U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

# Electric Vehicle Basics


Electric vehicles are charged by plugging the vehicle into an electric power source. *Photo courtesy of Forth.*

Electric vehicles (EVs) use electricity as their primary fuel or to improve the efficiency of conventional vehicle designs. EVs include all-electric vehicles, also referred to as battery electric vehicles (BEVs), and plug-in hybrid electric vehicles (PHEVs). In colloquial references, these vehicles are called electric cars, or simply EVs, even though some of these vehicles still use liquid fuels in conjunction with electricity. EVs are known for providing instant torque and a quiet driver experience.

Other types of electric-drive vehicles not covered here include hybrid electric vehicles, which are powered by a conventional engine and an electric motor that uses energy stored in a battery that is charged by regenerative braking, not by plugging in, and fuel cell electric vehicles, which use a propulsion system similar to electric vehicles, where energy stored as hydrogen is converted to electricity by the fuel cell.

## All-Electric Vehicles

All-electric vehicles do not have conventional engines but are driven solely by one or more electric motors powered by energy stored in batteries. The batteries are charged by plugging the vehicle into an electric power source and can also be charged through regenerative braking. All-electric vehicles produce no tailpipe emissions, although there are "life cycle" emissions associated with the electricity production.

All-electric vehicles typically have shorter driving ranges per charge than conventional vehicles have per tank of gasoline. Most new BEVs are designed to travel between 110 and over 300 miles on a fully charged battery, depending on the model. For context, 90% of all U.S. household trips cover less than 100 miles.[1] An all-electric vehicle's range varies according to driving conditions and driving habits. Extreme temperatures tend to reduce range because energy from the battery powers climate control systems in addition to powering the motor. Speeding, aggressive driving, and heavy loads can also reduce range.

### Regenerative Braking

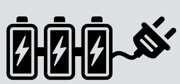
Regenerative braking allows EVs to capture energy normally lost during braking by using the electric motor as a generator and storing that captured energy in the battery.

## Plug-In Hybrid Electric Vehicles

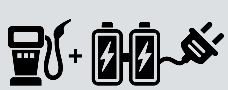
PHEVs use batteries to power an electric motor and use another fuel, such as gasoline, to power a conventional engine. The batteries are typically charged by plugging the PHEV into an electric power source, although they can also be charged by the conventional engine and through regenerative braking.

PHEVs have an all-electric driving range of about 15 to 60+ miles, depending on the model. As long as the battery is

### EVs at a Glance



**EVs** run on electricity alone. They are powered by one or more electric motors and a battery. The battery is charged by plugging the vehicle into an electric power source and through regenerative braking.



**PHEVs** can travel moderate distances on electricity alone. The battery can be charged by plugging into an electric power source, through regenerative braking, and by the engine.

PHEVs don't have to be plugged in before driving. They can also be fueled solely with conventional fuel. However, they will not achieve maximum fuel economy or take full advantage of their all-electric capabilities without plugging in.

1 National Highway Travel Survey, U.S. Department of Transportation, Federal Highway Administration, 2008, fhwa.dot.gov/policyinformation/pubs/pl08021/fig4_5.cfm.

charged, a PHEV can draw most of its power from electricity for typical daily driving. The engine will then power on when the battery is mostly depleted, during rapid acceleration, at high speeds, or when intensive heating or air conditioning is required.

When running on battery power alone, PHEVs produce no tailpipe emissions. Even when the conventional engine is running, PHEVs typically consume less gasoline and produce fewer emissions than similar conventional vehicles.

## What EV Models Are Available?

Nearly all major vehicle manufacturers have EV models available, and some have committed to transitioning to selling only EVs by 2030.

Medium- and heavy-duty options are also available for fleet applications. See **Considering an EV** for fleet-specific considerations.

For up-to-date information on available models, use the Alternative Fuels Data Center (AFDC) Vehicle Search tool (afdc.energy.gov/tools) or the Find a Car tool on FuelEconomy.gov (fueleconomy.gov/feg/findacar.shtml).

Getting started with an EV is easy thanks to the charging "cordset" that comes with most vehicles. *Photo by Erik Nelsen, NREL 64277.*

More heavy-duty vehicle manufacturers are now offering plug-in models for fleets. *Photo by Dennis Schroeder, NREL 46574.*

## How Do These Vehicles "Fuel Up"?

Charging equipment provides electricity to charge EV batteries. The charging unit communicates with the vehicle to ensure that it supplies an appropriate and safe flow of electricity.

There are more than 140,000 publicly available charging outlets—and counting—across the country. Most currently available light-duty BEVs have ranges between 110 and over 300 miles. Technological advances such as larger batteries and growing access to charging are increasingly addressing "range anxiety," or the fear of running out of charge. Learn more about trends in EV charging infrastructure (afdc.energy.gov/fuels/electricity_infrastructure_trends.html).

It may take as little as 30 minutes to fully charge an EV's battery, but charging times vary based on the type or level of charging; the type of battery, its capacity, and how depleted it is; and the capacity of the vehicle's internal charger (see **Charging Options** table).

