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Electric Vehicle Transportation Center

Prediction of Electric Vehicle Penetration

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Final Research Project Report
EVTC Project 5 – Prediction of Electric Vehicle Penetration

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The objective of the Prediction of Electric Vehicle Penetration was to identify past values and trends in electric vehicle (EV) sales to establish a baseline of electric vehicle penetration and to project electric vehicle sales and sales characteristics within the U.S. The project also compared EV sales by states and evaluated the types of barriers to EV usage and the actions or incentives to overcome the barriers. The work was conducted by Dr. David Block and Dr. Paul Brooker of the Florida Solar Energy Center.

Final Research Project Report

Prediction of Electric Vehicle Penetration

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1. Summary

The object of this report is to present the current market status of plug-in-electric vehicles (PEVs) and to predict their future penetration within the world and U.S. markets. The sales values for 2016 show a strong year of PEV sales both in the world and the U.S. China leads in yearly sales at 316,800 (a 53% increase for 2016 from 2015) followed by Western Europe at 209,300 vehicles sold. The U.S. is third at 159,600. These three regions comprise 91% of the global sales market. The world total of PEV sales for 2016 is estimated to be 756,000 up from 566,000 in 2015. The data shows that the overall world has a 34% growth rate for the past year. The world now has over two million PEVs on the road. PEVs in the world market are rapidly growing due to the various country policies and to the development of lithium-ion batteries from both a technological and manufacturing standpoint.

Within the U.S., the PEV sales results for 2016 show that 159,600 vehicles were sold as compared to 114,000 vehicles in 2015 for a yearly growth rate of 40%. On a state basis, California is the largest market with sales of 75,165 PEVs or 48% of the US sales. The total cumulative number of PEVs sold in the U.S. over the seven year lifetime is now at more than 560,000 vehicles.

The project also evaluated the types of barriers to PEV usage and the actions, incentives and research to overcome the barriers. These major barriers are related to cost, resale, infrastructure and range. Results show that the cost of PEVs are higher than conventional gasoline vehicles, and the used PEV market is only just starting to appear. Range is another barrier to EV adoption, with typical PEV ranges less than 100 miles. Related to range, the recharging time of EVs is significantly longer than gasoline, and charging stations are not as common as gasoline stations. The result of these barriers is to reduce PEV acceptance among the typical consumer.

2. Introduction

This report represents the final effort in the EV prediction project and is an update of the previous three reports. Because of the importance of the need to know and understand how PEVs were being sold and marketed, this effort has been conducted. For each year of the EVTC project, a report has been written covering PEV sales, predictions and technology advances. The three previous prediction reports are:

1. Block, D., & Harrison, J. (2014). Electric Vehicle Sales and Future Projections (FSEC Rep. No. FSEC-CR-1985-14). Cocoa, FL: Florida Solar Energy Center.
2. Block, D., & Harrison, J., Brooker, P. (2015). Electric Vehicle Sales for 2014 and Future Projections (FSEC Rep. No. FSEC-CR-1998-15). Cocoa, FL: Florida Solar Energy Center.
3. Block, D., & Brooker, P. (2016). 2015 Electric Vehicle Market Summary and Barriers (FSEC Rep. No. FSEC-CR-2027-16). Cocoa, FL: Florida Solar Energy Center.

Thus, this report presents the update of PEVs and barriers for the year 2016.

3. Electric Vehicle Definitions

Plug-in Electric Vehicle (PEV): This refers to any vehicle that plugs into the electric grid for all or part of its power source. PEVs are battery-electric vehicles (BEV) such as the Nissan Leaf, plug-in hybrid electric vehicles (PHEVs) such as the Chevy Volt, or extended-range electric vehicles (EREVs).

Hybrid Electric Vehicle (HEV): HEVs are those vehicles that combine a conventional internal combustion engine (ICE) propulsion system with an electric propulsion system, but that whose batteries are not recharged by plugging into the grid. Examples of HEVs include the original Toyota Prius, Honda Accord hybrid, or the Hyundai Sonata hybrid.

