PDHonline Course E435 (2 PDH)

A Guide to Electric Vehicles

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PDH Online | PDH Center

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Course Outline

As countries seek to address future energy requirements in a rapidly growing and changing world, achieving sustainable transportation has emerged as a vital mission. Electric vehicles (EVs), in particular, represent one of the most promising pathways to increased energy security and reduced emissions of greenhouse gases and other pollutants. In this course, we will review the history of electric vehicles since the 1800s, discuss various types of electric and hybrid electric vehicles, and explore their advantages and disadvantages. In addition, we will examine the new EPA window sticker for electric vehicles and go over some frequently asked questions.

This course includes a multiple-choice quiz at the end, which is designed to enhance the understanding of course materials.

Learning Objectives

At the conclusion of this course, the student will:

- Become familiar with the history and trend of electric vehicles (EVs);
- Know various types of electric vehicles;
- Understand the pros and cons of EVs; and
- Appreciate EVs' role in helping us achieve sustainable transportation.

Intended Audience

This course is designed for engineers, architects, contractors and land surveyors, or anyone who wishes to be up to date on the latest development of sustainable transportation.

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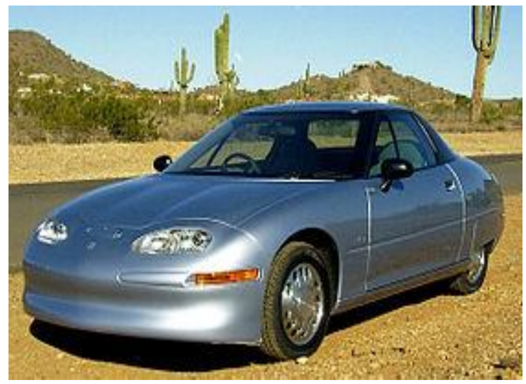
A Guide to Electric Vehicles

ACE Group, LLC

Introduction

Electric vehicles have come a long way since General Motors produced the first modern electric automobile EV-1 in 1996. With the recent introduction of the Chevrolet Volt, Nissan Leaf, and Tesla Model S, manufacturers of electric vehicles have made great strides in terms of technology and consumer acceptance. Vehicle electrification is considered to be an important step towards reducing petroleum dependence, protecting the environment, and improving transportation sustainability.



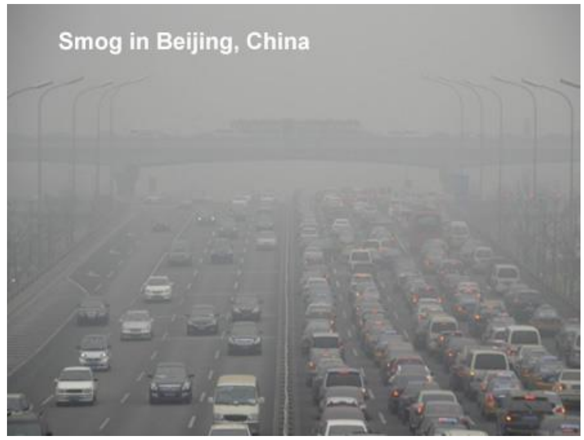
GM EV-1

What Is an EV?

An electric vehicle, or EV, is any vehicle that gets some of or all of the power it needs to move from electrical energy. Almost all electric vehicles store electrical energy in batteries to powers the motor. EV batteries must be replenished by plugging the vehicle into a power source. Some electric vehicles have onboard chargers; others plug into a charger located outside the vehicle. Both types, however, use electricity that comes from the power grid or through stationary renewable energy. An all-electric vehicle (also called a battery-electric vehicle, or BEV) is an electric vehicle that uses an electric motor powered by a battery to run the car — with no gasoline engine at all. Although electricity production may contribute to air pollution, BEVs are considered zero-emission vehicles because their motors produce no exhaust or emissions.

Why Vehicle Electrification?

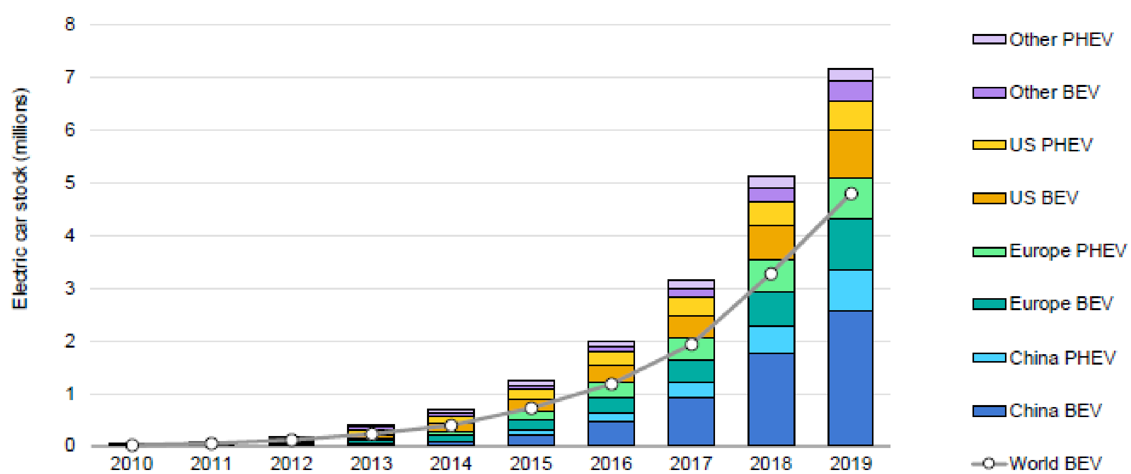
According to a report from Ward's Auto, the global number of cars exceeded one billion in 2010. In the US alone, there are more than 250 million passenger vehicles (roughly a quarter of the global number.) When cars burn gasoline, they emit pollutants and cause smog. Some pollutants are believed to cause cancer and contribute to such problems as asthma, heart disease, birth defects, and eye irritation. Emissions from cars also increase the levels of carbon dioxide (CO_2) and other greenhouse gases in the atmosphere, which leads to global warming. Vehicle electrification through plug-in hybrid electric vehicles (PHEV) and battery-electric vehicles (BEV) will help cut greenhouse gas emissions and other pollutants significantly.



In its publication *"Global EV Outlook - Understanding the Electric Vehicle Landscape to 2020,"* the Electric Vehicles Initiative (EVI), a multi-government policy forum, reported that the global EV stock exceeded 180,000 in 2012, which represents less than 0.02% of the total vehicles in operation worldwide. Among all the EVI countries, the United States had the largest share, over 70,000 electric vehicles in stock in 2012. The goal of the Electric Vehicles Initiative was to have at least 20 million electric vehicles on the road by 2020. However, the recent trend indicates that the actual global electric car stock would approach only half of the EVI's original goal set for 2020.

We can all help by educating the general public about the benefits of electric vehicles and asking people to drive less and combine trips for efficiency.

Global electric car stock, 2010-19



Sources: IEA analysis based on country submissions, complemented by other sources. For more details, see figure 1.1 in the main report.

Electric cars, which expanded by an annual average of 60% in the 2014-19 period, totalled 7.2 million in 2019.

Brief History of Electric Vehicles

Electric vehicles have been around in one form or another since the invention of the automobile. Many of the first automobiles were powered by a battery and not by gasoline. Electric vehicles even outsold gasoline-powered vehicles in the early 20th century. However, with improvements to gasoline engines and the availability of cheap fuel, electric vehicles fell out of favor. Throughout the 20th century, several models of electric vehicles were produced, but none became widely adopted by consumers.

