TECHNOLOGY

PLUG-IN ELECTRIC VEHICLES MARKET: STATE OF PLAY

CENTER FOR CLIMATE AND ENERGY SOLUTIONS

by

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PLUG-IN ELECTRIC VEHICLES CONNECT MANY INDUSTRIES

Nearly all major auto companies—as well as several new start-ups—plan to produce plug-in electric vehicles (PEVs) within the next 2 or 3 years. [1,2] According to transportation experts, the impact of the growing PEV market on the automobile market, electrical grid, and the transportation system could be significant, and will vary both regionally and over time.[3,4]

The introduction of PEVs into the automobile market presents a transformative opportunity for the transportation sector. Wherever these vehicles exist in sufficient numbers, significant technological, economic, and environmental change will occur. This opportunity affects automakers, electricity providers, vehicle charging companies, battery manufacturers, all levels of government and, most importantly, consumers. Deploying PEVs will bring together many of these stakeholders for the first time.

This paper outlines the state of play in the PEV market including ongoing deployment projects, expected consumer market demand, and public policies related to PEV deployment.

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PEV DRIVERS: LOCAL AIR QUALITY, ENERGY SECURITY, & CLIMATE CHANGE

Concerns over local air quality, energy security, and global climate change have motivated increasing interest in PEVs as well as interest in broader policies to overcome institutional and market barriers to their adoption. Recently, the federal government substantially increased fuel economy standards and the state of California reintroduced zero emission vehicle (ZEV) requirements.[5,6] In addition to improved fuel economy targets, existing and proposed legislation aims to identify options for batteries at the PEV's end-of-life, which could help lower the cost of PEVs.[7] Taken together, air quality improvement is on a positive trajectory.

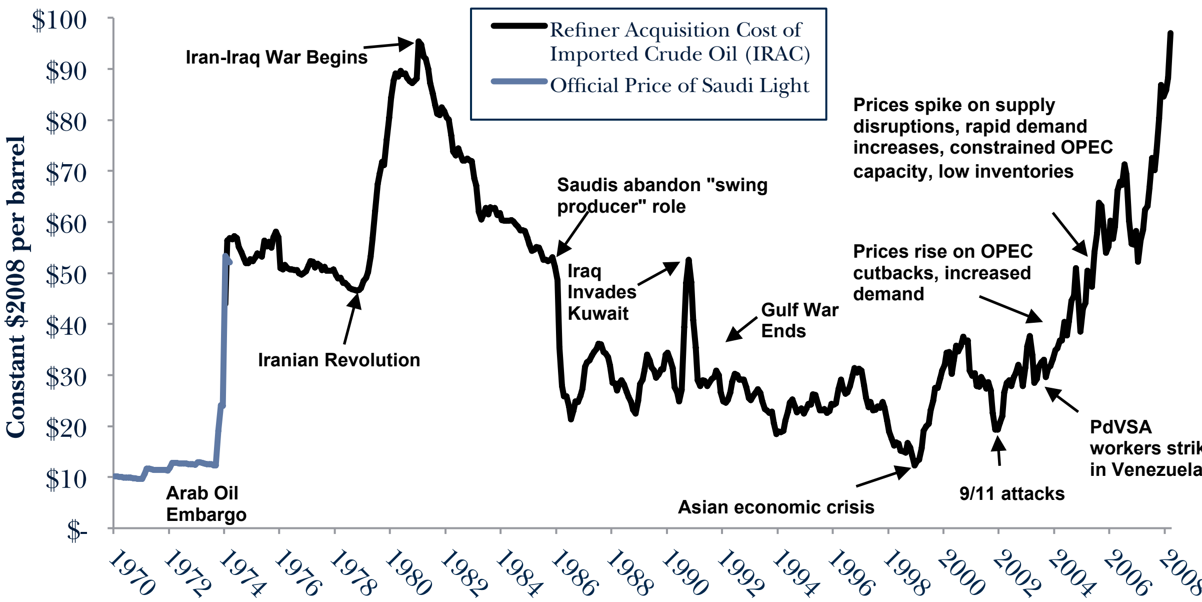
Human health benefits substantially from improved air quality. Since the 1970s, the implementation of the Clean Air Act by the U.S. Environmental Protection Agency (EPA) including vehicle emission standards, has mitigated major health problems and prevented the premature deaths of hundreds of thousands.[8]

