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Report

Plug-in Electric Vehicle Sales Forecast Through 2025 and the Charging Infrastructure Required

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Executive Summary

Today, technology improvements are expanding the opportunity for electric transportation, and electric companies are leading efforts to advance electric transportation and move the market forward. Electric transportation is a win-win; it meets customer needs while also supporting America's energy security and sustainability.

The Edison Electric Institute (EEI) and the Institute for Electric Innovation (IEI) developed a plug-in electric vehicle (PEV) sales forecast through 2025, including both plug-in hybrid electric vehicles and battery electric vehicles, and identified the associated charging equipment infrastructure needs. This paper identifies both the scope and scale of charging infrastructure needed to support PEVs and the different approaches to infrastructure build-out.

The results show the following:

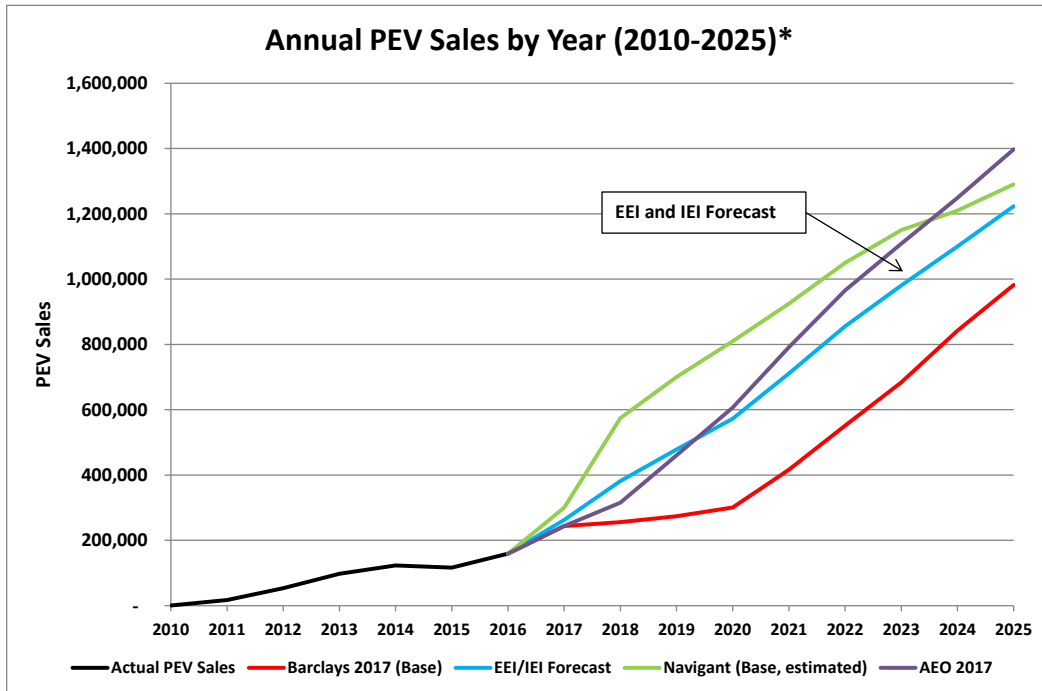
- **Annual sales of PEVs** will exceed 1.2 million vehicles in 2025, reaching more than 7 percent of annual vehicle sales by 2025 (see Figures 1 and 2).
- The **stock of PEVs** (i.e., the number of PEVs on the road) is projected to reach 7 million by 2025, up from 567,000 at the end of 2016 (see Figure 3). This is about 3 percent of the 258 million vehicles (cars and light trucks) expected to be registered in the United States in 2025.
- About **5 million charge ports will be required** to support 7 million PEVs in 2025 (see Figure 3). This represents a significant investment in PEV charging infrastructure.¹

Growing customer demand, corporate average fuel economy (CAFE) standards, and declining battery costs are all major drivers of PEV sales. A continued decline in battery costs will result in increased cost-competitiveness of PEVs with internal combustion engine (ICE) vehicles. However, relaxing current CAFE standards (54.5 MPG by 2025) will put downward pressure on PEV sales. Regardless, customers are buying PEVs in record numbers, and the demand for charging infrastructure is increasing.

Most PEV charging infrastructure to date is paid for by the entity that "hosts" the charging equipment (the "site host"), such as a homeowner, a commercial property owner, or a public entity. The PEV charging marketplace is evolving, and different approaches to providing the charging infrastructure for the PEV market are being tested. Electric companies are well-positioned to help develop PEV charging infrastructure.

