Long-Term Electric Report for Maryland (LTER)
Plug-In Electric Vehicles White Paper

November 30, 2010

Plug-in Electric Vehicle Input Assumptions – Reference Case

Plug-in Electric Vehicle technology:
Current technology allows Plug-in Electric Vehicles ("PEVs") to achieve 4 miles/kWh. This is expected to rise to 5 miles/kWh in the near future. The Long Term Electricity Report ("LTER") assumes PEVs will be able to drive 4-5 miles/kWh and have a 10 year effective life.

Plug-in Electric Vehicle usage:
Transportation statistics indicate that 90 percent of vehicle trips are less than 30 miles. The LTER assumes the average distance driven per day is 30 miles. Taking into account the technology assumptions, the required charge per day is 7 kWh.

Plug-in Electric Vehicle charging:
The Department of Energy has classified charging technology according to voltage level and electricity type (AC and DC). The LTER assumes charging infrastructure will consist primarily of Level 2 AC home chargers, which can provide a continuous maximum charge of 7.68 kW. The LTER assumes that utilities have installed smart grid devices to be able to manage PEV charging and spread the load evenly over charging hours. However, it is expected that some on-peak PEV charging will be required. Therefore, the LTER assumes 90 percent of PEVs are charged during off-peak hours and 10 percent during on-peak hours.

Plug-in Electric Vehicle penetration:
The penetration rate assumptions used to develop the LTER forecast were derived from work conducted by the Pacific Northwest National Laboratory. PEV market penetration reaches 5.4 percent of new vehicle sales by 2020 and 23 percent by 2030.

Introduction

Over the next 20 years, the study period for the LTER, it is expected that increasing electrification of the transportation sector in the form of plug-in electric vehicles will have a significant effect on the operation of the electric system. Battery Electric Vehicles ("BEVs") have a battery that can be recharged through an external connection to an electricity source and runs only on the batteries. A Plug-in Hybrid Electric Vehicle ("PHEV") has an internal combustion engine that can take over when the battery runs down. PHEVs have larger batteries than traditional hybrid vehicles, allowing them to be operated in all-electric driving mode for shorter distances, while the internal combustion engine effectively provides for an unlimited driving range. This versatility is especially appealing to consumers concerned about the range limitations of all-electric vehicles, making consumer adoption of PHEVs in significant numbers more likely. Additionally, once 'range anxiety,' as it has been termed, is no longer an issue due to the combustion engine back-up, consumers will not need to worry about charging their vehicles while away from home. Regardless of whether a consumer owns a BEV with a larger battery or a PHEV with a smaller battery, driving habits are expected to remain unchanged. As noted later in this section, the majority of daily vehicle trips are less than 30 miles, a distance within the range of both BEV and PHEV batteries. From an electrical standpoint, BEVs and PHEVs are equivalent and will require the same amount of electricity to recharge under normal daily driving. Additionally, BEV sales are expected to make up only a very small (1 to 2 percent) of total electric vehicle sales out to 2030.[1] Therefore, this white paper does not attempt to develop separate penetrations for PHEVs and BEVs. The issues discussed apply to both and they are collectively referred to as PEVs.

The technology, procedures, and regulations regarding PEVs are still in development and any forecast made through 2030 will be by nature speculative. Issues to be addressed in the coming decades include battery power and life as well as when, how, and where PEVs will be charged. Significant research and development are being conducted on advancing electric vehicle technologies. The American Recovery and Reinvestment Act ("ARRA") provided over $2.8 billion in grants for advanced vehicle technology and demonstration programs administered by the DOE's Vehicle Technologies Program and the Obama Administration set a target to have one million PEVs on the road in the U.S. within five years.

For the purposes of this paper, an estimate was developed based on the current thinking on PEV penetration and usage. The PEV market penetration scenarios presented below are based on work done by the Pacific Northwest National Laboratory ("PNNL")[2] and vehicle registration rates are developed from the National Automobile Dealers Association ("NADA")[3] and the Bureau of Transport Statistics ("BTS")[4] data.

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[1] J.D. Power and Associates, *Drive Green 2020: More Hope than Reality?*, The McGraw-Hill Companies, November 2010.

[2] Balducci, P.J., *Plug-in Hybrid Electric Vehicles Market Penetration Scenarios*, DOE Pacific Northwest National Laboratory, September 2008.

[3] NADA DATA, *State of the Industry Report 2010*, National Automobile Dealers Association, NADA Services Corp., 2010.

[4] Bureau of Transportation Statistics, *National Transportation Statistics 2010*, U.S. Department of Transportation, accessed October 13, 2010. http://www.bts.gov/publications/national_transportation_statistics/

PEV Market Penetration

Market penetration rates refer to the proportion of the new unit market that will be represented by PEVs. For example, if 100 new vehicles are sold in one year and 20 new vehicles are PEVs, then PEVs would have a 20 percent market penetration rate. New vehicles become a part of the entire national vehicle fleet. Saturation refers to the percentage of PEVs that make up the total vehicle fleet, e.g., a 1 percent saturation would indicate that 1 out or every 100 vehicles on the road would be a PEV. Though PEVs achieve a significant market penetration share, the entire vehicle fleet turns over relatively slowly and, therefore, the saturation rate is much lower and PEVs are still a relatively small portion of the total number of vehicles on the road. The report by PNNL cited above created three penetration rate scenarios representing high, medium, and low market penetration rates. The study was based on input received from technical experts and industry representatives and from reviewing previous work on the topic. For the LTER, these penetration scenarios have been adapted to create base, low, and high case PEV penetration and saturation scenarios out to 2030. The assumptions used in the scenarios are outlined in Table 1.

Table 1
PNNL PEV Market Rate Penetration Scenarios[a]

Scenario	Assumptions
Low Case	PEV forecast built off existing market forecasts of hybrid technology according to a 2004 report from the Oak Ridge National Laboratory.[b] PEV technology adoption is assumed to be the result of lessons learned through the advancements made in hybrid technology. The forecast is based on the historical mix of vehicle types in the U.S. fleet. The scenario does not attempt to capture how consumer preferences will change and assumes there will be no new policies or tax incentives for PEVs. The ultimate PEV share of the hybrid market is based on the penetration definition developed by the Electric Power Research Institute and the Natural Resources Defense Council.[c]
Base Case	Delphi approach asking domain experts for their best judgment given the following conditions:[d] • $4,000 marginal cost of PEV technology over existing hybrid technology; • 40 mile all electric range; • 100 miles per gallon equivalent (20 kWh at 5 miles/kWh); and, • PEV batteries meet industry standards regarding economic life and safety.
High Case	The adoption of PEVs in marketplace is only constrained by automotive and battery manufacturers' ability to keep up with surging consumer demand for PEVs. Existing idle off-peak capacity of electric infrastructure is able to meet the demand placed on it up to a 73% PEV share of the light-duty vehicle fleet in the U.S.

