

DEVELOPMENT OF MARKET ANALYSIS AND USE-CASES FOR MEDIUM & HEAVY-DUTY VEHICLE-GRID INTEGRATION

*Prepared for the CPUC's Vehicle-Grid Integration Working Group in R.18-12-006 by:
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Purpose of this Document

The purpose of this document is to capture and explain, at a summary level, the universe of medium and heavy-duty vehicle types, vocations/applications with potential relevance to vehicle-grid integration (VGI) in the next 3 years. This document specifically details the non-transit medium-and heavy-duty vehicle (MHDV) use-cases developed for the VGI working group valuation process so that the vehicle profiles and their capabilities can be better understood by working group members and policymakers.

About CALSTART

With four offices in California, as well as in Colorado, Michigan and New York, CALSTART works with over 220 member companies to accelerate commercialization of clean transportation technologies. CALSTART's members include vehicle manufacturers (OEMs), components suppliers, transit agencies, goods movement operators, large commercial fleets, such as UPS, Pepsi-Co, and Fed-Ex, utilities (including California's major utilities), and electric vehicle service providers. Many of our members are working to advance widespread adoption of zero and near-zero emission vehicles and equipment in the medium and heavy-duty vehicle, and off-road vehicles and goods movement sectors. CALSTART is also currently the program administrator for California Air Resources Board's (CARB) Hybrid and Zero-Emission Bus and Truck Voucher Incentive Project (HVIP) and the new Clean Off-Road Equipment (CORE) Voucher Incentive Project, while also managing research and fleet deployment projects across the U.S. CALSTART recently launched the "Global Drive to Zero", a partnership-based program aimed at spreading rapid commercialization of MHDV ZEVs across the world.

About Union of Concerned Scientists

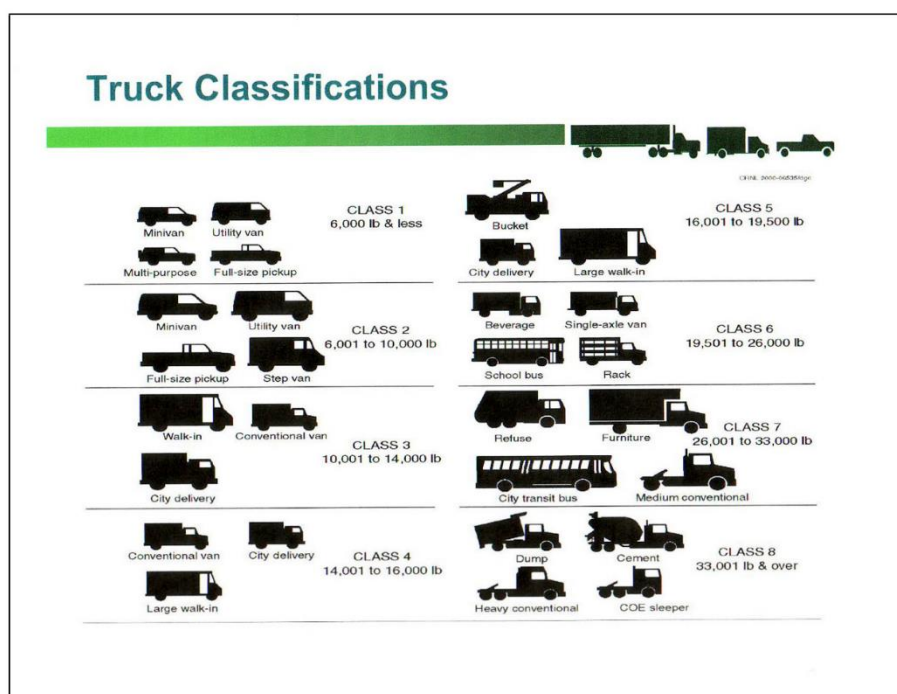
UCS is a nonprofit organization with over a half-million members and supporters nationwide, including over 85,000 supporters in California. UCS is nonprofit organization devoted to building a healthier environment and a safer world through the use of rigorous scientific analysis, innovative thinking, and committed citizen advocacy. UCS conducts scientific and technical analysis and research in the public interest, disseminates the results of this research and analysis to the general public and decisionmakers, presents its views and assists members in presenting their views before administrative agencies and courts. UCS has participated in numerous California Public Utilities Commission proceedings over the past 20 years, including a number of transportation electrification proceedings in recent years.

UCS is also actively engaged in electric truck and bus regulatory efforts at the California Air Resources Board to advance clean truck and bus adoption in the state. Most recently, UCS has carried out analysis to support the development of both the Innovative Clean Transit rule adopted by the Board in 2018 and the Advance Clean Truck rule which is currently under development.

