State of the Plug-in Electric Vehicle Market

EV Market Outlook

JULY 25, 2013

Summary and Highlights

- Since market introduction in January 2011, more than 110,000 plug-in electric vehicles have been sold in the United States.
- Compared to hybrids' first years on the U.S. market, twice as many plug-in electric vehicles have been sold since their market debut. The uptake rate of plug-in electric vehicles between 2011 and 2013 has been nearly three times what it was for hybrids between 2000 and 2002.
- Battery costs are expected to drop by about half by 2020, when the industry average price is projected to be $300-325 per kilowatt hour.
- Even today, short range plug-in hybrid electric vehicles are cost-competitive with conventional internal combustion engine vehicles and hybrids.
- Some plug-in electric vehicles are capturing unexpectedly large portions of their market segments.

INTRODUCTION

In 2009 and 2010, the Electrification Coalition released two major policy roadmaps designed to chart a course toward widespread adoption of plug-in electric vehicles (PEVs) among typical consumers as well as commercial and government fleets. Since the release of those reports, the PEV market has evolved and developed in terms of policy, structure, and offerings. With these changes in mind, the Electrification Coalition is providing a fresh look at the current market for PEVs.

State of the Plug-in Electric Vehicle Market is the first in a series of analyses conducted by the Electrification Coalition in consultation with PricewaterhouseCoopers that will assess the market and technical outlook for PEVs in the United States. This initial paper provides a high-level overview of the state of the market across a variety of topics, including: vehicle availability and sales of both light-duty vehicles and medium- and heavy-duty trucks; infrastructure deployment; consumer acceptance; and some basic total cost of ownership data. Subsequent papers in the series will be released quarterly and will provide additional analysis on various aspects of the market including infrastructure business models, cost trajectories of vehicle components and how those costs drive the total cost of ownership, and evolving dynamics in the broader automotive market.

There is plenty of good news in the PEV industry. There are currently 14 PEV models available from eight automotive manufacturers. Nine models are battery electric vehicles (BEVs) that run entirely on energy stored in the on-board battery. Five models are plug-in hybrid electric vehicles (PHEVs) that are capable of running on gasoline as well as using the battery.

PEV sales, while not matching up with original sales targets laid out by some auto manufacturers, have been strong for a new entrant in a market that has been dominated by internal combustion engine

Electrification Coalition

1111 19th Street, NW
Suite 406
Washington, DC 20036

TEL 202-448-9300
FAX 202-461-2379
ElectrificationCoalition.org

vehicles (ICEs) for a century. Through their first 30 months in the marketplace (2011-2013), sales of PEVs have been more than double the sales of hybrid electric vehicles (HEVs) in their first years in the U.S. market (2000-2002) and are continuing to grow—June 2013 saw the strongest PEV sales numbers yet, and more than 110,000 units have been sold to date. In the luxury segment, Tesla's Model S has captured 8.4 percent of the market in the first six months of 2013.

Customer experiences have typically been extremely positive. According to surveys conducted by J.D. Power and Associates, PEV owners are generally happy with their purchases and specifically like the vehicle performance—likely due to the instant torque provided by the electric motor.[2] Various PEV models have also won several major automotive awards in the past two years including World Car of the Year, North American Car of the Year, and European Car of the Year.[3] This year, the Tesla Model S received the highest score ever given to any vehicle by Consumer Reports.[4]

Nonetheless, several challenges to widespread adoption of vehicles powered by electricity still clearly exist. These challenges fall into three main categories: high initial vehicle cost; consumer acceptance; and infrastructure.

Due to the high cost of batteries, the initial purchase price of PEVs is generally significantly higher than a similarly equipped ICE vehicle. Lithium-ion batteries currently contribute a substantial portion of the incremental costs of PEVs, however, their cost is expected to decline by about 50 percent by 2020.[5] As battery prices drop, the original equipment manufacturers (OEMs) will be able to lower the price of the vehicles and/or increase vehicle range.

Although PEVs are more expensive to purchase than their ICE counterparts, they are cheaper to operate due to lower maintenance costs and low electricity prices relative to gasoline. Although combining purchase and operating costs is not how American consumers typically approach their vehicle purchase decisions, determining the total cost of ownership (TCO) gives a more accurate picture of real vehicle cost and brings PEVs more in line with ICEs in the coming years.

Consumer awareness and acceptance of this new technology poses another real challenge for widespread PEV adoption. In a survey done by IBM, 45 percent of respondents thought they had little to no understanding of PEVs.[6] A recent National Academy of Sciences report found that "Most potential PEV customers have little knowledge of PEVs and almost no experience with them. Lack of familiarity with the vehicles and their operation and maintenance creates a substantial barrier to widespread PEV deployment."[7]

When consumers are knowledgeable about the vehicles, one of the main concerns they articulate is the limited driving range.[8] Even though 68 percent of Americans travel less than 40 miles a day–well within the range of all available battery electric vehicles–consumers express concern that PEVs will not meet their driving needs.[9] PHEVs, which are able to use gasoline as well, do not have range restrictions like BEVs. Although recharging PEVs overnight at their residences will meet the daily driving needs of most Americans, some charging infrastructure will be required to ease consumer concerns. However, key questions regarding the amount of infrastructure required, funding sources, and the road to profitability in owning and operating charging stations are unresolved.

While overcoming these challenges may improve the penetration rate of electric vehicles, true success might require a more coordinated framework. The policy and regulatory environments need to be purposefully aligned with making owning and operating a PEV easy. Installing home infrastructure, being able to find and use publicly available charging stations, understanding the economics of operating a PEV, and being aware of the federal and state tax incentives for vehicle purchase are all critical pieces of information that must be aggregated and shared with consumers. This paper considers these issues while highlighting what has happened in the market since PEVs were introduced.

PLUG-IN ELECTRIC VEHICLE AVAILABILITY AND SALES IN THE LIGHT-DUTY SECTOR

In May of this year, the 100,000th light-duty PEV was sold in the United States. The Chevy Volt and the Nissan Leaf were the first two established OEM passenger market offerings, and were first available in Model Year (MY) 2011. Most other major OEMs either have vehicles on the market now or are planning to introduce PEVs in the next year or two. Currently there are 14 vehicle models available to consumers and at least eight additional models are expected between Q3 2013 and Q4 2014.

Plug-in electric vehicles (PEVs) include all cars that are propelled in whole or in part by electricity drawn from the grid and stored in an onboard battery. There are two main types of PEVs:

- **Battery Electric Vehicles (BEVs)** are propelled by one or more electric motors that receive power from an onboard battery.
- **Plug-in hybrid electric vehicles (PHEVs)** are propelled by an electric motor that receives power from an onboard battery and also have a gasoline engine and can switch seamlessly between the fuels. Series PHEVs, or extended range EVs (EREVs), only use electricity to propel the car, so the gasoline engine is used after the battery has been depleted as a generator to power the electric motor. Parallel PHEVs use both the electric motor and the gasoline engine to propel the vehicle and typically both are used simultaneously.

