Colorado State University
Extension

Electric Vehicles in Colorado

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By C. Weiner*

According to the U.S. Energy Information Administration[1], the U.S. imported 49% of its oil in 2010. In order to reduce our dependence on foreign oil—and to bring about potential environmental benefits—the United States set a new national goal of getting 1 million electric vehicles on the road by 2015. This fact sheet is intended to inform consumers in Colorado about electric vehicle technology, costs, and benefits in order to assist them in making sound decisions.

How Electric Vehicles Work

'Plug-in' electric vehicles are cars, trucks, or buses that use electricity from the power grid or other source to move the vehicle's wheels. There are two main types of plug-in electric vehicles:

- Battery-electric vehicles do not use any gasoline or other liquid fuel; all power is supplied from electricity stored in a battery. The *Nissan* 'Leaf' is an example of a battery-electric vehicle.
- Plug-in hybrid vehicles use a combination of electricity, an internal combustion engine, and regenerative energy from braking. In regenerative braking systems, the vehicle's electric motor generates power when braking. As that power is transferred to a battery the vehicle slows and the energy is stored for later use. The *Chevy* 'Volt' is an example of a plug-in hybrid vehicle.

Some plug-in hybrids run solely on electricity at certain times, such as starting and when maintaining a constant speed. The engine engages only when additional power is needed, such as accelerating or climbing. Other plug-in hybrids use a blended system where the battery and the conventional engine operate together. An extended-range plug-in hybrid vehicle uses an internal combustion engine to recharge the battery or power an electric generator when the electric range capacity has been met[2].

Non-plug-in hybrid electric vehicles such as the *Toyota* 'Prius' are not designed to travel extended distances in electric-only mode. These hybrids generally use battery power only while stopped or at low speeds, and cannot typically operate at high speeds while being powered by electricity alone. They are charged using regenerative braking and the internal combustion engine and the vehicles do not get plugged into charging equipment.

Figure 1: The standard receptacle (right) can receive charge from level 1 or level 2 equipment. The DC fast charge receptacle (left) uses a different type of connector. Photo courtesy of National Renewable Energy Laboratory.

Range and Charge

Plug-in hybrids are intended for consumers who most frequently drive only short distances. For this reason, they are designed to run on electricity stored in a battery for a limited range—such as 35 miles—before the gas-powered internal combustion engine takes over and provides the primary power for the vehicle. After the full electric mileage range of the vehicle is met, the battery needs to be recharged and/or gasoline needs to be utilized. These vehicles

*C. Weiner, Colorado State University, clean energy Extension specialist. 5/2012.

Quick Facts

- Plug-in hybrids are intended for consumers who most frequently drive only short distances and are designed to run on electricity stored in a battery for a limited range before the gas-powered internal combustion engine takes over.
- Plug-in hybrids do have the parts associated with gasoline-powered vehicles but those parts do not degrade as quickly as they do in gasoline-powered vehicles because the internal combustion engine is not used as often.
- Battery-electric vehicles only accept electricity as the fuel source and therefore have a greater electric range than plug-in hybrids.
- Battery-electric vehicles do not have timing belts, water pumps, radiators, fuel injectors, motor oil, transmission fluid, or tailpipes to replace and do not require oil changes.

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commonly make use of deep cycle lithium-ion batteries that can be discharged and recharged regularly.

Battery-electric vehicles, on the other hand, only accept electricity as the fuel source and therefore have a greater electric range than plug-in hybrids. Various rating agencies have assigned ranges between 73 to 110 miles for today's commercially available battery-electric vehicles. The range of battery-electric vehicles—like all vehicles—varies depending on conditions such as driving habits, terrain, weather, accessory use, and battery age. In particular, cold temperatures can significantly reduce electric battery ranges and exposure to extreme hot or cold temperatures can inhibit proper battery operation.

Both battery-electrics and plug-in hybrids can be recharged using a standard (home) 120-volt plug or a 240-volt plug. Using a 120-volt plug (level 1 charging), two to five miles of range per hour of charging time can be added. In this scenario, an electric vehicle plugged in overnight (12 hours) will gain 24 to 60 miles of charge by the morning.

