Electric Vehicle Charging Guidebook

For Medium- and Heavy- Duty Commercial Fleets

2019

Prepared by gna Gladstein, Neandross & Associates

Bay Area Air Quality Management District
PG&E Pacific Gas and Electric Company
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Authorship and Uses

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Contents

Introduction

Fleet managers in California are navigating a mix of business opportunities and technology innovations as they consider adopting clean, sustainable fuels. The selection of clean medium- and heavy-duty vehicles is expanding, with a growing number of manufacturers providing battery electric options now or in the next several years for a variety of applications. As battery electric vehicle (BEV) technologies for these applications approach commercial readiness there is a clear need for charging infrastructure that can provide cost-effective vehicle charging on a reliable schedule. The optimal charging solution is unique to each fleet, and depends on a variety of factors.

This guidebook walks you, the fleet manager, through the key steps of selecting, installing and maintaining a charging solution that meets your needs. The first section provides context for your new BEV charging operations by summarizing the basics of electricity as a vehicle "fuel" and the electrical grid as the supplier of that electricity. Subsequent sections walk you through the process of assessing your fleet's charging needs, engaging with your utility during the design process, and securing the permits required to install your charging stations. Sample calculations, average costs, and key terms and definitions (indicated in italics and Key Terms boxes) are included with supporting graphics for your reference and use.

After reading this guidebook, you will be able to:

- Estimate your fleet's baseline energy needs and charging time requirements.
- Identify the charging equipment options that meet your fleet's needs in terms of physical interface, speed of charge, and cost.
- Develop charging station configurations that work with your facility's existing space, support current and future operations, maximize equipment lifecycles, and control costs.
- Identify which entities to engage in your jurisdiction for project design, permitting, and construction.
- Discuss important details of your electric service and electricity price bands with your utility.
- Find funding opportunities to reduce your total project costs.

This guidebook has been designed to provide a comprehensive overview of the BEV charging station procurement process for managers of medium- and heavy- duty commercial fleets. As this guidebook makes clear, the information presented here is meant as a general reference with theoretical examples only. When developing your charging solution it is critical that you consult your vehicle manufacturer, local utility, local jurisdiction, and other relevant entities in your business and area for project-specific guidance.

The Electric Grid: An Overview

In the simplest terms, electricity is "the flow of electrical charge." [1]. It is transported over the electric grid, an interconnected group of power lines and associated equipment that delivers electricity from where it is *generated* (at high voltage), to where it is *distributed* to and used by customers (usually at much lower voltage). The U.S. electric grid consists of more than 5.5 million miles of *transmission* lines, supported by countless subsystems and components. As indicated in Figure 1, it is managed and used by numerous entities. Using this complex system, electric utilities generate, procure, and distribute electricity, ensuring that their customers receive reliable and affordable electricity at all times.

Figure 1: Most of California's electric grid is managed and maintained by nearly a dozen utilities.

The grid carries electric power, as measured in *watts*. This refers to the rate at which electric energy is (or can be) consumed in an electrical *circuit*. To avoid outages or infrastructure damage, the amount of power on the grid must equal the amount of power demanded by customers at any given time. Maintaining this critical balance is an important task that involves many entities moving quickly in regulated markets.

The following sections describe key steps in producing, selling and distributing electricity over the grid to consumers.

KEY TERMS

Amperage: The rate of flow of electrons through a circuit, a.k.a. *current.*

BEV: Battery-Electric Vehicle

Circuit: The path along which electricity flows.

Distribution: The process of delivering power from transmission lines to the customer.

EVSE: Electric Vehicle Supply Equipment, or the charger unit.

Generation: The process of producing electricity from a fuel source.

Substation: A set of electric equipment that reduces high-voltage power to a voltage suitable for distribution to customers.

Transformer: A device that changes electricity from one level of voltage to another.

Transmission: The process of moving power in large quantities across long distances.

Voltage: Pressure created by a difference in electrical charge between two points.

Watt: The speed at which power is consumed, measured as energy per second.

[1] "Electricity 101". United States Department of Energy. https://www.energy.gov/oe/information-center/educational-resources/electricity-101#sys1

Grid 101: Generation to Distribution

The electric grid serves as the bridge between power producers and electricity consumers. Most traditional power plants generate electricity by burning fuel – typically coal or natural gas – to release heat that powers large generators. These centralized thermal (heat-based) power plants typically have large space requirements, and are located for convenient access to their fuel source (e.g., near a natural gas pipeline or rail terminal). Electrical power can also be produced in plants that use other mechanical or thermal energy to turn generators; example power plants of this type use hydro, wind or nuclear energy. Solar plants work differently; they use photovoltaic cells to absorb sunlight and induce electron flow, thereby generating power. California's electric grid utilizes all of these types of power generation and will increasingly use more power from zero-carbon sources; in September 2018, Governor Brown signed State Bill 100 committing the state to achieving carbon-free electricity by 2045. Generally, a common trait among power plants is that they are located in low population density areas (where land use is less constrained), and they have good access to sufficient amounts of their primary energy source (e.g., coal, natural gas, wind, sunshine, dammed rivers, etc.).

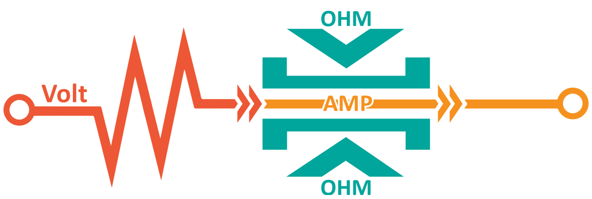


Figure 2: The movement of power is similar to the movement of water. Units of power (amps) flow through power lines according to the system's pressure, or volts, and the resistance, or ohms.

To reach consumers, power producers feed electricity into their local grid's network of transmission lines. As shown in Figure 3, step-up *transformers* prepare electricity for transmission in large quantities over long distances by increasing the voltage at which the power is transmitted. These are analogous to water pumps that push water through pipes over hills and across long distances while regulating the pressure (*voltage*) at critical transition points (Figure 2).

Distribution lines are used to complete localized delivery of electricity to the customer, by passing power from a *substation* (step-down transformer) so residences and businesses can receive the power at the lower voltages suitable for their equipment. The voltage at which your facility receives power will depend on the needs of your facility and can range from low voltages (208 V or 240 V) to very high voltages (>50 kV).

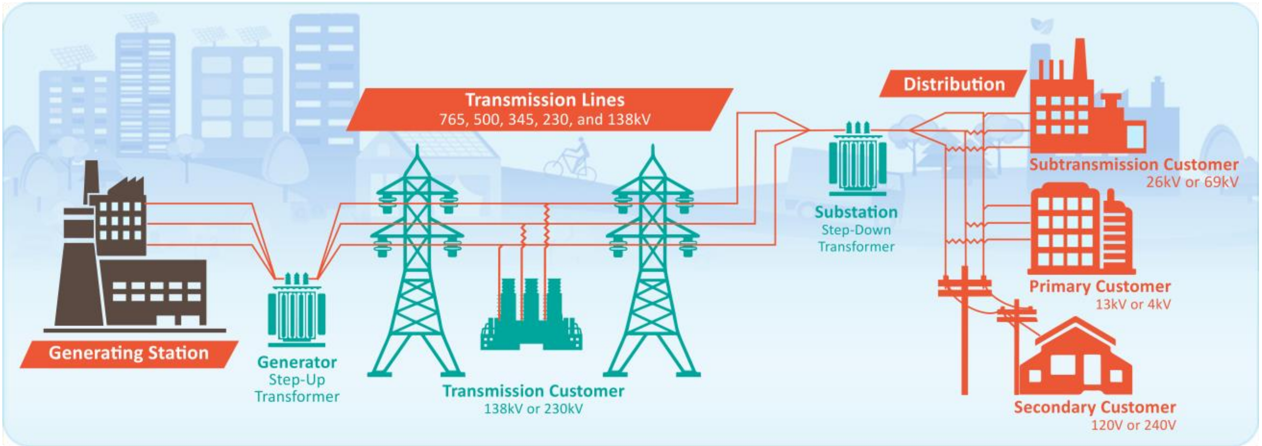


Figure 3: The electric grid carries electrical energy from generators to the end user.

Generating, transmitting, and delivering power involves multiple entities, which means that ownership structures vary across the electricity supply chain. Power plants may be publicly or privately owned. The electric grid is managed by Independent System Operators (ISOs) and utilities. The latter also provides maintenance and collects revenue from consumers. The prices that these entities pay varies by the time of day and rate at which the electricity is consumed. More details on the key components that go into the price of electricity is provided in the section, Purchasing Electricity for Your Fleet.

Utilities are responsible for expanding the grid's capacity to deliver power, while minimizing delivery interruptions. This includes ongoing grid maintenance and new infrastructure development. To manage these responsibilities, utilities maintain regular inspection and operational review schedules for power lines, transformers and substations. As more *BEVs* are put on the road, some utilities are developing long-term maintenance protocols for newly-laid BEV charging infrastructure. On the other side of this equation, consumers who own/operate chargers – here referred to as electric vehicle supply equipment (*EVSE*[2]) – are responsible for conducting regular maintenance to ensure that their equipment safely and successfully receives power and transmits it to vehicles.

[2] EVSE technically refers to the equipment used to supply AC power to a vehicle for charging. The EVSE is not a true battery charger, but instead ensures a safe connection of the grid power to the vehicle's on-board battery charger. However, the term is commonly used to refer to all types of EV charging equipment, including off-board DC fast chargers and AC EVSE.

Power Market 101: Buying and Selling Electricity

A range of stakeholders coordinate closely to buy and sell electrical power on the grid. The initial vendor is the fuel provider who sells fuel to the power producer at a market-determined price; the power producer may also be the fuel provider. Power producers sell the power they produce to utilities at prices determined under a variety of structures ranging from long-term *power purchase agreements* (*PPAs*) to last-minute bids for immediate use (*spot market)*. These transactions are brokered by *ISOs*, which ensure that the power flow across the grid's transmission lines is balanced. This is done by constantly and rapidly matching utility purchase requests with power plant sales bids. Utilities may also buy power through a *Community Choice Aggregation* (*CCA*), a program that buys electricity from a select set of suppliers and sells it to customers through their utilities.

Utilities typically use PPAs to supply baseload power, or the minimum amount of power that they expect to provide at any given time. To meet variable next-daily needs, they buy power as it is bid on the *day-ahead market*, where market participants purchase and sell electric energy at financially binding prices for the following day. Finally, to meet minute-to-minute needs, utilities buy power as it is bid on the *spot market* under immediate market conditions. This is typically the power with the most volatile pricing, with high costs during peak hours and low costs during low demand times of day.

While utilities pay a range of prices to maintain balance in their service territories, they bill their customers at a pre-determined rate that accounts for these fluctuations over the course of a billing cycle. Utilities' approaches to establishing these rates vary by their structure (Table 1). *Investor-owned utilities* (*IOUs*) in California propose and request rate approval from the California Public Utilities Commission (CPUC), while *publicly-owned utilities* (*POUs*) apply rates set by their governing board or city council. The electricity rate structures result in a price of power for a BEV fleet that can change by time of day. Further discussion on electricity rates as they affect your bill is provided in the section, Purchasing Electricity for Your Fleet.

KEY TERMS

CCA: Community Choice Aggregations, local entities that buy electricity on behalf of customers in a geographic area.

Day-ahead market: Market on which power is traded for next-day delivery.

IOU: Investor-Owned Utility

ISO: Independent System Operator, an entity that monitors, coordinates, and directs operations on the electric grid.

POU: Publicly-Owned Utility

PPA: Power Purchase Agreement, a contract for one entity to delivery power to another within a defined period of time.

Spot market: Market on which power is traded for immediate delivery.