4. Yearly PEV Sales

Many references present PEV sales for 2010 through 2016. The world historical sales data in tabular form is as follows [1]:

Table 1 - World PEV Sales by Year

Country	Year						**Totals**
	2011	2012	2013	2014	2015	2016	
China	5,202	10,699	15,004	61,984	207,000	316,800	616,689
Europe	14,160	40,000	71,233	102,565	188,300	209,300	625,558
U S	17,763	53,169	97,102	118,882	114,000	159,600	560,516
Japan	12,600	20,667	28,716	30,567	22,800	24,300	139,650
Other	275	1,225	931	1,521	33,900	46,300	84,152
Totals	50,000	125,760	212,986	315,519	566,000	756,300	2,026,565

The sales values in Table 1 show that China leads in yearly sales at 316,800 (53% increase for 2016) followed in second place by Western Europe at 209,300 vehicles sold. The U.S. is third at 159,600. These three regions comprise 91% of the global sales market. The world total of EV sales for 2016 is estimated to be over 756,000 up from 566,000 last year. This data also shows that the year-over-year growth is 34% for 2015-2016 (led largely by China). The world sales figures are graphical shown in Figure 1 below.

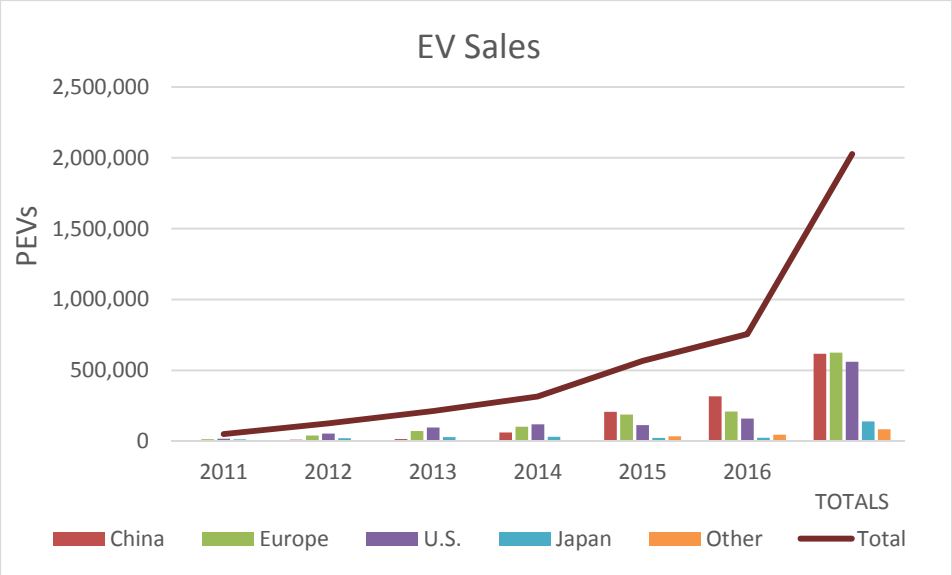

Figure 1. Annual PEV sales worldwide

The U.S. sales figures for 2016 show EV yearly sales at 159,600 as compared to sales of 114,000 for 2016 [1]. Table 2 shows the sales by year of plug-in hybrid EVs (PHEVs) and EVs with the total sales for each year.

Table 2 – US EV Sales per Year

Year	PHEVs	EVs	**Total**
2016	71,000	86,736	159,600
2015	43,000	72,900	114,000
2014	57,906	64,532	122,438
2013	51,211	46,296	97,507
2012	39,458	13,149	52,607
2011	7,671	9,754	17,425
2010	326	19	345
Total	270,572	293,350	563,922
Percent	48%	52%	

For the U.S., the Table 2 sales show that EVs comprised 52% of the total as compared to 48% for PHEVs. And, in 2016, the largest selling EV was the Tesla Model S with 30,200 vehicles followed by the Chevy Volt with 24,739 vehicles and third was the Tesla Model X with 19,600 vehicles. Looking at past sales values, the data shows that that for the total seven years of sales, the Volt has sold 113,489 vehicles, followed by Nissan Leaf with 103,600 and Tesla Model S 94,623. Of the total PEVs sold, these three account for 56%.

5. Projected PEV Sales

Looking at Table 2 there is a 2016 one year EV sales growth rate of 40% which is very positive when considering the -4% rate experienced in 2015. For the long term, a 40%

rate cannot be maintained. Thus, moderate growth rate calculations were made for EV sales predictions using growth rates of 5, 10, and 15% from the 2016 sales value of 159,000 vehicles sold. Results from these calculations are presented in Table 3 and graphically in Figure 2 which shows the number of PEVs predicted for 10 years in the future.