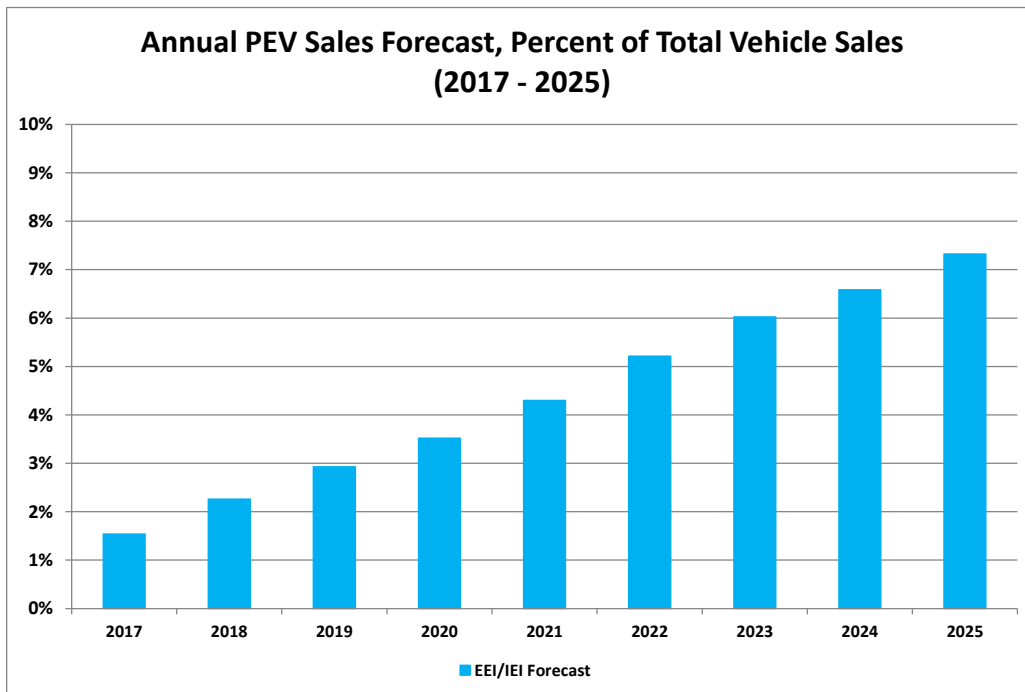
1. The share of battery electric vehicles is expected to increase from 52 percent of annual PEV sales in 2016 to more than 60 percent in 2025. This impacts charging infrastructure needs because BEVs directly influence the number of DC fast chargers.

Figure 1. EEI/IEI Annual PEV Sales Forecast Compared to Selected Forecasts²



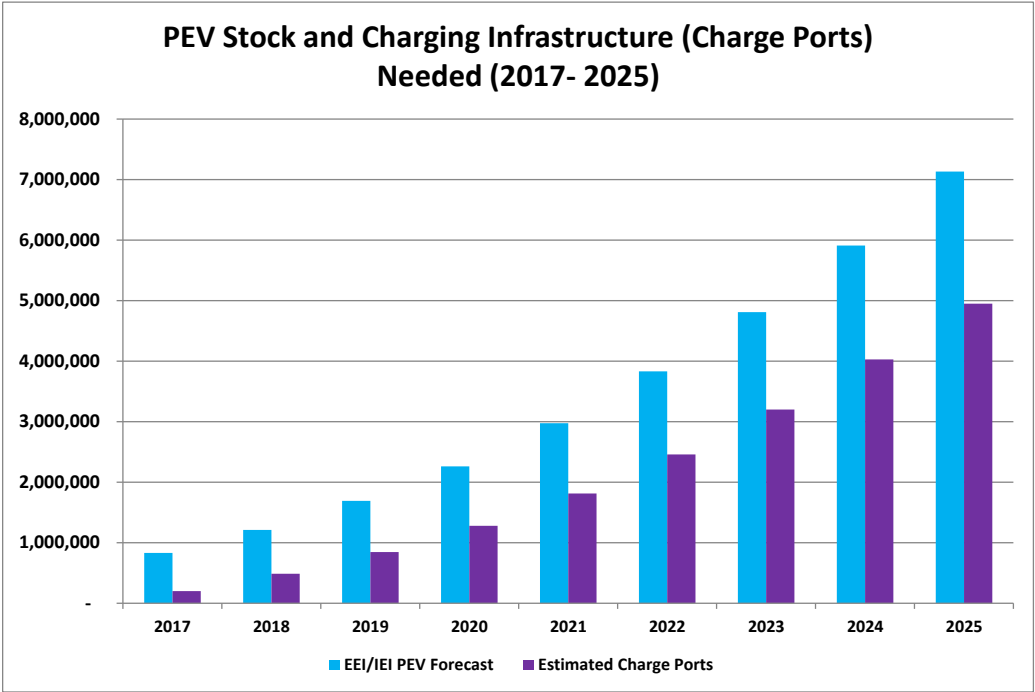
*Includes battery electric vehicles and plug-in hybrid electric vehicles