Investor-Owned Utilities (IOUs)	Publicly-Owned Utilities (POUs)
• Owned by Shareholders or Investors in and outside the Service Area	• Owned by Citizens or Local Government Body in Service Area
• Private, For-profit	• Public, Not-for-profit
• Regulated by a State Agency	• Regulated by its Elected Board

Table 1: Key structural differences between IOUs and POUs

As this section illustrates, multiple stakeholders are involved in producing and delivering your electricity. Utilities play a central role in the grid's day-to-day as well as future operations. Upgrading the grid to accommodate more customers, more power, and more renewables is a time- and cost- intensive process that requires careful forecasting from utilities, often over five- to ten- year periods. As a result, the growing demand for BEV charging infrastructure requires significant utility input and oversight. With this business context in mind, the following sections walk you through the electricity supply, charging equipment, and construction considerations you will face as you transition your fleet to electricity, and provide strategies to help you optimize your EVSE project.

Transitioning to Electricity for Your Fleet

If you are considering transitioning your fleet from conventionally fueled vehicles (gasoline and diesel) to BEVs, then there are several important infrastructure-related factors to address. Some of these factors involve familiar issues and decisions you already know from operating conventionally fueled vehicles. Others introduce new concepts that are unique to BEVs. Regardless of your fleet's specific needs and transition schedule, every project should start by clearly defining the charging requirements for the BEVs you are planning to deploy. This exercise allows you to build all other project components around ensuring that your BEVs are optimally charged and deployed to best fit your fleet's bottom-line characteristics and duty cycles.

This section provides strategies and examples to help you answer key questions, including:

- **How much energy does my fleet need, and when does it need it?**
- **What charger type is the best match for my BEV fleet?**
- **What other equipment will I need to put on my lot?**
- **Where do I put my new charging infrastructure?**
- **Who approves my EVSE project?**

KEY TERMS

Average Power: The amount of power that your fleet requires while charging, averaged over the charging window.

Charge Rate: The rate at which a BEV is charged, measured in kilowatts (kW).

Charging Window: The period of time in your fleet's duty cycle when vehicles can charge.

kWh: Kilowatt-hour, a unit of measure for electrical energy. 1 kWh is the energy delivered by 1 kW of power for 1 hour.

Load profile: A graph showing the amount(s) of power that your fleet requires over the course of a day.

Watt: A unit defining the speed at which electrical energy is consumed (energy per second).

Understanding your Fleet's Energy Needs

The first step in the development of charging infrastructure is to understand how much electricity must be delivered to the vehicles you have selected, and when that energy must be delivered. These two factors, "how much" and "when", define your *load profile*. Understanding your load profile enables you to determine what equipment you will need to fuel your vehicles in a timely and cost-effective manner, and to forecast your electricity costs. Constructing a basic load profile is straightforward, provided that you know how much electricity you will need to supply to each vehicle during charging events. Figure 4 illustrates the information you will need to build your load profile, and the examples on the following pages walk you through the calculations.

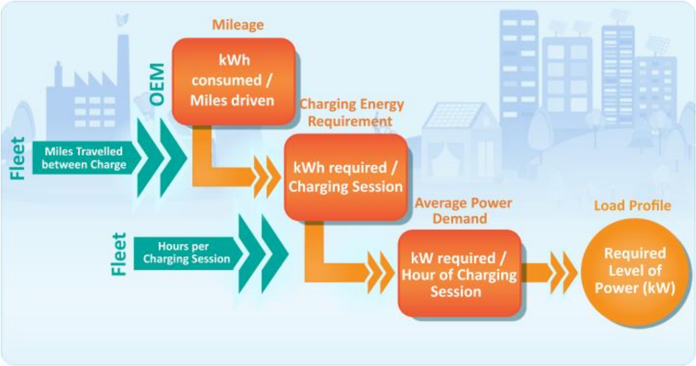


Figure 4: Components and process for developing your load profile

Kilowatt or Kilowatt-hour? Appropriate Use Cases

Knowing when to use the terms *kW* and *kWh* can be confusing. It can help to remember that *kW* is a rate that defines the energy-per-second that a system can produce, while *kWh* is a quantity of energy that can be transferred or stored. Battery capacities are measured in *kWh*, while EVSE are measured in terms of the maximum *kW* at which they can charge a vehicle.

A good place to start is to work with your vehicle manufacturer to estimate your BEV's energy consumption in your specific operations. This will be calculated in terms of *kilowatt-hour* (kWh) per mile (or kilowatt-hour per hour for some vocational fleets). Note that this reverses the mile per gallon (mpg) fuel economy that you may recognize from traditional fuels. Under this conventional metric of distance travelled per energy consumed a higher value indicates better energy efficiency (8 mpg is better than 5 mpg), but when reversed to describe energy consumed per distance a lower value is preferred (8 kWh/mile is worse than 5 kWh/mile). Manufacturers commonly phrase BEV mileage in terms of kilowatt-hour (energy) per mile, although as with conventionally fueled vehicles these are estimates and subject to change with a vehicle's payload. If you have not yet determined this value for your vehicles, reasonable illustrative values for different vehicle types are shown in Figure 5; these energy consumption rates will be used for the examples further below. Once you have estimated the energy consumption rate that a given type of BEV will achieve in your fleet, you can use the following steps to determine your basic load profile.

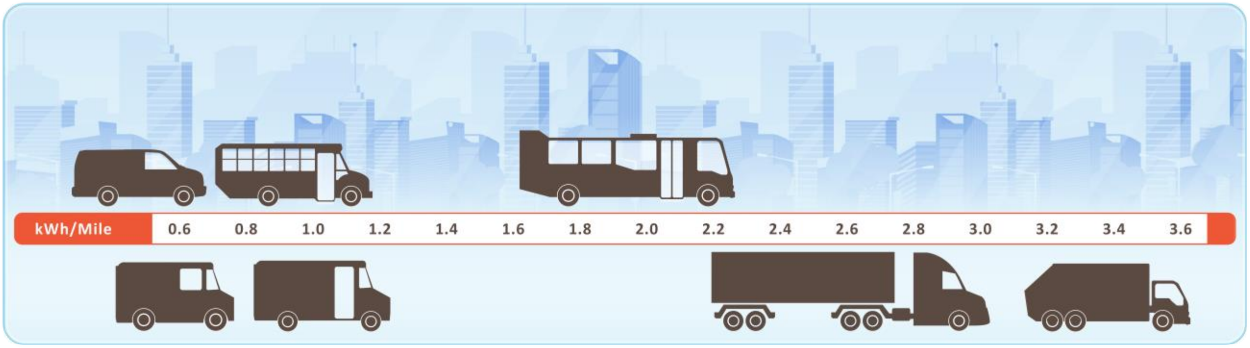


Figure 5: Typical BEV energy consumption rates for medium- and heavy- duty vehicles.

First, calculate how much energy will be needed per charge for each BEV you purchase. This will be the BEV's energy consumption rate (kWh/mile) multiplied by the miles traveled between charging events, or:

*Charging Energy Requirement (kWh/charge) = VMT (Vehicle Miles Traveled between charges) * BEV Energy Consumption Rate (kWh/mile)*

The "Total Charging Energy Requirement" for the fleet is simply the sum of the energy requirements for each vehicle during that *charging window*.

Total Charging Energy Requirement (kWh/charge) = Charging Energy Requirement $_{\text{Vehicle 1}}$ + Charging Energy Requirement $_{\text{Vehicle 2}}$ + Charging Energy Requirement $_{\text{Vehicle 3}}$ …

Next, determine when the vehicles are available for charging. For example, if all of the vehicles at the fleet yard are available for charging between 6:00 pm and 4:00 am, then there is a 10-hour charging window available to deliver the required electricity to the vehicles. The *average power* required to charge these vehicles is calculated as:

Average Power Demand (kW) = Total Charging Energy Requirement (kWh) / Charging Window (hours)

Vehicles that are only available to charge for short time periods will require faster charging speeds to deliver the same amount of energy as those vehicles that can be charged over longer periods of time. Faster charging is typically more expensive because it requires an electrical system to operate at peak power, or the maximum level at which it can deliver power in a short period of time. Operating at peak power puts stress on the overall electric grid, and so utilities often charge more for peak power than for non-peak power. As a result, charging a vehicle over the entire time period that it is available to charge can reduce costs. Figure 6 below illustrates the difference in power demand when vehicles are charged over a ten-hour window (requiring 70 kilowatts peak power) versus a four-hour window (requiring 175 kilowatts peak power).

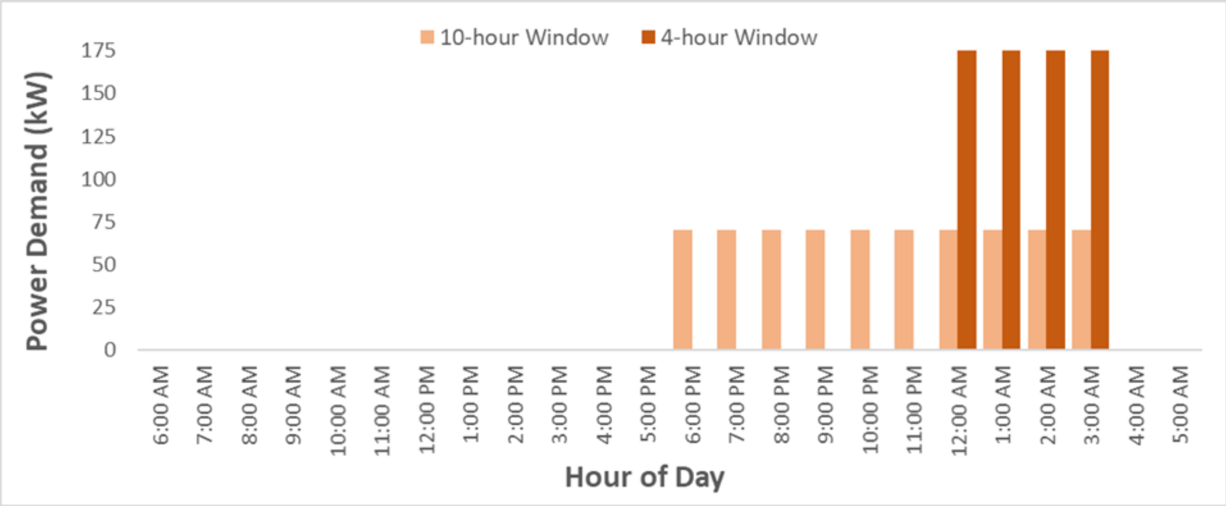


Figure 6: Power demand over 4- and 10- hour charging windows

The above illustration of a BEV fleet's charging window is also its load profile. In this case, the load profile is a simple constant power level because all of the vehicles are assumed to be available for the same time period. More complex load profiles exist when not all vehicles can be charged during the same time period or at the same rate. For example, Figure 7 illustrates the load profile from three vehicles that arrive at the yard at different times but must all finish their charging at the same time. In Figure 7, all vehicles must depart at 3 am but Vehicle 1 arrives at 6 pm, Vehicle 2 arrives at 9 pm, and Vehicle 3 arrives at 11 pm, allowing for a 9-hour, 6-hour, and 4-hour charging window, respectively. Fleets may have multiple charging windows per day, depending on when and how vehicles are utilized.