Table 3 – 10 Year Predicted PEV Sales and Cumulative Numbers

Growth Rate	2017 Sales	2026 Sales/Year	Cumulative Vehicles on Road
5%	159,000	260,000	2.7 million
10%	159,000	412,000	3.3 million
15%	159,000	643,000	4.3 million

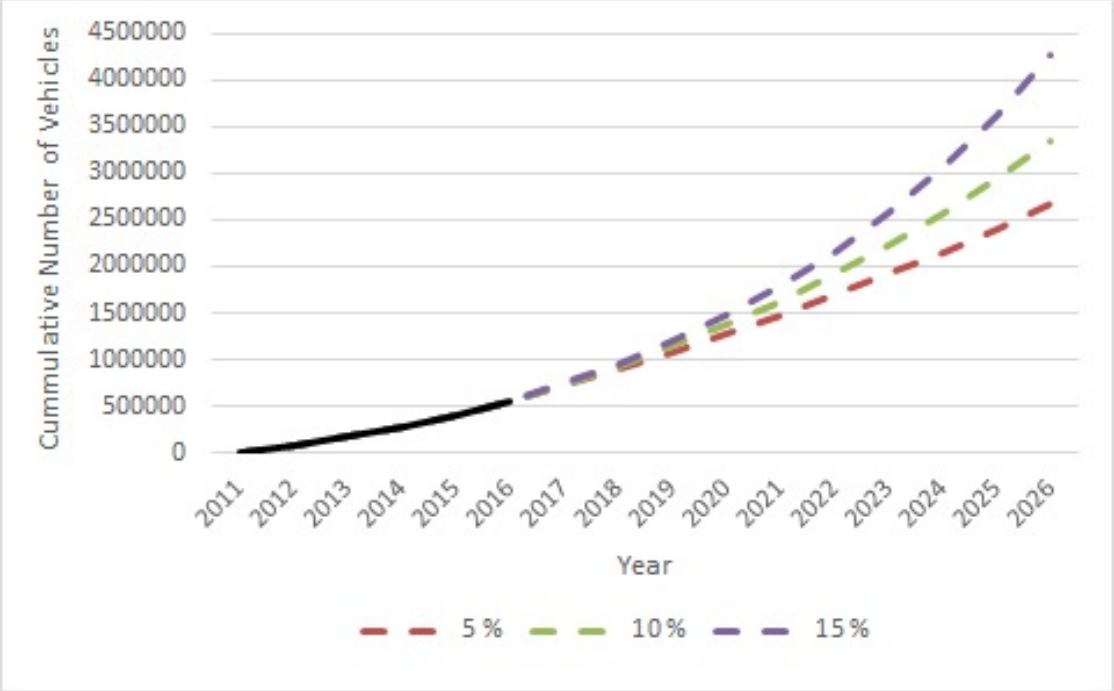

Figure 2 – U.S. PEV sales and growth predictions.

The Table 3 numbers show that in 10 years and for a 10% growth rate, the PEV yearly sales would be 412,000 vehicles and the number of PEVs on the road would be 3.3 million. These calculations assume that no PEVs are retired from the fleet.

6. Data Analysis

The world and the U.S. now have seven years of PEV sales data available for evaluation. This data shows the following:

- China is increasing its presence as the world's leader by producing 42% of all new PEVs, up from 36% the previous year.
- World-wide PEV sales were 34% more for 2016 compared to 2015.

- World-wide there are now over two million PEVs on the road.
- U.S. saw a 40% increase in sales for 2016 compared to 2015.

In addition to the above facts, the following statements add to future growth [2].

- China added 160,000 commercial EV vehicles (mostly buses).
- The number of PEV models by OEMs increased from 70 to 130 in three years.
- Battery costs have decreased by 50% in last three years.
- Tesla's giga-battery manufacturing facility is close to being on-line.

Also, the U.S. market now has over 26 EV models and 15,948 charging stations giving 42,611 charging outlets as compared to 13,864 charging stations giving 34,133 public outlets for charging in 2015, a 25% increase in new stations [3].

