Environmental and Energy Study Institute

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Fact Sheet

Plug-in Electric Vehicles

August 2017

Plug-in electric vehicles (PEVs) use electricity from the energy grid to charge large battery packs, then use the batteries to power an electric motor. They are primarily powered by electricity instead of liquid fuels and produce no tailpipe emissions. Plug-in vehicles can also generate power from regenerative braking systems, which convert kinetic energy from the vehicle's brakes into electricity that is stored in the battery pack. Since plug-in vehicles rely on rechargeable batteries for power, each vehicle has an **electric range**—the maximum number of miles it can travel on battery power before it needs to recharge. Applications for these vehicles go beyond just passenger cars (though U.S. consumer passenger PEVs are largely the focus of this fact sheet), as there are currently plug-in electric buses, utility trucks, high-performance vehicles, and motorcycles.

There are two main types of plug-in electric vehicles:

- **All-electric (or battery electric) vehicles (BEVs)** only use electric power from the grid; they do not have an internal combustion engine and do not use any type of liquid fuel. BEVs use large battery packs to give the vehicle a long electric range, with some traveling up to 335 miles on a single charge.[1]

- **Plug-in hybrid electric vehicles (PHEVs)** are powered by a combination of grid electricity and liquid fuel. A PHEV runs on battery power until the battery charge is exhausted, and then switches over to its internal combustion engine. If a trip is within the vehicle's electric range, a PHEV will run entirely on its battery pack.

Because plug-in vehicles consume electricity instead of liquid fuel, the U.S. Environmental Protection Agency (EPA) rates their **miles per gallon equivalent (MPGe)** instead of their miles per gallon (MPG) to measure how efficient such a vehicle is with the electricity it consumes. The EPA equates 33.7-kilowatt hours (kWh) of electricity to one gallon of gasoline. A PHEV receives an MPGe rating for its battery-electric motor and a separate MPG rating for its combustion engine. Carmakers must also list the vehicle's average energy consumption over 100 miles, either in kilowatt-hours of electricity or gallons of gasoline, to show the true usage of energy by a vehicle.[2]

It is important to note that while plug-in vehicles produce no tailpipe emissions, generating the electricity plug-in vehicles use may produce pollution, depending on the energy source used. Nevertheless, even though about two-thirds of U.S. electricity is generated by carbon-emitting natural gas and coal, the electricity required to power BEVs produces less than half the carbon dioxide of a conventional internal combustion engine (ICE) vehicle.[3] And, BEVs do not emit the harmful particles released by gasoline-powered engines, which means battery electric vehicles have the potential to save billions of dollars in health and climate costs. Indeed, a study performed by the American Lung Association of California found that gasoline vehicles are responsible for $37 billion in health and climate costs each year. Put differently, every 16-gallons of gasoline (representative of a typical tank) combusted adds $18.42 to public health and climate costs. The study found that if electric vehicles represent 65 percent of all cars on the road in 10 western and eastern states by 2050, those costs would drop by $21 billion.[4]

U.S. Market for Electric Vehicles

Battery electric vehicles and plug-in hybrid electric vehicles now account for just over one percent of all new vehicle sales in the United States, with seven models accounting for 81 percent of plug-in vehicle sales.[5]

Table 1: Popular Plug-in Electric Vehicles				
Make/Model	Type	Starting Price	Electric Range (miles)	MPGe (city/highway)
Chevrolet Volt	PHEV	$33,220	53	106
Tesla Model S	BEV	$69,200	210-315	90/94
Tesla Model X	BEV	$90,000	238-289	81/92
Ford Fusion Energi	PHEV	$31,120	21	104/91
Nissan LEAF	BEV	$31,545	107	124/101
Ford C-Max Energi	PHEV	$27,120	20	104/87
BMW i3	BEV or PHEV	$43,395	81-114	BEV: 137/111 PHEV: 117