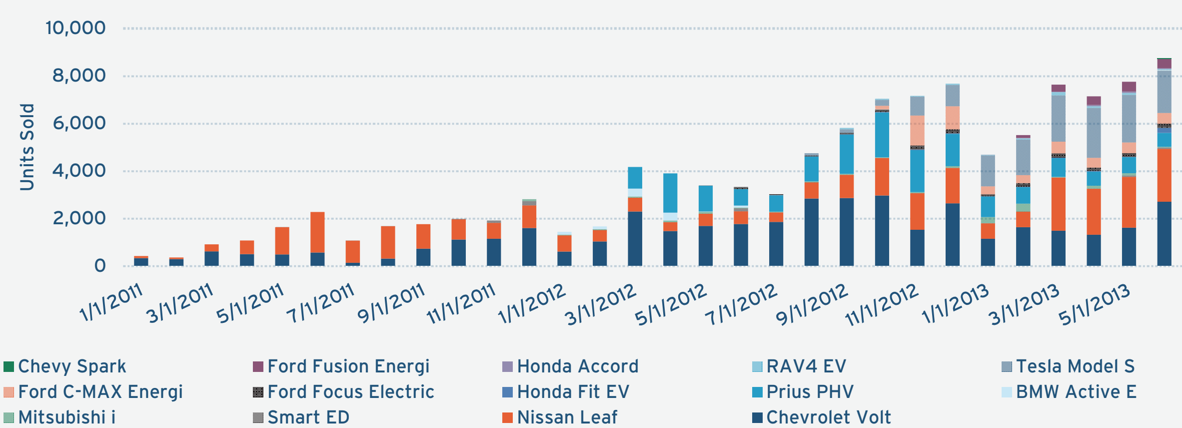
The pace of PEV sales has also steadily increased. In 2011, 17,000 PEVs were sold. It only took six months of 2012 to sell the same number of units that were sold in all of 2011. In 2013, that threshold was crossed in the first quarter, marking nearly 200 percent year-over-year growth since PEVs have been commercially available.[10] Vehicle sales per month continue to improve, with June 2013 having the highest sales yet. The Nissan Leaf, Chevy Volt, Toyota Plug-in Prius, and Tesla Model S are the best sellers to date, together comprising 79 to 100 percent of total monthly sales.[11]

BEVs and PHEVs have both, at times, been the dominant market technology. Popular new market entrants seem to have tipped the scale either way; PHEVs had the majority of the market share when the Toyota Plug-in Prius was first introduced and BEVs captured the majority position when the Tesla Model S hit its stride. The Zero Emission Vehicle mandate in California and the thirteen states that are adopting California standards are driving sales. Nearly a third of all PEV sales to date have been in California, which is not surprising as that is the only state in which all PEVs have been made available for purchase.[12]

Some have criticized automakers for not meeting their projected vehicle volumes in the first two years on the market. Although it is true that they did not meet their initial goals, this shortcoming points to overly optimistic projections rather than a lack of execution or a cool reception of the technology. To put vehicle sales volumes in proper context, it is useful to compare the vehicle availability and sales of PEVs and HEVs during their first years on the market. Compared to hybrids' first years on the market, more than twice as many PEVs have been sold. Further, the uptake rate of PEVs is nearly three times what it was for HEVs in their first three years on the market.[13] Overall, in terms of sales from date of market launch, PEVs have outperformed HEVs by double.

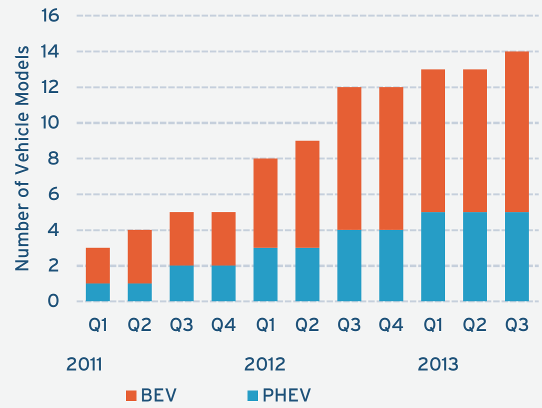
PEVs also have the edge on the number of models available. In their first two years on the market, there were two HEVs available, which increased to three in the third and fourth years and finally to four models in the fifth year. HEVs were on the market for eight years

Chart 1 - U.S. Monthly PEV Sales



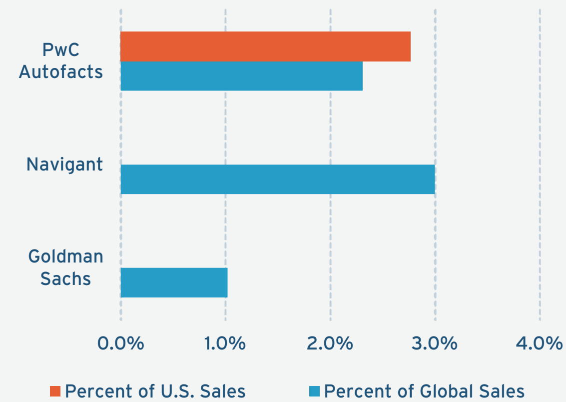
Source: hybridcars.com

Chart 2 - U.S. Availability of Passenger PEVs



Source: EC analysis of data from hybridcars.com

Chart 4 - PEV Sales Projections, 2020

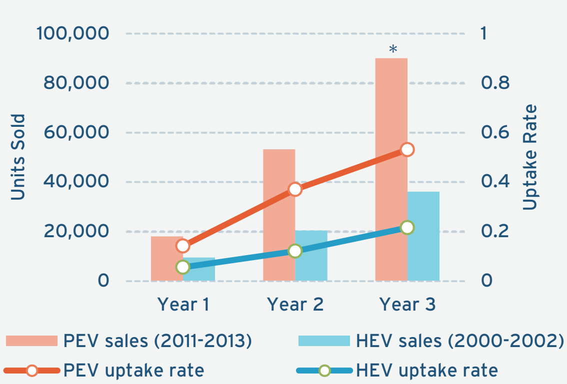


Source: PwC Autofacts, Navigant, Goldman Sachs

before the same number of models were available as are currently available in the third year of PEV sales.

In addition to outperforming the launch of hybrids, some of the PEVs on the market are selling tremendously well in their size class. In the first quarter of 2013, sales of the Tesla Model S were higher than several of its competitors, including the Audi A8, BMW 7-series, and the Mercedes S class.[14] In fact, in the first six months of this year, the Model S has captured 8.4 percent of the luxury market, selling more than 10,000 units.[15] The Nissan Leaf has also done very well in the first half of 2013, capturing 3.3 percent of the sub-compact vehicle market.[16] In the very competitive compact market, the Chevy Volt, Toyota Plug-in Prius, Ford Focus Electric and CMax Energi have together captured 1.4 percent of vehicle sales in the first half of 2013.[17]

Chart 3 - U.S. PEV vs HEV Sales and Uptake Rates in First Years on the Market



Source: hybridcars.com

* Projected sales, PEV uptake rate through June 2013

According to several forecasts, strong growth in PEV sales is expected globally. Goldman Sachs has the lowest projection, forecasting that one percent of global vehicle sales will be PEVs by 2020, with compound annual growth rates (CAGR) of 28 percent for BEVs and 34 percent for PHEVs from 2011 to 2040.[18] Navigant forecasts that three percent of global vehicle sales will be PEVs in 2020 with a 32 percent CAGR from 2012-2020.[19] PwC Autofacts projects that PEVs will be 2.3 percent of global and 2.8 percent of U.S. auto sales by 2019.[20] These numbers are in line with current HEV sales, which were 3.2 percent of total vehicle sales in June, a number that is up from 2.7 percent in June, 2012.[21]

