

# A U.S. CONSUMER'S GUIDE TO ELECTRIC VEHICLE CHARGING

OCTOBER 2016

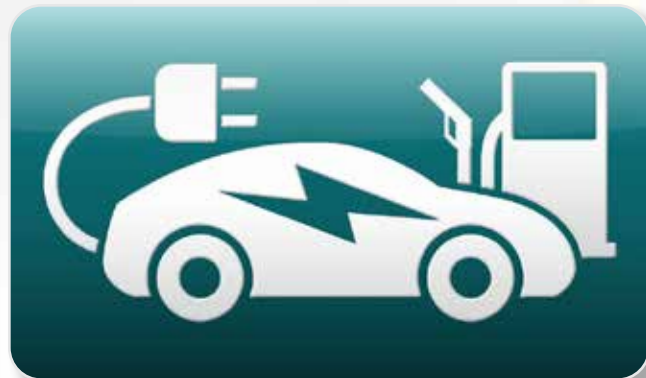


# Electric Vehicle Charging 101

Nationwide, consumers are discovering that plug-in electric vehicles are fun to drive, safe and comfortable, convenient to refuel, and economical to operate. In the United States today, global automakers offer consumers more than 20 electric car models and many have announced plans to offer more options in coming years. As of August 2016, U.S. electric vehicle sales were up 29% over the previous year.

Drivers can plug in to charge their cars almost anywhere, but most choose to charge at home—for convenience and savings. At the U.S. national average price of 12.5 cents per kilowatt-hour (kWh), “fueling” a car with electricity is roughly equivalent to buying gasoline at \$1 per gallon.

Electric cars have lower greenhouse gas emissions than the average new gasoline car today, even when charged in areas where much of the electricity is generated by power plants that use coal or natural gas. Electric cars also reduce petroleum use and smog, benefiting public health.



## ABOUT THIS GUIDE

Electric vehicles are a new technology that requires consumers to change the way they refuel. This guide addresses the most commonly asked questions about electric vehicle charging. It is a companion to *A Consumer's Guide to Plug-in Electric Vehicles, January 2016, EPRI TR 3002005948*, which answers common questions about electric vehicles and lists models available or coming soon from major carmakers.

Plug-in electric vehicles' batteries are recharged by plugging into the electricity grid, as easily as charging your phone or laptop. There are two main types, plug-in hybrids and battery electric vehicles.

Plug-in hybrids are powered by an electric motor (or two) and battery paired with a gasoline engine that takes over once the battery is depleted. Some can travel 50 miles or more on electricity before they need to be charged. Their engines extend total range to between 300 and 600 miles.

Battery electric vehicles are powered by an electric motor and battery alone; they never use gasoline. Their total range is limited by their battery size. Most current models have a range of 80 – 100 miles. Some can be driven more than 200 miles between charges. Future models promise a range of 200 – 300 miles.

## IN THIS GUIDE

### Where to Charge..... 4

You can charge at home, at work, or at public charging locations.

### Charging Levels and Times .....6

Level 1, Level 2, DC Fast Charging – what it means and why it matters.

### Hardware: Stations and Connectors .....8

Choosing the hardware to fit your needs, and demystifying tech-talk.

### Software: Networks and Apps..... 10

New tools help you find a charging station, track your car's charging status, and more.

### Installation Considerations ..... 11

Avoid installation pitfalls, learn from others.

### Additional Resources..... 12

It takes 30 seconds or less to plug in your car. Forget the hurried stop at the dirty gas station. Your electric car is charging while you carry on with life – being productive, playing, or sleeping.

## WHAT DOES IT COST?

### COST TO PURCHASE AND INSTALL CHARGING STATION



Level 1 uses a regular 120V wall outlet, so installation is free.



For Level 2 charging station, \$400 – \$2,000 for purchase and installation; equipment and installation costs vary.

### COST TO CHARGE

Table 1 – The cost to charge depends on your electric rate, battery size, and how far you drive. Cost range shown is for two average electric cars (one driving 3 miles per kWh and the other driving 4 miles per kWh) assuming an average electricity price of \$0.125 per kWh.