On the negative side of the growth picture are the following [2]:

- Europe will probably not be able to maintain its past growth.
- China's growth is also slowing.
- The U.S. federal tax credit of $7,500 will eventually phase-out. The reduction for GM and Tesla may begin in 2019-2020 time frame. GM is currently at 124,200 vehicles sold, Nissan is at 103,600 and Tesla is at 110,850 sold (200,000 is the value for reduction to $3,750). Note that the federal tax credit applies to an auto manufacture, thus, the totals for GM and Tesla cover all qualifying electric vehicles whereas Nissan only has one qualifying vehicle.

In last year's report, data was presented that compared over time, HEV and PEV sales vs. gasoline price. This data showed that HEV sales follow gas prices, but PEV sales do not. The results for 2016 still support this result.

Another factor in U.S. auto sales is the total number of vehicles sold as shown in the following Table 4.

Table 4 - U.S. Total Vehicle Sales

YEAR	TOTAL U.S. SALES (million vehicles)	% HEV of Total	% PEV of Total
2007	11.8	2.99	--
2008	13.3	2.39	--
2009	10.5	2.78	--
2010	11.6	2.37	--
2011	12.7	2.09	0.14
2012	14.4	3.01	0.37
2013	15.5	3.19	0.62
2014	16.4	2.75	0.72
2015	17.4	2.12	0.66
2016	17.5	1.99	0.91

Table 4 shows that 2016 was again a record in total vehicles sold at 17.5 million vehicles and that total auto sales have now increased every year for the past 7 years.

The total sales for 2017 are now forecast be lower at 17.1 million. Table 4 also presents the total sales of HEV and PEV vehicles (as a percentage) of total sales for each year. Note is also made that light trucks (SUVs, vans and pickups) have outsold cars for the fourth year at 63% of the market up from 57% last year [4]. It is also interesting to note that hybrid sales have decreased steadily while PEV sales have increased. This may be the result of hybrid owners switching to PEVs, or because of improved incentive for PEVs. As affordable, long range PEVs enter the market in 2017, it is expected that PEV sales will continue to climb.

7. PEVs by State

As in the past, California continues to lead the nation in the sale of PEVs. In 2016, California auto dealers sold 75,165 PEVs (34,818 plug-in and 40,347 electric only) [5]. Thus, California continues to lead the nation with 48% of the PEVs sold. In 2015, California sold 62,217 PEVs, thus, comparing 2016 to 2015 shows a one year sales growth rate of 21%. The other 9 states with ZEV mandates (CT, ME, MD, MA, NJ, NY, OR, RI, VT) account for another 25% [6].

8. Historical Sales of Hybrid Electric Vehicles (HEV)

Although this study does not involve hybrid vehicles (HEVs), the historical sale trends of HEVs are of interest in looking at future PEV trends. Hybrid vehicles were introduced in the U.S. in 1999 and 2013 was the largest sales year at 495,530 HEV vehicles. Sales for 2016 were at 346,984 vehicles, a decrease from 2015. Table 2 below presents the yearly sales and the cumulative sales of HEVs.

Table 5 - Yearly HEV Sales

Year	Sales	Cumulative
1999	17	17
2000	9,350	9,367
2001	20,287	29,654
2002	35,000	64,654
2003	47,525	11,2179
2004	88,000	20,0179
2005	215,000	415,179
2006	250,000	665,179
2007	352,274	1,017,453
2008	313,673	1,331,126
2009	290,292	1,621,418
2010	274,210	1,895,628
2011	266,329	2,161,957
2012	434,645	2,596,602
2013	495,530	3,092,132
2014	452,172	3,544,304
2015	384,404	3,928,708
2016	346,984	4,275,692

As presented in Table 5, the sales of HEVs have declined since 2013. This may be indicative of hybrid owners switching to electric vehicles, or a result of lower gasoline prices.

9. Activities to Overcome Barriers

9.1 Barriers

PEV sales have increased nearly every year since their introduction to the market in 2010, suggesting consumer acceptance is increasing. Notwithstanding these gains, barriers still exist which may prevent a consumer from purchasing PEVs. These barriers are related to cost, resale, infrastructure and range. The cost of PEVs are higher than conventional gasoline vehicles, and the used PEV market is only just starting to appear. Fleet owners (e.g. municipalities, car rental companies) are reluctant to purchase PEVs due to uncertainties around the resale value of these vehicles. As more PEVs enter the market, the resale value of EVs will become clearer. Range is another barrier to PEV adoption, with typical PEV ranges less than 100 miles. Gasoline vehicles have ranges that are 3-4 times longer than PEVs, and gasoline refueling infrastructure is widespread. Related to range, the recharging time of PEVs is significantly longer than gasoline, and charging stations are not as common as gasoline stations. The result of these barriers is to reduce PEV acceptance among the typical consumer.

