

Pepco Demand Management Pilot for Plug-In Vehicle Charging in Maryland

Jamie Dunckley¹, Barbara Gonzalez², Dan Bowermaster¹

¹*Electric Power Research Institute, 3420 Hillview Ave, Palo Alto, CA 94304, jdunckley@epri.com*

²*Potomac Electric Power Company (Pepco), 701 Ninth Street NW, Washington, DC 20068*

Summary

Here, the results of a Potomac Electric Power Company (Pepco) Demand Management Pilot are presented. While the main objective of the study was to assess the effectiveness of customer participation in demand-response events, the study also aims to address a number of fundamental questions regarding the Plug-in Electric Vehicle adoption. This data set examines 101 customers over a two year period. Preliminary results show that their demand-response program was very effective at reducing PEV load on the grid. With three different rate structures and a variety of different vehicles, Pepco was able to address the questions:

1. How do different rates affect customer charging behaviors? When did these customers charge?
What was their average kwh/day?
2. What are the costs of a TOU rate program for the utility and for PEV customers?
3. How do PEVs affect transformer loading?
4. Do customers like programs like these?

The pilot program found that PEV owners almost exclusively charged off peak times. Transformer analysis found that a TOU rate helped reduce transformer upgrade costs and that shifting the TOU time to 10PM from 8 PM further reduced these costs. PEV owners generally liked the program.

Keywords: charging, PHEV, power management, energy consumption, BEV

1 Introduction: Electric Vehicles Nationwide

Over the past four years, more than 400,000 plug-in vehicles (PEVs) have been sold in the US. This includes both plug-in hybrids (PEHVs) as well as fully-electric battery electric vehicles (BEVs) with a wide range of prices and travel range. Looking ahead, the electric vehicle market is expected to continue to expand and with it the demand for EV charging in a variety of locations: at home, in public, and at work locations. The cumulative EVs sold in U.S. as of November 2015 are shown in Figure 1.