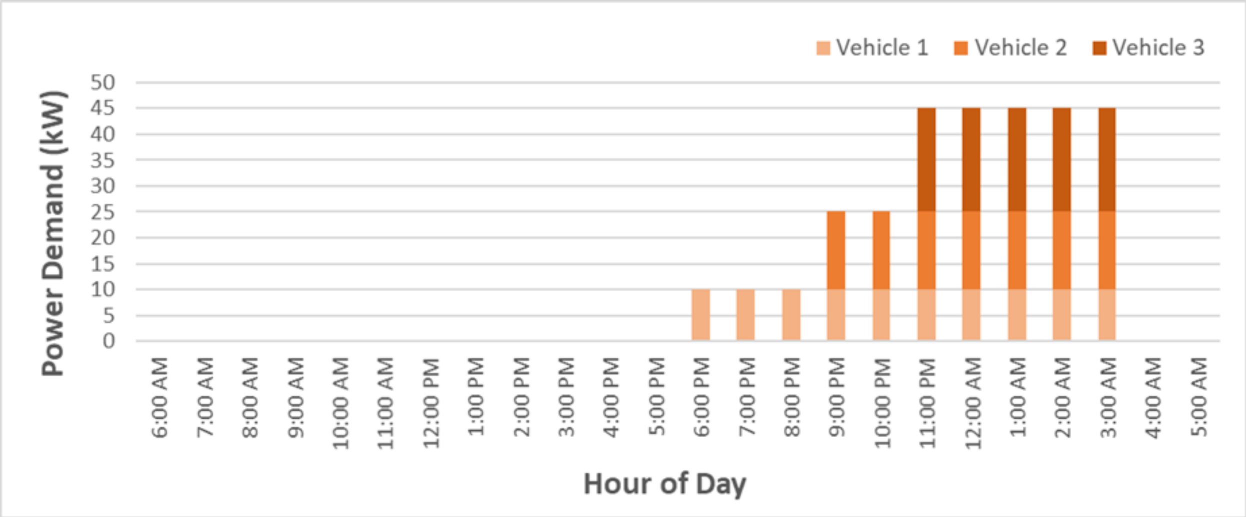


Figure 7: Power demand for multiple vehicles with different charging windows due to arrival times

Three Examples for Estimating your Basic Load Profile

Below, we look at three examples of BEV charging scenarios that further illustrate the process of determining basic load profiles. In these examples we will calculate the total energy demand and the average power demand during a charging window, and the average *charging rate* per vehicle. These values will be used later to inform infrastructure options and electricity prices.

EXAMPLE 1: CITY DELIVERY VANS

In a fleet of 10 delivery vans, each vehicle uses 0.7 kWh of electricity per mile. All vans travel an average of 100 miles per day. They return to the fleet yard by 6:00 pm and must be ready to depart by 4:00 am.

Charging Window Energy Requirement

Energy (kWh) = 10 vehicles * 100 miles/vehicle/day * 0.7 kWh/mile = **700 kWh/day**

Charging Window

All vehicles return to the fleet yard by 6:00 pm and must be ready to depart by 4:00 am. Therefore, the charging window is **10 hours**.

Load Profile and Average Power Demand

All vehicles are available for the same charging window, so the load profile shows a flat power demand during the charging window (Figure 8).

Average Power Demand (kW) = 700 kWh / 10 hours = **70 kW**

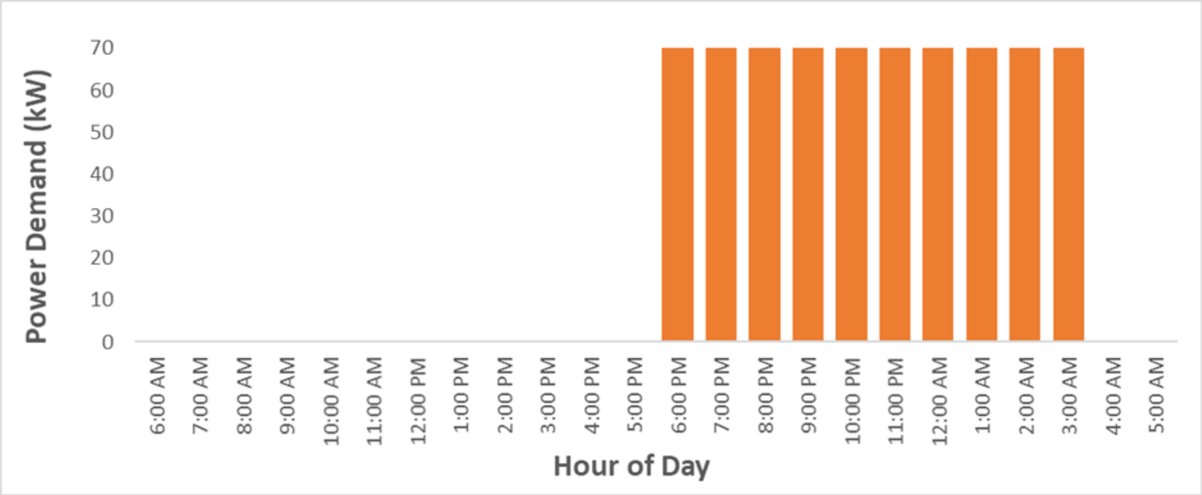


Figure 8: Average power demand for 10 delivery vans over night

Per-Vehicle Charging Rate

Because your vehicles charge at the same time, for the same amount of time, your per-vehicle *charging rate* is simply your average power demand distributed over the total number of vans.

Per-Vehicle Charging Rate (kW) = 70 kW / 10 vans = **7 kW / van**

EXAMPLE 2: LOCAL CLASS 8 TRUCKS (SINGLE SHIFT)

Ten Class 8 semi-tractors each use 2.2 kilowatt-hours of electricity per mile. All 10 trucks travel an average of 100 miles per day. They return to the fleet yard by 8:00 pm and must be ready to depart by 4:00 am.

Charging Window Energy Requirement

Energy (kWh) = 10 vehicles * 100 miles/vehicle/day * 2.2 kWh/mile = **2,200 kWh/day**

Charging Window

All vehicles return to the fleet yard by 8:00 pm and must be ready to depart by 4:00 am. Therefore, the charging window is **8 hours**.

Load Profile and Average Power Demand

All vehicles are available for the same charging window, so the load profile is a flat power demand during the charging window (Figure 9).

Average Power Demand (kW) = 2,200 kWh / 8 hours = **275 kW**

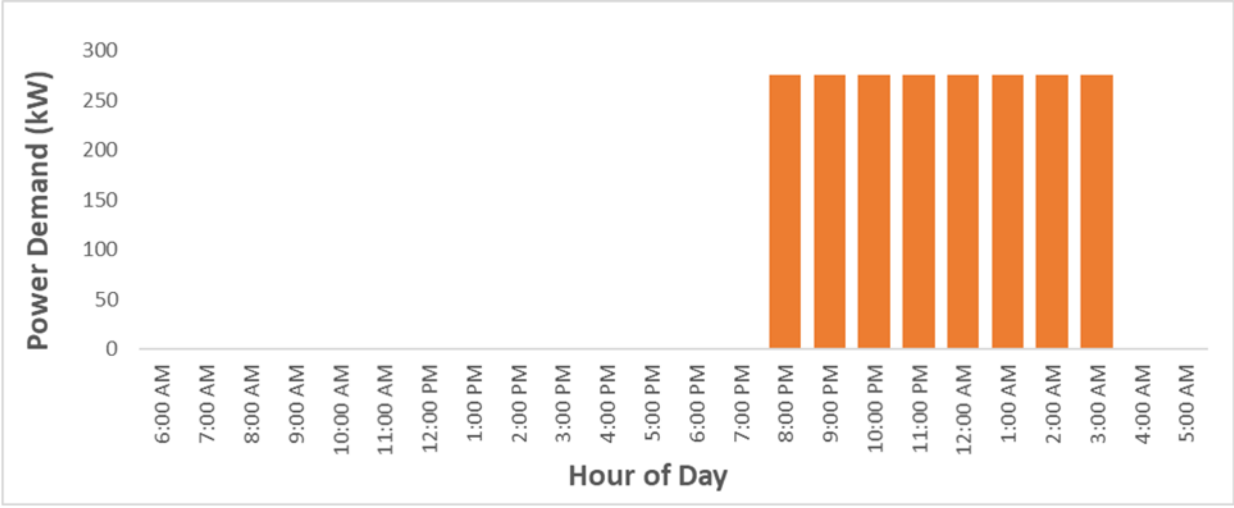


Figure 9: Average power demand for 10 Heavy-duty trucks over 1 shift

Per-Vehicle Charging Rate

Per-Vehicle Charging Rate (kW) = 275 kW / 10 trucks = **27.5 kW / truck**

EXAMPLE 3: LOCAL CLASS 8 TRUCKS (TWO SHIFTS)

Ten Class 8 semi-tractors use 2.2 kilowatt-hours of electricity per mile. All 10 trucks are used for two shifts per day, and travel an average of 150 miles during the first shift and 100 miles during the second shift. The first shift returns to the fleet yard by 12:00 pm and must be ready to depart by 4:00 pm. The second shift returns to the fleet yard by 12:00 am and must be ready to depart by 4:00 am.

Charging Window Energy Requirement

First Shift Energy (kWh) = 10 vehicles * 150 miles/vehicle/shift * 2.2 kWh/mile = **3,300 kWh/shift**

Second Shift Energy (kWh) = 10 vehicles * 100 miles/vehicle/shift * 2.2 kWh/mile = **2,200 kWh/shift**

Charging Windows

The first shift returns to the fleet yard by 12:00 am and must be ready to depart by 4:00 am. The second shift returns to the fleet yard by 12:00 pm and must be ready to depart by 4:00 pm. Therefore, the charging window is **4 hours for each shift**.

Load Profile and Average Power Demand

All vehicles are available for the same charging window, so the load profile is a constant power demand during the charging window (Figure 10).

First Shift Average Power Demand (kW) = 3,300 kWh / 4 hours = **825 kW**

Second Shift Average Power Demand (kW) = 2,200 kWh / 4 hours = **550 kW**

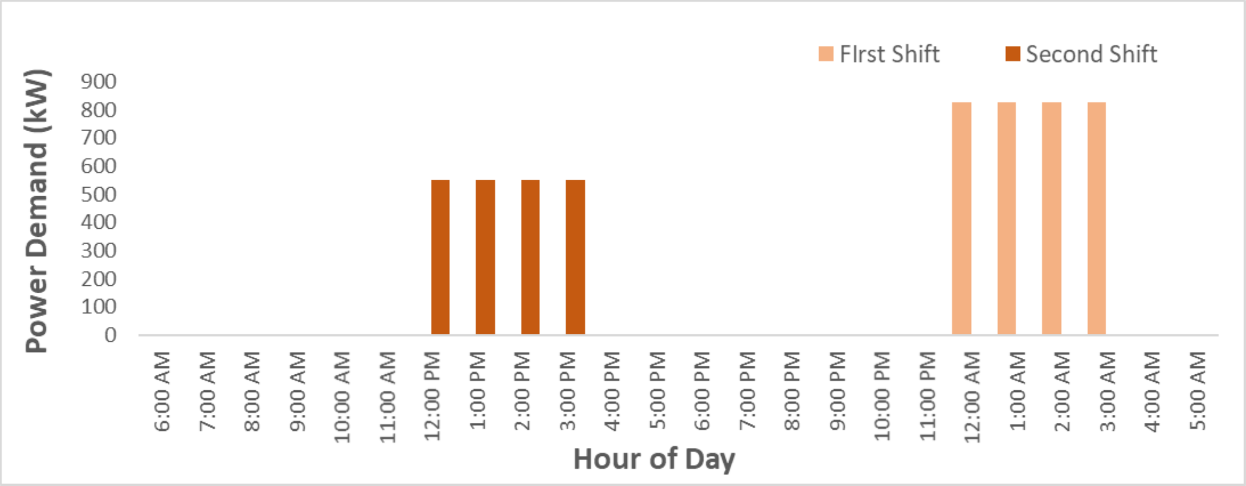


Figure 10: Average power demand for 10 heavy-duty trucks over 2 shifts

Per-Vehicle Charging Rate

First Shift Per-Vehicle Charging Rate (kW) = 825 kW / 10 trucks = **82.5 kW / truck**

Second Shift Per-Vehicle Charging Rate (kW) = 550 kW / 10 trucks = **55 kW / truck**

The examples above illustrate three charging scenarios with different total energy requirements and average power demands. They also illustrate three different per-vehicle charging rates, ranging from 7 kilowatts to 82.5 kilowatts, that are important factors to consider when choosing an EVSE to meet your daily charging needs. If the per-vehicle charging rate for your charging scenario is greater than the charging rate that your BEV can support, you must either select a different BEV or extend your charging window to reduce the required charging rate. For example, if you need to charge at a rate of 50 kilowatts per BEV (to fulfill the time per charger requirements identified in your BEV charging scenario), but the BEV you have selected can only accept a charge rate of 25 kilowatts, your charging scenario does not work for your selected BEV type.