According to the U.S. Energy Information Administration (EIA), in 2009, the United States consumed over 18 million barrels of oil per day, the majority of which was imported. Transportation accounts for over 70 percent of total U.S. oil consumption.[9] EPA estimates that the United States receives energy benefits from a reduction of imported oil at a rate of $12.38 per barrel.[10]

> Because of the importance of oil to the U.S. economy, the lack of economical substitutes, and the concentration of the world's oil resources in the Organization of the Petroleum Exporting Countries (OPEC), the U.S. faces higher oil prices than a competitive market would produce… In 2008 alone, the estimated economic cost of oil dependence was half a trillion dollars: $350 billion in wealth transfer, $150 billion in lost GDP.[11]

Concern about the threat of climate change is also a significant contributor to the development of and increased demand for PEVs. According to a 2010 study conducted by the National Research Council (NRC), "climate change is occurring, is caused by human activities, and poses significant risks for—and in many cases is already affecting—a broad range of human and natural systems."[12] The U.S. Department of Defense (DOD) identifies the threats from climate change as a significant factor in future U.S. security.[13] PEVs have the potential to reduce greenhouse gas (GHG) emissions from the transportation sector significantly so long as efforts are made to decarbonize the electrical grid. This effort is critical if PEVs are to realize their potential for reducing the transportation sector's impact on global climate.[14]

FIGURE 1: World Oil Price Variations and Associated Events. Price adjusted by CPI for all Urban Consumers.[15]



CHALLENGES FOR THE PEV MARKET

The largest barrier to PEV market growth today is arguably the vehicle's higher upfront cost compared to conventional automobiles. The high cost of the battery system required in a battery electric vehicle (BEV) along with the advanced drivetrain system in a plug-in hybrid electric vehicle (PHEV) accounts for much of this additional cost. Though upfront cost will remain a major challenge, this paper focuses on other challenges involving the integration of PEVs with the U.S. electrical grid.

Compared to the conventional automobile market, an unprecedented number of stakeholders are involved in the PEV market and the integration of PEVs with the grid (see Figure 2). PEV stakeholders have different and sometimes competing interests. Further, the opportunities for each stakeholder vary greatly and, of course, the barriers to success differ among the stakeholders in both size and scope. Smart PEV deployment strategies are essential to meet the needs for PEV market growth as identified by a Massachusetts Institute of Technology (MIT) energy symposium in April of 2010 (see the box above). Stakeholders and policy makers must carefully consider how to maximize the benefits and minimize the costs of PEV deployment and coordinate policy implementation. Poor or mismanaged deployment of PEVs would create misperceptions of the value of the technology and harm the PEV market, the

One challenge often overlooked is how PEVs' would contribute to the maintenance of the transportation system. Currently, the road system is maintained through federal and state fuel taxes on gasoline and diesel. Some states such as Washington and Oregon are considering programs to tax PEV use so the electrified miles traveled also contribute to transportation system maintenance.

BOX 1: PEV deployment needs according to MIT

"The role of EV infrastructure and policies to support its development need considerable analysis, planning, clarification, and innovation in order to enable significant market penetration of EVs. Uniform definitions, such as smart charging, should be developed and established by requisite policy and standards-setting bodies.

Because the degree of electrification of EVs is still unclear, it is difficult to determine how much or what type of infrastructure is needed to support EVs. There is agreement that the lack of public infrastructure will impede EV market penetration but disagreement on timing and degree of public support for its development.

Critical regulatory issues will have to be resolved to enable EVSE installation, both in homes and for public use. State Public Utility Commissions (PUCs) will have to determine if and how to regulate public EV Supply Equipment (EVSE).

Rationalization of regulations will have to occur between government jurisdictions to ensure ease of travel and reliability of the system.

EV charging will have an impact on the grid. The extent of that impact depends on the existing transmission and distribution infrastructure in areas where EVs are being purchased. It may be necessary to upgrade transformers for residential or commercial customers' installation of EVSE. It is not clear how these upgrades should be paid for and who specifically should bear the cost.

