EPRI

CONSUMER GUIDE TO ELECTRIC VEHICLE CHARGING



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EPRI

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CHARGING 101

Electric cars are catching on across the country making up 9%[1] of new car sales in 2023.

New-car buyers are discovering that electric vehicles (EVs) are fun to drive, safe, comfortable, and convenient to refuel. They also cost less to run.

Almost 100 electric car models are available in the United States today, and global automakers plan to offer more in coming years. With EVs, consumers change the way they refuel. Instead of going to a gas station, they plug into the electric grid— usually at home, at work, or at public charging stations.

Even with a growing public charging network, most drivers prefer to charge at home when possible. It's more convenient, and it usually saves money. Charging your EV is as easy as charging your smart phone or computer. Simply plug it in—then carry on with life. Your car charges while you sleep, play, or work.

This guide addresses commonly asked questions about EV charging. It includes information on where to charge, charging speeds, charging on the go, charging station hardware, connectors, helpful apps, and installation considerations. It serves as a companion to ***Consumer Guide to Electric Vehicles*** *Sep 2024 (EPRI Product ID 3002031124).*

1 EPRI sales data sourced from Experian





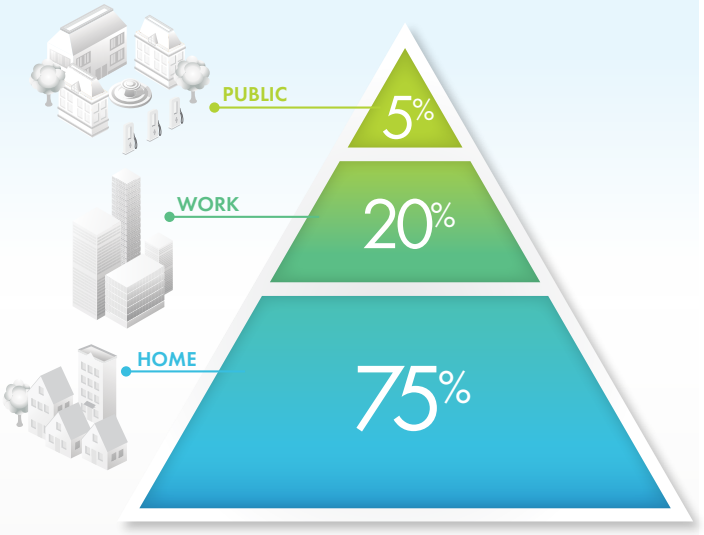




WHERE TO CHARGE

You can charge your EV at home, at work, or on the go at public charging stations.

FIGURE 1. *Charging station usage varies by location.* Today, approximately 75% of charging occurs at home, 20% at public locations, and 5% at work.



HOME

Today, most charging occurs at home, where it is most convenient and cost-effective. You can plug into a 120 Volt AC outlet (called Level 1 charging) using the charging cord (or "cordsets") that often comes standard with the EV. Some newer charging cords can also use a 240 Volt AC receptacle called Level 2 charging, which charges faster. Another option is to install a dedicated Level 2 charging station. Drivers with dedicated parking at home simply park, plug in, and walk away.

Drivers residing in multi-family housing, apartments, and condos face unique challenges around access to charging. A large barrier to charging is getting the consent of landowners and/or property managers to pursue charger installation although many states have specifically passed laws allowing renters to install charging. Those who have access to shared parking require additional coordination. A few charging solutions are available:

Assigned Charging: Charging stations are assigned to individual residents, with the property owner or driver covering the costs. This setup is convenient for residents with consistent parking spots.

Community Charging: Shared charging stations are provided, allowing drivers to use them as needed. This approach is advantageous when parking spaces are not fixed, and residents frequently change their parking location.

Mixed-Use Charging: This solution accommodates residents and visitors, providing flexibility and accessibility.

WORK

The workplace, where many people spend several hours each day, is another convenient place to refuel. Charging at work enables drivers to extend their car's range during work hours, increasing the number of electric miles they can drive each day. Some companies offer electric car charging as an employee perk, and to demonstrate corporate sustainability. Most workplaces develop their own rules for charging station use.

PUBLIC

Many EV drivers start with a "going to the gas station" mindset, so they (incorrectly) think public charging is the only (or best) charging option. It's neither. Public charging supplements home or workplace charging and provides another option to boost your car's range while you're on the go. The number of public stations nationwide is growing rapidly, from shopping centers to stops along highways. Parking and payment arrangements vary. Availability is first-come, first-served.