Charging units can be installed in residential, fleet, workplace, and public settings. Most EVs come with a 110-volt "Level 1" cordset that can be plugged into a typical electrical outlet. For quicker charging, homeowners can install a 240-V "Level 2" unit on a dedicated electrical circuit. This can often be done with little or no required electrical upgrades, as most homes have 240-V service for appliances like dryers and electric ranges. A Level 2 unit can be portable or "hard wired" into a building and can be purchased for as little as $200. For more information on installing charging equipment, see Charging Infrastructure Procurement and Installation on the AFDC (afdc.energy.gov/fuels/electricity_infrastructure_development.html).

To make long-distance travel more accessible, the Federal Highway Administration is establishing a network of alternative fueling and charging infrastructure along highway corridors. Designated EV corridors[2] supported by DC fast charging stations are under development nationwide. To find public stations, use the Alternative Fueling Station Locator (afdc.energy.gov/stations), which is available as an iPhone and Android app.

## Equipment Types and Costs

Charging units are classified according to the rate at which they charge batteries. Two types—Level 1 and Level 2—provide AC power to the vehicle, with the

### Charging Made Simple

Most EV owners charge at home or at work because charging is more convenient and cost-effective than using public stations. But public equipment is also easy to use. Depending on the station, drivers might use a network card, credit card, phone, cash, or even just enter an account number. There are also free chargers where users can just plug in.

An added benefit of going electric is that electricity prices are less volatile than gasoline and diesel prices, so drivers can more easily forecast their fueling expenses. See a comparison of all fuel prices over time on the AFDC Fuel Prices page (afdc.energy.gov/fuels/prices.html).

[2] fhwa.dot.gov/environment/alternative_fuel_corridors

### Charging Options

| | Typical Charging Time | Cost for Equipment, Installation, and Site Costs* |
|---|---|---|
| **Level 1** | 2–5 miles of range per hour of charging | $0 to $1,800 |
| **Level 2**** | 10–30 miles of range per hour of charging | $800 to $33,000 |
| **DC Fast Charging**** | 100–200+ miles of range in 30 minutes | $30,000 to over $120,000 |

*Costs do not include the price of operation (network charges, electricity, utility demand charges). Factors affecting the price include equipment (charging equipment, electrical supplies), electrical installation (upgrading or adding electrical service, upgrading the electrical panel, conduit, and trenching), site improvements (adding pavement), activating a network, payment collection, labor, permitting, and taxes.

**Charging unit cost (Level 2 and DCFC) is proportional to the unit's power rating. The higher its rating, the higher the cost. A Level 2 unit can range from 6.6 to 19.2 kW output. A DCFC unit can range from 25 to 350 kW. Charging varies by charging unit power, vehicle, and battery state of charge.

vehicle's onboard equipment converting AC to DC to charge the batteries. The other type—DC fast charging (DCFC)—provides DC power directly.

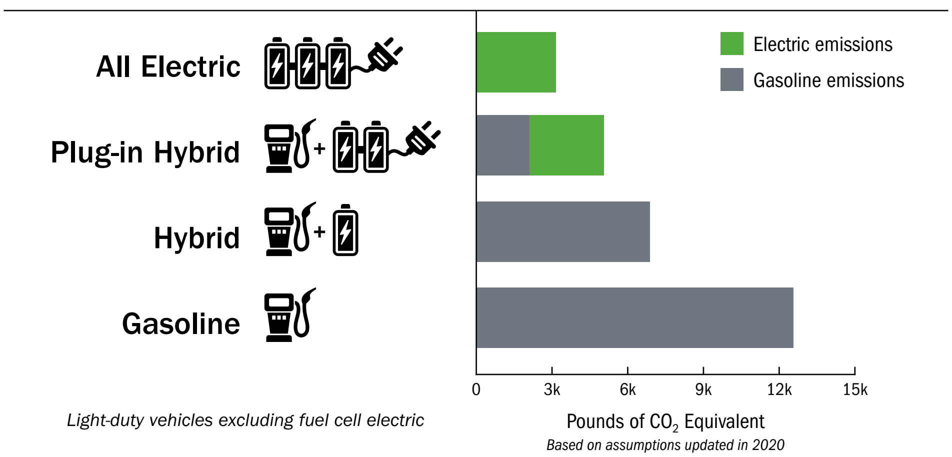
Wireless or "inductive" charging equipment uses an electromagnetic field to transfer electricity to an EV without a cord. Today, this technology is used primarily at higher power levels in heavy-duty applications like transit buses.

Some states and utilities offer financial incentives for charging stations; see the AFDC Laws & Incentives page for more information (afdc.energy.gov/laws).

## How Much Do the Vehicles Cost?

EVs are generally more expensive than their conventional counterparts. However, lower fueling and maintenance costs can make them a competitive option. For example, electric drivetrains are more efficient, making BEVs (and PHEVs operating in electric mode) more than three times as efficient. Electricity is also less expensive than gasoline or diesel on an energy-equivalent basis. BEV drivers can save as much as $14,500 in fuel costs alone over 15 years (see table: **Benefits of Electric-Drive Vehicles**).