[a] In the PNNL study the scenarios are called Hybrid Technology-Based Assessment (low case), R&D Goals Achieved (base case), and Supply Constrained (high case).

[b] Green et al. (2004): Greene et al., *Future Potential of Hybrid and Diesel Powertrains in the U.S. Light-Duty Vehicle Market,* Oak Ridge National Laboratory, 2004.

[c] EPRI and NRDC (2007): Electric Power Research Institute and Natural Resources Defense Council, Environmental Assessment of Plug-in Hybrid Electric Vehicles – Volume 1: Nationwide Greenhouse Gas Emissions, 2007.

[d] The Delphi method is a systematic, interactive forecasting method which relies on a panel of experts that answer questionnaires in two or more rounds. After each round, a facilitator provides an anonymous summary of the experts' forecasts from the previous round as well as the reasons they provided for their judgments. The process is stopped after a pre-defined stop criterion (e.g., number of rounds, achievement of consensus, stability of results) and the mean or median scores of the final rounds determine the final results.

Source: Balducci, P.J., *Plug-in Hybrid Electric Vehicles Market Penetration Scenarios*, PNNL, September 2008.

As noted in the PNNL penetration study, traditional technology adoption rates in the transportation sector exhibit an S-shaped curve with slow uptake from 0 percent to 10 percent, then acceleration to 90 percent, and a leveling off afterward. This leads to a forecast of the percentage of new vehicle sales that would go to PEVs out to 2030. Table 2 shows the penetration rates for 2020 and 2030.

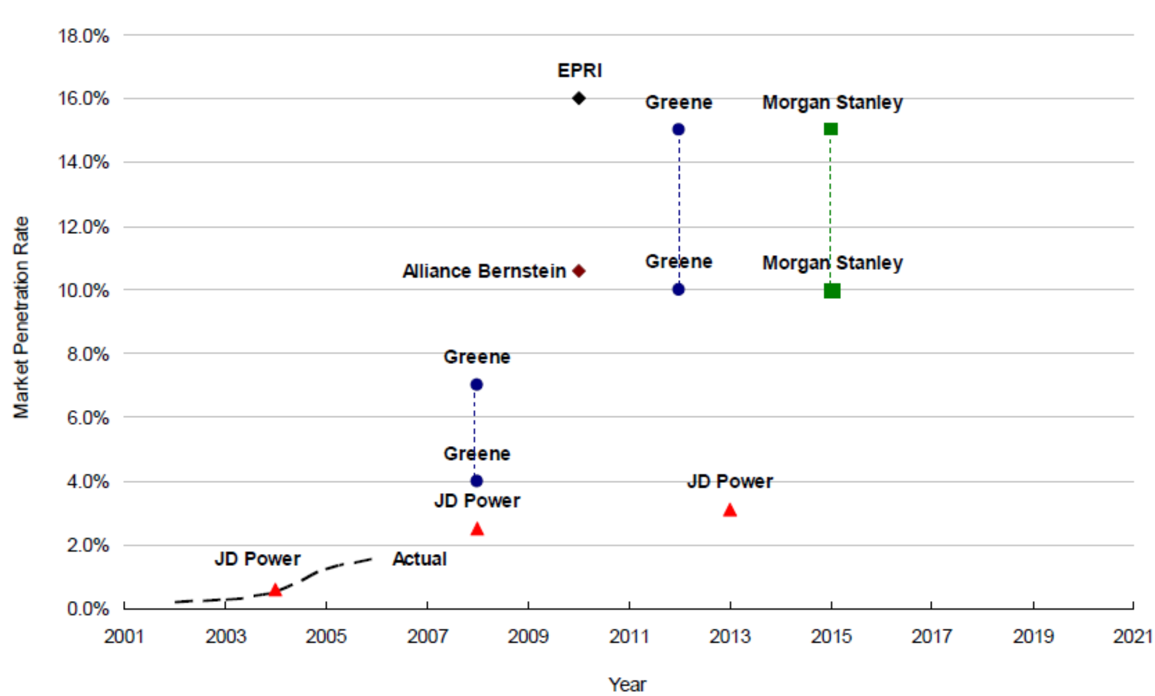
Table 2
Percent of New Vehicles Sales

Scenario	**2020 Market Penetration**	**2030 Market Penetration**
Low Case	5.9%	11.8%
Base Case	5.4%	23.0%
High Case	15.0%	58.0%

Source: Balducci, P.J., *Plug-in Hybrid Electric Vehicles Market Penetration Scenarios*, PNNL, September 2008.

For comparison purposes the PNNL report also examined several previous reports on market penetration. These reports contained a wide variety of assumptions and penetration rate scenarios looking forward to 2015. Figure 1 outlines the penetration rate scenarios from these other studies.

Figure 1
Various PEV Market Penetration Studies Examined by PNNL



Source: Balducci, P.J., *Plug-in Hybrid Electric Vehicles Market Penetration Scenarios*, DOE Pacific Northwest National Laboratory, September 2008.

Studies used in graphic:

Alliance Bernstein, *The Emergence of Hybrid Vehicles: Ending Oil's Stranglehold on Transportation and the Economy,* 2006.

Greene et al., *Future Potential of Hybrid and Diesel Powertrains in the U.S. Light-Duty Vehicle Market*, Oak Ridge National Laboratory, 2004 (also source of JD Power forecast).

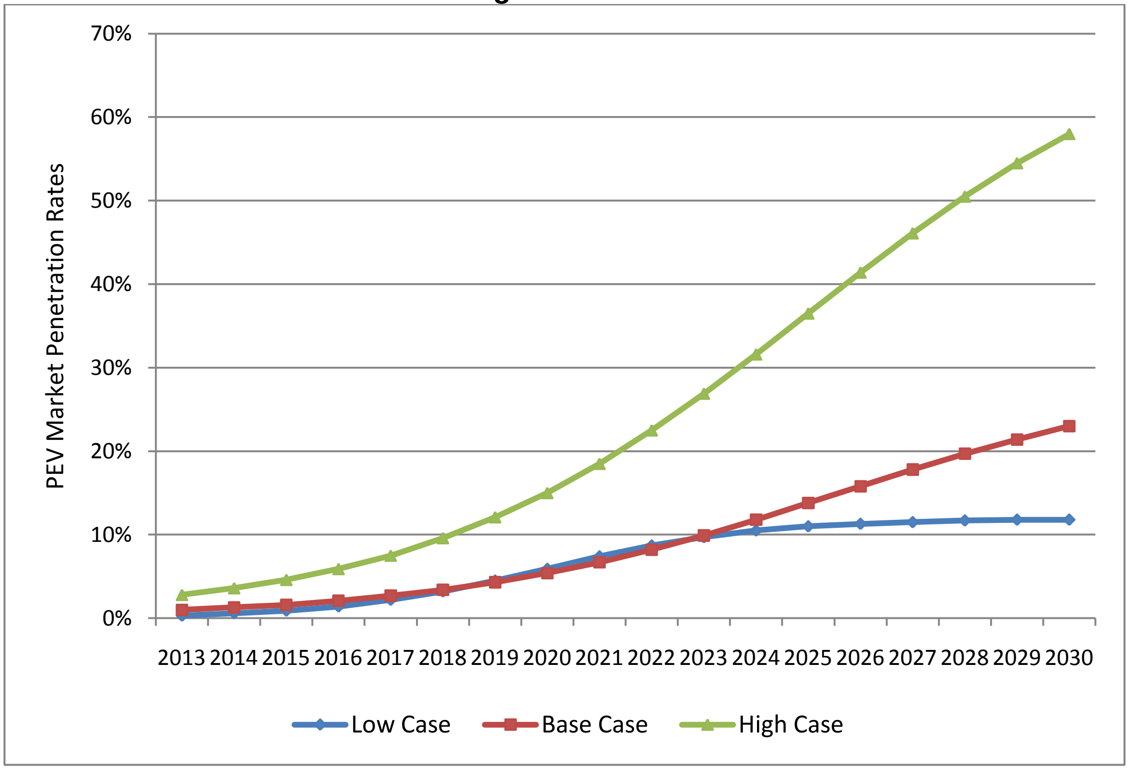
Morgan Stanley, *Plug-in Hybrids: The Next Automotive Revolution*, 2008.