CHARGING SPEEDS

Three factors determine how fast your car charges: how much electricity is delivered from the source, how much electricity the car can accept, and the energy need of the car's battery.

The terms, AC Level 1, AC Level 2, and DC Fast describe how energy is transferred from the electrical supply to the car's battery. Equipment on electric cars converts AC to DC to charge the batteries, which operate on DC. DC Fast Charging delivers DC current directly to batteries in fast-charging capable cars.

AC Level 1 (120 Volt AC charging) is the slowest charging speed. It's a popular choice for home charging, especially for plug-in hybrids with small batteries, because people park at home for longer periods. It requires only the charging cord that comes standard or optional with every electric car, plugged into a new household outlet, so there's minimal installation cost.

A dedicated (i.e. hardwired) Level 1 charging station is also an option and is recommended for Level 1 charging at workplaces and in public.

AC Level 2 charging is generally faster than Level 1. Level 2 charging can occur at home, workplaces, and in public.

DC Fast Charging is limited to public or commercial applications due to its high power demand from the electric grid. Stations are increasingly available in strategic locations such as near shopping centers and along highway corridors. DC Fast Charging, as implied in its name, is much faster than the AC charging options.

	AC LEVEL 1	AC LEVEL 2	DC FAST CHARGING
Connector Type[1]	J1772 connector	J1772 connector	CCS connector CHAdeMO connector Tesla connector (NACS)
Estimated PHEV charge time from empty[2]	5-6 hours	1-2 hours	N/A
Estimated BEV charge time from empty[3]	40-50 hours	4-10 hours	20 minutes – 1 hour [4]
Estimated electric range gained per hour of charging	2-5 miles	10-20 miles	180-240 miles
Typical locations	HOME	HOME / WORK / PUBLIC	PUBLIC
Voltage[5]	120 V AC	208 - 240 V AC	400 V - 1000 V DC
Typical voltage output	1KW	7KW-19KW	50-350KW

Overview of EV chargers: power output and charge time for light-duty vehicles. (Adapted from the Alternative Fuels Data Center) [6]

1 Different vehicles have different charge ports. For DCFC, the Combined Charging System (CCS) connector is based on an open international standard and is common on vehicles manufactured in North America and Europe; the Charge de Move (CHAdeMO) connector was once most common for Japanese manufactured vehicles, but largely has been replaced with CCS. DCFC stations, while non-Tesla vehicles require adapters at these stations. Tesla vehicles have a unique connector that works for all charging speeds, including at Tesla's "Supercharger."
2 Assuming an 8-kWh battery, most plug-in hybrids do not work with fast chargers.
3 Assuming a 60-kWh battery.
4 To 80 percent state-of-charge. Charging speed slows as the battery gets closer to full to prevent damage to the battery. Therefore, it is more cost- and time-efficient for EV drivers to use direct current (DC) fast charging until the battery reaches 80 percent, and then continue their trip. It can take about as long to charge the last 10 percent of an EV battery as the first 90 percent.
5 AC = alternating current; DC = direct current.
6 https://www.transportation.gov/rural/ev/toolkit/ev-basics/charging-speeds



CHARGING COST

Charging cost depends on several factors: the price of electricity, your vehicle's efficiency (how much electricity it uses to travel one mile), and how many miles you drive. Home charging is the most economical—and the most convenient. Many utilities offer special time-of-use and EV rates for their residential customers.

The variety of charging network fee structures can be confusing for consumers. Public charging costs vary by region and network provider with some public charging stations being free and open to all. In this case electricity is subsidized by the property owner. Some automakers offer free public charging in certain networks for a limited time while other charging networks require a membership and charge a monthly fee plus usage (or a connection fee with a per-minute or per-kWh charge). They may also charge additional fees after a charging session is complete, to encourage drivers to move their cars. Another option is a monthly flat rate for all-you-can-charge. Charging on the go usually costs less than or equal to the cost of gasoline but more than that of home charging.

U.S. commercial rates for electricity are $0.111 per kWh on average. The efficiency of gasoline coupled with the electric vehicle efficiency ratio (EVER) (the ratio of miles per gallon of gasoline to miles per gallon of gasoline-equivalent) is what is used to calculate the approximate cost to charge an EV *(Table 2)*. With commercial rates in mind, the cost to charge an EV is approximately $1 per gallon of gasoline-equivalent.