Nissan Leaf, All-Electric Vehicle

The 1990s saw a renewed interest in electric vehicles because of increasing concerns about the environment and higher fuel costs. General Motors introduced the EV-1 all-electric vehicle and began leasing the vehicles in 1996. However, the EV-1 was discontinued after several years. In 2000, hybrid-electric vehicles hit the market when Honda introduced the Insight in the United States, and Toyota followed with the highly successful Prius several months later.

The other event that helped reshape electric vehicles was the announcement in 2006 that a small Silicon Valley startup, Tesla Motors, would start producing a luxury electric sports car that could go more than 200 miles on a single charge. In 2010, Tesla received a $465 million loan from the U.S. Department of Energy's Loan Programs Office to establish a manufacturing facility in California. In the short time since then, Tesla has won wide acclaim for its cars and has become the largest auto-industry employer in California.

Tesla's announcement and subsequent success spurred many big automakers to accelerate work on their own electric vehicles. In late 2010, the Chevy Volt and the Nissan LEAF were released in the U.S. market. The first commercially available plug-in hybrid, the Volt has a gasoline engine that supplements its electric drive once the battery is depleted, allowing consumers to drive on electricity for most trips and gasoline to extend the vehicle's range. In comparison, the LEAF is an all-electric vehicle (often called a battery-electric vehicle, an electric vehicle, or just an EV for short), meaning it is only powered by an electric motor.

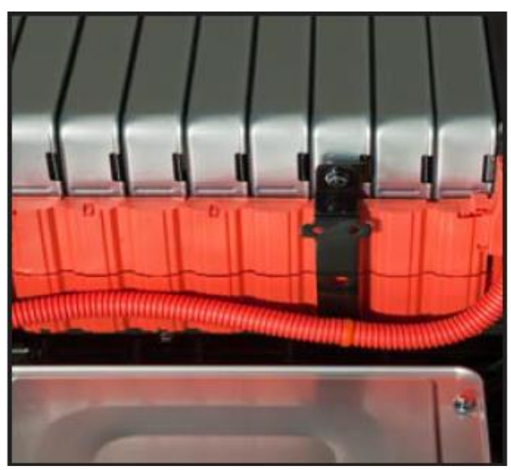
Over the next few years, other automakers began rolling out electric vehicles in the U.S.; yet consumers were still faced with one of the early problems of the electric vehicle - where to charge their vehicles on the go. Through the Recovery Act, the U.S. Energy Department invested more than $115 million to help build a nationwide charging infrastructure, installing more than 18,000 residential, commercial and public chargers across the country. Automakers and other private businesses also installed their own chargers at key locations in the U.S., bringing today's total of public electric vehicle chargers to more than 8,000 different locations with more than 20,000 charging outlets.

At the same time, new battery technology began hitting the market, helping to improve a plug-in electric vehicle's range. In addition to the battery technology in nearly all of the first-generation hybrids, the Energy Department's research also helped develop the lithium-ion battery technology used in the Volt. More recently, the Department's investment in battery research and development has helped cut electric vehicle battery costs by 50 percent in the last four years, while simultaneously improving the vehicle batteries' performance (meaning their power, energy, and durability). This in turn has helped lower the costs of electric vehicles, making them more affordable for consumers.

Consumers now have more choices than ever when it comes to buying an electric vehicle. Today, there are 23 plug-in electric and 36 hybrid models available in a variety of sizes - from the two-passenger Smart ED to the midsized Ford C-Max Energi to the BMW i3 luxury SUV. As gasoline prices continue to rise and the prices of electric vehicles continue to drop, electric vehicles are gaining in popularity - with more than 234,000 plug-in electric vehicles and 3.3 million hybrids on the road in the U.S. today.

Differences between Electric and Traditional Vehicles

Electric vehicles share many of the same basic components found in traditional automobiles, but they have unique components that separate them from conventional vehicles, such as the lithium-ion battery and electric motor.



Electric Vehicle Battery

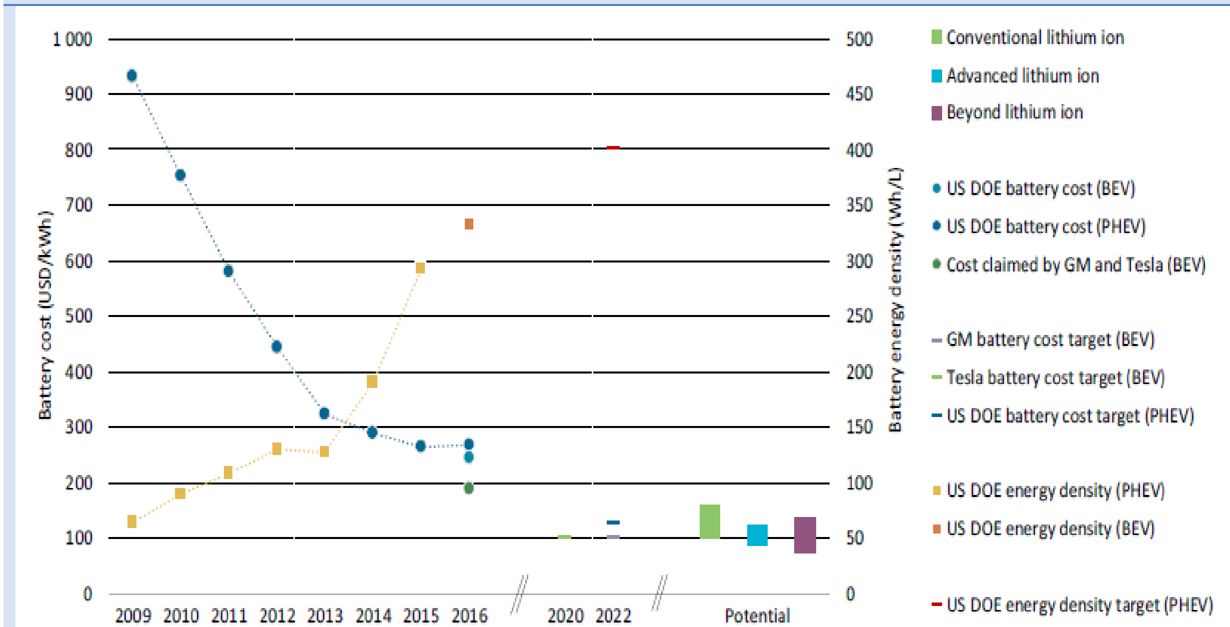
Batteries

Most conventional gasoline-powered vehicles use lead-acid batteries. Electric vehicles, however, require large lithium-ion batteries or other batteries that use new technologies that provide more power and weigh less than older batteries of a similar size.

Batteries in electric vehicles must also supply a much greater amount of electricity and recharge faster than those in conventional vehicles. Thus, electric vehicle batteries are much larger than conventional vehicle batteries; they usually weigh several hundred pounds, need to be replaced after several years, and can cost thousands of dollars. Scientists and engineers continue to develop new technologies to create smaller, lighter batteries that last longer and provide more power.

The following chart shows the evolution of EV battery cost and energy density since 2009. As you can see from this chart, in 2016 the battery cost is around $280/kWh while the battery energy density is 330 Wh/L. In the year 2022, the US DOE's targeted battery cost (PHEV) is around $125 while the battery energy density target is 400 Wh/L.