Defining MHD-EVs

The phrase “medium- and heavy-duty vehicles” (MHDV) is generally used to refer to vehicles that fall into classes 2B through Class 8 vehicles, or from larger pickup trucks with towing capacity to long-haul tractor-trailers. Differentiation between vehicle classes is done by Gross Vehicle Weight (GVW).¹ Within each vehicle class there are many different vehicle types, which in some cases bear little similarity to each other (e.g. a class 8 coach bus and a tractor-trailer) but they share the same weight class, and in some cases, vehicles can share chassis as well. Class 4-5 vehicles can include delivery vans, such as those used by package delivery companies, as well as shuttle buses. In the VGI valuation tool, the MHDV classes are represented by the following Commercial: Fleet “sectors”: Small Truck(class 2-5), Large Truck(class 6-8), School Bus, Transit Bus.

A helpful reference to MHDV classes can be found below:²



MD and HD vehicles are used for a variety of *vocations*, such as package delivery, passenger movement (school buses and transit buses), regional delivery, local delivery, utility work-trucks, refuse trucks, etc.

The large batteries in MHD-EVs are designed to accommodate the mileage and “payload”, whether packages, shipping containers or people. Unlike passenger vehicles, these vehicles are also generally designed to be *in* use for 7-12 hours and are the primary part of operating a business or public service, such as transit. Their duty cycles may be most closely matched by TNCs in the light-duty sector in terms of the hours of use per day and miles driven per day. Stakeholders have been discussing the potential

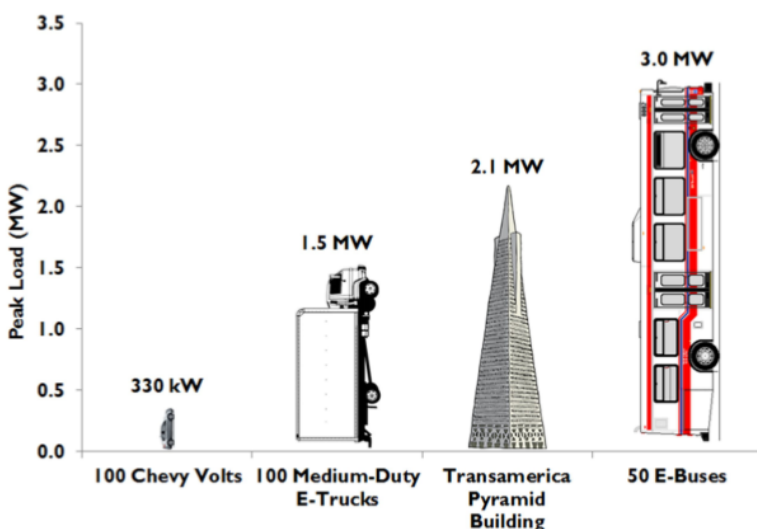
¹ It is worth noting that the conversion of a vehicle from ICE to BEV often adds enough weight to the vehicle to increase its class.

² <https://peterbilt.cummins.com/on-highway-truck-weight-rating-class>

grid impacts of these vehicles for many years already, but now we are seeing fleet roll-outs in significant quantities.

Peak Loads for Vehicle Fleets – CALSTART 2015

Figure 14: Peak loads for various electric vehicle fleets (without mitigating grid impacts)



Assumptions: the Chevy Volt charging rate is 3.3 kW, the medium-duty E-Truck charging rate is 15 kW and the E-Bus charging rate is 60 kW. The peak load for the Transamerica Pyramid building is from [26].

Process of Use-Case Development

CALSTART began the process of developing a market survey, beginning with a substantial understanding of the MHD-EV market, primarily informed by its administration of the HVIP program. Market status is further informed by the development of CALSTART's MHDV "beachhead strategy" for commercializing successive waves of ZEV technology across the MHDV universe. Through HVIP, CALSTART has visibility into basically all MHD-EVs currently "on order" in California and awaiting delivery by fleets.

Using CALSTART's extensive network of 220+ members, OEMs,

public agencies and fleets, CALSTART conducted outreach to major OEMs, of trucks, delivery vehicles and school buses. We also discussed plans for vehicle procurement and use with several large private fleets, which we will discuss more below. We also relied on UCS industry and technical expertise, as well experience from demonstration and pilot projects with electric buses and trucks. Our process did not focus on transit buses for two reasons: 1) E3 produced a significant market report on transit bus electrification that captured various drive-and charging cycles of transit buses, which we thought would provide a very good sub-set of transit bus use cases, and 2) transit agencies and their technology partners were directly engaged with the VGI working group and were developing their own use-cases.