Miles Driven	Cost Range
30	\$0.94 – \$1.25
100	\$3.13 – \$4.17
200	\$6.25 – \$8.33

Between June 1, 2015 and June 1, 2016, the number of public charging stations in the U.S. increased by 8,308, or 49%. During the same period, the number of DC Fast Charging stations increased by 1,407, or 66%. *Source: PlugShare*

# Where to Charge

The most common places to charge your electric vehicle are at home, at work, or at public charging stations.

## CHARGING AT HOME

You can charge your car anywhere you have access to a 120V outlet or a charging station—but you will probably find it most convenient to charge at home. You can plug into a household outlet using the cord that comes with the car, or for faster charging install a 240V charging station.

Home charging is as easy as plugging in your cell phone at bedtime. You wake up with a full charge and the freedom to go. Many utilities offer lower electricity rates overnight or electric vehicle rates that encourage charging overnight, when electricity is plentiful.

A dedicated parking space, garage or carport enables you to charge at any time. If you live in an apartment or condo, talk to your building manager and neighbors. See page 11 for installation considerations and the back cover for additional resources on charging in multi-family buildings.



## CHARGING AT WORK

The workplace is the second most likely place to charge since most people spend several hours at work. Charging at work enables drivers to extend their car's range during the work day, increasing the number of electric miles they can drive each day.

Some companies offer charging to attract and retain employees and demonstrate commitment to environmental goals, among other benefits. Most develop their own rules about charging station use. See the back cover for links to additional resources on workplace charging.



## PUBLIC CHARGING

With public charging stations at strategic locations, you can supplement your range while you're on the go. Charging stations in parking garages, parking lots, or on the street are typically first-come, first-served. Some are free, others require payment. Some are networked, others are not. Parking and payment arrangements depend on the site and reflect the property managers' or owners' decisions.

Many people mistakenly think public charging is the only (or best) option for charging electric vehicles. With a "going to the gas station" mindset, they may not consider the benefits of charging at home or work. Society's experience with gasoline cars influenced early discussions about how much public charging is needed. A study of average U.S. driving behavior, however, finds that a relatively modest deployment of public charging can meet the needs of most electric vehicle drivers.





## NETWORKED VS. NON-NETWORKED CHARGING STATIONS

A handful of private charging networks operate in different regions of the country. A networked charging station is connected to one of these established networks, and may require payment and/or membership for use. A non-networked station typically has open access. See pages 8 and 10 for details on charging stations and networks.

### PUBLIC CHARGING ETIQUETTE

- Don't park at a charging station if you're not charging.
- Charge only when necessary.
- Charge up, then open the space for the next driver.
- Don't unplug another car unless it's finished charging or has a note on the dashboard indicating when it's OK to unplug.





### CHARGER AND RANGE ANXIETY

Most drivers overcome initial fears of being stranded as they become familiar and comfortable with their car's range. Charger anxiety results when drivers worry that a charging station shown on their charging app may not exist, or may be blocked by a gasoline car, in use by another electric vehicle, or broken. In a pinch, emergency roadside assistance offered by some carmakers or through insurance companies can provide a tow home or to the nearest charging station.

# Charging Levels and Times

The time it takes to charge depends on multiple factors, including the charging level, electrical circuit capacity, the vehicle's onboard charger capacity or charging limit, and battery size. Table 2 summarizes the variables.

Table 2 – Charging levels and times

	CHARGING LEVEL	CIRCUIT CAPACITY; DESCRIPTION	LOCATION	ONBOARD CHARGER CAPACITY	MILES/HOUR OF CHARGING*	COMMENTS
	AC Level 1	Dedicated 110-120V, 15- or 20-amp circuit; three-prong outlet; cordset comes with car; or charging station.	Home Work Public	1.4kW	4 – 6	Since cars are often parked at work or home for 8+ hours a day, Level 1 may be sufficient.
	AC Level 2 (Low)	Dedicated 240V, 30-amp circuit; charging station.	Home Work Public	3.3kW	8 – 12	Sufficient to charge many electric vehicles with no time limitations.
	AC Level 2 (High)	Dedicated 240V, 40-amp – 100-amp circuit; charging station.	Public Work Home	6.6kW – 19.2kW	16 – 24 for lower power; >60 for higher power	Lower power sufficient to charge most electric vehicles with no time limitations; 40-amp circuit most common for home charging. Higher power sufficient for battery electric vehicles with time limitations; infrequently used for home charging.
	DC Fast	Dedicated 480V – 600V, up to 300-amp circuit; charging station.	Public	30 – 100kW**	150 – 200***	Charges most battery electric vehicles to 80% in 20 minutes.