TABLE 2. *Cost to Charge by Vehicle Type*[1]

Vehicle Type	Average Fuel Economy *(miles per gallon of gasoline)*	Average Cost to Charge ($) *(per gallon of gasoline equivalent)*	Average Cost to Charge ($) *(per mile)*
Subcompact cars	31.3	$0.78	$0.02
Compact cars	31.3	$1.44	$0.05
Midsize cars	31.3	$0.85	$0.03
Large cars	22.6	$1.01	$0.04
Small station wagons	26.2	$1.07	$0.04
Small SUV	30.5	$0.80	$0.03
Standard SUV	24	$0.83	$0.03

Electricity rates[2] are influenced by various factors such as location, time of year, and time of day for peak charges. Generally, electricity usage and costs are lowest late at night. This is advantageous for EV drivers who can do the majority of their charging overnight at home, which is typically the cheapest option. Some utilities offer special low rates during off-peak hours. Geographic location significantly affects electric bills, with states like Massachusetts and California having higher kWh costs (around 30 cents) compared to states like Louisiana or Wyoming (less than 12 cents per kWh).

1 EVER is based on calculations done by the National Renewable Energy Laboratory (NREL) (Electric Vehicle Efficiency Ratios for Light-Duty Vehicles Registered in the United States). The calculations for "Average Cost to Charge" assume: an average US commercial electricity rate of $0.111 (ElectricRate Electricity Rates By State (Updated October 2024)); a fuel economy of 33.7 kWh/gallon of gasoline using a conversion factor of lower heating values (U.S. Department of Energy Office of Energy Efficiency & Renewable Energy Fueleconomy.gov Top Ten); and average fuel economies (Statista, Fuel economy levels for MY 2016 through 2021 light-duty vehicles sold in the United States, by vehicle type).

2 Kelley Blue Book (kbb.com)



CHARGING ON THE GO

Most electric car drivers appreciate the convenience of plugging in at home and starting each day with a full charge. But not everyone has a dedicated parking space at home, and sometimes people need to drive beyond their EV's range. In these cases, public charging is essential.

Both Level 2, which adds 10 to 20 miles for each hour of charging, and DC Fast Charging, which adds 120 to 240 miles each hour and is used mostly for road trips, are well-suited for public charging.

The number of public charging locations nationwide is growing. Some are operated as part of regional or national networks and others have open access. The industry is developing software and standards to enable anyone to use any network's chargers regardless of membership. For more information, see page 8 for charging stations and page 10 for networks and apps.

Even with the growth in public charging locations, drivers may encounter range anxiety. What if a station shown on your charging app is in use by another EV, blocked by a gasoline car, or broken? While more work is needed to address concerns related to charger uptime and repairs, fear of being stranded will likely decline as more long-range EVs become available and more people become comfortable with their car's actual range.



PUBLIC CHARGING ETTIQUETTE

As more drivers transition to EVs, more must be done to ensure a smooth charging experience can be had by all. While most improvements will be policy-driven, there are a few measures EV drivers can take to ensure a more positive user-experience for one another such as:

- Not parking in spaces with a designated EV charger if not actively charging,
- Moving to another open parking space once the EV has gotten a sufficient charge, and
- Letting other EVs complete their charge session and/or not unplugging other EVs.