Understanding your EVSE Options

EVSE deliver power at one of three basic charging levels: Level 1, Level 2, and Level 3 (commonly known as DC fast charge, or DCFC). Level 1 is the slowest charging option available, typically delivering power at a rate of 1.4 kilowatts (120 volts) in alternating current (AC) form. Level 2 delivers power at up to 20 kilowatts (240 volts), also in AC form. DC Fast Charging refers to charging rates of at least 25 kilowatts using direct current (DC), although commercial charging products today can provide power at rates in excess of 300 kilowatts. The electric grid transmits and delivers power to consumers in AC format, yet batteries only accept power that is transmitted in DC format. Therefore, charging a BEV from the grid requires that AC power be converted to the DC format using power electronics, which may be located inside or outside of the vehicle (see section on AC versus DC Charging).

There are also three basic types of EVSE: 1) plug-in, 2) overhead, and 3) wireless. Each EVSE type is briefly described in Table 2 with supporting details provided in the paragraphs below. Figures 11 and 12 summarize the key features as well as the pros and cons of each type.

Table 2. Basic EV Charging Interface Types

	Plug-in	Overhead	Wireless
Activation	Manual	Automated	Automated
Connection	Conductive 	Conductive 	Wireless (Inductive) 
Power Range	Up to 350 kW	Typically 350-500 kW	Up to 250 kW
Voltage Type	AC, DC, and AC + DC	DC	AC

As the term implies, each **plug-in EVSE** is equipped with a charging cord that is manually plugged into a BEV's charging receptacle (see Figure 11). Plug-in charging is by far the most common interface used today. These are considered "conductive" systems, because power is transferred to the vehicle by conductors in the plug and receptacle. There are many different plug-in interfaces based on various standards (e.g., SAE J1772, CHAdeMO, SAE Combo CCS). In addition, some BEV manufacturers (e.g., Tesla) have adopted their own proprietary standards.

Figure 11: The EVSE plug connects with the EV receptable to transmit power over a conductive system

Overhead systems are another type of conductive interface that provide power by connecting a BEV to a DC Fast Charger using an overhead connector, or pantograph. Because the pantograph can handle large conductors that would be difficult for an individual to physically move and adjust, overhead systems can charge at higher power levels than plug-type interfaces. Currently, overhead charging is mostly used in certain transit bus applications. However, it could eventually be used to provide rapid charging for trucks and other heavy-duty applications (e.g., cargo-handling equipment).

Wireless charging is a non-conductive interface that transfers power from a ground-mounted "transmitter" coil to a receiving coil mounted to the bottom of a vehicle. In practice, it is similar to wireless cell phone charging. The power received by the receiving coil is provided to the vehicle's AC charging electronics, as if the vehicle was connected to a plug-in AC charger or is used to directly charge the battery using additional power electronics on the vehicle. Wireless charging systems with power levels as high as 250 kilowatts have been demonstrated, but lower power levels down to 3 kilowatts are also possible. Wireless charging typically requires retrofitting the receiving coil to a BEV because MD and HD vehicle manufacturers do not currently offer wireless BEV charging interfaces as an integrated option.

Figure 12. Advantages and Disadvantages of BEV Charging Interface Types

Manual Conductive

Pros

- Proven solution (standard BEV charging approach)
- Lower capital cost per charge port
- Very high power (>300 kW)
- Subsurface work generally limited to trenching for power cabinets

Cons

- Requires personnel to connect vehicle before charging
- Cable management logistics

Automated Conductive

Pros

- No delay waiting for personnel to connect BEV
- Similar subsurface work as manual systems
- Improved worker safety
- Reduced operator error

Cons

- Cable management / connection logistics
- Not yet proven
- Higher capital cost per port (expensive)
- Large footprint
- Parking misalignment can prevent charging

Automated Wireless (Inductive)

Pros

- No delay waiting for personnel to connect BEV
- No cable management issues
- Reduced vulnerability to damage
- Improved worker safety

Cons

- Slightly lower power range (50-250 kW typical)
- Higher capital cost per port (expensive)
- Requires retrofit of vehicle to incorporate interface
- Parking misalignment can prevent charging
- Requires extensive subsurface work

Many charging types are now available with advanced communications software allowing users and charging station managers to monitor and even manage charging activity over their computer or mobile phone. Chargers equipped with this software are often defined as "networked" chargers. Further discussion of networking and its potential benefits to a fleet operation is provided in the section on Networking and Cloud-based Services for your EVSE.

AC versus DC Charging

In addition to the physical interface types described above, EVSE are further divided into AC (alternating current) and DC (direct current) charging. AC EVSE essentially pass power from the utility to the vehicle. On board the vehicle, electronics convert the AC power to the DC power that is required to charge the battery. AC charging is typically limited to power levels of 20 kilowatts or less, because vehicles may not have space for the larger electronics required to support higher power levels at these relatively low voltages. There are some exceptions, particularly on large transit buses and some off-road equipment where space is less constrained. Above 20 kilowatts, the electronics required to convert power from AC to DC are placed outside the vehicle, and the DC Fast Charger (DCFC) provides DC power to the BEV. These chargers are currently capable of supplying power up to approximately 350 kilowatts, and future product forecasts indicate that power supply could be as high as 3 megawatts. More information is available in the following section, High Power DC Charging.

Common EVSE Interfaces in the US

Currently, most medium- and heavy-duty BEVs in the US are equipped with at least one of three standard plug-in charging interfaces. For lower power AC charging (less than 20 kilowatts), the Society of Automotive Engineers (SAE) J1772 AC interface is typically specified. For higher power levels, between 20 and 50 kilowatts, vehicles may be equipped with either a Combined Charging System Type 1 (CCS-1) or CHAdeMO DC charging interface. Above 50 kilowatts, most vehicles will be equipped with a CCS-1 DC charging interface. These interfaces are summarized in Table 3**.**

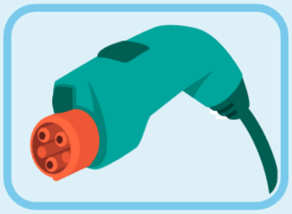
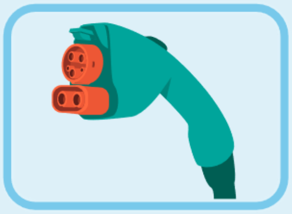
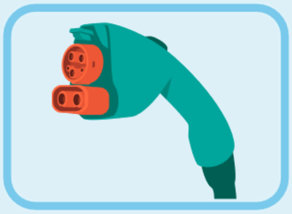
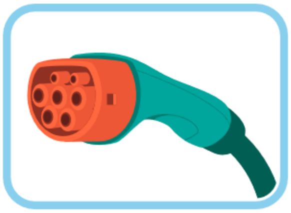
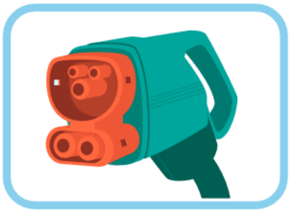
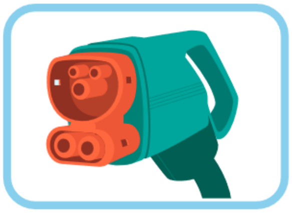
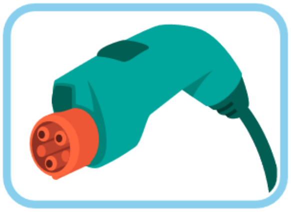
The CCS-1 plug is actually a combination plug that includes a J1772 AC interface (the large round portion at the top of the connector) and a DC interface (the two large pins at the bottom of the connector). In theory, vehicles equipped with a CCS-1 interface could use either AC or DC chargers. In practice, most vehicles that are equipped with a CCS-1 plug only support DC charging; this should be clarified with your vehicle manufacturer before assuming that a CCS-1 equipped vehicle can use a J1772 AC charger.

As previously noted, a few manufacturers have developed their own proprietary charging systems. Additionally, some vehicles may use interfaces based on the Chinese GB/T 20234 standard or European versions of the CCS standard.

SAE recently adopted a new charging interface standard known as J3068 that is intended replace the CCS-1 interface in North America. J3068 is compatible with the CCS standard used in Europe and harmonizes standards between the two regions. The standard is new and very few vehicles are currently equipped with this interface but future vehicles will likely begin to adopt it.

As the demand for heavy-duty BEVs grows, an association of automakers known as the Charging Interface Initiative (CharIN) is working to develop a charging standard for heavy-duty vehicles capable of supporting charge rates up to three megawatts, although the terms and timeline for this standard are not defined.

Table 3: EVSE Connection Standards; while the DC and AC+DC connector nozzles look identical in the SAE category, the AC pins are only installed in the AC+DC version.

	AC	DC	AC + DC
SAE J1772	 **SAE J1772 AC** **Charging Rate:** Up to 20 kW **Supply Voltage:** 120/240V/208V **Supply Amperage:** Up to 80A	 **Combined Charging System** **(CCS Type 1)** **Charging Rate:** Up to 350 kW (DC) **Supply Voltage:** 480V **Supply Amperage:** Up to 500A	 **Combined Charging System** **(CCS Type 1)** **Charging Rate:** Up to 20 kW (AC) or 350 kW (DC) **Supply Voltage:** 480V **Supply Amperage:** Up to 500A
SAE J3068	 **SAE J3068 AC_6** **Charging Rate:** Up to 133 kW **Supply Voltage:** 208-480V 3P **Supply Amperage:** Up to 160A	 **SAE J3068 DC_8** **Charging Rate:** Up to 200 kW (DC) **Supply Voltage:** 480V 3P **Supply Amperage:** Up to 200A (DC)	 **SAE J3068 AC_6/DC_8** **Charging Rate:** Up to 133 kW (AC) or 200 kW (DC) **Supply Voltage:** 208-480V 3P **Supply Amperage:** Up to 160A (AC) or 200A (DC)
CHAdeMO	**NOT AVAILABLE**	 **CHAdeMO** **Charging Rate:** Up to 400 kW (DC) **Supply Voltage:** 208-480V 3P **Supply Amperage:** Up to 500A	**NOT AVAILABLE**
GB/T 20234	 **GB/T 20234 AC** **Charging Rate:** Up to 40 kW **Supply Voltage:** 240V/480V **Supply Amperage:** Up to 63A	 **GB/T 20234 DC** **Charging Rate:** Up to 238 kW **Supply Voltage:** 480V 3P **Supply Amperage:** Up to 300A	**NOT AVAILABLE**

High-Power DC Charging

DC chargers are available in a range of sizes and power capacities, with maximum power ratings currently ranging from 25 kilowatts to over 350 kilowatts. They are most commonly offered as wall boxes, integrated cabinets/dispensers, and modular systems. Wall box or pedestal-mounted units are typically available in the lower end of the power range while integrated cabinets/dispensers are available up to approximately 100 kilowatts. Modular systems use one or more power cabinets to supply one or more dispensers and can supply up to 350 kilowatts to a single dispenser, or they can split power among multiple dispensers. A DC charger that delivers power at a rate greater than 150 kilowatts typically requires liquid cooling of the cable assembly. While these systems exist, they require additional equipment and typically have a shorter cable length. Keeping charging power levels below 150 kilowatts will increase a fleet's charging options, reduce equipment costs, and allow greater flexibility with respect to cable lengths.