\* Numbers are approximate. Charging time varies based on the car's battery size.

\*\* Most fast-charging stations currently are rated at 50 kW; Tesla Superchargers can be higher; 150 kW is planned and up to 350 kW is in research.

\*\*\* Tesla Superchargers are slightly faster.

## CHARGING IN THE REAL WORLD



### LEVEL 1 CHARGING AT HOME

Jane Jones commutes 21 miles each way to work and sometime runs errands on the way home. Her battery electric vehicle with 80 – 100 miles range meets her daily driving needs and allows her to use the carpool lane as a single driver, a bonus perk in her state.

Alberto Alhambra is a stay-at-home dad who ferries the kids to school and afterschool activities every day. Alberto's plug-in hybrid vehicle with 40 – 50 miles electric range equips him to drive most days on electricity, alone. Twice a week he drives his son to little league games out of town, extending his range with gasoline.



### LEVEL 1 AND 2 CHARGING AT WORK

Sam Simonitz landed a new job 55 miles from home, his roundtrip commute exceeding the comfortable range of his electric car. Because his new employer offers workplace charging, he can keep his beloved car, drive it occasionally for work, and charge at home overnight and at work. This essentially doubles his daily driving range to about 160 miles.



### LEVEL 2 PUBLIC CHARGING

Bonnie Barnes never knows for sure how far she will drive on a given day. She commutes eight miles to work, often runs home at lunch to walk the dog, drives to meetings, and shuttles her daughter to soccer practice, 20 miles from home. Because there are public chargers at the soccer field, she can use those two-plus hours to boost her electric vehicle's 80-mile range, arriving home with electrons to spare.



### DC FAST CHARGING ON THE GO

Ruben Richardson works from home and occasionally visits clients up to 150 miles away. He typically charges at home, but also relies on the regional DC Fast Charging network along the highways. On weekend visits to his in-laws, 90 miles away, he charges on the way home. Sometimes he relies on the DC Fast Charging network to take his family on road trips across the state, up to 400 miles.








# Hardware: Stations and Connectors

A new electric vehicle buyer may find the different charging station and service options confusing.

## CHARGING STATIONS

Electric vehicle drivers encounter different charging stations at home, at work, and in public. For home charging, the station and functionality you choose depends on your needs. Most car companies have partnered with charging station manufacturers and service providers, but you don't have to purchase your carmaker's chosen charging station and network provider.

Table 3 – Charging options and hardware

HOME CHARGING	WORKPLACE CHARGING	PUBLIC CHARGING
		
<p>Using the 120V cordset that comes with your car may be sufficient to charge at home overnight.</p>	<p>Cars parked at the office all day can use Level 1 charging.</p>	<p>Some public charging is free or subsidized by car companies. Other locations charge a fee or work through a third-party network provider.*</p>
		
<p>A Level 2 charging station speeds charging. A non-networked station is sufficient for many home charging needs.</p>	<p>Level 2 charging speeds charging, allowing more users to share charging stations. Some employers offer free charging. Others charge a fee or work through a third-party network provider.*</p>	<p>DC Fast Charging stations are springing up along portions of key U.S. travel corridors on the East and West Coast.</p>
		 <p>Tesla has its own network of Level 2 and fast-charging Supercharger stations; free for Model S and Model X drivers.</p>

\* Employers and property managers may want network functionality. Networked stations can provide some or all of the following: energy monitoring, usage analysis, access control, a payment system, cellular/Wi-Fi communications, and back-office support. See *Installation Considerations*, page 11, and *Additional Resources*, back cover.

Charging stations are also called electric vehicle supply equipment, or EVSE, in the industry.








## CONNECTORS

The connector is the plug that delivers current from the electrical source to charge the car's battery. It also facilitates communication between the car and the charging station so the charging process is automatic once the car is plugged in.

All electric vehicles except Tesla use a standard connector for Level 1 and Level 2 charging. There are two standard connectors for DC Fast Charging: one adopted by Asian automakers, and the other adopted by European and American automakers. Tesla uses its own connector.

Before driving to a public charging station, it's helpful to know the different connectors and whether your car accepts DC Fast Charging, so you can be sure of compatibility.

