchers sent the survey to 1,956 additional contacts, which were included on a public list of fleets with clean trucks provided by the Port of Los Angeles.[a]

To avoid results that were geographically skewed toward southern California, and to ensure that the researchers also obtained survey responses from northern California, Oregon, and Washington, the researchers also sent the survey to contacts at the following organizations, requesting them to share it with their fleet contacts: Seattle Clean City Coalition; Portland Clean City Coalition; Port of Olympia, Washington; Port of Portland, Oregon; Port of Stockton, California; Port of Seattle; Northwest Seaport Alliance; Port of Vancouver USA; American Trucking Association; Puget Sound Clean Air Agency; Port of Oakland; and Columbia-Willamette Clean Cities Coalition.

The researchers also collaborated with other study partners to distribute the survey to their shared networks. From this effort, the researchers obtained responses to the online survey from 11 respondents, which represent 11 separate fleets. One additional fleet deferred the survey for a phone interview because of the complexity of its answers and the vast network of the fleet's operations (Table 2).

Table 2. Summary of Fleet Survey Respondents

	Number of Fleets Represented
Online survey responses	11
Phone Interview	1
Total	12

While conducting the fleet survey for this study, CALSTART also led a simultaneous separate study that had a very similar scope. This study, the West Coast Collaborative Alternative Fuel Infrastructure Corridor Coalition (WCC AFICC), was a US Environmental Protection Agency-funded effort to identify alternative fuel infrastructure needs for MD/HD vehicles in California,

a https://www.portoflosangeles.org/environment/air-quality/clean-truck-program

Oregon, and Washington.[b] This effort also involved a survey of MD and HD vehicle fleets in the West Coast states. While the questions asked in the WCC AFICC fleet survey did not exactly mirror those asked in this study's fleet survey, they were very similar.

The biggest difference between the surveys was that the WCC AFICC survey included multiple alternative fuels in its scope: electricity, hydrogen, propane, and natural gas. Also, the WCC AFICC survey inquired regarding buses and trucks, not just trucks alone. Given the similarities between both studies and their surveys, a summary of the WCC AFICC fleet survey results is provided later in this section.

Online Survey Responses

States of Operation

When asked in which states each fleet operates, almost all of them stated that they operate in California (at 82 percent), while 45 percent operate in Washington, and 27 percent operate in Oregon. The uneven distribution can likely be partially attributed to the set of targeted survey recipients. While the Port of Los Angeles' List of Companies with Clean Trucks (with nearly 2,000 contacts) was easily and publicly accessible, similar lists for ports in Oregon and Washington were not as available and the researchers had to rely on referral-based survey methods, asking local ports and Clean Cities Coalition partners to distribute surveys to their fleet contacts. It is important to keep this geographical distribution in mind when reviewing the remaining results of this survey.

Fleet Ownership Model

When asked to explain what ownership model each respondent uses for their fleet, 45 percent stated that their fleet uses an owner-operator model and 45 percent stated that their fleet uses a licensed motor carrier model. One respondent chose the "other" answer, simply saying their fleet ownership model was "mixed."

Fleet Vocation

The majority of fleet respondents stated that they work as drayage fleets, followed closely by regional shipping, and then parcel delivery, school bus fleets, and food and beverage distribution. Two respondents that selected "other" stated their vocations as municipal government transit service and electric utility. It is important to note that these results are likely because many of the survey recipients were truck fleets serving West Coast ports.

Fleet Makeup

When asked how many vehicles were in each respondent's fleet, the response varied by number and by vehicle type. On average across all respondents in aggregate, most vehicles were Class 8 trucks, followed by Class 2a trucks. This trend remains when examining the responses by maximum values. The highest number of vehicles of any given type in any responding fleet was 120 Class 8 trucks, followed by 119 Class 2a trucks. Some respondents also stated that they owned transit buses and shuttle buses.

Several respondents chose the "other" option and reported they own a number of vehicle types not included as answer options, largely LD vehicles. Other responses included 51 sport utility vehicles, 25 "wagon and cargo" vans, 21 sedans, two electric semi-trucks, two electric forklifts, and one electric reach-stacker.

Results also varied when respondents were asked to describe the makeup of their fleets by fuel type. In general, most of the vehicles in the respondents' fleets run on diesel, followed by gasoline. Some fleets already use EVs.

On average across all respondents, these fleets are made up of 58 percent diesel vehicles, 17 percent gasoline vehicles, 7 percent EVs, 6 percent compressed natural gas (CNG) vehicles, and 1 percent hybrid vehicles. Keep in mind that, since these are average values across responses, they need not add up to 100 percent. Note also that 7 percent of the fleets already own EVs, a much higher adoption rate than the overall truck fleet population currently.

Fleet Duty Cycles

When asked what type of geography each respondent travels, 45 percent of respondents stated that they travel rural terrain, 100 percent travel urban terrain, and 73 percent travel suburban terrain. This again reflects the port-based focus of the survey respondents, with a bias toward urban environments.

b See https://westcoastcollaborative.org/workgroup/wkgrp-fuels.htm for more information.

When asked how many miles each respondent's vehicles travel per day, the responses varied depending on the fleet's vocation and the type of vehicles they operated. The average minimum number of miles per day across the responses was 129, and the average maximum daily miles was 340.

Respondents' paraphrased answers to this question were:

- It varies depending on the type of work done.
- Some vehicles travel less than 100 miles per day, and some travel more than 200 miles per day.
- 100 miles per day.
- 150 miles per day.
- 80 miles per day on average.
- Class 8 trucks range from 250 to 1,500 miles per day.
- Electric trucks travel less than 150 miles per day and other trucks fluctuate between 125 and 250 miles per day.

Responses also varied for how many hours each respondent's vehicles operate per day. Multiple respondents provided ranges in their responses, with overall averages of 8.2 minimum hours per day and 10.2 maximum hours per day—these hours of operation reflect the nature of the fleets responding, generally one- or two-shift vocations, with drivers returning home each night.

Refueling and Electric Charging Methods

Respondents varied in how frequently they refuel their vehicles. Figure 3 shows the results to this question. The majority of respondents refuel twice a week or more often, while only 9 percent of respondents refuel once a week or less. The respondents that chose the "other" answer elaborated with the following:

- Vehicles refuel when needed.
- Local vehicles fuel twice a week, and regional vehicles fuel every other day.

The majority (55 percent) of respondents that already have EVs in their fleets charge them overnight at a depot.

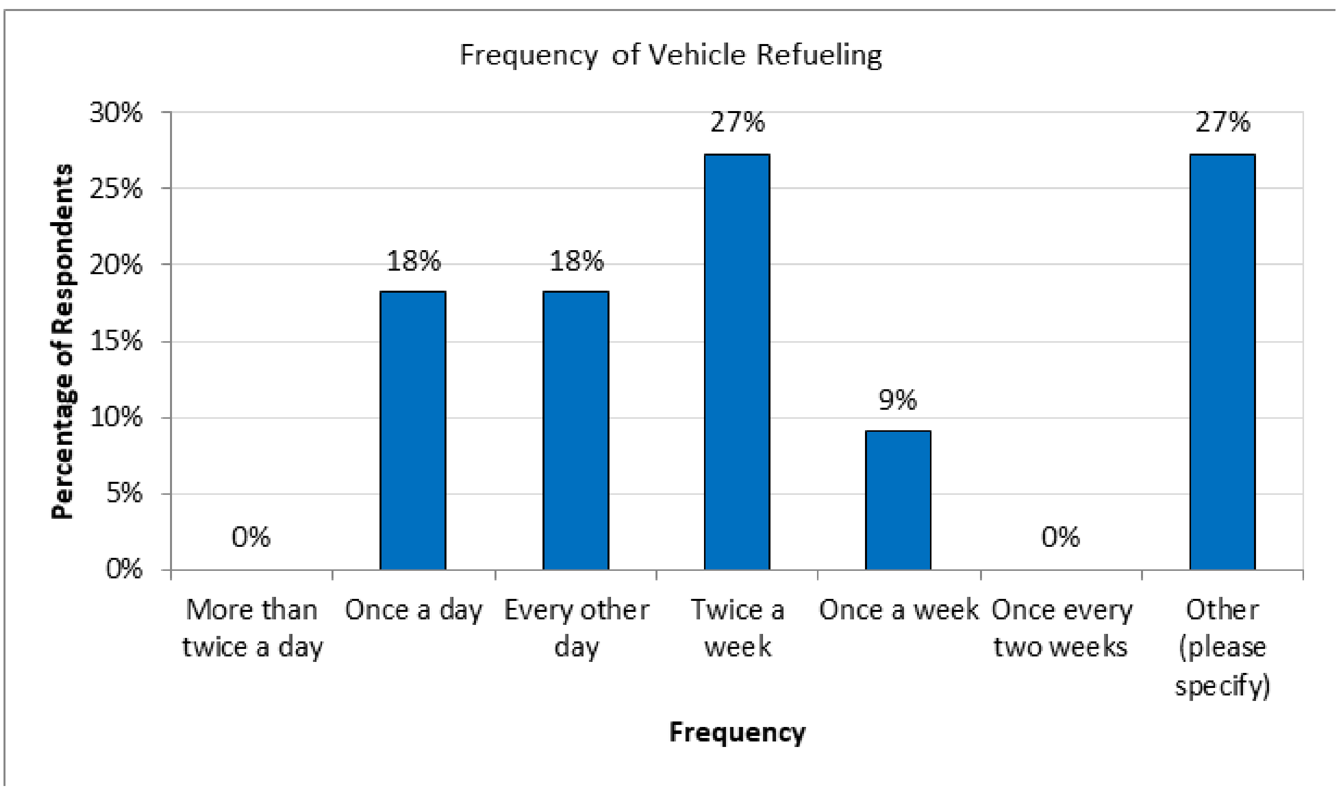


Figure 3: Frequency of Vehicle Refueling

The 45 percent of respondents that chose the "other" answer stated that they use opportunity charging. None are using on-route chargers.

Future Vehicle Procurement Plans

When asked how they think their fleet size will change in the next three to five years, most respondents (72 percent) stated that they expect either no change or a small increase of up to 10 percent. Just 18 percent of respondents stated that they expect a large decrease of more than 10 percent, and half as many (9 percent) respondents expect a large increase of more than 10 percent. These fleets are positive about future growth but not overly enthusiastic.

When asked if they have plans to acquire MD or HD EVs in the next three to five years, most respondents said yes, at 73 percent, showing a very positive perception of EV trucks among these fleet operators. Nine percent of respondents said they do not have plans to acquire MD/HD EVs, and 18 percent of respondents said they do not know.

The respondents that do have plans to acquire MD/HD EVs in the next three to five years were asked to state how many MD/HD EVs they plan to acquire by vehicle type. These fleets said they planned to purchase Class 8 electric tractors, and some said they were getting transit buses. Note that respondents stated no plans to acquire EVs of any other type. As stated earlier, many of the respondents are drayage and regional delivery fleets that serve West Coast ports, so they primarily operate Class 8 trucks.

Electric Charging Infrastructure Needs, by Location

California

The researchers asked survey respondents where they require electric charging sites in California, Oregon, and Washington within the next three to five years. Respondents gave several locations in California, which vary in specificity. These anecdotal mentions were not considered as part of the analysis determining potential locations along the corridor because the fleets surveyed were limited in number and variety, and because the location details varied greatly. These locations are listed below, exactly as reported by respondents.

- 10th Avenue Marine Terminal, San Diego, CA
- I-5 and Cesar E. Chavez Parkway, San Diego, CA
- 3500 Fruitland Avenue, Maywood, CA
- 4916 Dudley Blvd., McClellan, CA
- At major intersections in Riverside County
- At major intersections in San Bernardino County
- At major intersections in San Diego County
- At major interstate intersections in Los Angeles County
- Highway 80 and 4610 Gateway Park Blvd., Sacramento, CA
- Los Angeles County
- Near the Port in San Pedro, CA
- Near the Ports of Los Angeles and Long Beach (with overnight truck parking)
- San Diego County
- Ventura County

Oregon

When asked where they require electric charging sites in Oregon, none of the respondents stated any locations. One respondent said that they need over 30 stations in Oregon, but did not state where those stations are needed.

Washington

Respondents gave only two answers when asked where they require electric charging stations in Washington within the next three to five years. The following is a list of these locations, as reported by respondents:

- I-5 Southbound Exit 194 near Everett Avenue, Everett, WA
- Tacoma, WA

Another respondent stated that they need over 30 electric charging sites in Washington but did not state where those stations are needed.

Perceptions on Barriers to MD/HD EV Infrastructure Development, Needed Support, and Planning for Scale

When asked what are the biggest barriers to deploying EV charging infrastructure for MD and HD vehicles, respondents gave a number of answers. This question was asked with an open answer format, allowing respondents to write in whatever they chose. Upon examining these responses, the researchers coded them based on common themes. The four most stated barriers were:

- lack of charging sites
- long charging wait times
- low range of EVs
- high cost of infrastructure

Other barriers listed by respondents are shown in Figure 4.

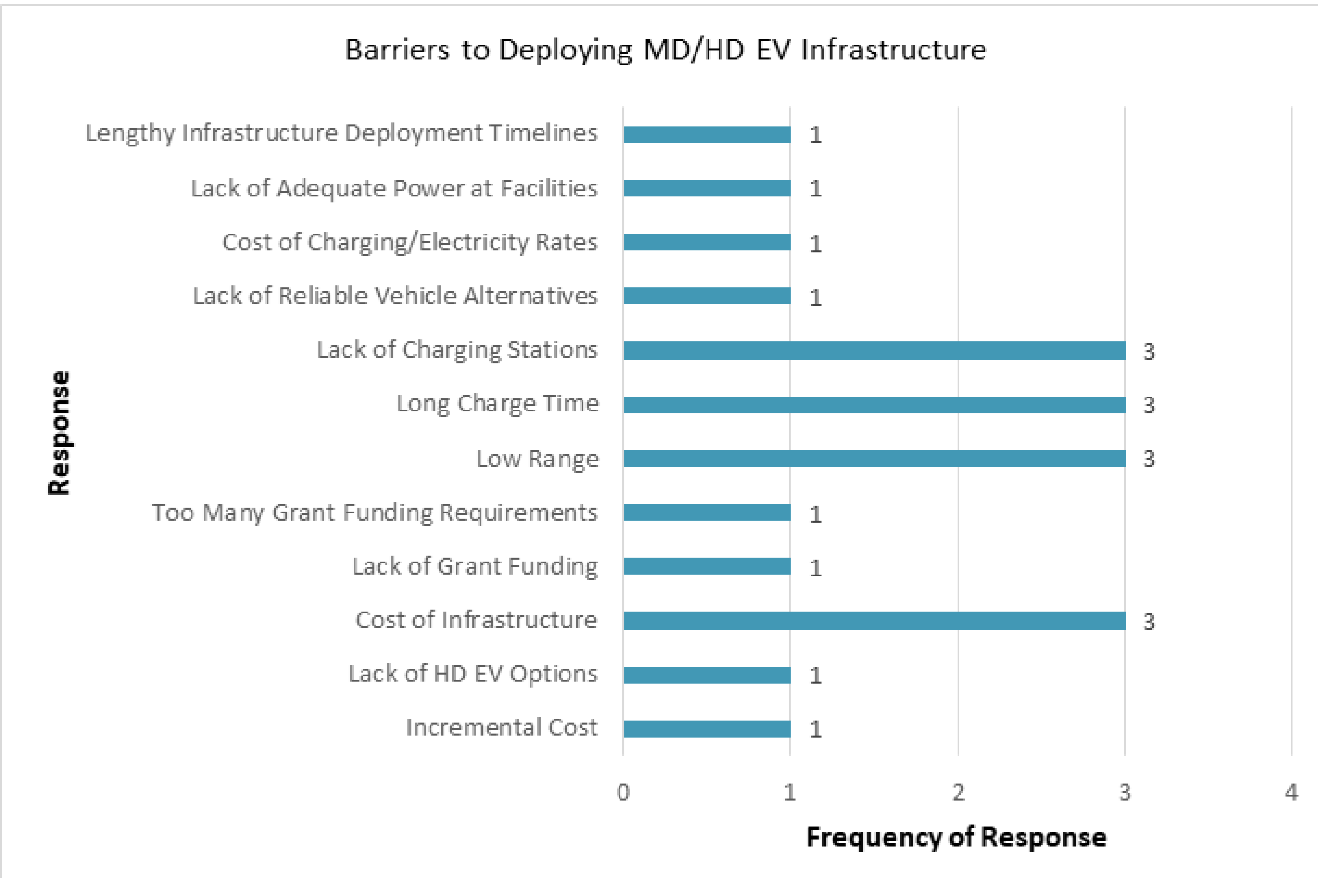


Figure 4: Barriers to Deploying MD/HD EV Infrastructure

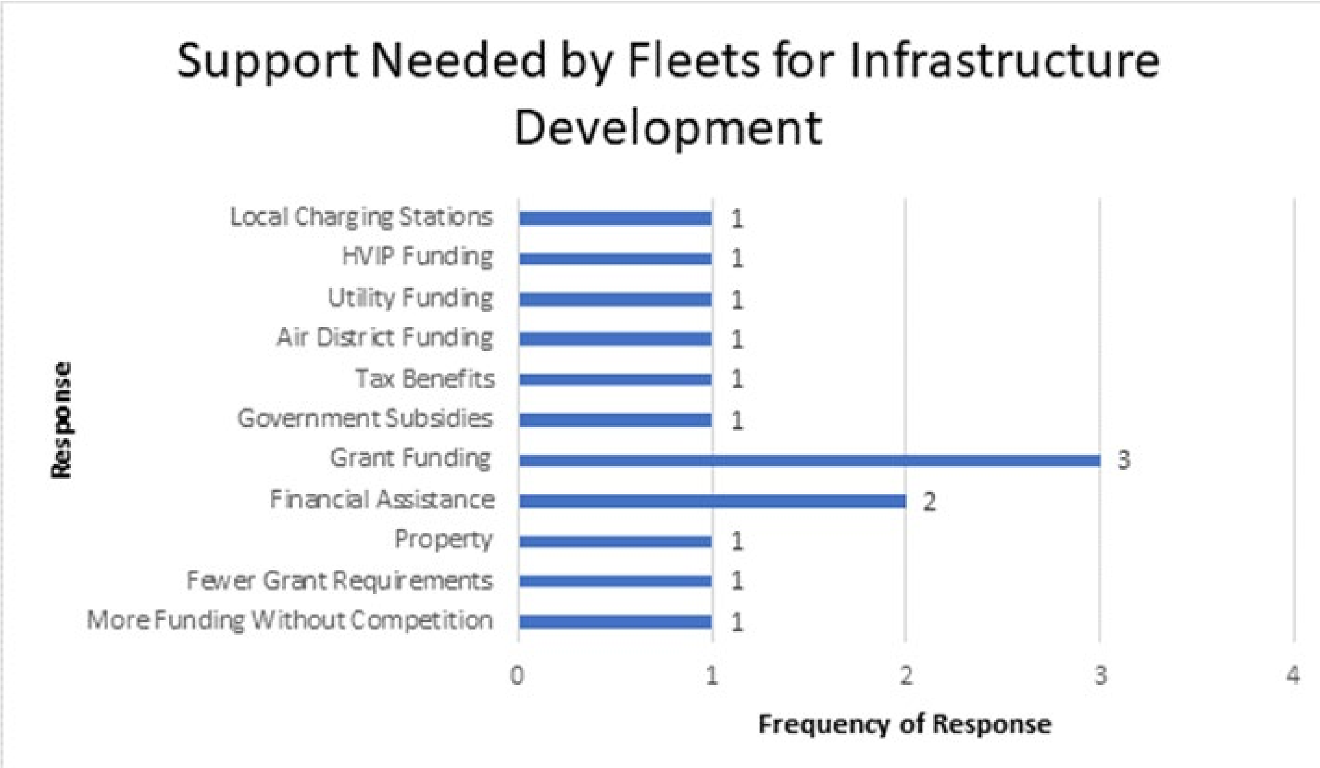


Figure 5: Support Needed by Fleets for Infrastructure Development

When asked what support or resources are needed to plan for infrastructure development, respondents gave several answers. Like the previous question regarding barriers to infrastructure development, this question was asked with an open answer format, and the responses were coded based on common themes. The two most frequent responses were:

- additional grant funding
- financial assistance

Other forms of needed support mentioned by respondents are shown in Figure 5.

When asked if respondents plan for future scaling-up of EV charging infrastructure when deploying their first sets of EVs and infrastructure, 82 percent said yes and 0 percent said no. Eighteen percent said that they do not know. This makes it clear that fleets are planning on adding charging infrastructure as they add electric trucks.

Phone Interview with a Large Food and Beverage Fleet

As mentioned earlier, one fleet chose to have a phone interview with the researchers in lieu of the online survey. This fleet is quite advanced in planning for EVs, and is large. The fleet belongs to a food and beverage manufacturer and distribution company with operations in all three states on the West Coast. The phone interview with this fleet was conducted in the spring of 2019, speaking to one of its fleet sustainability managers. In the conversation, the fleet discussed plans for company-wide transportation electrification and highlighted specific areas on the West Coast where charging infrastructure is needed.

This fleet is currently working on an electrification strategy for its operations, beginning with electrifying its short-range, urban delivery vehicles, which operate on a back-to-base fueling/charging system. In later phases, they plan to electrify longer-range, over-the-road trucks.

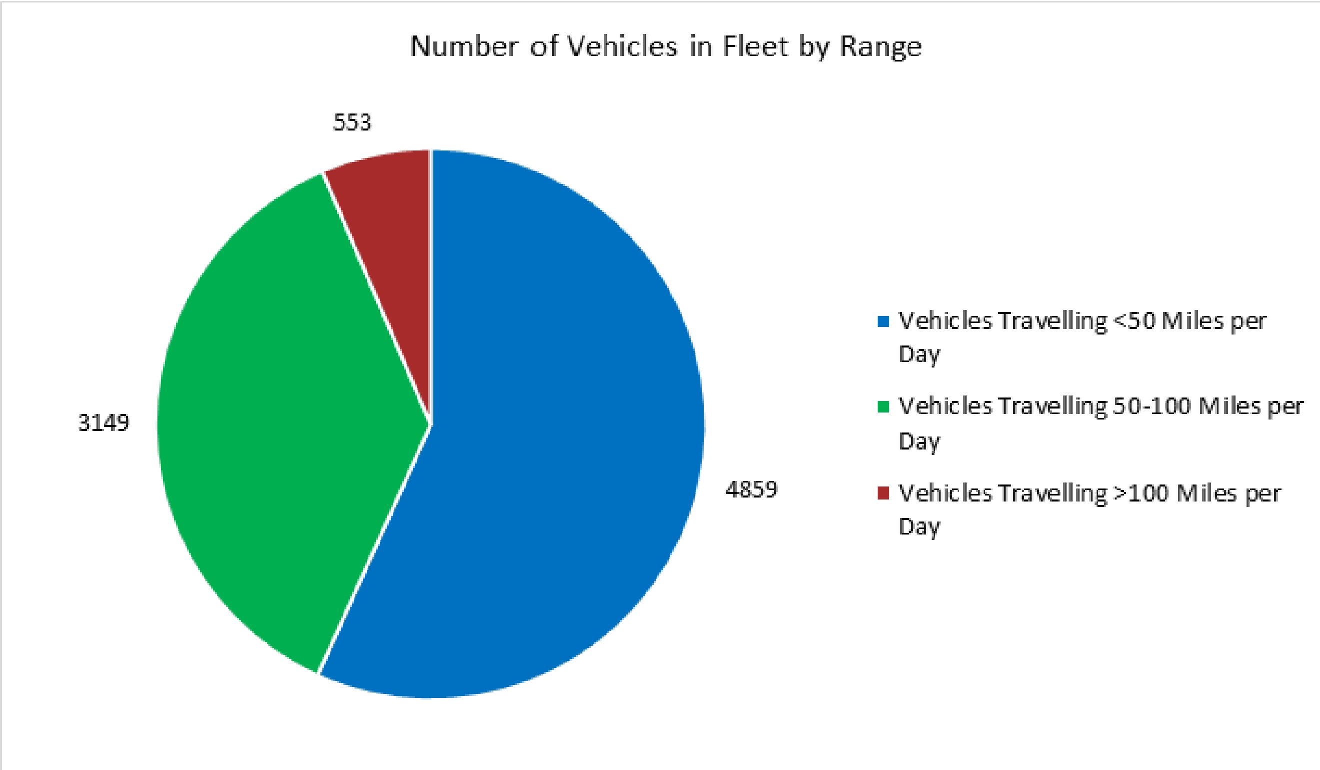


Figure 6: Number of Vehicles in Fleet by Range

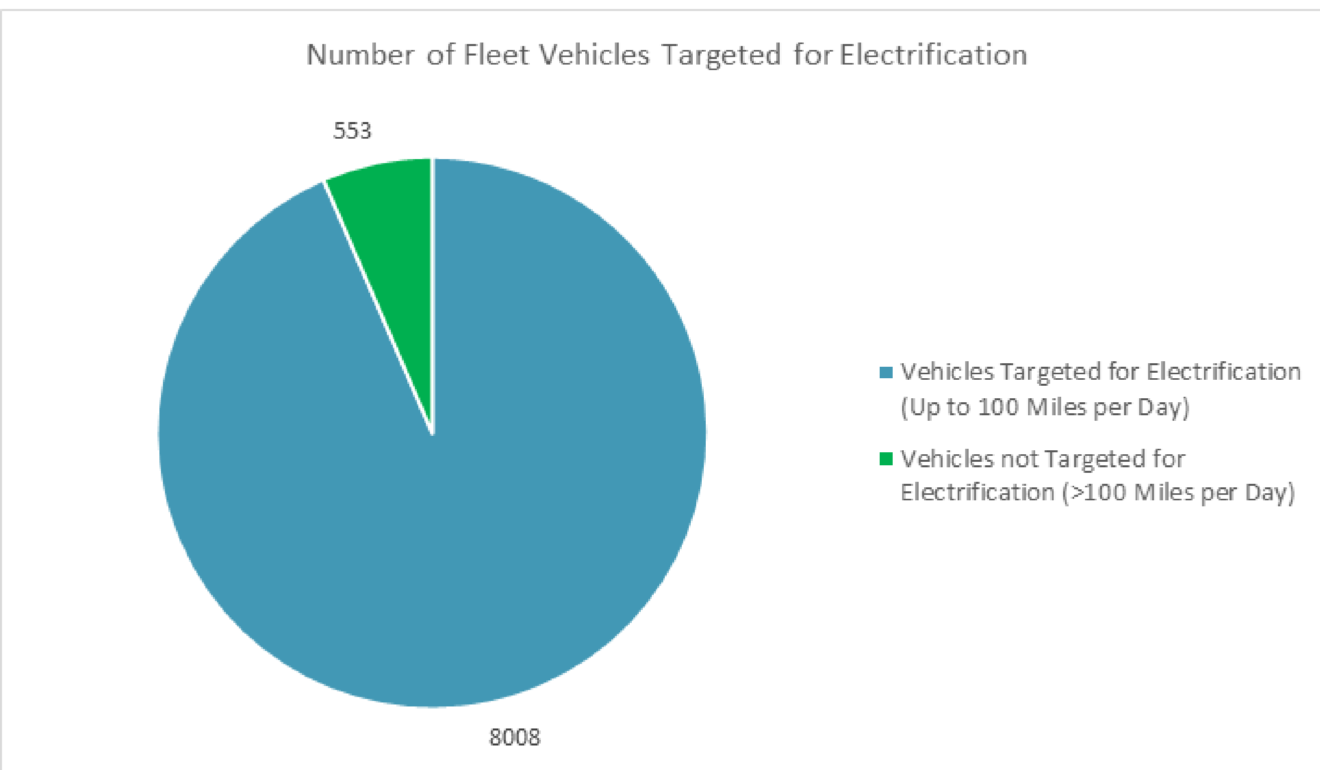


Figure 7: Number of Fleet Vehicles Targeted for Electrification

The trucks targeted for electrification include Class 3 delivery vans, Class 6 delivery box trucks, and Class 8 tractors. The fleet estimates that it has 4,859 (57 percent of the total fleet) delivery vehicles that travel less than 50 miles per day, 3,149 (37 percent) vehicles that travel 50 to 100 miles per day, and 553 (6 percent) vehicles that travel over 100 miles per day, totaling a fleet of 8,561 vehicles with a rough weighted average range of 51 miles per day. The fleet operator would like to electrify the vehicles that travel up to 100 miles per day, which accounts for about 94 percent of the fleet.

When asked where MD and HD charging sites would be best suited for the fleet near I-5 in California, Oregon, and Washington, this fleet listed the following locations. The locations are ordered by fleet activity, with those sites seeing most activity shown first. Because this was just one fleet with certain specific needs, these locations were not directly considered in the analyses for determining potential charging locations.

- I-5/HWY-165 near Hamburg Farms, CA
- I-82/HWY-395 near Kennewick, WA
- I-80/I-50 near Sacramento, CA
- I-5/I-205 near Banta, CA
- I-5/HWY-20 near Williams, CA
- I-15/I-40 near Barstow, CA
- HWY-99/HWY-41 near Fresno, CA
- I-10/HWY-78 near Blythe, CA
- HWY-20/HWY-97 near Bend, OR
- I-8/HWY-95 near Yuma, AZ

Results from the West Coast Collaborative Alternative Fuel Infrastructure Corridor Coalition Infrastructure Study

As mentioned previously, CALSTART led a separate study that had a very similar scope as this study. This WCC AFICC was a US Environmental Protection Agency-funded effort to identify alternative fuel infrastructure needs for MD/HD vehicles in California, Oregon, and Washington.[c] This effort also used a survey of MD and HD vehicle fleets in West Coast states. While the questions asked in the WCC AFICC fleet survey did not exactly mirror those asked for this study's fleet survey, they were very similar. The questions in the WCC AFICC fleet survey were as follows:

- Where do fleets believe MD/HD alternative fuel vehicle infrastructure is needed in California, Oregon, and Washington?
- What current MD/HD alternative fuel vehicle infrastructure development projects do fleets already have underway in California, Oregon, and Washington?
- What funding needs do fleets have for deploying MD/HD alternative fuel vehicle infrastructure, specifically to offset the capital expenditures for development?

The biggest difference between the surveys was that the WCC AFICC survey included multiple alternative fuels in its scope: electricity, hydrogen, propane, and natural gas. Also, the WCC AFICC survey inquired regarding buses and trucks, not just trucks. Given the similarities between both studies, there is opportunity to leverage the additional data and findings of the WCC AFICC, as outlined in the following sections.