TOTAL COST OF OWNERSHIP

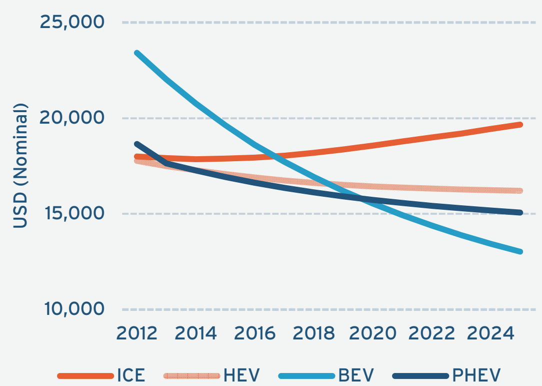
Assuming an efficiency of 3.5 miles per kWh for PEVs and 30 miles per gallon (mpg) for ICEs, an electric mile costs 3 cents to drive whereas a gasoline mile costs 12 cents.[22] Assuming a BEV owner drives 14,000 miles per year[23], he or she would save approximately $1,256 in fuel costs annually. Coupled with reduced maintenance and repair costs—BEVs have fewer moving parts and don't require regular maintenance such as oil changes—the lower annual costs pay for the initial upfront premium, in many cases make owning a PEV less expensive than a conventional ICE over the lifetime of the vehicle.

In order to easily compare the lifetime ownership costs of a variety of automotive technologies, the Electrification Coalition, in consultation with PricewaterhouseCoopers, developed an updated TCO model for this—and future—analysis. This paper provides summary level TCO data for a comparison of ICE and electric drive compact vehicles, while a later paper in this series will focus exclusively on the TCO of vehicles in various classes and segments powered by a variety of technologies (including natural gas and propane).

The model uses individual component costs to build up the total cost of a vehicle when manufactured at scale. U.S. government projections of gasoline and electricity prices and a realistic model of residual value of the vehicle and battery are also incorporated. Chart 5 summarizes one set of output from the model for representative compact cars, including a traditional internal combustion vehicle, a conventional hybrid electric vehicle, a BEV-100, and a PHEV-10.[24] Each point assumes that a vehicle was purchased new in that year and was driven 14,000 miles per year for five years. The federal tax incentives of $7,500 for the BEV-100 and $2,500 for the PHEV-10 are included in the analysis.[25]

One striking result of this analysis is that the PHEV-10 is immediately cost-competitive with the HEV and ICE on a total cost of ownership basis (see Table 1). The BEV-100, however, will still cost a consumer slightly more to own and operate than a conventional ICE over the next few years due to its high purchase price. By 2017, however, a consumer purchasing a BEV-100 could expect to achieve a lower TCO than an ICE vehicle, and by 2022, the BEV-100 will be the cheapest vehicle to own over its lifetime.

Chart 5 - Total Cost of Ownership



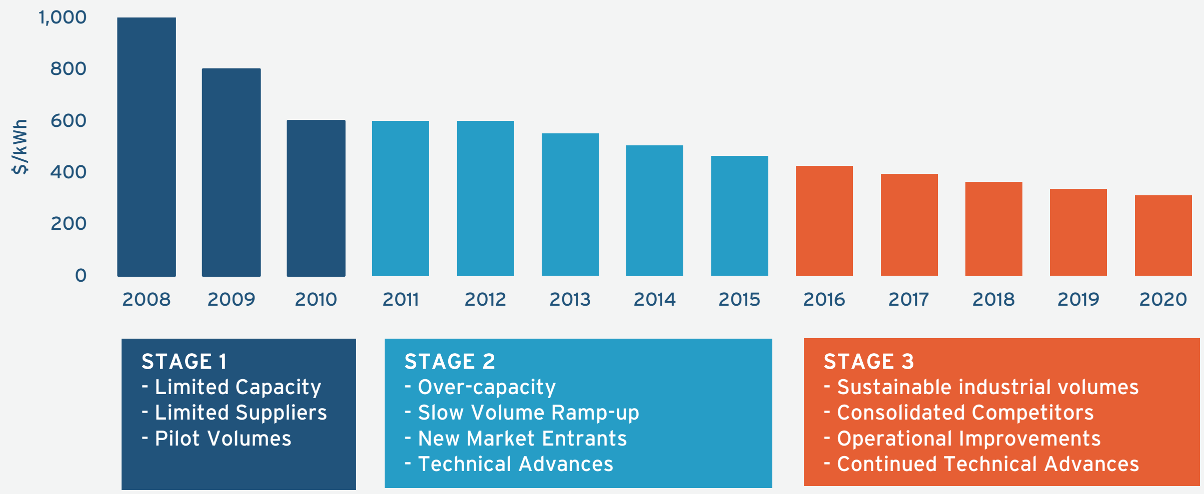
Source: EC analysis

The main driver of the incremental cost increase between an ICE and a PEV is the cost of the lithium-ion battery. In 2008, battery prices were as high as $1,000/kWh for the pack (nameplate capacity) and there were relatively large production inefficiencies due to lack of scale.[26] The second phase of market evolution of battery production is underway and battery prices have dropped to about $600/kWh.[27] In fact, some industry players claim that they will produce battery packs for $450-550/kWh in the near future.[28] Large

Table 1 – Total Cost of Ownership for Representative Vehicles in 2013

	ICE	HEV	BEV-100	PHEV-10
Acquisition Cost	17,978	21,924	28,938	22,037
Infrastructure Cost			2,036	436
Fuel Cost	6,710	4,242	2,578	3,537
Maintenance & Repair	2,230	1,873	1,615	2,091
Vehicle Residual Value	(9,021)	(10,172)	(8,164)	(9,587)
Battery Residual Value		(382)	(5,003)	(895)
Total Cost Of Ownership	**17,897**	**17,486**	**22,000**	**17,619**

Chart 6 - Lithium-ion Battery Cost



Source: PwC analysis

battery manufacturing plants have been built but are not yet fully utilized due to the relatively low volume of vehicles being manufactured. As is natural in this stage of a new industry, there are new market entrants (Bosch recently made its move into the PEV battery space), and not all startup companies have been successful.[29]

As the market moves into phase three, battery prices will continue to decline as higher vehicle sales support battery manufacturing at scale. Eventually, even fewer players are expected to be in the market as promising intellectual property (IP) is purchased by the larger, established players. In the 2009 *Electrification Roadmap* and the 2010 *Fleet Electrification Roadmap*, the Electrification Coalition projected that battery prices would fall to $325-350/kWh by 2020. Based on recent interviews with OEMs, battery suppliers, and industry experts, the progress of battery cost reductions appears to be on par with—or slightly ahead of—what was expected in 2010. The latest projections for battery costs are in the range of $300-325/kWh by 2020.[30] As the cost of the battery accounts for the majority of the total incremental cost, the halving of battery costs could effectively decrease the incremental cost of PEVs by nearly the same amount. It is also possible that OEMs will choose to increase the range of the vehicles instead of maintaining the range and decreasing vehicle prices. The Department of Energy has set a battery cost target of $150/kWh by 2020.[31] If that target is achieved, the incremental cost of PEVs would drop even further.