Between 2014 and 2016, approximate sales for the top four models were 70,000 Model Ss, 60,000 Leafs, 60,000 Volts, and 40,000 Fusion Energis (see Table 2). Additional models are scheduled to roll out within the United States in late 2017, such as the larger battery BMW i3, the Chevy Bolt EV, and the Hyundai Ioniq Electric.[6]

Table 2: Top U.S Sales of Plug-in Electric Vehicles[7]					
Make/Model	Type	2014	2015	2016	Total
Tesla Model S	BEV	16,689	25,202	29,421	71,312
Nissan LEAF	BEV	30,200	17,269	14,006	61,475
Chevrolet Volt	PHEV	18,805	15,393	24,739	58,937
Ford Fusion Energi	PHEV	11,550	9,750	15,938	37,238
BMW i3	BEV or PHEV	6,092	11,024	7,625	24,741
Ford C-Max Energi	PHEV	8,433	7,591	7,957	23,981
Tesla Model X	BEV	0	214	18,223	18,437
Toyota Prius Plug-in	PHEV	13,264	4,191	52	17,507
Fiat 500e	BEV	5,132	6,194	5,330	16,656
VW e-Golf	BEV	357	4,232	3,937	8,526
Total		122,438	116,099	159,139	397,676

Availability and Customer Awareness

The availability of electric vehicles has been spotty in most of the United States. Between the years 2010 and 2016, automakers have brought more than 24 electric vehicles to the market, and sold over 400,000 new PEVs; however, almost half of these sales occurred in California, where electric vehicles benefit from generous rebates, a widespread charging infrastructure, and carpool lane privileges. California sales were mostly comprised of the Chevrolet Volt, the Nissan Leaf, and the Tesla Model S.

California and nine Section 177[1] states have the **Zero Emission Vehicle (ZEV) program**, which requires automakers to sell electric vehicles. But because of a loophole, the ZEV program has caused automakers to make more models available for sale in California rather than in other participating ZEV states.[8] Indeed, the ZEV program's travel provision allows for earned ZEV credits in any ZEV state to be counted toward the mandate of any other participating state. This allows automakers to sell enough electric vehicles in California to meet the obligations of the other nine states; however, this provision will end after 2017, forcing auto dealers to meet ZEV sales quotas for individual states beyond California.[9]

The travel provision has also impacted the customer awareness of PEVs. Car companies are focusing much less on PEV advertising outside of California. According to studies performed by CompetiTrack and Motor Intelligence, GM advertised the Volt nearly 800 times in California in 2015, but only advertised the Volt to a Northeast-focused audience about 10 times. Lesser known PEV models fare even worse. Ford advertised its gasoline-powered Ford Focus 4,750 times nationally, but the Focus Electric was only advertised 200 times. BMW, Nissan, GM, and Ford spent virtually no money on advertising the i3, Volt, Leaf, or Fusion Energi to Northeast audiences, but for California, their range of spending was between $1-3.5 million. Among national audiences, electric vehicle advertising ranged from zero dollars, for Ford, to nearly $19 million for BMW.[10] Even with this low level of advertising and awareness, the sales of electric vehicles have continued to rise.

Automakers are showing a deep interest in further developing the plug-in vehicle marketplace. In 2015, Ford announced that it was going to invest $4.5 billion into electric vehicles that would yield 13 new models. In addition, Ford also declared it would invest another $700 million in expanding the company's Flat Rock factory in Michigan to help in the manufacturing of electric vehicles.[11] Volkswagen has declared it will invest $2 billion over the next 10 years in the United States to support electric vehicles, develop charging infrastructure, and build awareness. This investment will take place under a new subsidiary of Volkswagen, Electrify America LLC, and is part of the legal settlement with EPA following Volkswagen's cheating on emissions tests for diesel vehicles.[12]