Assuming significant market penetration of EVs, access to public EVSE must be fair and widely available. Municipalities will need to ensure that rules and regulations are in place regarding charging time, charging order, etc., and will need to penalize those who monopolize charging facilities."[17]

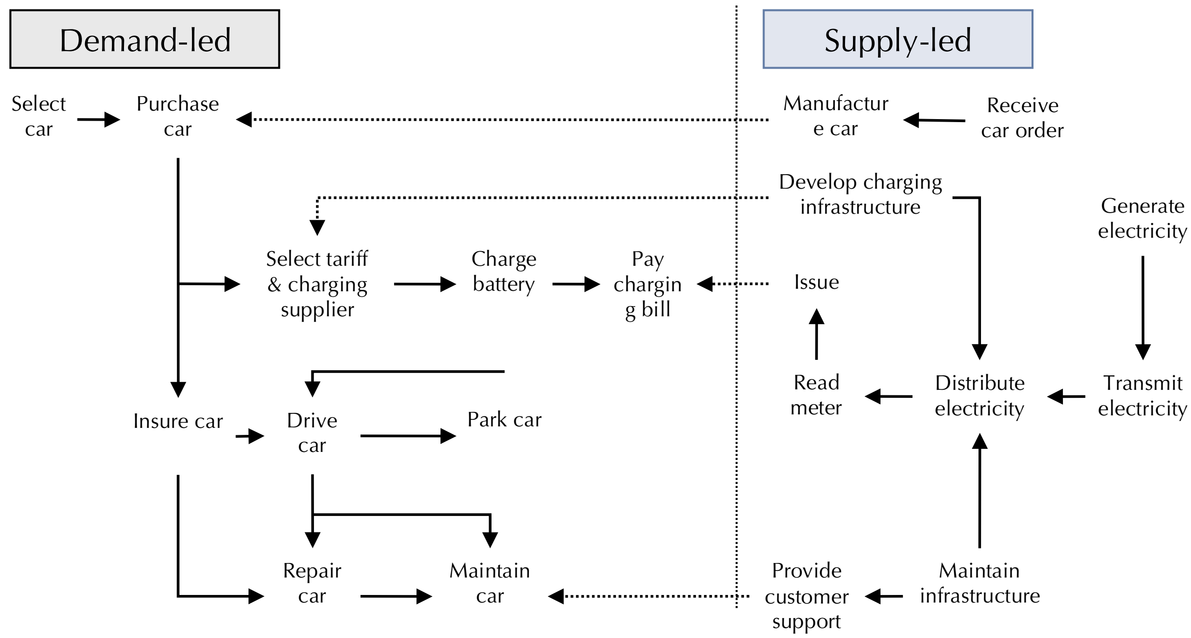
American consumer, the electric power system, and the environment.

Opportunities exist for current market participants and new entrants on both the supply side and demand side of the PEV market. Integration of the supply-led and demand-led activities outlined in Figure 2 require capabilities in three areas: hardware (e.g., PEV supply equipment[16]), software (e.g., PEV charging software), and support services (e.g., electrical grid infrastructure maintenance). The steps required for these stakeholders to interact with each other are not shown in this figure. Thousands of jurisdictions are likely to work on PEV deployment; each will engage in a unique process, that may vary in terms of transparency and other factors.

> Challenges also present opportunities including new business models. Some companies are exploring consumer subscription models to pay for electricity (noted in Figure 2 as "Select tariff and contract supplier").

The PEV market offers significant opportunities to private sector stakeholders, including vehicle manufacturers, battery manufacturers, electric power providers, and recharging equipment providers. Whether it is selling the fuel (i.e., electricity), the PEV components, or the vehicles themselves, there are many barriers to success, including the high upfront cost of the vehicles, uncertainty of consumer acceptance, a lack of trained technicians, and a much more complex sales and delivery process than for a conventional vehicle.[18] PEV component providers, such as battery manufacturers, face additional challenges such as competition from Asia, and safety concerns with new battery chemistries.