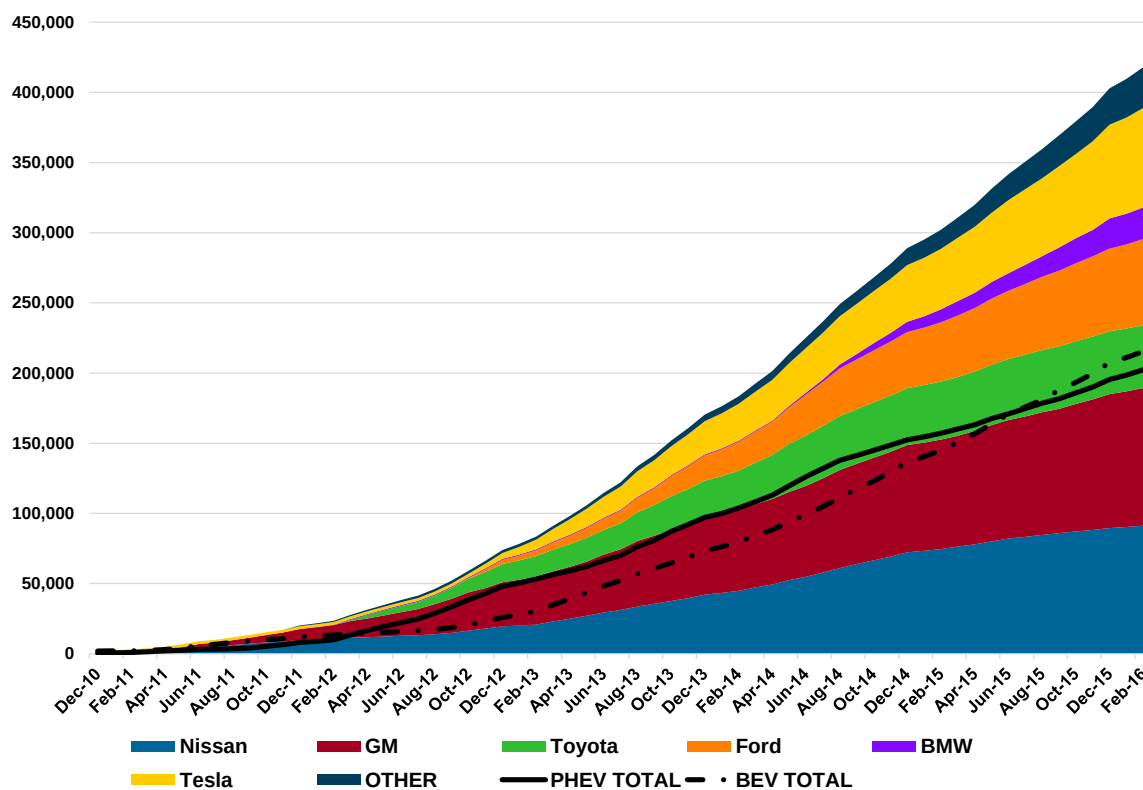


Figure 1: Cumulative plug-in electric vehicle sales for the U.S. through February 2016. PHEV is Plug in Electric Vehicle and EREV is Extended Range Electric Vehicle.

1.1 Pepco Electric Vehicle Sales

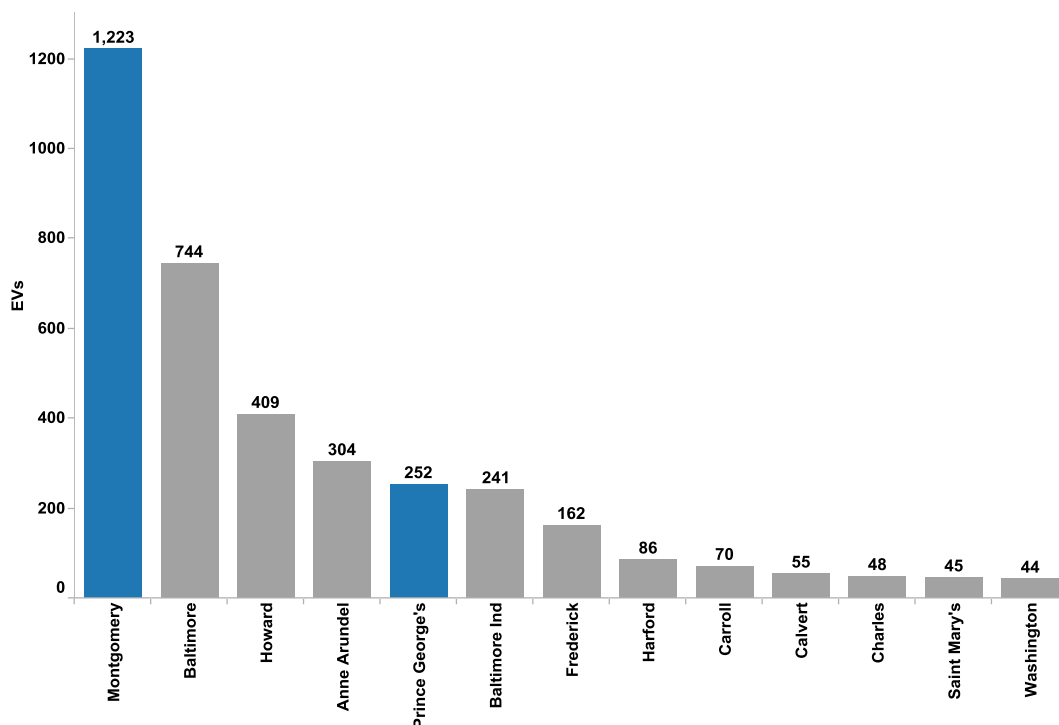


Figure 2: Maryland cumulative sales of EVs from 2010 to September 2015 grouped by county. Only counties with more than 40 vehicle sales are shown. Montgomery and Prince George's counties are highlighted in blue as they are predominantly serviced by Pepco. These numbers were obtained from the Polk sales numbers.

2 Customer Program Information

While there were many more applications for enrollment, the data presented here is a summary of 101 customers who met the criteria over a two year period. The specifics of customer qualifications, rates, meters and enrollment are shown below.