Using a 240-volt plug (level 2 charging) requires installation of a home charging station or access to a public charging station. Based on the battery type and circuit capacity, 240-volt charging adds 10 to 20 miles of range per hour of charging time. In this scenario, an electric vehicle plugged in overnight (12 hours) will gain 120 to 240 miles (or the maximum range) of charge by the morning. A home charging station requires a 220/240V, 40 amp dedicated circuit connected to a breaker. It should be hard-wired directly to the circuit by a certified electrician.

Certain battery-electric vehicles are beginning to make 480-volt direct current (DC) charging an option as well. This level 3 fast charge can take 30 minutes or less to fully charge a depleted 24kWh battery. It should be noted that frequent use of level 3 charging may result in shortened battery life[3].

According to the U.S. Department of Energy[4] (DOE), as of late 2011 there were 10 public charging stations available for electric vehicles in Colorado, exclusively in Denver and along the Front Range. Eight of these stations offer level 2 charging. A database of electric vehicle charging stations by state and zip code is available at DOE's online Alternative Fuels and Advanced Vehicles Data Center: www.afdc.energy.gov.

Environmental Considerations

One of the main reasons consumers are interested in electric vehicles is the fact that while in electric mode there are no tailpipe emissions. It should be noted, however, that electricity from the grid used to charge the batteries is primarily produced from fossil-fuel burning power plants that do emit greenhouse gases. The tables to the right show emissions associated with tailpipes and charging (from Xcel Energy in Colorado's electricity grid) for electric and non-electric vehicles using a conservative list of assumptions.

As shown, electric vehicles charged using Colorado's electricity grid would emit less CO_2 equivalent than a new, average light duty vehicle traveling the same number of miles per day. As Colorado uses a greater percentage of renewable energy in its electricity portfolio, CO_2e emissions from electric vehicle charging will decrease. And of course individual charging systems powered by clean energy such as solar or wind would reduce or completely negate emissions from charging.

Another environmental consideration for electric vehicle use is that these vehicles are relatively new to the U.S. auto market and only a small number of them have approached the end of their useful lives. As a result, few post-consumer batteries from electric vehicles are available, thus limiting the extent of battery-recycling infrastructure. As electric drive vehicles become increasingly common, the battery-recycling market will likely expand.

Widescale battery recycling would keep hazardous materials from entering the waste stream, both at the end of a battery's useful life, as well as during its production. Work is now under way to develop battery-recycling processes that minimize the life-cycle impacts of using lithium-ion and other kinds of batteries in vehicles[3].

Table 1: Annual Tailpipe CO_2e Emissions Under Various Mileage Schedules (Lbs).

	Daily Mileage			
Vehicle	**15**	**30**	**45**	**60**
Battery-electric	0	0	0	0
Plug-in hybrid	0	0	3,603	7,206
New non-electric	3,603	7,206	10,809	14,411

Table 2: Annual Charging CO_2e Emissions Under Various Mileage Schedules (Lbs).

	Daily Mileage			
Vehicle	**15**	**30**	**45**	**60**
Battery-electric	2,520	5,039	7,559	10,079
Plug-in hybrid	2,520	5,039	5,039	5,039
New non-electric	0	0	0	0

Table 3: Total Annual CO_2e Emissions Under Various Mileage Schedules (Lbs).

	Daily Mileage			
Vehicle	**15**	**30**	**45**	**60**
Battery-electric	2,520	5,039	7,559	10,079
Plug-in hybrid	2,520	5,039	8,642	12,245
New non-electric	3,603	7,206	10,809	14,411

Assumptions:

- Plug-in hybrid can travel 30 miles before switching to gasoline
- Plug-in hybrid achieves 37 mpg after switching to gasoline
- New non-electric vehicle rated at 33.7 miles/gallon per U.S. Bureau of Transportation Statistics 2010 new vehicle average[5]
- 19.6 lbs. of CO_2e emitted/gallon of gasoline
- 1.0 lbs. of CO_2e emitted/kWh per National Renewable Energy Laboratory study[6]
- Mileage converted to electricity consumption at a rate of 0.37 ACkWh/mile[7]
- Daily charging

Initial Costs and Incentives

Commercially available electric vehicles—similar in size and performance to traditional light-duty gasoline-powered vehicles—currently cost upwards of $30,000. An at-home level 2 charging station may add between $1,000 and $4,000 installed, not including the costs of any upgrades necessary to accommodate a dedicated 240-volt circuit.

