Plug-In Vehicles

Ready for Prime Time?

Banish the notion of a souped-up golf cart—plug-in electric vehicles are being manufactured that replace the traditional internal combustion engine (ICE) automobile. If you're looking for an EV, here are answers to the questions you might ask before you buy.

by Andy Kerr

What are the various kinds of electric vehicles?

All commercially manufactured electricity-powered vehicles have an electric motor drive, automatic start/shutoff, and regenerative braking (an energy recovery mechanism that slows a vehicle or object down by converting its kinetic energy into electrical energy, which helps charge the propulsion battery). There are three varieties of electric vehicles.

Hybrid electric vehicles (HEVs) are powered by an ICE, as well as by electrical energy stored in a battery. The battery is charged through the ICE and regenerative braking. Typically, HEVs are not plugged in to charge (see PHEVs, below). The Toyota Prius is the most common HEV.

Electric vehicles (EVs) are powered only by the battery, which is recharged by plugging the vehicle into an electric power source (and to a small degree, by regenerative braking). Examples are the Nissan Leaf and Ford Focus Electric.

Plug-in hybrid electric vehicles (PHEVs) are powered, like an HEV, through a combination of an ICE and an electric motor. Unlike an HEV, a PHEV can be plugged into an electric power source to recharge the battery, in addition to recharging it using regenerative braking. There are two types of PHEVs:

- Extended-range PHEVs, such as the Chevrolet Volt, which has a gasoline engine that spins the electric motor (which propels the vehicle) when the battery reaches a low state of charge.
- "Blended" PHEVs, such as the Toyota Prius Plug-in, where the electric motor or gasoline engine can work singly or jointly to power the engine.

This article focuses mainly on EV and PHEVs, as they are the only vehicles that can accept an outside electrical charging source.

Pros & Cons of EV Ownership

	Pros	Cons
Less expensive fuel	✓	
No tailpipe emissions (with pure EVs)	✓	
Quieter	✓	
Fun to drive	✓	
Coolness factor (the "Prius effect")	✓	
You may save money (depending on fuel prices & how much you drive)	✓	
Limited range (EVs only)		✓
Higher initial cost		✓
Limited selection		✓

The all-electric Nissan Leaf is one of the few EVs on the market.

Courtesy Nissan Motor Co.

What EVs are or will soon be available?

Several models are on sale now and more are coming. Plugincars.com maintains up-to-date information on current and prospective EVs. Many new models show a "2012" availability date, which refers not to the model year, but the manufacturers' best hopes for getting it to market. Plugincars.com currently features 31 vehicles, 12 of which are available now; five more are expected before the end of 2012.

The Chevrolet Volt is a plug-in EV paired with a gasoline engine for extended range.

Courtesy General Motors

What about "range anxiety?"

According to *Consumer Reports*, 77% of EV drivers suffer from "range anxiety"—the dread of running out of energy before your trip is completed and being stranded. But in reality, 78% of Americans who commute by car drive 40 miles or fewer daily. Most people buy an automobile to meet much more than their average, typical, or normal need. They buy a car based on taking a few long trips each year rather than for everyday use. According to the Federal Highway Administration, the vast majority of automobile trips are one to 10 miles, well within the range of any EV. Only 1% of vehicle trips are in excess of 100 miles.

- The Chevrolet Volt addresses range anxiety by running exclusively on electricity for the first 35 miles. With its 9.3-gallon fuel tank, it can travel another 300 miles or so using its gas engine.
- The Toyota Prius Plug-in travels 11 miles on a fully charged battery, and then can go another 500 miles or so using a combination of its gas engine and electric motor, for a combined 49 mpg. A smaller battery means a more limited all-electric range, but it also means a lower purchase price.
- The Nissan Leaf and Ford Focus Electric are both all-electric and have a maximum range of about 75 miles.

For those relatively few times your EV won't go the distance, you can rent an ICE car or use a car-sharing service such as Zipcar or Car2go (see Carsharing.net).

How do I charge an EV?

Like any other battery-powered device, an EV's battery will need to be recharged regularly—depending upon how much the EV is used. The table below shows the EV charging options available now—and those coming in the future.

For levels 1 and 2, the Society of Automotive Engineers J1772 standard connector is the norm. Level 3 and DC fast-charging connector protocols have yet to be standardized. Inductive (wireless) charging, where a vehicle need only be placed near the charging unit for the batteries to be recharged, is also under development.

Courtesy Toyota Motor Corp.

Toyota's Prius Plug-in uses the J1772 standard for its charging connectors.