2.1 Customer Qualifications

While there are additional enrolment qualifications in addition to these, the main ones include:

- Customers must have a PEV with an electric range greater than 50 miles
- The Customer's EVSE needs to be located on the customer owned property.
- The Customer's electrical panel must comply with electrical standards and must have capacity for the EVSE's additional electrical load.
- The customer must agree to let Pepco manage the charger and gather charging information for the study.

2.2 Rates, Meter Options and Customer Enrollment

Depending on the customer's EVSE infrastructure prior to program enrollment, there were a number of rates to choose from. For EVSEs, the customer could decide to charge on the house meter, use their existing Level 2 charger or chose to have Pepco install a Level 2 charger. The details of each option are outlined below.

2.2.1 Rates offered

1. **R-PIV**: Whole House Time of Use (TOU) rates that apply to the entire house demand including the EV. This is the rate assigned to customers that didn't have a separate Level 2 EVSE.
2. **PIV**: EV-only TOU charging rate; the home charging station was on the PIV rate with its own meter; the home was on a different rate with its own meter. Customers needed to have a separate Level 2 charger to use this option (either existing or newly installed).
3. **PIV Green¹**: EV-only TOU charging rate with a 'Green Power' adder option for an additional \$0.0179 per kWh to allow for the additional expense of zero emission charging. Customers needed to have a separate level 2 charger to use this option (either existing or newly installed).

The majority of customers were located in Montgomery County. The different rate types are color coded by county in Figure 3 below.

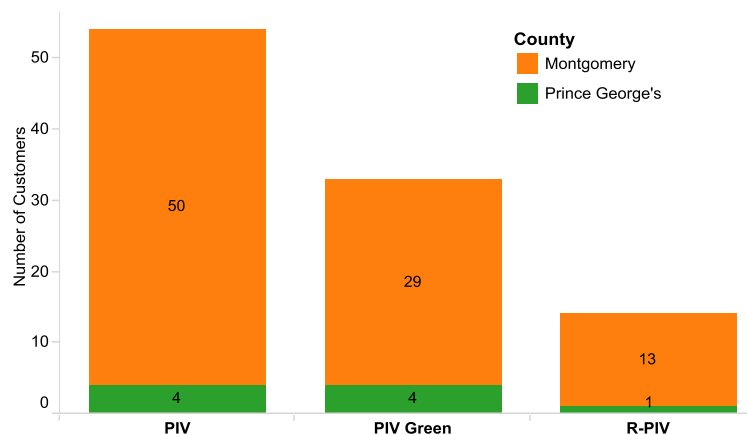


Figure 3: Total Pilot enrollees divided by rate type and county.

¹ The PIV- Green option gives customers the opportunity to have their energy supplied from 100% green energy which could allow for the claim of zero tailpipe emissions when charging an all-electric vehicle. This is done through purchasing Renewable Energy Credits (RECs) from the Maryland Renewable Portfolio Standard ('RPS') Blend which is comprised of a combination of Solar and Wind RECs and adds approximately \$0.0179 per kWh to the rate.

2.2.2 Meter options

Customers who did not have a separate EVSE for their PEV (and did not want to install a new one) used the R-PIV rate.

The customers enrolled in the PIV and PIV Green had two options:

1. Customer used their existing, separate, 240V Level 2 charging station. Pepco installed a second AMI meter at the customers premise.
2. Customer purchased a 240V Level 2 EVSE (specified by Pepco) charging station with an embedded revenue grade meter from Itron with communication capabilities. Pepco installed this second AMI meter at the customer's premise.

The Pepco-installed EVSEs have an embedded revenue grade meter that uses Wi-Fi or cell communication to check in with the server after a charging event is complete or at a predetermined time. At the customers' permission, a demand response event allows Pepco to reduce the charging level from a level 2 to a level 1 charge during a peak load event.

2.2.3 Customer Enrollment

Figure 4 displays what utility rate and when each customer enrolled. Out of 101 customers, 54 (53%) elected a PIV rate, 33 (33%) elected PIV-Green and 14 (14%) elected R-PIV. There was a steady enrollment rate throughout the Pilot Program. Of the 87 PIV and PIV Green customers, 35 opted for Pepco's installation of their level 2 EVSE with the embedded Itron meter.