Figure 6 • Evolution of battery energy density and cost



Electric Motors

Electric motors have been used for over a century; in fact, they were used in some of the earliest cars. Electric motors are powered by an electric current that creates a magnetic charge and turns a driveshaft. Electric motors waste less energy in the form of heat than do internal combustion engines, so they are more efficient. Torque (a measure of the turning force on an object) and revolutions per minute (RPM, or the speed that the motor turns) can be controlled by the electric motor as it adjusts the electrical current fed through the motor, even making a transmission unnecessary in some vehicles.

Internal combustion engines

Most hybrid vehicles contain an internal combustion engine as the primary source of power, with a battery and electric motor acting as secondary power sources. Because power is also available from the battery and electric motor, these engines are typically smaller than those found in regular automobiles. Internal combustion engines in hybrid vehicles can also be used to recharge the battery. Plug-in hybrids get most of their power from the electric system and use the internal combustion engine to recharge the battery or to power the vehicle after the battery runs out.

Types of Electric Vehicles

For more than 100 years, the predominant energy choice for cars has been the internal combustion engine. Electric vehicles being designed today either augment internal combustion or eliminate the need for it altogether.

Hybrid and electric vehicle system components may include a battery for energy storage, an electric motor for propulsion, a generator, a mechanical transmission, and a power control system.

These components are brought together in different ways by different systems. There are four main types of electric cars:

- Hybrid Electric Vehicle (HEV)
- Plug-in Hybrid Electric Vehicle (PHEV)
- Extended-Range Electric Vehicle (EREV)
- Battery Electric Vehicle (BEV)

Hybrid Electric Vehicle (HEV)

The hybrid electric vehicle uses a small electric battery to supplement a standard internal combustion engine and increase fuel efficiency by about 25 percent from conventional light-duty vehicles. Its driving energy comes only from liquid fuel.

The electric motor minimizes idling and boosts the car's ability to start and accelerate, which is important in stop-and-

Powertrain of a Hybrid Electric Vehicle

go city driving. Hybrids are dual-fuel vehicles in which both the electric motor and internal combustion engine can drive the wheels.

The electric motor accelerates the car to about 40 mph, depending on the vehicle, and then the internal combustion engine takes over.

The battery is recharged by the gasoline engine and regenerative braking. Regenerative braking converts kinetic energy that otherwise would be lost as heat in the brake pads into electricity to charge the battery. The Ford Fusion Hybrid and Toyota Prius are examples of this type of hybrid.

Plug-in Hybrid Electric Vehicle (PHEV)

The plug-in hybrid electric vehicle is also a dual-fuel car in which both the electric motor and the internal combustion engine can propel the car. It has a larger battery pack that is charged directly from the power grid, increasing the amount of electric power available to the car.

This larger battery usually supplements an internal combustion engine smaller than those used in hybrid or conventional vehicles. Toyota began selling a plug-in hybrid for the U.S. market in February 2012, though kits to convert other cars into plug-in hybrids were available before that.

Powertrain of a Plug-in Hybrid Vehicle

Both the hybrid and plug-in hybrid combine an internal combustion engine with a battery and electric motor to increase fuel efficiency. The difference is that plug-ins also can be recharged from an electric outlet, extending the use of electricity as fuel.

Most plug-in hybrids run on electric power only up to about 40 mph, where the internal combustion engine takes over. Thus, drivers could commute around a city solely on electric power without ever engaging the internal combustion engine. However, the majority of commuters from rural areas would need to engage the gas engine at some point in order to safely use the interstates.

The batteries in these vehicles can be charged by the gas engine, regenerative braking, and by plugging in at home during off-peak hours.

While this reduces the immediate need for public charging stations, the ideal situation would be to build an infrastructure of charging stations to provide more options for plug-in hybrid owners.

Extended-Range Electric Vehicle (EREV)

An extended-range electric vehicle uses an internal combustion engine to power an electric generator that charges the battery system in a linear process — the engine powers a generator, which in turn charges the battery.

Chevrolet Volt

Unlike dual-fuel hybrid and plug-in hybrids, only the electric motor powers the wheels of an extended-range electric car. The internal combustion engine only charges the batteries.

The General Motors Chevrolet Volt, which went on sale in the U.S. in late 2010, is an extended-range electric vehicle with an electric-only range of about 40 miles. The Volt extends its range with a small internal combustion engine that charges the batteries. The Volt also can be recharged by plugging into the grid during periods of low power use.

Battery Electric Vehicle (BEV)

Powertrain of a Battery Electric Vehicle

Battery electric vehicles are all electric. They have no internal combustion engine and must be plugged into the electric power grid for recharging. The major benefit of all-electric cars is that they consume no gasoline and have zero tailpipe emissions. To accommodate a range of 80-plus miles per charge, electric-only vehicles require larger batteries than the combined electric-petroleum cars — from 18 kilowatt-hours to more than 35 kilowatt-hours.

To more quickly recharge these larger batteries at night when power demand is low, most homes and businesses will require special outlets to be installed that provide 240 volts or higher.

The Nissan Leaf (available since 2010) and Tesla Model S (available since 2012) are examples of this type of vehicle. Although the typical usable range of BEVs is from 60 to 80 miles, Tesla Model S with a 90-kWh battery pack could reach 315 miles per charge in 2016.

Converted Electric Vehicles

Some traditional gas-powered vehicles that have internal combustion engines are converted to electric vehicles that use electric propulsion. Because of the limited number of electric vehicle models on the market, conversion companies often perform vehicle conversions for consumers who prefer a certain type of vehicle not currently available with an electric motor. Businesses also do vehicle conversions for specific types of vehicles that are required for business, such as light trucks or passenger vehicles.

Other Personal Electric Vehicles

Other electric vehicles — smaller vehicles with maximum speeds of 25 mph or less — are classified as neighborhood electric vehicles. Golf carts dominate this vehicle category, but other options are increasingly available, such as electric bicycles.

Various manufacturers offer three- and four-wheel electric vehicles that can be used in private and commercial applications, such as airport shuttles.

Global Electric Motorcars, a Chrysler subsidiary, is the U.S. sales leader in this category. Some cities use these small vehicles for parking meter enforcement. Some power companies use them to move people and resources at their generating plants.

Benefits of Electric Vehicles

Hybrid and plug-in electric vehicles can help increase energy security, improve fuel economy, lower fuel costs, and reduce emissions.

Energy Security

In 2019, the United States imported about 3% of the petroleum it consumed, and the transportation sector accounts for approximately 30% of total U.S. energy needs and 70% of U.S. petroleum consumption. Using more energy-efficient vehicles like hybrid and plug-in electric vehicles is an important part of continuing this successful trend of minimizing imported petroleum. This supports the U.S. economy and helps diversify the U.S. transportation fleet. Additionally, using an energy source such as electricity for transportation creates a resiliency benefit. The multiple fuel sources used in the generation of electricity result in a more secure and domestically generated energy source for the electrified portion of the transportation sector. All of this adds to our nation's energy security.

Using hybrid and plug-in electric vehicles instead of conventional vehicles can help reduce U.S. reliance on imported petroleum and increase energy security. Hybrid electric vehicles (HEVs) typically use less fuel than similar conventional vehicles, because they employ electric-drive technologies to boost efficiency. Plug-in hybrid electric vehicles (PHEVs) and all-electric vehicles (EVs) are both capable of using off-board sources of electricity, and almost all U.S. electricity is produced from domestic coal, nuclear energy, natural gas, and renewable resources.