Table 4 – Electric vehicle charging connectors

	CONNECTOR DESCRIPTION	CHARGING LEVEL	POWER
	120V cordset with SAE J1772 standard connector comes with all electric vehicles except Tesla. The J1772 connector plugs into the car; the other end plugs into a three-prong outlet.	Level 1	1.4kW
	SAE J1772 standard connector used with charging station.	Level 1 Level 2	3.3kW – 19.2kW
	SAE Combo connector used with American and European cars that are fast-charging capable.	DC Fast Charge	30kW – 100kW
	CHAdeMO connector used with Asian cars that are fast-charging capable.	DC Fast Charge	30kW – 50kW
	Tesla connector used only with Tesla Model S and Model X.	Level 2	10kW – 20kW
		Supercharger	Up to 145kW

### KEEP AN EYE OUT FOR...

- **Wireless Charging.** Currently in demonstration phase. Technical standards, still in development, have slowed widespread adoption.
- **Vehicle-to-Grid.** Future technology may enable energy transfer from electric vehicle batteries to the electricity grid.
- **Vehicle-to-Home.** Future technology may enable the electric vehicle to act as a backup generator for the home or other electrical loads.

# Software: Networks and Apps

One of the most convenient features of driving electric is the connectivity offered by different charging networks and apps.

## CHARGING NETWORKS

Electric vehicle service providers are private companies that offer charging options to meet drivers' varying needs. Although most networks operate on a membership basis, the industry is working to improve access to all drivers regardless of membership.

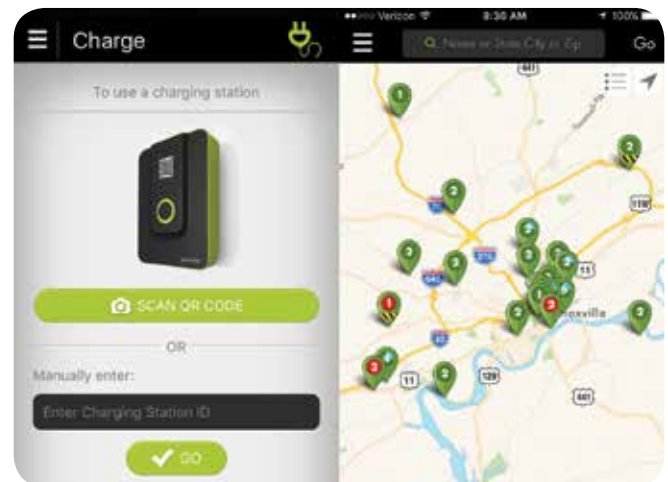
Table 5 – Charging network basics

TYPICAL NETWORK FEE OPTIONS	NETWORK ACCESS	TRAVEL BETWEEN NETWORKS
Monthly flat rate for all-you-can-charge.	Cloud-based mobile app with activation code.	Not yet standardized, but interoperability is improving.
Monthly membership fee + fee per kWh or fee per minutes/hours of charging.	RFID key tag or key fob.	Instead of joining multiple networks, a credit card works for many, but not all.
Some offer free charging in one location and levy a fee in another, usually depending on the host location.	Credit card swipe.	It's best to join a network that effectively serves your area.

## APPS

Apps help electric vehicle drivers locate charging stations, plan trips based on available charging stations, and remotely manage charging or cabin conditioning. Most automakers provide their own apps to display their chosen charging networks on the car's screen or on the driver's mobile smartphone. Several unaffiliated companies offer apps that show all charging options, regardless of network.

New social apps connect electric vehicle drivers. Drivers post equipment reports and photos of charging installations, compare their driving efficiency and energy consumption, and—most helpful in a pinch, perhaps—request permission to unplug another car.



Electric vehicle service providers go by the industry acronym EVSP.

# Installation Considerations

The following considerations apply whether you're installing a charging station or a simple 120V outlet. Property managers and employers may wish to consult Additional Resources, back cover.