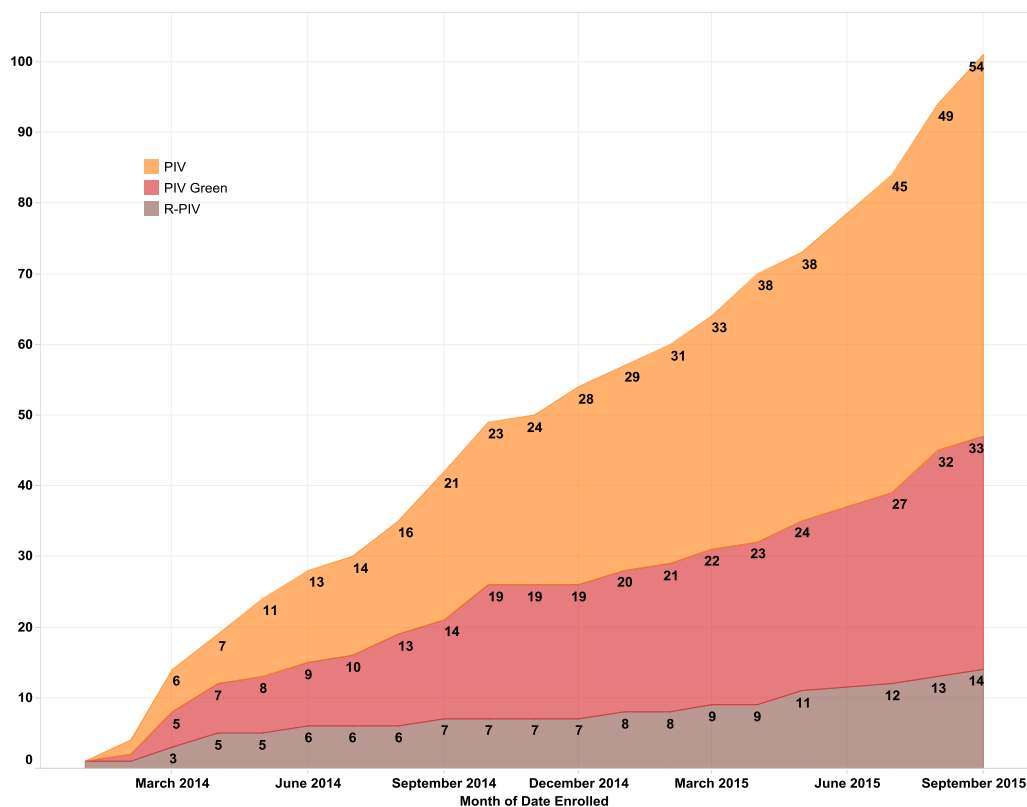


Figure 4: Customer enrollment over the course of the Pilot Program grouped by rate type.

3.0 Results

3.1 Weekly Load Shapes

There were two rates offered in the Pilot Program (for those with a second meter); PIV and PIV Green. Figures 5 and 6 show the average weekly EV load shape for both those rate types (these load shapes do not include house load). For each of these plots, the weekly load was averaged over the number of customers

for the entire length of the program. For both plots, the x-axis are the hours over the day and the y-axis are the days in the workweek (Monday through Friday). The colors are indicative of kW load. Pepco's off peak rates begin at 8 PM.

For PIV customers, the increase in load begins around 6PM while for PIV Green it begins later at 7PM. This hour difference potentially reflects that the PIV Green customers are a bit more engaged/informed about the charging times since they are also willing to pay more for 'Green' power. For both rate types, the majority of charging begins after 8 PM, when Pepco has reduced rates. Both rate types have charging that extend into the early morning hours until approximately 3AM. PIV customers have a higher max load (6-8 kW) mainly concentrated on Wednesday while the PIV Green customers have max load of 4-6 kW that is distributed evenly between Tuesday, Wednesday and Thursday. This is due to the fact that there are more Teslas in the PIV group, which charge less frequently and over a longer period of time causing a higher kW and a peak on Wednesday.

