Electric-Drive Vehicle Basics

With the release of electric-drive vehicles into the mainstream marketplace, the buzz is hitting a fever pitch. Because they use electric power as their primary fuel source or to improve fuel economy, these vehicles hold great promise for reducing U.S. dependence on foreign oil. That's why the U.S. Department of Energy's (DOE) Vehicle Technologies Program and Clean Cities initiative are helping deploy them across the country.

There are three types of electric-drive vehicles:

- Hybrid electric vehicles (HEVs)
- Plug-in hybrid electric vehicles (PHEVs)
- All-electric vehicles (EVs)

In this fact sheet, you'll learn the basics about the types of electric-drive vehicles, including how they work, the benefits of using them, and the various charging options. You'll also read about what DOE is doing to further the deployment of these vehicles through Clean Cities and projects funded by the American Recovery and Reinvestment Act (ARRA).

All-electric and plug-in hybrid electric vehicles are charged by plugging the vehicle into an electric power source. *Photo by Andrew Hudgins, NREL/PIX 17634*

Hybrid Electric Vehicles

Clean Cities has long encouraged the use of HEVs, which are well established in the mainstream marketplace. These vehicles are powered by an internal combustion engine that can run on conventional or alternative fuel and an electric motor that uses energy stored in batteries. The extra power provided by the electric motor allows for a smaller engine, resulting in better fuel economy without sacrificing performance.

HEVs combine the benefits of high fuel economy and low emissions with the power and range of conventional vehicles. Some HEVs achieve fuel economy of 40 to 50 miles per gallon. They also produce lower levels of air pollutants and greenhouse gases than conventional vehicles do.

HEVs don't require a plug to charge the battery; instead, they use regenerative braking and their internal combustion engine to charge. They capture energy normally lost during braking by using the electric motor as a generator and storing the captured energy in the battery. The energy from the battery provides extra power during acceleration and auxiliary power when idling.

Plug-In Hybrid Electric Vehicles

PHEVs are powered by conventional fuels as well as electrical energy stored in a battery. Using electricity from the grid to charge the battery some of the time costs less and reduces petroleum consumption compared with conventional vehicles. PHEVs might also reduce emissions, depending on the electricity source.

Electric-Drive Vehicles at a Glance

HEVs: HEVs are powered by conventional or alternative fuels as well as electrical energy stored in a battery. The battery is charged through regenerative braking and the internal combustion engine and is not plugged in to charge.

PHEVs: PHEVs are powered by conventional fuels and electrical energy stored in a battery. The vehicle can be plugged into an electric power source to charge the battery in addition to using regenerative braking and the internal combustion engine.

EVs: A battery stores the electrical energy that powers the motor. EV batteries are charged by plugging the vehicle into an electric power source.

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PHEVs have an internal combustion engine and an electric motor, which uses energy stored in batteries. PHEVs have a larger battery pack than HEVs, making it possible to drive using only electric power (approximately 10 to 40 miles). This is commonly referred to as the "all-electric range" of the vehicle.

PHEV batteries can be charged in three ways: by an outside electric power source, by the internal combustion engine, or through regenerative braking. If a PHEV is never plugged in to charge, fuel economy will be about the same as a similarly sized HEV. If the vehicle is fully charged and then driven a shorter distance than its all-electric range, it is possible (depending on the powertrain design) to use electric power only.

PHEVs are powered by conventional fuel and by electrical energy stored in a battery.
Photo from Greater Indiana Clean Cities Coalition, Inc./PIX 17152