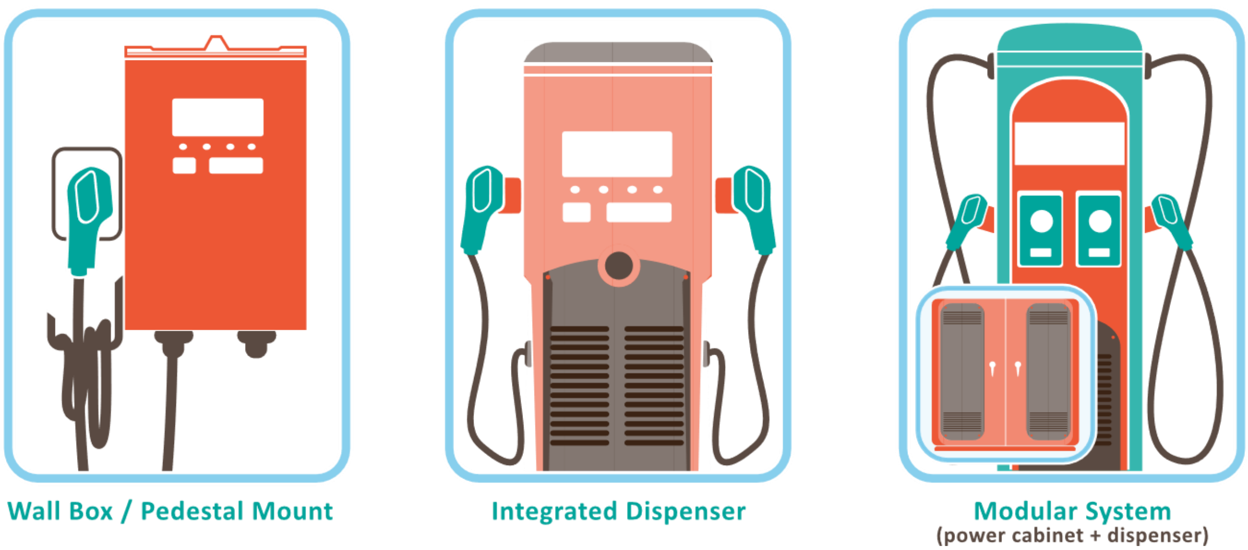


Figure 13: EVSE Equipment Configurations for DC Fast Chargers.

Charging Interface Options for Example Fleets

Previously, three fleet charging examples were shown that identified three different Per-Vehicle Charging Rates: 7 kilowatts, 27.5 kilowatts, and 82.5 kilowatts. The following examples illustrate how this information can help you identify an appropriate charging interface.

EXAMPLE 1: CITY DELIVERY VANS

Previously, we determined in Example 1 (page 10) that the per-vehicle charging rate for 10 delivery vans would be 7 kilowatts/van:

Per-Vehicle Charging Rate (kW) = 70 kW / 10 vans = **7 kW / van**

The 7-kilowatt charging rate is well within the power range for the J1772 AC interface that is commonly used in the US. J1772 AC EVSE are available in several standard sizes as determined by common circuit breaker ratings and electrical code requirements. According to these requirements, the continuous load on a circuit should not exceed 80% of the circuit's rated capacity. For example, and as shown in the table below, a Level 2 EVSE has a maximum power draw of 32 amps on a 240-volt circuit, providing 7.7 kilowatts (32 amps * 240 volts = 7,700 watts, or 7.7 kilowatts) of peak power and meeting the delivery van fleet's minimum charging requirements. The following formula is helpful for understanding these relationships:

*Watts = Volts * Amps*

In this example, a Level 2 charger drawing power at 32 amps from a 240-volt circuit provides a charge rate of 7,680 watts, or 7.7 kilowatts.

Although this meets the van fleet's calculated charging requirement of 7 kilowatts it leaves little margin for error when a vehicle uses more than the average daily energy usage or has a shorter than anticipated charging window. Specifying a 9.6-kilowatt EVSE in your design instead would provide a reasonable amount of additional margin without unnecessarily adding costs for greater electrical service capacity or EVSE capability. Networked chargers may be controlled through load management software to minimize the actual charging rate and associated costs while meeting fleet requirements (see section on Networking and Cloud-based Services for your EVSE).

Table 4: Common Level 2 EVSE power ratings and their supporting circuits

Minimum Breaker Rating (Amps)	Maximum Continuous Draw (Amps)	Power Rating (kW @ 240V)
20	16	3.8
25	20	4.8
30	24	5.8
40	32	7.7
50	40	9.6
60	48	11.5
80	64	15.4
100	80	19.2

EXAMPLE 2: LOCAL CLASS 8 TRUCKS (SINGLE SHIFT)

Previously, we determined in Example 2 (page 11) that a fleet of Class 8 trucks running local routes on a single shift schedule would require a charging rate of 27.5 kilowatts per truck:

Per-Vehicle Charging Rate (kW) = 275 kW / 10 trucks = **27.5 kW / truck**

The 27.5 kilowatt charging rate exceeds the J1772 AC standard rating, and would likely require a DCFC based on either the CCS-1 or CHAdeMO standard. Table 5, below, illustrates the circuit sizing requirements for the wide range of DCFC power ratings advertised on the market today. Vehicle manufacturers will typically specify which standard is available on their vehicles, and very few manufacturers offer the option to have more than one standard on the vehicle. For this reason, the standard of your charging equipment is determined by the standard of the interface on the BEVs you are purchasing. If a fleet plans to purchase a mix of vehicles using the CCS-1 and CHAdeMO standards, DC fast chargers are available with multiple cables, and can be configured to support both CCS-1 and CHAdeMO connector standards on a single dispenser.

Table 5: Common DCFC power ratings and their supporting circuits.[3]

Minimum Breaker Rating (Amps)	Maximum Continuous Draw (Amps)	Power Rating (kW @ 480V)
40	30	25
75	60	50
150	120	100
225	180	150
300	240	200
530	420	350

EXAMPLE 3: LOCAL CLASS 8 TRUCKS (TWO SHIFTS)

Previously, we determined in Example 3 (page 11) that a fleet of Class 8 trucks running local routes on a two-shift schedule would require two different charging rates.

First Shift Per-Vehicle Charging Rate (kW) = 825 kW / 10 trucks = **82.5 kW / truck**

Second Shift Per-Vehicle Charging Rate (kW) = 550 kW / 10 trucks = **55 kW / truck**

In a situation where the Per-Vehicle Charging Rates vary between shifts, the higher charging rate (in this example, 82.5 kilowatts per truck) sets the minimum charging rate required from your EVSE. In other words, your charging infrastructure should be capable of delivering at least 82.5 kilowatts per port. Both CCS-1 and CHAdeMO are viable options for this charge rate, in addition to various proprietary chargers that may be required by your BEV manufacturer. At this power level, it is common to consider modular DC fast charging systems rather than integrated dispensers. As previously explained, modular systems connect one or more power cabinets to one or more dispensers to provide up to 350 kilowatts, while most integrated dispensers are limited to between 50 and 100 kilowatts. As a two-part system, the modular

[3] These minimum breaker ratings are estimated based on an 80% continuous load rating. Breakers can be rated for 100% continuous loads.

option also offers more flexibility for your layout because their power cabinets can be sited at distance from the dispensers. This is valuable at sites with significant space constraints.

EVSE Selection Guidance

The following are general rules of thumb to consider when selecting EVSE for your fleet application.

- AC chargers are less expensive than DC chargers and are supplied by 240V single phase or 208V three phase circuits commonly available in most commercial facilities. Where AC charging is sufficient for your fleet's needs, it is generally the most cost-effective option.
- Specifying EVSE charge rates that are greater than the calculated average required charge rate will help avoid incomplete charging cycles. Regardless of your charge rate, most batteries currently available in BEVs charge more slowly (approximately 20% of their typical charge rate) when they are nearly depleted or nearly full.
- Keeping charge rates below 150 kilowatts will increase your DC charging equipment options, reduce equipment and electricity costs, and allow greater flexibility with respect to cable lengths.
- Rightsizing (neither under- nor over-sizing) your charging scenario for your fleet's specific application may also optimize the lifetime of your BEV's battery and energy storage system.
- Ambient temperature affects BEV charging rates and range. Fleets that may operate in cold environments with sustained average daily temperatures at or below freezing should account for extended charging times and shorter vehicle ranges during seasonal cold periods.
- Meet with your electrical utility early in the process to understand your site's power supply options, and where chargers can be sited. Your utility may also be able to advise on available funding programs.

Cost Guidelines and Funding Solutions for your EVSE

Charging equipment costs vary by vendor, order size, and level of sophistication. The following average BEV charger price ranges, listed according to level of delivered power, are useful benchmarks for estimating your capital cost, exclusive of major capital costs for utility or on-site electrical upgrades. Electrical infrastructure upgrade costs may range from a few hundred to a few thousand dollars for lower-power EVSE, and in the tens to hundreds of thousands of dollars for higher-power EVSE. Note that these ranges are estimates only based on 2018 data, and are not inclusive of extended warranties, maintenance service contracts, or recurring subscription fees. Ultimately, your project's EVSE costs are tied to the specific conditions of your site.

Table 6: Per unit EVSE average cost ranges by power level and networkability

Charging Type	Power Level	Networkable	Price Range ($)
Level 1 AC	<2 kW	No	500-1,000
Level 2 AC	<8 kW	No	500-1,000
Level 2 AC	10-20 kW	No	700-1,500
Level 2 AC	<8 kW	Yes	500-1,000
Level 2 AC	10-20 kW	Yes	3,000-6,500
Level 3 DCFC	20-30 kW	Yes	10,000-40,000
Level 3 DCFC	50-150 kW	Yes	50,000-100,000
Level 3 DCFC	>150 kW	Yes	150,000+

Note: The power level ranges presented cover the standard offerings. There are currently few standard DCFC offerings between 30 kW and 50 kW.

While transitioning a vehicle fleet to BEVs can offer significant cost savings over the long term, today's upfront costs to procure new vehicles and their chargers can be prohibitively high for many fleets. Several types of grant and buydown programs are available to reduce your fleet's infrastructure costs. The State of California has dedicated funding pools for BEV infrastructure, and several utilities offer incentive programs to buy down the capital equipment cost for their customers. Several federal programs are also available. Key funding programs for commercial and fleet EVSE infrastructure that are currently available or under development are summarized in the Appendix. Note that programs may have specific requirements such as data capture or public access to chargers, or may require that projects include vehicle purchases as well as infrastructure.

Siting your BEV Charging Infrastructure

Deciding where to site and install the charging infrastructure you need to accommodate your planned BEV fleet requires pre-planning to optimize your fleet yard's geography and operations, as well as the service you receive from your electric utility. The information that you gather from your utility and prospective vendors during the steps described in the previous sections lays an important foundation for your site plan. Engaging with these stakeholders early and throughout all stages of your design process will ensure that your team considers all options, and that your final plan is serviceable, durable, and cost-effective.

When assessing your site's physical layout, it is important to consider not just the entry, park, and exit pathways, but also the vertical surfaces, protected areas, and locations of existing electrical equipment. Figure 14 depicts one layout with the array of infrastructure you may need to consider. Walls, light posts and other vertical structures may serve as EVSE mounting locations if adjacent parking space is available; some may support overhead charging equipment. Using existing surfaces can reduce capital costs by eliminating the need for a dedicated EVSE post and in-ground wiring. However, if the space between vehicles and the wall serves as a walkway, then stretching EVSE cords across that space could create a hazard that forces pedestrians to walk through more exposed parts of your lot. If your existing surface is far from your electrical panel, the construction to extend the wired connection may be costly and disruptive. Finally, when mapping your layout, consider the space that protective infrastructure such as bollards and parking blocks will require to prevent vehicles from colliding with your EVSE or your personnel.