Respondent Profiles

In total, 26 organizations responded to the WCC AFICC fleet survey, representing all three West Coast states. Respondents varied widely in the vocations they represented, including the following: drayage, transit, refuse, school districts, food and beverage distribution, locomotive services, cargo handling, construction, regional government, air quality inspection and monitoring, road maintenance, airport shuttle services, marine cargo handling, electric utilities, and municipal street sweeping.

Fuel Type Preferences and Fuel Demand

Most of the vehicles currently operated by the fleets responding to the WCC AFICC survey were gasoline or diesel, at an average of 608 and 541 vehicles per respondent, respectively. CNG was the next in line at 38 vehicles per respondent, liquefied natural gas at nine, liquefied petroleum gas at four, EV at 20, and hydrogen at less than one (0.27) on average. When asked what alternative fuel type they are most interested in adding to their fleets in the next three to five years, most said EVs, followed by CNG, hydrogen, liquefied natural gas, and liquefied petroleum gas. This again shows a higher-than-average interest in EVs from this large fleet operator.

---

c See https://westcoastcollaborative.org/workgroup/wkgrp-fuels.htm for more information.

When asked to estimate the average megawatts (MW) of electric power capacity required to meet their needs for an MD to HD EV charging site, fleet responses averaged 2.14 MW of EV charging capacity.

Funding Needs

Most WCC AFICC respondents (69 percent) stated they will need funding support to purchase alternative fuel vehicles or equipment, while 15.4 percent said they would not need funding, and 15.4 percent said that they did not know if funding would be needed. Likewise, 73 percent of fleet respondents stated they would need funding to purchase alternative fuel infrastructure, with 19 percent stating they did not know if funding would be needed, and 8 percent stating that they would not need funding for infrastructure.

When asked how much funding would be needed to cover the cost of purchasing alternative fuel vehicles and infrastructure, 23 percent of fleets said that at least 50 percent of the total cost of an alternative fuel vehicle would need to be covered by funding assistance in order to justify the purchase. Similarly, 27 percent of fleets stated that 50 percent of capital expenditures for developing alternative fuel infrastructure would need to be covered to justify the development. The second-ranked answer to that question was 100 percent of capital expenditures, with 23 percent of fleets responding with that answer. Clearly these fleets are showing a desire for external support in financing ZEVs and charging infrastructure.

Infrastructure Projects Underway

When asked if fleets currently have alternative fuel infrastructure projects underway, a majority reported that they do (65 percent), while 27 percent do not, and 8 percent of respondents did not know if they had projects underway. Of those respondents who reported having projects currently underway, 65 percent of them say they have EV projects underway, and the remainder have other non-EV alternative fuel infrastructure activities underway.

Proposed Infrastructure Locations

Fleets provided numerous locations where they would like EV charging sites installed. As with other survey responses to this question, the locations provided were not directly used in the process of determining potential corridor facilities, because of the many variables and different interpretations of charging infrastructure needs. Below are the mentioned sites, exactly as provided by the respondents:

- California: 10 FWY in San Bernardino County, 15 FWY in Riverside County, 210 FWY in San Bernardino County, 215 FWY in San Bernardino County, 60 FWY in Riverside County, Bakersfield, Barstow, Commerce, Cottonwood, HWY 299 Eureka to Susanville, HWY 44 Eureka to Susanville, I-5 Sacramento to Mt. Shasta, Long Beach, Los Angeles County Disadvantaged Communities, San Bernardino, and Stockton.
- Oregon: 5 FWY, Airports in Oregon, Eugene, and Portland.
- Washington: Coordinates: 47,171432, -122.484975, 5 FWY, Bellevue, I-5 Exit 193 Northbound Everett, Olympia, Puget Sound, Seattle, Spokane, Tacoma, Tri-Cities, and Yakima.

Findings from Fleet Surveys

The fleet surveys discussed above provide similar qualitative findings regarding fleet operator interest, plans, and needs regarding EV trucks and charging infrastructure. Those findings include:

- Greater adoption and positive interest in EV trucks than would be predicted from sales forecasts and published reports. Many fleets already had EVs, and/or had projects underway. The interest in acquiring EVs and installing charging infrastructure was higher than would be expected of an average fleet based on available forecast adoption rates.
- Lack of charging infrastructure is a major barrier to EV adoption, as are limited range, long recharging times, and high upfront cost. These MD/HD concerns mirror LD EV adoption concerns as outlined in multiple analyses of that market.
- There is great interest in funding assistance to overcome high costs for vehicles and infrastructure, as grants or other sources of funding.
- These fleets indicated more interest in Class 8 EVs than other sizes, perhaps a reflection of a sample bias toward port drayage fleets.

Electric Truck Manufacturer Survey

Electric truck manufacturers were surveyed to gather information regarding the types of electric trucks currently available and on the horizon of a quickly evolving market. The OEM survey recipients were asked about the following topics:

- vehicle classes designed and sold
- sales trends for conventionally fueled models
- sales trends for electric models
- fleet vocations that represent highest sales
- types of electric charging required by vehicles manufactured (power level, charging standard)
- barriers to market entry for EVs
- barriers to charging infrastructure development

Sales of conventionally fueled trucks increased over the last three years for four respondents, and stayed the same for one respondent. When asked how much conventionally fueled model sales have increased in this time frame, respondents generally stated a range from 30 to 50 percent. Additionally, most respondents expect sales of conventionally fueled models to increase slightly (less than 10 percent) within the next three to five years, while one respondent expects a small decrease, and another expects no change.

According to respondents, the top five fleet vocations in terms of sales are long-haul trucking, regional shipping, drayage, food or beverage distribution, and transit.

Regarding EVs, most respondents stated that their EV sales have stayed the same within the last three years, with two stating that sales have increased. Those with increased sales explained that such increases have been modest. One explained that sales went from 0 in 2016 to a projected 100 by the end of 2019.

Most OEMs stated that they expect a large increase in sales in the next three to five years. However, most OEMs report not yet selling EVs.

Several respondents have announced plans to develop EVs, but those vehicles are not yet commercially available. Two OEM respondents plan to release a variety of vehicles across class and type including refuse, regional haul truck, Class 8 electric and fuel cell trucks, and MD electric trucks.

With regard to charging standards, respondents preferred to design for the Society of Automotive Engineers (SAE) Combined Charging Standards (CCS), but also design for CCS Type 2 and wireless charging.

Most respondents are designing charging systems for higher-powered charging, while some are designing for Level 1 and Level 2 charging compatibility to serve some specific customer needs.

The largest barriers to entry for electric trucks were cited as inadequate business case, EV purchase price being too high for customers, and lack of charging infrastructure.

Finally, the researchers asked OEMs what barriers they saw in terms of developing charging infrastructure for MD/HD EVs. Respondents gave several answers, listed below:

- The power grid is not yet ready for added demand to supply end users.
- Power is currently very expensive and will need to be heavily subsidized.
- The cost and weight of batteries are barriers.
- Standardized infrastructure is needed for fast charging at MW and above rates.

Charger Provider Survey

Electric truck charger providers were surveyed to gain their perspectives on the barriers and opportunities related to implementing electric charging sites for MD/HD trucks.

All EVSE respondents design for the SAE CCS, while roughly 86 percent design for Charge de Move (CHAdeMO), and about 43 percent design for other standards including 3-phase Level 2, Tesla Level 2, and SAE J1772.

When asked to elaborate on barriers, each respondent gave a unique answer, including:

- Time to complete an infrastructure project can take up to two years, posing a barrier for quick deployment.
- Use case is not clear enough.
- Total deployment costs, combined with the true costs of ongoing operations and maintenance, can be prohibitive.

- Not enough aggregate demand exists yet for public MD/HD EV charging sites.
- Uncertainty exists regarding the charging standards required for sites.
- Large-scale deployment of HD EV charging is not yet well-understood from a cost, technology, and grid services perspective.
- Emergency conditions are not considered.

When asked to provide recommendations for policies or regulations that might help advance MD/HD EV charging site development, respondents gave multiple responses, listed below:

- Policy programs designed to alleviate total cost of ownership (TCO) issues would be beneficial.
- Demand charges are cost-prohibitive and may be addressed via policy approaches.
- Incentives to subsidize early adopters would be beneficial.
- Clean fuel goals incentivizing fleets to adopt EVs have been a productive approach so far.
- At least five years of operational cost support would be required to make up for operational start-up losses while the public MD/HD EV charging market develops.
- A global standard for common charging connectors and protocols would keep costs down and optimize maturation of technology.

When asked to elaborate on best practices as they relate to MD/HD EV charging infrastructure deployment, respondents listed the following items:

- Land acquisition and site planning: Work with each fleet owner and determine the best solution between behind-the-fence depot charging versus in-route charging, and ensure easy access to 480 VAC 3-phase power sources.
- Product design and engineering: Hire/outsource an engineering firm, establish three phase Type 2 CCS for large vehicles, adopt a common charging standard, and comply with National Electric Code and Underwriters Laboratory and relevant safety standards.
- Collaboration with electric utilities: Start early and work with electric utilities to determine incentives for vehicles and infrastructure.
- Collaboration with fleets: Understand the battery design and power requirements.
- Demand management and load balancing: Work with network management software companies, consider this approach in sites with multiple chargers, require adherence to open standards (openADR), and incorporate energy storage.

When asked if they employ any demand management or load balancing software in their EV charging solutions, all respondents said yes. Further, respondents elaborated on challenges that exist in deploying and operating demand management or load balancing software, including the following:

- Load balancing in DC fast charging sites adds significant costs and can reduce reliability.
- The number of vehicles charging at a charger is limited to five. Scaling up this number will make demand management and load balancing more beneficial.
- Ensuring site design and wiring is planned for maximum potential is beneficial.
- It takes significant time and cost to integrate the technology.
- Not all charging equipment provides the same software access (application program interface, or API) to control charging speeds.

Respondents were also asked to elaborate on any unique challenges presented by MD/HD EV charging as compared with LD EV charging. One respondent stated that DC fast charging ports for MD/HD vehicles will time out if charging does not start within a matter of minutes, and it currently is not possible to remotely start a charge session. Another respondent highlighted the importance of coordinating with an electric utility company as power requirements increase, adding complexity. And, another respondent stated that MD/HD EV charging likely requires energy storage and an emergency back-up charging plan for commercial vehicles.

Finally, respondents were asked to discuss any new EV charging product or service trends they see as significant in the next five years. Their responses are listed below:

- Bigger batteries will require high kilowatt (kW) needs, and there is a need for wireless charging.
- EV charging could be provided as a service rather than paying up front for the entire cost of installation and hardware.
- Wireless charging can be provided for transit buses, DC fast charging for commercial trucks, and 3-phase alternating current (AC) charging for parcel delivery fleets.

Industry Task Force and Working Group Collaboration

This section presents the feedback from an industry task force and working group regarding the barriers and needs that must be overcome to advance zero-emission MD/HD vehicles. Potential solutions and important opportunities are also presented.

E-Truck Task Force Meeting, Novi, Michigan (2018)

Through the E-Truck Task Force (ETTF) and the CARB Zero-Emission MD/HD Working Group, CALSTART has regularly met with government agencies, vehicle manufacturers, battery suppliers, EVSE providers, electric utilities, and end users to understand the current electric truck landscape, emerging technologies, market challenges impeding technology adoption, and industry needs to accelerate technology development, deployment, and commercialization.

CARB MD/HD ZEV Working Group (2018)

ETTF was created in 2011 to help understand, support, and expand the production, deployment, and use of plug-in electric trucks and buses. The report published the E-Truck Task Force Findings and Recommendations in 2012 and again in 2015 outlining key industry barriers, including recommendations and tools to help advance market growth.

Since 2015, meetings with the ETTF and, through the management of CARB's HVIP, has led a complementary stakeholder engagement effort with the California MD/HD Zero-Emission Vehicle Working Group to evaluate opportunities to increase electric truck and bus adoption in California. These collaborative efforts identified seven major barriers that must be overcome to foster growth in the electric truck market. These barriers, and potential solutions, are discussed below.

Identified Barriers and Needs

The following summarizes key market barriers and recommended solutions that have been identified through the multi-stakeholder engagement efforts of the ETTF and the California MD/HD Zero-Emission Vehicle Working Group.

Market Barriers

- Infrastructure
- Cost of Technology
- Technology Maturity
- Information Gap
- Consumer Confidence
- Data and User Feedback
- Partnership and Driving Action

Infrastructure

Infrastructure continues to be one of the biggest industry barriers to the adoption of electric trucks. Challenges such as infrastructure lead time, costly upgrades, and demand charges are examples of barriers that impede a fleet's ability to successfully deploy electric trucks. As fleets explore the benefits of transitioning to an electric fleet, there is a significant knowledge gap regarding the necessary planning and development requirements of implementing infrastructure. For decades, conventional fuels (diesel and gasoline) have been the norm, and the practices for fleet deployment have been consistent. With electrification, terminology and practices are different. Depending on the fleet size, its vocation, and its duty cycle, infrastructure needs will vary, and there is no single solution. The following are examples of infrastructure barriers to electric truck fleet deployment:

- Lack of coordination and support with electric utilities, electrical engineers, and consultants is a big barrier to fleets planning their infrastructure needs. In many cases, fleets will move forward with procuring vehicles before realizing the necessity of getting electric utilities involved from the onset. Additionally, fleets may not realize the need to seek input from an electrical engineer or consultant to advise them of the necessary steps for infrastructure planning. As a result, a fleet may have committed to deploying EVs without having adequate power to charge the vehicles or without the understanding that upgrades to the grid could take longer or cost more than expected before the EVs can be deployed.
- Scaling energy needs for a growing fleet presents challenges because fleets often start with a few demonstration vehicles and are not prepared for the infrastructure upgrades and costs that come with growing a fleet (for example, 10 to 100 vehicles) and the power that is required to charge the vehicles. Public charging infrastructure could alleviate some of this burden, depending on the fleet's duty cycle and vehicle choices, but to date few charging sites have been deployed aimed at MD/HD vehicles.
- High electric utility costs such as needed upgrades, rates, and demand charges can present financial challenges to fleets requiring charging schedules during peak hours.
- Standardization for voltage, battery pack size, chargers, and other accessories presents challenges to fleets looking to identify the best electric truck and infrastructure solution.

Electric Truck Solutions: Infrastructure

- Provide educational guidelines on infrastructure planning to electric truck fleets.
- Encourage fleets to first coordinate with the electric utility to determine a rate base and evaluate electrical system upgrades required for the installation of charging infrastructure.
- Open a dialogue with fleets to anticipate scaling needs and the necessary infrastructure to support their EV growth.
- Conduct an optimization study to understand the power demand, number and type of chargers, and where to place them to best meet facility and duty cycle demands.
- Help fleets ensure all reliability options are considered and optimized to fit power needs and reduce demand charges, including energy storage, microgrids, and smart charging software.
- Encourage government agencies to administer incentives for EV infrastructure and electric trucks together in a voucher or similar incentive structure.

Cost of Technology

Although electric truck technologies are emerging in the market, production volumes are not at the levels needed to drive down technology costs. The incremental cost of electric truck technologies continues to be the biggest barrier to electric truck purchasing and production. Energy storage prices also continue to remain expensive; although battery prices continue to drop at the cell level, they remain high at the customized, low-volume pack level. Customer experience with battery pack sizing in earlier fleet trials has also led customers to ask for larger battery pack sizes to overcome range and cold-weather battery degradation concerns, further increasing the cost of the battery system. Other cost barriers potentially include the need to bring in outside experts to maintain the electric truck. In-house maintenance staff are often not trained to perform maintenance on EVs, requiring additional costs and delays as technical support is brought in. The following are examples of cost barriers to electric truck adoption:

- Fleets struggle to make the business case for electric truck adoption because of the high cost of the vehicles and infrastructure combined with low cost of conventional fuel. Without incentives, financing is challenging, and limited leasing options are available for fleets that seek to lease versus purchase electric trucks.
- Battery pack cost continues to be high, although battery cell costs are decreasing. Replacement costs concern fleets when looking at the TCO. Fleets based in colder locations worry about climate effects on battery performance and the resulting need for larger, more expensive batteries.
- Warranty looks at the life of the vehicle versus the life of battery.
- Sales tax assumes the total cost of a vehicle and not a discounted or incentivized vehicle.

Vehicle voucher incentive programs such as the HVIP, the New York Truck Voucher Incentive Program, and Illinois's Drive Clean Chicago have been instrumental in expanding the marketplace for electric truck technologies. California has been a launch pad for the electric truck market and, in the last few years, has supported new manufacturers of MD/HD electric trucks. All three voucher programs have made important program modifications based on feedback from the ETTF, such as increasing the incentive amount to cover 80 to 100 percent of the incremental cost of advanced vehicle technologies. While incentives are designed to accelerate technology advancement and market penetration, they are also intended to reward early adopters of these technologies. As the cleaner technologies become commercially available, costs continue to fall, and market adoption increases. Incentives help bring more of the vehicle and equipment fleets into compliance ahead of potential regulation. Planned regulations also provide a higher level of certainty to fleet owners who may be hesitant about upgrading their equipment and increase acceptance of the new technologies.

Industry feedback suggests that incentives need to cover 80 to 100 percent of the incremental cost of a vehicle to sway a purchasing decision. Infrastructure incentive levels are less well-defined and newer to the market.

While in theory maintenance costs for electric trucks are lower than for conventional trucks, requiring the use of outside technicians and the higher chance of a new technology having an issue early in its deployment can cut these savings. As early deployments gain more years in operation, real-world maintenance savings will become clearer.

Electric Truck Solutions: Cost of Technology

- Encourage government agencies to promote voucher incentive programs to cover 80 to 100 percent of incremental cost while increasing the “cap” amount allowed on the incremental cost to levels more appropriate to real product costs (some caps now reach $150,000).
- Call on the vehicle and battery industry to develop cost-effective solutions for batteries such as a using a battery leasing model, extending battery warranties beyond 5 years, and working with fleets to “right-size” the battery to each customer’s duty cycle.
- Encourage dealerships to provide electric truck leasing options (7- to 10-year period suggested), combined with a support package.
- Encourage regulators to evaluate soft incentives to encourage electric truck adoption, such as high-occupancy vehicle lanes, green loading zones, and preferential access.

Technology Maturity

Electric truck technology has experienced challenges with its level of maturity and ability to match the performance of conventional trucks. Additionally, as smaller vehicle manufacturers have launched their electric truck products, issues such as delayed production timelines and lack of parts have affected manufacturers’ ability to build trust with consumers and increase vehicle sales. Customer support has also been a struggle with smaller vehicle manufacturers. The perceived lack of support poses a deployment barrier for vehicle purchases as fleets learn from peers the difficulties of maintaining an electric truck fleet without reliable support.

Although performance has certainly improved, there are occasions when an electric truck may not meet the performance requirements of a fleet and require additional power or maintenance. For instance, a fleet may procure an electric truck that is not suitable for its duty cycle because it may not meet range or load requirements. For fleets to make the investment in electric trucks, there needs to be a level of predictability and reliability. The following are examples of technology maturity barriers:

- Technology availability continues to be a challenge as it remains difficult for manufacturers to meet fleet procurement schedule needs.
- Lack of range of electric trucks prevents a fleet from adding a battery electric truck to its standard duty cycle without operational changes.
- Lack of robust customer service because of smaller production volumes and current lack of large OEMs is causing fleets to buy conventional trucks to replace electric trucks that are out of service because of technical issues or a lack of parts.

Electric Truck Solutions: Technology Maturity

- Encourage suppliers of electric trucks and batteries to build out local and regional service support in key market areas and to create a critical parts reserve to allow for timelier same-day service and support.
- Encourage suppliers to increase quality control checks before vehicle delivery and to provide regular and timelier service calls to ensure successful vehicle operation.
- Encourage suppliers to train fleet technicians on technical repair and vehicle maintenance.
- Develop a “Buyer’s Best Practices Guide” to help fleet users make smarter purchasing decisions on electric trucks. The guide would include business case, user experience profiles, case studies, infrastructure needs, and other best practices.

Information Gap

The lack of information and outreach to fleet users regarding the availability and benefits of electric trucks continues to affect overall technology adoption. Manufacturers, vehicle suppliers, and incentive program administrators have struggled to find the best strategy to reach fleets. At times, unless fleets are looking specifically for electric trucks, a fleet manager may continue to invest in conventional trucks and remain unaware of the options that are available. Alternatively, fleets may learn about electric trucks from peers who have had a poor experience or are misinformed about the technology and, thus, may decide not to pursue electric trucks. There is also the challenge of providing information to fleets regarding available resources that present the technology availability, use-case best practices, business case, and other guidance on electric truck deployment. Lack of appropriate training is also a barrier to technology adoption. Fleets may feel overwhelmed with the idea of moving toward a new technology and, without appropriate training or understanding of technology deployment needs, a fleet may be dissuaded from moving forward. The following are information gap barriers to electric truck adoption:

- Poor fleet and industry engagement on electric truck technology availability
- Lack of understanding on best strategies to engage with truck fleets
- Lack of readable informational resources on electric trucks
- Stigma of poor performance from previous electric truck fleet owners
- Lack of use-case best practices of technology transfer/information sharing between fleets
- Poor guidance and training for fleet managers on electric truck deployment
- Poor dealer education on the benefits and operational needs of electric trucks

Electric Truck Solutions: Information Gap

- Carry out marketing and outreach campaigns to educate fleets on available electric truck technologies, technology suitability across fleet vocations/duty cycle, deployment of best practices, fleet testimonials, and vehicle ride and drives to allow user experience. Ensure that there are ongoing and timely outreach events to keep fleets engaged and aware of the latest electric truck technologies.
- Evaluate best strategies (outreach mediums) to reach fleet audiences through vocational industry associations, trade journals, National Association of Fleet Management Administrators, Clean Cities Coalitions, sustainability leaders, business chambers of commerce, port/goods movement affiliations, etc.
- Develop use cases to share best practices for technology deployment across vocational sectors/duty cycles.
- Train dealers on the technical needs and operation of electric trucks. Develop training manuals for dealers to encourage effective customer marketing. Ensure vehicles are available on the lot to allow fleet users to experience electric trucks.
- Encourage manufacturers and suppliers to provide training to customers on technology use, fleet deployment, charging needs, and maintenance.
- Provide a TCO calculator to help fleets evaluate the business case for electric truck adoption.

Consumer Confidence

Building consumer confidence among fleets remains a barrier for electric truck manufacturers. As mentioned before, although new electric truck technologies are emerging, the lack of information on availability and diversity of technologies continues to discourage fleets from evaluating whether electric trucks are feasible for their operations. More electric truck options are needed to support a variety of fleet applications. As smaller electric truck manufacturers continue to build their supply chains and increase electric truck production, signals from the bigger manufacturers are needed to demonstrate that there is a growing future in electric transportation and a long-term commitment on technology development and demonstration. Delays in vehicle production have also affected consumer confidence as fleets await delivery. The following are consumer confidence barriers:

- Lack of electric truck vehicle choices
- Lack of product availability
- Technology needed to work for small fleets
- Need for big manufacturers to send signals/ share plans for electric truck development
- Delays in vehicle production and delivery

Electric Truck Solutions: Consumer Confidence

- Encourage manufacturers to provide informational resources and outreach on electric truck technology options.
- Encourage manufacturers to continue building diverse electric driveline applications across a variety of vocational sectors and duty cycles.
- Ask big manufacturers to support awareness-building regarding electric truck development, benefits, and future plans.
- Encourage manufacturers and dealers to provide improved training and guidance on technology deployment needs to fleet customers.
- Encourage industry groups to develop guidance tools for fleets, both large and small.

Data and User Feedback

The lack of available data and user feedback is impeding the market's ability to address technical barriers and consumer confidence in a timely manner. There is insufficient engagement between industry and fleet users. Increasing the exposure of fleets to this technology through extended trials will develop manufacturers' knowledge of technical barriers and what specific support resources need to be improved. More operational data are required to identify opportunities for technological and operational improvements. The following are data and user feedback barriers:

- Lack of quantitative and qualitative operational data from fleets extensively testing electric trucks in their day-to-day operations
- Lack of ongoing communication/relationship between user and vehicle supplier
- Lack of understanding of fleet needs to ensure electric truck technology is adequate to meet fleet demands
- Difficulty in evaluating TCO and business case, with more tools needed to provide better guidance

Electric Truck Solutions: Data and User Feedback

- Encourage manufacturers to provide fleets with access to telematics and smart charging software and tools to help obtain in-use performance data.
- Ask industry groups to facilitate working groups to share information and feedback on technology use, such as the ETTF.
- Encourage manufacturers to develop a performance tracking program with customers to ensure meaningful and ongoing engagement, track vehicle performance, and provide opportunities for customer feedback.
- Encourage manufacturers or vehicle suppliers to provide a TCO calculator/tool to help fleets evaluate the business case.

Partnership and Policy to Drive Action

Partnerships and policy are needed to build momentum for increased electric truck adoption. There is a need for more partnerships between utilities, manufacturers, and state agencies to understand technology barriers, incentivize technology adoption, and develop infrastructure to support transportation electrification for MD/HD vehicles. By building public-private partnerships to encourage technology growth and adoption, each partner is playing a critical role in protecting the environment, growing the economy, and paving the way for future transportation sustainability.

Policies also play an important role in advancing near to zero-emission solutions. The following are examples of potential policies that could be market drivers for electric trucks:

- Zero-emission zones in urban and freight hubs would incentivize the adoption of zero-emission trucks in duty cycles that serve the city. If conventional trucks simply were not allowed to enter the city center, the business case for zero-emission delivery trucks would improve.
- Utility rate structures can be confusing and unpredictable for fleets that do not track their electricity use or peak demand closely. Simplified rates that favor electric truck charging would remove one of the barriers commonly experienced by fleets.
- ZEV regulations would play a key role in advancing the electric truck market. Bringing costs in line with conventional vehicles through increased fees or incentivizing EV purchases would spur adoption.
- Technology phase-in requirements would provide a stronger push toward adopting electric trucks by requiring fleets to electrify their trucks over a predetermined time period. The predictability of this approach helps both fleets and manufacturers plan their acquisition and product development schedules, respectively.

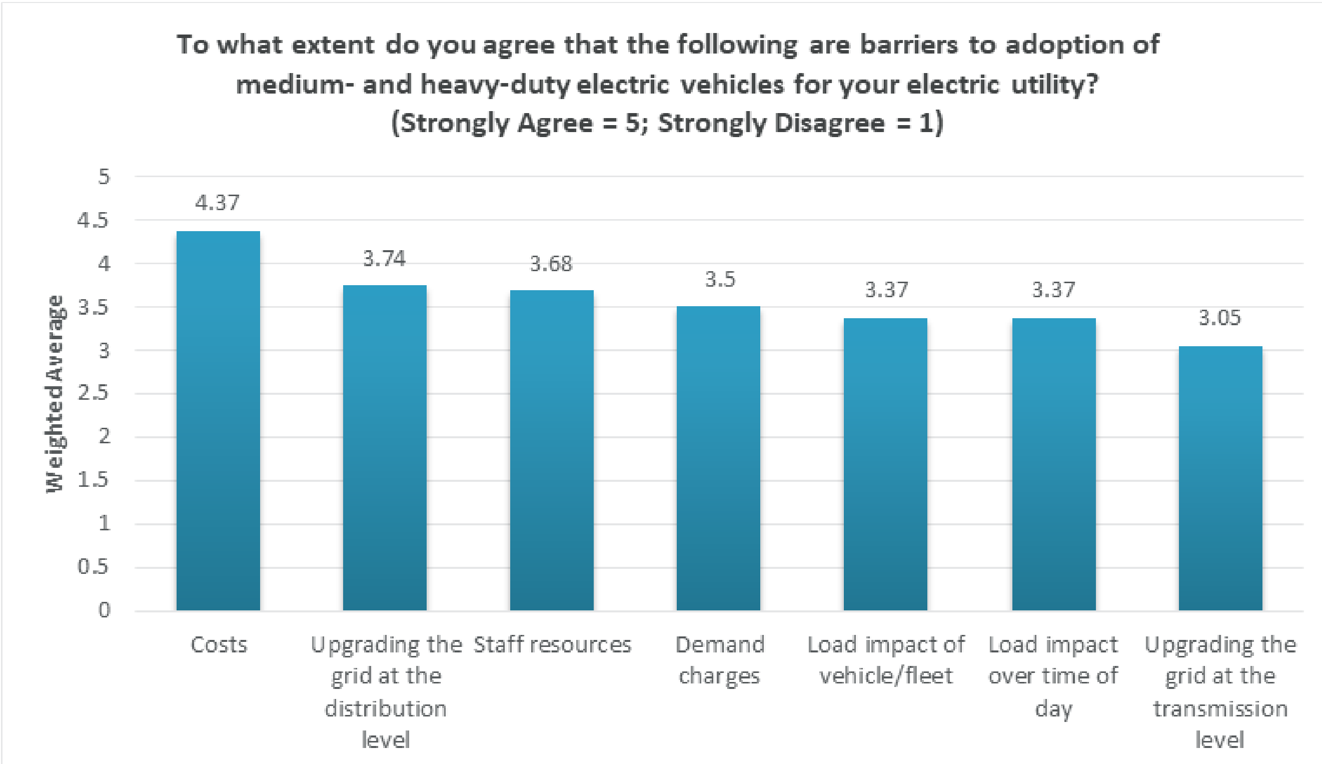
Utility Perspectives

This section describes the results of interviews and surveys conducted with utility partners to characterize the barriers to the adoption of electric trucks. Nineteen utilities participated, either by filling out surveys or by participating in interviews. This supplements the previous sections highlighting the perspectives of other stakeholders. Chapter 6 provides additional information gathered from the utilities regarding their existing and planned electric truck infrastructure.

The three top barriers to the adoption of MD/HD EVs for the utilities surveyed are: costs, upgrading the grid at the distribution level, and staff resources. The results are summarized in Figure 8.

Other barriers mentioned by the electric utilities are as follows:

- Commercial availability of technology
- Cost of infrastructure investment; existing structure protects ratepayers from cost increases associated with infrastructure expansion projects for new loads that may not materialize
- Sporadic infrastructure usage requiring large investment to meet load peak, but no consistent utilization
- Capital investment for infrastructure
- Timing for when electric trucks come onto market
- Up front cost of vehicle
- Lack of awareness and education among fleets
- Differences between depot charging and corridor charging
- Potential for concentrated new load at HD EV charging depots could require further distribution system upgrades
- Lack of data and information
- Administrative burden to customers (for example, stacking sources of funding from different agencies)



Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Figure 8: Electric Utility Survey Response on Barriers to Adoption of MD/HD Vehicles

4. Truck Market Overview

This chapter provides an overview of the truck market, including the existing markets for both conventional trucks and electric trucks. It concludes with a discussion of several trends affecting the electric truck market, including battery price and weight and financing options.