<b>01</b>	<b>TALK TO YOUR UTILITY.</b> Research your utility's rate plans and do the math. 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.
<b>02</b>	<b>LOOK FOR LOCAL, STATE, AND FEDERAL INCENTIVES.</b> Some charging infrastructure incentives are available. See Additional Resources, back cover.	Consult your tax advisor or accountant.
<b>03</b>	<b>DECIDE ON YOUR CHARGING NEEDS.</b> Level 1 (standard 120V outlet)?	Level 2 (dedicated charging station)?
<b>04</b>	<b>HIRE AN ELECTRICIAN AND ASSESS AVAILABLE POWER.</b> Level 1 = 120V, dedicated 15- or 20-amp circuit. If you're DIY, research local permitting requirements.	Level 2 = 240V, dedicated 30- to 100-amp circuit (most are 40 amps; higher amperage accommodates future higher power, faster chargers).
<b>05</b>	<b>IF YOU WANT A LEVEL 2 HOME CHARGING STATION, CONSIDER THESE OPTIONS.</b> Physical size; some are quite large and heavy. Wall-mount vs. pedestal.	Cable length; 25 ft. cable recommended. Networked or non-networked.
<b>06</b>	<b>CONSIDER COSTS.</b> \$0 for existing dedicated 120V outlet in your garage (nothing needs to be done).	\$400 – \$2,000 to purchase and install a Level 2 charging station; equipment and installation costs vary.
<b>07</b>	<b>INSTALL STATION.</b> Charging stations can be hardwired or can use a plug. Pros and cons include portability, cost, adaptability, and appearance. If possible, locate the station close to the electrical panel, for simplicity and savings.	Mount it so the cable can reach the front or back of a car. Charge ports are located in different places on every car, and you may want to charge outside your garage.

## CONTACT YOUR UTILITY

University of California, Davis researchers surveyed more than 4,000 electric vehicle drivers, finding that only 5% talked to their utility before buying their electric car. Electric utilities committed to serving customers and growing numbers of electric vehicle owners typically offer special electric vehicle programs or rates. Talk to your local utility to learn about electric vehicle programs in your community.

## ADDITIONAL RESOURCES

### YOUR LOCAL UTILITY

Contact your utility for information about electric vehicle rates, and local and regional resources.

### ELECTRIC DRIVE TRANSPORTATION ASSOCIATION

Electric vehicle incentives

[www.goelectricdrive.org/you-buy/incentives](http://www.goelectricdrive.org/you-buy/incentives)

Electric vehicle charging 101, products, station locator

[www.goelectricdrive.org/owning-ev](http://www.goelectricdrive.org/owning-ev)

### U.S. DOE ALTERNATIVE FUELS DATA CENTER

[www.afdc.energy.gov/fuels/electricity.html](http://www.afdc.energy.gov/fuels/electricity.html)

### CALIFORNIA PLUG-IN ELECTRIC VEHICLE COLLABORATIVE

Workplace charging resources

<http://www.pevcollaborative.org/workplace-charging>

Multi-family buildings resources

<http://www.pevcollaborative.org/MuD>

### U.S. DOE AND U.S. DOT FUNDING AND FINANCING GUIDE FOR CHARGING STATIONS

<https://goo.gl/J8sVsq>

### U.S. DOE EV EVERYWHERE WORKPLACE CHARGING CHALLENGE

[www.energy.gov/eere/vehicles/ev-everywhere-workplace-charging-challenge](http://www.energy.gov/eere/vehicles/ev-everywhere-workplace-charging-challenge)

### PLUG IN AMERICA

[www.pluginamerica.org](http://www.pluginamerica.org)

### PLUG-IN CARS

Guides on electric vehicles, buying, charging, etiquette, etc. [www.plugincars.com/guides.html](http://www.plugincars.com/guides.html)

### The Electric Power Research Institute, Inc.


(EPRI, [www.epri.com](http://www.epri.com)) conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public.

An independent, nonprofit organization, EPRI brings together its scientists and engineers as well as experts from academia and industry to help address challenges in electricity, including reliability, efficiency, affordability, health, safety and the environment. EPRI also provides technology, policy and economic analyses to drive long-range research and development planning, and supports research in emerging technologies. EPRI members represent 90% of the electric utility revenue in the United States with international participation in 35 countries.

EPRI's principal offices and laboratories are located in Palo Alto, Calif.; Charlotte, N.C.; Knoxville, Tenn.; and Lenox, Mass.

Together . . . Shaping the Future of Electricity

©2016 Electric Power Research Institute (EPRI), Inc. All rights reserved. Electric Power Research Institute, EPRI, and TOGETHER... SHAPING THE FUTURE OF ELECTRICITY are registered service marks of the Electric Power Research Institute.

 Printed on recycled paper in the United States of America

3002009442