We conducted in-depth interviews with 4 manufacturers who combined represent close to 75% of the heavy-duty truck market, as well as two manufacturers who are producing electric delivery vehicles (class 4-6) in large quantities. We confirmed our understanding of which vehicles are not currently available but will likely be coming to market in the next 3-5 years, and, as requested by this working group, we tried to break that down further into expectations regarding vehicle offerings in 2022 vs. 2025.

Next, we tried to learn as much as we could about whether those OEMs currently manufacture vehicles with V2G capability (the ability to charge as well as discharge the vehicle battery through an in-charger on on-board inverter), or whether they have short-term plans for doing so. We also wanted to capture specifics about vehicles such as battery size and understand what types of chargers the OEMs expected

their customers to use, based on the expected drive cycles of the vehicles. We provide more details on drive cycles and charging sizes/ rates in each of the sub-sections below.

Discussion with Delivery Fleets

We spoke with two of the nation's largest delivery fleet operators about their plans for EV purchases, the expected duty cycles, routes, hours of charging, whether they would use managed charging as standard practice, and whether they plan to use management software or manage their fleets in-house. We also discussed their interest or willingness to adopt V2G technology and to take advantage of VGI, if it provided the opportunity to improve vehicle total-cost-of-ownership (TCO). Our goal was to understand what fleets would be willing to do and how much they may be willing or able to shift their charging or export energy to generate value through either V1G or V2G.

Small Trucks Sector: Medium-Duty (Class 4-5) Delivery Vehicles

Description, Battery Size

For the small trucks sector, we focused our use-cases on delivery vehicles, as they are a vehicle segment that is most rapidly electrifying in California and beyond. Currently in HVIP there are nearly 1,000 delivery vehicles with voucher reservations that fall in the Class 4 category. There have been many major announcements in the news from delivery companies like Amazon, that they will be adding thousands of ZEVs to their delivery fleets in the coming years. Therefore, we thought it was paramount that we understand the VGI capabilities of this segment, and whether/ how the drive cycles of these vehicles would lend themselves to either V1G load shifting or full V2G energy export.

From discussions with OEMs we learned that in the short term (next few years) it does not appear that vehicles in this segment will be V2G capable. The manufacturers we spoke with are not adding V2G capability to vehicles because of additional cost and because the customers are not asking for it. Primarily, these customers will be learning how to use these vehicles and gaining confidence in their ability to meet the demanding duty cycles as they transition away from gasoline / diesel trucks to electric.

We estimate a battery size within a 70-100kWh range for these medium-duty delivery vehicles.

Drive Cycles

Primarily, these vehicles will be driven during an 8-10-hour delivery route, leaving a central depot in the early morning (4-6 am) and returning to the depot in the mid-late afternoon (2-5 pm). That said, different delivery companies will run slightly different schedules. Fleet operators expect each delivery vehicle to complete its duty cycle on a single charge, and they need their vehicles to have 100% state-of-charge by the time the vehicle leaves the depot to conduct its duty cycle.

Charging Profile

We expect these vehicles to be charged either using Level 2 charging overnight or low-power 25 kW DC-FC, because generally the dwell times are long enough to accommodate lower-powered charging.

Charging Management

We concluded that these vehicles would make use of managed charging as a standard practice—OEM and fleet managers alike indicated that they expect fleets will conduct managed charging—either by the fleet manager itself or a third party—in order to strategically manage and minimize fuel costs in a large fleet, with very sophisticated fleet operators.

Large Truck Sector: Class 6 Local Delivery, Drayage (Class 8) and Regional Delivery Vehicles (Class 7-8)

Description, Battery Size

This grouping of medium/heavy-duty vehicles is meant to represent a few different vehicle types that are either available as a BEV today, or are expected to be available by 2022. We included two distinct vehicle types in our *use cases* under the overall “Large Trucks Class 6-8” Sector. The first is a class 6 delivery truck. This is a heavy-duty truck (up to 26,000 GVWR) that can haul very heavy cargo and is used in local and regional delivery. We know of at least one large fleet that is planning to adopt an electric class 6 trucks in their operations in California on an aggressive timeline for their local product deliveries and expect these to be commercially available in 2022. The estimated battery size range is 120-200 kWh.