Electric Power Research Institute and Natural Resources Defense Council, *Environmental Assessment of Plug-in Hybrid Electric Vehicles – Volume 1: Nationwide Greenhouse Gas Emissions*, 2007.

The wide range of forecasts in the studies outlined in Figure 1 demonstrate the uncertainty involved in attempting to estimate future PEV penetration rates. The forecasts in these studies only go to 2015, and even in that short timeframe there is very little agreement on how quickly (or slowly) consumers will adopt this technology.

The market penetration curves showing the percentage of new vehicle sales going to PEVs for each scenario are shown in Figure 2.

Figure 2
PEV Percentage of New Vehicle Sales

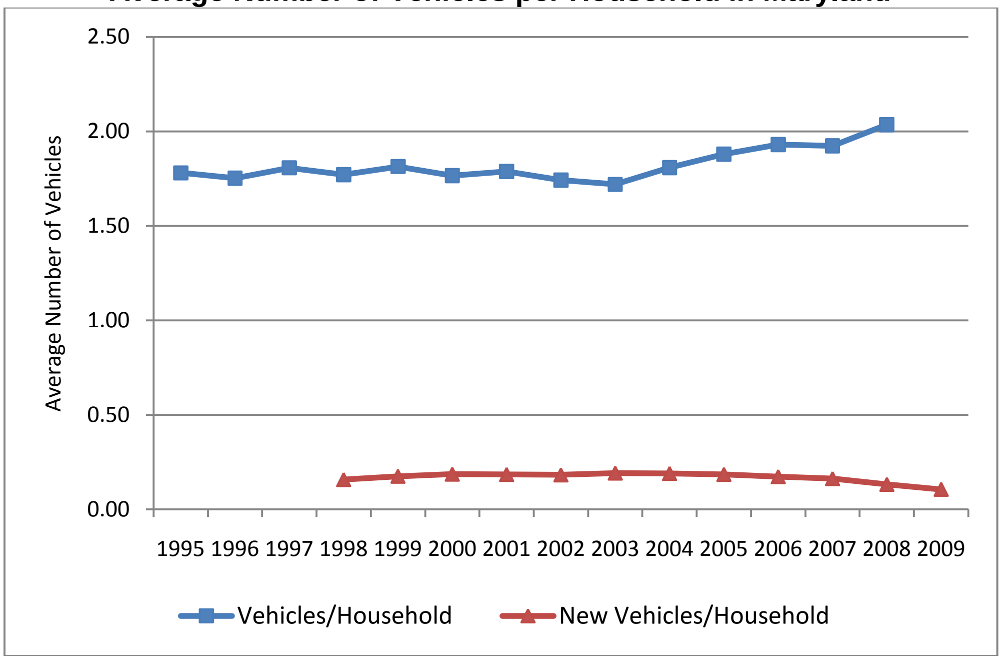


PEVs in Maryland

To estimate the total number of PEVs in Maryland over the 2010 through 2030 study period, several different sources of historical vehicle data were used. Maryland new vehicles sales data was obtained from the Maryland Motor Vehicle Administration for the years 1998 to 2010. The NADA reports new vehicle sales data at the state level and PJM region new vehicle figures were derived from the NADA figures. Total annual vehicle registrations for the years 1995 to 2008 in Maryland were obtained from the Federal Highway Administration. The number of household units in Maryland was from the U.S. Census Bureau estimates. Figure 3 outlines the average number of vehicles per household and the average number of new vehicles sold per household in

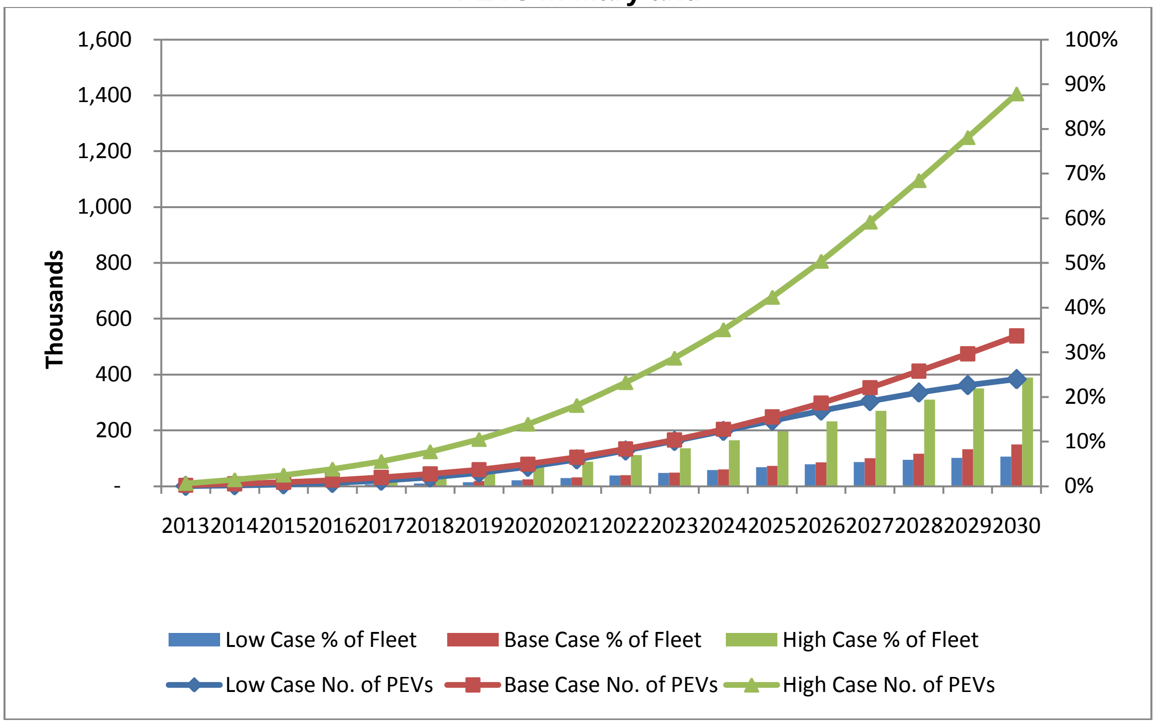
Maryland. While the total vehicle fleet has been increasing along with population growth, new vehicle sales have been declining since 2004.