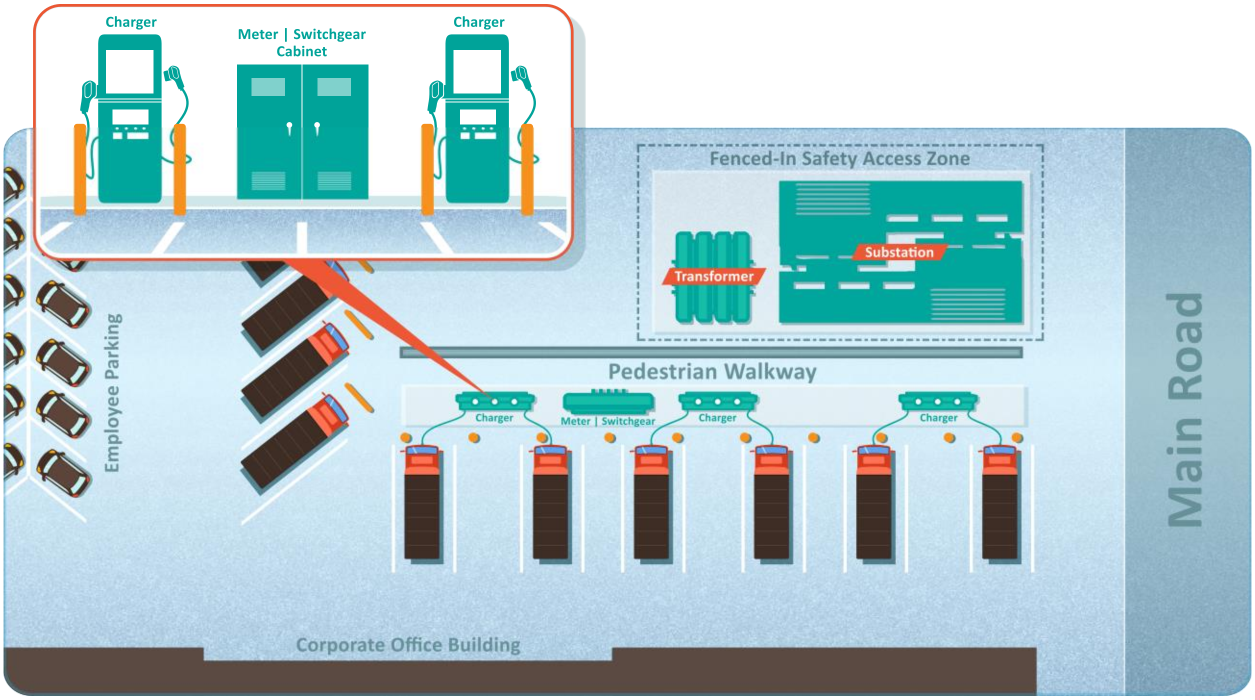


Figure 14: Electrical equipment layout at a charging depot.

Your choice of charging equipment plays an important role in your site's electrical design. If your EVSE selection requires an electrical upgrade, you may be installing a new meter, transformer, and electrical panels/switchgear. The size of this equipment depends on its capacity, and may require modifications to your building or lot. Planning for this upgrade should take into account the equipment's footprint, safe-distance requirements, allowable or recommended cable lengths, and worker access. If this is likely to be the first of several BEV projects at your facility, you may want to notify your utility early and plan for that larger future upgrade cost. Additionally, keep in mind that the nature or size of the project may trigger certain regional building code requirements to upgrade the facility and that these costs should be included in your budget development.

When designing your EVSE layout, use the following questions to guide your process.

Table 7: Guiding questions for designing your EVSE layout

Question	Things to Consider
What are your fleet's parking logistics and other operational characteristics at the depot?	• Parking location – daytime, overnight • Parking duration – daytime, overnight • Vehicle requirements – turn radius, cargo transfer, washing
What existing surfaces, structures or spaces will support the EVSE that you plan to procure?	• Wall, bollard, or overhead features' proximity to current and potential vehicle parking locations • Wall, bollard, or overhead features' proximity to your electrical equipment • Level of EVSE exposure to moving vehicles or other hazards

Can your existing electrical equipment support your expected maximum load?	• Transformer and electrical panel capacity ratings • Utility supply
What areas are commonly used for pedestrian activity?	• EVSE hazards to current pedestrian activity • Pedestrian activity as a hazard to EVSE layout

Charging Infrastructure Permitting and Procurement

EVSE installations require a building permit or similar nondiscretionary permit regardless of the project's size or charging level. Under Assembly Bill 1236, all California jurisdictions have been required to adopt an expedited approval process for EVSE permits, and to provide the public with a checklist of the information that an applicant must provide to be eligible for expedited review.[4] A project manager or prospective EVSE owner should download or request the checklist from the jurisdiction in which the EVSE will be installed, as well the appropriate application forms, at the beginning of the project development process.

EVSE permit applications typically require information on the proposed site, equipment (including manufacturer), utility service, and expected level of use. This information is collected from vendors and contractors during the technology and site assessments previously described; utility approval of the project design must be included. In California, you must notify your utility of any electrical additions or upgrades at your facility regardless of the scope or scale. The notification process varies by utility and project size, but it is good practice to engage the utility once you have determined your on-site energy needs and existing electrical equipment's capacity (see section on Choosing the Right BEV Charging Infrastructure for your Fleet). Once notified, the utility can then indicate whether its current service meets your new electricity needs, or if infrastructure upgrades are required and over what timeframe.

Permit applications are typically completed by your contracted engineer, and reviewed by a designated building official for compliance with local building, electrical, accessibility, and fire safety codes. Public safety, structural, and engineering reviews may also be required. These reviews may be conducted sequentially or concurrently, depending on the jurisdiction and the proposed project. Permit approvals typically take at least a couple of months including obtaining your utility's approval, but the actual timeline varies by jurisdiction, utility, and project complexity. Once a permit is approved the applicant is required to host a final site visit with a building inspector before beginning construction and commissioning.

[4] https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160AB1236

Although permit applications may require detailed information on your EVSE, it is advised that equipment should only be purchased once your project has been approved. A project may be rejected under an exemption, or the jurisdiction may request a revision that can only be addressed by changing your equipment type. When developing your project permit and construction timelines, you should build in time for the possibility of a permit revision process and a post-approval equipment delivery period to maintain your planning flexibility and minimize your financial risk.

Development Timelines

A project's duration depends on a variety of factors; however, some general guidelines can be useful in the early planning stages. In most utility territories, a small project with no infrastructure upgrades may only require that you notify the utility. A larger project requiring utility construction may require several weeks or months of discussion and review, and potentially a year or more for particularly complex projects. For example, the planning and construction for a transformer upgrade by a utility is typically a three-month job, but larger projects requiring new equipment such as cabling and substation modifications may require six to nine months. Your utility can provide the best estimate based on its project load and approval procedures.

Construction timelines on your property will depend on your site design and chosen vendors. If the wiring is already in place and no ground trenching is required to connect your EVSE to your electrical service, a charging station can typically be installed in one to two weeks. If electrical work is required then the construction period may extend over several weeks or months. The type of EVSE you choose will also play a role in estimating timelines. Currently, a growing number of vendors offer Level 2 EVSE as an off-the-shelf product with efficient installation, while DC Fast Chargers are sold by fewer vendors. The lower power EVSE may also require fewer infrastructure upgrades than a DC Fast Charger. Your electrical contractor and EVSE vendor can advise on the timelines, and if appropriate, how delivery and construction can be staggered to minimize disruption to your existing operations.

Ongoing Maintenance and Support for your BEV Charging Infrastructure

Once you have designed, purchased, and installed your new EVSE, you will continue to make adjustments to your operations and maintenance schedule. You may find that your staff needs basic guidance on maintaining the new infrastructure, or that your business would benefit from a sophisticated EVSE management system.

This section provides valuable pointers on the post-installation questions that you may need to consider for your business, including:

- **What is the difference between EVSE Networking and Cloud-based services?**
- **How will networked and cloud-based communications services work for my fleet?**
- **What basic maintenance should I do on my EVSE?**
- **How are my electricity prices determined?**
- **What can I do to optimize my electricity costs and fleet operations?**

KEY TERMS

Cloud-based Communications: A wireless internet-based service carrying information on EVSE status, energy consumption, location, and payments for use between the owner and the user(s).

Networking Service: An internet-based service that allows an EVSE owner to analyze basic activity data from one or more EVSE.

Networking and Cloud-based Services for your EVSE

EVSE vendors may offer advanced communications options that allow users and managers to monitor or manage their charging activity. These options typically take two forms: (1) *networking service* using a cabled or wireless internet connection, or (2) a *cloud-based communications platform*. These services are valuable to fleet managers who need to collect more activity data from their EVSE than what is reported on their monthly utility bill. Networking allows EVSE owners to monitor charging activity and detect failures in real-time over a desktop or mobile device. Additional functionality including payment collection and user interface can be added with a cloud-based communications service. Most EVSE that utilize the Open Charge Point Protocol (OCPP) should be compatible with most network providers, but may require the EVSE provider and network provider to spend time integrating the EVSE into the network provider's systems (in the case where the EVSE provider does not offer its own networking service). EVSE that use only proprietary communication protocols are likely to only communicate with the EVSE vendor's network services, restricting the fleet's choices for network providers.

Most EVSE and network vendors offer networking and cloud-based services for an up-front cost plus a monthly fee (typically $100-$900 per cord, annually). It is important to consider these costs as well as the reliability of internet and cellular service in your area. While EVSE vendors provide the software for networked or cloud-based communications, their software's reliability depends on the quality of your internet connection. If you've determined that networking or cloud-based communications are a good fit for your business, and your EVSE project's success depends on that connection, then it is important to review contingency plans in the event of less than 100% reliability from your internet service provider. If you are using grant funds for your EVSE, you may want to find out whether the grant's reporting requirements include data from a cloud-based communications platform, and plan accordingly.

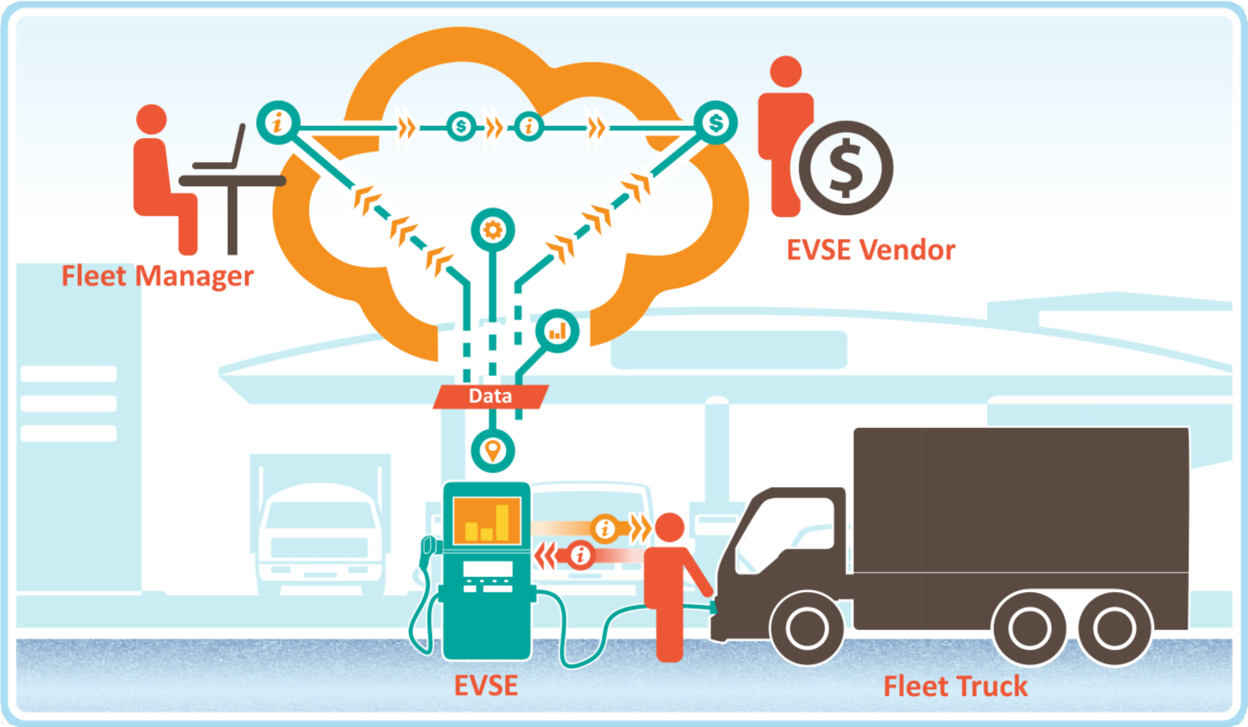


Figure 15: Cloud-based services allow fleet managers, EVSE vendors and EVSE users to share data and even payments over a wireless connection. Networked EVSE allow fleet managers to collect a smaller set of data from their EVSE.