Fuel Economy

HEVs typically achieve better fuel economy and have lower fuel costs than similar conventional vehicles. For example, FuelEconomy.gov lists the 2020 Toyota Corolla Hybrid at an EPA combined city-and-highway fuel economy estimate of 52 miles per gallon (MPG), while the estimate for the conventional 2020 Corolla (four cylinders, automatic) is 34 MPG.

HEVs, PHEVs, and EVs can reduce fuel costs dramatically because of the high efficiency of electric-drive components. Because PHEVs and EVs rely in whole or part on electric power, their fuel economy is measured differently than that of conventional vehicles. Miles per gallon of gasoline equivalent (MPGe) and kilowatt-hours (kWh) per 100 miles are common metrics. Depending on how they are driven, today's light-duty EVs (or PHEVs in electric mode) can exceed 130 MPGe and can drive 100 miles consuming only 25–40 kWh.

The fuel economy of medium- and heavy-duty PHEVs and EVs is highly dependent on the load carried and the duty cycle, but in the right applications, PEVs maintain a strong fuel-to-cost advantage over their conventional counterparts.

Unlike conventional gasoline-powered vehicles, electric vehicles have higher miles per gallon equivalent in the city than on the highway because of the low speed and regenerative braking technology.

Among the four main types of EVs, BEVs offer the greatest fuel cost savings.

Infrastructure Availability

PHEVs and EVs have the benefit of flexible charging. Since the electric grid is in close proximity to most locations where people park, they can charge overnight at a residence, as well as at a multi-unit dwelling, workplace, or public charging station when available. PHEVs have added flexibility because they can also refuel with gasoline or diesel (or possibly other fuels in the future) when necessary.

Public charging stations, or electric vehicle supply equipment, are not as ubiquitous as gas stations. Charging equipment manufacturers, automakers, utilities, Clean Cities coalitions, municipalities, and government agencies are rapidly establishing a national network of public charging stations. The number of publicly accessible charging stations reached more than 26,000 in 2020, offering more than 80,000 places to charge, according to the Alternative Fueling Station Locator. You may search for electric charging stations near you using GPS or Google Map.

Costs

Although energy costs for hybrid and plug-in electric vehicles are generally lower than for similar conventional vehicles, purchase prices can be significantly higher. Prices are likely to equalize with conventional vehicles, as production volumes increase, and battery technologies continue to mature. Also, initial costs can be offset by fuel cost savings, a federal tax credit, and state and utility incentives. The federal Qualified Plug-In Electric-Drive Motor Vehicle Tax Credit is available for PHEV and EV purchases from manufacturers that have not yet met certain thresholds of vehicle sales. It provides a tax credit of $2,500 to $7,500 for new purchases, with the amount determined by the size of the vehicle and the capacity of its battery.

Emissions

Hybrid and plug-in electric vehicles can have significant emissions benefits over conventional vehicles. HEV emissions benefits vary by vehicle model and type of hybrid power system. EVs produce zero tailpipe emissions, and PHEVs produce no tailpipe emissions when in all-electric mode.

The life cycle emissions of an EV or PHEV depend on the sources of electricity used to charge it, which vary by region. In geographic areas that use relatively low-polluting energy sources for electricity production, plug-in vehicles typically have a life cycle emissions advantage over similar conventional vehicles running on gasoline or diesel. In regions that depend heavily on conventional electricity generation, PHEVs and EVs may not demonstrate a strong life cycle emissions benefit.

Batteries

2011 Nissan Leaf Battery

Like the engines in conventional vehicles, the advanced batteries in plug-in electric vehicles are designed for extended life but will wear out eventually. Several manufacturers of plug-in vehicles are offering 8-year/100,000-mile battery warranties. Test and simulation results from the National Renewable Energy Laboratory indicate that today's batteries may last 12 to 15 years in moderate climates (eight to 12 years in extreme climates).

Check with your dealer for model-specific information about battery life and warranties. Although manufacturers have not published pricing for replacement batteries, some are offering extended warranty programs with monthly fees. If the batteries need to be replaced outside the warranty, it may be a significant expense. Battery prices are expected to decline as battery technologies improve and production volumes increase.

Infrastructure to Charge Plug-In Electric Vehicles

To widely accept the use of plug-in hybrid electric vehicles (PHEVs) and all-electric vehicles (EVs), consumers and fleets need a developed infrastructure of charging stations. Drivers need affordable, convenient, and compatible options for charging at home (or at fleet facilities, in the case of fleets). Charging stations at workplaces and public destinations may also bolster the market acceptance of PEVs. Charging plug-in electric vehicles requires plugging into electric vehicle supply equipment (EVSE). Hybrid electric vehicles (HEVs) are charged using regenerative braking and the internal combustion engine and are not plugged into charging equipment.

Charging Equipment

Charging equipment for plug-in hybrid electric vehicles (PHEVs) and all-electric vehicles (EVs) is classified by the rate at which the batteries are charged. Charging times vary based on how depleted the battery is, how much energy it holds, the type of battery, and the type of EVSE. The charging time can range from 20 minutes to 20 hours or more, depending on these factors.

The rate at which charging adds range to a vehicle depends on the vehicle, battery type, and type of EVSE. The following are typical rates for a light-duty vehicle.

AC Level 1: 2 to 5 miles of range per hour of charging

AC Level 2: 10 to 20 miles of range per hour of charging

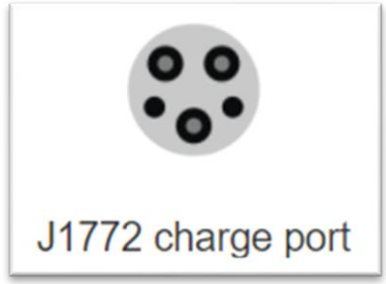
DC Fast Charging (sometimes called DC Level 2): 60 to 80 miles of range in 20 minutes of charging

AC Level 1 Charging

AC Level 1 EVSE (often referred to simply as Level 1) provides charging through a 120 volt (V) AC plug and requires electrical installation per the National Electrical Code. Most, if not all, PEVs will come with an AC Level 1 EVSE cordset so that no additional charging equipment is required. On one end of the cord is a standard, three-prong household plug (NEMA 5-15 connector). On the other end is a J1772 standard connector (see the Connectors and Plugs section below), which plugs into the vehicle.

Level 1 charging is typically used when there is only a 120 V outlet available, such as while charging at home, but can easily provide charging for all of a driver's needs. Based on the battery type and vehicle, AC Level 1 charging adds about 2 to 5 miles of range to a PEV per hour of charging time. For example, 8 hours of charging at 120 V can replenish about 40 miles of electric range for a mid-size PEV. As of 2020, less than 5% of public charging outlets in the United States were Level 1.