CONSUMER ACCEPTANCE

As noted by the National Academies of Science report, lack of consumer education is a significant barrier to adoption of PEVs.[32] An IBM survey showed that 45 percent of respondents felt they had little to no understanding of PEVs and 60 percent thought that the TCO would be the same as for ICEs.[33] If consumers are unaware of the technology, how it can fit their lifestyle, and the potential economic savings, or if they are misinformed, they are unlikely to purchase PEVs. In order to combat consumer misunderstanding of the technology, industry and advocates have used several strategies to raise consumer awareness. The most common, and probably most effective, method is to let the vehicles speak for themselves. One popular way to provide the PEV experience is allowing people to experience them at a “ride and drive” event in their community. eVgo (an infrastructure provider) produced a series of events in Dallas and Houston to give thousands of people test rides and educate them about their infrastructure network. They found that before learning about eVgo and taking a test ride, 23 percent of people said they would be interested in purchasing a

PEV. After the test ride, the number went up to 55 percent.[34]

A 2012 survey by Maritz Research showed that consumers rely predominantly on personal interactions to make their vehicle purchase decisions. Although friends and family are regularly consulted, the auto dealers themselves are actually the most influential resource in individual purchase decisions.[35] Some auto dealers are very motivated to sell PEVs, like Serra Chevrolet in Southfield, MI, which was selling a Volt almost daily in 2012.[36] Other dealerships are not placing tremendous emphasis on these vehicles, citing greater time commitment to sell a PEV compared to an ICE (due to the necessary increased consumer education) and the fact that the margins on PEVs are lower than on ICEs.[37]

PEV owners are usually the best advocates for the vehicle, and are generally very enthusiastic about sharing their experiences with other PEV drivers, friends, and family. OEMs report that they see sales radiating out from individual owners who talk to their relatives, friends, and coworkers about the vehicles and/or let them test drive their car.[38]

Advertising the vehicles in traditional ways has also raised consumer awareness. A coalition of industry players and non-profits is initiating a comprehensive media campaign called GoElectricDrive that will reach more Americans and utilize the natural grassroots networks that have formed to help educate consumers about PEVs.[39]

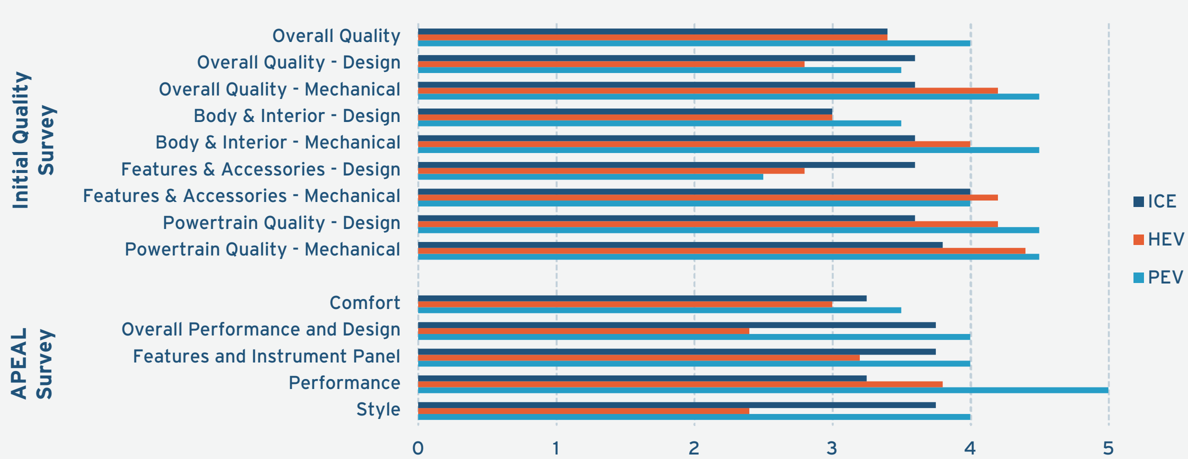
The high level of consumer satisfaction with their PEV purchases is underplayed in the media. Owner satisfaction is frequently determined through surveys. While it would be simple to compare PEVs to their platform counterparts (Nissan Leaf/Versa and Chevy Volt/Cruze), in many ways these are deceptive comparisons because the Leaf and Volt are both drawing from a consumer base that would typically purchase a more luxurious conventional vehicle. It is more appropriate to compare these PEVs to the vehicles that they compete with in the marketplace.

To get a better picture of consumer satisfaction with PEVs relative to their competitors, this analysis used blended data from J.D. Power and Associates surveys[40] for appropriate vehicles for each category: ICEs included the BMW 3-series, Mini Cooper, Buick Verano, Infiniti G37, and the Volvo C30; HEVs included the Honda Insight and CR-Z, Toyota Prius and Prius V, and the Lexus c200h; and PEVs included the Chevy Volt and the Nissan Leaf.

In this comparison, PEVs outperformed both ICEs and HEVs on almost all counts. PEVs were strongly preferred in the performance category, likely due to their instant torque for rapid acceleration. PEVs also scored higher than the others on overall quality and in most subcategories of quality.

Just as individual consumers are extremely satisfied with their purchases, the major auto magazines and other vehicle raters have been giving extremely high ratings to PEVs since their introduction. The Volt, Leaf,

Chart 7 - Consumer Satisfaction Survey Responses



Source: EC analysis of J.D. Power and Associates data and Model S have all received multiple awards in the past three years.

In 2011, the Chevy Volt received several accolades including being named the 'Motor Trend Car of the Year,' with *Motor Trend* stating, "This automobile is a game-changer."[41] The Volt also won the *Automobile Magazine* 'Automobile of the Year' and 'North American Car of the Year' awards, and was included in the *Car and Driver* '10Best' list.[42] The Nissan Leaf was named the 'World Car of the Year' and the 'European Car of the Year' in 2011, and was noted in the *Popular Mechanics* 'Breakthrough Awards' of 2010, which stated that "the real triumph lies in its family-car practicality and normalcy."[43] The Tesla Model S was named 'Automobile of the Year' by *Automobile Magazine* and the 'Motor Trend Car of the Year' in 2013.[44] In its 2013 review of the Model S, *Consumer Reports* awarded the highest score any automobile has ever received, stating "The Tesla Model S outscores every other car in our test ratings. It does so even though it's an electric car. In fact, it does so because it is electric."[45]

CHARGING INFRASTRUCTURE

The availability, or perception of availability, of electric vehicle charging stations (also referred to as electric vehicle service equipment, or EVSE) is critical to the widespread adoption of PEVs. Most PEV owners will charge their cars overnight at their residences, which many consider more convenient than going to the gas station. However, driving range and ability to find public charging stations are the concerns most often cited by people who are considering a PEV purchase, so it is critical that there are some publicly available, easily located charging stations.[46] While drivers of BEVs might be expected to plug in frequently, data suggests that PHEV drivers actually charge more times per day (1.4 versus 1.1) than BEV drivers, presumably to maximize electric miles.[47]

Although it has been robustly discussed, how to best match charging station type and location is still a subject of some debate. The type of charging station that is best to install in a given location is a function of how long people are willing to spend at that location and, for home charging, the size of the battery. Table 3 outlines the general principles that are being used to determine the type of charging station that is most appropriate to install in a given location.