FIGURE 2: The activities in the PEV market adapted from Narich et al.[19]



Electrical grid operators face the challenge of maintaining the reliability of the grid in the face of dynamically varying demand and unexpected equipment failures. They must maintain reliability while making the most cost-effective use of existing assets and maximizing the environmental and other benefits of PEVs. The existing grid is a complex network of many layers. Regulated utilities, Independent Power Producers (IPPs), Independent System Operators (ISOs), Regional Transmission Organizations (RTOs), and state Public Utility Commissions (PUCs) will all play critical roles in integrating PEVs with the grid. PEVs' immediate impact on the grid is only just now being understood with the help of deployment pilot projects and exhaustive research.

By controlling rates of charge, and potentially the rates of discharge from the vehicle to the electrical grid (V2G[20]), PEVs could become a resource for grid management and a key enabler for business innovation in the PEV and electricity markets. Using PEV batteries to store energy can help offset the cost of a PEV, lower electrical grid operating cost, and even allow greater penetration of intermittent energy sources like renewables. Creation of V2G control technology by universities[21] evolved to technology demonstrations such as the Mid-Atlantic Grid Interactive Cars Consortium (MAGICC), and now to small-scale production by companies such as AC Propulsion, Nuvve, and AutoPort, Inc.

PUBLIC POLICY TO SUPPORT PEV DEPLOYMENT

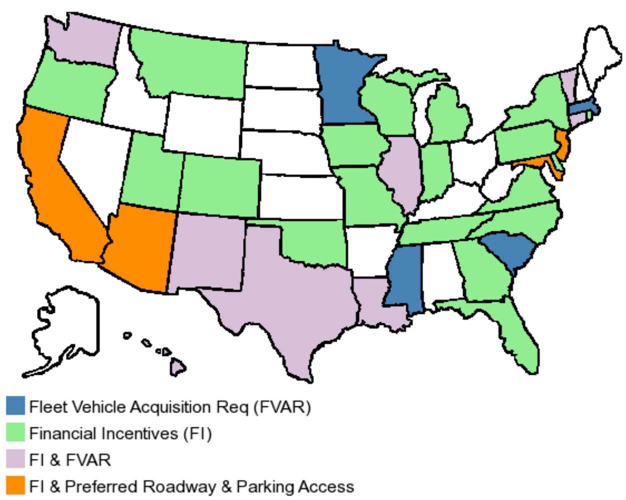
Thus far, government action at all levels has greatly influenced PEV sales and the integration of these new vehicles into the electrical grid. In order to meet its goal of one million PEVs on the road by 2015, the Obama Administration has made a concerted effort to stimulate the growth of the PEV market through public-private matching grants leveraging billions of stimulus dollars. Table 1 summarizes action by the federal government including investments made under the American Recovery and Reinvestment Act (ARRA). This law included $2 billion in grants to support 30 factories that produce PEV components. Further, ARRA provides tax incentives of up to $4000 per vehicle for using conversion kits to retrofit conventionally powered vehicles, and tax incentives of between $2,500 and $7,500 per PEV (depending on battery capacity).

TABLE 1: Federal government initiatives to support PEV deployment.[22,23]

	PROGRAM	LEGISLATION	DESCRIPTION	INVESTMENT
Batteries, Infrastructure & Manufacturing Investments	Advanced Battery & Electric Drive Component Manufacturing Grants	ARRA	Advanced battery and electric drive components manufacturing grants	$2.0 billion
	Advanced Technology Vehicle Manufacturing Loan Program	Energy Independence & Security Act of 2007 (EISA)	Manufacturers are eligible for direct loans of up to 30% of the cost to reequip, expand, or establish manufacturing facilities	$2.4 billion
	Battery Research & Development Grants from ARPA-E	ARRA	Direct grants for high-risk/high-reward research on next-generation batteries, specifically ultra-capacitors & metal-air batteries	$80 million
PEV Deployment	PEV Tax Credit	Energy Policy Act of 2005, adjusted with EISA, Emergency Economic Stabilization Act of 2008, & ARRA	For batteries of at least 4 kWh in capacity, this program offers a $2,500 income-tax credit with an additional $417 for each added kWh of capacity, with a maximum credit of $7,500 for up to 200,000 vehicles per manufacturer	$1.5 billion
	Vehicle Electrification Initiative	ARRA	Provides grants to 11 localities for deployment & integration, includes the cost of vehicles, infrastructure, & workforce education programs	$400 million