AC Level 2 Charging



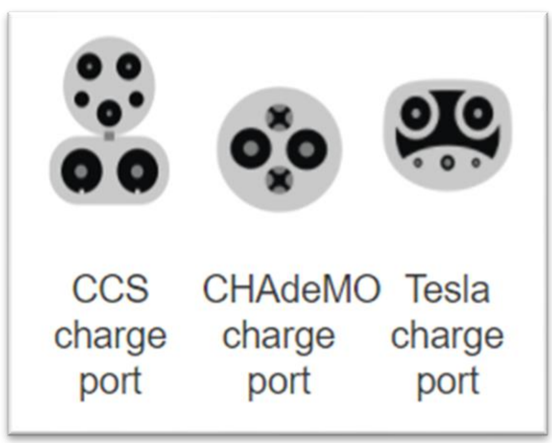
AC Level 2 equipment (often referred to simply as Level 2) offers charging through 240 V (typical in residential applications) or 208 V (typical in commercial applications) electrical service. AC Level 2 EVSE requires the installation of home charging or public charging equipment and a dedicated circuit of 20 to 100 amps, depending on the EVSE requirements. This charging option can operate at up to 80 amperes and 19.2 kW. However, most residential AC Level 2 EVSE will operate at lower power. Many such units operate at up to 30 amperes, delivering 7.2 kW of power. These units require a dedicated 40 amp circuit. As of 2020, over 80% of public outlets in the United States were Level 2.

Most homes have 240 V service available, and because AC Level 2 EVSE can charge a typical EV battery overnight, this will be a common installation for homes. AC Level 2 equipment uses the same connector on the vehicle that Level 1 equipment uses. Based on the vehicle and circuit capacity, AC Level 2 adds about 10 to 20 miles of range per hour of charging time.

Tesla vehicles have a unique charge port and connector that works for all their charging options, including their Level 2 Destination Chargers and chargers for home. All Tesla vehicles come with a J1772 adapter which allows them to use non-Tesla charging equipment.

DC Fast Charging

Direct-current (DC) fast charging equipment, sometimes called DC Level 2 (typically 480 V AC input), enables rapid charging along heavy traffic corridors and at public stations. A DC fast charge can add 60 to 80 miles of range to a light-duty PHEV or EV in 20 minutes. As of 2020, over 15% of charging outlets in the United States were DC fast chargers.



There are three types of DC fast charging systems, depending on the type of charge port on the vehicle: SAE Combined Charging System (CCS), CHAdeMO, or Tesla.

Inductive Charging

Inductive charging equipment, which uses an electromagnetic field to transfer electricity to a PEV without a cord, has been introduced commercially for installation as an aftermarket add-on. Some currently available wireless charging stations operate at power levels comparable to Level 2, though this technology is more common for transit or other fleet operations at higher power levels comparable to DC fast.

Additional Charging Options

Another standard (SAE J3068) was developed in 2018 for higher rates of AC charging using three-phase power, which is common at commercial and industrial locations in the United States. Some components of the standard were adapted from the European three-phase charging standards and specified for North American AC grid voltages and requirements. In the United States, the common three-phase voltages are typically 208/120 V, 480/277 V. The standard targets power levels between 6 kW and 130 kW.

Connectors and Plugs

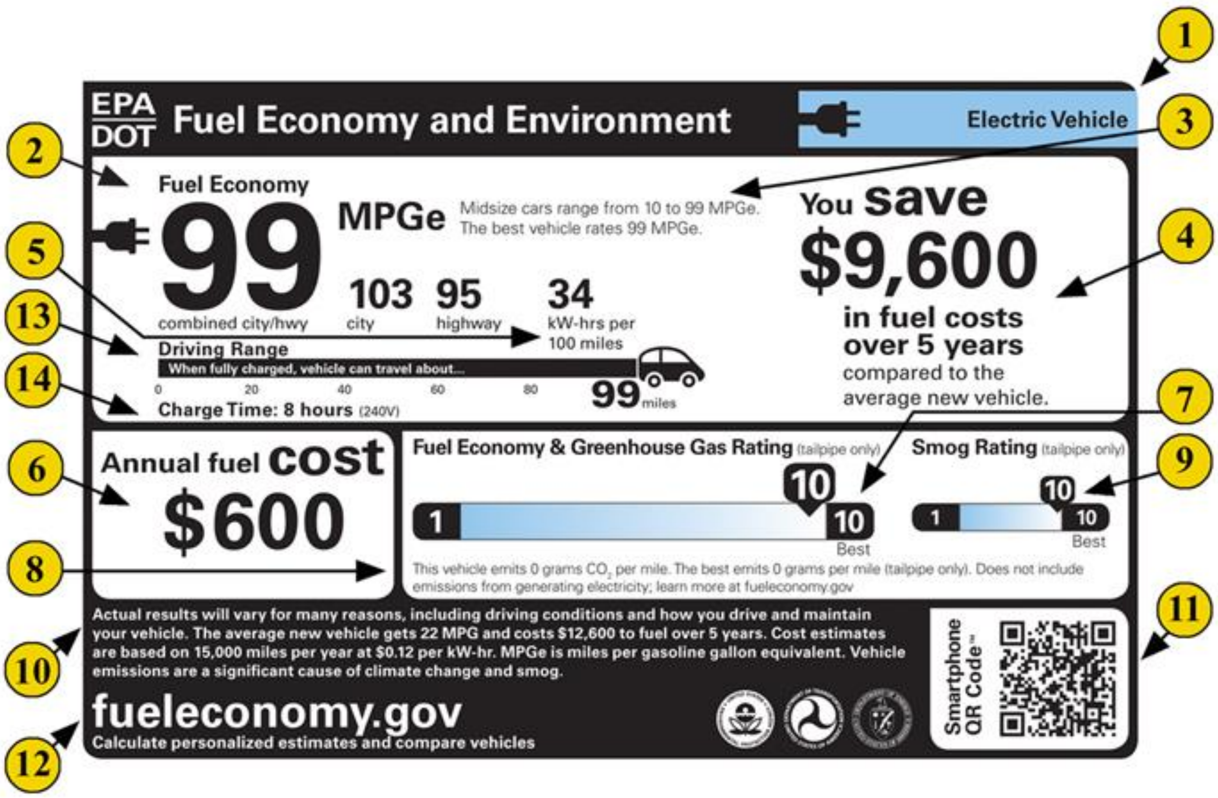
Most modern charging equipment and vehicles have a standard connector and receptacle based on the SAE J1772 standard developed by SAE International. Any vehicle with this plug receptacle should be able to use any J1772-compliant AC Level 1 or AC Level 2 EVSE. All major vehicle and charging system manufacturers support this standard in the U.S., which should eliminate drivers' concerns about whether their vehicle is compatible with the infrastructure. Some currently available plug-in vehicles that are equipped to accept DC fast charging (like the Nissan Leaf and Mitsubishi i-MiEV) are using the CHAdeMO connector. SAE International recently finalized a "combo connector" standard for fast charging that adds high-voltage DC power contact pins to the J1772 connector, enabling the use of the same receptacle for all levels of charging. The new standard is now available on a limited number of vehicles.

The SAE J1772 charge port (right) on a vehicle can be used to accept charge with Level 1 or 2 charging equipment. The DC fast charging receptacle (left) uses a different type of connector. In this photo, it is a CHAdeMO.

New EPA Window Sticker for EVs

Below is an image and explanation of EPA's new label (window sticker) for electric vehicles. It includes city, highway, and combined city/highway MPGe. It also provides consumers valuable information such as estimated driving range, charge time, battery power consumption rate, annual fuel cost, cost savings, smog rating, and fuel economy & greenhouse gas ratings.