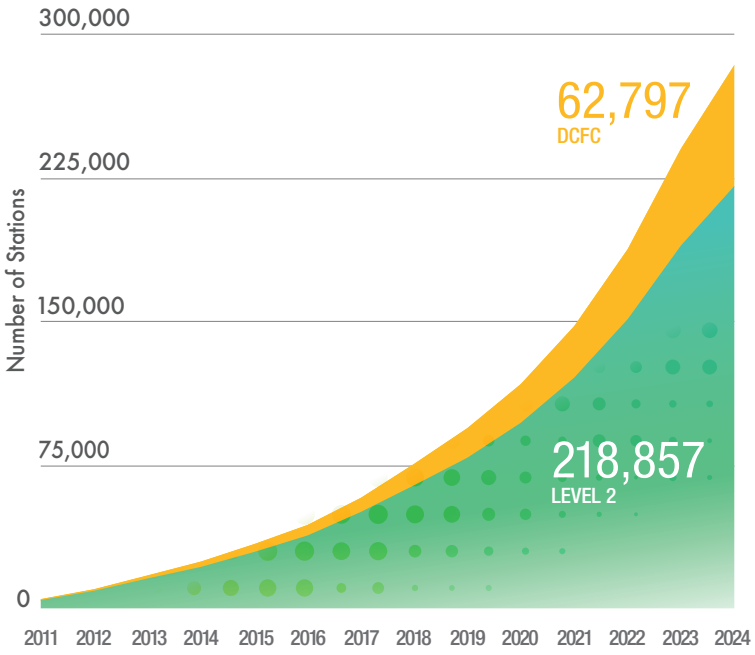


FIGURE 2. ***U.S. national growth of public EV charging infrastructure is increasing over the years.*** *(Source: Plugshare, October 2024).*



CHARGING IN THE REAL WORLD

Let's consider a few different electric vehicle drivers and their real-world driving needs.

AC LEVEL 1 AND 2 AT HOME

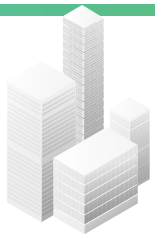


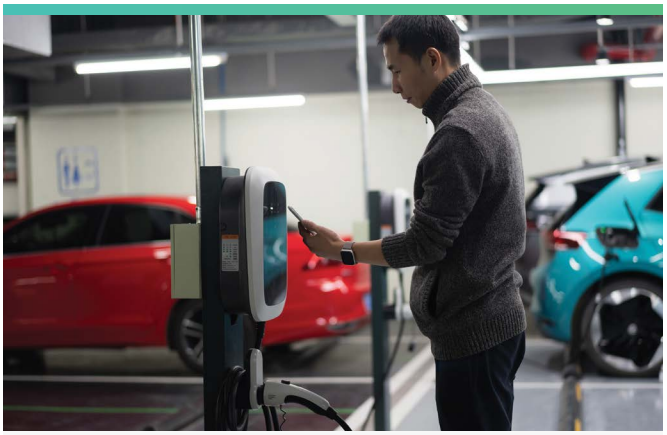


Robert used to charge his 300-mile EV every other night when he drove a lot for work. Now retired, he drives shorter distances most days and only needs to charge every four or five days, or before family trips to the mountains.

Alberto ferries the kids around town in his plug-in hybrid. Its 26-mile electric range is enough for him to drive on electricity alone most days. If he drives farther, the gasoline engine kicks in. When he gets home each night, he plugs in to have a full battery the next morning.

AC LEVEL 1 AND 2 AT WORK



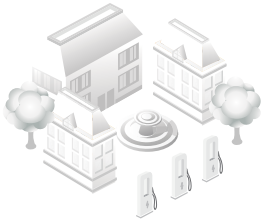


Sam commutes 35 miles each way and occasionally drives to meetings away from the office. Thanks to workplace charging, Sam can essentially double his older EV's daily driving range, to about 230 miles.

Cindy can't always rely on accessing the charging station in her condo community. But since her employer has workplace charging and she only commutes 18 miles each way, her EV with 124 miles of range meets her daily driving needs—even if she doesn't charge every day. Another perk: In her state, she can drive solo in the carpool lanes.



AC LEVEL 2 PUBLIC | DC FAST PUBLIC







Bonnie never knows how far she'll drive on a given day. She juggles a 55-mile roundtrip commute, daytime errands from work, evening choir practices, and kids' activities. She occasionally uses Level 2 public chargers when parked, allowing her to arrive home at night with range to spare.

Nandini commutes 18 miles one-way to work, attends evening classes, and frequently drives 120 miles to the state capital for meetings. In a typical commute week, she charges her 200-mile EV at home every other night to cover her daily driving needs. On longer travel days, she starts with a full charge from home and drives straight to the capital. Heading home, she stops at one of several DC Fast Charging sites along the highway to supplement her range. The 20-minute charging stop allows her to catch up on email or grab a quick snack.



HARDWARE: CHARGING STATIONS

The appliances that allow energy transfer to your electric car are usually called chargers or charging stations. (The official term is electric vehicle supply equipment or EVSE, though consumers don't use it.) Their size, functionality, power needs, and costs vary. Always be sure to choose a product certified by Underwriters Laboratories (UL).