Existing Conventional Truck Market

To more accurately forecast the truck market (conventional and electric), the market was divided into segments that are more descriptive than a simple weight class, and was organized by use—with expected vocational categories by vehicle class and with an emphasis on Class 3 through Class 8 trucks. The data in this section have been condensed; additional information is presented in Appendix B, Existing Conventional Truck Market Supporting Documentation.

Table 3 shows the average daily and annual vehicle miles traveled (VMT) across the US, by vehicle type. The table includes both trucks and passenger vehicles.

Table 3: US Average Daily and Annual Vehicle Miles Traveled, by Vehicle Type

Vehicle Type	Average Daily VMT	Average Annual VMT	Source
Class 8 truck	203	63,428	Federal Highway Administration (2016)
Transit bus	109	34,012	American Public Transit Association (2017)
Refuse truck	80	25,000	Gordon et al. (2003)
Paratransit shuttle	73	22,679	American Public Transit Association (2017)
Delivery truck	42	12,958	FHWA (2016)
School bus	38	12,000	American School Bus Council (2018)
Light truck/van	38	11,991	Federal Highway Administration (2016)
Light-duty vehicle	37	11,507	Federal Highway Administration (2016)
Car	36	11,370	Federal Highway Administration (2016)
Motorcycle	8	2,356	Federal Highway Administration (2016)

Notes: Light-duty vehicles are a sales-weighted combination of cars, wagons, vans, SUVs, and pickups. Vehicles with short wheelbases (<121 inches) are generalized as cars, and vehicles with long wheelbases are generalized as light trucks. Delivery trucks are single-unit trucks with two axles and six or more tires. Class 8 trucks are combined tractor-trailer trucks, also known as long-haul trucks. Worksheet is available at www.afdc.energy.gov/data/. Last updated 11/28/2018.

Table 4 shows the US annual and daily VMT, by vehicle segment and class, for trucks only. Note that Tables 2 and 3 are derived from different sources and are not intended to match; they show two ways of considering VMT for current trucks.

Table 4: US Average Annual Vehicle Miles Traveled, by Truck Type

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

The estimated number of trucks on the road in California, Oregon, and Washington is shown in Table 5. California has the most trucks, with over 1.2 million—about 70 percent of the over 1.7 million trucks in all three states.

US Average Annual VMT per Segement						
Segment	Class					
	3	4	5	6	7	8
Construction Truck	15,000	10,700	15,000	12,000	12,000	12,000
Regional Truck	9,100	15,000	23,000	23,000	23,000	65,000
Motor Home	10,000	20,000	35,000	35,000	35,000	35,000
Pickup	24,000					
Long Haul Truck					170,000	170,000
Drayage					10,000	10,000
Bus		12,600	15,000	35,000	30,000	
Step Van	16,500	16,500	16,500	16,500		
Refuse				23,400	23,400	23,400
School Bus				15,000	15,000	15,000
VAN CARGO	27,000					
City Bus				35,000	35,000	35,000
Shuttle Bus	15,000	15,000	30,000	35,000		
Coach						35,000
Fire Truck						6,600
SUV	13,000					
Terminal Tractor						35,000
Emergency Truck			75,800	75,800		

Table 5: Number of Trucks On the Road in West Coast States, by Class

State	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Total
California	345,023	170,793	107,463	152,048	115,599	325,944	1,216,870
Oregon	82,415	25,024	16,345	20,406	14,882	36,361	195,433
Washington	121,986	43,964	25,284	32,573	23,658	65,754	313,219
Total	**549,424**	**239,781**	**149,092**	**205,027**	**154,139**	**428,059**	**1,725,522**

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

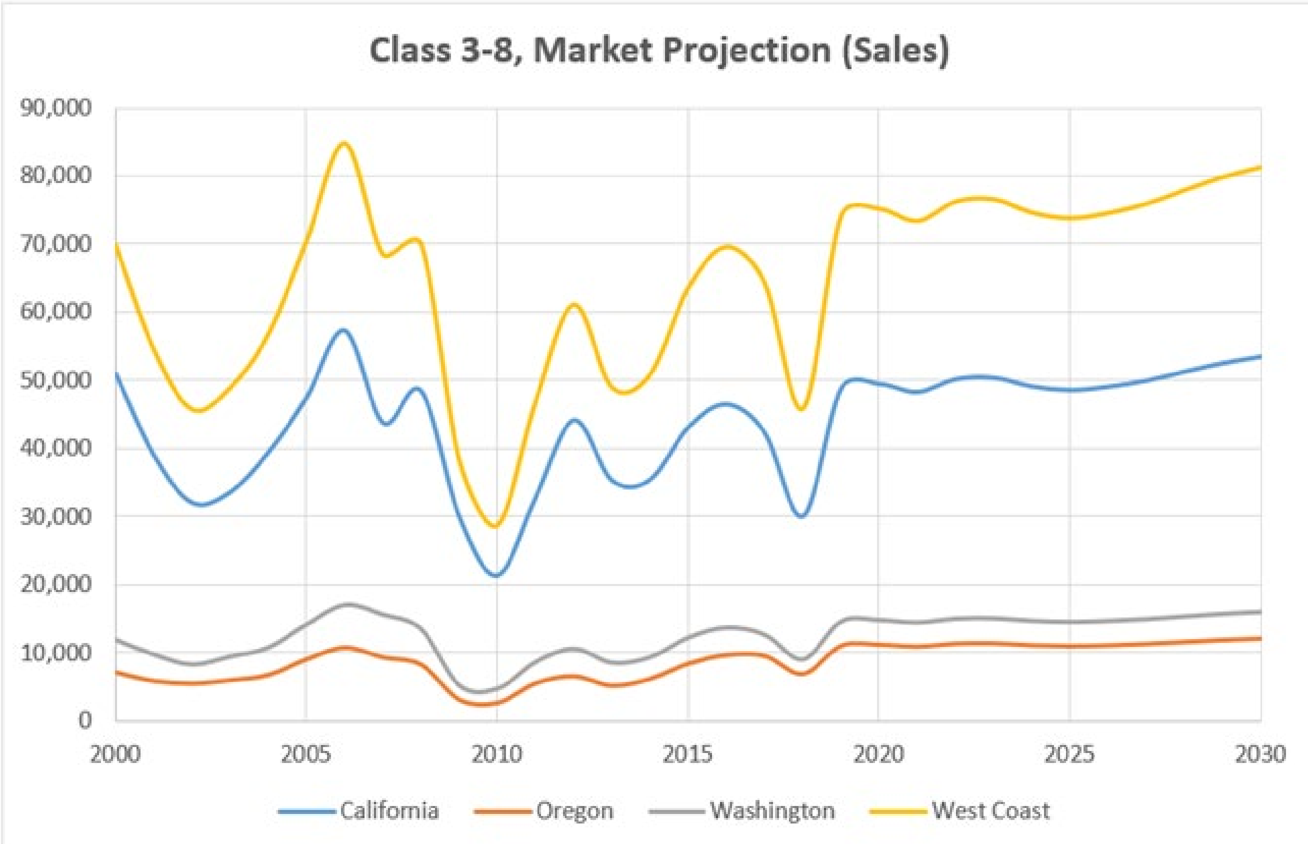
Conventional Truck Market Projections and Sales

The EV market is correlated with the overall market for vehicles of all powertrains. To better understand the EV market going forward, forecasts were first made for the conventional vehicle market. MD/HD vehicle sales were compiled from the IHS Automotive database for the past 19 years and were projected through 2030. The sales data are presented in Table 6 for the US, California, Oregon, Washington, and a summation of the West Coast states. The number of vehicle sales is presented first, followed by the percentage of sales. The forecast sales of conventional trucks showed double-digit percentage growth between 2018 and 2030 for all three states combined. Figure 9 depicts the historic and projected sales data for MD/HD vehicles along the West Coast from 2000 to 2030.

Table 6: US and West Coast Historic and Projected Sales of Medium- and Heavy-duty Trucks

Year	US Sales Class 3-8	California	Oregon	Washington	West Coast	California	Oregon	Washington	West Coast
2009	311,390	29,957	3,143	5,251	38,351	9.6%	1.0%	1.7%	12.3%
2010	369,144	21,324	2,687	4,789	28,800	5.8%	0.7%	1.3%	7.8%
2011	501,478	32,824	5,516	8,693	47,033	6.5%	1.1%	1.7%	9.4%
2012	569,200	44,086	6,525	10,590	61,201	7.7%	1.1%	1.9%	10.8%
2013	605,508	35,247	5,160	8,576	48,983	5.8%	0.9%	1.4%	8.1%
2014	670,589	35,407	6,163	9,394	50,964	5.3%	0.9%	1.4%	7.6%
2015	732,092	43,083	8,365	12,247	63,695	5.9%	1.1%	1.7%	8.7%
2016	605,343	46,410	9,590	13,682	69,682	7.7%	1.6%	2.3%	11.5%
2017	583,155	42,226	9,464	12,649	64,339	7.2%	1.6%	2.2%	11.0%
2018	635,452	30,011	6,861	9,072	45,944	4.7%	1.1%	1.4%	7.2%
2019	673,658	48,779	10,933	14,612	74,324	7%	2%	2%	11%
2020	682,153	49,394	11,071	14,796	75,261	7%	2%	2%	11%
2021	665,998	48,225	10,808	14,446	73,479	7%	2%	2%	11%
2022	691,909	50,101	11,229	15,008	76,338	7%	2%	2%	11%
2023	694,823	50,312	11,276	15,071	76,659	7%	2%	2%	11%
2024	677,059	49,025	10,988	14,686	74,699	7%	2%	2%	11%
2025	669,774	48,498	10,870	14,528	73,895	7%	2%	2%	11%
2026	676,652	48,996	10,981	14,677	74,654	7%	2%	2%	11%
2027	689,043	49,893	11,182	14,946	76,022	7%	2%	2%	11%
2028	707,251	51,212	11,478	15,341	78,030	7%	2%	2%	11%
2029	724,444	52,457	11,757	15,714	79,927	7%	2%	2%	11%
2030	737,480	53,401	11,969	15,996	81,365	7%	2%	2%	11%

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic



Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Figure 9: West Coast Vehicle Historic and Projected Sales

Projections of MD/HD vehicles in stock by 2030 show that California will have over 1.4 million, Oregon will have over 225,000, and Washington will have over 360,000, for a total of almost 2 million trucks in all three West Coast states.

Existing Electric Truck Market

This section discusses the research performed to compile a comprehensive list of all currently available zero-emission MD/HD trucks. Information about yet-to-be-released vehicles was gathered from press releases, news articles, and other announcements of manufacturers' plans. In the case of vehicles planned for the future, 2030 was used as the end of the time horizon, although no vehicles were announced for production beyond 2023. This does not include prototype vehicles, one-off concepts, or technology demonstrations, but rather vehicles currently in production or planned for production soon. Specification details were often unavailable for the announced vehicles.

When specification and performance information was mentioned, it was taken at face value without interpretation. In some cases, certain specifications were not available, even for currently available vehicles. This is to be expected, given the low volumes of production and the room for customization in these smaller production runs. This discussion provides a snapshot of today's market, but will quickly be outdated, given the rapid pace of technology development. Table 7 lists the currently available vehicles, by type, and those currently under development.

Table 7: Medium- and Heavy-duty Electric Truck Availability

OEM	Technology	Description	Vehicle Type	Availability Year	Weight Class/ Size	Estimated Range (miles)	Battery Capacity (kWh)	Estimated Payload	Charger Types
BYD	Electric	6R Class 6	Refuse truck	Currently available	Class 6	125	221	14,756 lbs	Type 2/J3068 connector, 33 kW AC, 120 kW DC
BYD	Electric	8R Class 8	Refuse truck	Currently available	Class 8	56	295	35,895 lbs	Type 2/J3068 connector, 33 kW AC, up to 240 kW DC
BYD	Electric	8Y Class 8	Yard tractor	Currently available	Class 8	10+ hrs	217	82,200 lbs	Type 2/J3068 connector, up to 200 kW
BYD	Electric	8TT Class 8	HD truck	Currently available	Class 8	125	435	78,765 lbs	Type 2/J3068 connector, up to 200 kW
BYD	Electric	5D Class 5	MD step van	Currently available	Class 5		145		Type 2/J3068 connector
BYD	Electric	6D Class 6	MD step van	Currently available	Class 6	124	221	10,233 lbs	Type 2/J3068 connector, 33 kW AC, 120 kW DC
BYD	Electric	5F Class 5	MD truck	Currently available	Class 5	155	145	8,093 lbs	Type 2/J3068 connector, up to 150 kW
BYD	Electric	6F Class 6	MD truck	Currently available	Class 6	124	221	15,639 lbs	Type 2/J3068 connector, up to 150 kW
Chanje	Electric	V8100	Cargo van	Currently available	Class 5	150	100	6,000 lbs	J1772 CCS, Level 2 DCFC optional
Cummins	Electric	AEOS	HD truck	2019	Class 7	100	140	44,000 lbs	
Freightliner	Electric	eM2 106	MD truck	2021	Class 6, Class 7	230	325		
Freightliner	Electric	eCascadia	HD truck	2021	Class 8	250	550		
Fuso	Electric	eCanter	MD truck	Currently available	Class 4	Up to 80	82.8	9,380 lbs	J1772 10 kW and CHAdeMO up to 50 kW DC
Fuso	Electric	Vision One	HD truck	2023	Class 8	217	300	11 tons	
Kalmar Ottawa	Electric	T2E Terminal Tractor	Yard tractor	Currently Available	Class 8		132-220		
Lightning	Electric	Ford Transit	Cargo van	Currently available	Class 3	60-120	43-86	3,700-2,900 lbs	J1772 CCS 6.6 kW Level 2, 50 kW Level 3
Lightning	Electric	6500XD	MD truck	Currently available	Class 6	66-130	96-192	14,000-12,000 lbs	J1772 CCS 6.6 kW Level 2, 50 kW Level 3
Lightning	Electric	F-59	MD step van	Currently available	Class 6	80-110	96-128		J1772 CCS, Level 2 6.6 kW, Level 3 50 kW
Lion	Electric	Lion8	HD truck	Currently available	Class 8	Up to 250	Up to 480	30,000 lbs	Level 2, Level 3
Mack	Electric	electric LR	Refuse truck	2019	Class 8				J1772
Mercedes-Benz	Electric	eActros	HD truck	2021	Class 8	124	240	40,000 lbs	Level 2 20 kW, Level 3 80 kW
Motiv	Electric	F-59	MD step van	Currently available	Class 6	90	106, 127	9,000 lbs	J1772 or three-phase Meltric connector, 15 kW
Motiv	Electric	E-450	MD truck	Currently available	Class 4	100	106, 127		J1772 or three-phase Meltric connector, 15 kW
Motiv	Electric	Work truck	MD truck	Currently available	Class 4	85, 100	106, 127		J1772 or three-phase Meltric connector, 25 kW
Nikola	Electric	Nikola Tre	HD truck	2023	Class 8	500-1,000	500-1,000		
Nikola	Electric	Nikola Two	HD truck	2022	Class 8	100-350	250	58,000 - 56,000 lbs	
OrangeEV	Electric	T-Series	Yard tractor	Currently available	Class 8	24+ hours	160		
Peterbilt	Electric	220EV	MD truck	2020	Class 6	100	148		Level 2 11 kW, DCFC optional
Peterbilt	Electric	579EV	HD truck	2020	Class 8	130-225	308-450		
Peterbilt	Electric	520EV	Refuse truck	2020	Class 8				
Phoenix Motorcars	Electric	Zeus E-450 Flatbed	MD truck	Currently available	Class 4	110	105		Level 2 11 kW, DCFC optional
Phoenix Motorcars	Electric	Zeus E-450 Utility	MD truck	Currently available	Class 4	110	105		Level 2 11 kW, DCFC optional
Roush	Electric	F-650	MD truck		Class 6	50-130	90-230		J1772 CCS, Level 2 20 kW, 50 kW DCFC
Roush	Electric	F-750	HD truck		Class 7				
Tesla	Electric	Semi	HD truck	2019	Class 8				Planned up to 1.6 MW, proprietary port
Transpower	Electric	Yard tractor	Yard tractor	Currently available	Class 8	60			
Transpower	Electric	Tractor	HD truck	Currently available	Class 8	100	215	80,000 lbs	
US Hybrid	Electric	eCargo	MD step van	Currently available	Class 3	75	35.84		J1772 Level 2 6.6 kW
Volvo	Electric	FL Electric	HD truck	2020	Class 8	186	100 - 300		CCS2, 22 kW AC, 150 kW DC
Volvo	Electric	FE Electric	Refuse truck	2020	Class 8	124	200 - 300		CCS2, 22 kW AC, 150 kW DC
Workhorse	Electric	NGEN 450 and NGEN 1000	Cargo van	Currently available	Class 3	100		6,500 lbs	
Workhorse	Electric	E-100	MD step van	Currently available	Class 3-Class 5	Up to 100	123	5,000 - 7,000 lbs	J1772 Level 2 20kW
XOS	Electric	Step van	MD step van	Currently available	Class 6	200			
XOS	Electric	ET-One	HD truck	Currently available	Class 8	300		80,000 lbs	
Zenith	Electric	Class 3	Cargo van	Currently available	Class 3	80 - 135	51.8 - 70		J1772 6 or 12 kW
Zenith	Electric	Class 3	MD step van	Currently available	Class 3	90	100	6,000 lbs	J1772 6 or 12 kW
Zenith	Electric	Class 3	MD truck	Currently available	Class 3	90	100	6,000 lbs	J1772 6 or 12 kW

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Electric Truck Market Trends

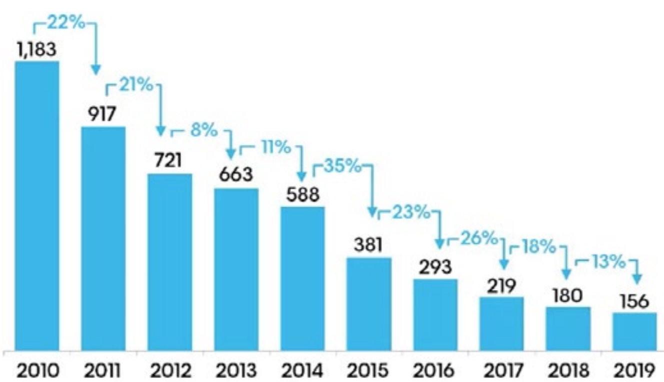
This section provides an overview of electric truck market trends, including battery prices, voucher incentives, truck mobility strategies, first and last mile delivery requirements, and autonomous technologies. It concludes with a discussion of electric utility surveys that focused on customer demand for electric trucks.

Battery Prices

Battery prices have decreased significantly since 2010. Bloomberg NEF has been tracking battery pricing data since 2010 (Goldie-Scot 2019). In its most recent report, BloombergNEF noted a price decrease of 85 percent in an average battery pack between 2010 and 2019. Today's cost is $156 per kilowatt hour (kWh), compared with $1,183 per kWh in 2010 (Figure 10).

Lithium-ion battery price survey results: Volume-weighted average

Battery pack price (real 2019 $/kWh)



Source: BloombergNEF

Figure 10: Battery Price Decreases

Similar battery price trends were reported by MJ Bradley (2019). Numbers reported by several analysts indicate that EVs will reach cost parity with internal combustion engine vehicles when the battery pack price reaches $100 per kWh. These projections approach the US Department of Energy's 2020 goal to reduce the production cost of an EV battery to $125 per kWh (Howell et al. 2016).

Some vehicle manufacturers have proposed the idea of leasing battery packs to mitigate the financial uncertainty of the largest component cost in an EV. This is an emerging finance method without many representative case studies.

Voucher Incentive Programs

One of the most direct methods of promoting electric truck adoption is creating a financial incentive that makes owning and operating these vehicles less expensive. Reducing the up-front cost of an electric truck, which typically is higher than a conventional truck, has been accomplished in regions with the highest rates of electric truck adoption. Vouchers and direct subsidies allow fleet operators to earn point-of-sale savings on electric trucks. These incentives have helped develop robust markets in China, California, and New York, although the greatest impact has been on transit bus deployments rather than delivery vehicles (CARB 2019f; Institute for Transportation and Development Policy 2018; New York State Energy Research and Development Authority 2019).

California Hybrid and Zero-emission Truck and Bus Voucher Incentive Project

California's HVIP provides funding through vouchers to make electric trucks more affordable for fleets (CARB 2019f). Incentive amounts target incremental costs, reducing the purchase price of electric trucks and buses. HVIP funding also can be applied to reduce the capitalized cost in a lease, substantially reducing monthly lease payments. Since 2009, the state has invested over $300 million in the HVIP. Parcel delivery trucks have accounted for 20 percent of approved vouchers, beverage delivery trucks for 7 percent, food distribution trucks for 4 percent, and other trucks for over 11 percent.

HVIP is the earliest model in the US to demonstrate the function, flexibility, and effectiveness of first-come, first-served vouchers that reduce the incremental cost of commercial vehicles. HVIP's success as a powerful tool for rapid deployment has encouraged regional adoptions of the voucher model in other states and on a localized basis, such as within California's air districts. Given the program's popularity, waiting lists have occurred. However, every vehicle eventually gets funded. To date, HVIP has funded over 7,000 hybrid and zero-emission MD/HD vehicles.

FedEx is deploying the largest order in HVIP history: 1,000 electric delivery vans using HVIP discount vouchers totaling $90,000 per vehicle (FedEx 2018). FedEx is purchasing 100 vans from Chanje Energy (Figure 11) and leasing the other 900 from Ryder Systems, which will service all 1,000 vehicles. HVIP's overall investment is $90 million in vehicle vouchers, and additional contributions will support charging infrastructure. The trucks will be deployed across California starting in fall 2019.

Beyond FedEx, Ryder is working with Chanje Energy to offer the Chanje V8100 panel van to customers across the US. Ryder offers service and support from 800 service facilities across the country, allaying fleets' concerns about how to maintain and service new technology vehicles. Leasing options are also available.

Figure 11: Chanje Energy's V8100 Van, Similar to Those Ordered by FedEx

To reduce infrastructure costs, HVIP offers an EVSE voucher enhancement of up to $30,000 per vehicle. The EVSE voucher enhancement can be applied to hardware costs, load management software for smart charging, and energy storage, but does not cover labor or electric utility upgrade costs.

Truck Mobility Strategies

An important truck technology trend is truck ownership and usage. Several companies are exploring the use of trucks as a service, with on-demand trucking matching carriers and shippers through digitization. Software would ensure trucks are always fully loaded and that loads are matched. Examples of companies, many still start-ups, include:

- Convoy – where carriers connect with shippers
- Doft – on-demand truck-sharing app where shippers can book a trucker via mobile app and truck drivers are notified of available loads close to them
- Huochebang – a Chinese logistics company with on-demand trucking
- K2, Konnect Cloud – matching exporters and importers with containers to ensure that drayage trucks are moving fully loaded containers
- Jupigo – real-time tracking and dispatching tool to match trucks and loads
- OnTruck – Spanish company offering on-demand connections between businesses and road freight companies
- Uber Freight – matching supply and demand for trucking and logistics industries
- Others – Transfix, Trucker Path, France's Convargo and Chronotruck, Brazil's Cargox, and the Netherlands' iCanDeliver

Another technology important to mention is truck platooning. Peleton Technology is developing a platform to improve fuel consumption and efficiency through truck platooning, or having trucks autonomously travel in groups with very small gaps between them to improve aerodynamic efficiency. The technology is being tested and demonstrated for pairs of trucks and may expand to larger convoys in the future. Vehicle-to-vehicle communication is necessary to operate the vehicles safely and efficiently, leading to operational cost savings.

Vehicle-to-grid technology may also affect how trucks and buses with larger battery packs get used while parked. If vehicle-to-grid systems are implemented, allowing for two-way power flow and communication, excess grid energy can be stored in vehicles locally and fed back to the grid as needed to balance demand or to provide local energy to the building or local microgrid.

First- and Last-mile Delivery Requirements

Commercial MD/HD trucks account for 30 percent of US on-road energy use, a figure projected to rise to 39 percent by 2050 (US Energy Information Administration 2019). E commerce has grown nearly 29 percent in value since 2013, resulting in expanded last-mile deliveries to residential areas—with potentially adverse health and climate consequences (Reuters 2019). On-road diesel vehicle emissions were linked to over half of 385,000 premature deaths globally in 2015, with dense urban environments experiencing two to three times as many premature deaths as the global average (International Council on Clean Transportation 2019a).

Considering the increasing reliance on local truck freight, the impacts of climate change looming, and the health effects on local populations from emissions, there is a clear need to transition as quickly as possible to zero-emission commercial vehicles for first- and last-mile deliveries.

Metropolitan areas throughout the US and Europe are seeking solutions to meet climate change and air pollution emissions reduction goals for commercial vehicles. Transportation and freight management studies are being undertaken by regional, state, and local transportation departments and planning agencies to identify ways to reduce congestion and improve air quality. Logistics companies are also leading the industry movement to adopt zero-emission trucks.

Low-emission Zones or Exclusion Zones

Low-emission zones are being established or evaluated for congested downtown areas in cities worldwide. Some cities have implemented zones in their city centers or ports that create preferential access for low-polluting vehicles or exclude vehicles that are not zero-emission. Those zones may be tailored for ports, city centers, or the broader city. Excluding all vehicles that are not low-emission creates a clear opportunity for zero-emission delivery vehicles and sends a market signal for manufacturers to innovate and develop technologies to meet the regulations. Low-emission zones or areas with congestion pricing that offer preferential pricing create a financial reward for adopting electric trucks. London has implemented an ultra-low emission zone, and Stockholm and other Swedish cities have congestion pricing with differential pricing based on a vehicle's emissions (Transport for London 2019; Transport Styrelsen 2019). The Port of Rotterdam is considering incentives to achieve an entirely zero-emission port by 2050 (Port of Rotterdam 2019).

Signatory cities to C40's Fossil Fuel Free Streets Declaration must designate a major area of their cities as free of transportation emissions by 2030 (C40 Cities 2019). More than two dozen cities have signed on, including Paris, London, Copenhagen, Mexico City, and Los Angeles. Seattle has already indicated that it will close one of its major downtown avenues to passenger vehicle traffic and reserve the avenue exclusively for buses for most of the working day (Bliss 2018). Permitted commercial vehicles will still be allowed to make deliveries along the avenue.

Zero Emission Loading Zones

Reserving curbside spaces for zero-emission trucks would make deliveries more efficient and profitable for fleets operating electric trucks by avoiding time lost trying to park. Delivery fleets often incur expensive parking fines as a matter of business in many cities because they are illegally parked while making deliveries. Zero-emission loading zones would allow drivers of zero-emission trucks to park legally and avoid fines. Oslo is installing zero-emission freight loading zones in its zero-emission city center, and New York City has evaluated the practice and may implement it as part of its congestion pricing program (DB Schenker 2019; New York State Energy Research and Development Authority 2014).

Industry Procurement Requirements

Companies in the transportation and energy sectors with significant carbon footprints have begun to pledge large-scale commitments to adopting zero-emission trucks and building infrastructure for their fleets. Adopting these vehicles helps companies meet their corporate commitments to sustainability and make their fleet operations more efficient and cost-effective. The EV100 Project, organized by The Climate Group, is coordinating industry efforts to switch corporate fleets to ZEVs (The Climate Group 2019). Industry commitments include FedEx leasing 1,000 ZEV delivery trucks, DHL committing to operating with zero emissions by 2025, and Ikea committing to making home deliveries almost entirely with electric trucks by 2020 in Amsterdam, Los Angeles, New York, Paris, and Shanghai (DHL 2017; FedEx 2018; Hinchliffe 2018).

Autonomous Technologies

Transportation in the US and across the world is increasingly becoming more electric, connected, and automated. The LD market is not the only transportation sector experiencing this change; the MD/HD sectors are being transformed as well through LD market technology transfer. It is important to note that when talking about automated vehicles, those vehicles are also likely to be electric because of the engineering benefits of an EV for incorporating the sensors and electrical devices needed to ensure safe automated operation. Two examples follow:

- Einride – developing an autonomous truck that can be controlled remotely (T-pod)
- Volvo – testing automated garbage trucks

Vehicle automation will greatly affect the future of the transportation network and will eventually affect all industries. However, the greatest impact will be on the freight industry. From first- and last-mile delivery to long haul trucking to material handling in warehouses, automated vehicle stakeholders see the advantages that automated driving systems will bring to their operations.

Automated vehicles can provide greater safety, efficiency, and mobility, opening numerous opportunities for the MD/HD vehicle. Technologies that are a precursor to full automation (such as lane warning systems, adaptive cruise control, collision avoidance, automated braking, and blind spot detection) are beginning to enter the MD/HD markets. These systems help to remove human error, which accounted for more than 90 percent of total truck accidents from 2014 to 2017 (Absolute Reports 2018). Across the world and in the US, these safety features are increasingly becoming mandated in all commercial vehicles.

To date, more than 30 truck manufacturers or automated vehicle companies are developing or piloting automated truck operations where the vehicle is driving itself under limited conditions and the human driver is not expected to take control (SAE level 4 automation). This includes well-established firms such as Daimler and start-ups operating in "stealth mode" whose names are not yet publicized, and the list keeps growing. It is expected that SAE level 5 automation (fully autonomous, operating independently under all conditions with no driver interaction) programs for MD/HD vehicles will be realized as early as 2020. The global market for autonomous vehicles is expected to grow by more than 5 percent annually through 2023 because of the growing penetration of automated systems in commercial vehicles.

Customer Demand for Electric Trucks

This section describes the results of interviews and surveys conducted with electric utility partners to characterize customer demand for electric trucks. Further information regarding the perspectives of the electric utility partners on transportation electrification is provided in Chapter 6.

Electric utilities are currently seeing the most interest and demand in MD and transit applications, where use patterns are more predictable, and vehicles can use depot charging rather than corridor charging. For example, Trimet (Portland) and King County Metro (Seattle/Puget Sound) are piloting electric transit, including depot and on-route infrastructure. Electric utilities are using data from transit pilot programs to better understand how MD/HD charging will affect distribution systems.

A common thread of concern is the availability of vehicles and products. They cited the number of start-ups fulfilling their first orders and are unsure of how they will help customers scale to the size of large diesel and trucking customers when there are numerous gaps to be filled.

When asked about how many customers drive MD/HD EVs in the survey, most respondents either do not have customers, have very few, or do not have data available.