Figure 2. EEI/IEI Annual PEV Sales Forecast, Percent of Total Vehicle Sales



2. Applied Barclays' North American PEV sales forecast to estimate U.S. sales.

Figure 3. PEV Stock and Charging Infrastructure Needed By 2025 Based on EEI/IEI Forecast



Background

EEI and IEI developed a consensus forecast of PEV sales projections from 2017 to 2025 based on three independent forecasts:

- U.S. Energy Information Administration (EIA) Annual Energy Outlook 2017 Reference Case (January 2017).³
- Barclays Equity Research Note – Together in Electric Dreams (January 2017).⁴
- Navigant Research – Electric Vehicle Geographic Forecasts (June 2016).⁵

These forecasts were selected because they include three key factors: customer preference models that determine interest in PEVs; declining battery costs that influence PEV cost competitiveness with ICE vehicles and manufacturer profitability; and fuel efficiency standards and environmental regulations.

Declining battery costs and growing customer demand for PEVs act as an accelerant to PEV sales. Cost reductions in battery packs enable longer-range PEVs, increase cost-competitiveness with ICE vehicles, and result in automobile manufacturers producing a wider variety of PEVs across more vehicle segments to better meet customer demand.

- Between 2010 and 2016, battery pack costs [\$ per kilowatt-hour (kWh)] declined by about 20 percent per year. The U.S. Department of Energy estimated battery pack costs in 2016 at \$245 per kWh.
- Barclays projects that battery pack costs at \$100 per kWh will create price parity with ICE vehicles.

Comparing the forecasted PEV sales to automaker announcements is a useful reality check. Based on public announcements by BMW, Mercedes, Tesla, Volkswagen, and Volvo (ranging from 20 percent to 100 percent) and on a conservative estimate of 5 percent PEV sales for other mainstream manufacturers (Fiat-Chrysler, Ford, General Motors, Honda, Hyundai-Kia, Nissan, and Toyota), **annual PEV sales** are expected to reach 1.2 million in 2025.

Table 1 shows the actual percent of PEV sales in 2016, the percent expected in 2025, and the likely number of PEV sales in 2025 projected by manufacturer. Given manufacturer projections, the EEI and IEI forecast is reasonable and likely conservative.

3. See <https://www.eia.gov/outlooks/aeo/>

4. Together in Electric Dreams. Energy & Autos. Barclays. January 27, 2017.

5. See <https://www.navigantresearch.com/research/electric-vehicle-geographic-forecasts>

Table 1. Annual PEV Sales in 2025 Projected by Vehicle Manufacturer

Manufacturer	% PEV Sales in 2016 (Actual)	All Vehicle Sales Expected in the U.S. in 2025	% PEV Sales Expected in 2025	Estimated PEV Sales in 2025
BMW	4.4	370,000	20	74,000
Mercedes	0.6	380,000	20	76,000
Tesla	100	200,000	100	200,000
Volkswagen	1.9	750,000	20	150,000
Volvo	2.4	80,000	20	16,000
Subtotal (Automaker announcements)	--	1,780,000	32	516,000
Fiat-Chrysler	0.2	2,200,000	5	110,000
Ford	1	2,600,000	7	182,000
General Motors	0.9	3,000,000	5	150,000
Honda	0	1,500,000	3	45,000
Hyundai-Kia	0.3	1,400,000	5	70,000
Nissan	0.9	1,750,000	6	105,000
Toyota	0.1	2,400,000	2	48,000
Subtotal (Estimated)	--	14,850,000	5	710,000
Total	--	16,630,000	7.4	1,226,000

CAFE & GHG Standards Compliance Issues

CAFE standards are a primary driver for the 31 PEV models available today in the United States from 17 automakers. Fuel efficiency standards and environmental regulations [i.e., CAFE and greenhouse gas (GHG) regulations] act as a floor for PEV sales (i.e., minimum compliance). To comply with CAFE & GHG standards, automakers have had to:

1. Advance technologically via improved vehicle aerodynamics, light-weight materials, turbo-charged engines, continuously variable transmissions, and stop-start technologies.
2. Offer a range of PEVs.