At the state and regional level, governments are also incentivizing the sales of PEVs. Figure 3 provides an overview of the incentives that exist throughout the country. For example, many states allow HOV access and waive emission inspections for drivers of low- or no-emission vehicles. Other state efforts include acquiring vehicles for state-owned fleets (denoted as FVAR in Figure 3), establishing new vehicle and fuel standards as was done in California, creating incentives for purchasing low-carbon fuels and vehicles, and trading low-carbon fuel credits between providers. Other notable efforts to accelerate the growth of the PEV market include the West Coast Green Highway Initiative and the related Washington State Electric Highway Project,[24] the Transportation and Climate Initiative,[25] and the California Plug-in Electric Vehicle Collaborative.[26]

FIGURE 3: State initiatives that support PEV deployment.[27]



PUBLIC POLICY OUTLOOK

PEVs provide an opportunity for bipartisan cooperation in a mostly polarized Congress. For instance, a bipartisan group of legislators introduced the Promoting Electric Vehicles Act of 2011 in May.[28] The legislation encourages PEV deployment through a $100 million 6-year national deployment program, a large PEV community support program, and investments in advanced battery research and development. The fate of this bill is unclear in the 112th Congress.

Thus far, governments at all levels have been willing to address current barriers to PEV deployment. With tightening budgets across all levels of government in 2011, however, expanding or continuing incentives to purchase PEVs and install charging infrastructure will be very difficult. Cost-effective policies that decrease the time it takes to purchase a PEV could prove popular, such as breaking down electricity regulatory barriers that unnecessarily delay home charger installations.

PEV MARKET FORECASTS

The current PEV market is very small and future PEV sales are uncertain, as shown in Table 3. Estimates for sales depend on the technological progress of batteries versus gasoline vehicles and those powered by other fuels, as well as fuel prices and consumer behavior.

According to studies of consumer behavior with respect to PEVs, consumers will be more likely to purchase a PEV if they understand the benefits of electric driving, such as financial and environmental benefits.[30] The size of any market depends on the consumption patterns of competing and complementary goods. Thus, a significant influence on the extent of PEV market penetration is the price of oil, which has recently been above or near $100 per barrel for the first time since 2008. The average price of oil in 2010 was $79 per barrel, the second highest level ever in nominal terms. Lowering component system costs (e.g., battery system costs) that make the Chevrolet Volt twice the price of its conventional counterpart is critical.[31] And, of course, the success of PEVs in the automobile market will ultimately depend on consumer acceptance.

Table 2 summarizes DOE estimates for PEV production levels through 2015. In February 2011, DOE

TABLE 2: Expected PEV production levels through 2015.[29]

MAKE & MODEL	TYPE	2011-2015
Fisker Karma	PHEV	36,000
Fisker Nina	PHEV	195,000
Ford Focus	BEV	70,000
Ford Transit Connect	BEV	4,200
Chevrolet Volt	PHEV	505,000
Navistar eStar (truck)	BEV	4,000
Nissan LEAF	BEV	300,000
Smith Electric Vehicles Newton (truck)	BEV	5,000
Tesla Motors Model S	BEV	55,000
Tesla Motors Roadster	BEV	1,000
Think City	BEV	57,000
Total		1,232,200

reported that the United States would achieve the goal of one million PEVs on the road by 2015 as laid out by President Obama in the 2008 Presidential election campaign. Despite this projection, it is important to note that the DOE report did not use General Motors' official announced production levels for the Chevrolet Volt, and consumer demand will ultimately determine if the goal of one million PEVs by 2015 is met.

TABLE 3: Forecasts for PEV sales.