As of June 30, 2013, there were 7,794 U.S. locations with charging stations available to the public (although the use of some of these is restricted to subscribers or customers).[48] Of these, 199 are DC fast charge stations, 7,519 are Level II stations and the remainder are Level I

Charging stations are categorized by the voltage they draw from the grid:

- Level I uses a standard 120 volt outlet with a 12-15 amp circuit.
- Level II uses a standard 240 volt outlet (used for clothes dryers and electric stoves) with 12-80 amp circuits.
- DC Fast Chargers require three phase power at 400+ volts and provide power to the vehicle at 20-100 kW.

Table 2 – Miles Gained From an Hour of Charging with Different On-Board Chargers at Various Types of Charging Stations

TYPE	3.3 kW	6.6 kW
Level I	5	5
Level II	11.5	23
DC Fast Charge*	168	168

* Values are theoretical. Most vehicles will receive an 80 percent charge in less than 30 minutes.

Table 3 – Best Locations for Charging Infrastructure

	HOME	OFFICE	PUBLICLY AVAILABLE	HIGHWAY
Level I	X	X		
Level II	X	X	X	
DCFC				X

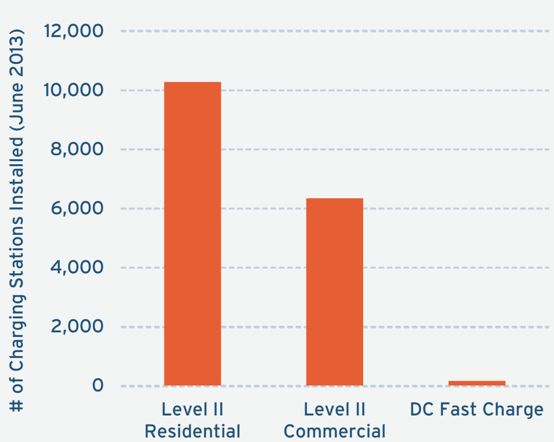
stations. When all of the plugs are counted, there are 18,349 total connectors available nationwide.[49]

Installation of a large number of these charging stations was funded through the American Reinvestment and Recovery Act (ARRA, 2009) which invested $130 million in installing charging infrastructure in 30 early adopter cities through grants to ECOtality for the EV Project and ChargePoint America.[50] These grants leveraged another $130 million in matching funds. Due to ARRA funding, ChargePoint America installed 4600 Level II charging ports and the EV Project installed 11,292 Level II charging stations (8,278 residential and 3,166 publicly available) and 76 DC fast charge stations.[51]

After the ARRA funds were depleted, infrastructure installation slowed considerably. Policymakers and advocates are now examining station usage data as it becomes available to better guide future installations. Some level of public charging infrastructure is required to overcome range anxiety, but the questions of how much and where it should go are still open for debate.

Currently, the additional load on the electricity grid due to the deployment of PEVs is fairly low. A study done by PNNL showed that the existing electrical infrastructure could fuel 73 percent of the light-duty vehicle fleet if they were transitioned to PEVs.[52] It is also critical to examine the regional and local impacts on the grid–most utilities are already analyzing their local systems to predict any issues that may arise from the integration of PEVs in their service territories. Most

Chart 8 - U.S. Installed Charging Infrastructure



Source: Alternative Fuels Data Center, DOE

utilities, even in California, where vehicle sales are the highest, are not concerned about the impacts that PEVs will have on their systems, saying that upgrading transformers is well within the normal cost of doing business.[53] They also note that they have effectively dealt with every large energy consuming technology that Americans have integrated into their households, including air conditioning, plasma TVs, and pool pumps.[54]

Another big unanswered question is how much consumers are willing to pay to charge their batteries while they are away from home. The charging stations installed by The EV Project did not start charging a fee per use until mid-2012. To date it does not appear that usage patterns have changed much since the fees were enacted, but more data is required to understand how consumers will react over the long term.[55] A survey of PEV drivers in California found that two thirds of drivers would be willing to pay up to one dollar per hour for Level II charging, but less than one third would pay $1.50.[56] Drivers' sensitivity to the charging fee will be critical in determining which business models for owning and operating infrastructure are likely to work over the long term.

In addition, there are a number of regulatory and standards issues that affect vehicle charging equipment and impact decisions made by consumers, municipalities, charging station installers and service providers, and OEMs. The station installation processes are controlled by municipalities, meaning that the process for installing a charging station may be a simple online process for a customer in one city but may take days or weeks for a customer in a different city. There are also currently two standards that are competing in the marketplace for DC Fast Charging connectors, and this lack of a common standard may be problematic in the years to come.

Finally, there are several standards that affect back-office communication of charging equipment with network providers and between network providers, and the ability to accept payment on other networks. The most obvious issue that these standards will help address is to allow members of one charging network to use and pay for charging on a different network, similar to cell phone roaming or using another bank's ATM. The process of setting any national standard can be very long, making it necessary for even this nascent industry to take a long view of what will be needed to make charging convenient for consumers and profitable for companies.

A future paper in the EV Market Outlook series will examine the opportunities and challenges with charging infrastructure, including regulatory issues and potential business models.

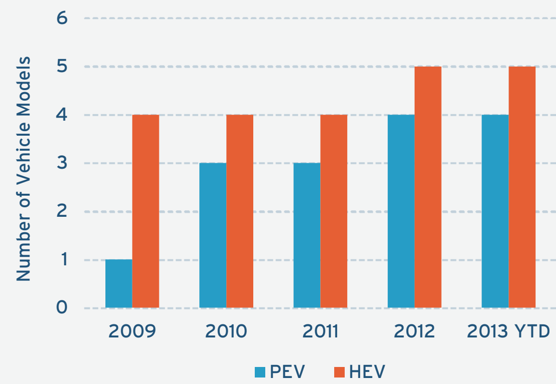
MEDIUM- AND HEAVY-DUTY VEHICLES

Medium- and heavy-duty (MDHD) PEVs offer a substantial value proposition for fleets in certain applications. As discussed earlier, the operating costs of PEVs are substantially less than ICEs, mostly due to the lower cost of fuel. Fleets that have highly predictable routes can benefit from these reduced operating costs without concerns about range. Most fleet managers take a total cost of ownership approach to vehicle acquisition, which encourages purchase decisions based entirely on the economics (unlike the average person searching for a passenger vehicle).

This proposition is supported by a broader set of survey research targeting fleet customers. In one recent survey of 180 government, utility, and private fleet directors, 58 percent of respondents purchasing electric vehicles said they had done so based on lower operating costs. Another 16 percent cited their desire to hedge against volatile petroleum fuel prices. Perhaps more interesting, operators reported EV maintenance costs at just 42 percent of conventional vehicles in light-duty applications, 36 percent in medium truck applications, and 26 percent in heavy trucks.[57] Factors like predictable routes and high vehicle utilization rates also aid in making the TCO calculation for PEVs attractive to fleet managers.