Excerpt from: http://www.fueleconomy.gov/feg/label/learn-more-electric-label.shtml



1. Vehicle Technology & Fuel

The upper right corner of the label will display text and a related icon to identify it as a vehicle that is powered by electricity. You will see different text and icons on the labels for other vehicles:

- Gasoline Vehicle
- Diesel Vehicle
- Compressed Natural Gas Vehicle
- Hydrogen Fuel Cell Vehicle
- Flexible-Fuel Vehicle: Gasoline-Ethanol (E85)
- Plug-In Hybrid Vehicle Electricity-Gasoline

2. Fuel Economy

For most vehicles, the label shows City, Highway, and Combined MPG (miles per gallon) values. The Combined MPG value is the most prominent for the purpose of quick and easy comparison across vehicles. Some form of the miles per gallon metric has been on vehicle labels since 1977. Combined fuel economy is a weighted average of City and Highway MPG values that is calculated by weighting the City value by 55% and the Highway value by 45%.

For those vehicles that do not use liquid fuels--such as electric vehicles, plug-in hybrid electric vehicles operating on electricity, and compressed natural gas vehicles-- the labels display miles per gallon of gasoline-equivalent (MPGe). Think of this as being similar to MPG, but instead of presenting miles per gallon of the vehicle's fuel type, it represents the number of miles the vehicle can go using a quantity of fuel with the same energy content as a gallon of gasoline. This allows a reasonable comparison between vehicles using different fuels. For example, you can use MPGe to compare a compressed natural gas (CNG) vehicle with a gasoline vehicle; even though CNG is not dispensed or burned in actual gallons.

3. Comparing Fuel Economy to Other Vehicles

This text indicates the category of the vehicle (e.g., Small SUV, Station Wagon, Pickup Truck, etc.) and the best and worst fuel economy within that category for the given model year. There are nine car categories, six truck categories, and a "special purpose vehicle" category. These categories are used only for labeling and consumer information purposes and do not serve any other regulatory purpose. For each model year, EPA publishes lists identifying the best and worst fuel economy performers in each category available at http://www.epa.gov/fueleconomy/data.htm. This text also tells you the best combined fuel economy among all new vehicles.

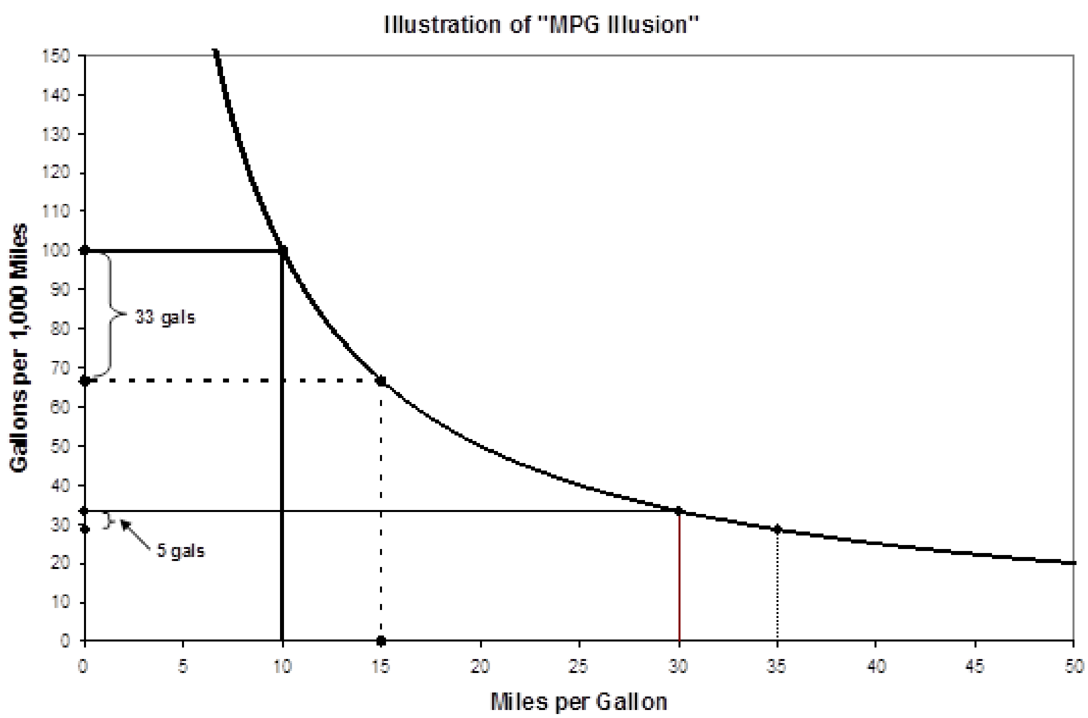
4. You Save/Spend More over 5 Years Compared to Average Vehicle

The label shows the estimated fuel cost over a five-year period for the vehicle compared to the average new vehicle. If the vehicle would save the consumer money compared to the average vehicle, the label would state, "You save $x,xxx in fuel costs over 5 years compared to the average new vehicle." If the vehicle would be more expensive to operate than the average vehicle, the label would state, "You spend $x,xxx more in fuel costs over 5 years compared to the average new vehicle. "These estimates are based on 15,000 miles per year, for five years, and the projected fuel price for the year (12 cents per kilowatt-hour in this example). For more information on the source of projected fuel prices see "10. Details in Fine Print".

5. Fuel Consumption Rate

Kilowatt-hours is an energy unit for electricity. This value tells you how many kilowatt-hours the vehicle would use to travel 100 miles. Like gallons per 100 miles, this kilowatt-hours per 100 miles relates directly to the amount of electricity used, and thus to cost. This is an estimated rate of consumption; any given vehicle may or may not be actually capable of traveling 100 miles on a fully charged battery.

While a miles per gallon (MPG) estimate is a required feature that has appeared on the fuel economy label for several decades, this metric can be potentially misleading when consumers compare fuel economy improvements, particularly when they use it in place of fuel costs. The following chart shows the non-linear relationship between gallons used over a given distance and miles per gallon. The fuel savings, in gallons, for a vehicle that gets 10 MPG versus a vehicle that gets 15 MPG is about 33 gallons (assuming 1000 miles). On the other hand, the fuel savings in gallons, for the same 5 MPG fuel economy jump, for a 30 MPG versus a 35 MPG vehicle is only about 5 gallons.



This "MPG illusion" demonstrates why it may be more meaningful to express fuel efficiency in terms of consumption (e.g., gallons per mile or per 100 miles) rather than in terms of economy (miles per gallon). A fuel consumption metric allows for more accurate energy usage comparisons among vehicles.

The revised label includes both fuel economy and consumption information for all vehicle types.

6. Estimated Annual Fuel Cost

The annual fuel cost is based on two assumptions: an annual mileage of 15,000 miles and a projected electricity price. For more information on the source of projected fuel prices see "10. Details in Fine Print".

7. Fuel Economy and Greenhouse Gas Rating

The new label assigns each vehicle a rating from 1 (worst) to 10 (best) for fuel economy and greenhouse gas emissions (i.e., how much carbon dioxide the vehicle's tailpipe emits each mile), as shown below. Consumers may note that a higher fuel economy is associated with a better GHG emissions profile.

There are two ratings that apply to each vehicle—one for fuel economy and one for greenhouse gas emissions—but in practice, most vehicles will display only one rating. This is because carbon dioxide emissions are directly related to the amount of fuel consumed. This relationship varies from fuel to fuel, but both rating systems are based on gasoline vehicles, meaning that gasoline vehicles get the same rating for fuel economy and greenhouse gas emissions. In cases where the fuel economy performance and greenhouse gas emissions do not yield the same rating, the rating bar will display two pointers.