Figure 3
Average Number of Vehicles per Household in Maryland



U.S. vehicle registrations are reported by the Bureau of Transport Statistics ("BTS") and the data go back to 1990. According to the national data, new vehicle registrations in the U.S. have also been relatively flat (or falling) over the last decade. Given the current economic climate, new vehicle registrations can be expected to remain flat, therefore average new vehicle sales over the 1998 through 2010 period were used as a proxy for future sales, that is, Maryland new vehicle registrations are held constant over the study period. Historical new vehicle sales data suggest households are keeping older vehicles longer. Survey data from BTS found that vehicles 10 years old and older made up 37 percent of the household vehicle fleet in 2008. Testing on PEVs at the Southern California Edison, Electric Vehicle Technical Center indicates that PEVs can easily be driven for 100,000 plus miles. Therefore, this study assumes a 10-year life per vehicle, which is a generally accepted industry estimate. Applying the market penetration scenarios to the forecast of new vehicle registrations yields the curves outlining the number of PEVs on the road in Maryland each year and vehicle fleet saturation rates shown in Figure 4.

Figure 4
PEVs in Maryland



The penetration curves provide estimates for the number of PEVs on the road in Maryland in 2020 and 2030 under alternative scenarios (see Table 3).

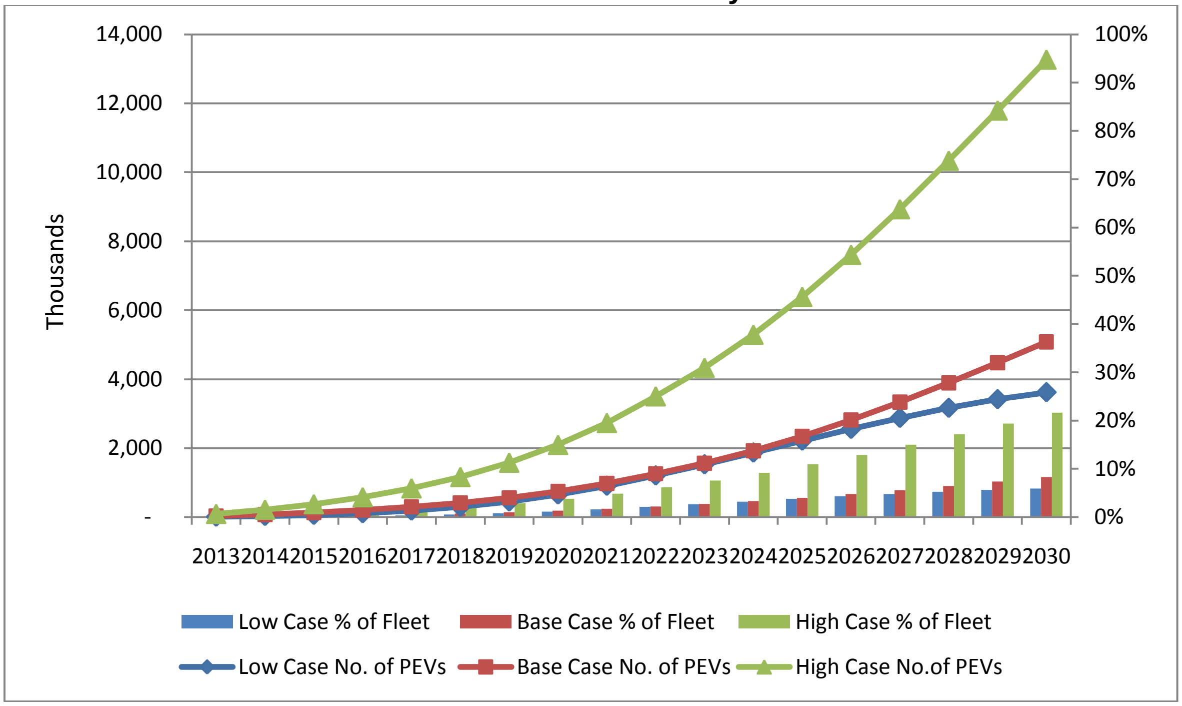
Table 3
PEVs in Maryland

		Low Case	Base Case	High Case
2020	No. of PHEVs	69,114	79,299	222,256
	Percent of Fleet	1.3%	1.5%	4.3%
2030	No. of PHEVs	383,400	538,724	1,405,921
	Percent of Fleet	6.6%	9.3%	24.4%

PEVs in PJM

Following the same process as for the Maryland PEV growth yields projected numbers of PEVs in PJM as a whole. The penetration curves and vehicle sales data result in the PEVs-in-PJM numbers and saturation rates for the three cases as outlined in Figure 5.

Figure 5
PEVs in PJM Territory



The projected number of PEVs in PJM as a whole in 2020 and 2030 is outlined in Table 4.

Table 4
Number of PEVs in PJM

		Low Case	Base Case	High Case
2020	No. of PHEVs	652,197	748,310	2,097,328
	Percent of Fleet	1.2%	1.4%	3.8%
2030	No. of PHEVs	3,617,976	5,083,703	13,267,057
	Percent of Fleet	5.9%	8.3%	21.6%

PEV Electricity Demand

The Department of Energy's Office of Energy Efficiency and Renewable Energy ("EERE") has an electric vehicle research program that has been field testing vehicles. EERE has identified four charging infrastructure terms based on voltage levels:

- Level 1 – 110 / 120 VAC, 15 amp (12 amp continuous). Can provide a continuous maximum charge at 1.44 kW. This will be an onboard vehicle charger.
- Level 2 – greater than Level 1, with 208-240 VAC and up to 40 amp (32 amp continuous). Can provide a maximum of 9.6 kW with a continuous maximum of 7.68 kW. This can be either an onboard or off-board charger.
- Level 3 – greater than Level 2, generally an off-board charger supporting more than one vehicle. Energy to vehicle can be 440 VDC or higher.
- Fast Charge – returns 50% of a battery's capacity in under 30 minutes. This is generally an off-board charger for large batteries, usually at Level 3 voltage.