The J1772 standard specifies a five-pin connector for delivering 120 or 240 VAC to an EV. Pins include AC Line 1 and Line 2, ground, controller pilot, and a proximity detector.

Courtesy Society of Automotive Engineers

EV Charging Equipment Options

Charging Option	Primary Use	Current Supplied to Vehicle	Charging Current (Amps)	Charger Input (Volts)	Power (kW)	Hrs. to Recharge*
Level 1	Residential	AC	≤15	120	≤1.8	6–20
Level 2	Residential	AC	≤30	240	≤7.2	3–8
	Public	AC	80	240	≤19.2	3–8
Level 3	Public	AC	To be determined			≤0.5
DC Fast Charging	Public	DC	200	480	50–150	≤0.5

*Varies, depending of battery state of charge; Source: DOE Energy Efficiency and Renewable Energy Vehicle Technologies Program

How does maintenance compare between plug-in and conventional ICE vehicles?

With an EV, there is no regular scheduled maintenance needed for the battery, electric motor, and associated electronics. Fewer moving parts means less maintenance and replacement. Only after many charge/discharge cycles will the propulsion battery need to be replaced. But even the batteries in the earliest Prius models regularly go beyond the warranty period, achieving 100,000, sometimes 150,000, and occasionally even 200,000 miles, with little significant deterioration.

Regenerative braking not only recovers energy that would be lost in braking, but reduces brake wear. With HEV and PHEVs, the ICE isn't running all the time, meaning longer intervals between oil changes and other engine maintenance.

Are electric vehicles as safe as petroleum-powered vehicles?

It was widely reported in the media that, three weeks after a side-impact test conducted by the National Highway Traffic Safety Administration, a Chevrolet Volt's crystallized battery coolant ignited from current in the battery. As a result, General Motors has upgraded the steel structure and cooling system surrounding the battery.

But there have been no real-world battery-related Volt fires. NHTSA closed its investigation saying, "Based on the available data, NHTSA does not believe that Chevy Volts or other electric vehicles pose a greater risk of fire than gasoline-powered vehicles." Crash safety information for all vehicles can be obtained from the Insurance Institute for Highway Safety (iihs.org/ratings) and the NHTSA (safercar.gov).

As plug-in vehicles are quiet, they can be a danger to hearing- and/or sight-impaired pedestrians. A new government standard is intended to be in place by the summer of 2012 that requires an alert mechanism.

Does driving an EV cause less pollution than driving a petroleum-powered vehicle?

Yes, an EV pollutes less—even if you're recharging with electricity from a utility that offers the dirtiest portfolio of mostly coal- and oil-fired electricity generation. Of course, you can reduce your EV pollution if more of your energy comes from CO_2-free wind, solar, hydro, and/or nuclear sources. Plugging various ZIP codes into the U.S. EPA's power profiler, we find that California's electricity mix includes the least coal (1%) and the most nonhydro renewable energy (10%). In contrast, West Virginia generates most of it electricity with coal (69%), with negligible contributions from renewable sources (see 1.usa.gov/EPAPowerProfiler).

Using the national average of about 70% fossil-fuel-based electricity in a state's energy mix, a PHEV has slightly more greenhouse gas emissions than an HEV. In states less reliant on fossil fuels for electricity, PHEVs pollute less than HEVs. In states more reliant on fossil fuel, PHEVs pollute far more than HEVs (see table below).

Because they are much more efficient users of energy—no matter the electricity source—EVs and PHEVs always have fewer greenhouse gas emissions compared to conventional gasoline vehicles. You can learn about your state's carbon emissions at the Department of Energy's Emissions from Hybrid and Plug-In Electric Vehicles website (http://bit.ly/AFAVDCemissions).

The Union of Concerned Scientists report, *State of Charge: Electric Vehicles' Global Warming Emissions and Fuel-Cost Savings Across the United States*, found that EVs fueled from the dirtiest of utilities emit less CO_2 than a new ICE compact car that averages 27 mpg. If powered by the cleanest grid, EVs beat the best HEV. If powered by wind- or solar-generated electricity, an EV will have no CO_2 emissions.

Typical Carbon Emissions Per Vehicle (Lbs. of CO_2 Per Yr.)