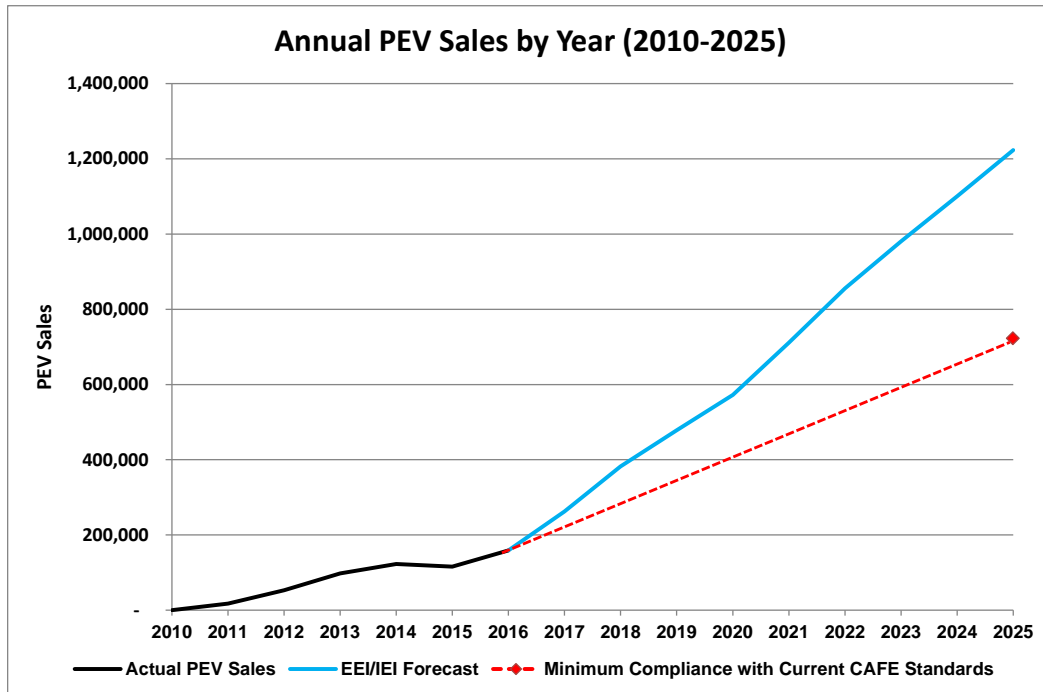
Figure 4 shows a comparison of the EEI/IEI forecast relative to PEV sales under minimum compliance with CAFE standards as projected by the U.S. Environmental Protection Agency (EPA), National Highway Traffic Safety Administration (NHTSA), and California Air Resources Board under the current regulation.⁶

Minimum compliance with CAFE is a floor for PEV sales, and any reduction in current CAFE standards likely will depress PEV sales. As part of the rulemaking that established model year

6. Draft Technical Assessment Report: Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas Emissions Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025. U.S EPA, NHTSA, and CARB. July 2016.

(MY) 2017-2025 standards, EPA and NHTSA made a regulatory commitment to conduct a midterm evaluation of the standards for MY 2022-2025, which increase fuel economy from 46.8 MPG to 54.5 MPG. Recently, EPA Administrator Scott Pruitt and Department of Transportation Secretary Elaine Chao announced that EPA and NHTSA intend to reconsider the appropriateness of the MY 2022-2025 standards by no later than April 1, 2018.

Figure 4. PEV Sales: EEI/IEI Forecast vs. Minimum Compliance With Current CAFE Standards



PEV Charging Infrastructure

The availability of PEV charging infrastructure is fundamental to the growth of PEVs. Unlike conventional vehicles, which typically refuel only at gasoline stations, PEVs may charge while parked at home, at work, or in public spaces.