As discussed earlier, the majority of PEVs will likely be charged at home using the existing AC infrastructure. The EERE research indicates the average energy used per charging event ranges from 2.8 to 3.5 kWh, as the batteries were seldom fully depleted. However, as PEVs are increasingly adopted by commuters a higher usage level can be assumed. EERE transportation data indicates that more than 90 percent of vehicle trips are less than 30 miles. PEV's achieve approximately 4 to 5 miles/kWh. Therefore a reasonable estimate of daily charging requirements would be 7 kWh per vehicle. Charging a vehicle given these assumptions would take approximately five to six hours with a Level 1 charger, while only about one to two hours with the Level 2 charger, depending on the size of the on-board vehicle charging equipment. Therefore it is reasonable to assume that the majority of PEV buyers will opt to install the Level 2 charger. In PJM, the on-peak hours are 8am to 11pm weekdays, not including holidays. Current charger technology already allows the unit to interface with a smart meter and provide two-way communication and control with the local utility. As Maryland utilities are in the process of installing an advanced metering infrastructure in the State this study assumes that utilities will be able to implement managed PEV charging. Therefore, the study assumes that 90 percent of vehicles will be manage charged during the off-peak hours utilizing existing currently idle electric capacity. The series of figures below outline the weekday on-peak and off-peak energy usage for Maryland and for PJM through 2030.