STUDY	CONCLUSIONS
J.D. Power & Associates[32] *Drive Green 2020*	1.249m BEVs sold worldwide in 2020 (<2% of market) and 108k in the U.S.; HEVs/PHEVs will be 3.88m in 2020 (5.5%).
EIA[33] *AEO 2011*	140k PEVs sold in U.S. in 2020
Indiana University[34] *Transport Electrification Panel*	U.S. will not achieve 1m PEVs on the road by 2015 unless consumer demand increases
DOE[35] *One Million Electric Vehicles By 2015*	1.2m PEVs on the road in the U.S. by 2015
Center for Automotive Research[36] *Deployment Rollout of Electric Vehicles 2011-2015*	469k PEVs on the road in the U.S. by 2015 with 140k being sold in 2015 alone.
NRC[37] *Plug-in Hybrid Electric Vehicles*	13-40m PHEVs on the road by 2030 in maximum practical case.
Pike Research[38] *Plug-in Electric Vehicles*	PEV annual sales of over 1m worldwide by 2015; cumulative sales of 3.24m between 2010 and 2015.

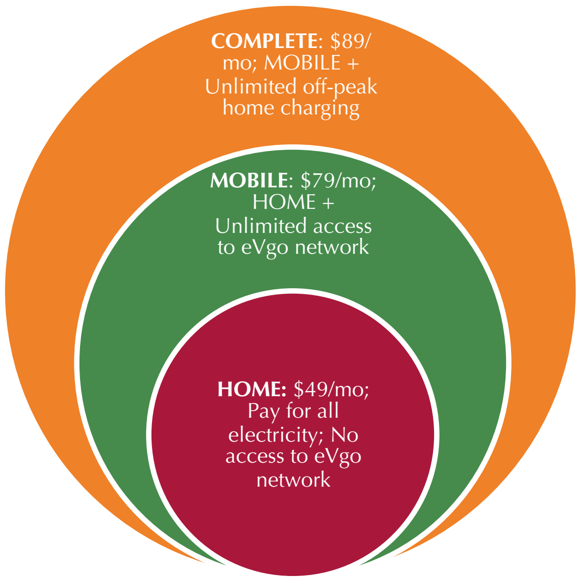
PEV DEPLOYMENT

Smart strategies are essential to overcoming barriers to PEV deployment. Unsuccessful deployment would reduce GHG emission reductions and oil savings, and could also strain local grid reliability and harm public acceptance and private investment in current and future technology, such as V2G.

DEPLOYMENT STRATEGIES

There are differing perspectives on the most effective approach to achieving market commercialization of PEVs. One is that PEV deployment should begin in selected communities.[39] This approach focuses on the network of support and the regulatory framework required to integrate PEVs with the electrical grid, as well as the range of electronic communication protocols for charging equipment and other services that PEV drivers will require. Proponents argue that the possibility of achieving deep penetration in a handful of markets as opposed to much more limited penetration nationwide would achieve proof of concept and facilitate learning-by-doing on a scale that nationwide deployment cannot accomplish in the near term. This strategy assists in overcoming one of the major obstacles to BEV adoption,

FIGURE 4: NRG Energy's eVgo subscription plans



known as range anxiety.[40] Such communities would be chosen based on past hybrid electric vehicle purchasing trends, utility company collaboration, and commitment to vehicle electrification by local governments.

Another approach suggests that PEV deployment should begin nationwide at once. This could result in charging stations that are much farther apart than in the community model. Because of the large scale of the nationwide approach, this deployment model could favor PHEVs since they do not have the range limitation of BEVs. In this scenario, all consumers can participate even if they do not live in a designated PEV community.

ONGOING DEPLOYMENT EFFORTS

There are several PEV deployment efforts being undertaken in the United States right now, paid for by both public and private dollars.

In 2009, ARRA provided a big boost to PEV deployment in the United States. The DOE is working with ECOtality North America, Coulomb Technologies, and other PEV partners to support PEV deployment. Of the $400 million allocated to PEV deployment in ARRA, DOE granted $15 million to Coulomb's ChargePoint America project and over $100 million to ECOtality's EV Project. With matching funding from partners, the total value of the ChargePoint America project is $37 million while the EV Project is valued at approximately $230 million. ChargePoint America will install vehicle charging stations in public places, private garages, commercial places, and other desirable locations free of charge, and collect data on charging usage patterns over two years. The ECOtality EV Project will also provide charging stations for free and collect data on charging usage patterns, but on a scale about three times the size of ChargePoint America. Both networks include unique features to assist with consumers finding and utilities managing vehicle charging.[41] A membership is not required to use any publicly available station. Fees for using charging stations will vary, however. Proprietors who have charging stations installed on their property set the price for their use, including potentially making them available free to customers. Stations installed at residences could use off-peak electricity rates depending on whether the local utility offers such rates.