Another resource for tracking vehicle charging may be your BEV manufacturer. Some manufacturers offer charging management systems on-board their vehicle which may produce sufficient information for some fleets and potential grant reporting requirements.

Maintaining your EVSE

Performing maintenance on EVSE is generally considered simpler than maintaining diesel fueling equipment. Still, maintaining your EVSE will initially involve unfamiliar components and procedures, which may require new training, knowledge and/or skills.

Fleets can significantly reduce their EVSE maintenance load by incorporating preventative designs into your site plan as you develop it. During the design stage, ask prospective EVSE vendors about the following features:

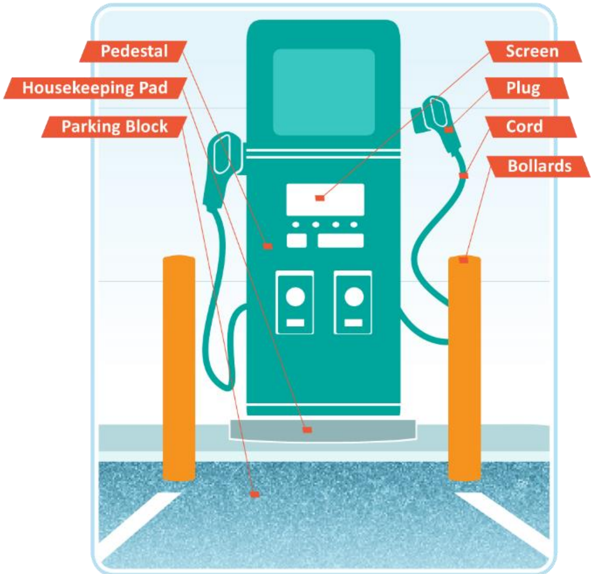


Figure 16: Anatomy of an EVSE

Housekeeping pads: Installing these under EVSE posts can limit exposure to heavy rain, snow, and dust.

Screen protection: Using protected screens that are oriented away from direct sun exposure minimizes overheating, avoiding malfunctions.

Collision protection: Installing bollards and clear signage can protect the EVSE from accidental vehicle collision, particularly in poor visibility conditions.

Cord length: Using shorter cords and/or cord controls to securely store cords when not in use limits your EVSE cord's exposure to moving vehicles and people.

Cord management: Safely storing cords on EVSE dispensers or using cord retractors when not in use will increase safety and reduce the chances of damaging equipment.

Once your EVSE is up and running, incorporating the following best practices into your regular maintenance schedule can help maximize your EVSE's useful life. If you have chosen a networked or cloud-based communications service, you may be able to receive regular alerts about problems or cleaning schedules. You can enlist the help of your EVSE vendor to understand these practices, and should always engage a professional to implement them. Before conducting electrical maintenance, it is critical that the power to the affected equipment be turned off.

- Turn off the power to your EVSE equipment before conducting maintenance.
- Inspect cords, plugs, and cord storage devices for wear and tear, or mis-use.
- Clean plugs, including the pins, with a light detergent and non-abrasive washcloth to eliminate buildup of grit or grime, which can compromise your EVSE's efficiency.
- For DCFC, inspect A/C or other cooling filters for clogging or buildup.
- Inspect area surrounding the EVSE for changes that could compromise the equipment's integrity, such as cracked pavement, flooding, access barriers, or compromised building structures (for wall-mounted EVSE).
- Review data reports for unusual results or other signs of an error in the network or cloud-based communications platform, as applicable. Comparing EVSE data with your utility bills is another way to confirm that the equipment is functioning as intended.

Most EVSE vendors currently offer a three-year warranty on their equipment. If you are purchasing networking and/or cloud-based communications services, the warranty on these features may be separate. Ask your EVSE vendor to clearly explain what components of your EVSE are covered under warranties, and their time frame.

Purchasing Electricity for Your Fleet

The process of estimating costs and buying electricity for your fleet differs from the process of procuring conventional fuel in several ways. When buying electricity (for charging BEVs or otherwise), many fleets only have one vendor to choose from – the local utility. In some areas of California, fleets may have the option to buy from a Community Choice Aggregator (CCA) or to procure power from their own renewable power source.

As a utility customer, you are billed according to your utility's *rate structure*, which defines the prices that it will charge different kinds of customers (i.e. residential, commercial, industrial, agricultural) and over different time frames throughout the day (i.e. peak and off-peak). As state policies push for an increase in BEV deployments, many utilities are introducing special rates to encourage customers to switch to electricity. It can be challenging for unfamiliar fleet managers to understand rate structures offered by the utility. This makes it challenging to select a charging plan that minimizes charging costs while fully meeting the fleet's charging needs. This section describes key components of a typical electric bill, and identifies opportunities to manage BEV charging costs through special rates and charging strategies.

KEY TERMS

BEV Demand: The amount of power supplied to BEVs during charging.

Meter: A device that records the amount of power (kW) and energy (kWh) flowing through a circuit.

Peak Shaving: A strategy to reduce power consumption during periods of high demand.

Rate Structure: A set of parameters used to define the prices that a customer may be

The following terms commonly appear on electric bills; a given utility's bill may or may not include some or all of these terms.

Flat Rate: A rate structure under which you are billed at a single price per kilowatt-hour consumed regardless of time, season or application.

Time-of-Use (TOU): A rate structure under which you are billed different prices for power you consume according to the time and season when it is consumed.

Fixed Charge: A fee covering the regulator-approved costs that the utility pays to supply your power such as distribution and transmission ($/month).

Energy Charge: Your baseline price of electricity, charged based on the amount of energy you consume ($/kWh).

Demand Charge: A fee applied to your greatest power draw during peak periods, on top of the rate that you pay for the energy ($/kW).

Seasonal Rates: Additional distribution fees covering the costs of addressing weather stressors on the electric grid during winter or summer.

Power Factor Adjustment: An adjustment to your demand charge according to how efficiently your facility consumes power.

As mentioned above, customers are billed at a rate based on the applicable use profile – some rates may be tailored to agricultural businesses, while others are suitable for the average commercial operation. If the utility bills at a flat rate, then the fleet customer pays a single price per kilowatt-hour that reflects the average cost of electricity during the billing period. If the utility bills under a TOU rate structure, the fleet may pay a lower-than-average price per kilowatt-hour during off-peak periods and a higher-than-average price per kilowatt-hour during on-peak periods. For this reason, your fleet's charging window can have a significant effect on the total EVSE project's cost profile over time. Peak and off-peak billing periods vary by utility, and may change from winter to summer as well as weekend to weekday, but are generally selected to encourage people to distribute their power use evenly over the day, to avoid demand spikes and valleys.

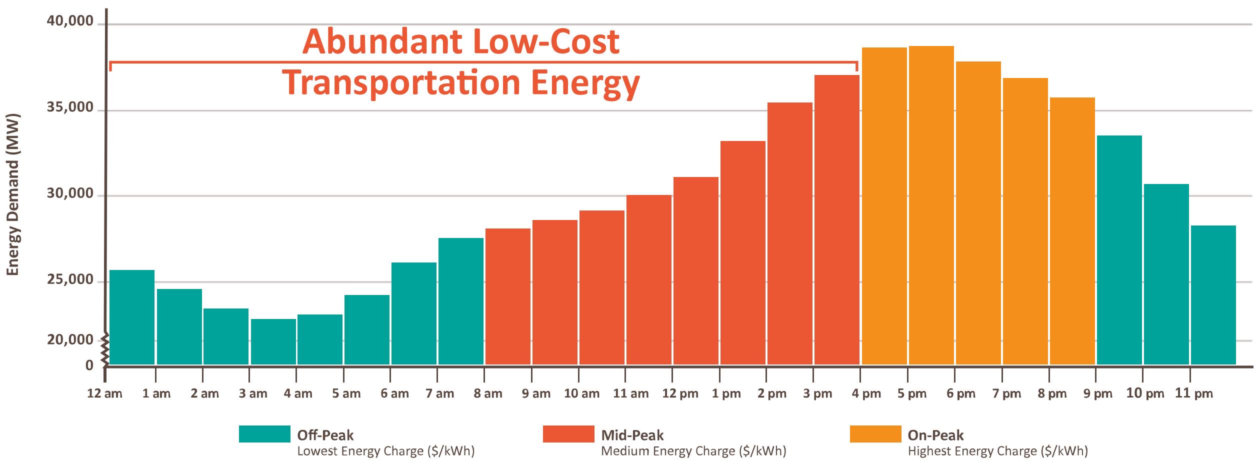


Figure 17: A typical time-of-use rate schedule to meet California's statewide electricity demand. BEV fleets can control costs by charging during off- or even mid- peak periods, as defined by your local utility.

Utilities apply Seasonal Rates when the cost of transmitting power rises due to weather-related conditions that prompt changes in customer behavior, such as a rise in demand for air conditioning during heat waves. Utilities may also apply a Power Factor Adjustment, which basically measures how efficiently the customer's equipment consumes electricity. A higher power factor at your site indicates more efficient equipment. An electrician or your utility can help you understand whether this is a concern at your facility.

Building on the City Delivery Van scenario in Example 1, the following scenario illustrates how the demand charge affects your cost of power. In this scenario, the fleet is idle between 4 pm and 4 am.

As the owner of a city delivery van fleet of 10 vehicles, you pay a Flat Rate of $0.17/kWh. You previously estimated that each van requires 70 kWh/day, so you expect that your monthly bill will show a monthly fleet consumption of approximately 14,700 kWh (70 kWh/day/van * 10 vans * 21 business days). You correctly calculate that you owe the utility $2,499. This is because:

14,700 kWh * $0.17/kWh = **$2,499**

Suppose that instead you are billed under a TOU rate structure, where peak hours are between 2 pm and 9 pm. In this case, your off-peak Energy Charge is $0.08/kWh, your On-Peak Energy Charge is $0.13, and your Demand Charge is $10/kW. Your drivers plug the vans into 12 kW chargers when they return at 4 pm, and they finish charging around 10 pm (70 kWh/12 kW = 5.8 hours). This means that 86% (5 hours on-peak/5.8 hours total) of their charging occurs during peak hours with a maximum power demand of 120 kW (10 vans * 12 kW). To calculate the amount you owe, you multiply 86% of your monthly energy consumption by the on-peak energy charge, 14% by the off-peak energy charge, and your peak demand by the demand charge.

(12,600 kWh * $0.13/kWh) + (2,100 kWh * $0.08/kWh) + (120 kW * $10/kW) = **$3,006**

You notice that demand charges comprise about 40% of your total bill. By adjusting your procedure to have half of your drivers plug in their vans at 4 pm, and the overnight manager to plug in the other half at 10 pm, you calculate that you can shift about 50% of your peak consumption to an off-peak period and reduce your peak power demand by the same fraction, yielding a 30% cost savings overall.

(6,300 kWh * $0.13/kWh) + (8,400 kWh * $0.08/kWh) + (60 kW * $10/kW) = **$2,091**

Note: Charging management software can automatically start and stop charging to reduce electricity costs, as an alternative to manually plugging in vehicles on a specific schedule.