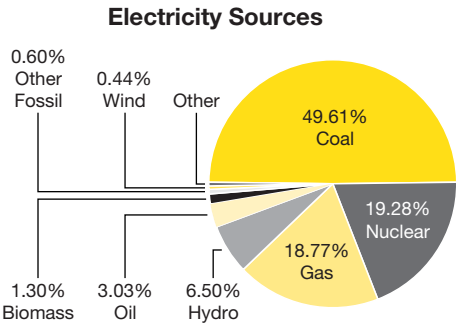
	EV	PHEV	HEV	ICE
National average	8,035	8,875	8,571	13,043
California	4,329	6,123	8,571	13,043
West Virginia	9,870	10,324	8,571	13,043

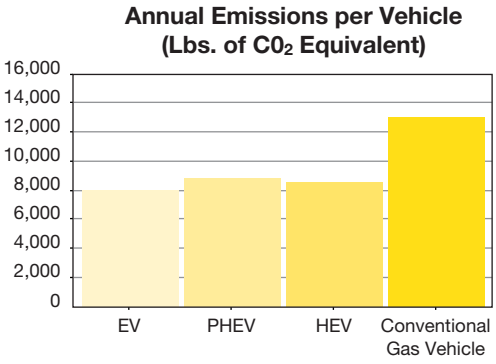
Source: U.S. DOE Alternative Fuels & Advanced Vehicles Data Center

Courtesy Ford Motor Co.

Ford's Focus Electric has a maximum range of 76 miles before its batteries need to be recharged.

Electricity Sources & Vehicle Emissions





Source: DOE Alternative Fuels & Advanced Vehicles Data Center

Will saved operating costs offset an EV's higher purchase price?

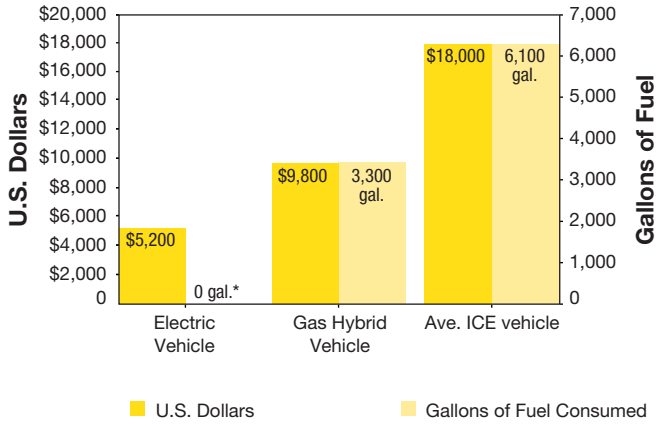
This depends partly on how much you drive—the more you drive, the more you will save. It also depends on the initial purchase price of the EV or PHEV compared to an ICE vehicle. In general, the higher the upfront capital cost of a plug-in car, the lower the per-mile operating cost.

Cost recovery depends upon how much you paid for the vehicle's "EV-ness." To determine that, you must compare what you will pay for a PHEV or EV to the most similar ICE model. For example:

- The Chevrolet Volt ($32,780 MSRP, after $7,500 federal income tax credit) costs $9,590 more than its closest ICE equivalent, the well-accessorized Chevrolet Cruze Eco.
- The Toyota Prius Plug-in (starting at $25,000 MSRP, after the credit) costs $2,945 more than a Toyota Camry.
- The Nissan Leaf (starting at $27,700 MSRP, after credit) costs $16,710 more than a Nissan Versa sedan.
- The Ford Focus Electric ($31,500 MSRP, after credit) costs $13,200 more than an ICE Ford Focus.

The generally useful Department of Energy's vehicle cost calculator (bit.ly/AFDCcalc) uses the miles you drive and the cost of gasoline. But it bases its calculations on the regional average price of electricity, assumes maintenance costs per mile are the same for both EVs and ICE vehicles, and presumes a five-year car loan at 10% interest. If the calculator allowed users to change these parameters, it would be provide a more accurate result.

Lifetime Fuel Cost & Consumption



*In this comparison, the EV consumes approximately 57,000 kWh (an equivalent of 99 mpg) in its lifetime.
Note: Fueling/charging costs are based on gasoline costs of $3.50/gallon; an electricity price of $0.11/kWh; a discount rate of 3%; 166,000 lifetime miles; and an EV efficiency rating of 0.34 kWh/mile.
Source: *State of Charge: Electric Vehicles' Global Warming Emissions and Fuel-Cost Savings Across the United States* (www.ucsusa.org/EVfacts).

What government and other incentives are available?