The second truck type we included in our use cases is a Class 8 tractor-trailer used for either “drayage” or regional delivery. These trucks are available now from various manufacturers. Drayage trucks transport freight over a short distance to and from a port and within the logistics industry. Drayage is often part of a longer overall move, such as from a ship to a warehouse. Regional Delivery includes trucks that travel up to 150 miles/ day. For these class 8 trucks we included three example battery sizes based on input from OEMs, 200,300 kWh and 450kWh.

CALSTART estimates that by the end of 2019, or early 2020 there will be over 500 ZEVs in this class range on the road in California. Vehicles with the 450 kWh batteries will likely be later to roll out, and may come post 2022.

Drive Cycles

Based on our discussions with OEMs and fleets, we expect that these vehicles will mostly be driven during the day. Delivery vehicles may likely work an early morning (3 am)- late afternoon (2-7pm) schedule. Regional Delivery vehicles may follow a similar schedule, but drayage vehicles may have a more unpredictable schedule and could sometimes be used overnight.

Charging Profile

We presume that the Class 6 delivery vehicles would use a 30-50 kW DC-FC. For the Class 8 vehicles we presume a minimum DC-FC of 100 kW, but also included a use case with a 150 kW charger. We expect that in the next 3-5 years the adoption of higher powered superchargers, up to 300kW, will be adopted by these heavy-duty truck operators.

With the possible exception of drayage trucks, we expect vehicles to follow a nighttime plateau; typically starting charging either briefly in the afternoon, but certainly avoiding peak periods, so then (re)starting charging at 9 pm under existing TOU rates and reach 100% SOC between 1 and 6 am. For drayage vehicles, we can imagine uses where there may be an opportunity for a short period of mid-day charging using super-chargers. Especially for those vehicles who may work overnight.

Charging Management

We concluded that these vehicles would make use of managed charging as a standard practice, both to maximize TOU rates and to ensure resiliency. This charging would either be managed by the fleet or third-party vendor.

School Buses

Description, Battery Size

School buses come in various types (A, B, C, and D) with Type A being the smallest and Type D the largest. The battery size in electric school buses goes up to 160 kWh. They are currently available from 5 manufacturers with additional models expected in 2020.

Drive Cycles

School buses have an average daily mileage of 66 miles with a route in the morning (6-8 am) and another in the afternoon (1-3 pm). However, there is some variability in use depending on the urban or rural school district and additional use of school buses for field trips. The buses are parked most of the time making them available for VGI. In fact, V2G demo projects with e-school buses have been underway or are planned.

Charging Profile

Electric school buses charge using Level 2 equipment at 19.2 kW or 3-phase Level 2 at 33 kW. We do not presume that school buses will use managed charging as a standard practice and are less likely to contract with a third-party vendor, however, they are pairing with the local utilities to conduct pilot projects, and seem like good candidates for utility-managed charging.

Small Trucks: Shuttle Buses

Description, Battery Size

We included shuttle buses in this exercise in part because we believe they are a good candidate for widespread electrification given their duty cycles, and also because CARB has adopted a Zero-Emission Airport Shuttle regulation which will drive adoption of ZEV shuttle buses and vans. 33% of all airport shuttles must be zero-emission by 2027, but after January 2023, if you're buying a new shuttle, you must buy a ZEV. Obviously, airport shuttles are only part of the shuttle bus market in California, but they are certainly leading transformation of this market segment. CARB's regulation applies to all vans, and "cutaway" vehicles greater than 8,000 GVW, however our use cases for shuttle buses are focused on class 5 vehicles with a GVW of 16,000 lbs or greater. For this use case, we estimate a battery size of 100-125 kWh.

Drive Cycles & Charging Profile

CARB's regulatory documents estimated an average drive cycle of 94 miles a day or 34,000 miles a year, and potentially up to 148 miles a day (54,000 miles/ year) for a class 5 airport shuttle. Given that not all shuttles are airport shuttles, potentially a lower mileage should be assumed for a transit or other type of

shuttle bus operation. The drive cycles for these vehicles are short routes to and from the airport with a high frequency of trips. We understand these vehicles will potentially be in use from 5 am-midnight, and therefore may need to either make use of 50 kW DC-FC to do on-route charging for the higher mileage routes. Lower mileage shuttle routes, such as those used by transit agencies, may be able to make use of Level 2 charging.

Charging Management

It is unclear whether airport shuttles will be able to take advantage of managed charging because their operating hours are long; they will likely need to do opportunistic charging and may not have much ability to shift charging to different times. Other types of shuttles, such as those operated by transit and paratransit may have shorter operating hours and would be able to take advantage of managed charging, but it may not be the default for all transit properties.

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