- 7 electric utilities (37 percent) reported that the number was unknown, or the data were not available
- 9 electric utilities (47 percent) reported no electric trucks or very few
- 3 electric utilities (16 percent) reported having more than a few MD/HD EVs:
  - Port of Oakland: 40 MD/HD EVs
  - City of Lodi: approximately 140 MD/HD EVs
  - Pacific Gas & Electric: 423 electric trucks; 168 electric buses (2019 data)

Many electric utilities know which fleets may be good transportation electrification candidates based on those large customers who operate fleets in their territory. Most respondents had not studied long-haul trucking fleets within their service territory but could name the top 5 to 10 commercial fleets anecdotally. Responses included:

- municipal fleets
- hotel fleets
- school district bus fleets
- educational institution fleets
- airport and marine port vehicles
- food service and delivery vehicles
- municipal service vehicles such as utility vehicles, sweepers, sewer trucks, snowplows, and road equipment
- logistics companies' fleets
- waste pickup vehicles
- retailer fleets
- transit agency fleets
- private corporate fleets

Electric utilities recognized that early engagement with commercial customers will be important to recruit MD/HD charging customers, particularly to help commercial fleets understand how to transition to all electric because truck fleet managers generally come from a diesel background and mindset. The fueling process and cost calculations for an electric fleet will be different from diesel, and there is a lack of understanding about electric truck technology, how to charge the vehicles, and how to account for fueling costs. Outreach and education are needed—along with infrastructure—so fleets can better understand how electric utilities can help meet their need and better articulate their power needs if transitioning to EVs.

Some electric utilities have technical sales teams that work with transit customers to identify infrastructure, and they predict that a similar model of targeted outreach to fleet customers will be needed to scale MD/HD charging.

Most electric utilities acknowledge there is a lot more that can be done to engage with customers, helping them understand electric utilities are available to support them, make their transportation electrification projects go more smoothly, and help electrify more of their fleets faster. They state, however, there is still a lack of awareness of the vehicles, costs and needs around charging, and how customers could be managing the EVs. While electric utilities feel this is a good role for them to educate customers, they feel more of this burden of education could be borne by the vehicle manufacturers.

Some electric utilities said a portion of EV manufacturers understand the utilities' role by opening lines of communications with the utility, while other EV manufactures are very hands-off with utilities. Manufacturers are focused on the design and construction of their vehicles (which is good) so they can be ready to enter the market; however, the charging and energy management of their customers' fleets becomes an afterthought. This leads to electric utility challenges in grid preparation.

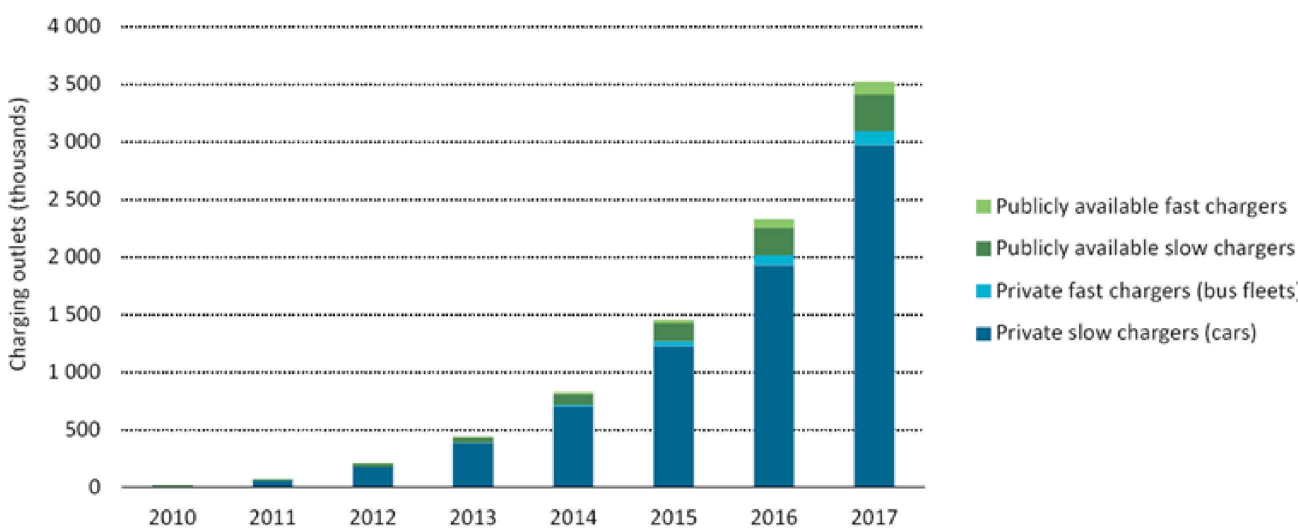
5. Electric Truck Charger Market Overview

This chapter discusses the electric truck charger market, including the currently available electric truck charger technologies, charger efficiency, and future charger technologies. It concludes with a brief discussion of the variable cost of building a charging site.

Current State of Electric Truck Charger Technologies

Currently, for all EV applications three levels of charging equipment are available on the market: AC Level 1 charging, AC Level 2 charging, and fast charging. Charging equipment for EVs is classified by the rate at which the batteries are charged. The IEA predicts that fast chargers will be supplemental to Level 1 and Level 2 slow chargers, with most charging for LD vehicles happening at home or work when the vehicle normally sits idle (Figure 12) (IEA 2018). However, government policies are helping expand fast charging networks around the globe, and fast chargers are vital to MD/HD electrification because Level 1 and Level 2 chargers cannot replenish the energy required to operate these vehicles fast enough.

Table 8 provides information about currently available chargers, including the manufacturer, power level, and charger standard. Table 8 provides an overview of the characteristics of chargers in North America, with an emphasis on MD/HD charging.



Source: IEA (2018)

Figure 12: Growth of EV Chargers around the Globe, by Type

Table 8: Charger Product Market Assessment

Charger Model	Manufacturer	Power Level (kW)	Charger standard	Charger Type	Smart Charging	ISO 15118	Price
HVC 150 E-Bus Charger	ABB	150	Combo CCS1	plug-in, overhead	Y	Y	$120,800
Blink DC Fast Charger	Blink	30-60	CHAdeMO	plug-in	Y		
High Performance DC Charging Station	BTC Power	200-475	Combo CCS1, CHAdeMO	plug-in	Y	optional	$243,000
Chargion DC Fast Charger	BTC Power	50	Combo CCS1, CHAdeMO	plug-in			$25,900
EVA200KS/01	BYD	200	CSS1	plug-in	N		$30,000
EVA100KS/01	BYD	100	CSS1	plug-in	N		
EVA040KS/01	BYD	40	CSS1	plug-in	N		$3,000
Ultracharge 500S	Chargemaster	50	CSS, CHAdeMo, AC (43 kW)	plug-in	Y	Y	
CPE100/200/250	ChargePoint	24/50/62	CSS1, CHAdeMO	plug-in	Y	N	
Express Plus	ChargePoint	Modular 31.25-500	CSS1, CHAdeMO	plug-in	Y	N	
HV160	efacec	160	CSS1	plug-in		optional	
HV175	efacec	175	CSS1	plug-in		optional	
HV350	efacec	350	CSS1	plug-in		optional	
QC Bus	efacec	40-150	CSS1	plug-in			
DC- HPC	EVBOX	350	CHAdeMO, CCS2 (not used in North America)	plug-in	Y		
Power Control System	Proterra	60	J1772 CSS Plug-in J3105 Inverted Pantograph J3105 Bus-up Pantograph	plug-in inverted pantograph roof-mounted pantograph	Y		$42,500
Power Control System	Proterra	125	J1772 CSS Plug-in J3105 Inverted Pantograph J3105 Bus-up Pantograph	plug-in inverted pantograph roof-mounted pantograph	Y		$62,000
Power Control System	Proterra	500	J3105 Inverted Pantograph J3105 bus-up pantograph	overhead	Y		
Evlink DC Fast Charger	Schneider Electric	50	CHAdeMO, AC	plug-in	Y		
QC 20/45	efacec	25/50	CCS1, CHAdeMO	plug-in			

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Table 9: Overview of Charger Characteristics in North America

Characteristic	Slow Charger		Fast Charger			
Charge level	Level 2		Fast chargers			
Current	AC	AC	AC, 3 phase	DC		
Voltage (V)	240 V (residential),208 V (commercial, 3 phase)		480 V+			
Power	>3.7 kW and ≤22 kW	≤19.2 kW	>22 kW and ≤45 kW	<350 kW	<1 MW (theoretical)	<350 kW
Connector types	SAE J1772 Type 1	Tesla	SAE J3068 (CCS2 equivalent)	CCS Combo 1 (SAE J1772 and IEC 62196-3)	SAE-3105	CCS2, Tesla and CHAdeMO (IEC 62196-3 Type 4)

Sources: SAE International (2018), ChargePoint (2019)

DC fast charging is the most likely type of EVSE to support MD/HD vehicle deployment. The CCS standard has two formats—Combo 1 and Combo 2—with Combo 1 being used in the US and Combo 2 in Europe. The main difference is in AC charging capability. CCS includes DC contacts to allow for DC fast charging. CCS-capable EVSEs can accept either AC or DC charging. For MD/HD EVs, only DC charging is relevant and both CCS versions can deliver up to 350 kW DC. There is a desire to reconcile CCS into a single new standard, and that process merges with other standard development efforts across LD and MD/HD charging. The charging standards support up to 400 amps, but that level of current will result in heavy and stiff cables, or require liquid cooling for thinner cables.

CHAdeMO is the name of a quick charging standard delivering up to 62.5 kW at 500 V and 125 amps DC via a special electrical connector. LD charging sites will sometimes include both CHAdeMO connectors and CCS connectors, but it is expected that trucks will not use the CHAdeMO standard.

The Tesla Supercharger EVSE is a 480 V DC fast charging site built specifically for Tesla vehicles. Each stall has a connector to supply electrical power at up to 150 kW via a DC connection, but the new V3 Supercharger will support peak rates of 250 kW per vehicle. The Tesla truck is expected to use the new high-power HD standard being developed, and so Telsa chargers are not applicable to MD/HD applications.

Overhead, pantograph, and inductive charging are all additional emerging technologies. SAE J 3105 standardizes overhead and pantograph charging, targeting in-route DC fast chargers. This interface is seeing increasing use in public transit applications, with buses taking advantage of end-of-route breaks to charge batteries. MD/HD vehicles would be especially suited to this kind of charging. For example, an EVSE could be sited so drayage and delivery trucks are able to charge while waiting to load or unload at warehouses and logistics hubs.

The battery's charge time depends on how depleted it is, how much energy it holds, the battery type, the battery management system of the vehicle, and the type of charging equipment. The charging time can range from 20 minutes to 20 hours depending on all these factors. Thus, it is not possible to determine an exact charging time based solely on the power level of the charger. Trucks with large battery packs would take much longer, hence only DC fast charging is applicable.

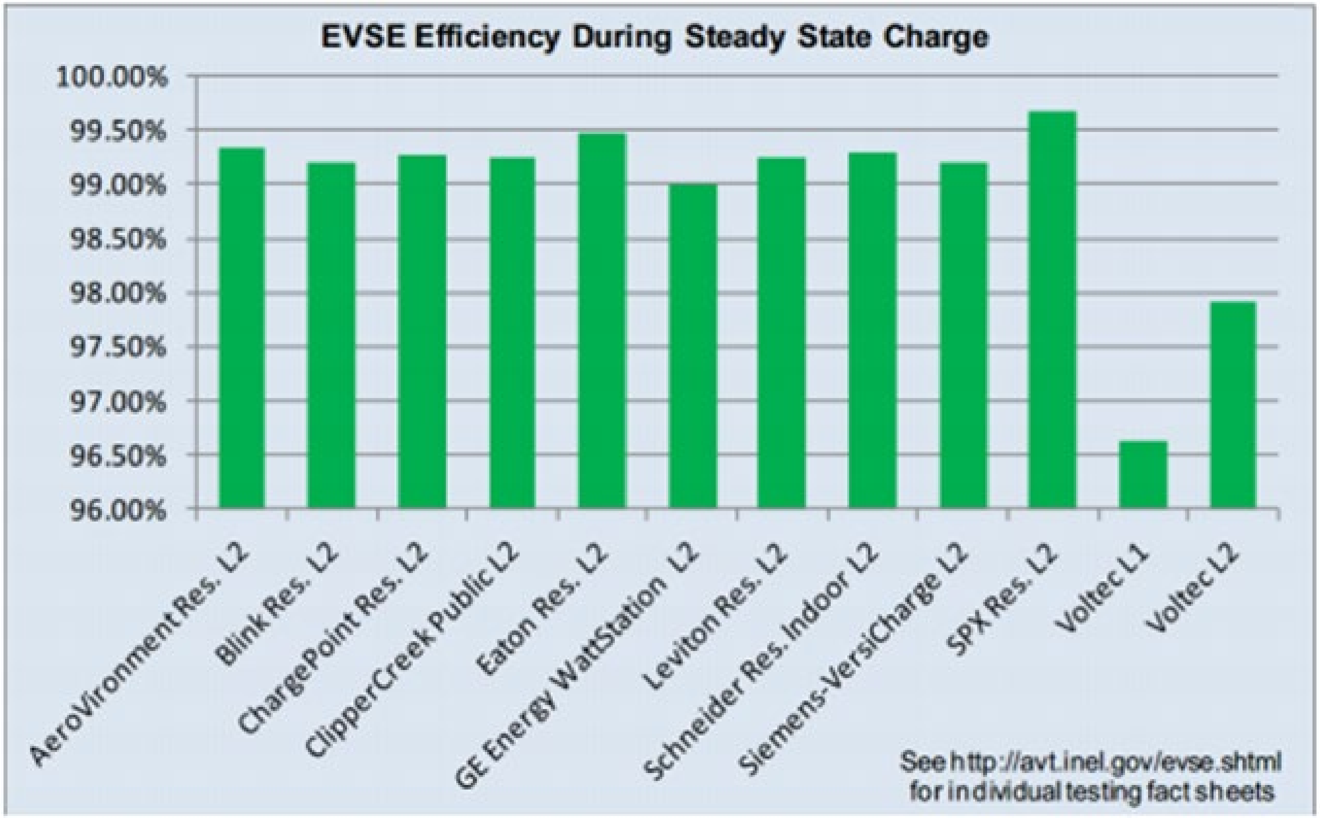
Charger Efficiency

The efficiency of a charger is also variable and depends on how efficient the charger is at converting electricity. For many EVs, roughly 10 percent of energy is lost during this conversion. A 2013 study found that nine out of eleven Level 2 chargers tested for steady state efficiency scored over 99 percent efficient (Figure 13). The same study analyzed a Level 1 charger and found it to be only 96 percent efficient, although the manufacturer of the single Level 1 charger in the study was the same as the worst-performing Level 2 charger (97 percent efficient). A DC fast charger tested in the same way was only 88.7 percent efficient. Wireless vehicle chargers are still an emerging technology, primarily using inductive approaches, but the efficiencies of earlier, lower-powered models have improved in the last several years from around 70 percent to around 90 percent, as seen in contemporary, higher-powered inductive charging models.

Future Charger Technologies

As EVs become more prevalent, there is greater demand for new EVSE technologies that can better match the refueling profiles of conventional vehicles. The US Army's Ground Vehicle Support Center is working with industry to develop specifications for a prototype EV for deployment by 2028. The minimum specifications require a full charge in 30 minutes, meaning a 6 MW charger. Ideally, they would like to charge in 15 minutes, requiring 12 MW of charging capacity. This multi-fold increase in power may not be achievable with today's battery chemistry, but the Ground Vehicle Support Center's work with industry demonstrates that research and development dollars are being invested to expand charger capacity significantly in the next 10 years.

Extremely high-power charging sites are at the earliest stages of development. A few companies are working on 1.2 to 2 MW charging, but the CHAdeMO and the CCS standards provide the maximum charging power available currently, with 350 kW of charging capacity. Germany finished the installation of a 1.2 MW charging site in March 2019, but this is divided into four modules with a capacity of 300 kW each. In Norway, two companies have announced a joint venture to commercialize ultra-fast charging sites up



Sources: Bi et al. (2016), Morris (2016), US Office of Energy Efficiency and Renewable Energy (2019)

Figure 13: Efficiency of Different Charging Arrangements

to 1.2 MW per vehicle, but nothing is built yet. The SAE 3105 protocol for overhead charging can be applied to chargers up to 1 MW, but currently no chargers or vehicles are on the market that can handle such loads. The next generation of electric trucks will need to arrive before these charging speeds are achievable.

Wireless charging is another emerging technology with a lot of potential, but is not yet ready for widespread or large-scale deployment. Wireless charging could provide potential benefits, including a smaller footprint for the subterranean dispenser and potentially less training for drivers charging the vehicles. Given the seamless operational nature of charging wirelessly, opportunity charging during a vehicle's duty cycle is simple. Scenarios are being studied to optimize these systems by, for example, balancing the downsizing of battery capacity (and therefore vehicle cost) with strategically placed wireless charging pads for on-route charging (Bi et al. 2016). However, the technology itself, typically using inductive methodologies, remains expensive and requires more extensive construction and trenching at the site. The distance between the vehicle and the charging pad, uncertainty over the maintainability of a buried system, lack of operational data or case studies, and the start-up nature of most companies developing this technology are challenges that must be overcome (Brecher and Arthur 2004).

Looking ahead, we are likely to see an increasingly electrified and interconnected transportation system. Combined with the increasing concentration of renewables in electric utility portfolios, smart and interconnected charging systems are needed to ensure the most efficient use of vehicles. To maximize the economic and environmental benefits of EVs, batteries in these vehicles may be considered an expansion of the current electric grid, with chargers as the translators between the vehicle and the grid.

Vehicle-to-grid Integration and Smart Charging

As the electrical grid and vehicles become more complex and interconnected, they need to be able to talk to each other. Using a common system between all the pieces of technology involved in charging an EV will accelerate the deployment of managed charging systems (Smart Electric Power Alliance [SEPA] 2019a). While multiple standards currently exist in the marketplace, the Open Charge Point Protocol is an initiative led by the Open Charge Alliance, positioning the alliance as an early leader. It is an open-source communication protocol that allows EV charging sites and central management software to communicate. Open protocols enable interoperability between charging sites, vehicles, and site management services. They promote innovation and collaboration and ensure the cost of EV charging remains competitive for business owners and EV drivers. Open Charge Point Protocol is not highly adopted in the US because of the large number of US Department of Energy grants that allow the network providers to choose their protocols (SEPA 2019a).

Smart charging and vehicle-grid integration help align vehicle charging with the needs of the electric grid. Vehicle-grid integration can refer to scheduling, planning, or varying the charging of an EV to reduce grid impacts and even provide benefits such as load shifting to more affordable times of use and increased charging efficiency. West Coast electric utilities are already experimenting with these technologies. Avista Utilities in Oregon and Washington carried out a pilot program that involved commercial customers, where the electric utility installed and retained ownership of charging infrastructure, allowing it to collect data and test demand reduction strategies (SEPA 2019a). The electric utility was able to reduce the load by as much as 75 percent. Southern California Edison's Charge Ready Program includes a requirement that fleets receiving funding agree to be subject to demand reduction events, allowing the electric utility to shift power demand as needed. Pacific Gas & Electric, through the Electric School Bus Renewables Integration program, is testing managed charging among electric school buses in its territory with the goal of minimizing cost and emissions. Smart charging can help reduce peak demand, saving consumers money while also storing excess energy in off-peak times.

ISO 15118, or the "Road Vehicles – Vehicle to grid communication interface" standard, is an international standard that outlines the digital communication protocol that an EV and charging site use to recharge the EV's high-voltage battery. The smart charging built into ISO 15118 makes it possible to match the grid's capacity with the energy demand for the growing number of EVs that connect to the electrical grid. It also enables the transfer of energy from the EV to the grid. As these products become more prevalent, they can help maximize the benefits EVs provide to the grid by optimizing when EVs charge to help distribute the load throughout the day.

Variable Cost of Building a Charging Site

Pricing for EVSEs and installation costs can greatly vary depending on the equipment selection, site location, available electricity capacity, permits, number of units per site, and labor costs. It is extremely challenging to accurately predict the exact cost of setting up a charging site without looking into many site-specific details. One study found that the distance between the EVSE and power distribution panel had a greater impact on the installation cost than even the number of units installed per site (The EV Project 2015a). Of 111 DC fast charging sites studied, installation costs alone varied by more than 500 percent, from $8,500 to over $50,000 (The EV Project 2015b). Because the cost of the EVSE itself is static, good planning may save money by defraying installation and labor costs. If a property is planning to scale up its electric fleet over time, consideration may be given to the ultimate electrification goals during the initial planning process by consolidating the construction work or making sure the electrical supply upgrade has the capacity to accommodate the load growth projections. Tables 10 and 11 show the results of other studies that looked at the fixed costs of EVSE sites by power level.

Table 10: Fixed Costs Estimates for EVSE Installations at Various Levels

Capital Costs	Commercial		
	50 kW	150kW	350kW
Installation (per charger)	$22,626	$22,626	$22,626
Site preparation (per charger)	12,500[C]	12,500	12,500
Utility service (per station)	17,500[D]	17,500	17,500
Transformer (per station)	32,500[F]	40,000[G]	40,000
Equipment (per charger)	35,000[J]	50,000	100,000

C, D Clint, J., et al. 2015. "Considerations for Corridor Direct Current Fast Charging Infrastructure in California."

F, G Clint, J., et al. 2015. "Considerations for Corridor Direct Current Fast Charging Infrastructure in California."

J Clint, J., et al. 2015. "Considerations for Corridor Direct Current Fast Charging Infrastructure in California."

Source: Lee and Clark (2018)

In Table 11, note that the authors divide DC fast chargers into three categories: DC fast charger (up to 50 kW), Level 4 (150 kW), and Level 5 (350 kW) (Lee and Clark 2018).

Table 11: Installation Costs per DC Fast Charger, by Power Level and Chargers per Site

	50 kW				150 kW				350 kW			
	1 charger per site	2 chargers per site	3-5 chargers per site	6-50 chargers per site	1 charger per site	2 chargers per site	3-5 chargers per site	6-20 chargers per site	1 charger per site	2 chargers per site	3-5 chargers per site	6-10 chargers per site
Labor	$19,200	$15,200	$11,200	$7,200	$20,160	$15,960	$11,760	$7,560	$27,840	$22,040	$16,240	$10,440
Materials	$26,000	$20,800	$15,600	$10,400	$27,300	$21,840	$16,380	$10,920	$37,700	$30,160	$22,620	$15,080
Permit	$200	$150	$100	$50	$210	$158	$105	$53	$290	$218	$145	$73
Taxes	$106	$100	$64	$42	$111	$89	$67	$45	$154	$123	$92	$62
Total	$45,506	$36,235	$26,964	$17,692	$47,781	$38,047	$28,312	$18,577	$65,984	$52,541	$39,097	$25,654

Source: International Council on Clean Transportation (2019b)

The installation of charging infrastructure for MD/HD applications faces additional challenges when trying to develop accurate estimates, given that the sites need to be larger—requiring more real estate and longer trenching when compared with the currently available public charging sites for LD vehicles. Larger MD/HD sites with ports delivering higher power would also have load demands that would most likely trigger upgrades in the distribution system.

A service upgrade or a new service extension that can support new loads up to 1 MW can take between 6 months and 3 years from planning through construction, and potentially need to be supported with the installation of a new service transformer and upgrades to the supply conductor. Table 12 provides the costs associated with upgrading distribution transformers based on their size, location, and labor (SEPA 2019b).

A new feeder that can support new loads over 1 MW, but less than 10 MW, can take between 9 months to 4 years to complete (from planning to construction), and would most likely require service at a medium voltage level along with re-conductor and other upgrades to the distribution grid. The costs associated with upgrades to an existing service or a new feeder for a commercial or industrial customer are complex, and it is important to discuss the options available from the electric utility (SEPA 2019b).

A new customer-dedicated substation may be required for loads over 10 MW. An interconnection study would be the first step to understand the project requirements and potential upgrades to the electric utility's subtransmission facilities. Such a study would discuss different options available for the interconnection, and how the costs would be allocated between the customer and the electric utility. Considering the planning stages, permit requirements, environmental constraints, potential right-of-way acquisitions, equipment lead times, and construction duration, a new dedicated substation could take between 3 to 5 years, or more. One of the most critical components for a new substation is the permit application process. It is vitally important that these projects be closely coordinated with the electric utility to avoid potential higher costs and duration for completion.

Table 12: Transformer Upgrade Cost Estimates, by the City of Palo Alto Utilities

Transformer Ratings and Location	Equipment Costs ($)	Labor Costs ($)	Total Costs ($)
5 kVA to 25 kVA Pole Top	$1,000-$3,000	$3,000-$7,000	$4,000-$10,000
25 kVA Pad-mounted	$3,000-$7,000	$5,000-$9,000	$8,000-$16,000
75 kVA Pad-mounted	$7,000-$12,000	$7,000-$12,000	$14,000-$24,000
100 kVA-750 kVA Vault Mounted (underground)	$7,000-$20,000	$11,000-$16,000	$18,000-$36,000
1,000 kVA or 25,000 kVA Pad-mounted	$20,000-$50,000	$13,000-$20,000	$33,000-70,000

Source: SEPA (2019b)

6. Existing and Planned Electric Truck Charging Infrastructure

HDR's study partners, S Curve Strategies and Ross Strategic, collected information from electric utility partners about past, current, and pending infrastructure programs; transportation electrification incentive programs; grid preparation; and charging site location considerations. This chapter highlights comprehensive findings from electric utilities in California, Oregon, and Washington gathered through online surveys and interviews with electric utility partners.

Thirty-six electric utilities and municipalities were asked to participate, and 19 completed surveys. Those who did not participate cited that they were located far off I-5 or its intersecting corridors, which are the focus of the study. Of the 19 electric utilities, nine participated in a phone interview to provide additional feedback (see sidebar). The results and findings are identified at a high level and are anonymous to protect potentially sensitive information.

Appendix C shows a summary of the electric utility EV programs in California, Oregon, and Washington.

Electric Utilities Interviewed

Los Angeles Department of Water and Power (California)

Pacific Gas & Electric (California)

Pacific Power (Oregon)

Portland General Electric (Oregon)

Puget Sound Energy (Washington)

Southern California Edison (California)

Sacramento Municipal Utility District (California)

San Diego Gas & Electric (California)

Seattle City Light (Washington)

Southern California Public Power Authority (California)

Transportation Electrification Programs

This section describes past, current, and pending programs that promote transportation electrification. Also discussed are current incentive programs for purchasing EVs and pending non-infrastructure programs.

Past Programs

About half (nine; 47 percent) of the 19 survey respondents reported past transportation electrification programs for LD vehicles. Seven respondents did not have past programs to report. Components from past programs included:

- public Level 2 and DC fast charging in parking lots and shopping centers
- incentives for commercial customers to purchase EVs
- incentives or rebates for commercial customers to install charging infrastructure
- electric fleet programs for municipally owned vehicles
- rebates for residential customers installing in-home charging infrastructure
- rebates to install workplace charging
- rebates to purchase EVs

Current Programs

Nearly all (17; 89 percent) of the respondents have current programs promoting LD electrification. Of those, three have pilot programs for electric transit, and two have programs to support electrification of MD/HD trucks. In interviews, most California electric utilities cited rate design as a key component to any MD/HD transportation electrification program. New rate designs that remove demand charges for commercial EV charging go hand-in-hand with the acceleration of adoption by larger and more sophisticated fleet owners who will not invest in fleet electrification if they will not see the payback.

Components from current programs include:

- LD vehicles:
  - EV charging site equipment rebates (residential and commercial)
  - EV charging site installation incentives and rebates (commercial, workplace, multifamily, and residential)
  - fast charger rebates and plazas
  - residential EV charging installation programs
  - public Level 2 and DC fast charging
  - grant funding program for non-residential electric transportation infrastructure
  - deployment of EV charging in disadvantaged communities, or communities with high levels of pollution
- MD/HD vehicles:
  - charging infrastructure equipment and installation rebates for MD/HD and on- and off-road technologies, including delivery vans, transit buses, forklifts, and truck refrigeration units
  - electric transit pilot programs, including deploying infrastructure for in-depot and on-route charging equipment
- Other:
  - funding for port equipment electrification projects
  - custom programs to add new loads (not specific to loads from EV charging infrastructure), as noted by one electric utility

Programs Pending Approval

About half (nine; 47 percent) of the survey respondents reported transportation electrification programs pending approval. Of those, six had to do primarily with charging infrastructure for LD vehicles, one electric utility reported a pending MD/HD infrastructure program, one reported a transit electrification program, and one reported preparing for truck and bus electrification. Eight respondents did not report pending programs or reported they were in the early stages of development. One electric utility could not release draft program information. Components from pending programs include:

- LD vehicles:
  - infrastructure and charging equipment advisory services program with a rebate program that will cover some costs of infrastructure and charging equipment
  - funding for transportation electrification projects for municipalities
  - workplace and school charging
  - vehicle purchase rebates
  - deployment of electric utility owned and operated commercial LD make-ready infrastructure for workplaces, destination centers, fleets, and multiunit dwellings
  - public charging at parks, beaches, and remote locations
- MD/HD vehicles:
  - MD/HD infrastructure programs
  - development of a roadmap that will include preparing for truck and bus electrification
  - transit full ownership program (transit agency owns buses and charging infrastructure)

Current EV Incentive Programs

Most electric utilities (16; 84 percent) that responded to the survey are offering EV rates, incentives, and grants in addition to infrastructure or vehicle incentives. Components from current non-infrastructure program examples include:

- ride-and-drive events
- EV purchase or lease incentives
- designing customer-centric rates for fast chargers
- monetary support of electric bus purchase
- no-cost charging at municipally owned site
- rebate program for used EVs (at least two model years old)
- time-of-use rates for residential customers that install a dedicated meter for the installation of a Level 2 charger ($0.025/kWh)
- no-demand charge time-of-use rebate

- on-site technical support for business customers
- dedicated rate plans for EV customers
- education and financial incentives for auto dealers to sell EVs

Pending Non-Infrastructure Programs

Only 5 of 19 electric utilities reported pending non-infrastructure transportation electrification programs, including (Table 13):

- EV incentives for electric utility customers
- point of purchase rebate program for new EV purchases
- new rates for non-residential EV charging
- self-service tools for customers
- EV and charger rebates for low- and moderate-income customers
- creation of a new customer class for commercial EVs to allow full cost-of-service rates that do not include traditional demand charges

Grid Preparation

For many electric utilities, it is challenging to plan for the load that MD/HD vehicles will bring. The amount of time it will take an electric utility to perform an electrical service upgrade for installing charging infrastructure to support electric MD/HD vehicles depends on the amount of power needed for a site, the closest distribution circuit or substation, the capacity of the circuit or substation, and the proximity of the charging site to the circuit or substation. Feeder upgrades could take more than a year, substation upgrades could take 1 to 2 years, and new substations could take 3 years or more considering the planning stage, load interconnection studies, and the complex permitting process involved. Charging sites in rural locations on undeveloped land where existing distribution circuits or transmission lines are not in close proximity or where the electric grid may not have additional capacity for new loads may experience significant challenges related to environmental permits and approval processes. These factors are essential when planning future corridor infrastructure planning upgrades. For the larger California electric utilities, for example,

Table 13: Transportation Electrification Programs – Survey Summary

Programs	Utilities Surveyed Reporting Light-Duty Transportation Electrification Programs	Utilities Surveyed Reporting Transit Electrification Programs	Utilities Surveyed Reporting MD/HD Transportation Electrification Programs
Past Infrastructure Programs	47% (9)	0	0
Current Infrastructure Programs	89% (17)	16% (3)	11% (2)
Infrastructure Programs Pending Approval	32% (6)	5% (1)	5% (1)
Current Non-Infrastructure Programs	84% (16)		
Non-Infrastructure Programs Pending	26% (5)		

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

while military bases, universities, and refineries are currently their largest customers, in the future they see this changing and electric fleets of hundreds of vehicles could become their largest customers.