Model Year 2021 Ratings		
Rating	**MPG**	**CO_2 (g/mile)**
10	≥ 53	0-169
9	43-52	170-209
8	36-42	210-250
7	31-35	251-291
6	27-30	292-335
5	23-26	336-395
4	20-22	396-456
3	17-19	457-539
2	15-16	540-613
1	≤ 14	≥ 614

For those vehicles that only run on electricity, the tailpipe greenhouse gas emissions are zero. Of course, these vehicles do cause emissions at the electric power plant, with amounts varying greatly based on the source of electricity (such as coal, nuclear, natural gas, hydro, or wind). Consumers can use our greenhouse gas calculator to estimate GHG emissions associated with the production and distribution of the electricity used to charge an electric vehicle or plug-in hybrid electric vehicle in their region of the country.

8. CO_2 Emissions Information

This text provides three key pieces of information:

Combined city/highway CO_2 tailpipe emissions

The labeled vehicle's CO_2 tailpipe emissions are based on tested tailpipe CO_2 emission rates. The rate of CO2 emissions is displayed in grams per mile.

Vehicles with the lowest CO_2 emissions

The label identifies the lowest tailpipe CO_2 emissions of available vehicles. If there are electric or fuel cell vehicles on the market, which by definition have zero tailpipe emissions, this value will be zero grams per mile.

Learn more about emissions from the production of fuels at www.fueleconomy.gov

Driving your vehicle can yield both greenhouse gas (GHG) emissions from your vehicle's tailpipe and GHG emissions related to the production of the fuel used to power your vehicle. For example, activities associated with fuel production such as feedstock extraction, feedstock transport to a processing plant, and conversion of feedstock to motor fuel, as well as the distribution of the motor fuel, can all produce GHG emissions.

The Fuel Economy and Environment Label provides a Greenhouse Gas Rating, from 1 (worst) to 10 (best), based on your vehicle's tailpipe carbon dioxide emissions only, and this rating does not reflect any GHG emissions associated with fuel production.

You can estimate the total GHG emissions that would be associated with driving an electric vehicle or plug-in hybrid electric vehicle, including GHG emissions from the production of electricity used to power the vehicle, with our greenhouse gas calculator.

9. Smog Rating

This is a rating for vehicle tailpipe emissions of those pollutants that cause smog and other local air pollution. This information, listed as "Smog" on the labels, will be displayed using a slider bar with a scale of 1 (worst) to 10 (best). The scale is based on the U.S. vehicle emissions standards, which incorporate specific thresholds for nitrogen oxide, non-methane organic gas, carbon monoxide, particulate matter, and formaldehyde. For those vehicles that run on electricity, the tailpipe emissions are zero.

10. Details in Fine Print

This part of the label has a reminder that your fuel economy and emissions may be different due to a number of factors, such as how you drive and maintain your vehicle, how much you use air conditioning and other accessories, the weather, road conditions, how much the vehicle is loaded, and other factors. EPA periodically evaluates ways to improve our fuel economy estimates so they better reflect real-world driving. For more information on how your fuel economy can vary, or tips to improve your fuel economy, please see Gas Mileage Tips.

This part of the label also details the assumptions that are used to determine the estimated annual fuel cost and the value used to compare 5-year costs to the average vehicle. EPA assumes annual mileage of 15,000 miles. The price of electricity listed on new vehicle labels is based on projections from the U.S. Energy Information Administration for the applicable model year. It will typically be updated annually in coordination with the Department of Energy. Since EPA won't publish the fuel prices for 2013 model year labeling until 2012, the sample labels include an example price that is intended for illustrative purposes only.

11. QR Code®*

When you are looking for a new vehicle at a dealership, you will be able to scan the QR Code® on the new label using your smartphone, provided you have downloaded a scanner app. The QR Code® will link you to helpful tools and additional information about the vehicle. The same tools and information are available to everyone on www.fueleconomy.gov. (* QR Code is registered trademark of DENSO WAVE INCORPORATED.)

12. fueleconomy.gov

The label directs you to the fueleconomy.gov website, where you can compare vehicles and enter personalized information (e.g., local gas prices and individual driving habits) to get the best possible cost and energy-use estimates.

13. Driving Range

When the vehicle is fully charged, this value represents the approximate number of miles that can be traveled in combined city and highway driving before the vehicle must be recharged.

14. Charge Time

This indicates how long it takes to charge a fully empty battery using a 240-volt electrical service. For the purposes of equivalent comparisons, all vehicles with external charging capability will display a charge time based on the use of 240-volt service, unless the vehicle is not capable of receiving the higher voltage. Some owners may choose to install a 240-volt service (in their garage, for example) and others may choose to use a standard household outlet providing 120 volts. Use of lower voltage than that specified on the label will result in longer charging times. The vehicle manufacturer should be able to provide complete information on charging times and the capabilities of their vehicles.

Solar Charge Station

Frequently Asked Questions

Q. How do you charge electric vehicles?

A. Charging is simple: you plug in your car and go. Most consumers charge their vehicles in their garages at night, but public charging stations are also available. In fact, the network of charging stations is growing. Electric-car maker Tesla Motors has recently expanded its network of fast-charging stations, called Superchargers, to allow drivers of the Tesla Model S sedan to drive across the U.S. without the long charging times and "range anxiety" long associated with electric vehicles.

Q. What is the miles-per-gallon equivalent for an electric car?

A. That's a hard comparison to make since different plug-in vehicles have different systems — some that use gasoline and some that don't. For example, the Environmental Protection Agency has estimated that the Nissan LEAF can go 99 mpg on the energy equivalent of one gallon of gas, which the EPA says is 33.7 kWh of electricity. For city-only driving, the LEAF's MPGe increases to 106. By comparison, the Toyota Prius hybrid has a 51-mpg rating in the city. The EPA gave the Chevy Volt an overall rating of 60 MPGe, with 93 MPGe when driven in its electric mode and 37 MPG when it uses gasoline only. These ratings are expected to change as technology advances.

Q. Do electric cars need regular tune-ups like gasoline cars?

A. Like all vehicles, electric vehicles will require regular maintenance. But unlike traditional gasoline vehicles, battery electric vehicles (BEVs) will not require regular oil changes, will have significantly fewer moving parts and fluids, and have simpler components that will decrease the frequency and expense of vehicle maintenance. Plug-in hybrid (PHEV) and extended range vehicles (EREVs), which have an internal combustion engine as well as electrical drive components, will require regular maintenance on the whole system.

Q. What kind of tax incentives are available for EVs?

A. Electric vehicles (EVs) purchased in or after 2010 may be eligible for a federal income tax credit of up to $7,500. The credit amount will vary based on the capacity of the battery used to fuel the vehicle. State and/or local incentives may also apply.

Q. What's the difference between a tax deduction and a tax credit?

A. A tax deduction reduces the amount of income for which you are taxed. For example, if your taxable income were $60,000, a $5,000 deduction would reduce it to $55,000. So, you would pay taxes on an income of $55,000 instead of $60,000. This means your actual savings would be a fraction of the $5,000 deduction.

A tax credit reduces the total amount of income tax you owe. So, if you owed $20,000 in federal income tax, a $5,000 credit would reduce the amount you owed to $15,000. With a credit, your actual savings would be $5,000.