Figure 6
Total Daily On-Peak Energy Required by PEVs in Maryland

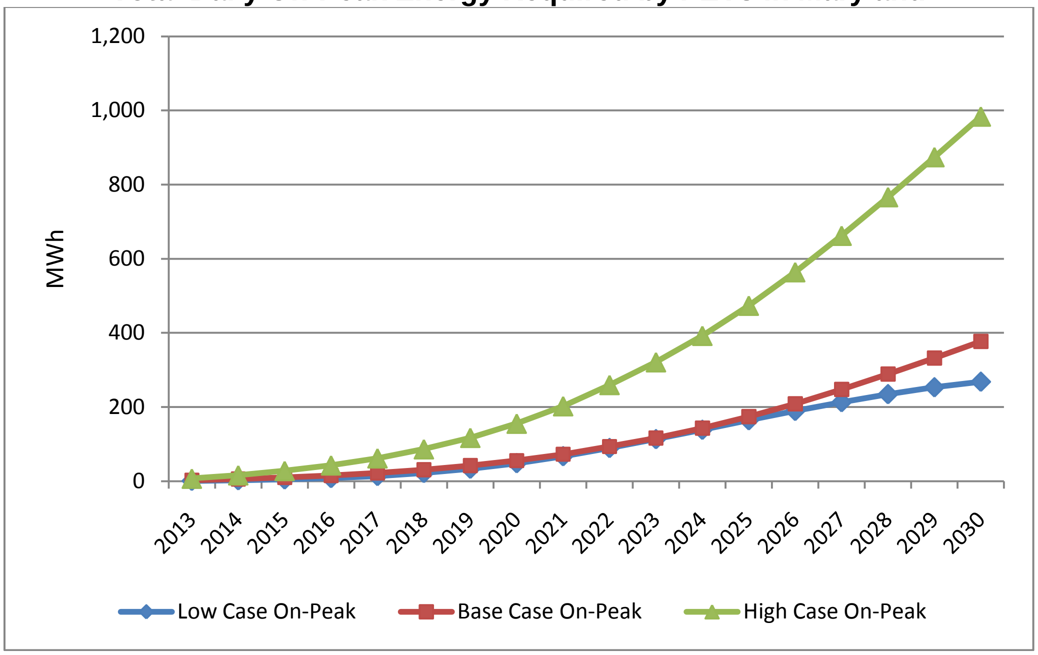


Figure 7
Total Daily Off-Peak Energy Required by PEVs in Maryland

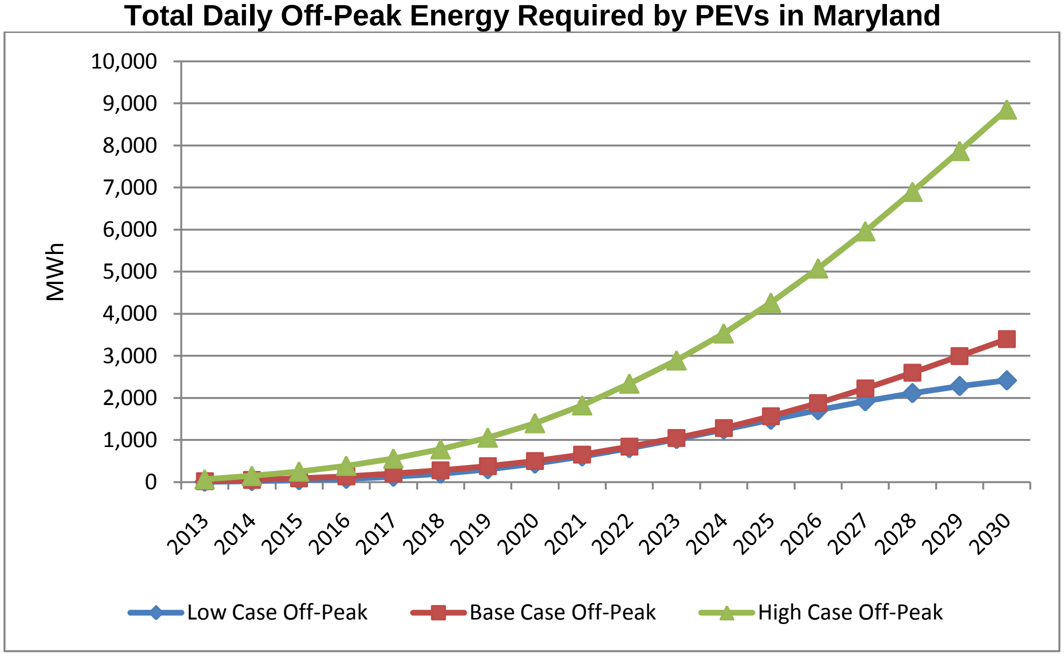


Figure 8
Total Daily On-Peak Energy Required by PEVs in PJM

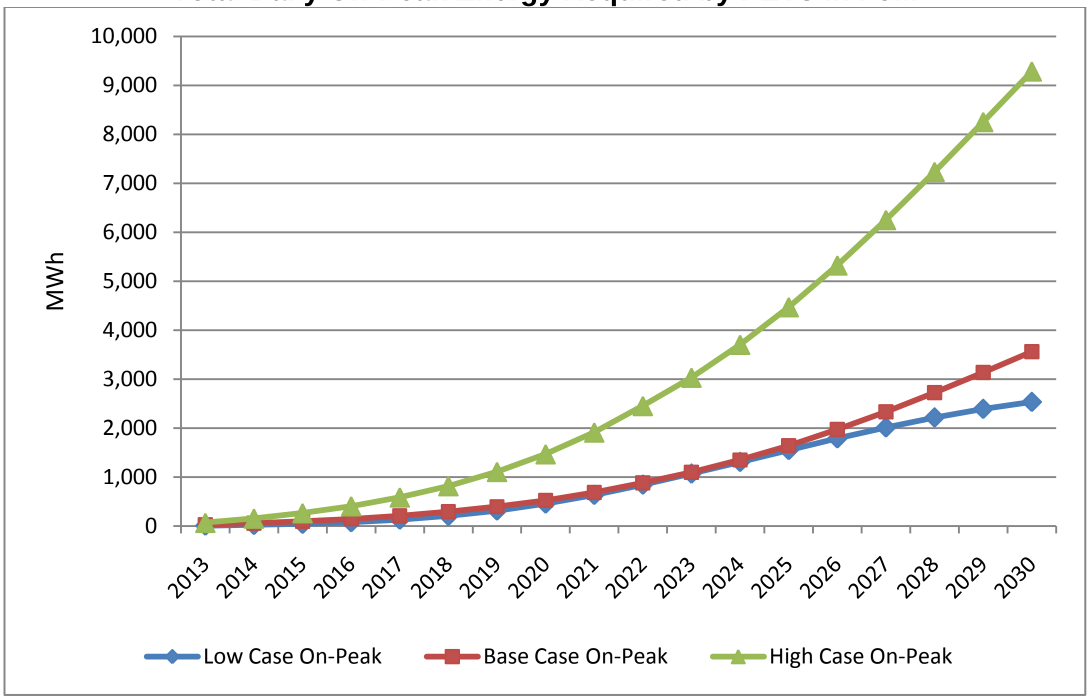
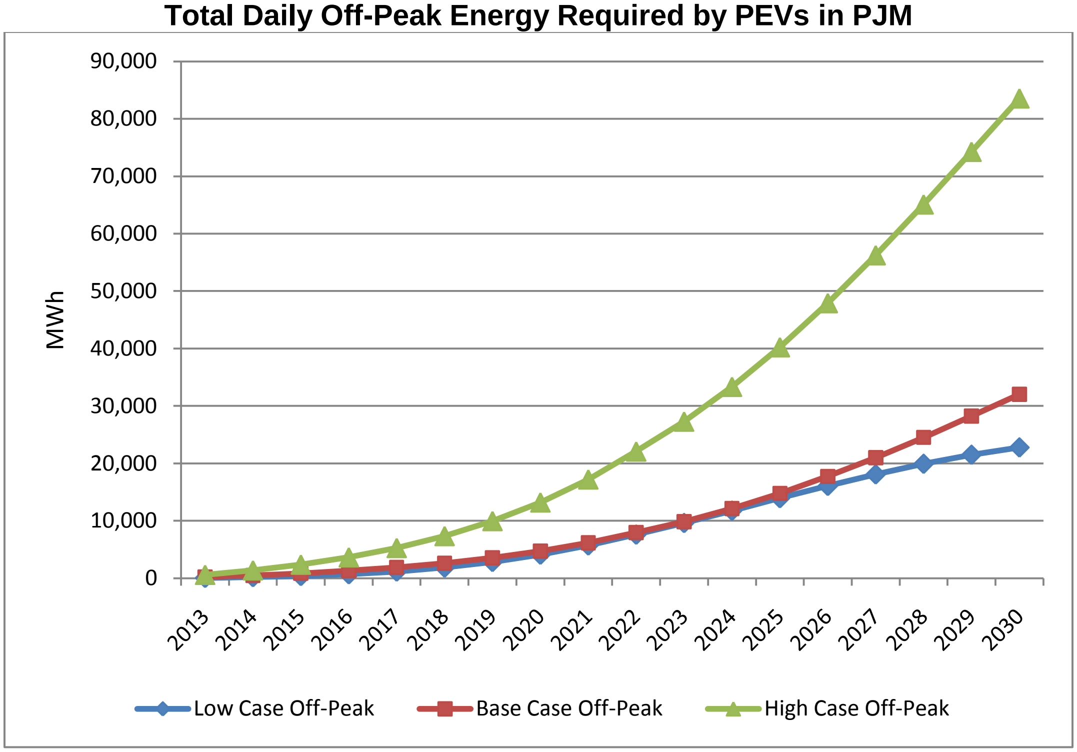


Figure 9
Total Daily Off-Peak Energy Required by PEVs in PJM



The total daily energy usage represented by the estimated number of PEVs is outlined in Table 5 for the years 2020 and 2030.

Table 5
Total Daily PEV Energy Use in Maryland and PJM

			Low Case (MWh)	Base Case (MWh)	High Case (MWh)
2020	Maryland	Total On-Peak	48	56	156
		Total Off-Peak	435	500	1,400
	PJM	Total On-Peak	457	524	1,468
		Total Off-Peak	4,109	4,714	13,213
2030	Maryland	Total On-Peak	268	377	984
		Total Off-Peak	2,415	3,394	8,857
	PJM	Total On-Peak	2,533	3,559	9,287
		Total Off-Peak	22,793	32,027	83,582

A total daily charge requirement of 7kWh and managed on- and off-peak charging (which spreads the total load evenly over the on- and off-peak hours) yields the weekday hourly demand curves in shown in the Figures 10 through 13.