Charging equipment is needed to connect a vehicle to the energy grid. This charging equipment, which often is referred to as a charging station or a charge port, comes in a variety of types and configurations, but is generally categorized by power level:

- **Level 1 (L1):** 120-volt, alternating current (AC) power. Level 1 charging refers to charging stations, as well as typical electric outlets that a driver plugs into via a cord set included with the vehicle. A PEV connected to a Level 1 charger takes about 12 hours to charge a fully depleted 50-mile battery (about 4 miles of electric range per hour of charging).
- **Level 2 (L2):** 240-volt, AC power. Level 2 chargers typically are mounted on a wall or on a pedestal. A PEV connected to a Level 2 charger takes between 3 to 5 hours to charge a fully depleted 50-mile battery (about 10 to 20 miles of electric range per hour of charging depending on the PEV).
- **DC Fast Charger (DCFC):** Converts AC electricity to direct current (DC) and delivers charge to the vehicle at higher power, typically 50 kilowatt or greater. A PEV connected to a DC fast charger takes about 30 minutes to charge a fully depleted battery to about 80 percent, depending on battery size. Not all PEVs are able to accept DC fast charging.

Table 2 summarizes likely PEV charging infrastructure locations, durations, and the charging equipment that is commonly installed at each location.

Table 2. PEV Charging Equipment By Use

Category	Use Case	Park/Charge Time	Charger Type
Home	Single family home	Overnight (~12 hours)	L1, L2
	Multi-unit dwelling	Overnight (~12 hours)	L1, L2
Work	Workplace charging	Work day (~8 hours)	L1, L2
Public	Short/medium-dwell (e.g., retail)	1-2 hours	L2
	Long-dwell (e.g., airports)	2-4 hours or longer	L1, L2
	Metro-based (intra-city)	~ 30 minutes or less	DCFC
	Long-distance (inter-city)	~30 minutes or less	DCFC

To date, the vast majority of PEV charging occurs at home. However, having charging infrastructure at workplaces or in public settings allows PEV owners to drive more miles on electric, enables longer trips, and reduces range anxiety. In addition, public charging

infrastructure is important for PEV owners who do not have dedicated home charging, such as in multi-unit dwellings (e.g., apartment buildings) or those with street parking.

Charging Infrastructure Needs

EEI and IEI estimated the PEV charging infrastructure needed to support the projected 7 million-plus PEVs on the road in 2025 based on two models: the National Renewable Energy Laboratory (NREL) model, as described in the National Economic Assessment of Plug-In Electric Vehicles (December 2016)⁷ and the Electric Power Research Institute’s (EPRI’s) Red Line/Blue Model (June 2014).⁸

The NREL and EPRI models typically are used by electric companies and state organizations to support PEV charging infrastructure analysis and to identify the need for at-home and away-from-home charge ports.⁹ The NREL model estimates infrastructure needs separately for battery electric vehicles and plug-in hybrid electric vehicles, while the EPRI model estimates infrastructure needs for PEVs. Table 3 provides the number of charge ports by location and type per 1,000 PEVs.

Table 3. Estimated Charge Ports By Vehicle Type and Location per 1,000 PEVs: NREL and EPRI Models

Charger Location and Type	NREL Model (Charge ports per 1,000 PHEVs)	NREL Model (Charge ports per 1,000 BEVs)	EPRI Model (Charge ports per 1,000 PEVs)
Home	327	328	500
<i>Single Family (Level 2)</i>	283	286	<i>Unspecified</i>
<i>Multi-unit Dwelling (Level 2)</i>	44	42	<i>Unspecified</i>
Work	334	332	270
<i>Level 1</i>	167	166	<i>Not Included</i>
<i>Level 2</i>	167	166	270
Public	3	11	72
<i>Level 1</i>	0.5	0.4	<i>Not Included</i>
<i>Level 2</i>	2.4	10.1	67
<i>DC Fast Charger</i>	0	0.5	5

Both models assume most charging will occur at home. For the purposes of this analysis, the “home” charging accounted for here includes only Level 2 chargers, which have an incremental cost to the driver, and not home-based Level 1 chargers that are simple electrical outlets. These