Global Sales Versus Sales in the United States

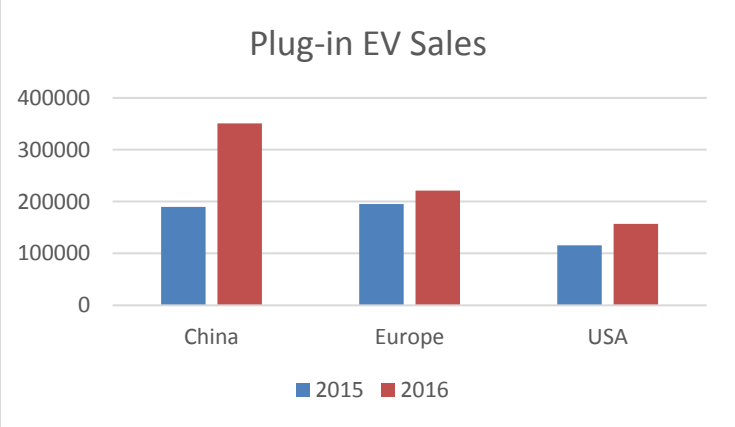

Figure 1: Plug-in Electric Vehicle Sales 2015-2016. Data from EV Volumes.[13]

Global sales of plug-in vehicles have continued to rise over the last several years. China alone has seen an 85 percent growth in plug-in vehicles, with nearly 351,000 plug-in vehicles sold in 2016, up from 190,000 in 2015. The Chinese government is making a concerted push towards what they call "new energy vehicles" to help with reducing greenhouse gas emissions, smog, and traffic congestion. China's commitment to pushing electric vehicles has positioned electric vehicle manufacturers BYD Auto Company and BAIC Automotive Group as industry leaders. Europe is closely behind with overall sales around 221,000 vehicles, though their growth has slowed to 13 percent as the result of incentive changes in some countries. The United States lags behind both China and Europe with around 157,000 plug-in vehicles sold in 2016, but its rate of growth from 2015 was 36 percent.[13] However, there is the potential that rolling back fuel efficiency standards in the United States would hinder the growth of American manufacturers such as Tesla and General Motors.[14]

[1] Section 177 of the Clean Air Act allows other states to adopt California's motor vehicle emission standards (their standards must be identical to California's).

Cost of Ownership

Since electricity is a cheaper power source than liquid fuel, ownership of a plug-in vehicle can result in large savings over the life of the vehicle. To compare the price of electricity to the price of gasoline, the Department of Energy (DOE) has created the eGallon metric. According to the DOE, the "eGallon represents the cost of driving an electric vehicle the same distance a gasoline-powered vehicle could travel on one gallon of gasoline."[15] As of March 2017, the average U.S. price of regular gasoline is $2.32, whereas the average gallon equivalent of electricity is $1.11.[16] On average, it costs less than half as much to drive an electric vehicle as it does to drive a gasoline-powered car, and electricity prices are also much more stable than gasoline prices. This is an important benefit, as the average U.S. household spends about one-fifth of its total family expenditures on transportation costs.