9.2 Actions to Overcome Barriers

Costs of electric vehicles have declined significantly over the past few years. A report from GreentechMedia stated that prices have fallen 70% between January 2015 and June 2016 [7]. These declining prices are a result of significant increases in battery manufacturing capacities, for both stationary and vehicle applications. As battery manufacturing output continues to increase, it is expected that costs will decrease, leading to further reductions in PEV prices. This price reduction is reflected in the introduction of new, low priced-long range PEVs such as the Chevy Bolt ($37,500 / 238 mile range) and Tesla’s Model 3 ($35,000 / 215 mile range). The Bolt went on sale in late 2016 (CA and OR only), and initial indicators are positive, indicating that consumers are eager to purchase the vehicle. Tesla’s Model 3 has already received several hundred thousand pre-orders, which indicate a very strong interest in this EV, but most vehicles won’t be delivered until 2018 or 2019.

Government incentives continue to prop up PEV sales. Currently, federal incentives provide up to $7,500 for PEV purchases, depending on the battery size and the number of vehicles sold. As battery size decreases and/or after PEV sales exceed 200,000 the federal tax credit will begin to phase out. As previously stated the reduction for GM and Tesla may begin in 2019-2020 time frame. This approach tends to incentivize early adoption that will cause more PEV purchases and enable car manufacturers to achieve high production volumes sooner. Several states also have EV purchase incentives, with tax credits up to $7,500, although most are between $1,000 and $2,000 [8].

Although EV purchase prices have declined substantially in the past few years, one drawback of the rapid decline in original purchase price is the low resale values of used PEVs. Since PEVs continue to roll out with longer ranges at lower prices, the earlier generations are not as desirable on the used market, so the re-sale prices drop. A report in August 2016 stated that a 5-year old Nissan Leaf was selling at 11% of its original price [9]. As PEV models stabilize and battery manufacturing technology matures, new vehicle purchase prices are likely to level off, stabilizing the used PEV market. At that point, more PEVs may be purchased by fleet owners, since there will be greater confidence in the ability to recover some initial costs through used vehicle sales.

Charging station installations have increased substantially over the past several years, which is a result of government incentives and market opportunities. Again, as previously stated there are now 15,948 charging stations giving 42,611 charging outlets. Government grants, such as the ARRA, allowed installation of both public and private charging stations. Several companies (EVGo, ChargePoint, others) have identified opportunities in the public charging market, although the economics of owning and operating a public charging station are challenging. One factor that reduces the economics of public charging from an operator point of view is the low utilization. Profiting from public charging requires maximizing the number of transactions, and studies have shown that public charging utilization is low [10]. This may be due to high availability of residential charging, battery range, or insufficient public charging stations.

In the case of home charging events, data has shown that over 80% of all charging occurs at home, but this will depend on the size of the battery. Smaller batteries, like the Chevy Volt, will have a higher likelihood of public charging than larger batteries, like the Nissan Leaf because as EV electric range increases, the number of public charging events is likely to go down. There is also a balance that must be achieved between the number of charging stations and the number of EVs that those stations serve. At low levels of EV ownership, there are relatively few vehicles that require charging at all, and an even smaller fraction of those that need public charging. Clearly, for a large deployment of EV stations that serves a small population of EVs, the utilization factor will be low. At this point in time, there may be more stations than are actually needed to serve the EV population, and public station utilizations will be low. As EV ownership increases, it’s expected that station utilization will increase.

The correlation between public charging station infrastructure and PEV acceptance is not well understood. An analysis of charging station installation data from DOE’s Alternative Fuel Data Center, shows that the number of actual “plugs” (i.e. charging ports) available for PEV charging increased at a rate similar to PEV sales (see Figure 3). Data is reported as “plugs” since some charging stations house multiple charging ports, and does not consider residential charging stations. However, the ratio of EVs to number of plugs is fairly high, suggesting very limited access to charging infrastructure (see Figure 4). This analysis indicates that only a single plug is available for every 11-12 EVs nationwide. When considering the number of PEVs purchased and new plugs installed, it can be seen that the number of new PEVs is considerably higher than the number of plugs being installed.