Current large customers are usually those whose load requires a dedicated distribution circuit or exceeds the capacity of a single distribution circuit. For each electric utility, the limitation of the distribution circuits in close proximity to the customers is different, but normally that limit is around 8 to 12 MW and, if exceeded, this triggers the need to serve the load through the subtransmission grid and, in turn, the creation of a dedicated customer substation and potentially additional upgrades to the grid.

One California electric utility has done a thorough analysis of its territory and the potential load of customers with large fleets, providing more certainty for its grid preparation and overall planning efforts. Others are taking a project-by-project approach to such analyses, focusing first on market sectors where MD/HD incentive money is available, such as transit agencies, as opposed to targeting geographic areas. Some stated this project-by-project analysis presents a gap, citing that when looking across their territory, they have obvious data such as how much electricity their commercial customers use, but do not have data on what they drive.

San Francisco is an example of the importance of a current and thorough territory-wide analysis versus a project-by-project analysis. Two years ago, the city's grid capacity was highly constrained and since then has seen numerous upgrades because of the city's real estate boom. Therefore, an analysis done prior to this upgrade would provide the wrong conclusion to a customer there looking to transition its MD/HD fleet to electric. In another example, a circuit may have very low capacity; however, it is near a pending electrification project. In both cases, it is assumed electric utilities would ensure their needs assessment analyses are not based on outdated information.

Other transportation electrification planning challenges arise in rural areas along highway corridors and highly networked cities such as the downtown core of Oakland, where there is more complexity. Electric utilities have seen Tesla supercharger sites, for example, run into challenges along rural highway corridors because not much development has occurred there over the last 50 years. Adding 2 MW of charging load can double what was already there. Rural circuits can be many miles in length and were not originally designed to accommodate the additional load of rapid EV charging. Upgrades may include additional poles and upsized conductor, which can be expensive. Certain costs are borne by the customer, but if run to common areas, then the costs can be socialized.

The perimeters of urban areas seem to be the best locations for potential charging infrastructure sites.

Overall, electric utility planners have concerns regarding high charging levels over 1.5 MW per charging port for infrastructure that would be used to support HD electric trucks. As one planner stated, "I have had the same worry for more than a year about expectations to build out the truck stop inventory along I-5 and replace every diesel pump, for example, with 1.5 MW at the handle. This is a big concern as to whether we can do that. Are we talking about building a new substation at every corner for every truck stop? In such a case, each one will need a 20 MW substation to support it." One of the truck stops on the I-5, for example, has four or five truck stops on either side with 10 diesel pumps each. An extreme example of potential truck stop requirements is an East Coast truck stop that has 120 pumps—the maximum load potential if this site were to be fully electrified would be 180 MW. However, planning capacity may be a smaller percentage depending on assumed simultaneous utilization rates. Managed charging and DER solutions such as battery energy storage systems can also be used to reduce peak load and, in turn, additional upgrades to the electric grid.

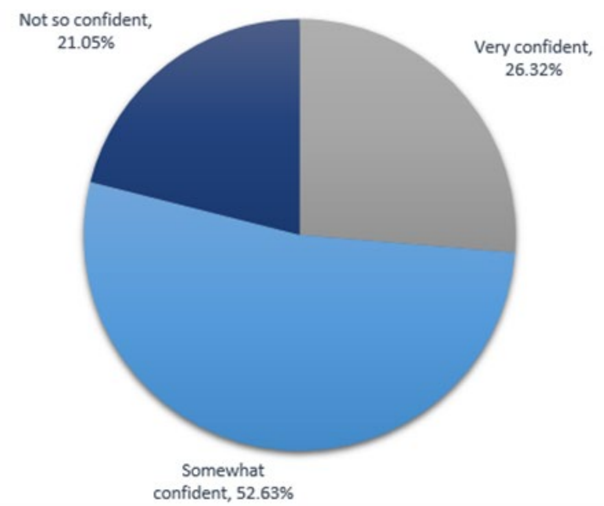
Distance from the substation, anticipated power demand, and anticipated utilization were the biggest factors affecting whether an electric utility can handle MD/HD charging on existing infrastructure. Generally, the closer a charging location is to the substation, the easier it is to support the load. Electric utilities expressed concern with many uncertainties around power demand that is influenced by the state of electric truck technology, including battery size, how fast batteries will charge, and how long drivers are willing to wait to recharge, among other factors.

Another consideration for grid impacts is the utilization of each charging site. While overnight depot charging may not overwhelm the grid, DC fast charging could draw a large amount of power that may strain the grid, depending on how many vehicles charge at the same time. On the other hand, the load needs to support the investment to make it cost-effective to the electric utility. Consideration must be given to the need for infrastructure to periodically cool down to operate properly versus operating 24/7.

Rate design will also affect charging use. Distribution planners need a better sense of where the technology will be, where the market is going, adoption timing, and where customers will need charging. Since electric utilities can add infrastructure to support new customer load, the concern is anticipating these affected locations and receiving advance notice from MD/HD customers of additional load.

Electric utility partners were asked to rate their level of confidence with whether their electric utility's local grid is prepared to support the electrification of MD/HD vehicle classes. Responses are summarized in Figure 14.

How prepared is your utility's local grid to support transportation electrification of medium- and heavy-duty vehicle classes?



Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Figure 14: Survey Response on How Prepared West Coast Electric Utilities Feel to Support Electrification of MD/HD Vehicles

Some of the responses to the question "How prepared is your utility grid?" are depicted in Table 14.

Table 14: Responses to the Question, "How Prepared is Your Utility Grid?"

Response	Comments
Not so confident *(4 responses, 21percent)*	• Early stages of development; will need customized programs due to 99 percent of customer base being commercial or industrial • Capacity of 12 kilovolt distribution line circuits on both sides of I-5 is relatively small; difficult to scale in the short-term to meet an uncertain level of demand for MD/HD EVs • Limited amount of space on I-5 on/off ramps to facilitate MD/HD vehicles • Still in the process of assessing impacts • Anticipate grid will be affected by fast charging for long-haul trucks
Somewhat confident *(10 responses, 53 percent)*	• Robust system built with load growth in mind • Confident in ability to support MD/HD vehicle classes, but some uncertainty around mandates and regulations that create variables for the distribution system • Know how much growth the electric utility can handle today, but not enough for 10-year expectations • No official discussion of any issues • Confident can serve customers' needs, but unknowns around speed and location of MD/HD EV growth create uncertainties for the grid. Potentially significant demand requests (for example, 5 MW sites) coupled with long lead times for system upgrades of this magnitude could affect timely infrastructure deployment. Using transit locations to investigate deployment scenarios and solutions. • Projects requiring large primary distribution or transmission upgrades pose timeline challenges • Don't have the processes in place yet to move fast • Have not performed analysis on the potential impacts of MD/HD EVs on the grid
Very confident *(5 responses, 26 percent)*	• Have enough electric capacity to support MD/HD EVs • Depends on details of the charging installations (size, location, capacity of circuit at that location) • Adding new load is a standard operating procedure, but some locations will be capacity constrained. The electric utility will design an appropriate solution for the location in question. Most significant concern is advance notice.

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Electric Truck Charging Site Location Considerations

As discussed above, distance from the substation, anticipated power demand, and anticipated utilization emerged as the most critical variables for how MD/HD charging could affect the grid and, therefore, are major considerations for the required EV infrastructure. Electric utilities also identified the following considerations for MD/HD charging infrastructure locations:

- Real estate and space constraints: Electric utilities mentioned a need to focus first on where property is available because tractor trailers require space to maneuver and access charging. The available real estate for the required EV infrastructure at a location could be a limiting factor, regardless of grid capacity. Electric utility partners mentioned that opportunities to expand the size of existing charging areas (for example, for LD vehicles) to accommodate MD/HD charging could be a possibility since current gas stations manage to have diesel pumps for MD vehicles and pumps for LD vehicles. However, since the existing LD charging stations were not designed with MD/HD EVs in mind, there could also be limitations for accessibility and expansion to accommodate MD/HD EVs. Co-locating facilities or sharing infrastructure could also risk inconveniencing drivers and degrade the charging experience when accelerating EV adoption requires that the experience be as easy as possible.

- Aligning with highway exits: Locations for corridor charging need to be easily accessible from I-5. Some electric utilities have identified charging bases for transit along I-5. Others noted a limited amount of space on the I-5 on/off ramps to facilitate MD/HD vehicles within their service areas.

- Network gaps: Electric utilities are interested in investing in infrastructure where other entities are not investing, to help fill network gaps. For example, filling gaps for LD vehicle charging in rural areas.

- Airports and marine ports: Several electric utilities noted that airports and marine ports are interested in opportunities to electrify and could be potential customers for MD/HD charging infrastructure.

Insights from EVSE Providers

The study team also contacted three EVSE provider companies to discuss MD/HD electrification, including plans to develop charging infrastructure that could support MD/HD vehicles, considerations for location selection, and lessons learned from their experience coordinating with electric utilities. Key themes from these conversations are summarized below:

- The EVSE providers interviewed did not have any MD/HD corridor charging infrastructure projects planned yet. The farthest along in planning for MD/HD electrification was an EVSE provider identifying travel stop partners along major corridors as possible MD/HD site locations. One EVSE provider interviewed was an infrastructure provider for electric transit projects and has developed depot charging and on-route charging networks for electric transit vehicles.

- The consensus from EVSE providers was that the customer base for long-haul corridor charging infrastructure does not yet exist, and MD/HD transportation electrification will happen through depot and back-to-base charging in the near-term. The technology for electric trucks has not reached the level of feasibility or availability needed for long-haul operation. One person predicted government or subsidized funding of charging installations would likely be needed to build a customer base. Alternatively, a coalition of trucking fleets could consolidate demand to sway an infrastructure provider. As battery capacity increases, there will be less need for back-to-base vehicles to use on-route or corridor charging.

- Preventing queues at charging sites is a priority for EVSE providers. MD/HD vehicles could clog a site if co-located. EVSE providers have not planned for those uses in location selection of existing infrastructure. EVSE providers are looking at large-format charging sites to minimize queuing.

- Demand charges are a significant issue for EV chargers and can hurt a site's economics. Demand charges may be considered when planning how to support deployment of MD/HD transportation electrification. Additionally, the amount of electric utility work needed will increase the cost of building the site.

- Involving the electric utility early and establishing a process is key to successful infrastructure development. While EVSE providers can often build a site in four to six weeks once construction is able to begin, it is the design, planning, and permitting that can exponentially increase the time before construction starts, in addition to the amount of time electric utilities may need to bring power to the site. A backlog of installations and upgrades can delay the ability of EV infrastructure providers to move quickly.

Questions Raised by Electric Utilities

The electric utility partners surveyed and interviewed raised the following questions for the study team to consider:

- Will the study consider how building out a charging system for MD/HD vehicles could influence LD charging on the I-5 corridor?
  - Electric utilities are interested in how the deployment of MD/HD electrification can also influence LD electrification, including opportunities to bundle infrastructure investments that serve a broad range of vehicles.
- How can electric utilities become more knowledgeable of the use cases for electric trucks from a logistics perspective to be able to better serve customers interested in MD/HD electrification?
- What strategies will help electric utilities get to MD/HD electrification at scale?
- How can electric utilities educate freight companies and MD/HD customers about the business case and how to account for fueling costs with electric trucks?
  - MD/HD customers know how to purchase typical fuel and incorporate costs into shipping charges and bottom line. They will need to adjust to account for the costs of electric charging.
  - Different rate structures, demand charges, etc., will make it more difficult to translate electric charging costs into their bottom line and pass those costs on to shippers.
  - How can electric utilities restructure rates to make them easier to understand for customers?
- How does rate design compare across the three West Coast states and what are the best mechanisms for rate design that can encourage adoption and use of charging infrastructure?
- Who will maintain these MD/HD sites? Electric utilities? Third party? How reliable will they be?
- Electric utilities do not have full expertise in MD/HD EVs. Should electric utilities be the ones to educate MD/HD customers?
- MD/HD EV manufacturers seem hands-off; would auto dealers be more engaged?

Electric Utility and Municipality Survey Participants

Survey responses were collected from the following electric utilities:

- Burbank Water and Power (California)
- City of Anaheim, Public Utilities Department (California)
- City of Lodi Electric Utility (California)
- City of Shasta Lake (California)
- City of Vernon (California)
- Glendale Water & Power (California)
- Los Angeles Department of Water and Power (California)
- Pacific Gas & Electric (California)
- Pacific Power (Oregon)
- Pasadena Water and Power (California)
- Plumas-Sierra Rural Electric Cooperative (California)
- Port of Oakland (California)
- Portland General Electric (California)
- Redding Electric Utility (California)
- Riverside Public Utilities (California)
- San Diego Gas & Electric (California)
- Seattle City Light (Washington)
- Southern California Edison (California)
- Truckee Donner Public Utility District (California)

7. References

Absolute Reports. 2018. "Global Autonomous Truck Market Size – Segmented by Autonomous Level, ADAS Features, Sensor Technology, and Geography - Growth, Trends, and Forecast (2018–2023)." August. https://www.absolutereports.com/global-autonomous-truck-market-size-segmented-by-autonomous-level-adas-features-sensor-technology-and-geography-growth-trends-and-forecast-2018-2023--13104649.

American Public Transit Association. 2017. "Public Transportation Fact Book 2017." https://www.apta.com/resources/statistics/Documents/FactBook/2017-APTA-Fact-Book.pdf.

American School Bus Council. 2018. "National School Bus Fuel Data." Accessed November 21, 2018. http://www.americanschoolbuscouncil.org/issues/environmental-benefits.

Argonne National Laboratory. 2017. "AFLEET Tool." 2017. https://greet.es.anl.gov/afleet_tool.

———. 2018. "GREET Model." Updated 2018. https://greet.es.anl.gov/.

Bi, Z. et al. 2016. "A Review of Wireless Power Transfer for Electric Vehicles: Prospects to Enhance Sustainable Mobility." Applied Energy. July. https://chrismi.sdsu.edu/publications/113.pdf.

Bliss, L. 2018. "Why Seattle Is America's Bus-Lovingest Town." CityLab. May 2018. https://www.citylab.com/transportation/2018/05/seattle-the-city-that-respects-the-power-of-the-bus/559697/.

Brecher, A., and D. Arthur. 2004. "Review and Evaluation of Wireless Power Transfer (WPT) for Electric Transit Applications." US Department of Transportation. August. https://www.transit.dot.gov/sites/fta.dot.gov/files/FTA_Report_No._0060.pdf.

C40 Cities. 2019. "Fossil Fuel Free Streets Declaration." Accessed May 2019. https://www.c40.org/other/fossil-fuel-free-streets-declaration.

California Air Resources Board (CARB). 2018a. "Advanced Clean Trucks – Battery-Electric Truck and Bus Energy Efficiency Paper." May. https://ww2.arb.ca.gov/resources/documents/advanced-clean-trucks-battery-electric-truck-and-bus-energy-efficiency-paper.

———. 2018b. "Assessment of a Zero-Emission Vehicle Requirement for Light and Heavy-Duty Vehicle Fleets." August. https://www.arb.ca.gov/msprog/zev_fleet_workshop_presentation_083018.pdf.

CALSTART. 2016. "Commercial Electric Vehicle Working Group (CEVWG)." November. https://www.arb.ca.gov/msprog/bus/calstart_pres_te_wg.pdf.

ChargePoint. 2019. "Driver's Checklist: A Quick Guide to Fast Charging." Accessed May 2019. https://www.chargepoint.com/files/Quick_Guide_to_Fast_Charging.pdf.

CleanTechnica. 2018. "The Secret Life of an EV Battery." August. Accessed November 2019. https://cleantechnica.com/2018/08/26/the-secret-life-of-an-ev-battery/.

The Climate Group. 2019. "EV100." Accessed May 2019. https://www.theclimategroup.org/project/ev100.

ClipperCreek. 2018. "10 Tips to Extend the Life of Your EV Battery." March. Accessed November 2019. https://www.clippercreek.com/extend-life-ev-battery/.

Davis, S., and R. Boundy. 2019. "Transportation Energy Data Book: Edition 37.1." Oak Ridge National Laboratory. April. https://tedb.ornl.gov/wp-content/uploads/2019/04/2016_Vehicle_Technologies_Market_Report.pdf.

DHL. 2017. "Zero Emissions by 2050: DHL Announces Ambitious New Environmental Protection Target." March. http://www.delivered.dhl.com/en/articles/2017/05/zero-emissions-by-2050.html.

Edison Electric Institute. 2018. "Electric Vehicle Sales Forecast and the Charging Infrastructure Required Through 2030." Prepared by Adam Cooper (IEI) and Kellen Schefter (EEI). November.

Electrek. 2017. "Tesla Battery Expert Recommends Daily Charging Limit to Optimize Durability." September. Accessed November 2019. https://electrek.co/2017/09/01/tesla-battery-expert-recommends-daily-battery-pack-charging/.

Energy and Environmental Economics, Inc. 2014. "California Transportation Electrification Assessment: Phase 2." October. http://www.caletc.com/wp-content/uploads/2016/08/CalETC_TEA_Phase_2_Final_10-23-14.pdf.

The EV Project. 2015a. "What Were the Cost Drivers for Publicly Accessible Charging Installations?" Idaho National Laboratory. July. https://avt.inl.gov/sites/default/files/pdf/EVProj/WhatWereTheCostDriversForPubliclyAccessibleChargingInstallation.pdf.

———. 2015b. "What Were the Cost Drivers for DCFC Installations?" Idaho National Laboratory. July. https://avt.inl.gov/sites/default/files/pdf/EVProj/WhatWereTheCostDriversForDCFCinstallations.pdf.

Federal Highway Administration. 2016. "Highway Statistics 2016." Table VM-1. Accessed November 20, 2018. http://www.fhwa.dot.gov/policyinformation/statistics/2016/.

FedEx. 2018. "FedEx Acquires 1,000 Chanje Electric Vehicles." November. https://about.van.fedex.com/newsroom/fedex-acquires-1000-chanje-electric-vehicles/.

Gatti, D. 2018. "Principles for Utility Investment in Electric Vehicles." Union of Concerned Scientists. June. https://www.ucsusa.org/sites/default/files/images/2018/06/cv-ev-infrastructure.pdf.

Goldie-Scot, L. 2019. "A Behind the Scenes Take on Lithium-Ion Battery Prices." March. BloombergNEF. https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/.

Gordon, Deborah, Juliet Burdelski, and James S. Cannon. 2003. Greening Garbage Trucks: New Technologies for Cleaner Air. Inform, Inc.

Hinchliffe, E. 2018. "Ikea Sets Goal for Zero Emissions Delivery in 5 Cities by 2020." September. Fortune. http://fortune.com/2018/09/16/ikea-zero-emissions-delivery-2020/.

Hledik, R., and J. Weiss. 2019. "Increasing Electric Vehicle Fast Charging Deployment." Edison Electric Institute. January. http://files.brattle.com/files/15077_increasing_ev_fast_charging_deployment_-_final.pdf.

Houston, S. 2019. "Electric Utilities Can Accelerate Electric Truck and Bus Deployment." Union of Concerned Scientists. April. https://blog.ucsusa.org/samantha-houston/utilities-can-accelerate-electric-truck-and-bus-deployment.

ICF International and Energy and Environmental Economics, Inc. 2014. "California Transportation Electrification Assessment: Phase 1." September. http://docs.cpuc.ca.gov/PublishedDocs/SupDoc/A1701021/937/196609903.pdf.

InsideEVs. 2018. "Let's Look at Fast Charging Curves for Popular Electric Cars." August. Accessed May 2018. https://insideevs.com/news/338777/lets-look-at-fast-charging-curves-for-popular-electric-cars/.

Institute for Transportation and Development Policy. 2018. "China Tackles Climate Change with Electric Buses." September. https://www.itdp.org/2018/09/11/electric-buses-china/.

International Council on Clean Transportation. 2019a. "New Study Quantifies the Global Health Impacts of Vehicle Exhaust." February. https://www.theicct.org/news/health-impacts-transport-sector-pr-20190227.

———. 2019b. “Estimating Electric Vehicle Charging Infrastructure Costs Across Major U.S. Metropolitan Areas.” https://theicct.org/sites/default/files/publications/ICCT_EV_Charging_Cost_20190813.pdf.

International Energy Agency (IEA). 2017. “The Future of Trucks.” https://webstore.iea.org/the-future-of-trucks.

———. 2018. “Global EV Outlook 2018.” https://www.iea.org/gevo2018/.

Lee, H., and A. Clark. 2018. “Changing the Future: Challenges and Opportunities for Electric Vehicle Adoption.” Harvard Kennedy School of Government. September. https://projects.iq.harvard.edu/files/energyconsortium/files/rwp18-026_lee_1.pdf.

MJ Bradley. 2019. Electric Vehicle Market Status. May.

Morris, C. 2016. “WAVE Wireless Charging Helps Transit Agencies Save Money by Going Electric.” Charged Electric Vehicles Magazine. April. https://chargedevs.com/features/wave-wireless-charging-helps-transit-agencies-save-money-by-going-electric/.

Smart Electric Power Alliance (SEPA) 2019a. “A Comprehensive Guide to Electric Vehicle Managed Charging”. July.

———. 2019b. “Preparing for an Electric Vehicle Future: How Utilities Can Succeed”. October

National Renewable Energy Lab. 2017. “National Plug-In Electric Vehicle Infrastructure Analysis.” US Department of Energy. September.

New York State Energy Research and Development Authority. 2014. “New York City Green Loading Zones Study.” July. https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Transportation/New-York-City-Green-Loading-Zones-Study.pdf.

New York State Energy Research and Development Authority. 2019. “New York Truck – Voucher Incentive Program.” Accessed May 2019. https://truck-vip.ny.gov/.

North American Council for Freight Efficiency. 2019. “Medium-Duty Electric Trucks: Cost of Ownership.” Accessed May 2019. https://nacfe.org/future-technology/medium-duty-electric-trucks-cost-of-ownership/.

Office of the Governor of the State of Oregon. 2018. “Oregon Climate Agenda.” November 28. https://www.oregon.gov/gov/policy/Documents/Governor%20Kate%20Brown%20Climate%20Agenda.pdf.

Port of Rotterdam. 2019. “Zero-emission Port by 2050.” Accessed May 2019. https://www.portofrotterdam.com/en/news-and-press-releases/zero-emission-port-by-2050.

Reuters. 2019. “Global Last Mile Delivery Market 2019: By Market Insights, Types, Service, Segmentation Analysis, Vendor Landscape, End-User Industry, & Regional Outlook till 2023.” January. https://www.reuters.com/brandfeatures/venture-capital/article?id=76919.

SAE International. 2018. “SAE International Releases New Specification (SAE J3068) for Charging of Medium and HD Electric Vehicles.” April. https://www.sae.org/news/press-room/2018/04/sae-international-releases-new-specification-sae-j3068-for-charging-of-medium-and-heavy-duty-electric-vehicles.

Transport for London. 2019. “ULEZ: Where and When.” Accessed May 2019. https://tfl.gov.uk/modes/driving/ultra-low-emission-zone/ulez-where-and-when.

Transport Styrelsen. 2019. “Congestions taxes in Stockholm and Gothenburg.” Accessed May 2019. https://www.transportstyrelsen.se/en/road/Congestion-taxes-in-Stockholm-and-Goteborg/.

Union of Concerned Scientists. 2008. "How is Electricity Measured?" Updated October 22, 2013. Accessed November 2019. https://www.ucsusa.org/resources/how-electricity-measured.

US Energy Information Administration. 2019. "Annual Energy Outlook 2019, Transportation, Energy Use by Mode." https://www.eia.gov/outlooks/aeo/data/browser/#/?id=7-AEO2019&cases=ref2019&sourcekey=0.

US Environmental Protection Agency. 2009. "California Greenhouse Gas Waiver Request." July. https://www.epa.gov/regulations-emissions-vehicles-and-engines/california-greenhouse-gas-waiver-request.

US Environmental Protection Agency. 2017. "Fast Facts on Transportation Greenhouse Gas Emissions." June. https://www.epa.gov/greenvehicles/fast-facts-transportation-greenhouse-gas-emissions.

US Office of Energy Efficiency and Renewable Energy. 2019. "Wireless Charging for Electric Vehicles." Accessed June 2019. https://www.energy.gov/eere/videos/wireless-charging-electric-vehicles.

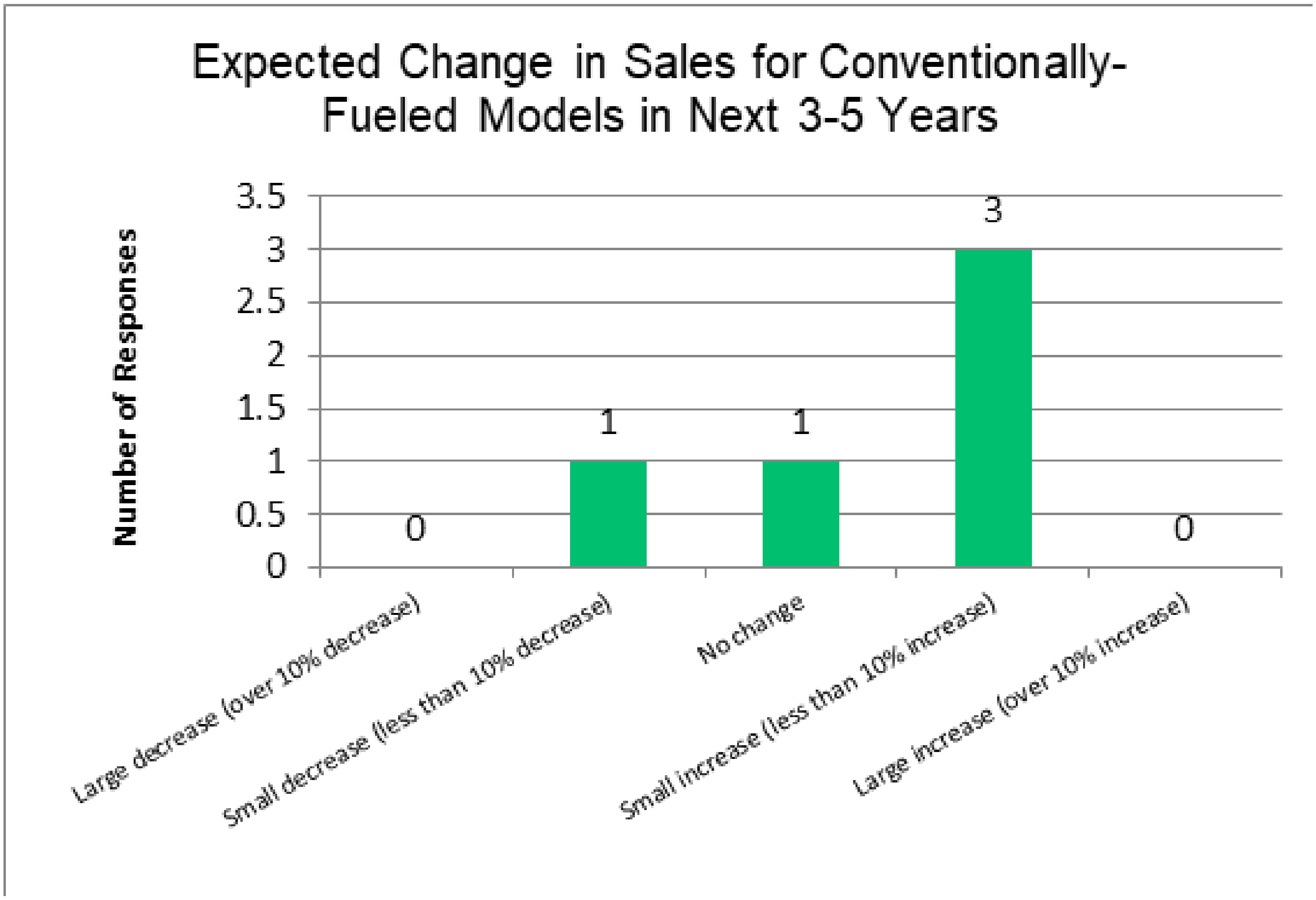
Washington State Department of Transportation. 2020. "Innovative Partnerships – Electric Vehicle Charging Infrastructure." https://www.wsdot.wa.gov/business/innovative-partnerships/electric-vehicle-charging-infrastructure.

This page is intentionally left blank.

Appendix A. Stakeholder Surveys Supporting Documentation

As an aside, one respondent indicated that they assume Class 9 is large off-highway vehicles, although this designation does not exist.

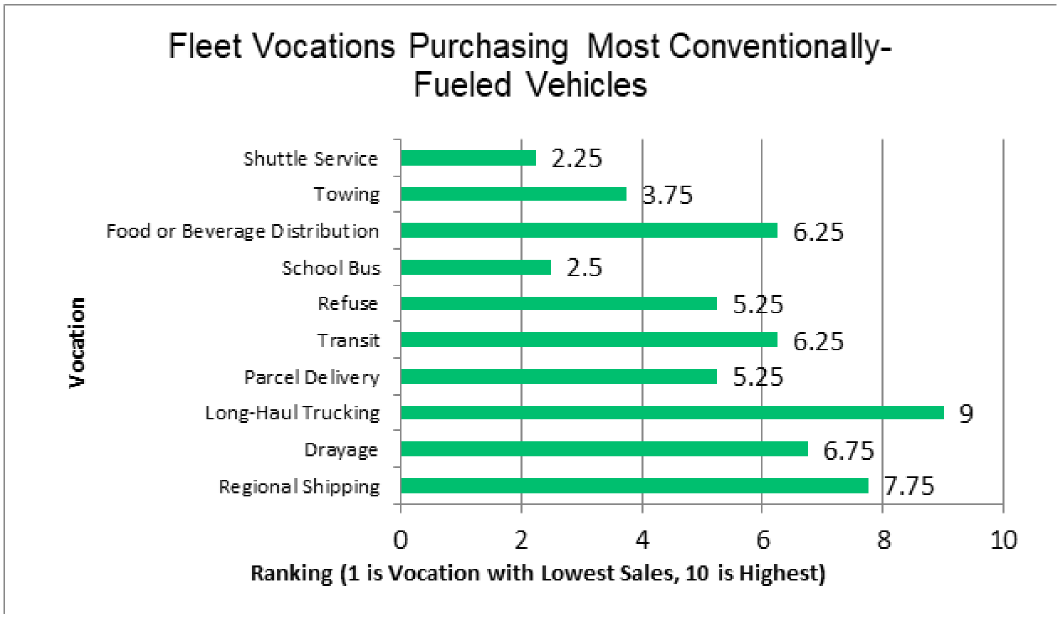
Sales for conventionally fueled trucks have increased over the last three years for four of the respondents, and they have stayed the same for one respondent. When asked to elaborate on how much conventionally fueled model sales have changed in this time frame, respondents generally stated a range from 30 to 50 percent. Additionally, most respondents expect sales for conventionally fueled models to increase slightly (less than 10 percent) within the next three to five years, while one respondent expects a small decrease, and another expects no change (Figure A-2).



Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Figure A-2: Expected Change in Sales for Conventionally Fueled Vehicles

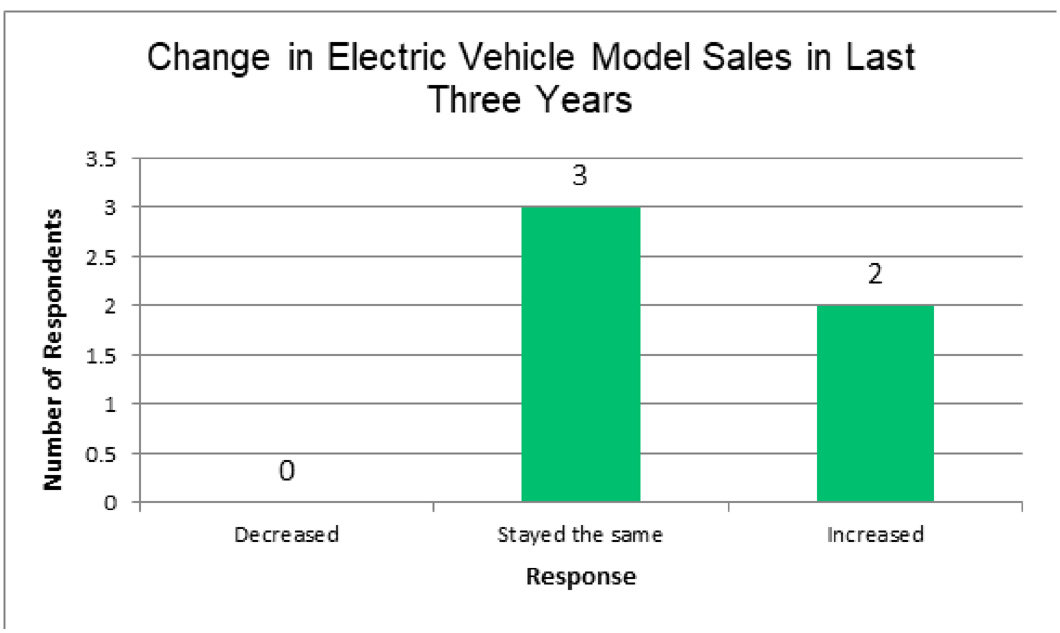
The vocations with the most purchases are shown in Figure A-3. According to respondents, the top five fleet vocations in terms of sales are long-haul trucking, regional shipping, drayage, food or beverage distribution, and transit.



Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Figure A-3: Sales by Vocation for Conventionally Fueled Vehicles

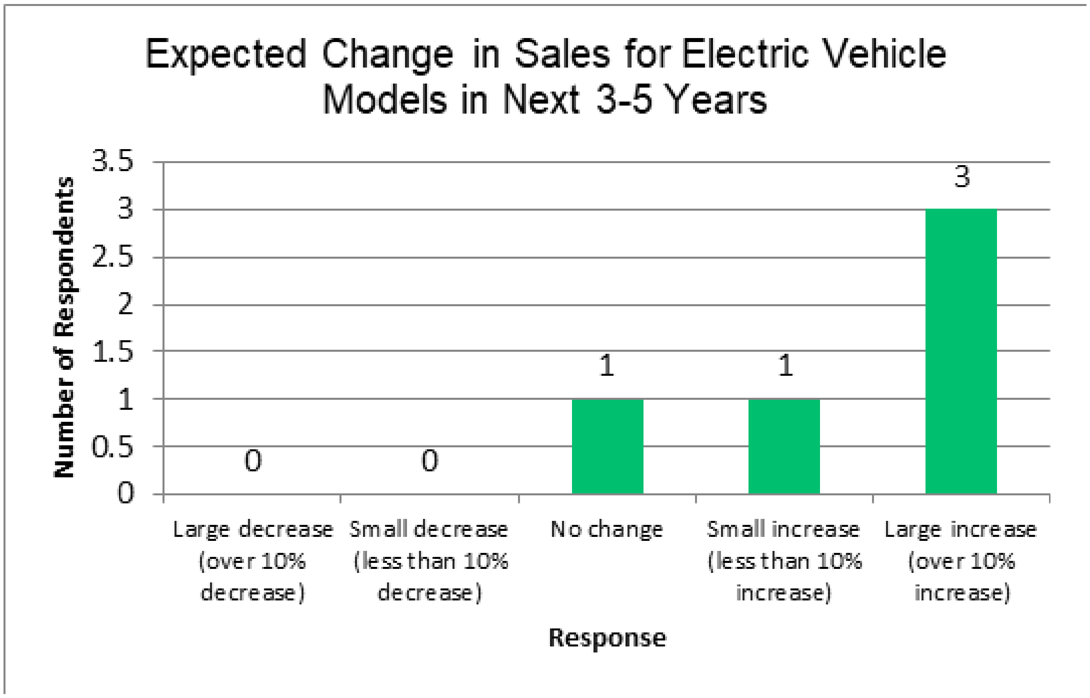
Regarding EVs, most respondents stated that their EV sales have stayed the same within the last 3 years, with two stating that sales have increased (Figure A-4). Those that stated that their sales have increased explained that increases have been modest. One explained that sales went from 0 in 2016 to 100 (projected total) by the end of 2019.



Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

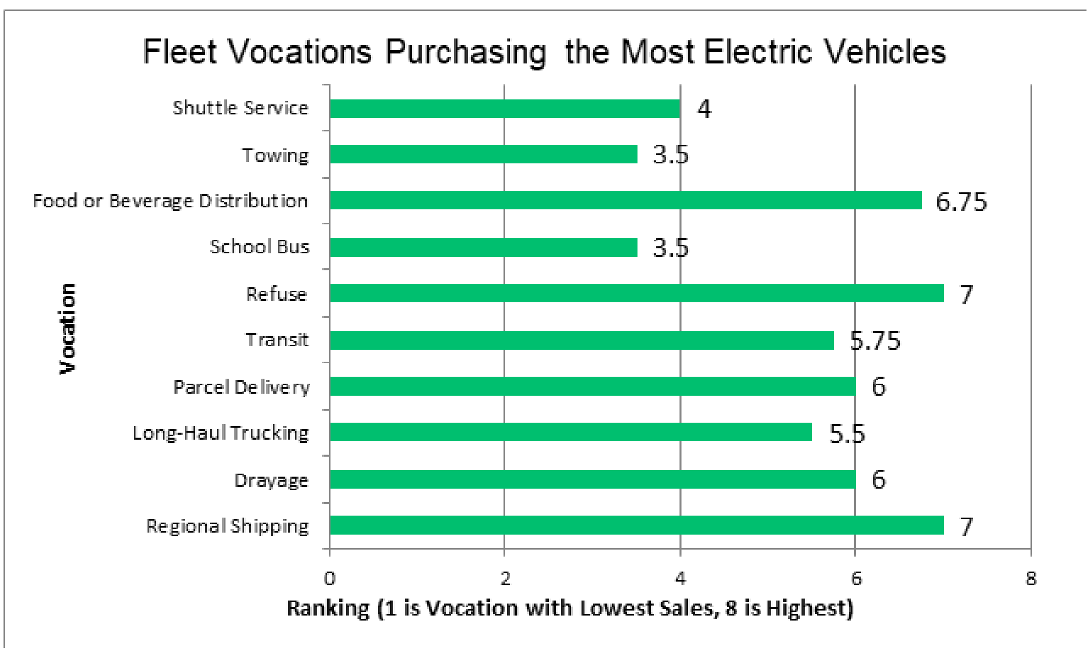
Figure A-4: Sales Change for EVs

Most OEMs stated that they expect a large increase in sales in the next 3 to 5 years. However, because most OEMs report not yet selling any EVs, any increase is a large increase percentage-wise (Figure A-5). Predicted sales by vocation are shown in Figure A-6.



Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

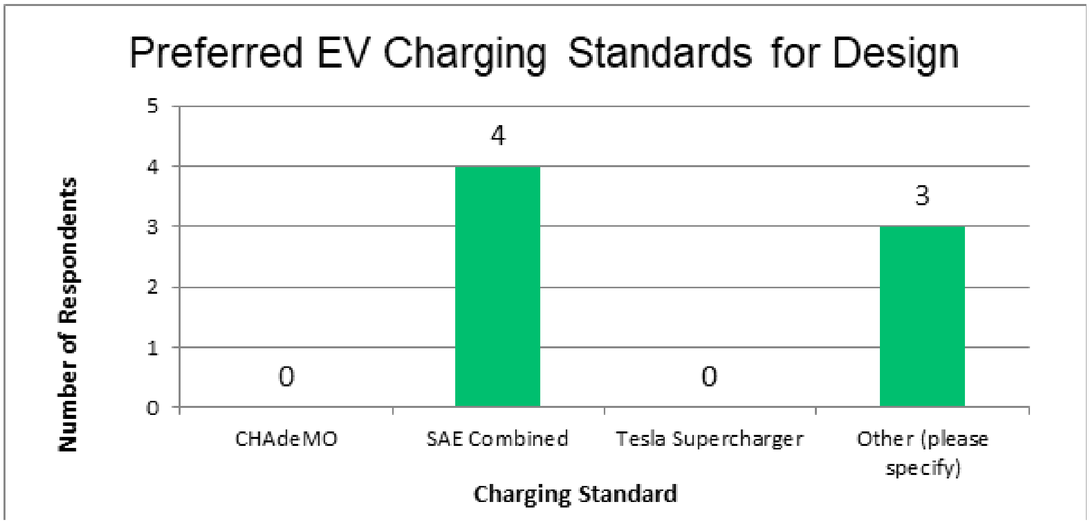
Figure A-5: Expected Percentage Increase in EV Sales



Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Figure A-6: Predicted Sales of EVs, by Vocation

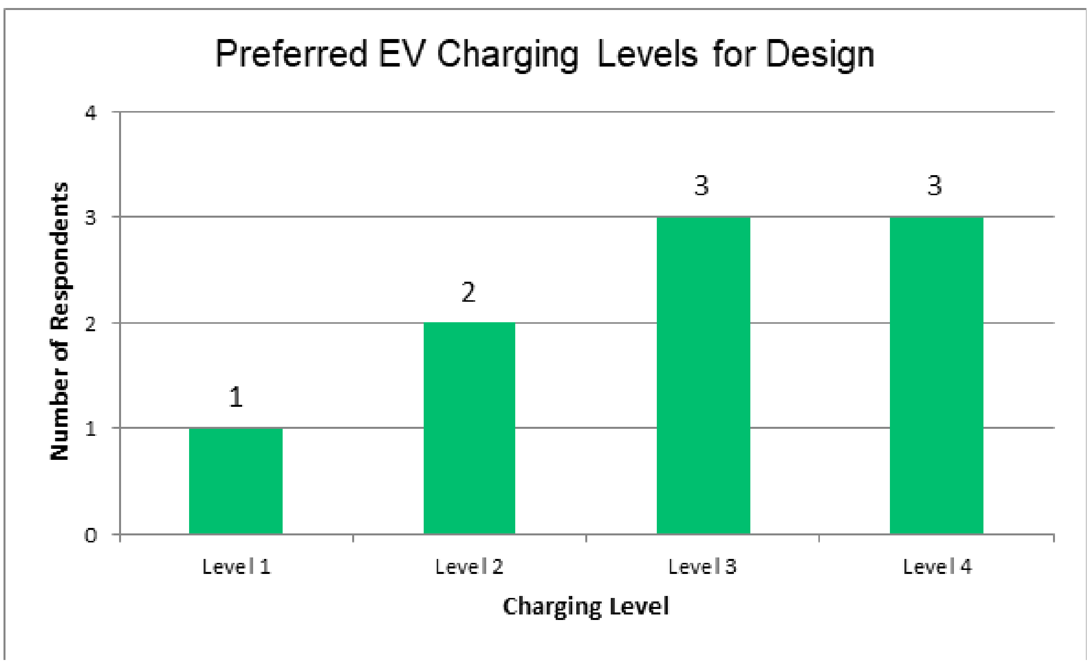
A few respondents explained that they have announced plans to develop EVs, but those vehicles are not yet commercially available. Two OEMs plan to produce and sell an electric refuse truck. One of those two plans to manufacture an electric regional haul truck, and the other of those two plans to sell a Class 8 electric truck. A third respondent plans to create and sell an MD electric truck, an HD electric truck, and an HD fuel cell electric truck. When manufacturing electric trucks, respondents prefer to design for the SAE CCS, but also design for CCS Type 2 as well as wireless charging (Figure A-7).



Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Figure A-7: Preferred Charging Standards for OEMs

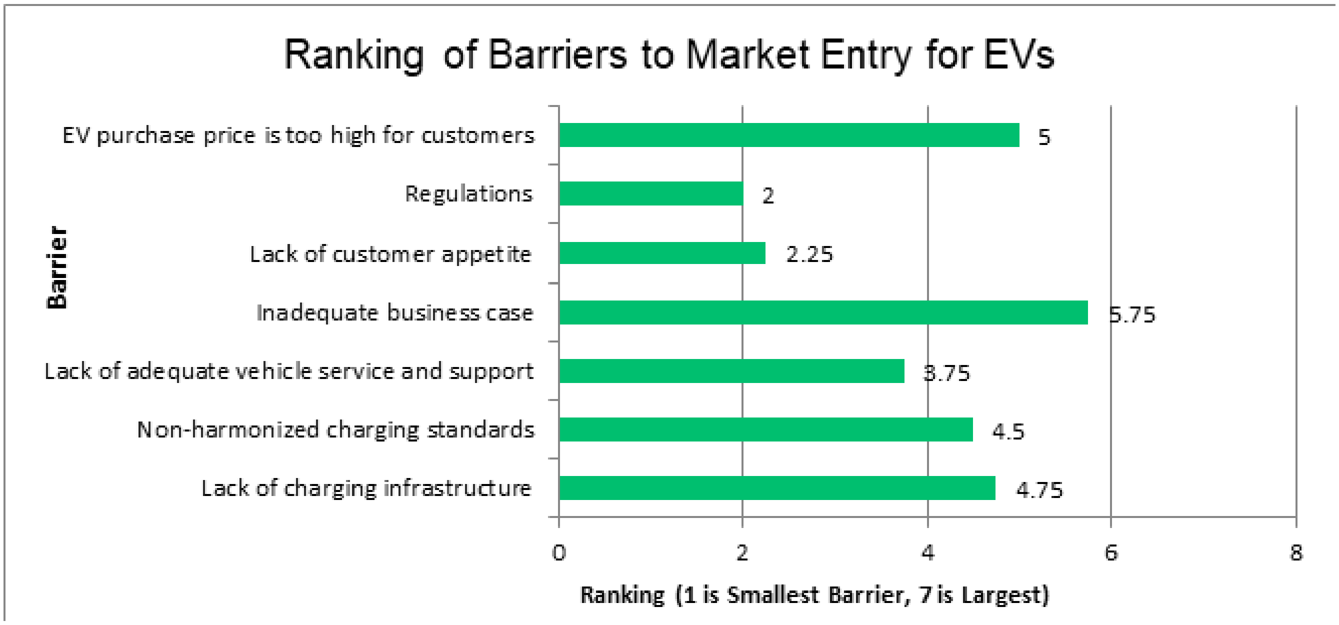
Additionally, most respondents design trucks for Level 3 and higher charging, while two respondents design for Level 2 charging, and one respondent designs vehicles compatible with Level 1 charging (Figure A-8).



Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Figure A-8: Charging Levels OEMs Use in Designing Vehicles

The largest barriers to entry experienced by electric trucks were cited as inadequate business case, EV purchase price is too high for customers, and lack of charging infrastructure. Figure A-9 shows how all pre-provided potential barriers ranked among OEM respondents.



Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Figure A-9: Ranking of Barriers to Entry for EVs

In addition to the barriers shown in the figure above, OEMs stated that the following are also barriers: lack of vehicle range, lack of battery storage, vehicle weight (loss of payload), insufficient supplier readiness, gaps in the supply chain between raw materials and tier one suppliers, and currently unknown demand for MD/HD EVs.

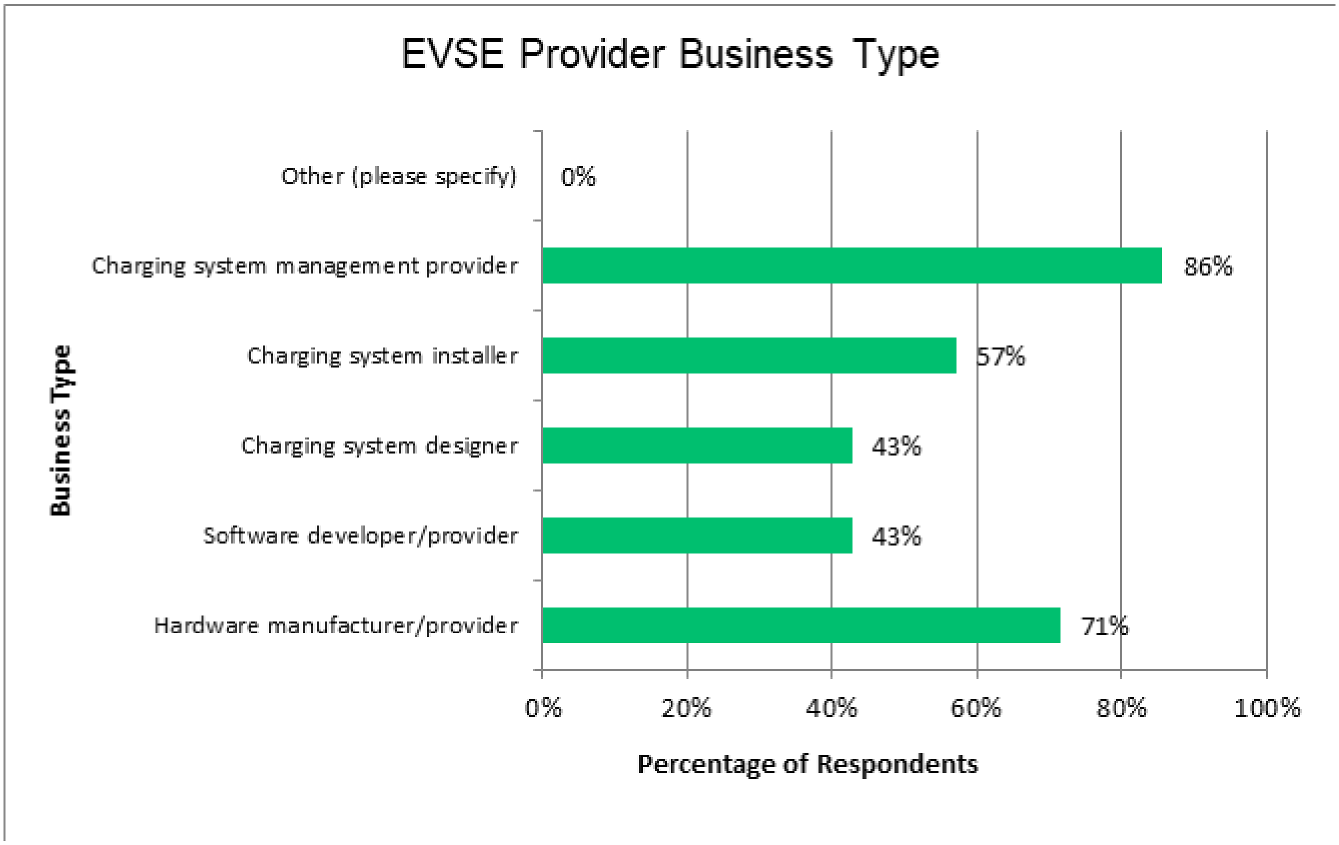
Finally, the researchers asked OEMs what barriers they saw in terms of developing charging infrastructure for MD/HD EVs. Respondents gave a number of answers, listed below:

- Oregon and Washington do not seem to be investing in charging infrastructure.
- The power grid is not yet ready for added power demand to supply end users.
- Power is currently very expensive and will need to be heavily subsidized.
- The cost and weigh of batteries are barriers.
- Standardized infrastructure is needed for fast charging at MW and above rates.

Electric Vehicle Supply Equipment Provider Survey

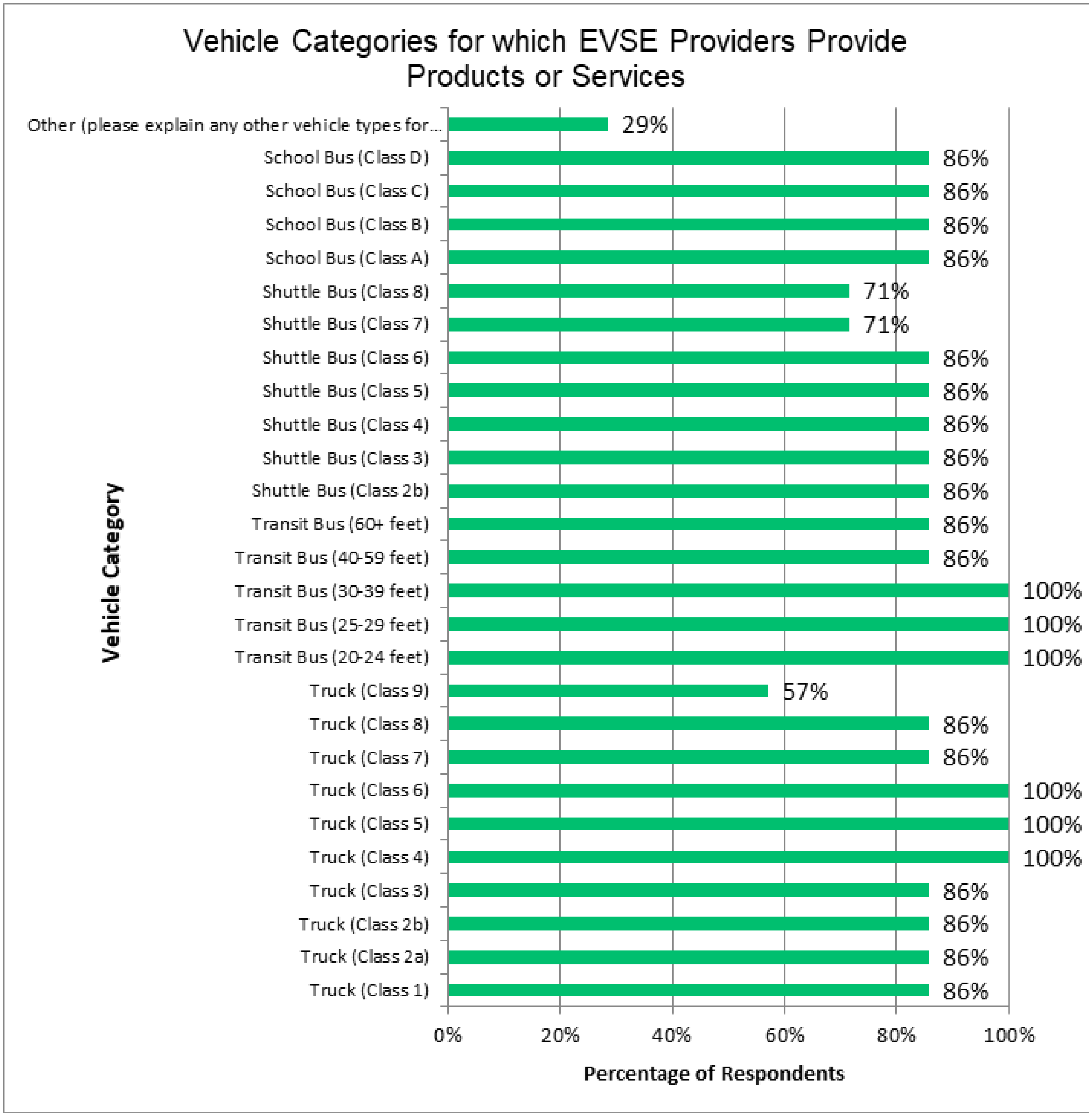
EVSE providers were surveyed to gain their perspectives on the barriers and opportunities related to implementing electric charging sites for MD/HD trucks.

EVSE respondents serve the following functions (Figure A-10) for the following vehicle types (Figure A-11).



Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

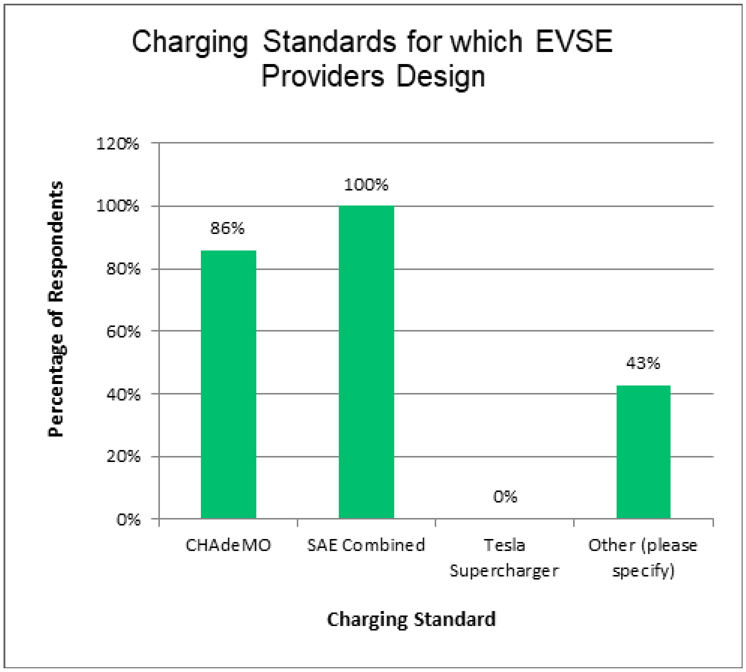
Figure A-10: EVSE Providers, by Type



Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

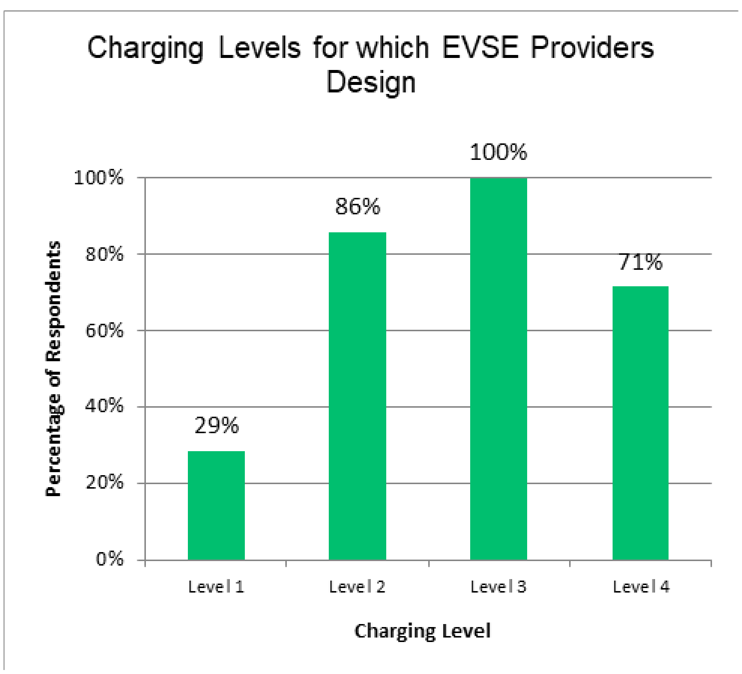
Figure A-11: Vehicle Types Supplied by EVSE Providers

All EVSE respondents design for the SAE CCS, while roughly 86 percent design for CHAdeMO, and about 43 percent design for other standards including 3-phase Level 2, Tesla Level 2, and J1772 (Figure A-12 and Figure A-13).



Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

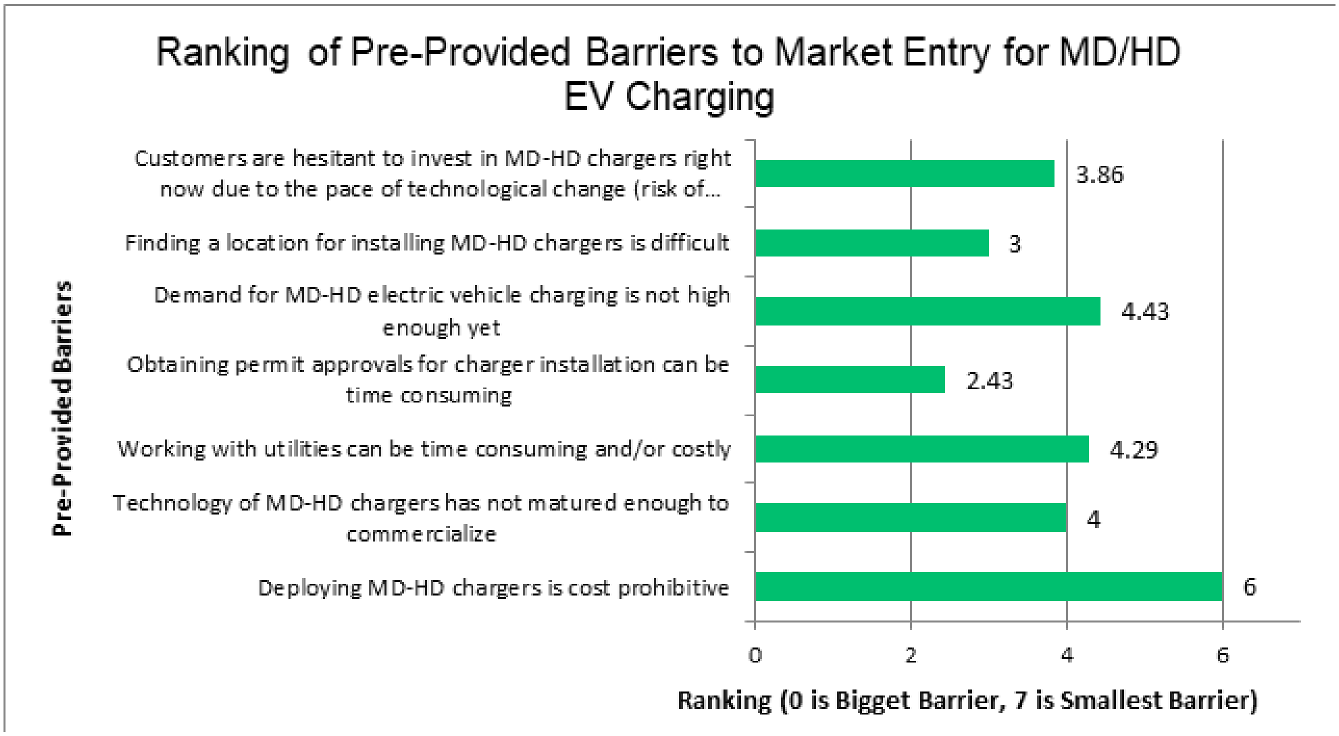
Figure A-12: Charging Standards Supplied by EVSE Providers



Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Figure A-13: Charging Levels Designed for by EVSE Providers

When asked to rank a pre-provided list of barriers to market entry for MD/HD EV charging solutions, the respondents ranked the barriers as shown in Figure A-14.



Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Figure A-14: Market Barriers for EVSE Providers

When asked to elaborate on barriers, each respondent gave a unique answer, including:

- Time to complete an infrastructure project can take up to 2 years, serving as a barrier in quick deployment.
- Use case is not clear enough.
- Total deployment costs, combined with the true costs of ongoing operations and maintenance, can be prohibitive.
- Enough aggregate demand for public MD/HD EV charging sites does not yet exist.
- Uncertainty exists regarding the charging standards required for sites.
- Large-scale deployment of HD EV charging is not yet well understood from a cost, technology, and grid services perspective.
- Emergency conditions are not considered.

When asked to provide any recommendations for policies or regulations that might help advance MD/HD EV charging site development, respondents gave multiple responses. These responses are listed below:

- Policy programs designed to alleviate total cost of ownership issues would be beneficial.
- Demand charges are cost-prohibitive and should be addressed through policy approaches.
- Incentives to subsidize early adopters would be beneficial.
- Clean fuel goals incentivizing fleets to adopt EVs have been a productive approach so far.
- At least 5 years of operational cost support would be required to make up for operational start-up losses while the public MD/HD EV charging market develops.
- A global standard for common charging connectors and protocols would keep costs down and optimize maturation of the technology.

When asked to elaborate on best practices as related to MD/HD EV charging infrastructure deployment, respondents listed the following items:

- Regarding land acquisition and site planning: Work with each fleet owner and determine the best solution between behind-the-fence depot charging versus in-route charging, and ensure easy access to 480 VAC 3-phase power sources.
- Regarding product design and engineering: Hire/outsource an engineering firm, establish 3 phase Type 2 CCS for large vehicles, adopt a common charging standard, and comply with National Electric Code and Underwriters Laboratory and relevant safety standards.
- Regarding collaboration with electric utilities: Start early and work with electric utilities to determine incentives for vehicles and infrastructure.
- Regarding collaboration with fleets: Understand the battery design and power requirements.
- Regarding demand management and load balancing: Work with network management software companies, consider this approach in sites with multiple chargers, require adherence to open standards (openADR), and incorporate energy storage.

When asked if they employ any demand management or load balancing software in their EV charging solutions, all respondents said “yes.” Further, respondents elaborated on challenges that exist in deploying and operating demand management or load balancing software, including the following:

- Load balancing in DC fast charging sites adds significant costs and can reduce reliability.
- The number of vehicles charging at a charger is limited to five. Scaling up these numbers will make demand management and load balancing more beneficial.
- Ensuring site design and wiring is conducted to the maximum potential is beneficial.
- Significant time and cost is involved in integrating the technology.
- Not all charging equipment provides the same software access (application program interface, or API) to control charging speeds.

Recipients were also asked to elaborate on any unique challenges presented by MD/HD EV charging as compared with LD EV charging. One respondent stated that DC fast charging ports for MD/HD vehicles will time out if charging does not start within a matter of minutes, and it currently is not possible to remotely start a charge session. Another respondent highlighted the importance of coordinating with an electric utility company as power requirements increase, adding complexity. And, another respondent stated that MD/HD EV charging likely requires energy storage and an emergency back-up charging plan for commercial vehicles.

Finally, recipients were asked to explain any new EV charging product or service trends they see as significant in the next 5 years. Their responses are listed below:

- Bigger batteries will require high kW needs, and there is a need for wireless charging.
- EV charging could be provided as a service rather than paying up front for the entire cost of installation and hardware.
- Wireless charging provided for transit buses, DC fast charging provided for commercial trucks, and 3-phase AC charging provided for parcel delivery fleets.

Appendix B. Existing Conventional Truck Market Supporting Documentation

The MD/HD truck market was divided into segments and organized by use case with expected vocational categorizes by vehicle class and emphasis on Class 3 through Class 8.

The average VMT annually and daily across the US is shown by vehicle type in Table B-1.

Table B-1: Average Vehicle Miles Traveled, by Vehicle Type

Vehicle Type	Average Annual VMT	Source	Average Daily VMT
Class 8 truck	63,428	A	203
Transit bus	34,012	B	109
Refuse truck	25,000	C	80
Paratransit shuttle	22,679	B	73
Delivery truck	12,958	A	42
School bus	12,000	D	38
Light truck/ van	11,991	A	38
Light-duty vehicle	11,507	A	37
Car	11,370	A	36
Motorcycle	2,356	A	8

Sources:

1. *Federal Highway Administration (2016), calculations based on statistics from*
2. *American Public Transit Association (2017),*
3. *Gordon et al. (2003)*
4. *American School Bus Council (2018)*

Notes: Light-duty vehicles are a sales-weighted combination of cars, wagons, vans, SUVs, and pickups. Vehicles with short wheelbases (<121 inches) are generalized as cars, and vehicles with long wheelbases are generalized as light trucks. Delivery trucks are single-unit trucks with two axles and six or more tires. Class 8 trucks are combined tractor/trailer trucks, also known as long-haul trucks. Worksheet is available at www.afdc.energy.gov/data/. Last updated 11/28/2018.

The US annual and daily VMT by vehicle segment and class is shown in Table B-2 and Table B-3.

Table B-2: US Average Annual VMT per Segment

US Average Annual VMT per Segement						
Segment	Class					
	3	4	5	6	7	8
Construction Truck	15,000	10,700	15,000	12,000	12,000	12,000
Regional Truck	9,100	15,000	23,000	23,000	23,000	65,000
Motor Home	10,000	20,000	35,000	35,000	35,000	35,000
Pickup	24,000					
Long Haul Truck					170,000	170,000
Drayage					10,000	10,000
Bus		12,600	15,000	35,000	30,000	
Step Van	16,500	16,500	16,500	16,500		
Refuse				23,400	23,400	23,400
School Bus				15,000	15,000	15,000
VAN CARGO	27,000					
City Bus				35,000	35,000	35,000
Shuttle Bus	15,000	15,000	30,000	35,000		
Coach						35,000
Fire Truck						6,600
SUV	13,000					
Terminal Tractor						35,000
Emergency Truck			75,800	75,800		

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Table B-3: US Average Daily VMT per Segment

US Average Annual VMT per Segement						
Segment	Class					
	3	4	5	6	7	8
Construction Truck	48	34	48	38	38	38
Regional Truck	29	48	74	74	74	208
Motor Home	32	64	112	112	112	112
Pickup	77					
Long Haul Truck					545	545
Drayage					32	32
Bus		40	48	112	96	
Step Van	53	53	53	53		
Refuse				75	75	75
School Bus				48	48	48
VAN CARGO	87					
City Bus				112	112	112
Shuttle Bus	48	48	96	112		
Coach						112
Fire Truck						21
SUV	42					
Terminal Tractor						112
Emergency Truck			243	243		

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

The estimated number of vehicles within each segment for California, Oregon, and Washington are shown in Table B-4 through Table B-6, respectively.

Table B-4: California Vehicles, by Segment

CALIFORNIA							
Segment	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Total Number of Vehicles
Construction Truck	37,553	51,769	64,834	54,033	55,965	43,615	**307,769**
Regional Truck	54,415	31,016	18,069	59,650	29,266	82,033	**274,449**
Motor Home	60,612	40,007	21,115	32,940	18,089	8,750	**181,513**
Pickup	174,365			9			**174,374**
Long Haul Truck					4,980	168,395	**173,375**
Drayage					170		**170**
Bus		39,402	423	580	472	272	**41,149**
Step Van	304	6,426	2,314	2,830	79		**11,953**
Refuse				35	502	11,081	**11,618**
School Bus			73	1,515	5,485	2,433	**9,506**
VAN CARGO	14,364						**14,364**
City Bus				127	191	1,852	**2,170**
Shuttle Bus	2,007	2,173	621	293	1		**5,095**
Coach						4,280	**4,280**
Fire Truck					398	2,332	**2,730**
SUV	1,403						**1,403**
Terminal Tractor					1	880	**881**
Emergency Truck			14	36			**50**
Heavy Haul Truck						21	**21**
Total Number of Vehicles	**345,023**	**170,793**	**107,463**	**152,048**	**115,599**	**325,944**	**1,216,870**

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Table B-5: Oregon Vehicles, by Segment

OREGON							
Segment	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Total Number of Vehicles
Construction Truck	2,419	6,632	9,490	6,851	6,121	7,936	**39,449**
Regional Truck	7,697	3,259	1,926	5,560	2,106	6,853	**27,401**
Motor Home	9,594	5,779	4,447	7,309	4,522	2,528	**34,179**
Pickup	58,804			1			**58,805**
Long Haul Truck					202	17,228	**17,430**
Drayage					7		**7**
Bus		8,162	40	101	51	21	**8,375**
Step Van	29	811	308	286	4		**1,438**
Refuse				7	50	746	**803**
School Bus			14	237	1,785	218	**2,254**
VAN CARGO	3,636						**3,636**
City Bus				12	10	149	**171**
Shuttle Bus	139	381	111	20			**651**
Coach						344	**344**
Fire Truck					24	249	**273**
SUV	97						**97**
Terminal Tractor						87	**87**
Emergency Truck			9	22			**31**
Heavy Haul Truck						2	**2**
Total Number of Vehicles	**82,415**	**25,024**	**16,345**	**20,406**	**14,882**	**36,361**	**195,433**

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Table B-6: Washington Vehicles, by Segment

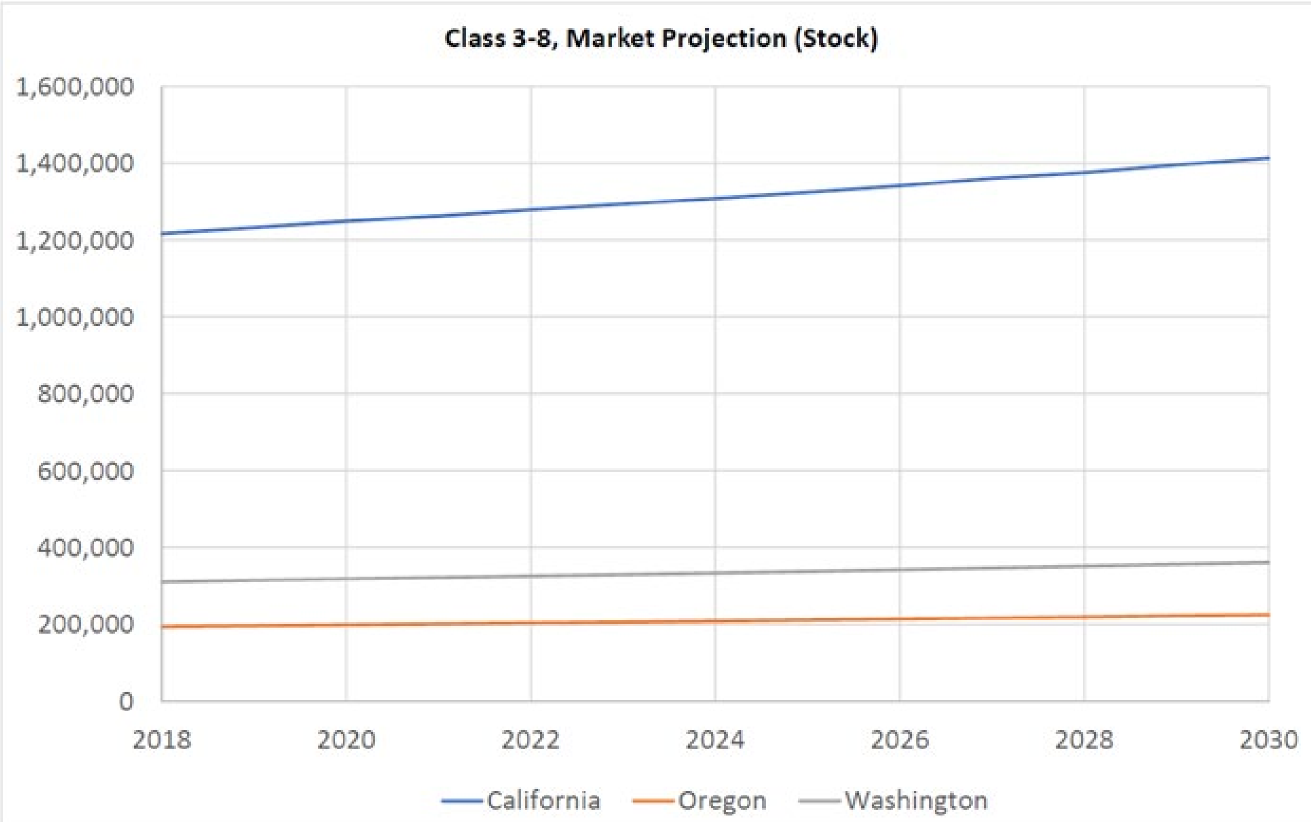
WASHINGTON							
Segment	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Total Number of Vehicles
Construction Truck	5,853	11,953	14,425	11,115	9,928	15,948	**69,222**
Regional Truck	15,439	6,366	3,127	9,440	3,825	10,799	**48,996**
Motor Home	16,327	9,806	6,847	10,565	5,773	2,537	**51,855**
Pickup	79,134			5			**79,139**
Long Haul Truck					185	31,719	**31,904**
Drayage					10		**10**
Bus		13,699	88	158	68	98	**14,111**
Step Van	86	1,274	532	652	6		**2,550**
Refuse				2	61	1,668	**1,731**
School Bus			69	547	3,754	996	**5,366**
VAN CARGO	4,761						**4,761**
City Bus				9	4	541	**554**
Shuttle Bus	212	866	185	32	1		**1,296**
Coach						680	**680**
Fire Truck					43	609	**652**
SUV	174						**174**
Terminal Tractor						155	**155**
Emergency Truck			11	48			**59**
Heavy Haul Truck						4	**4**
Total Number of Vehicles	**121,986**	**43,964**	**25,284**	**32,573**	**23,658**	**65,754**	**313,219**

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

The total projected stock of MD/HD vehicles through 2030 is shown in Table B-7 and Figure B-1.

Table B-7: West Coast Stock Projection for Medium- and Heavy-duty Trucks

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic



Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Figure B-1: West Coast MD/HD Vehicles in Stock Projection

Further analysis provides the most common number of vehicles by segment classes within each of the three states (Table B-8 through Table B-11).

Table B-8: Most Common Number of Vehicles in California, by Segment Classes 3 to 5

CALIFORNIA		
Segment Class 3	Number of Vehicles	%
Pickup	174,365	51%
Motor Home	60,612	18%
Regional Truck	54,415	16%
Construction Truck	37,553	11%
VAN CARGO	14,364	4%
Shuttle Bus	2,007	1%
SUV	1,403	0%
Step Van	304	0%
Total Number of Vehicles	345,023	100%

CALIFORNIA		
Segment Class 3	Make and Model (Most Common Vehicles)	Vehicles
Construction Truck	CHEVROLET C3500	26,928
	GMC C3500	8,966
Motor Home	FORD E350	46,353
Pickup	FORD F350	102,597
Regional Truck	CHEVROLET G3500	11,397
	ISUZU NPR	11,740
	FORD E350-SUPER DUTY	10,162
SUV	HUMMER HMCS	713
Shuttle Bus	FORD E450-SUPER DUTY	1,775
Step Van	WORKHORSE CUSTOM CHASSIS P42	98
VAN CARGO	MERCEDES-BENZ SPRINTER 3500 170 WB	9,091
	FORD T-350 HD	2,035
	DODGE 3500 170 WB	1,272
	Total Number of Most Common Models	233,127

CALIFORNIA		
Segment Class 4	Number of Vehicles	%
Construction Truck	51,769	30%
Motor Home	40,007	23%
Bus	39,402	23%
Regional Truck	31,016	18%
Step Van	6,426	4%
Shuttle Bus	2,173	1%
Total Number of Vehicles	170,793	100%

CALIFORNIA		
Segment Class 4	Make and Model	Vehicles
Bus	FORD E450-SUPER DUTY	39,401
Construction Truck	FORD F450	20,813
	FORD F-SUPER DUTY	16,515
Motor Home	FORD F53	1,385
Regional Truck	ISUZU NPR HD	14,914
Shuttle Bus	CHEVROLET G4500	2,136
Step Van	FREIGHTLINER MT45	946
	Total Number of Most Common Models	96,110

CALIFORNIA		
Segment Class 5	Number of Vehicles	%
Construction Truck	64,834	0%
Motor Home	21,115	0%
Regional Truck	18,069	0%
Step Van	2,314	0%
Shuttle Bus	621	0%
Bus	423	0%
School Bus	73	0%
Emergency Truck	14	0%
Total Number of Vehicles	107,463	0%

CALIFORNIA		
Segment Class 5	Make and Model	Vehicles
Bus	IC CORPORATION AC COMM BUS	51
Construction Truck	FORD F550	38,060
	FORD F450	9,443
Emergency Truck	GMC C4V042	14
Motor Home	FORD F-SUPER DUTY	9,198
Regional Truck	ISUZU NRR	3,878
School Bus	IC CORPORATION BE SCHOOL BUS	34
Shuttle Bus	CHEVROLET C5V042	82
Step Van	FREIGHTLINER MT45	947
	Total Number of Most Common Models	61,707

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Table B-9: Most Common Vehicles in California, by Segment Classes 6 to 8

CALIFORNIA		
Segment Class 6	Number of Vehicles	%
Regional Truck	59,650	39%
Construction Truck	54,033	36%
Motor Home	32,940	22%
Step Van	2,830	2%
School Bus	1,515	1%
Bus	580	0%
Shuttle Bus	293	0%
City Bus	127	0%
Emergency Truck	36	0%
Refuse	35	0%
PickUp	9	0%
Total Number of Vehicles	152,048	100%

CALIFORNIA		
Segment Class 6	Make and Model	Vehicles
Bus	FREIGHTLINER MB LINE	189
City Bus	EL DORADO ESCORT RE	85
Construction Truck	FORD F650	10,023
	HINO 258/268	6,191
Emergency Truck	INTERNATIONAL 4400 LP	36
Motor Home	FORD F550	12,190
	WORKHORSE CUSTOM CHASSIS W22	8,311
PickUp	FREIGHTLINER SPORT CHASSIS	6
Refuse	CRANE CARRIER CENTURION	7
Regional Truck	INTERNATIONAL 4300	16,378
	FREIGHTLINER M2 106	10,553
School Bus	IC CORPORATION CE SCHOOL BUS	275
Shuttle Bus	CHEVROLET C5V042	261
Step Van	FREIGHTLINER MT55	1,108
	Total Number of Most Common Models	65,613

CALIFORNIA		
Segment Class 7	Number of Vehicles	%
Construction Truck	55,965	48%
Regional Truck	29,266	25%
Motor Home	18,089	16%
School Bus	5,485	5%
Long Haul Truck	4,980	4%
Refuse	502	0%
Bus	472	0%
Fire Truck	398	0%
City Bus	191	0%
DRAYAGE	170	0%
Step Van	79	0%
Terminal Tractor	1	0%
Shuttle Bus	1	0%
Total Number of Vehicles	115,599	100%

CALIFORNIA		
Segment Class 7	Make and Model	Vehicles
Bus	IC CORPORATION HC INTEGRATED COMMERCIAL BUS	65
	IC CORPORATION CE COMMERCIAL	34
City Bus	EL DORADO LOW FLOOR	155
Construction Truck	INTERNATIONAL 4900	5,756
	FREIGHTLINER M2 106	5,740
Fire Truck	PIERCE MFG. INC. ARROW XT	45
Long Haul Truck	FREIGHTLINER CASCADIA 125	900
Motor Home	FREIGHTLINER RAISED RAIL	1,815
Refuse	AUTOCAR LLC XPERT	42
Regional Truck	INTERNATIONAL 4300	3,246
	HINO HINO 338	1,487
School Bus	IC CORPORATION CE SCHOOL BUS	269
Shuttle Bus	GMC C5V042	1
Step Van	FREIGHTLINER MT55	37
Drayage	OTTAWA YT30	148
	Total Number of Most Common Models	19,592

CALIFORNIA		
Segment Class 8	Number of Vehicles	%
Long Haul Truck	168,395	52%
Regional Truck	82,033	25%
Construction Truck	43,615	13%
Refuse	11,081	3%
Motor Home	8,750	3%
coach	4,280	1%
School BUS	2,433	1%
Fire Truck	2,332	1%
City Bus	1,852	1%
Terminal Tractor	880	0%
Bus	272	0%
Heavy Haul Truck	21	0%
Total Number of Vehicles	325,944	100%

CALIFORNIA		
Segment Class 8	Make and Model	Vehicles
Bus	IC CORPORATION FE COMMERCIAL	1
City Bus	GILLIG LOW FLOOR	286
Construction Truck	KENWORTH T880	1,549
	PETERBILT 357	3,101
Fire Truck	KOVATCH FIRETRUCK	244
Heavy Haul Truck	CRANE CARRIER IRL	12
Long Haul Truck	FREIGHTLINER CASCADIA 125	32,373
Motor Home	FREIGHTLINER CASCADIA 126	2,515
Refuse	PETERBILT 320	2,113
Regional Truck	FREIGHTLINER M2 106	2,294
School BUS	THOMAS SAF-T-LINER HDX	1,033
Terminal Tractor	KALMAR OTTAWA 4 X 2	251
Coach	PREVOST 45 FOOT	576
	Total Number of Most Common Models	46,348

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Table B-10: Most Common Vehicles in Oregon, by Segment Class

OREGON		
Segment Class 3	Number of Vehicles	%
Pickup	58,804	71%
Motor Home	9,594	12%
Regional Truck	7,697	9%
VAN CARGO	3,636	4%
Construction Truck	2,419	3%
Shuttle Bus	139	0%
SUV	97	0%
Step Van	29	0%
Total Number of Vehicles	82,415	100%

OREGON		
Segment Class 4	Number of Vehicles	%
Bus	8,162	33%
Construction Truck	6,632	27%
Motor Home	5,779	23%
Regional Truck	3,259	13%
Step Van	811	3%
Shuttle Bus	381	2%
Total Number of Vehicles	25,024	100%

OREGON		
Segment Class 5	Number of Vehicles	%
Construction Truck	9,490	58%
Motor Home	4,447	27%
Regional Truck	1,926	12%
Step Van	308	2%
Shuttle Bus	111	1%
Bus	40	0%
School Bus	14	0%
Emergency Truck	9	0%
Total Number of Vehicles	16,345	100%

OREGON		
Segment Class 6	Number of Vehicles	%
Motor Home	7,309	36%
Construction Truck	6,851	34%
Regional Truck	5,560	27%
Step Van	286	1%
School Bus	237	1%
Bus	101	0%
Emergency Truck	22	0%
Shuttle Bus	20	0%
City Bus	12	0%
Refuse	7	0%
PickUp	1	0%
Total Number of Vehicles	20,406	100%

OREGON		
Segment Class 7	Number of Vehicles	%
Construction Truck	6,121	41%
Motor Home	4,522	30%
Regional Truck	2,106	14%
School Bus	1,785	12%
Long Haul Truck	202	1%
Bus	51	0%
Refuse	50	0%
Fire Truck	24	0%
City Bus	10	0%
DRAYAGE	7	0%
Step Van	4	0%
Total Number of Vehicles	14,882	100%

OREGON		
Segment Class 8	Number of Vehicles	%
Long Haul Truck	17,228	47%
Construction Truck	7,936	22%
Regional Truck	6,853	19%
Motor Home	2,528	7%
Refuse	746	2%
coach	344	1%
Fire Truck	249	1%
School BUS	218	1%
City Bus	149	0%
Terminal Tractor	87	0%
Bus	21	0%
Heavy Haul Truck	2	0%
Total Number of Vehicles	36,361	100%

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Table B-11: Most Common Vehicles in Washington, by Segment Class

WASHINGTON		
Segment Class 3	Number of Vehicles	%
Pickup	79,134	65%
Motor Home	16,327	13%
Regional Truck	15,439	13%
Construction Truck	5,853	5%
VAN CARGO	4,761	4%
Shuttle Bus	212	0%
SUV	174	0%
Step Van	86	0%
Total Number of Vehicles	121,986	100%

WASHINGTON		
Segment Class 4	Number of Vehicles	%
Bus	13,699	31%
Construction Truck	11,953	27%
Motor Home	9,806	22%
Regional Truck	6,366	14%
Step Van	1,274	3%
Shuttle Bus	866	2%
Total Number of Vehicles	43,964	100%

WASHINGTON		
Segment Class 5	Number of Vehicles	%
Construction Truck	14,425	57%
Motor Home	6,847	27%
Regional Truck	3,127	12%
Step Van	532	2%
Shuttle Bus	185	1%
Bus	88	0%
School Bus	69	0%
Emergency Truck	11	0%
Total Number of Vehicles	25,284	100%

WASHINGTON		
Segment Class 6	Number of Vehicles	%
Construction Truck	11,115	34%
Motor Home	10,565	32%
Regional Truck	9,440	29%
Step Van	652	2%
School Bus	547	2%
Bus	158	0%
Emergency Truck	48	0%
Shuttle Bus	32	0%
City Bus	9	0%
PickUp	5	0%
Refuse	2	0%
Total Number of Vehicles	32,573	100%

WASHINGTON		
Segment Class 7	Number of Vehicles	%
Construction Truck	9,928	42%
Motor Home	5,773	24%
Regional Truck	3,825	16%
School Bus	3,754	16%
Long Haul Truck	185	1%
Bus	68	0%
Refuse	61	0%
Fire Truck	43	0%
DRAYAGE	10	0%
Step Van	6	0%
City Bus	4	0%
Shuttle Bus	1	0%
Total Number of Vehicles	23,658	100%

WASHINGTON		
Segment Class 8	Number of Vehicles	%
Long Haul Truck	31,719	48%
Construction Truck	15,948	24%
Regional Truck	10,799	16%
Motor Home	2,537	4%
Refuse	1,668	3%
School BUS	996	2%
coach	680	1%
Fire Truck	609	1%
City Bus	541	1%
Terminal Tractor	155	0%
Bus	98	0%
Heavy Haul Truck	4	0%
Total Number of Vehicles	65,754	100%

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Appendix C. Summary of Utility Electric Vehicle Programs (Survey Results)

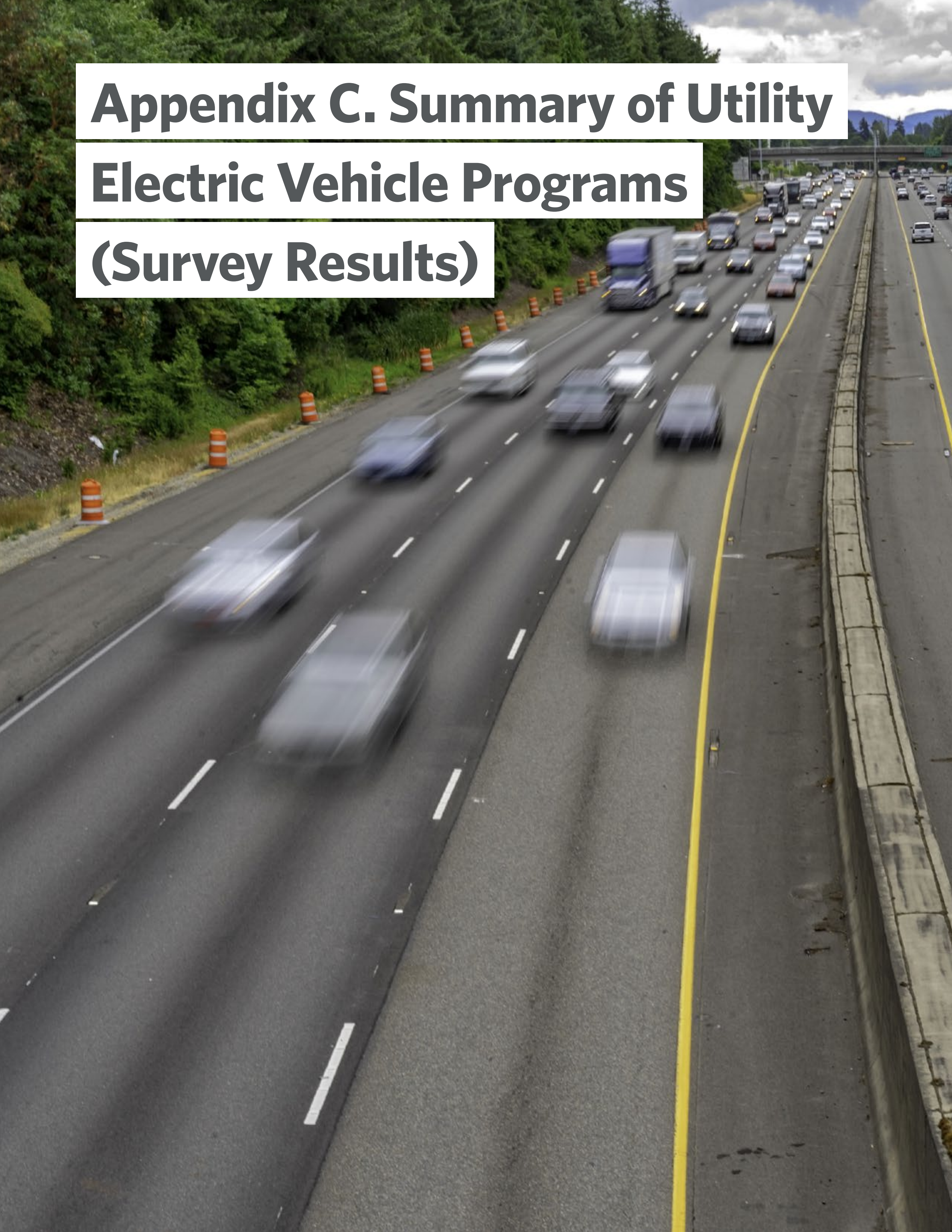


Table C-1: Summary of EV Programs (Survey Results)