7. See <http://www.nrel.gov/docs/fy17osti/66980.pdf>

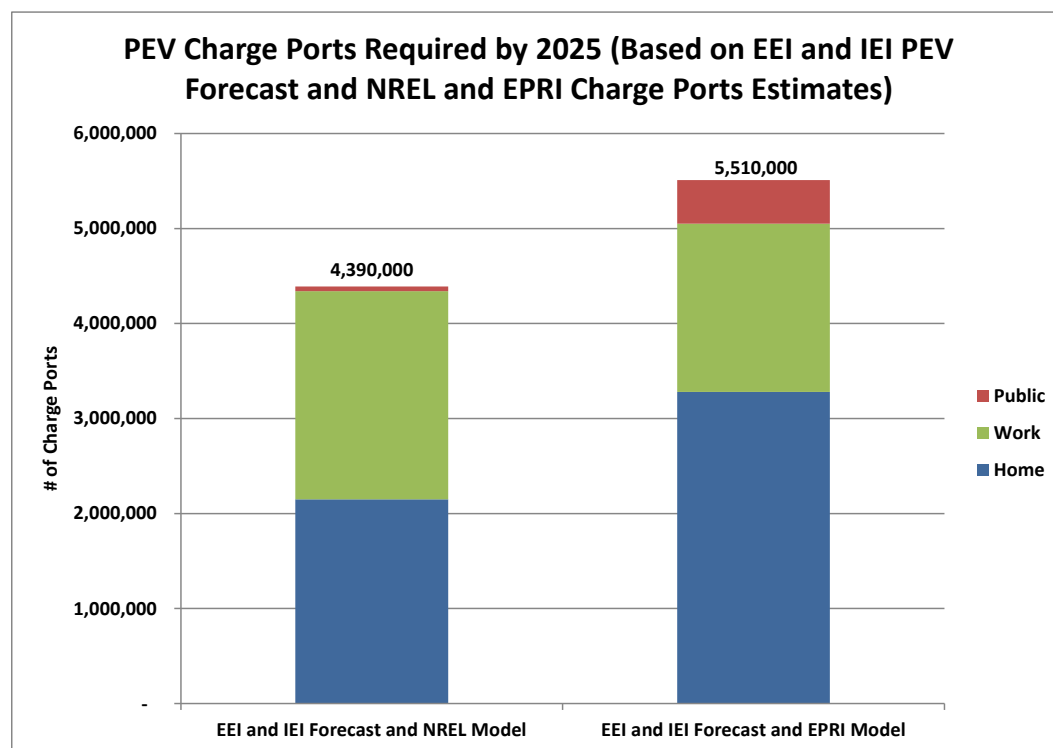
8. See <https://www.epri.com/#/pages/product/000000003002004096/>

9. See filings from Avista Utilities, Pacific Gas & Electric Company, and Southern California Edison.

models predict about 327 to 500 charge ports at home per 1,000 PEVs, and 270 to 334 charge ports at work per 1,000 PEVs. Public charging infrastructure estimates vary widely between the two models, from 3 to 72 charge ports per 1,000 PEVs.

About 4.4 to 5.5 million charge ports will be needed by 2025 to support the EEI and IEI projected 7 million PEVs on the road. As shown in Figure 5, almost all charge ports are estimated to be at home or at work.¹⁰

Figure 5. Estimated Number of PEV Charge Ports Required By 2025 (Based on EEI and IEI PEV Forecast and NREL and EPRI Charge Ports Estimates)



Approaches to Deploying PEV Charging Infrastructure

The NREL and EPRI models used in this report simply estimate the charging infrastructure needed to support a certain level of PEVs. The PEV market is driven by a myriad of dynamics, including customer awareness and acceptance; the types of PEVs available; affordability; the availability of infrastructure; and other factors. It is well known that the lack of PEV charging infrastructure is a barrier to PEV adoption.¹¹

10. For comparison purposes, EEI and IEI made the following clarifying assumptions: (1) DC fast chargers are built to serve the needs of battery electric vehicle owners. (2) Level 1 chargers for home use—simple electrical outlets—are not included in the estimate. Only Level 2 charges are included.

11. See for example: NREL, *Consumer Convenience and the Availability of Retail Stations as a Market Barrier for Alternative Fuel Vehicles*, <https://www.afdc.energy.gov/uploads/publication/56898.pdf>

The costs of PEV infrastructure can vary widely, from a few hundred dollars to install a Level 2 charger at home, to tens of thousands of dollars to install a multi-port DC fast charging station. The cost includes the equipment itself, as well as the installation, permit, and inspection needed to get power to the charging station. Much of the PEV charging infrastructure to date has been paid for by the customer or entity that hosts the charging equipment (the “site host”), whether that is a homeowner, a commercial property owner, or a public entity. (See Appendix for examples.)