Table 1. Electric-Drive Vehicle Benefits

Benefits	Hybrid Electric Vehicles	Plug-In Hybrid Electric Vehicles	All-Electric Vehicles
Fuel Economy	**Better than similar conventional vehicles** The fuel savings of driving a Honda Civic Hybrid versus a conventional Civic is about 38% in the city and 20% on the highway.	**Better than similar HEVs and conventional vehicles** PHEVs use 40% to 60% less petroleum than conventional vehicles and permit driving at slow and high speeds using only electricity.	**No liquid fuels** Fuel economy of EVs is usually expressed as cost per mile, which is discussed below.
Emissions Reductions	**Lower emissions than similar conventional vehicles** HEV emissions vary by vehicle and type of hybrid power system. HEVs are often used to offset fleet emissions to meet local air-quality improvement strategies and federal requirements.	**Lower emissions than HEVs and similar conventional vehicles** PHEV emissions are projected to be lower than HEV emissions, because PHEVs are driven on electricity some of the time. Most categories of emissions are lower for electricity generated from power plants than from vehicles running on gasoline or diesel.	**Zero emissions** EV emissions do not come from the tailpipe, so EVs are considered zero-emission vehicles. However, emissions are produced from the electric power plant. Most categories of emissions are lower for electricity generated from power plants than from vehicles running on gasoline or diesel.
Fuel Cost Savings	**Less expensive to operate than a conventional vehicle** Because of their improved fuel economy, HEVs usually cost $0.05 to $0.07 per mile to operate, compared to conventional vehicles, which cost $0.10 to $0.15 per mile to operate.	**Less expensive to operate than an HEV or conventional vehicle** When operating on electricity, a PHEV can cost $0.02 to $0.04 per mile (based on average U.S. electricity price). When operating on gasoline, the same vehicle can cost $0.05 to $0.07 per mile, compared to conventional vehicles, which cost $0.10 to $0.15 per mile to operate.	**Less expensive to operate than conventional vehicles** EVs operate using only electricity. A typical electric vehicle costs $0.02 to $0.04 per mile for fuel (based on average U.S. electricity price).
Fueling Flexibility	**Same as conventional vehicles**	**Can get fuel at gas stations or charge at home or public charging stations**	**Can charge at home or public charging stations**

Source: Alternative Fuels and Advanced Vehicles Data Center, www.afdc.energy.gov/afdc/vehicles/electric_benefits.html

All-Electric Vehicles

EVs use a battery to store the electrical energy that powers the motor. EV batteries are charged by plugging the vehicle into an electric power source. Although electricity production may contribute to air pollution, the U.S. Environmental Protection Agency considers EVs to be zero-emission vehicles because their motors produce no exhaust or emissions.

EVs have a shorter range per charge than conventional vehicles have on a full tank of gas. For example, the custom-order, all-electric Tesla Roadster has a 220-mile range. The Nissan Leaf can travel between 62 and 138 miles on a single charge, depending on driving style, topography, and speed. According to the U.S. Department of Transportation Federal Highway Administration, 100 miles is sufficient for more than 90% of all household vehicle trips in the United States.

Charging Equipment

PHEVs and EVs plug into electric vehicle supply equipment (EVSE) to recharge. Charging equipment for PHEVs and EVs is classified by the maximum amount of power in kilowatts provided to the battery. Charging times can range from 30 minutes to more than 20 hours, depending on how depleted the battery is, the type of battery, battery capacity, and the type of charging equipment.

There are several EVSE options:

- **Level 1:** Level 1 equipment provides charging through a 120 V, alternating-current (AC) outlet (up to 15 amperes and 1.8 kW). Level 1 EVSE does not require installation of charging equipment. On one end of the cord is a standard, three-prong household plug. On the other end is a connector, which plugs into the vehicle. Level 1 works well for charging at home and work. Based on the battery type, Level 1 charging can take four to 20 hours to reach a full charge, accumulating about five to six miles of range per hour of charging time, depending on the vehicle.

EV owners can charge their vehicles at this public charge station in Sacramento, California. *Photo from Roger Borkenhagen, PIX 17032*

- **Level 2:** Level 2 equipment offers charging through a 208 V or 240 V AC outlet and requires installation of home charging or use of public charging equipment. This charging option can operate at up to 80 amperes and 19.2 kW. However, most residential Level 2 EVSE will operate at lower power. Most homes have 240 V service available, and, because Level 2 EVSE can easily charge a typical EV battery overnight, this will be a common installation for homes. Level 2 equipment uses the same connector on the vehicle as Level 1 equipment. Based on the battery type and circuit capacity, Level 2 charging can take three to eight hours to reach a full charge, adding about 25 miles of range per hour of charging time, depending on the vehicle.

- **Level 3:** Level 3 charging, also known as direct-current (DC) fast charging, can provide a full charge in less than 30 minutes—the fastest rate available. This equipment operates at higher voltage and current than Level 2 charging. It uses AC power input from the grid and supplies DC power directly to the vehicle battery. This option, not yet widely available, will enable charging along heavy traffic corridors and at public stations.