EVs and PHEVs qualify for up to $7,500 in federal income tax credits. Many states offer other incentives as well. For example, Californians can get a $2,500 rebate on qualifying vehicles; Oregonians can take an income tax credit equal to 25% of the cost of an at-home charging station ($750 maximum) or 35% of the cost of a business charging station. District of Columbia residents receive reduced registration fees for the first two years of the car's ownership; plus, the sales tax is waived on the vehicle purchase. You may also be able to get time-of-use (TOU) utility pricing so you can coordinate recharging your vehicle when electricity demand (and rates) are low.

There are also private and utility incentives, including free at-home charging stations. The DOE's Federal and State Incentives and Law website (bit.ly/AFDCincentive) can help you determine your eligibility. For example, in portions of California, you can take a state tax credit after installing a charging station at your home. San Diego Gas & Electric offers customers lower rates for EV charging.

The Toyota Prius Plug-in costs about $3,000 more than a comparable Camry, and about $8,000 more than the Prius without plug-in capability.

Courtesy Toyota Motor Corp.

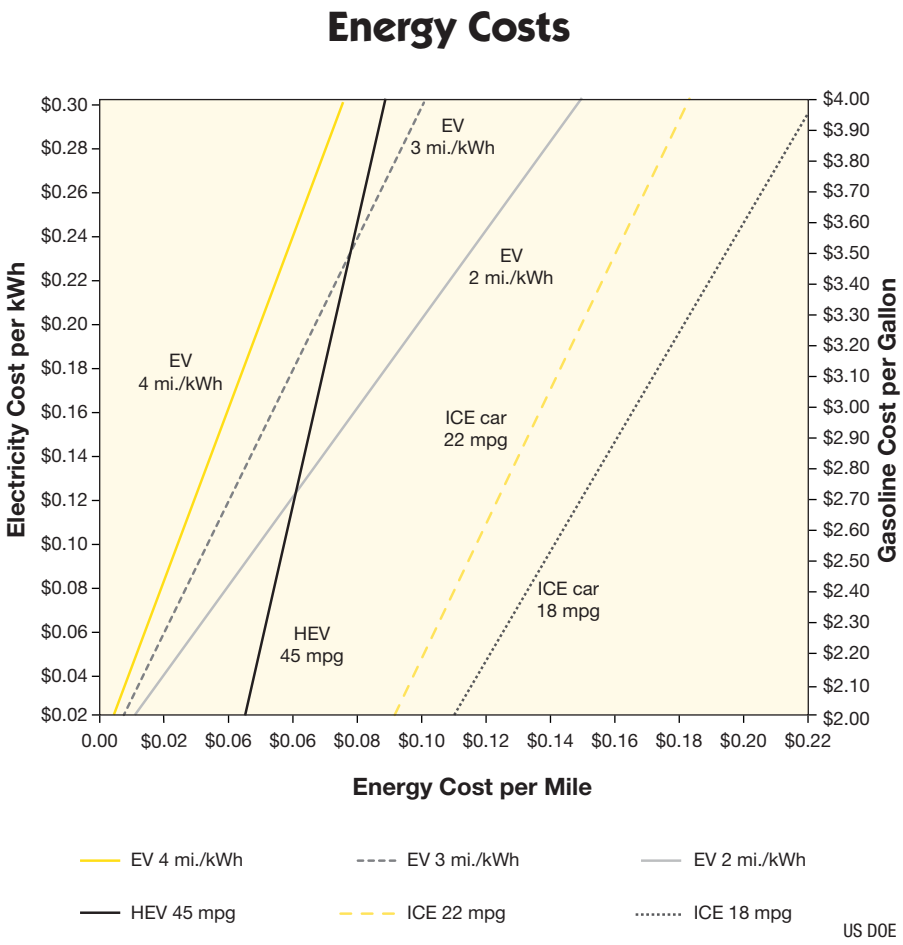
How do fuel costs compare?

The DOE estimates that conventional ICE vehicles cost 10 to 15 cents per mile in fuel (gasoline or diesel). EV's typically cost 2 to 4 cents per mile for fuel (electricity). A PHEV's fuel costs usually fall somewhere between the two, depending on how much the gasoline engine is used to supplement the electric motor.

In June 2012, the national average price of regular gasoline was $3.60 per gallon. Gasoline prices are generally expected to rise as demand increases in the developing world and supplies tighten due to availability.