Q. How plug-in hybrids save money?

A. Plug-in hybrids save money on fuel by operating on both electricity and gasoline and by saving energy typically wasted by conventional vehicles. Like regular hybrids, plug-in hybrids use both a gasoline engine and an electric motor but have a higher-capacity battery to store electricity. They take advantage of electricity's low cost and the electric motor's energy efficiency but retain the convenience of gasoline's widespread availability and quick refueling. Plug-in hybrids also save energy through regenerative braking, which recovers much of the energy typically lost when you apply the brakes. Regenerative braking slows the vehicle by converting its momentum into electricity, and stores the electricity in the vehicle's battery. Plug-in hybrids also save fuel by using a start-stop system that saves fuel by turning off the engine when it would otherwise be idling, and starting it automatically when the accelerator is pressed.

The big advantage of a plug-in hybrid is that you can plug it into re-charge the battery. It's much cheaper to run your vehicle on electricity from your outlet than on gasoline. Based on typical average rates, operating a plug-in on electricity costs less than half as much as it would on gasoline.

Plug-in hybrids have a larger battery than a regular hybrid. So, you can use more electricity and less gas. When the electricity runs out, it operates just like a regular hybrid. You don't have to plug it in to drive it, but re-charging it whenever you can, will maximize your fuel savings.

A plug-in hybrid's motor is also more powerful than a regular hybrid's, so the plug-in hybrid can be driven in electric-only mode at higher speeds, not just during low-speed driving.

If you're considering a plug-in hybrid, it's important to understand that all plug-ins are not alike. Some have batteries that hold more electricity than others, and some can go farther on electricity without using any gasoline. Since using electricity instead of gasoline is key to saving money with a plug-in hybrid, your driving habits, especially the distance your drive between re-charging the battery, can have a big effect on your fuel bill.

With all of these factors affecting electricity use, it can be difficult to estimate how much fueling a hybrid will cost you. Luckily, Fueleconomy.gov has developed a tool to take some of the guesswork out of your decision. "My Plug-in Hybrid Calculator" estimates gasoline and electricity costs for any available plug-in hybrid using your driving habits and fuel costs. So, check it out and see if a plug-in hybrid could be right for you!

Q. What are the major challenges facing EVs?

A. The major challenges facing EVs are all battery-related:

- **Driving range.** Most EVs can only go about 100–200 miles before recharging—gasoline vehicles can go over 300 miles before refueling.
- **Recharge time.** Fully recharging the battery pack can take 4 to 8 hours. Even a "quick charge" to 80% capacity can take 30 min.
- **Battery cost:** The large battery packs are expensive and may need to be replaced one or more times during the life of the vehicle.
- **Bulk & weight:** Battery packs are heavy and take up considerable vehicle space.

However, researchers are working on improved battery technologies to increase driving range and decrease recharging time, weight, and cost. These factors will ultimately determine the future of EVs.

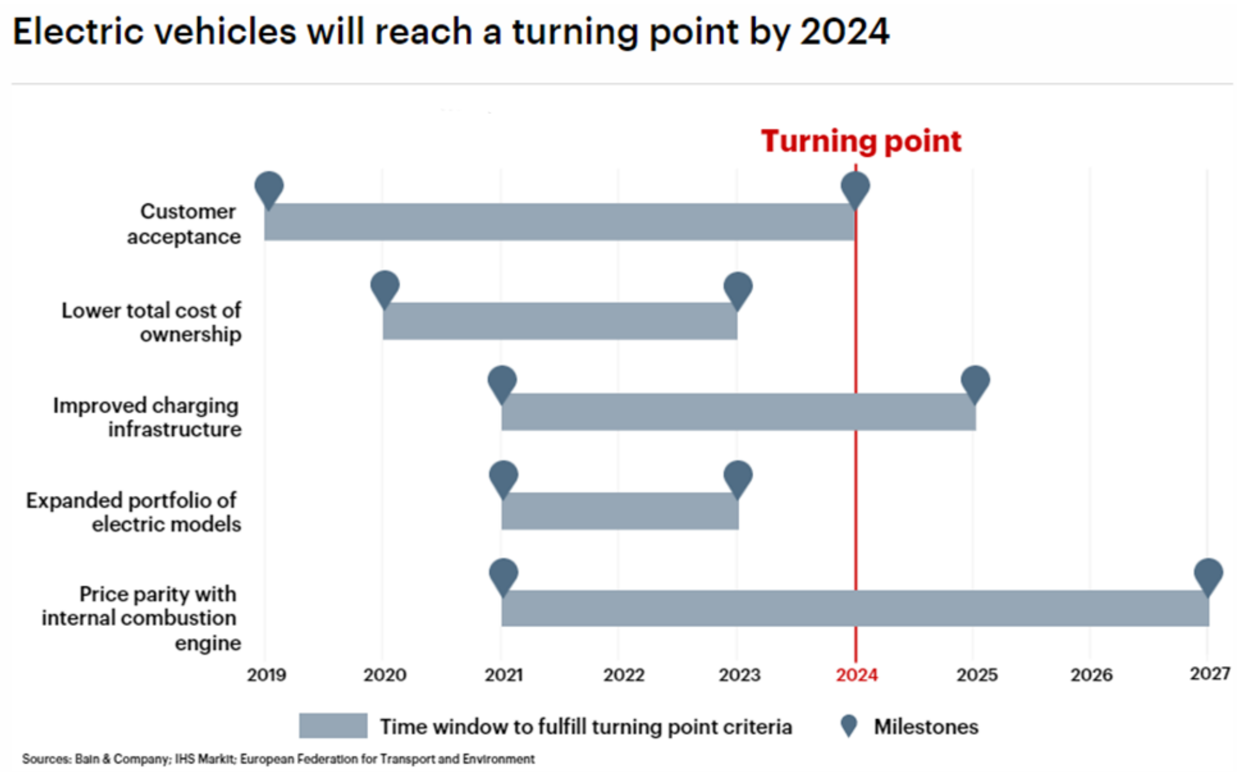
The Future of Electric Cars

It's hard to tell where the future will take electric vehicles, but it's clear they hold a lot of potential for creating a more sustainable future. If we transitioned all the light-duty vehicles in the U.S. to hybrids or plug-in electric vehicles using our current technology mix, we could lower the carbon pollution from the transportation sector by as much as 20 percent.

On the battery front, both private and public sectors are working hard to overcome the biggest scientific and technical barriers that prevent large-scale improvements of batteries. In 2020, the battery accounts for around 30% of the manufacturing costs of electric vehicles. Technology improvements and optimized production at scale will enable further reduction in battery costs, which will make EVs more affordable.

According to Bain analysis, global EV adoption will rapidly increase as prices decrease over the next two to eight years, reaching a turning point in 2024 (see chart below).

In the end, only time will tell what road electric vehicles will take in the future.



Summary

Over the past two decades, the pace of technological developments in the automotive industry has picked up considerably as vehicle manufacturers focus on increasing the fuel efficiency of their vehicles and cutting CO_2 emissions. Besides being considered to be zero-emission, all-electric vehicles (EV) or battery electric vehicles (BEV) offer many advantages: simpler transmission, fewer moving parts, lower maintenance costs, and lower operating costs than their gasoline/diesel-powered counterparts. The most significant technological challenge currently facing electric-drive vehicles is the cost and performance of the battery. Scientists around the world are engaged in many different aspects of battery research, ranging from improving their durability and lifetime to optimizing them for integrating renewable energy systems (like solar and wind) into the electrical grid. Better battery technologies could lead to a lower initial cost, longer battery life, and extended driving range between recharging.