There are also broader financial benefits of incorporating PEVs in commercial fleets. Some of these are tangible, some less so. Several companies have noted that the reduced noise and lack of tailpipe emissions promote increased driver satisfaction, leading to higher retention rates and, ultimately, reduced costs for training and onboarding of new drivers. There is also early evidence that PEVs contribute to brand enhancement. Regarding its Manhattan-area fleet of parcel delivery vehicles, one company stated that "our EV drivers are like rock stars."[58]

Chart 9 - U.S. Availability of Medium- and Heavy-Duty PEVs and HEVs



Source: EC analysis of publicly available information

Utility, telecommunications, and other service fleets are also developing ancillary applications for the onboard batteries. This mobile source of power storage has applications for everything from power tools to lift buckets. As documented in a 2012 EC case study, Pacific Gas and Electric is increasingly deploying MDHD service vehicles that use battery power to operate lift buckets that would ordinarily rely on power from an idling engine.[59] In many cases, the reduction in fuel consumption associated with this system is greater than the potential savings from electrifying the drivetrain—and large enough to generate a 2.5 year payback on the trucks.[60]

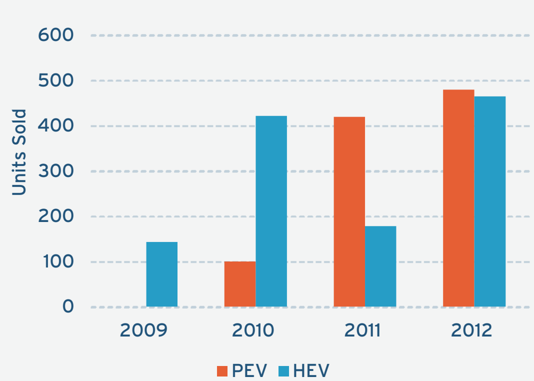
Based on all of these factors, some of the nation's most recognizable brands have already begun integrating PEVs into their fleets, including FedEx Express, GE, Coca-Cola Refreshments, UPS, Frito-Lay, Staples, Enterprise, Hertz and others. [61]

In 2010, the Electrification Coalition identified fleets as a potential main driver of the deployment of PEVs. However, vehicle sales have not picked up as anticipated. One reason for this is likely the lack of vehicle availability. Currently, there are only four MDHD PEV models available in the U.S. and none of them are made by the dominant manufacturers in this segment. Navistar is the only established MDHD vehicle manufacturer which had a PEV offering, the eStar. However, in May 2013, Navistar restructured and discontinued the eStar.[62] Although fleet managers are sensitive to the TCO of their fleet vehicles, they also tend to be somewhat risk adverse and many do not want to take a chance on a new market entrant. If a vehicle proves to be unreliable, they have not only wasted time and money training their employees on the new vehicle and installing infrastructure, but have also jeopardized the reliability and profitability of the business. It is worth noting that even hybrid electric vehicles have not had much success being integrated into MDHD vehicle fleets because their TCO is not as favorable as it is in the light-duty segment.

One reason why the established manufacturers may not be quick to design a MDHD PEV offering is the size of the market. The medium- and heavy-duty vehicle segment is a much smaller market than light-duty vehicles, with annual sales that number between 500,000 and 600,000 units as opposed to 13 to 15 million units.[63] The vehicle manufacturers tend to focus on their main vehicle lines and likely do not see a short-term path to getting PEV models to scale, given relatively weak demand for the currently expensive technology.

In the absence of larger players, small start-ups have tried to fill the MDHD PEV niche. Perhaps the most successful manufacturer of MDHD PEVs is Smith Electric, with its scalable Newton. One reason for their success is their choice of a base vehicle that is scalable from 16,500 to 26,000 pounds, and allowing a fleet manager to choose a battery size that is right-sized for their application.[64] Even though sales have been relatively strong, production has been slow due to battery supplier problems, and customers currently have to wait more than a year for one of their vehicles.[65]

Chart 10 - U.S. MDHD PEV and HEV Sales



Source: EC analysis of publicly available information

Since the battery is the main determinant of the incremental cost of PEVs, being able to purchase a battery appropriately sized for the application is one way to increase the penetration of PEVs into the MDHD fleet.

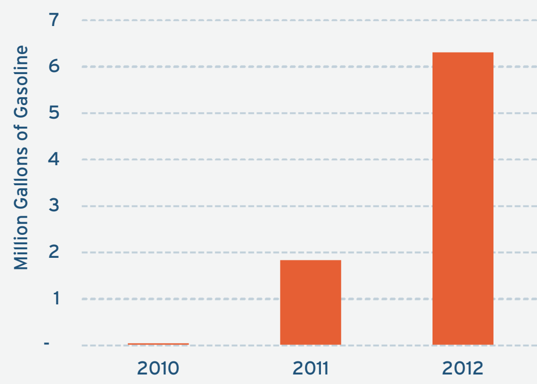
Another potential barrier to entry of PEVs in the MDHD segment is the cost of installing infrastructure. Whereas the cost of installing one or two charging stations is generally fairly low, installing larger numbers of charging stations in a single location can be exponentially more expensive. In addition to the physical construction (trenching, etc.), it is possible that the depot would need to upgrade the transformer and/or start paying additional demand charges for the electricity.[66] These costs could make it uneconomical for the integration of multiple PEVs into a single fleet location even if the vehicles themselves would be ideal for daily routes.

PUBLIC POLICY

Introducing a new technology into the very competitive and established automotive market is a herculean effort. Congress recognized this when it implemented tax incentives for both vehicle purchase and infrastructure installation. Consumers who purchase a PEV are allowed to claim up to a $7,500 tax credit on their federal income taxes. The incentive also applies to leases, but the lessor takes the tax credit and passes through the value in the lease price. The vehicle purchase incentive is available until the manufacturer has sold 200,000 PEVs (with no sunset date). Infrastructure installation is also incentivized through a tax credit that covers one third of the cost to purchase and install charging infrastructure (valued up to $1,000 in homes and up to $30,000 in commercial applications). The infrastructure tax credit is set to expire on December 31, 2013, but may be extended by Congress.

In addition to the federal incentives, some states have also provided financial and non-financial incentives. The largest vehicle purchase incentive is in Colorado, where purchasers can receive up to an additional $6,000 back on their state income taxes. Some states also further incentivize infrastructure installation and others offer reduced registration fees or waive sales tax on the cars. The most common non-

Chart 11 - Gallons of Gasoline Saved from Operation of Plug-in Electric Vehicles



financial incentive is access to HOV lanes, which can be a strong motivator in congested areas.

PEVs have already provided some of the promised benefits of their adoption; even as a tiny portion of the LDV fleet, they are already reducing gasoline consumption and greenhouse gas emissions. The PEVs on the road have already displaced at least 6.3 million gallons of gasoline, conservatively assuming that they replaced efficient ICEs and HEVs.[67] Although this is a small number with respect to total U.S. gasoline consumption, it demonstrates that PEVs will have a meaningful impact on energy security, even in the near-term when it is likely that consumers will be replacing vehicles that are increasingly fuel efficient.

The increased adoption of PEVs will also contribute to lower greenhouse gas emissions in the vehicle sector. Studies that compare GHG emissions for ICEs and PEVs from both the production and use phases find that PEVs have 27 to 52 percent lower GHG emissions based on an average grid mix.[68] The emissions from the production of the vehicle (including the battery) make up less than one third of the total emissions in most studies.[69] As the carbon intensity of the grid decreases—whether due to greater use of natural gas or renewable generation sources—the GHG benefits of driving electric vehicles will increase.