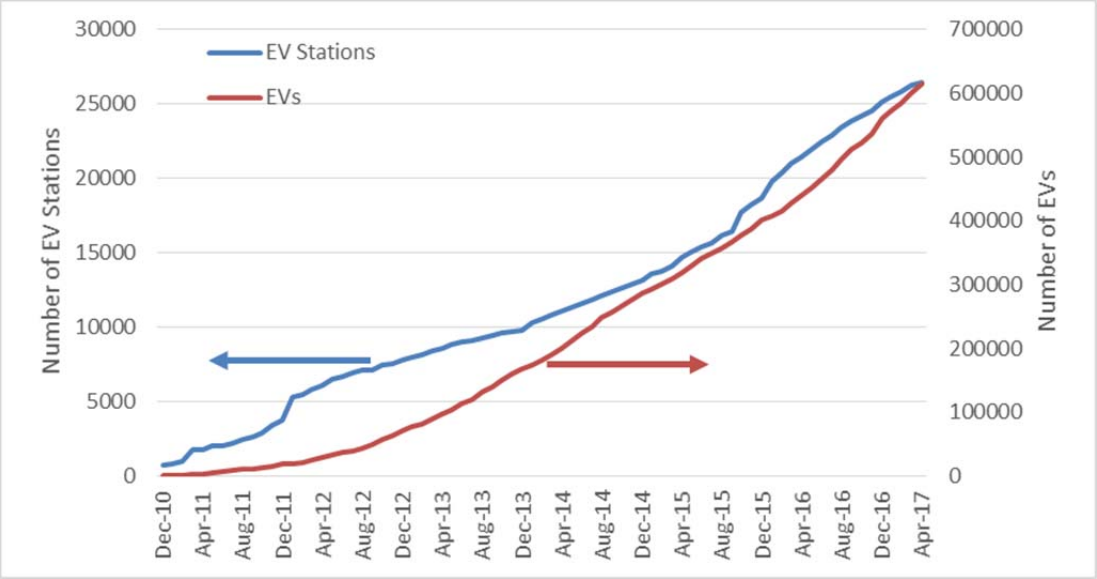

Figure 3. Cumulative PEV stations installed and PEVs purchased since December 2010. Data from Alternative Fuels Data Center and Hybridcars.com.

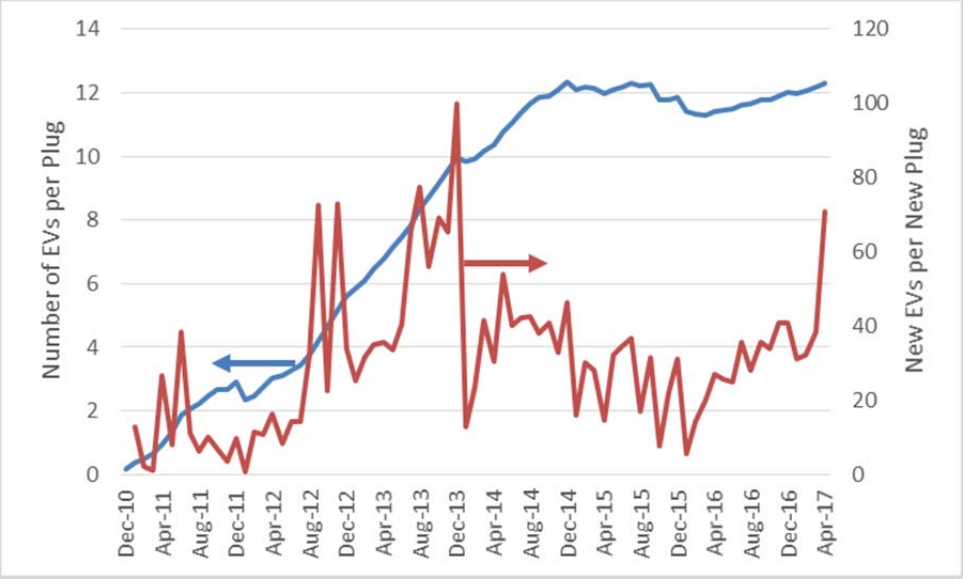

Figure 4. Relationship between PEVs and "plugs"