The final step in the example above illustrates a strategy called *peak shaving*. Consumers use this strategy to reduce their demand charges by moving power consumption to off-peak periods, or by relying on on-site energy storage during peak periods, to control costs. If your fleet is able to charge during off-peak periods, you may benefit from a TOU rate over a flat rate.

Finally, some utilities offer a special BEV rate for their commercial customers, or they may waive the demand charge on the power delivered to BEVs. In order to apply these discounts to your BEV fleet's electricity consumption, you may have to separate your EV load from the rest of your facility load by installing a dedicated *meter*. At the time of your equipment upgrade, your utility can install a new meter that measures only the electricity consumed by your BEVs, making it possible for your utility to apply their discount to your BEV's power consumption.

Even if you are not required to install a separate meter for your EVSE, there are some operational and financial benefits to separating your vehicle electricity consumption from the rest of your facility's electric needs. Specific considerations are listed below.

- Setting up your EVSE on a separate meter with your utility allows you to separately track how much power is consumed to charge your BEVs. This may be useful if you have chosen not to add network or cloud-based services to your EVSE.
- Your utility may require that your EVSE be set up with its own meter (a "dual meter" set-up) if you intend to take advantage of a special BEV rate. This enables the utility to apply the special rate structure solely to the electricity used to charge your BEVs. Utilities will typically assist their customers in setting up a dual meter tracking system, at a nominal service fee. Installation fees for the second meter can be significant but can be offset by construction cost allowances provided by the utility.
- Your utility will typically offer an allowance or credit for the cost of constructing new or expanded electrical service based on your new BEV electricity consumption. The size of this credit is often significant; for some projects it may offset most or all of the cost of required utility improvements.
- Under California's Low Carbon Fuel Standard (LCFS) Program, BEV owners may be eligible to earn carbon credits with the energy (kilowatt-hour) dispensed to charge BEVs. LCFS credits can then be sold at a market-determined price. Current credit prices equate to $0.20-$0.30 per kilowatt-hour for medium- and heavy-duty vehicles.[5] Eligibility depends on several factors including proof that the energy reported is only used to power BEVs. In many cases, a dedicated meter offers the most reliable and low-cost data source, although some BEV manufacturers may include energy use data as part of their on-board diagnostic software. Your BEV vendor can advise if their technology includes this option.

If adding your new *BEV demand* to your existing account does not tip your entire facility's load into a new rate category – and you do not need to track your EVSE energy consumption for a grant, LCFS program, or other opportunity – then it may be appropriate to add your EVSE to your existing meter account. This will eliminate the one-time cost (largely installation) of adding a dual meter, and it may reduce your administrative effort. It is worth noting that some utilities have waived demand charges on EVSE, but typically only for a limited time. Understanding when these charges may be re-introduced and their effect on your utility bill over the long term will help you avoid unexpected charges later, and optimize your EVSE design from the beginning.

Energy Management Best Practices

The previous sections described ways that managed charging, dedicated meters, and networked or cloud-based services can help optimize a fleet's plan to transition to BEVs in a cost-effective and operationally feasible manner. These are all important parts of your energy management protocol. A fourth strategy for managing your costs and your energy supply is to incorporate energy storage.

Energy storage refers to any technology that can store electrical energy over a period of time. Batteries are a common form today, and some fleets are exploring recycling BEV batteries to serve their on-site storage needs. Having a steady power reserve (e.g., a large battery) can be valuable to fleets that need to charge during peak times but would like to avoid demand charges, or that receive an unreliable power supply. In these scenarios, the energy storage resource typically draws power from a separate source or at a time when electricity prices are low. A fleet can then use that pre-paid power when prices are high or electricity is not available. This behavior reduces the fleet's exposure to volatile prices and operations interruptions. Batteries are the most common form of energy storage technology, and they are available

[5] https://ww3.arb.ca.gov/fuels/lcfs/credit/lrtmonthlycreditreports.htm

in a range of capacities, physical sizes, and chemistries. Depending on your basic load profile, EVSE options, and level of power supply, energy storage may be a useful option.

Continuing the Process

The State of California has set clear goals to increase the numbers of BEVs in medium- and heavy- duty fleets by the year 2030 and beyond. Meeting these goals will require significant expansion in the number of EVSE across the state, as well as change in standard fleet operations. Municipalities and utilities have begun introducing programs to help their customers make sound BEV infrastructure investments, through both funding support and accelerated project reviews. Additional programs are likely to emerge as needs become more defined over time.

Your first project to set up BEV charging for your transitioning fleet will likely be the most time-intensive, since you will be working on this with your utility, vehicle manufacturers, and EVSE vendors for the first time. You will likely find that subsequent projects – whether follow-on phases of your first project or projects at new facilities – become more efficient through established relationships. In either case, the following best practices will help protect your project from avoidable risk.

- **Notify your utility early and often** – not only are you required to notify your utility in the State of California, but your utility can be a valuable resource for discovering new equipment solutions and cost-saving opportunities.
- **Know your vehicle and fleet** – communicate your vehicle's charging standards and your fleet's charging needs clearly so that your team can design the project to support these requirements.
- **Faster is not always better** – consider the cost/benefit tradeoffs of all charging scenarios.
- **Plan for the future** – design your layout and electrical infrastructure today to support your fleet's needs tomorrow, minimizing future construction and connection costs.
- **Look for funding** – EVSE-supportive programs exist from a variety of sources, and will continue to evolve. Track the programs relevant to your business for right-sized opportunities.

Appendix

Table 8 summarizes funding opportunities for EVSE projects that are either open or under development in the State of California, and two federal programs. Note that these programs may have specific requirements such as public access, or may require that projects include vehicle purchases as well as infrastructure, and that these requirements are subject to change over time.

Table 8: EVSE-supportive funding opportunities as of Spring 2019

Agency	Program Name	Eligible Station Infrastructure	Component(s) Funded
Funding Programs Currently Open			
Anaheim Public Utilities	City of Anaheim Public Access EV Charger Rebates	Level 2 Charging Station	Hardware; Construction
Antelope Valley Air Quality Management District (AVAQMD)	Electric Vehicle Charging Station Program	DC Fast Charging Station; Level 2 Charging Station	Hardware; Construction
Bay Area Air Quality Management District (BAAQMD)	Carl Moyer Memorial Air Quality Standards Attainment Program (Carl Moyer Program)	DC Fast Charging Station; Level 2 Charging Station	Hardware; Construction
Burbank Water and Power	City of Burbank Charging Station Rebate	Level 2 Charging Station	Hardware
California Air Resources Board (CARB)	Hybrid and Zero Emission Truck and Bus Voucher Incentive Project (HVIP) - Hybrid and Zero Emission Incentives *Must be tied to a vehicle	Level 2 Charging Station; DC Fast Charging Station	Hardware
California Energy Commission (CEC)	California Electric Vehicle Infrastructure Project (CALeVIP) Fresno County	Level 2 Charging Station	Hardware; Operations and maintenance; Construction

California Energy Commission (CEC)	California Electric Vehicle Infrastructure Project (CALeVIP) Northern California Incentive Project	DC Fast Charging Station; Level 2 Charging Station	Hardware; Operations and maintenance; Construction
California Energy Commission (CEC)	California Electric Vehicle Infrastructure Project (CALeVIP) Sacramento County Incentive Project	DC Fast Charging Station; Level 2 Charging Station	Hardware; Operations and maintenance; Construction
California Energy Commission (CEC)	California Electric Vehicle Infrastructure Project (CALeVIP) Southern California Incentive Project (SCIP)	DC Fast Charging Station; Level 2 Charging Station	Hardware; Operations and maintenance; Construction
City of Colton Electric Utility	City of Colton Electric Vehicle Charger Rebate	Level 2 Charging Station	Hardware; Construction
Federal Transit Administration	Low or No-Emission (Low-No) Bus Program	Charging Station, level unspecified	Hardware; Construction
Glendale Water & Power	Glendale Water & Power Charging Station Rebate	Level 2 Charging Station	Hardware; Construction
Island Energy	Plug-In Electric Vehicle Program Rebate	Level 2 Charging Station	Hardware; Construction
Los Angeles Department of Water and Power	LADWP Charge Up L.A.!	Level 2 Charging Station	Hardware; Construction
Pasadena Department of Water and Power	Pasadena EV Charging Station Incentive	Level 2 Charging Station	Hardware; Construction
Pacific Gas & Electric (PG&E)	Fast Charging Infrastructure	DC Fast Charging Stations	Hardware; Construction
Pacific Gas & Electric (PG&E)	FleetReady Make Ready Infrastructure Program for Medium and Heavy Duty	DC Fast and Level 2 Charging	Construction
Rancho Cucamonga Municipal Utility	Rancho Cucamonga Electric Vehicle Commercial Charger Rebate	Level 2 Charging Station	Hardware; Construction

Sacramento Municipal Utility District	Commercial Charging Incentive - SMUD	DC Fast Charging Station	Hardware; Construction
San Joaquin Valley Air Pollution Control District (SJVAPCD)	San Joaquin - Charge Up!	Level 2 Charging Station	Hardware; Construction
Santa Barbara County Air Pollution Control District	Electric Vehicle Charging Station Infrastructure Program	DC Fast Charging Station	Hardware; Construction
South Coast Air Quality Management District (SCAQMD)	Carl Moyer Memorial Air Quality Standards Attainment Program (Carl Moyer Program)	DC Fast Charging Station; Level 2 Charging Station	Hardware; Construction
Southern California Edison (SCE)	Charge Ready Transport Program	DC Fast Charging Station; Level 1 Charging Station; Level 2 Charging Station	Hardware; Construction
Ventura County Air Pollution Control District (VCAPCD)	Clean Air Fund	DC Fast Charging Station; Level 1 Charging Station; Level 2 Charging Station	Hardware
Funding Programs in Development			
California Air Resources Board (CARB) (administered by SCAQMD)	California VW Program for Zero Emission Class 8 Freight and Port Drayage Trucks *Must be tied to a vehicle	DC Fast Charging Station	Hardware
California Air Resources Board (CARB) and Bay Area Air Quality Management District (BAAQMD)	California VW Program for Zero Emission Freight and Marine Projects *Must be tied to a vehicle	DC Fast Charging Station	Hardware
California Energy Commission (CEC)	EPIC Grid-Friendly PEV Mobility	DC Fast Charging Station; Energy Production Equipment; Level 1 Charging Station; Level 2 Charging Station	Hardware; Operations and maintenance; Construction
California Energy Commission (CEC)	California Electric Vehicle Infrastructure Project (CALeVIP) Central Coast Incentive Project	DC Fast Charging Station; Level 2 Charging Station	Hardware; Operations and maintenance; Construction

Department of Energy	Alternative Fuels Infrastructure Tax Credit	Charging Station, level unspecified	Hardware
Monterey Bay Air Resources District (MBARD)	Plug-In Monterey Bay FY 2020 (Year 3)	DC Fast Charging Station; Level 2 Charging Station	Hardware; Construction
Northern Sierra Air Quality Management District (NSAQMD)	2019 AB 2766 DMV Grant Program	DC Fast Charging Station; Level 2 Charging Station	Hardware
Pacific Power - California	EV Charging Grants - California	DC Fast Charging Station; Level 2 Charging Station	Hardware
San Joaquin Valley Air Pollution Control District (SJVAPCD)	California VW Program for Zero Emission Transit, School, and Shuttle Buses 2019 *Must be tied to a vehicle	DC Fast Charging Station; Level 2 Charging Station	Hardware
San Diego Gas and Electric (SDG&E)	Medium and Heavy-Duty Electric Vehicles (and forklifts) and a school-bus centric Vehicle-to-Grid Pilot	Proposed "construction make ready" for various formats of charging and hardware rebates	Hardware; Construction