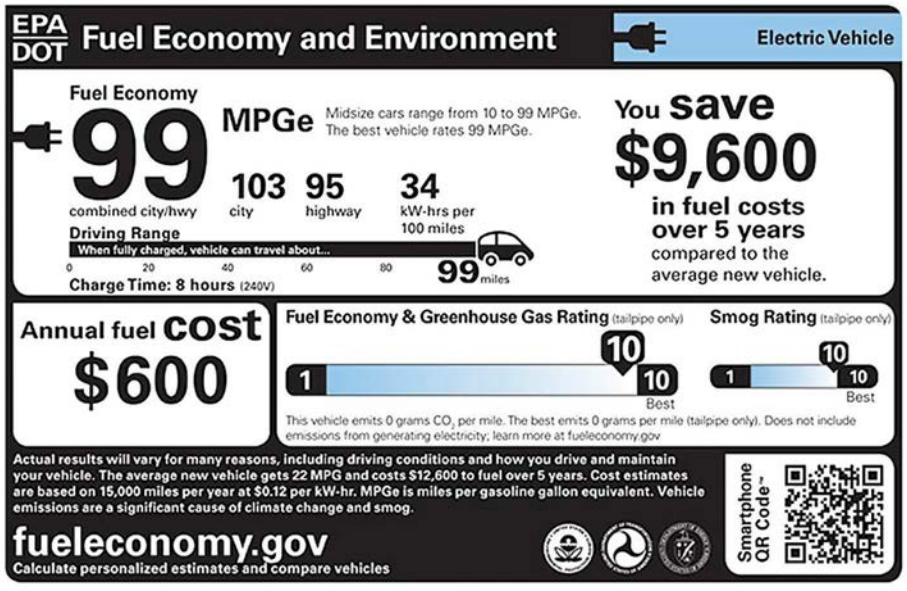
In 2010, the average residential cost of electricity was 11.6 cents per kWh. It varies quite a bit by state and between locales (compare Wyoming's average of 6.2 cents to Hawaii's average of 25.1 cents), depending upon the utility.

The graph (upper right) can help you compare costs for an EV that gets 2, 3, or 4 miles per kWh versus an ICE vehicle that gets 18, 22, or 45 miles per gallon (the latter is an HEV). Whether EV or ICE, a vehicle's operating cost has two variables: the fuel cost (cents per kWh or dollars per gallon), and the vehicle's efficiency (miles per kWh or miles per gallon). You can determine the energy cost per mile for either kind of fuel if you know the fuel cost. How much less an EV will cost to operate compared to a gasoline vehicle depends on the vehicle's efficiency and your fuel costs.



US DOE

The EPA's new-car label for EVs includes both fuel and environmental information for easier comparisons.



Grocery-Getters

Neighborhood electric vehicles (NEVs) are street-legal but limited to low-speed roads. With a maximum loaded weight of 1,850 pounds and a top speed of 25 mph, these vehicles have their place—but not on the open road. Best known is the Polaris GEM e2.

Any last thoughts?

Do your homework before you buy: Regardless of the propulsion technology, a car is a car is a car. Is it reliable? Does it have enough cup holders to satisfy you? Check out traditional sources of new car information and evaluation such as Consumer Reports, *Car and Driver* magazine, and Edmunds.

An electric car is not (yet) for everyone. But as gasoline prices continue to rise, EVs and PHEVs are bound to become a more attractive and affordable option.

Access

Andy Kerr (andykerr@andykerr.net) writes about renewable energy and energy efficiency from the dual perspectives of a net-zero energy homeowner in Ashland, Oregon, and is a policy wonk and advocate in Washington, D.C.

Other Resources:

Consumer Reports • consumerreports.com

Car and Driver magazine • caranddriver.com

Edmunds • edmunds.com

Electricity Doesn't Come in Gallons

To help consumers compare the fuel economy of an EV or PHEV, the EPA requires window stickers for gasoline, electric, and plug-in hybrid vehicles. For PHEVs and EVs, you'll find "miles per gallon equivalent" (mpg-e). A gallon of gasoline has the energy equivalent of 33.7 kWh of electricity—so a car consuming 33.7 kWh per 100 miles will be rated at 100 mpg-e.

MPG-E is only useful when comparing electric vehicles or PHEVs in electric mode. The new EPA PHEV label shows a gasoline-only mpg rating. The actual mpg-e for PHEVs will vary with the miles driven on electricity versus gasoline. You'll also find a one-to-10 fuel economy and greenhouse gas (GHG) rating and similar smog emissions (tailpipe only) rating on the label.

EPA One-to-10 Ratings

Rating	MPG	CO_2 Emissions Per Mile (Grams)
10	38+	0–236
9	31–37	237–290
8	27–30	291–334
7	23–26	335–394
6	22	395–412
5	19–21	413–479
4	17–18	480–538
3	15–16	539–612
2	13–14	613–710
1	0–12	711+

Source: Environmental Protection Agency