TABLE 3. *Breakdown of Charging Capabilities*

	HOME CHARGING	WORKPLACE CHARGING	PUBLIC CHARGING
AC LEVEL 1			
Use Case	Sufficient for Cars parked at home overnight or at work / public for 8-10 hours		
Charging Rate	Up to 2 KW		
Circuit Capacity	Dedicated 110-120 VAC, 15 or 20 amp circuit		
Purchase and Installation Cost	Free – Cord comes with car, plugs into standard household outlet	Varies by location	
AC LEVEL 2			
Use Case	Faster charging; many carmakers partner with electric vehicle charging networks; consumers can choose other providers; non-networked station is sufficient for most*	Faster charging allows employees to share charging stations; some employers offer free charging; others charge a fee or use a third-party network provider*	Faster charging; some public charging is free or subsidized by carmakers, some locations charge a fee or use a third party network provider*
Charging Rate	Up to 19.2 KW		
Circuit Capacity	Dedicated 240 VAC, 30-100 amp circuit	Dedicated 208-240 VAC, 30-100 amp circuit	
Purchase and Installation Cost	$200 - $2200	$2000 - $10000	
DC FAST CHARGING			
Use Case	Not applicable for home charging	Uncommon in typical workplace setting, unless it is also a public venue	Located along U.S travel corridors and in some shopping destinations
Charging Rate	Not applicable	Not applicable	50kW, 150kW, 250KW, 350kW
Circuit Capacity	Not applicable	Not applicable	Dedicated 208-240 VAC, 30-100 amp circuit
Purchase and Installation Cost	Not applicable	Not applicable	$50000 - $100000

* Most drivers find networked stations unnecessary for home charging, since many cars come with their own remote control features and apps. Employers and property managers may want network functionality for energy monitoring, usage analysis, access control, a payment system, cellular/Wi-Fi communication, and back-office support.



HARDWARE: PLUGS/CONNECTORS

With the help of a charging cable, the plug/connector is the link between the charging infrastructure and the vehicle. It delivers current from the electrical service to charge the car's battery. Once plugged in, it also facilitates communication between the car and the charging station.

Today, there are multiple connectors including J1772 (for home and work) and an expanded version of this called the CCS combo (for DC Fast Charging). Some vehicles come with a portable charging cord that can work with both 120-Volt (Level 1) and 240-Volt (Level 2) outlets. Three standard connector types are used for DC Fast Charging are: the SAE J1772 Combined Charging System (CCS), the CHAdeMO charging interface and the Tesla proprietary system. Many fast-charging stations offer multiple coupler types. However, the automotive industry is steadily adopting a fourth charging standard, the SAE J3400 North American Charging System (NACS – a standardized version of the Tesla connector) that was developed in 2024 is expected to be used by most auto makers in 2025[1]. As the transition to a uniform connector type takes place, the use of adapters will be pivotal in making charging more standardized.

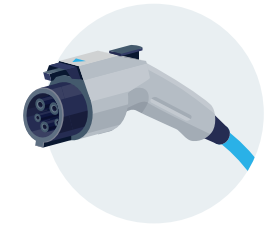
In parallel with this, Tesla began to open its Supercharger Network to non-Tesla vehicles, extending access to companies like Rivian and Ford. Other major automakers such as BMW, Genesis, General Motors, Honda, Hyundai, Jaguar, Kia, Lucid, Mini, Mercedes-Benz, Nissan, Polestar, Toyota, and Volvo are also expected to offer access to Tesla's Supercharger network.

To utilize these Superchargers, non-Tesla customers will require a special adapter, provided by the automakers themselves. At Tesla Supercharger locations, the use of third-party adapters (e.g. ordered on Amazon or eBay) is prohibited. This policy is meant to reduce the risk of serious injury and property damage. Ford and Rivian presently offer complimentary adapters to their customers for a limited time and other makers may follow suit. Tesla has also begun to modify a few of its charging stations to include built-in adapters for CCS vehicles under the name "Magic Dock"[2].

Today's charging apps typically identify the number and type of available connectors at each public charging station. *More on apps and networks on page 10.*

1 https://www.consumerreports.org
2 https://www.plugshare.com/map/tesla-ccs-locations

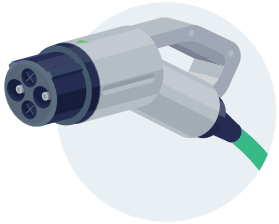
TABLE 4.
Electric vehicle charging connectors.