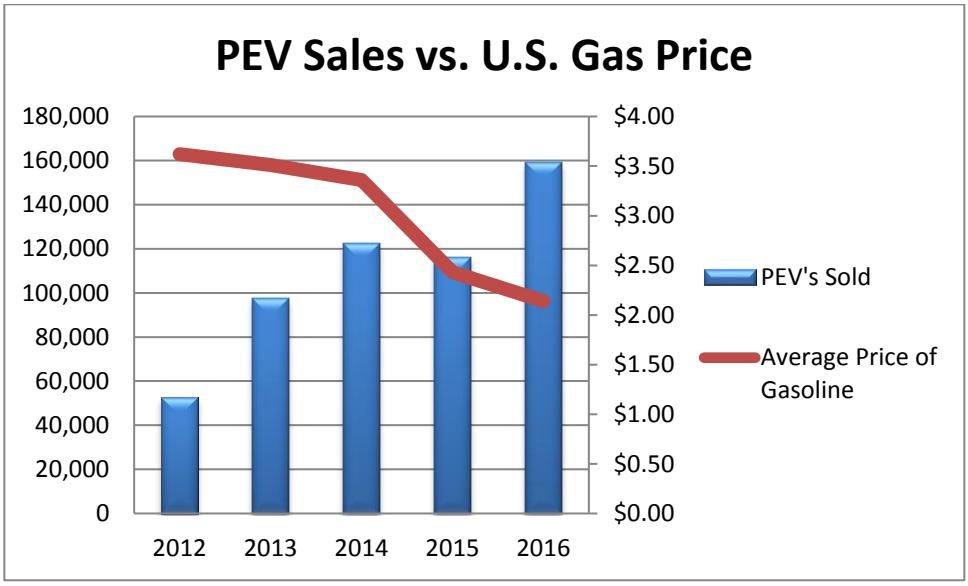

Figure 2: Sales of plug-in electric vehicles against the average price of gasoline in the United States. Adapted from data from Inside EVs and Statista.

Maintenance is also an area for which electric vehicles can reduce the lifetime cost of a car.[17] The battery, motor, and other electronics associated with electric vehicles usually require little to no maintenance. There are also fewer fluids that need to be replaced and brake wear is greatly reduced because of the application of regenerative braking systems. Since there are fewer moving parts in electric vehicles compared to gasoline-powered vehicles, there is less that can break.[18] So while the initial price of a plug-in vehicle (without government incentives) may be more expensive than that of a conventional car, the total cost of ownership of a plug-in vehicle—the initial cost, plus the cost of fuel and maintenance over the life of the vehicle—may be substantially less.

Plugging into the Grid

As the number of all-electric vehicles on the road increases, there is a greater need for electric vehicle infrastructure. The number of public charging stations has continued to rise within the past few years, and as of March 2017, there are around 15,000 public charging stations across the United States.[19] For comparison, there are 150,000 gasoline stations across the country.[20] Public charging stations are essential, as they can help extend the range of plug-in vehicles and make them more viable for long-distance trips.

There are three common electric vehicle charging station voltage levels, with 120-volt, 240-volt, and 480-volt models. The most common form is the 120-volt charging unit, or AC Level 1. This method of charging can use standard wall outlets and usually requires no additional installation cost on the part of the operator. Unfortunately, 120-volt charging is slow and typically provides only 3-5 miles of range per hour of charging. Depending on the BEV's battery size and its state of charge, charging to full capacity could take between 8 and 20 hours. For cars possessing especially large batteries, a full charge from a depleted battery would take even longer. The charging time is cut significantly by using an AC Level 2, 240-volt charging unit; however, they typically require a licensed electrician to install, as they need a dedicated circuit.[22] Some residential users choose to install these units for in-home charging, but they can cost between $600 and $3,600. As a result, Level 2 charging units are mostly confined to public charging stations. Fast-charging systems that use 480 volts DC allow for roughly 80 percent of the battery to be charged within about 30 minutes; however, they are the most expensive, and are only appropriate for public charging stations.

Table 3: Typical Charging Times by Power Level[21]

	Demand Impact	Plug-in Hybrid	All-Electric
Level 1: 120 volts <20 amps	1.4-2.0 kilowatts	6-9 hrs	12-14 hrs
Level 2: 240 volts <80 amps	<19 kilowatts	2-3 hrs	3-4 hrs
Level 3: 250-450 volts-DC <200 amps	<90 kilowatts	N/A	80% in 30 min

Utility companies and industry are also making a push to build charging networks for electric vehicles. In California, three of the largest utilities, Southern California Edison, Pacific Gas & Electric, and San Diego Gas & Electric, have proposals for building out charging stations for the state totaling $1 billion.[23] Both BMW and Nissan have partnered with EVgo to build 668 DC fast-charging stations in over 50 metro areas and are in the middle of building an additional 174 DC fast-charging stations across 33 states.[24] Tesla has continued to build out their Supercharger network, which currently stands at 373 sites across North America.[25]