CONCLUSION

During their first 30 months in the marketplace, plug-in electric vehicles have made important progress on a number of fronts. Perhaps most importantly, there is an increasingly diverse range of vehicles available to car buyers, and both consumers and leading automotive publications rate the vehicles highly. The adoption rate of PEVs is nearly triple what it was for HEVs in their third year on the market. Battery costs are on track to decline by roughly 50 percent by 2020. And while PEVs still occupy a small share of total passenger vehicle sales, several models are competitive in their market segments, most notably the Tesla Model S. Year-over-year growth has been substantial, and there is continued momentum.

Challenges, however, clearly remain, and PEVs have a way to go before the technology can reach the adoption levels required to address the public policy goals often associated with the technology, most notably improved energy security. A scalable, viable business model for public charging infrastructure has yet to fully emerge, though there has been some important progress since 2010. Consumers remain unsure and somewhat misinformed regarding PEVs, and there have been few meaningful initiatives designed to address this shortcoming. And while battery technology remains on track for significant improvement by 2020, reaching the aggressive goals set forward by policymakers requires greater investment in research and development. These and other topics will be the focus of in-depth research by the Electrification Coalition as we continue to evaluate the EV Market Outlook in the coming months.

State of the Plug-in Electric Vehicle Market is the first in a series of papers that will continue to analyze different aspects of the PEV market. New papers will be released quarterly and the next paper will focus on the current state of play in the charging infrastructure market. Additional papers will examine the total cost of ownership for PEVs both for personal use and in fleet applications, and evolving dynamics in the broader automotive market.

Endnotes

1 "Electrification Roadmap", Electrification Coalition, 2009; and "Fleet Electrification Roadmap", Electrification Coalition, 2010.
2 J.D. Power and Associates, Initial Quality Survey and Automotive Performance, Execution and Layout survey, 2013.
3 World Car Awards, http://www.wcoty.com/web/media_release.asp?release=69&year=2011; Car of the Year, http://www.caroftheyear.org/previous-winners/; and North American Car and Truck of the Year Awards, http://www.northamericancaroftheyear.org/2011_winners.html.
4 Consumer Reports, "Tesla Model S Review: An Electric Sports Car Earns Our Top Test Score," July 2013.
5 PwC analysis.
6 Kalman Gyimesi, and Ravi Viswanathan, "The Shift to Electric Vehicles: Putting Consumers in the Driver's Seat," IBM Global Business Services Executive Report, 2011.
7 National Academy of Sciences, "Overcoming Barriers to Electric Vehicle Deployment," Interim Report, 2013.
8 J.D. Power and Associates, "Electric Vehicle Ownership Experience Study," 2012.
9 Federal Highway Administration, "2009 National Household Travel Survey Data," U.S. Department of Transportation, 2009.
10 EC analysis of hybridcars.com sales data.
11 EC analysis of hybridcars.com sales data.
12 "California Plug-in Electric Vehicle Owner Survey," California Center for Sustainable Energy, May, 2013.
13 EC analysis based on publicly available data.
14 Jake Lingeman, "Tesla Outsells Luxury Competition," Autoweek, May 13, 2013.
15 EC analysis of hybridcars.com sales data.
16 EC analysis of hybridcars.com sales data.
17 EC analysis of hybridcars.com sales data.
18 Goldman Sachs Forecast, 2013.
19 Dave Hurst, "Electric Vehicle Market Forecasts: Global Forecasts for Light Duty Hybrid, Plug-in Hybrid, and Battery Electric Vehicles: 2013-2020," Navigant Research, June 2013.
20 PwC AutoFacts, 2013.
21 Sales data from hybridcars.com.
22 Analysis used Energy Information Administration data for average residential electricity prices of 11.88 cents/kWh and average gasoline price of $3.71/gallon from July 15, 2013.
23 The average annual miles driven by all drivers is 13,476, according to the Federal Highway Administration's "Our Nation's Highways," Publication NO. FHWA-PL-01-1012, updated April 4, 2011.
24 Assumed fuel economy was 24 mpg for the ICE, 50 mpg for the HEV, and 50 mpg for the PHEV when running on gasoline.
25 An upcoming paper in the series will concentrate on various TCO analysis, including investigating the effects of the federal tax credit on vehicle cost over the ownership period.
26 "Electrification Roadmap," Electrification Coalition, 2009.
27 PwC analysis.
28 PwC Analysis.
29 "Bosch Forms Robert Bosch Battery Systems; Fiat 500e First EV with a Bosch Pack," Green Car Congress, December 13, 2012.
30 PwC analysis.
31 Department of Energy, "2011 Annual Progress Report: Energy Storage R&D," 2011.
32 National Academy of Sciences, "Overcoming Barriers to Electric Vehicle Deployment," Interim Report, 2013.
33 Kalman Gyimesi, and Ravi Viswanathan, "The Shift to Electric Vehicles: Putting Consumers in the Driver's Seat," IBM Global Business Services Executive Report, 2011.
34 Personal communication.

35 "New Vehicle Customer Study Reveals Top Sources for Automotive Buying Decisions," Maritz Research Press Release, May 30, 2012.

36 Danny Green, "Michigan Dealer Sells Roughly a Chevy Volt a Day," AutoblogGreen, April 30, 2012.

37 John Voelcker, "Weakest Links in Electric Car Sales: Local Salespeople, Dealers," Green Car Reports, October 3, 2012; Nikki Gordon-Bloomfield, "Toyota Dealers Not Interested in Selling Electric Cars, Prefer Hybrids," Green Car Reports, October 15, 2012; and Alysha Webb, "Survey Says: Dealers are Key to Chevy Volt's Success," PluginCars, October 2, 2012.

38 EC interviews.

39 http://goelectricdrive.com/

40 J.D. Power and Associates has conducted two surveys for the Chevy Volt and the Nissan Leaf – the Initial Quality Survey identifies owner complaints and problems in the first 90 days of vehicle ownership and the Automotive Performance, Execution and Layout (APEAL) study ascertains what consumers like about their new vehicles after 90 days of ownership.

41 Motor Trend, "2011 Motor Trend Car of the Year: Chevrolet Volt: A Car of the Future You Can Drive Today," 2011.

42 Automobile Magazine Car of the Year, http://www.automobilemag.com/features/awards/1101_2011_automobile_of_the_year_chevrolet_volt/viewall.html; North American Car and Truck of the Year Awards, http://www.northamericancaroftheyear.org/2011_winners.html; and Car and Driver Ten Best Cars for 2011, http://www.caranddriver.com/features/10best-2011-10best-cars-feature.

43 World Car Awards, http://www.wcoty.com/web/media_release.asp?release=69&year=2011; Car of the Year, http://www.caroftheyear.org/previous-winners/; and Popular Mechanics, The Top Products of 2010. http://www.popularmechanics.com/cars/alternative-fuel/news/nissan-leaf-top-products-2010.