Figure 10
On-Peak Hourly Demand from PEVs in Maryland

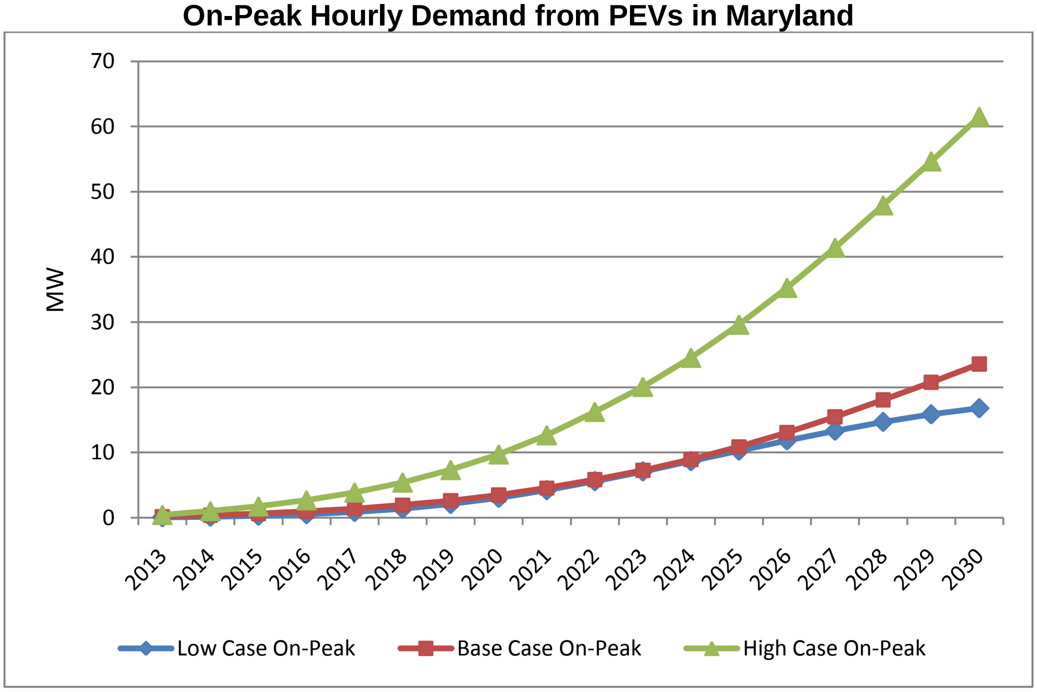


Figure 11
Off-Peak Hourly Demand from PEVs in Maryland

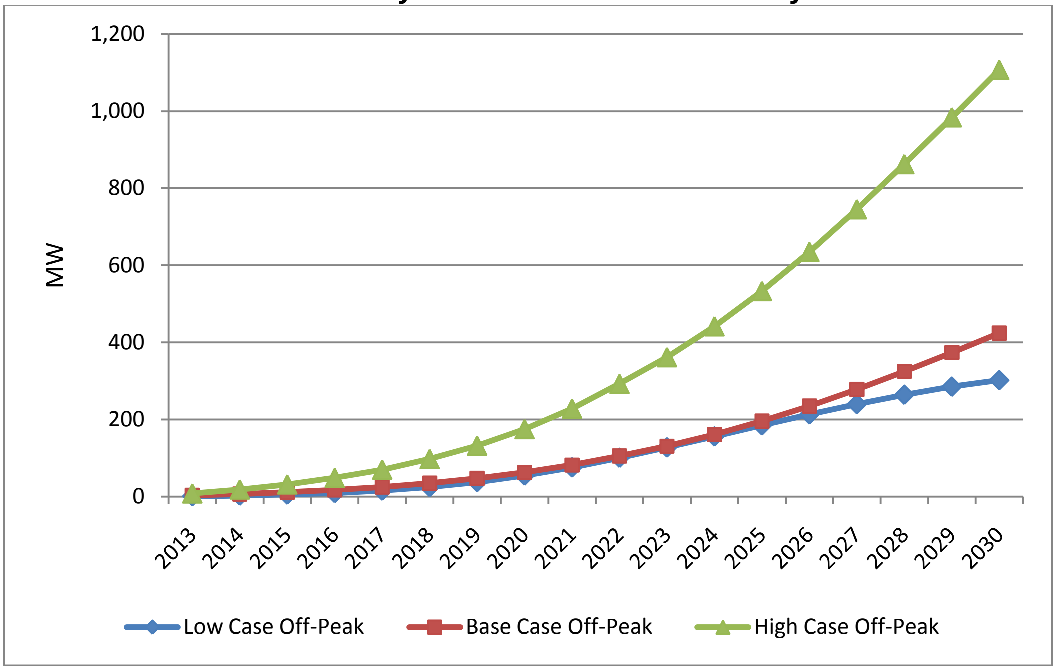


Figure 12
On-Peak Hourly Demand from PEVs in PJM

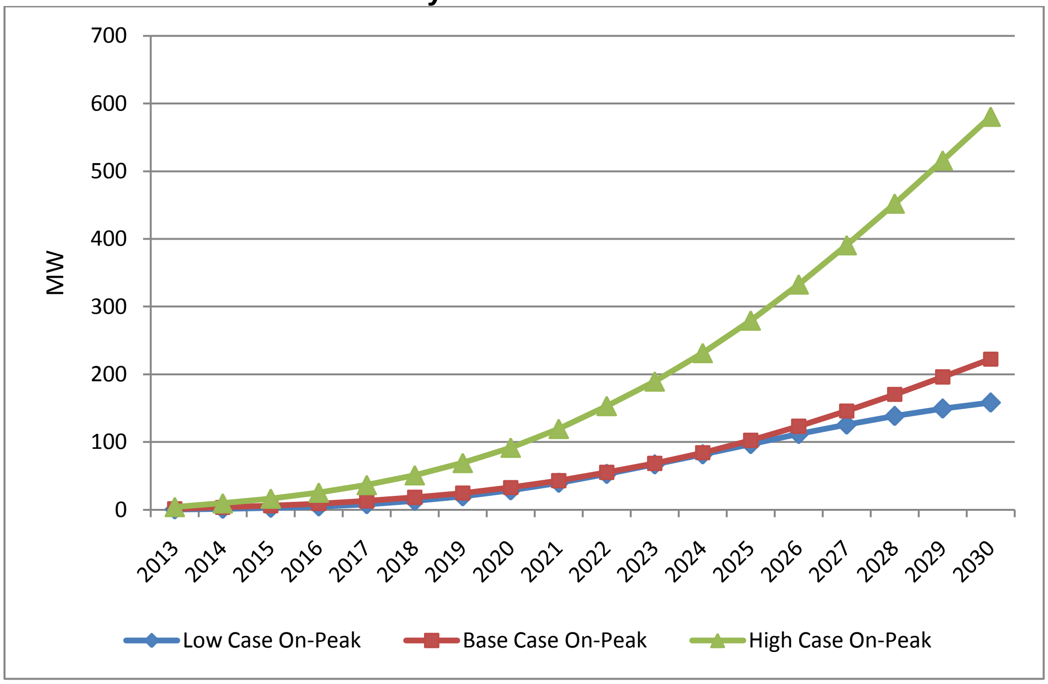
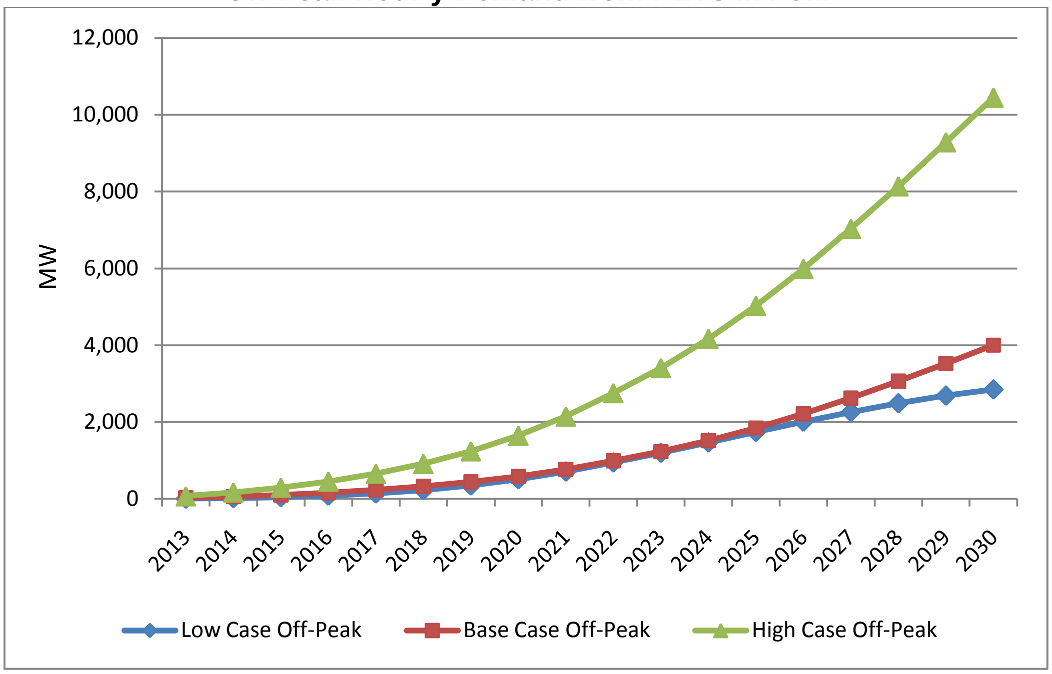


Figure 13
Off-Peak Hourly Demand from PEVs in PJM



The total weekday hourly demand represented by the estimated number of PEVs is outlined in Table 6 for the years 2020 and 2030.