If PEV recharging were dependent entirely upon public charging infrastructure, this high ratio would significantly decrease the ability of PEVs to recharge, and the sale of PEVs would likely suffer. However, the high volume of PEV sales versus the low volume of infrastructure installation indicates that public charging is not a major concern for PEV purchases. The EV Project reported that over 80% of all recharging events occurred at home, and over 95% of all charging could be met with residential and workplace charging [10]. As more individuals purchase PEVs, there will be a larger fraction that do not have residential or work charging options, which will cause an increase in public charging events.

Identifying the optimal amount of public charging stations has been problematic, and may be further complicated as longer range PEVs become available. With the ability to travel further between charges, the likelihood of charging at home increases. This was observed with The EV Project when comparing at-home charging events between Nissan Leafs (80 mile range) and Chevy Volts (40 mile range) [10]. In the case where charging stations were available at both home and work, the Leaf charged at home more frequently than the Volt, due to the ability to make the round trip on a single charge. As PEV range increases, the ability to meet daily travel needs on a single charge will increase, shifting more charging events to the home.

10. Concluding Remarks

Predicted values of world and U.S. PEV yearly sales and cumulative sales have been presented based on 2016 data. The sales values for 2016 show that China leads in yearly sales at 316,800 (53% increase for 2016) following in second place by Western Europe at 209,300 vehicles sold. The U.S. is third at 159,600 vehicles. These three regions comprise 91% of the global sales market. The world total of EV sales is now estimated to be over 756,000 up from 566,000 last year. The data also shows that the world growth is 34% and that China is moving to dominate the market.

Within the U.S., the PEV sales results for 2016 show that 159,600 vehicles were sold giving a 40% yearly increase in sales. On a state basis, California is the largest market with about 48% of the sales for 2016. The total cumulative number of PEVs sold in the U.S. over the seven year lifetime is now at more than 560,000 vehicles. Using a sale figure of 5% will give the U.S. in ten years a sales of 260,000 PEVs per year with cumulative number of vehicles on the road at 2.7 million.

The work also evaluated the types of barriers to PEV usage and the actions, incentives and research to overcome the barriers. The major barriers are related to cost, resale, infrastructure and range. Costs of electric vehicles have declined significantly over the past few years as a result of significant increases in battery manufacturing capacities, for both stationary and vehicle applications. As battery manufacturing output continues to increase, it is expected that costs will decrease, leading to further reductions in PEV prices. However, studies have shown that the rapid decline in original purchase price is causing low resale values of used PEVs. Since PEVs continue to roll out with longer ranges at lower prices, the earlier generations are not as desirable on the used market, so the re-sale prices drop.

The number of charging station installations have shown a substantial increase over the past several years due to government incentives and market opportunities. Government grants, such as the ARRA, allowed installation of both public and private charging stations. Several private companies have identified opportunities in the public charging market, although the economics of owning and operating a public charging station are challenging. Overcoming these charging barriers is discussed.

11. References

1. US Department of Energy, Office of Energy Efficiency & Renewable Energy, "China has the Highest Number of Sales of Plug-in Vehicles in the World," May 8, 2017.
2. EV Volumes: Global Plug-in Sales for 2016.
3. US Department of Energy, Office of Energy Efficiency & Renewable Energy, "Charging on the Road."
4. LA Times, Associated Press, "2016 U.S. auto sales set a new record high, led by SUV's," January 2017.
5. California New Car Dealers Association, California Auto Outlook, May 2017;
6. S. Trochaniak, EV Industry, reposted on Fleetcarma, "Electric Vehicle Sales in the United States: 2016 Final Update," January 19, 2017.
7. S. Lacey, "Stem CTO: Lithium-Ion Battery Prices Fell 70% in the Last 18 Months, " June 28, 2016, Accessed March 15, 2017
8. Plug In America, "State & Federal Incentives," Accessed March 15, 2017
9. B. Halvorson, "Tesla Aside, Resale Values for Electric Cars Are Still Tanking," August 10, 2016, Accessed March 15, 2017
10. US Department of Energy. "Plugged In: How Americans Charge Their Electric Vehicles". Idaho National Laboratory, October 2015.