44 Automobile Magazine Car of the Year, http://www.automobilemag.com/features/awards/1301_2013_automobile_of_the_year_tesla_model_s/viewall.html; and Motor Trend Car of the Year, http://www.motortrend.com/oftheyear/car/1301_2013_motor_trend_car_of_the_year_tesla_model_s/viewall.html

45 Consumer Reports, "Tesla Model S Review: An Electric Sports Car Earns Our Top Test Score," July 2013.

46 J.D. Power and Associates, "Electric Vehicle Ownership Experience Study," 2012.

47 EV Project, "Q1 2013 Report," May 13, 2013.

48 Department of Energy, Alternative Fuels Data Center, accessed 7/19/2013

49 Id.

50 "EV Project Expands to Los Angeles; Washington, D.C.; and Chevrolet Volts," EERE News, June 23, 2010, http://apps1.eere.energy.gov/news/news_detail.cfm/news_id=16115

51 EV Project,"Q1 2013 Report," May 13, 2013; and "Successful Completion of its ARRA-Funded ChargePoint America Program," ChargePoint Blog, June 11, 2013.

52 Michael Kinter-Meyer, Kevin Schneider, and Robert Pratt, "Impacts Assessment of Plug-in Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids – Part I: Technical Analysis," Pacific Northwest National Laboratory, 2007.

53 EC interviews.

54 Personal Communication.

55 EV Project, "Q1 2013 Report," May 13, 2013; and EV Project, "Q4 2012 Report," February 5, 2013.

56 "California Plug-in Electric Vehicle Owner Survey," California Center for Sustainable Energy, May, 2013.

57 Dow Kokam and Fleet Answers survey, 2012

58 Id.

59 "It's Electrifying: Positive Returns in PEV Deployment," Electrification Coalition, 2012.

60 Id.

61 EC interviews.

62 "Navistar Sells RV Business, Drops eStar Van as Part of its Turnaround Plan," Truckinginfo.com, May 16, 2013.

63 WardsAuto, U.S. Vehicle Sales, 1931-2012 excel sheet, last updated 2013, available at http://wardsauto.com/keydata/historical/UsaSa01summary

64 Smith Electric website, http://www.smithelectric.com/wp-content/themes/barebones/pdfs/SmithNewtonUS_SpecSheet_2011.pdf

65 Personal Communication.

66 "Fleet Electrification Roadmap," Electrification Coalition, 2010; "It's Electrifying: Positive Returns in PEV Deployment," Electrification Coalition, 2012.

67 EC analysis based on publicly available data.

68 Baptista, P., Tomas, M., & Silva, C., "Plug-in Hybrid Fuel Cell Vehicles Market Penetration Scenarios," International Journal of Hydrogen Energy , 35:10024-10030, 2009; Burnham, A., Wang, M. & Wu, Y., "Development and Applications of Greet 2.7 – the Transportation Vehicle Cycle Model," Argonne National Laboratory, Energy Systems Division, 2006; Hawkins, T., Singh, B., Majeau-Bettez, G., & Stomman, A., "Comparative Environmental Life Cycle Assessment of Conventional and Electric Vehicles," Journal of Industrial Ecology, 2012; Ma, H., Balthasar, F., Tait, N., Riera-Palou, X. & Harrison, A., "A New Comparison between the Life Cycle Greenhouse Gas Emissions of Battery Electric Vehicles and Internal Combustion Vehicles," Energy Policy, 44: 160-173, 2012; Michalek, J., Chester, M., Jaramillo, P., Samaras, C., Shiau, C. & Lave L., " Valuation of Plug-in Vehicle Life-Cycle Air Emissions and Oil Displacement Benefits," Proceedings of the National Academy of Science, 108(40): 16554-16558, 2011; Notter, D., Gauch, M., Widmer, R., Wager, P., Stamp, A., Zah, R., & Althaus, H., "Contribution of Li-Ion Batteries to the Environmental Impact of Electric Vehicles," Environmental Science and Technology, 44: 6550-6556, 2010; Samaras, C & Meisterling, K., "Life Cycle Assessment of Greenhouse Gas Emissions from Plug-in Hybrid Vehicles: Implications for Policy," Environmental Science and Technology, 42: 3170-3176, 2008; and United States Environmental Protection Agency, "Application of Life-Cycle Assessment to Nanoscale Technology: Lithium-ion Batteries for Electric Vehicles," Design for the Environment Program and National Risk Management Research Laboratory, 2013.

69 Burnham, A., Wang, M. & Wu, Y., "Development and Applications of Greet 2.7 – the Transportation Vehicle Cycle Model," Argonne National Laboratory, Energy Systems Division, 2006; Hawkins, T., Singh, B., Majeau-Bettez, G., & Stomman, A., "Comparative Environmental Life Cycle Assessment of Conventional and Electric Vehicles," Journal of Industrial Ecology, 2012; Notter, D., Gauch, M., Widmer, R., Wager, P., Stamp, A., Zah, R., & Althaus, H., "Contribution of Li-Ion Batteries to the Environmental Impact of Electric Vehicles," Environmental Science and Technology, 44: 6550-6556, 2010; and United States Environmental Protection Agency, "Application of Life-Cycle Assessment to Nanoscale Technology: Lithium-ion Batteries for Electric Vehicles," Design for the Environment Program and National Risk Management Research Laboratory, 2013.

Appendix

Available passenger models and sales of PEVs.

OEM	MODEL	TYPE	FIRST YEAR ON MARKET	SALES TO DATE
Audi	A3 e-tron	PHEV	2014[1]	
BMW	Active E	BEV	2012[2]	969
BMW	i3	BEV	2013[1]	
BMW	i8	PHEV	2014[1]	
BYD	e6	PHEV	2014[1]	
Coda	Coda sedan	BEV	2012[2]	78
Detroit Electric	SP:01	BEV	2013[1]	
Fiat	500e	BEV	2013[1]	
Fisker	Karma	PHEV	2012[2]	1,800
Ford	Focus Electric	BEV	2011	1,583
Ford	C-Max Energi	PHEV	2012	4,856
Ford	Fusion Energi	PHEV	2012	1,584
GM	Volt	PHEV	2010	41,050
GM	Spark EV	BEV	2013	27
GM	Cadillac ELR	PHEV	2014[1]	
Honda	Fit EV	BEV	2012	384
Honda	Accord Plug-In Hybrid	PHEV	2013	200
Mitsubishi	i-MiEV	BEV	2011	1,390
Mitsubishi	Outlander PHEV	PHEV	2014[1]	
Nissan	Leaf	BEV	2010	29,332
Nissan	Infinit LE	BEV	2014[1]	
Porsche	Panamera S E-Hybrid	PHEV	2014[1]	
Smart	Fortwo Electric Drive	BEV	2011	564
Tesla	Roadster	BEV	2008[2]	1,650
Tesla	Model S	BEV	2012	12,850
Tesla	Model X	BEV	2014[1]	
Toyota	RAV4 EV	BEV	2012	600
Toyota	Prius Plug-in	PHEV	2012	16,963

Sales data from Hybridcars.com
1 Expected
2 No longer available

Electrification Coalition

The Electrification Coalition is dedicated to reducing America's dependence on oil through the electrification of transportation. Our mission is to promote public and private action to facilitate deployment of electric vehicles on a mass scale. The Coalition serves as a dedicated rallying point for an array of electrification allies and works to disseminate informed, detailed policy research and analysis.

Acknowledgments

This report was informed by interviews with more than two dozen players in the electric vehicle space. Experts from the automotive industry, charging infrastructure manufacturers and service companies, battery companies, utilties, and deployment projects kindly agreed to be interviewed and their input has shaped this analysis.

This report was written in consultation with PricewaterhouseCoopers.

pwc