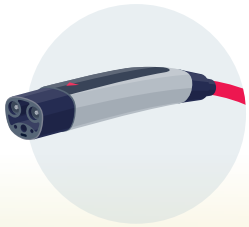
LEVEL 1/LEVEL 2/J1772



CCS 1



CHAdeMO



J3400/NACS



NETWORKS AND APPS

One of the most convenient features of driving electric is the connectivity offered by different charging networks and apps. Car companies are also working with the charging industry to show various charging networks all in the EV's central screen.

NETWORKS

EV charging networks are private companies that offer different options to meet drivers' varying charging needs. Although most networks operate on a membership basis—you sign up online, provide a credit card, download a mobile app, and get a charging card or key fob—the industry is working to improve access to all drivers regardless of membership. Some networks allow a simple credit card swipe or tap at the charging station. Others have a toll-free number that non-members can call to pay for a charging session via credit card.

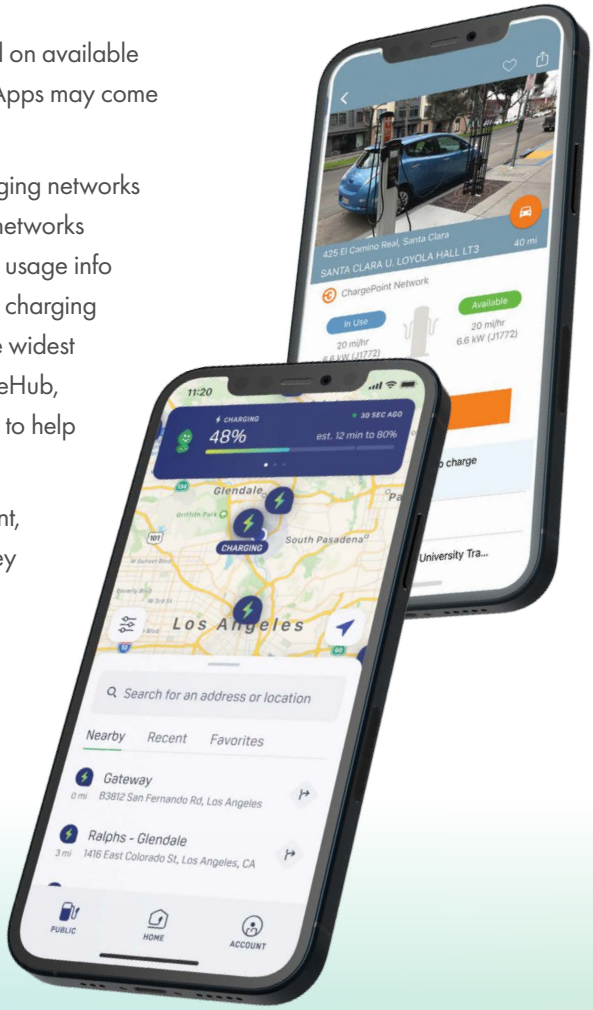
Automakers and networks are now working to develop a "plug-and-charge" capability using secure digital communication between the car's onboard software and the charger. The driver plugs in the car and walks away, the network identifies the car (owner data is hidden), and billing is handled in the background.

APPS

Apps help electric vehicle drivers locate charging stations, plan trips based on available charging stations, and remotely manage charging or cabin conditioning. Apps may come from one of three sources:

First, most automakers provide their own apps to display their chosen charging networks on the car's screen or on the driver's smartphone. Second, most charging networks have their own apps for users who register with the networks to get historic usage info over time. Finally, several independent companies offer apps that show all charging options, regardless of network. These are important because they show the widest array of charging sites. They include A Better Routeplanner (ABRP), ChargeHub, Chargeway, and Plugshare. Other apps let drivers upload tips and photos to help other drivers find the chargers.

While the amount of apps available for EV drivers is a positive improvement, it is important to note that EV drivers may begin to feel overwhelmed as they become increasingly dependent on them for their needs. Automakers and charging networks can help customers avoid this by helping them identify what services are appropriate for their specific needs and clarifying specific capabilities.





CHARGING INSTALLATION

CONSIDERATIONS:

- **TALK TO YOUR UTILITY:** Research your utility's rate plans. Driving on electricity can be much cheaper than gasoline when you choose the right rate. Ask your utility for information on charging network services, licensed local contractors, and additional local resources such as incentives. This may differ based on a utility's size and/or their capacity to provide resources as is the case for smaller municipals and co-ops.