### National Average Annual Emissions per Vehicle




Federal and state tax credits and private and utility rebates may also be available to help offset the cost of EVs. For information on available vehicle incentives, see the AFDC Laws & Incentives page (afdc.energy.gov/laws).

To find fuel economy ratings and fuel/vehicle cost comparisons among currently available models, visit FuelEconomy.gov.

## How Do Their Emissions Compare With Those of Conventional Vehicles?

EVs typically produce fewer emissions than conventional vehicles. All-electric vehicles produce zero tailpipe emissions, and PHEVs produce no tailpipe emissions when in electric-only mode.

Life cycle emissions are generated when fuel or electricity is produced, as well as during the manufacturing of the vehicle itself. The life cycle emissions of an EV largely depend on how the electricity is generated (and how much a PHEV's engine is being used), and this varies by region. Generally, all-electric vehicles and PHEVs produce one-third to half the emissions of conventional vehicles, respectively, considering both air pollutants and greenhouse gases. Regions with high use of renewable energy will see stronger emissions benefits. See a comparison of emissions by state using the AFDC emissions tool at afdc.energy.gov/ev-emissions.html.

## What About Safety and Maintenance?

All EVs undergo the same rigorous safety testing as conventional vehicles sold in the United States and must meet Federal Motor Vehicle Safety Standards (including those for batteries). For additional safety information, refer to the AFDC's Maintenance and Safety of Hybrid and Plug-In Electric Vehicles page (afdc.energy.gov/vehicles/electric_maintenance.html).

Because PHEVs have conventional engines, their maintenance requirements are similar to conventional vehicles.

| **Benefits of Electric-Drive Vehicles** *compared to conventional vehicles* | **PHEVs** | **All-electric vehicles** |
|---|---|---|
| **Fuel Economy** | Most achieve combined fuel economy ratings **higher than 90 mpge**.* | Most achieve fuel economy ratings **higher than 100 mpge**.* |
| **Emissions Reductions** | Produce **no tailpipe emissions** when in electric-only mode.<br>Generally, they produce **less than half the emissions**. | Produce **no tailpipe emissions**.<br>Generally, they produce **one-third the emissions**. |
| **Fuel Cost Savings**** | In electric-only mode, PHEV electricity costs range about **3¢–10¢ per mile**.<br>On gasoline only, fuel costs are about **4¢–36¢ per mile**. | All-electric vehicles run on electricity only. Electricity costs are **2¢–6¢ per mile**. |
| **Fueling Flexibility** | Can fuel at **gas stations**.<br>Can charge at:<br>· **home**<br>· **public charging stations**<br>· **some workplaces** | Can charge at:<br>· **home**<br>· **public charging stations**<br>· **some workplaces** |
| Electricity is produced from varied, domestic sources: | | |

Sources: AFDC (afdc.energy.gov), FuelEconomy.gov

* EVs are rated not in miles per gallon (mpg) but miles per gallon of gasoline equivalent (mpge). Similar to mpg, mpge represents the number of miles the vehicle can travel using a quantity of fuel (or electricity) with the same energy content as a gallon of gasoline.

**Compare to 10¢–15¢ per mile for conventional gasoline- or diesel-powered sedans.

For all EVs, the electrical system (battery, motor, and associated electronics) requires minimal scheduled maintenance. A manufacturer's warranty of a battery typically covers 8 years or 100,000 miles, and the expected battery lifetime is 12 to 15 years under normal operating conditions and in moderate climates. Check with your manufacturer about vehicle and battery warranties. Brake systems on these vehicles typically last longer than conventional vehicles because regenerative braking reduces brake wear.

All-electric vehicles lack conventional engines and have far fewer moving parts and fewer fluids to change, so they typically require less maintenance than conventional vehicles or even PHEVs.

## Considering an EV

Fleet managers should consider:

- Arranging for basic technician and driver training
- Conducting site planning for charging units, including setbacks, electrical service locations, potential service upgrade needs, and future upgrades
- Determining when and how the vehicles will charge (including working with utilities to understand time-of-use and demand charges), as well as managed charging
- Exploring private or utility incentives for equipment installation or power use
- Evaluating equipment vendors and considering needs/options such as smart charging, cloud communications, vendor payment, and equipment ownership and maintenance
- Timing the purchase and installation of charging units with the delivery of vehicles (this can be especially slow/complicated for municipal organizations).

For medium- and heavy-duty vehicles, there are additional considerations:

- Examining auxiliary loads (e.g., heating/cooling, lights, power take-off/hydraulics use), and optional auxiliary power units or heating, ventilating, and air-conditioning (HVAC) units powered by diesel or another fuel
- Determining the impacts of increased electricity consumption, especially when several vehicles need to be charged simultaneously at high charging rates
- Understanding original equipment manufacturer vehicle maintenance and support if issues arise.

Find additional information on EVs on the AFDC at afdc.energy.gov/vehicles/electric.html. ■

Clean Cities
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**For more information, visit:**
afdc.energy.gov

DOE/GO-102023-6050 · August 2023