Battery Outlook

Battery technology continues to improve with higher capacities and faster recharge times. Recently, Samsung has introduced an electric vehicle battery that has 372 miles of range and can be charged in 20 minutes. Samsung states the battery will be placed in commercial production in 2021. Tesla, an electric car and energy storage manufacturer, is also investing heavily in the development of batteries, with the company building a battery factory known as the "Gigafactory" outside Reno, NV. Tesla hopes to make the manufacturing of battery cells, which has until now been dominated by China, Japan, and South Korea, into an American industry in order to source their batteries domestically.[26]

Batteries represent a large portion of the cost of BEVs: lithium-ion batteries make up about 40 percent of an electric vehicle's total value.[27] Fortunately, battery pack prices are on a downward trend, having fallen 73 percent—from $1,000/kWh in 2010 to $273/kWh in 2016. This change has been the driving force behind the falling costs of EVs in recent years.[28] Used EV batteries also have the potential to be exploited in energy storage, once their capacity has become too degraded for continued use in automobiles. In fact, lithium-ion battery packs have shown less degradation of capacity and performance than expected, and could provide cost-effective, reliable power for energy storage devices.[29]

EV Incentives and Initiatives

The federal government offers incentives for individuals to purchase electric vehicles, including the federal tax credit for PEVs. This tax credit ranges from $2,500 to $7,500 per vehicle, depending on the battery's capacity, and is only available in the year the car is placed in service—it cannot be carried into the future[30]. A structured phase-out of the tax credit for each individual automaker is triggered once a company sells 200,000 electric vehicles. For example, if Tesla were to deliver its 200,000th EV on July 1, 2018, all its electric vehicles sold in the United States for the following 6 months would still qualify for the full tax credit. After that, the credit would decrease to 50 percent over the next six months ($3,750); then decrease to 25 percent ($1,875) for the final six months.[31] Other electric car manufacturers, such as GM, Ford, and Nissan, would not be affected by the phase-out, which applies to each manufacturer separately.

The federal government is also addressing EV infrastructure needs. As part of the *Fixing America's Surface Transportation (FAST) Act*, the Federal Highway Administration designated 25,000 miles along National Highway System corridors, containing 55 routes and spanning 35 states, for future development of a national alternative fuel and electric charging network.[32] In July 2016, the Department of Transportation announced $4.5 billion in guaranteed loans for organizations willing to build fast-charging stations across the country.[33]

Currently, more than half of all states (and the District of Columbia) have at least one type of plug-in vehicle incentive for consumers.[34] States such as California, Delaware, and Massachusetts offer rebates to consumers purchasing PEVs to reduce their financial burden, whereas other states, such as Maryland and Colorado, choose to offer assistance through tax credits. Some states and utility companies also provide incentives for electric vehicle charging stations for small businesses and private consumers.[35] Illinois offers a rebate that covers 50 percent of the cost of equipment and installation for non-networked stations, up to a $3,000 cap.[36] Austin Energy in Texas offers PEV owners a rebate of 50 percent of the purchase and installation costs of a Level 2 charging station, with the maximum rebate being capped at $1,500.[37]

Globally, the future of electric vehicles is looking very bright. Several countries have set ambitious targets to phase out gasoline-powered cars: Norway is aiming for 2025 and India for 2030—though in both cases these are aspirational, not mandatory, targets.[38,39] France and the United Kingdom have both announced they intend to ban the sale of gas and diesel cars by 2040.[40,41] At least 10 other countries have set sales targets for electric vehicles: Austria, China, Denmark, Germany, Ireland, Japan, the Netherlands, Portugal, Korea and Spain.[42] And, in July 2017, Volvo became the first major carmaker to announce it was phasing out conventional internal combustion engines: all of its models will be either battery-powered or hybrid by 2019.[43]

This fact sheet is available electronically (with hyperlinks and endnotes) at www.eesi.org/papers.

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The Environmental and Energy Study Institute (EESI) is a non-profit organization founded in 1984 by a bipartisan Congressional caucus dedicated to finding innovative environmental and energy solutions. EESI works to protect the climate and ensure a healthy, secure, and sustainable future for America through policymaker education, coalition building, and policy development in the areas of energy efficiency, renewable energy, agriculture, forestry, transportation, buildings, and urban planning.

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