- **LOOK FOR LOCAL, STATE, AND FEDERAL INCENTIVES:** Charging infrastructure incentives are available. *See Additional Resources on page 12.* Consultations with your tax advisor or accountant may also be useful.

- **HIRE AN ELECTRICIAN AND ASSESS AVAILABLE POWER:** If you are taking on charger installation independently, research local permitting requirements to ensure the install can be approved (Level 1 = 120-Volt AC, dedicated 15- or 20-amp circuit, Level 2 = 240-Volt AC, dedicated 30- to 100-amp circuit).

- **IF YOU WANT A LEVEL 2 HOME CHARGING STATION, CONSIDER THESE OPTIONS:**

  Physical Size – Make sure the selected charging station is sized appropriately to account for any constraints in spacing.

  Wall-Mount vs. Pedestal – Determine which option is better for your specific installation needs and constraints (i.e., indoor vs outdoor charging, trenching and/or wiring, etc.)

  Cable Length – The cable should belong enough to reach the vehicle port when parked (plus a little more for your next EV!),

  Networked or Non-networked – Always choose a product certified to the appropriate UL standards by a nationally recognized test lab.

- **CONSIDER INSTALLATION COST:** If you already have a dedicated 120-Volt AC outlet in your garage, there's no additional cost as no installation is required. However, purchasing and installing a Level 2 charging station can range from $200 to $2,200. Note that equipment and installation costs can vary significantly.

- **PURCHASE THROUGH AUTOMAKERS:** Most automakers facilitate programs through dealerships that offer third-party services for assessing EV buyers' needs and installing chargers (e.g., Qmerit).

- **TIPS ON WIRING AND LOCATION:** Charging stations can be hardwired or can use a plug. Pros and cons include portability, cost, adaptability, and appearance. If possible, place the station close to the electrical panel for simplicity and savings. Mount it so the cable can reach the charge port on your car. Note that charge ports are located to allow flexibility in parking location for charging.

ADDITIONAL RESOURCES

ADDITIONAL EPRI RESOURCES

- Consumer Guide to Electric Vehicles, Sep 2024 EPRI Product ID: 3002031124
  https://www.epri.com/research/products/000000003002031124
- Plug In America & EPRI's EVs2Scale2030 Collaborative Fourth Annual EV Driver Survey
  https://pluginamerica.org/survey/2024-ev-driver-survey/

OTHER RESOURCES

- A BETTER ROUTE PLANNER (ABRP) https://abetterrouteplanner.com/
- CHARGE HUB https://chargehub.com/en/
- CHARGEWAY https://www.chargeway.net/
- ELECTRIC DRIVE TRANSPORTATION ASSOCIATION https://electricdrive.org/
  Electric vehicle incentives: www.goelectricdrive.org/you-buy/incentives
  Electric vehicle charging 101, products, station locator: www.goelectricdrive.org/owning-ev
- NATIONAL RENEWABLE ENERGY LABORATORY (NREL)
  Electric Vehicle Efficiency Ratios for Light-Duty Vehicles Registered in the United States
  https://www.nrel.gov/docs/fy23osti/84631.pdf
- PLUGSHARE https://www.plugshare.com/
- U.S. DOE ALTERNATIVE FUELS DATA CENTER www.afdc.energy.gov/fuels/electricity.html
  Charging infrastructure https://afdc.energy.gov/fuels/electricity_infrastructure.html
- U.S. DOE AND U.S. DOT FUNDING AND FINANCING GUIDE FOR CHARGING STATIONS https://goo.gl/J8sVsq

CONTACT YOUR UTILITY

Over the last 10 years, University of California, Davis researchers have conducted a series of market studies about consumer awareness of EVs. One survey of more than 4,000 EV drivers found that only 5% talked to their utility before buying their electric car. Another survey of car-owning households found fewer than 20% had heard about incentives available from their electric utility. Electric utilities are committed to serving customers and the growing numbers of EV owners. They often offer special EV programs or rates, and some also have charging infrastructure incentives. Visit your local utility's website and call customer service to learn about EV programs in your community.

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For more information about EPRI Electric Transportation research activities contact:

Dan Bowermaster, Sr. Program Manager
Electric Transportation
dbowermaster@epri.com

EPRI
3420 Hillview Avenue, Palo Alto, California 94304-1338 USA
800.313.3774 | 650.855.2121 | askepri@epri.com | **www.epri.com**

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