The current charging infrastructure at workplaces and in public locations is estimated to be between 50,000 to 70,000 predominantly Level 2 charge ports.¹² Based on the NREL and EPRI models, Figure 5 shows a need for more than 2 million charge ports in work and public locations by 2025. The significant difference between the current availability of charging infrastructure and the expected charging infrastructure needed suggests a growing “infrastructure gap” that will need to be addressed.

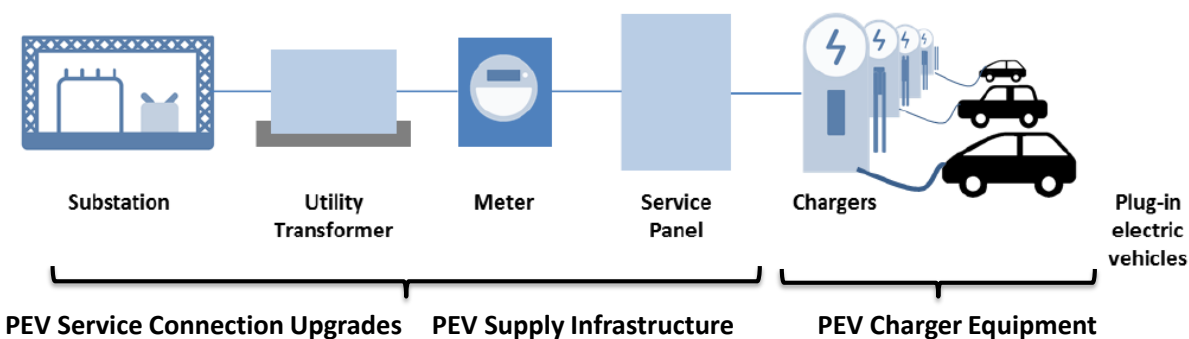
The PEV charging marketplace is evolving, and different approaches to providing the charging infrastructure for the PEV market are being tested.

Electric companies are well-positioned to help develop PEV charging infrastructure. Electric companies can support the development of PEV charging infrastructure and the smart integration of PEV charging load into the distribution grid in different ways, including:

- Developing “make-ready” grid infrastructure, which might include PEV service connection upgrades and new PEV supply infrastructure (see Figure 6);
- Owning and operating charging stations;
- Offering electric rates that incent PEV charging at specific times of the day (e.g., at off-peak times);
- Helping “site hosts” to connect with PEV charger equipment providers.

12. U.S. Department of Energy, Alternative Fuels Data Center.
http://www.afdc.energy.gov/fuels/stations_counts.html
UBS Presentation, January 9, 2017.

Figure 6. Illustration of PEV Charging Infrastructure



Currently, electric companies in several states are engaged in PEV charging infrastructure development. In 2016, the California Public Utilities Commission approved PEV charging pilots for its regulated electric companies—Pacific Gas and Electric Company (PG&E), San Diego Gas & Electric (SDG&E), and Southern California Edison (SCE)—that will establish 12,500 new charging locations by 2020.

- PG&E will install “make ready” infrastructure, including PEV service connection upgrades and new PEV supply infrastructure for up to 7,500 Level 2 charge ports at multi-unit dwellings and workplaces. Multi-unit dwellings and installations in disadvantaged communities can choose to own the charging equipment or let PG&E own it (up to 35 percent of the chargers).
- SDG&E will install and own up to 3,500 Level 1 and Level 2 charge ports at multi-unit dwellings and workplaces, with a special rate that encourages off-peak charging.
- SCE will install “make ready” infrastructure including new PEV supply infrastructure for up to 1,500 Level 1 and Level 2 charge ports at workplaces, multi-unit dwellings, and other locations where vehicles are parked for extended periods of time.

In addition, electric companies in Georgia, Kansas, Missouri, and Washington State also are supporting the development of PEV charging infrastructure in the following ways:

- Avista is installing and owning 265 Level 2 charging stations in homes, workplaces, fleet yards, and multi-unit dwellings, as well as 7 DC fast chargers in Spokane.
- Georgia Power is installing and will own, operate and maintain more than 35 charging “islands” in public locations throughout Georgia, each consisting of a DC fast charger and a Level 2 charger, including both CHAdeMO and CCS combo connectors. However, the charging island at the new SunTrust Park (Atlanta Braves stadium) consists of one DC fast charger and eight dual port Level 2 chargers.