<table>
<tr><th>Utility</th><th>Past Customer EV Programs</th><th>Current EV Programs</th><th>Future EV Programs</th></tr>
<tr><td rowspan="6">Los Angeles Department of Water & Power</td><td rowspan="2">CEC Grant Project (June 2014-June 2017):
▪ Received a $500,000 grant from the California Energy Commission (CEC) to install EV chargers at key destinations owned and operated by the City of Los Angeles.
▪ Combining the grant money with other sources of funding, installed 185 EV chargers by the end of the project.</td><td rowspan="3">“Charge-Up LA!” (July 2018- June 2021):
▪ Provides rebates of up to $500 to residential customers for the purchase of a qualifying EV charger.
▪ Provides rebates of up to $5,000 to commercial customers for the installation of qualifying EV chargers in workplace, publicly accessible locations, and multi-unit dwellings.
▪ The program has issued rebates for 1423 residential and 3170 commercial chargers as of 12/31/19.</td><td>Implement a program whereby LA City agencies can receive funding for various transportation electrification projects, i.e. public charger installations, or fleet electrification.</td></tr>
<tr><td>Developing agreement with LA Unified School District for a pilot project to install workplace charging at 6 sites, 5 of which will be at schools. They hope to expand this effort in the future once we've evaluated the success of the pilot.</td></tr>
<tr><td rowspan="2">LADWP Electric Vehicle Home Charger Rebate Program (May 2011-June 2013):
▪ Provided a rebate to residential customers to offset the cost of installing EV chargers at their residences.
▪ The program issued 893 residential EV charger rebates.</td><td rowspan="2">Develop contact rate for customers installing EV and energy storage for transit and commercial fleets:
▪ Working with LA Department of Transportation to electrify their entire bus line by 2030.
▪ They need back-up to operate buses in an emergency and are discussing battery storage and what that might look like.</td></tr>
<tr><td rowspan="2">Port of Los Angeles:
▪ Entered into an agreement with the Los Angeles Harbor Department to fund transportation electrification projects to develop and support zero carbon fuel emission mobile sources at the Port of Los Angeles.
▪ Will provide an aggregated amount of up to $15M in funding over five years toward the electrification of equipment at the Port of Los Angeles in support of their Clean Air Action Plan.</td></tr>
<tr><td rowspan="2">“Charge-Up LA – Home, Work, and On the GO!” (August 2013-December 2015):
▪ Provided rebates to residential and commercial customers for the installation of EV chargers in workplace, publicly accessible locations, and multi-unit dwellings.
▪ The program issued 1,227 residential and 235 commercial rebates.</td><td>Working with LA Metro to electrify their entire bus line by 2030.</td></tr>
<tr><td>Fast Charging Plazas:
▪ Issued an RFQ to identify qualified 3rd parties interested in designing, developing, installing, owning, operating and maintaining Fast Charging Plazas on LADWP owned property through a lease or license agreement.</td><td>Residential Smart Charger Rebate:
▪ Provide rebates to residential customers for the purchase and installation of a smart charger at home publicly accessible locations, and multi-unit dwellings.</td></tr>
</table>

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Table C-1: Summary of EV Programs (Survey Results) – Continued

Utility	Past Customer EV Programs	Current EV Programs	Future EV Programs
Los Angeles Department of Water & Power	"Charge-Up LA!" (March 2016-June 2018):	• A subsequent RFP for the first site is in development.	Regarding outreach for MD/HD customers, LADWP has a good number of customers reaching out to LADWP with plans to contract, purchase and deploy delivery of vehicles – due to their rebate program.
	• The program issued 1,043 residential and 271 commercial rebates. • Provided rebates to residential and commercial customers for the installation of EV chargers in workplace, publicly accessible locations, and multi-unit dwellings.	DC Fast Charger Rebate: • Provide rebates of up to $75,000 to commercial customers for the purchase and installation of a DCFC in workplace, publicly accessible locations, and multi-unit dwellings.	In order to assist City Agencies in meeting electrification goals outlined in the 2019 Sustainable City pLAn, LADWP is working very closely with various City of LA agencies to provide funding to incentivize and lower the intitial costs of infrastructure required for electrification for Medium Duty and Heavy Duty fleets, such as the Los Angeles Bureau of Sanitation's (LASAN) goal to transition to a zero-emission refuse fleet by 2035
	EV Charger Deployment Efforts: • To date, LADWP has installed 402 fleet chargers, 200 workplace chargers, and 99 public chargers across our facilities.	Medium/Heavy-Duty EV Charger Rebate: • Provide rebates of up to $125,000 to commercial customers for the purchase and installation of AC and DC charging stations used to charge medium and heavy duty EVs.	
		Used EV Rebate Program (April 2018 - March 2021): • Provides rebates of up to $1,500 to eligible residential applicants who acquire a used EV that is at least two model years old.	
		Time-Of-Use Rebate (July 2018-June 2021): • Provides a rebate of $250 to residential customers who install a dedicated TOU meter for the installation of a level 2 charger.	
NCPA City of Lodi Electric Utility	No past customer EV programs.	EV charging period and rate, public EV charging stations, and EV charger rebates for residential ($500 for Level 2 charger and $500 for installation), and commercial ($1,000 for Level 2 charger and $1,000 for installation) customers.	EV program expansion in design to include goal-setting, rebate on vehicle purchase, and rebate on installation of charging station; planning two EV drive events for the public.
NCPA City of Shasta	No past customer EV programs.	Maintains self-contained (solar with Li-ion battery) single-port Level 2 (3.84 kW) EV charging station at the intersection of Grand River Ave. and Shasta Dam Blvd.	No future EV programs to announce at this time.
NCPA Plumas-Sierra Rural Electric Cooperative	No past customer EV programs.	$500 customer EV rebate.	No future EV programs to announce at this time.
NCPA Port of Oakland	No past customer EV programs.	Provided incentives for multiple deployed EV trucks.	May expand incentives available for EV trucks.
			Creation of common truck charging station with solar and battery storage for multiple trucks.

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Table C-1: Summary of EV Programs (Survey Results) – Continued

Utility	Past Customer EV Programs	Current EV Programs	Future EV Programs
NCPA **Redding Electric Utility**	No past customer EV programs.	Have one DC fast charger at the local Target shopping location.	One electric bus is coming to the transit agency fleet.
		Residential Rebate: $1,000 rebate for a purchased or leased EV and $500 rebate for a charging station.	Received grant for $8M for a long-haul bus to take commuters from Redding to Sacramento and back and charge in each location for four trips a day.
		Commercial Rebate: $1,000 rebate for a purchased or leased EV and $3,000 rebate for charging and installation.	
		Actively electrifying city fleet vehicles.	Installing city-owned charging infrastructure.
		Co-funded inter-city electric bus currently operating.	
NCPA **Truckee Donner PUD**	No past customer EV programs.	Owns and operates five public access Level 2 chargers at three locations around town. EVgo owns and operates two DC fast charges in one location. Tesla has installed over 20 super chargers in three locations around town.	No future EV programs to announce at this time.
		ChargePoint has a project for multiple DC Fast charges in the Town's Railyard Redevelopment project (ChargePoint won a Town RFP).	
		Tesla is installing additional charging stations in a location on the north side of Town (Gray's Crossing's PJ's, Town of Truckee has an RFP for Level 2 chargers at Town Hall and Electrify America/VW has been in discussions with multiple landlords to locate a significant facility somewhere in Town.	
		Rebate for $500 for installation of Level 2 charger at a home within the ervice territory where an EV is registered with DMV (details at www.tdpud.org). This program is funded with credits to be sold in California's LCFS market.	
Pacific Gas & Electric Company	No past customer EV programs.	EV Charge Network: • 7,500 Level 2 chargers (10-20 chargers per site). • Installations began in Jan 2018. • $130 million; 3 years. • Targeting workplaces, multi-unit dwellings. • 15% of chargers deployed in disadvantaged communities.	Empower EV: • Piloting EV and EVSE rebates for low- and moderate-income customers. • Decision as soon as end of Q2 2019. • Program would open beginning 2020 and run for 1 year.
			Commercial EV rate: • Creates a new customer class for commercial EVs, allowing full cost-of-service rates that do not include traditional demand charges.

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Table C-1: Summary of EV Programs (Survey Results) – Continued

Utility	Past Customer EV Programs	Current EV Programs	Future EV Programs
Pacific Gas & Electric Company		• In disadvanataged communities and for multi-unit dwellings the site host has the option for PG&E ownership and operation of charger; in other cases, the site host is responsible for ownership and operation.	• Application pending at PUC. • Decision expected Q3-Q4 2019. • Implementation 2020.
		EV Fast Charge: • 50+ plazas with approx. 234 DC fast chargers; utility provides make-ready infrastructure. • Final CPUC approval received 05/31/18. • $22 million; 5 years. • Corridor and urban sites. • Plan for variety of power requirements (50 – 350 kW). • 25% of chargers in DACs. • Rebates up to $25,000 per charger in DACs.	EV Parks & Schools: • $11M for L2 charging at schools (130 chargers) and state parks (50 chargers). • Decision likely by end of Q2 2019. • Followed by 2-year implementation period. Developing EV fleet program. Developing programs around Low Carbon Fuel Standard credits in light-duty, but this is not applicable to MD/HD.
		EV Fleet: • Infrastructure for non-light-duty fleets (e.g. delivery vans, transit buses, forklifts, truck refrigeration units). • Final CPUC approval received 05/31/18. • $236 million; 5 years. • Sized to meet forecast adoption – 6,500 vehicles at 700 sites. • 25% of program budget to support projects in DACs. • Rebates up to 50% of EVSE cost.	Targeting market sectors vs. geographic areas where the incentive money is going. For example, transit and school buses and HVIP, HD Trucking and ports.
		CPUC approved rate design for commercial EV charging that eliminates demand charges in favor of a demand subscription fee and time-of-use usage charge. The rate will be a key component that goes hand-in-hand with the acceleration of electrification.	
		Administers an $800 upfront rebate ("Clean Fuel Rebate") for light duty EVs funded by LCFS.	
		Offers two residential EV rates: EV-A (whole-home metered service) and EV-B (separately metered EV service).	
		Three smaller priority review projects--infrastructure demonstrations with budgets in $1-4M range.	

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Table C-1: Summary of EV Programs (Survey Results) – Continued

Utility	Past Customer EV Programs	Current EV Programs	Future EV Programs
Pacific Power	No past customer EV programs.	Public Charging Pilot (OR): ▪ Ten-year pilot with stations to be installed by the end of 2020; tests the benefits of owning and operating public electric vehicle charging stations in its OR service area. ▪ Will partner with local governments to site chargers in visible and convenient public locations.	Considering how they will transition to MD/HD programs.
		Demonstration and Development Pilot (OR, WA, CA): ▪ Implementing a competitive grant funding program to help nonresidential customers implement creative, customer-driven electric transportation infrastructure. The pilot is in operation through the end of 2020. All Pacific Power non-residential customers are eligible.	Utilities in Oregon are required to file a transportation electrification plan. PacifiCorp will include how to address MD/HD in that plan.
		Outreach and Education Pilot (OR, WA, and CA): ▪ Pilot runs through the end of 2020. ▪ Resources and educational efforts will be targeted across customer segments are eligible. ▪ Self-service resources: Online calculators and additional tools accessible to all customers that provide information about electric transportation technologies, costs, benefits, and incentives. ▪ Community events: Funding for an estimated eleven "ride-and-drive" events throughout Oregon, Washington and California through 2020 along with additional event participation as budget and resources allow.	

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Table C-1: Summary of EV Programs (Survey Results) – Continued

Utility	Past Customer EV Programs	Current EV Programs	Future EV Programs
Pacific Power		Technical assistance: Expert, onsite technical assistance for non-residential charging infrastructure projects (e.g., charging for fleet electrification, workplace charging, public or customer charging).	
		Public DC Fast Charger Transitional Rate: • Available on a ten-year glide-path in Oregon and Washington. Eligible customers must has an electric vehicle charging stations with at least one DC fast charger, a load size less than 1 MW, provide availability to the public, and have a meter dedicated only to EV charging.	
		Clean Fuels Program (OR): • In 2017, registered to aggregate Clean Fuels Program credits on behalf of residential electric vehicle drivers. Pacific Power is currently working with stakeholders to develop programs that will meet the program principles adopted by the commission in October of 2018.	
		PacifiCorp has focused on filling gaps by investing in infrastructure to fill corridor gaps where others aren't investing. Electrify America and West Coast Electric Highway already investing infrastructure along I-5.	
Portland General Electric	No past customer EV programs.	Multiple demonstrations with public and workplace charging.	Residential smart charging rebates; business charging make-ready for L2; Transit full-ownership program.
		Public quick charging network (6 sites w/ 4 DCQC); high-powered transit pilot (450-kW charger and 2 100-kW chargers).	Near-term opportunity to partner with Tri-Met (Portland Metro transit agency) to install charging infrastructure for electric buses. Pilot will help PGE better understand the planning and distribution impacts.
		Outreach and technical assistance (ride and drive events and onsite technical support for business customers).	Filed a business charging program focused on business customers to install Level 2 chargers, but the program also includes components for a transit that would operate and maintain HD transit infrastructure.
		Schedule 38--no demand charge TOU rate: • Capped at 200 kW; applications for MD/HD are limited.	
		Clean fuels program (EV grant, school bus pilot).	

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Table C-1: Summary of EV Programs (Survey Results) – Continued

Utility	Past Customer EV Programs	Current EV Programs	Future EV Programs
Puget Sound Energy	No past customer EV programs.	Transit charging with King County Metro (pilot phase): • Part of KC Metro's stakeholder group to plan an electric bus fleet. • Evaluating bus operating patterns and needs for charging. • KC Metro has 4 chargers and a long-term plan for electrification.	Proposed services and products in October 2018 utility filing: • Education and outreach. • Single-family residential charging and off-peak charging. • Multi-family residential charging and off-peak charging. • Workplace/fleet charging. • Public charging. • Direct to service low-income customers. Proposed pilot programs (these programs are referred to as "pilots" because the benefits can't be quantified without further experience; need to get to a point of ensuring that non-EV customers aren't paying for the cost of EV charging): • Non-residential, Workplace charging pilot: -Charging station hosts can qualify for up to 10 chargers (number of chargers depends on estimate of EV-driving employees) -Charging rates (Jan 2019-2022) for Level 2 and DC fast charge • Residential: Installing and furnishing an EV charger at qualifying customer properties. -Customer completes annual surveys about charging preferences and patterns -Access and maintenance agreements • Multi-Family -Install and furnish an EV charger or chargers at qualifying MF host site -Provide an incentive toward electric usage in off-peak hours

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Table C-1: Summary of EV Programs (Survey Results) – Continued

Utility	Past Customer EV Programs	Current EV Programs	Future EV Programs
Puget Sound Energy			• Education and outreach -Print and digital, advertising and education, web-based learning, train-the-trainer, workshops • Low income programs -Provide electric service through approved low-income agencies or other entities -Non-emergency medical services transportation.A1 -Rural services low-income transportation -MF low-income housing transportation -Head start child transportation -Low-income weatherization fleet transportation
			PSE is part of a Joint Utility Transportation Electrification Stakeholder Group
			PSE's vehicle fleet includes hybrid-electric transit vans and pickup trucks (do not return to base to charge).
			WA State Ferries are exploring electrification of ferry routes; requires similar analysis of timing, route patterns, energy needs, and energy supply impacts: • Transit charging: 400 kW/bus (lower charging rate if overnight at a depot). • Electric Ferry: 5-10 MW.
			Considering different rate structures: • Accumulated rate – rolls together on-route charging and depot charging into one rate structure. • Piloting rebates for charging at times of lower grid demand.
SCPPA City of Azusa	No past customer EV programs.	Residential rebate for $150 for Energy Star rated EV chargers	No future EV programs to announce at this time.
		Residential Off-Peak Charging Discount rate (https://www.ci.azusa.ca.us/1191/Schedule-EV).	
SCPPA City of Vernon	No past customer EV programs.	Working to incentivize transportation electrification through investments in electric vehicle charging infrastructure.	Early stages of development.

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Table C-1: Summary of EV Programs (Survey Results) – Continued

Utility	Past Customer EV Programs	Current EV Programs	Future EV Programs
SCPPA **Anaheim Public Utilities**	DC Fast Charging Plaza (2018).	Private EV Charger Rebate Program (since 2012). Public Access EV Charging Station Rebate Program (since 2016). Residential customers have an EV Rate Option Non-residential customers have Developmental Schedule D-EV-2 (Developmental Non-Domestic EV) rate.	Does not release this information.
SCPPA **Burbank Water & Power**	EV Charge: Installed Level 2 public charging in publicly available parking lots. Program goals were to kickstart EV infrastructure in Burbank, and to help integrate renewable resources. Program was successful in getting 12 new Level 2 chargers placed in downtown parking lots and at our Lakeside Shopping Center. EV Charge'N'Go: Burbank Water and Power installed dual-port Level 2 Chargers at 8 different curbside locations. The program was developed to provide EV charging infrastructure for the public with an emphasis on MUD's.	EV Charging Station rebate: • Provide up to $500.00 for residential EV chargers and up to $2,000.00 per port for up to 8 EV chargers for commercial customers. • The rebate only covers the equipment costs. • There have been 109 residential rebates and 23 commercial rebates over the lifetime of the program. This is an on-going program, although we are looking to restructure the rebate by the end of the calendar year 2019.	Developing a comprehensive TE infrastructure program to promote TE and integrate renewable energy. Exploring a combined advisory services program, with a rebate program to cover some costs of infrastructure and charging equipment. Will provide solutions for all market segments, with a focus on workplace charging, MUDs, and LI/DAC communities. Estimated approval is by August 2019. Considering adding EV incentives, with a possible enhancement for LI/DAC customers.
SCPPA **Pasadena Water & Power**	Supported adoption of EVs for the last 20 years. Provided incentives to commercial customers for the purchase of EVs and charging infrastructure. Installed charging infrastructure at its city-owned parking infrastructure and made available "free charging" at this location for the last 20 years.	Residential EV program offers incentives up to $1,500 for the purchase or lease of new or used electric vehicle. Incentive bonuses are available for local purchase and Low-Income customers	Accelerate the adoption of plug-in electric vehicles by offering incentives to customers, outreach and education, and expansion of public and workplace charging infrastructure
		Residential EV program offers incentives up to $600 for the installation of a wi-fi Level 2 charger. A $200 incentive is also available for non-network chargers	Planing to implement a discount rewards smart EV charging program to encourage charging at desirable time windows.
		Commercial EVSE Program offers $3,000 per port incentive up to $50,000 per customer for the installation of network EV chargers. Incentives are doubled to $6,000/port if chargers are made available to the public or installed at DAC or affordable-housing	Continue to provide incentive for charging infrastructure to encourage workplace and public charging.
		Commercial program offers up to $15,000 incentives for the installation of non-network chargers or Level 1 chargers at MUDs.	Develop an EV specific electric rate for charging medium- and heavy-duty vehicle and transit.
		Launched the "Power Up Pasadena" marketing campaign with the goal to increase awareness of EVs a educated customers about advantages of drving electric and smart charging.	Partner with customers to install charging infrastructure to serve MUDs and destination charging.

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Table C-1: Summary of EV Programs (Survey Results) – Continued

Utility	Past Customer EV Programs	Current EV Programs	Future EV Programs
SCPPA **Pasadena Water & Power**		Expanded charging infrastructure at several city facilities and parking garages to support city electric fleet and employee vehcile charging. In partnership with Tesla, recently completed the largest charging plaza in the U.S. featuring 20 universal DC fast chargers and 24 Tesla Superchargers.	Continue to promote electric vehicles through the "Power Up Pasadena" marketing campaign using a variety of media (print and digital) and community events. Continue to expand charging infrastructure at city-owned facilities and public parking garages. Partner with EVSE vendors to install public charging plazas at strategic locations throughout the city.
SCPPA **Riverside Public Utilities**	$500 rebate for EVs if the owner is a resident of Riverside and purchased their vehicle at a Riverside auto dealership. RPU provided public EV charging in its downtown area and at some City facilities.	Electric Operations has $500,000 set aside to develop public EV charging. RPU is currently working with its Board to develop and offer a comprehensive EV program with rebates as well as charger deployment. Two TOU rates that supports residential customers with EVs. The Schedule EV is an EV only, separately metered rate. The Schedule D-TOU is a whole house domestic TOU rate that supports all household electric use, including EVs.	No future EV programs to announce at this time.
SCPPA **Glendale Power & Water**	No past customer EV programs.	Participating in the Local Government Partnership Program offered by the Mobile Source Air Pollution Reduction Review Committee and accepted the secure funding through Program. Funding to be used to assist in the implementation of the City of Glendale's EV charging station infrastructure. Ride and Drive Events: Glendale hosts multiple ride and drive events annually to promote the adoption of EV's in the City. Level 2 Charger Rebates: Program was launched by Glendale on July 2017 and it offers a maximum $500 rebate to residential customers who install a Level II (240V) EV charger. Looking into restructuring rebates for FY 20-21.	Currently in the design phase of multiple EV charging infrastructure projects in the City of Glendale. Designing new EV programs to be launched in FY 2020-2021.
Sacramento Municipal Utility District	No past customer EV programs.	Those who purchase or lease and EV can receive a $599 incentive to charge free for two years (approximately covers the average cost to charge a plug-in electric vehicle for two years), or a 240 Volt high-powered electric vehicle charger. $1,500 rebate on Level 2. Support structured incentive levels to a certain dollar value for the equipment. $100,000 rebate on DC fast chargers.	Does not have an EV commercial rate and won't have one for another three years, due to higher priorities in their overall rate making efforts; will be looking at demand charge relief.

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Table C-1: Summary of EV Programs (Survey Results) – Continued

Utility	Past Customer EV Programs	Current EV Programs	Future EV Programs
Sacramento Municipal Utility District		The Level 2 and DC fast charging rebates will be discontinued as SMUD works with The California Electric Vehicle Infrastructure Project (CALeVIP) offers incentives for the purchase and installation of EV charging infrastructure at publicly accessible sites throughout California.	
		Provide similar educational outreach programs as the other utilities.	
		Transitioning to statewide point of purchase next year and their own $599 rebate will stop.	
		For light-duty vehicles, owners can participate in a new TOU rate: • Rates are highest during weekdays in the summer from 5 p.m. to 8 p.m. • There is an additional 1.5¢ per kWh credit for charging your EV between midnight and 6 a.m. every day, all year long.	
		Save up to $3,500 on the purchase of a new 2019 Nissan Leaf.	
San Diego Gas & Electric	Power Your Drive: Supports approximately 3,000 Level 2 ports at workplace and multi-unit dwelling sites. Drivers are billed directly on an innovative hourly dynamic rate. Construction closed Q2 2019.	MD/HD EV Infrastructure Program: • Will support at least 3,000 MD/HD EVs at 300 sites, with construction through 2024.	Proposed new commecial rate for DCFC and MD/HD EV charging.
			Proposed an extension to the Power Your Drive program and install 2,000 charging ports in about 200 sites over a two-year period.
	Dealership Incentives: Pilot project to education and offer financial incentives for local auto dealers to sell EVs.	Schools, Parks, and Beaches (AB 1082/1083): • Will support Level 2 and DCFC stations at 50 educational institutions, state parks and beaches, and county parks.	
		Electrify Local Highways: • Supports Level 2 and DC fast charging stations at four Caltrans Park and Ride locations. • Construction through mid-2019.	
		Port electrification: • Supports up to 40 charging installations for electric MD/HD vehicles at Port of San Diego. • Construction through mid-2019.	
		Fleet delivery trucks: • Supports approximately 75 fleet delivery vehicles. • Construction through mid-2019.	

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Table C-1: Summary of EV Programs (Survey Results) – Continued

Utility	Past Customer EV Programs	Current EV Programs	Future EV Programs
San Diego Gas & Electric		Airport electrification: • Supports up to 45 new charging ports to support electric ground support equipment at San Diego International Airport.	
		Green Shuttles: • Installing charging stations at four sites to support fixed-route shuttles. SDG&E offers three residential EV TOU rates and the hourly dynamic vehicle grid integration rate for customers participating in the Power Your Drive Program.	
		EV Climate Credit incentive for EV drivers.	
Seattle City Light	The City of Seattle and Seattle City Light partnered to install 188 Level 2 chargers in the Seattle Municipal Tower parking garage. These chargers will support a large part of the City's municipal electric vehicle fleet.	Public DC Fast Charger Pilot Program: SCL is installing at least 20 fast chargers for public use throughout its service area. The fast chargers are being installed in locations that are not being served by privately-owned charging station operators. The chargers will be located at a wide variety of sites including curbside locations, municipal properties, transit hubs, highways, public parks, underserved communities, and retail destinations. This will provide SCL with the opportunity to understand customer charging trends and grid impacts under many different use cases. (Expected to be complete in Q2 2020.)	Future programs not publically available.
	Seattle City Light installed Level 2 chargers at its South Service Center. These chargers will support the electrification of City Light's fleet vehicles.	Residential EV Charging Program: SCL is installing 200 Level 2 chargers in customers' homes. Customers will pay a monthly lease fee to City Light and allow City Light to capture charging station data. When the lease ends, the ownership of the equipment will transfer from City light to the customer. The data obtained through this pilot program will allow City Light to better understand how at-home charging will impact the electric grid, including specific impacts to local distribution feeders and transformers.	
	Seattle City Light installed Level 2 chargers available to employees and the public in rural Newhalem, WA (Skagit River Hydroelectric Project).		

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Table C-1: Summary of EV Programs (Survey Results) – Continued

Utility	Past Customer EV Programs	Current EV Programs	Future EV Programs
Southern California Edison	Charge Ready Pilot: Deploy commercial light-duty make-ready infrastructure to serve workplaces, destination centers, fleets and multi-unit dwellings in SCE's service territory. Provided a rebate to participating customers to cover all of a portion of the cost of the charging equipment and its installation.	Charge Ready Pilot (Bridge Funding): • Additional funding to continue the Charge Ready Pilot which will deploy commercial light-duty make-ready infrastructure to serve workplaces, destination centers, fleets and multi-unit dwellings in SCE's service territory. • SCE will also provide a rebate to participating customers to cover all of a portion of the cost of the charging equipment and its installation. Charge Ready Transport Program Charge Ready Transport: • Will deploy commercial medium- and heavy-duty make-ready infrastructure to serve commercial and freight fleets in SCE's service territory. • Includes a rebate to participating customers to cover all of a portion of the cost of the charging equipment. Residential Make-Ready Rebate Pilot: • The Residential Make-Ready Rebate Pilot provides a rebate to residential customers living in single-family residences or multi-unit dwellings to install EV charging make-ready infrastructure. Urban DC Fast Chargers Pilot: • The Urban DCFC Clusters Pilot proposes to deploy and operate five DCFC sites, clustered in urban areas.	Charge Ready 2 Program: • Charge Ready 2 builds on the learnings from the Charge Ready Pilot to deploy commercial light-duty make-ready infrastructure to serve workplaces, destination centers, fleets and multi-unit dwellings in SCE's service territory. • CR2 also has proposed to offer a turnkey solution for multi-unit dwellings and government locations where SCE would own and operate the charging stations. • An additional support for multi-unit dwellings is a rebate at new construction buildings to install charging stations. • As in other Charge Ready programs, SCE will provide a rebate to participating customers to cover all of a portion of the cost of the charging equipment and its installation. AB 1082 (Charge Ready Schools) Pilot: • The AB 1082 Pilot proposes to deploy up to 250 Level 2 make readies at approximately 40 K-12 schools in SCE territory. • SCE also proposes to provide a student and faculty education program to teach about the benefits of EVs. • SCE intends to install, own and maintain make-ready infrastructure at participating customer sites. • Participating customers will have the opportunity to select charging stations qualified by SCE and receive a rebate to cover the base cost of charging stations deployed through the pilot, including hardware and installation.

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic

Table C-1: Summary of EV Programs (Survey Results) – Continued

Utility	Past Customer EV Programs	Current EV Programs	Future EV Programs
Southern California Edison		• Each site may include up to five dual-port charging stations, for up to 50 DCFC ports total. • Intends to install, own, and maintain make-ready infrastructure at participating customer sites. • Participating customers will have the opportunity to select DC fast charging stations qualified by SCE and receive a rebate to cover the base cost of charging stations deployed through the pilot, including hardware and installation.	AB 1083 (Charge Ready Parks and Beaches) Pilot: • The AB 1083 Pilot proposes to deploy up to 120 Level 2 make readies, up to 15 non-grid connected Level 2 charging stations and approximately 10 DCFC ports at approximately 27 state parks and beaches in SCE territory. • Will also promote the availability of charging station even in remote locations like state parks through a marketing campaign. • Intends to install, own and maintain make-ready infrastructure and charging stations at participating customer sites.
		Electric Transit Bus Make-Ready Pilot: • The Electric Transit Bus Make-Ready Program will deploy make-ready infrastructure to serve in-depot and on-route charging equipment for electric commuter buses operating in SCE's service territory. • Will provide a rebate to participating customers to cover the cost of the charging equipment and its installation.	Planning incentives on the light duty side, because for MD/HD they'll be coming up with a demand side management program. They may provide more incentives for charging, but it is very nascent. Of note is that The Transportation Electrification Framework OIR will dictate a lot of how they move forward on the MD/HD and imagines infrastructure requests will slow and any CPUC requests moving forward will be programmatic.
		Rate Schedules TOU-EV-7, TOU-EV-8, and TOU-EV-9 are applicable to businesses that separately meter the charging of their EVs: • TOU-EV-7 Rate Option Is available to customers with charging demands of 20 kilowatts (kW) or less. • TOU-EV-8 Rate Option Is available for customers with charging demands above 20 to 500 kW. • TOU-EV-9 Rate Option Is available for customers with charging demands exceeding 500 kW. Began rate design effort specifically for MD/HD high usage customers and it waves the demand charge for five years.	MD/HD outreach plans include: • Working with OEMs to find out where these loads might go. • They have funding for some MD/HD marketing and offer advisory services, customer tools assisting with total cost of ownership tolls and GHG assessments. • They have a business development arm in charge of creating a funnel to get customers to apply for programs and develop their education and outreach. • SCE is going to be revealing this campaign at the Act Expo.

Source: Analysis by HDR, CALSTART, S Curve Strategies, Ross Strategic