> In March 2011, the National Renewable Energy Lab announced that the American National Standards Institute's Electric Vehicle Standards Panel would jointly work to foster coordination and collaboration among public and private sector stakeholders. This includes industry, government agencies, utilities, standards assessment organizations, relevant code and standard officials (e.g., building), and more.

TABLE 4: PEV deployment projects in the United States.

PROJECT	VALUE (MILLIONS $)	COMPANY	CHARGING STATIONS	NUMBER OF STATES	INSTALLATION COMPLETION DATE
EV Project[42]	$230	ECOtality	15,000 Level II & fast chargers	6 (AZ, CA, DC, OR, TN, TX, WA)	Summer 2011
ChargePoint America[43]	$37	Coulomb Technologies	5,000 Level II	9 (CA, DC, FL, MA, MD, MI, NY, TX, WA)	October 2011
eVgo[44]	$10-$15	NRG Energy	Level II & fast chargers	1 (TX)	Throughout 2011

NRG Energy is one of the first private companies to invest significant capital in PEV deployment without public subsidy.[45] NRG Energy's eVgo charging system is unlike the EV Project and ChargePoint America in that it charges a monthly fee to subscribers, relying on this income base to build a comprehensive network. As shown in Figure 4, the company is offering three subscription plans ranging from $49 to $89 per month with no cost to install a home charger.[46] For plans that include electricity usage, the eVgo charging system is in part relying on fuel (i.e., electricity) price certainty to build a customer base. Launched in Houston in late 2010 and Dallas/Fort Worth in early 2011, NRG Energy plans to expand to other markets throughout 2011. AeroVironment will provide the charging stations for eVgo.

Smaller-scale deployment efforts exist too. Hawaii recently announced an effort to install 250 charging stations through a mix of public and private dollars totaling $4.6 million. The project participants include Better Place, AeroVironment, GreenCar Hawaii, Plug In America, Kauai County, and the City and County of Honolulu. To encourage electric vehicles, the state of Hawaii offers rebates of up to $4,500 per vehicle and $500 per charging system in addition to federal incentives (see *Public Policy to Support PEV Deployment*).

Non-profit partnerships also exist, like the Rocky Mountain Institute's Project Get Ready, a collaborative that includes research organizations, private companies, and public entities. The project aims to develop best practices for PEV deployment and house a database of American and international "plug-in readiness activities."

The DOE's Alternative Fuels and Advanced Vehicles Data Center released the Plug-in Electric Vehicle Deployment Case Studies in February 2011,[47] providing some valuable lessons learned. Existing deployment efforts are still in their nascent stage, so there is still substantial opportunity to provide guidance for future efforts.

ENDNOTES

[1] A PEV is either a plug-in hybrid vehicle (PHEV) or a battery electric vehicle (BEV).

[2] http://www.pluginamerica.org/vehicles

[3] Dow et al. (25-29 July 2010). A Novel Approach for Evaluating the Impact of Electric Vehicles on the Power Distribution System. Power and Energy Society General Meeting, 2010 IEEE (pp. 1 - 6). Minneapolis, MN: IEEE.

[4] Taylor et al. (25-29 July 2010). Evaluations of Plug in Electric Vehicle Distribution System Impacts. Power and Energy Society General Meeting, 2010 IEEE (pp. 1-6). Minneapolis, MN: IEEE.

[5] http://www.arb.ca.gov/msprog/zevprog/zevprog.htm

[6] http://www.c2es.org/federal/executive/vehicle-standards

[7] Estimates are that 80 percent of the capacity is still available from these batteries at the vehicle end-of-life.

[8] U.S. Environmental Protection Agency. (2011). The Benefits and Costs of the Clean Air Act from 1990 to 2020. Washington, D.C.: U.S. Environmental Protection Agency.

[9] http://www.eia.doe.gov/energyexplained/index.cfm?page=oil_home#tab2

[10] http://www.epa.gov/otaq/renewablefuels/420f09023.htm

[11] Greene, D., & Plotkin, S. (2011). Reducing Greenhouse Gas Emissions from U.S. Transportation. Arlington, Virginia: Center for Climate and Energy Solutions.