- Kansas City Power & Light (KCP&L) is installing and owning approximately 1,000 Level 2 charging stations and 15 DC fast chargers in public locations in and around Kansas City as part of its Clean Charge Network. The first two years of the program provided free charging to PEV drivers who joined the Clean Charge Network.

Conclusion

With more than 7 million PEVs anticipated to be on the road in the United States by 2025, and every PEV owner expecting to be able to charge his or her car at home, on the street, at the office, at shopping malls, or along major highways, targeted deployment of charging infrastructure and coordinated collaboration among all stakeholders are required. Electric company participation in the development of PEV charging infrastructure supports state-level clean energy and transportation goals, expands customer choice, and helps to scale and ensure the availability of needed PEV charging infrastructure.

Appendix

A wide range of public and commercial funding has supported PEV charging infrastructure deployment to date. Table A-1 shows some of the major funding.

Table A-1. Examples of PEV Charging Infrastructure Funding Sources to Date

Funding Entity	Program	Description
Automakers	Tesla (2012-ongoing)	Deployed "SuperCharger" network of 2,400 DC fast chargers at 350 locations (net book value \$215 million as of Q1 2017), and 3,900 "Destination Charging" L2 chargers at more than 2,000 public destinations.
	Automaker Funded Charging Networks (ongoing)	Includes Nissan and BMW partnership with EVgo to deploy nearly 300 DC fast chargers in 33 states; BMW and VW partnership with ChargePoint to install 100 DC fast chargers along coastal corridors.
	Electrify America (starting 2017)	VW subsidiary will invest \$2 billion over 10 years on ZEV investments, the majority of which will fund PEV charging infrastructure, as part of the VW diesel settlement.
Electric Companies	Electric Company Programs (ongoing)	Electric company investment in EV charging infrastructure (rebates and/or capital investment in infrastructure); examples include Avista, Georgia Power, KCP&L, PG&E, SCE, and SDG&E.
Customers	Customer-funded (ongoing)	Customers pay for the installation and operation of PEV charging equipment at their own premises; some costs potentially offset by an electric company, automaker, state, or federal program.
State Governments	NRG Settlement (2012-ongoing)	\$100 million settlement agreement, deploying 200 DC fast chargers and infrastructure for 10,000 L1 and L2 stations in public locations, workplaces and multi-unit dwellings.
	VW Settlement, Appendix D (starting 2017)	States may allocate up to 15 percent of their funds for EV charging infrastructure from the \$2.7 billion Environmental Mitigation Trust as part of the VW diesel settlement.
	State Funding (ongoing)	30 states have programs (rebates, tax credits, and/or grants) that support EV charging deployment.
Federal Government	ARRA EV Project (2009-2013)	\$115 million matching grant, deployed more than 12,500 L2 chargers in residential and public locations, at 110 DC fast chargers.
	ARRA ChargePoint America (2009-2013)	\$15 million matching grant, deployed more than 4,600 L2 chargers in residential, private, and public locations.
	Federal Tax Credit (2007-2016)	Alternative Fuel Vehicle Refueling Property Credit applied to 30 percent of the cost of infrastructure, up to \$30,000 for businesses and \$1,000 for others.

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The Institute for Electric Innovation focuses on advancing the adoption and application of new technologies that will strengthen and transform the energy grid. IEI's members are the investor-owned electric companies that represent about 70 percent of the U.S. electric power industry. The membership is committed to an affordable, reliable, secure, and clean energy future.

IEI promotes the sharing of information, ideas, and experiences among regulators, policy makers, technology companies, thought leaders, and the electric power industry. IEI also identifies policies that support the business case for the adoption of cost-effective technologies.

IEI is governed by a Management Committee of electric industry Chief Executive Officers. In addition, IEI has a Strategy Committee made up of senior electric industry executives and a select group of technology companies on its Technology Partner Roundtable.



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EEI is the association that represents all U.S. investor-owned electric companies. Our members provide electricity for 220 million Americans, and operate in all 50 states and the District of Columbia. As a whole, the electric power industry supports more than 7 million jobs in communities across the United States. In addition to our U.S. members, EEI has more than 60 international electric companies as International Members, and hundreds of industry suppliers and related organizations as Associate Members.



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