Table 6
Total Weekday Hourly Demand from PEVs in Maryland and PJM

			Low Case (MW)	Base Case (MW)	High Case (MW)
2020	Maryland	Total On-Peak	3.0	3.5	9.7
		Total Off-Peak	54	63	175
	PJM	Total On-Peak	29	33	92
		Total Off-Peak	514	589	1,652
2030	Maryland	Total On-Peak	16.8	23.6	61.5
		Total Off-Peak	302	424	1,107
	PJM	Total On-Peak	158	222	580
		Total Off-Peak	2,849	4,003	10,448

Literature Review

To corroborate the penetration rate scenarios a literature review of other studies was conducted.

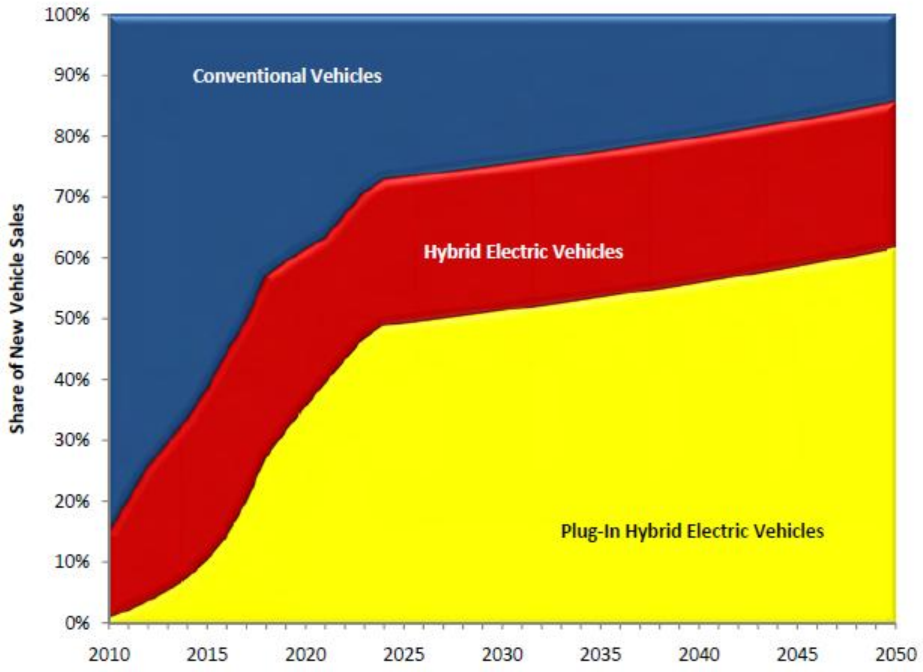
In November 2010, J.D. Powers released a study examining the penetration of hybrid and electric vehicles. The study develops a market penetration forecast out to 2020 for global sales of hybrid electric vehicles (“HEVs”), PHEVs and BEVs. The study projects that by 2020, global passenger-vehicle sales will reach 70.9 million units, of which 5.2 million units (7.3 percent) will feature some type of battery-powered drive train. In the United States, sales of HEVs and PHEVs will achieve a 9.6 percent market share, while BEVs will reach 1.9 percent market penetration. In the LTER base case, PEV market share reaches 5.4 percent in 2020.

A study from the University of Michigan developed an agent-based ‘virtual automotive market place model’ (“VAMMP”) for estimating PHEV penetration into the light duty vehicle fleet. The model predicted a 2-3 percent market penetration by 2015, and 4-5 percent by 2020. As noted above, the LTER base case forecasts PEV market share at 5.4 percent by 2020 in the base case.

An earlier study from PNNL analyzed PHEV loading on NERC regions – Mid-Atlantic Area Council (“MAAC”) contains Maryland – and how many PHEVs could be supported by under-utilized electric generation capacity if the vehicles charged at night. The study used Department of Transportation data to estimate there are approximately 20 million vehicles in the MAAC area. The generation profile for MAAC indicates that the region could support a 10.4 million (52 percent portion) PHEV fleet if the vehicles charged only at night. Estimated charging requirements range from 8.6 kWh to 15.2 kWh. The LTER assumes a daily charging requirement of 7 kWh and assumes the total PEV charging requirement is met through existing regional capacity.

An Electric Power Research Institute (“EPRI”) study examined the greenhouse gas reductions that could be achieved though adoption of PHEVs. EPRI developed scenarios for low, medium, and high PHEV market penetrations. Under the medium market share scenario, PHEVs reach a 62 percent market share by 2050 (see figure). The white paper includes a high scenario such as presented by the EPRI study, where market penetration for PEVs reaches 58 percent by 2030.

EPRI Estimates of PHEV Market Shares



Source: EPRI, Environmental Assessment of Plug-In Hybrid Electric Vehicles, Volume 1: Nationwide Greenhouse Gas Emissions, Electric Power Research Institute and Natural Resources Defense Council, July 2007.

A study from the Oak Ridge National Laboratory examined the impact of PHEV loading on the Southern Electric Reliability Council region. The study used Bureau of Transportation Statistics data on vehicle registrations for the area to create a profile of current PHEV market share then projected that share to 2018. The study estimated PHEV market share would reach 25 percent by 2018. As noted above, the white paper includes a high case where PEV market share reaches 15 percent by 2020.

A study by KEMA for the ISO/RTO Council did an assessment of the potential impacts of PEVs on the various regional grids. The study utilized total U.S. vehicles sales and registration data with data on Toyota Prius sales as the foundation for PEV market adoption forecasts. Projections for units sold in each area were developed out to 2020 under a slow, fast, and target scenarios, where the Obama's Administration's goal of one million PEVs on the road is the target penetration amount. In the target case, the one million PEV target is met by 2017. In the fast case, the one million target is reached by 2015 and by 2020 there are about 2.3 million PEVs on the road in the nation. The report finds that PEV impacts on regional electric grids can be minimized through managed charging. The LTER adopts this assumption.

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