According to the Electric Power Research Institute, most EV and PHEV owners are expected charge their vehicles overnight at home. For this reason, Level 1 and Level 2 charging equipment will be the primary options for homeowners. Charging at home is convenient and allows drivers to estimate and plan transportation costs because residential electricity rates tend to be stable and predictable.

General public stations are expected to use Level 2 or DC fast charging to enable quicker charging. Widespread public charging infrastructure will help facilitate the penetration of EVs and PHEVs and help address consumer “range anxiety.” Charging infrastructure will likely be placed at shopping centers, parking lots, airports, hotels, government offices, and businesses in regions of high EV and PHEV adoption.

For consumers to accept and use EVs and PHEVs, they need affordable, convenient, and compatible charging options at home and on the go. Clean Cities is advancing the deployment of these vehicles by helping municipal governments plan for the installation of residential charging equipment and find ways to remove roadblocks in the permitting process. Once home charging processes are in place, Clean Cities will help cities tackle the installation of public Level 2 and DC fast charging equipment in the places drivers work, shop, and play.

Vehicle and Infrastructure Projects

DOE is helping advance the market acceptance of EVs and PHEVs by managing projects funded through the ARRA Transportation Electrification Initiative, which is providing approximately $400

Table 2. ARRA Transportation Electrification Initiative Projects		
Organization	**Funding Amount**	**Project**
Electric Transportation Engineering Corp.	$114.8 million	Demonstrate more than 7,500 Nissan Leaf EVs and Chevy Volt PHEVs. Deploy more than 15,000 Level 2 charging stations and 250 Level 3 chargers in seven major metropolitan areas. Fully instrument vehicles and infrastructure for data collection and analysis.
Chrysler, LLC	$48 million	Develop, validate, and deploy 140 PHEV Dodge Rams. Deploy vehicles through 11 partner fleets across a variety of geographic, climatic, and operating environments.
South Coast Air Quality Management District	$45.4 million	Develop a fully integrated production PHEV system for Class 2-5 vehicles. Demonstrate 378 trucks and shuttle buses with partner fleets.
Navistar, Inc.	$39.2 million	Develop, validate, and deploy 950 advanced battery electric delivery trucks with a 100-mile range.
Smith Electric Vehicles	$32 million	Develop and deploy up to 500 medium-duty electric trucks in conjunction with 20 launch partners.
General Motors	$30.5 million	Develop, analyze, and demonstrate 125 Chevy Volt extended range electric vehicles (EREVs) for electric utilities and 500 Volt EREVs to consumers.
Cascade Sierra Solutions	$22.2 million	Deploy truck-stop electrification infrastructure at 50 sites along major U.S. Interstate corridors. Provide 5,450 rebates of 25% of the cost for truck modifications for idle reduction technologies.
Coulomb Technologies	$15 million	Deploy approximately 4,000 public and private charging stations in up to nine U.S. cities.

million in federal funding, leveraged through cost-shared grants with industry and educational institutions, to develop, demonstrate, and evaluate electric-drive vehicles and charging infrastructure.

Through the demonstration projects funded under this activity, more than 13,000 electric-drive vehicles will be deployed in conjunction with nearly 23,000 charging stations in residential, commercial, and public access applications in several focused geographic locations nationwide. See Table 2 for more information about these projects.

In addition, several projects funded through Clean Cities' ARRA awards focus on the deployment of EVs and supporting infrastructure. For more information, visit *www.energy.gov/recovery/cleancities.htm.*

Resources

Clean Cities developed the following resources to educate transportation decision makers about electric-drive vehicles and charging equipment. These Web pages and documents feature useful information about a number of EV-related topics.

- Alternative Fuels and Advanced Vehicles Data Center
  www.afdc.energy.gov/afdc/vehicles/electric_benefits.html
  - Hybrid, Plug-in Hybrid, and All-Electric Drive Vehicles
    www.afdc.energy.gov/afdc/vehicles/electric.html
  - Deployment of Hybrid, Plug-in Hybrid, and All-Electric Vehicles
    www.afdc.energy.gov/afdc/vehicles/electric_deployment.html
  - Federal and State Incentives and Laws
    www.afdc.energy.gov/afdc/laws
  - Electric Charging Station Locations
    www.afdc.energy.gov/afdc/fuels/electricity_locations.html
- Clean Cities 2011 Vehicle Buyer's Guide
  www.afdc.energy.gov/afdc/pdfs/49488.pdf
- FuelEconomy.gov
  www.fueleconomy.gov

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