A federal tax credit of up to $7,500 is available for purchases of qualified plug-in electric vehicles. Based on battery capacity, both the *Chevy* 'Volt' and *Nissan* 'Leaf' are currently eligible for the full $7,500 credit. The federal tax credits will be phased out by manufacturer once 200,000 qualifying electric vehicles are sold by that manufacturer in the United States.

The state of Colorado currently offers additional tax credits of up to $6,000 for the purchase of qualified electric vehicles[8]. As tax credits and incentives can change rapidly and are subject to income and other restrictions, consulting a tax professional is recommended before purchasing an electric vehicle.

Operating and Maintenance Costs

The following table compares the cost to fuel electric and new non-electric vehicles using the assumptions noted above plus a cost per kWh of 11 cents and $3.50 per gallon of gasoline:

Table 4: Total Annual Fuel Costs Under Various Mileage Schedules.

	Daily Mileage			
Vehicle	**15**	**30**	**45**	**60**
Battery-electric	$223	$446	$668	$891
Plug-in hybrid	$223	$446	$964	$1,481
New non-electric	$569	$1,137	$1,706	$2,274

Under this set of assumptions, an average American driver traveling 15,000 miles per year (41.1 miles/day) in a battery-electric vehicle would save over $900 in fuel costs annually, compared to a new gasoline-powered vehicle. Should gas prices rise quicker than electricity costs over the life of the vehicle, annual savings would grow; should electricity costs rise quicker than gas prices annual savings would decrease. In addition, many utilities are beginning to offer time-of-use rates for electric customers. Electric vehicle owners who are able to recharge their vehicle battery at night during off-peak hours are likely to see additional savings when compared to gasoline powered vehicles.

In terms of maintenance, battery-electric vehicles do not have timing belts, water pumps, radiators, fuel injectors, motor oil, transmission fluid, or tailpipes to replace and do not require oil changes. Plug-in hybrids do have the parts associated with gasoline-powered vehicles but those parts do not degrade as quickly as they do in gasoline-powered vehicles because the internal combustion engine is not used as often.

In the case of plug-in hybrids, internal combustion engines should be run as required to keep the engine properly lubricated and maintained. Similarly, gasoline should generally not be left in the tank for more than one year without being used. Follow the manufacturer's guidelines for performing engine and fuel maintenance.

Perhaps the biggest risk associated with maintaining a plug-in electric vehicle is the battery. To this end, it is important to secure a sound battery warranty from the dealer or manufacturer. Both the *Chevy* 'Volt' and the *Nissan* 'Leaf' currently have eight year or 100,000 mile warranties for their electric vehicle batteries. After the warranty expires, batteries may cost thousands of dollars to replace.

In addition, electric vehicles need to be service by trained professionals, who may be hard to come by in certain parts of Colorado.

Electric Vehicles and the Future

Electric vehicles are so new to the marketplace that their impact on the electrical infrastructure and environment is largely unknown. A 2007 report by Kintner-Meyer et. al[9] concluded that as much as 73% of vehicle miles traveled by U.S. light-duty vehicles could be supported by the existing electric power infrastructure. This would occur by maximizing the charging of electric vehicles during off-peak hours (i.e. at night). On the other hand, should charging habits occur to a significant degree during on-peak hours–as in the case of employees charging electric vehicles at or near their workplace during the day–U.S. power capacity may need to dramatically expand in order to accommodate a new generation of electric vehicles.

Should electric vehicles make a widespread dent in the world auto market, an opportunity to integrate renewable energy storage may exist. In essence, because electric vehicle batteries may have some capacity left once they reach their destination, that excess capacity could be used by the grid to offset peak power demands. The grid could then recharge the batteries when demand is lower. This approach would require the development of smart chargers and communication technology between drivers and utilities.

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