[12] NRC. (2010). Advancing the Science of Climate Change. Washington, D.C.: National Academies Press.

[13] DOD. (2010). Quadrennial Defense Review. Washington, D.C.: U.S. Department of Defense.

[14] Greene, D., & Plotkin, S. (2011).

[15] http://www.eia.doe.gov/emeu/cabs/AOMC/Overview.html

[16] The physical charging infrastructure including power equipment reinforcements to electricity substations and individual vehicle charging stations in order to maintain grid reliability.

[17] MIT. (April 8, 2010). Electrification of the Transportation System. Cambridge, MA: MIT.

[18] Installing a charging station for the vehicle can add a significant amount of time before a PEV can be taken "off the lot."

[19] Narich et al. (2011). Changing the game: Plug-in electric vehicle pilots. Accenture.

[20] The capability of a vehicle to supply power back to the electrical grid is known as V2G. With appropriate controls, V2G can be used to provide services such as meeting peak demand or ancillary services like frequency regulation.

[21] Kempton, W., & Tomic, J. (2005, June). Vehicle to Grid Fundamentals: Calculating Capacity and Net Revenue. J. Power Sources , 144 (1), pp. 268-279.

[22] MIT. (April 8, 2010).

[23] DOE. (2011). Department of Energy - Pillars - Transportation. Retrieved May 4, 2011, from Department of Energy: http://www.energy.gov/recovery/vehicles.htm

[24] http://www.westcoastgreenhighway.com/electrichighways.htm

[25] http://www.georgetownclimate.org/transportation/files/TCI-workplan.PDF

[26] http://www.evcollaborative.org

[27] http://www.c2es.org/what_s_being_done/in_the_states/plug_-_in_electric_vehicles

[28] http://thomas.loc.gov/cgi-bin/bdquery/z?d112:s.00948

[29] DOE. (2011). One Million Electric Vehicles by 2015: February 2011 Status Report. Washington, D.C.: Department of Energy.

[30] Kurani et al. (2010). Plug-in Hybrid Electric Vehicle (PHEV) Demonstration and Consumer Education, Outreach, and Market Research Program: Volumes I and II. Davis, California: Institute of Transportation Studies, University of California, Davis.

[31] The Volt is using about 10kWh of the 16kWh battery pack, which implies there will be significant residual value to the battery pack at the vehicle end of life.

[32] J.D. Power and Associates. (November 2010). Drive Green 2020: More Hope than Reality. Westlake Village, CA: J.D. Power and Associates.

[33] EIA. (2010, December 16). Annual Energy Outlook 2011. Retrieved March 11, 2011, from EIA: http://www.eia.doe.gov/forecasts/aeo

[34] Indiana University, School of Public and Environmental Affairs. (February 2011). Plug-in Electric Vehicles: A Practical Plan for Progress. Bloomington, IN: Indiana University.

[35] DOE. (2011).

[36] Center for Automotive Research. (January 2011). Deployment Rollout Estimate of Electric Vehicles: 2011-2015. Ann Arbor, MI: Center for Automotive Research.

[37] NRC. (2010a). Transitions to Alternative Transportation Technologies – Plug-In Hybrid Electric Vehicles. Washington, D.C.: National Academies Press.

[38] Hurst, D. (2010). Plug-in Electric Vehicles. Boulder, CO: Pike Research.

[39] This mirrors the approach of the first automakers to deliver PEVs. Both Nissan and General Motors have followed a careful rollout process focused on a limited number of initial markets.

[40] Many consumers are hesitant to consider purchasing an all-electric vehicle due to a fear of being stranded because of the vehicle's limited range. PHEVs do not have this issue because of their backup internal combustion engine.

[41] Managed charging includes the ability to enable and disable vehicle charging depending on grid considerations.

[42]http://theevproject.com

[43] http://chargepointamerica.com

[44] https://www.evgonetwork.com

[45] Utilities such as DTE Energy and Consumers Energy have offered incentives to install home chargers.

[46] The company says there is no cost unless the installation is "highly customized."

[47] http://www.afdc.energy.gov/afdc/vehicles/electric_deployment_case_studies.html

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