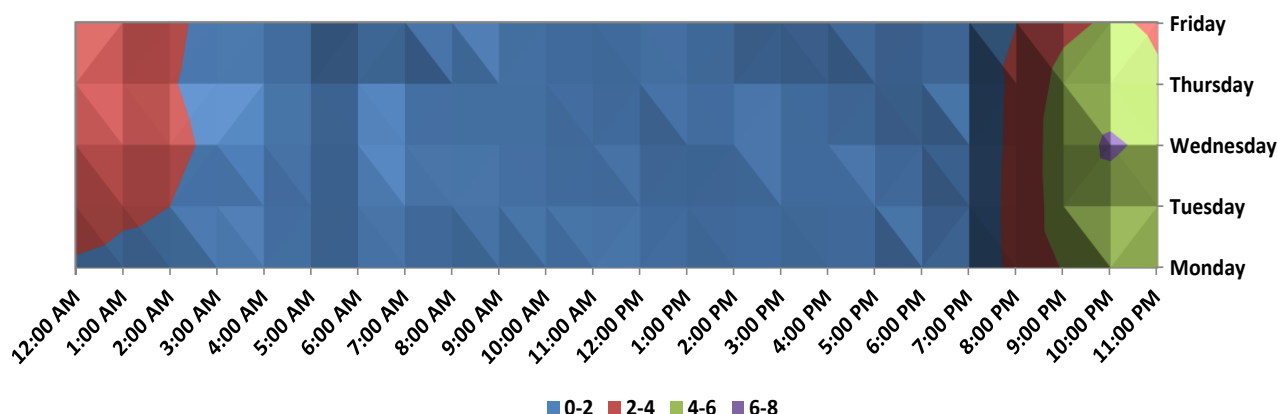


Figure 5: Average weekly load shape (kW) for PIV customers

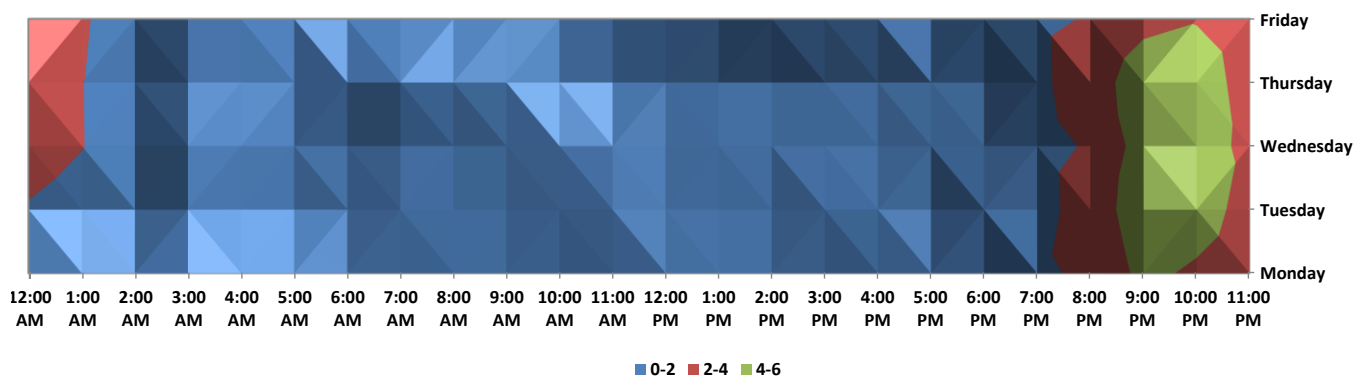


Figure 6: Average weekly load shape (kW) for PIV-Green Customers

3.2 Average and Aggregate Consumption

3.2.1 Daily average consumption and aggregate consumption

The total kWh/day/customer ranges from less than 2 to almost 50. For reference, a leaf has a battery capacity of 22 kWh, and a Tesla model S has a battery capacity of 85 kWh.

There doesn't seem to be a pattern between charging weekdays or weekends. The average daily kWh trends over time for both PIV and PIV Green rates do not show much difference between the two. Figure 7 shows the kWh/day/vehicle type.

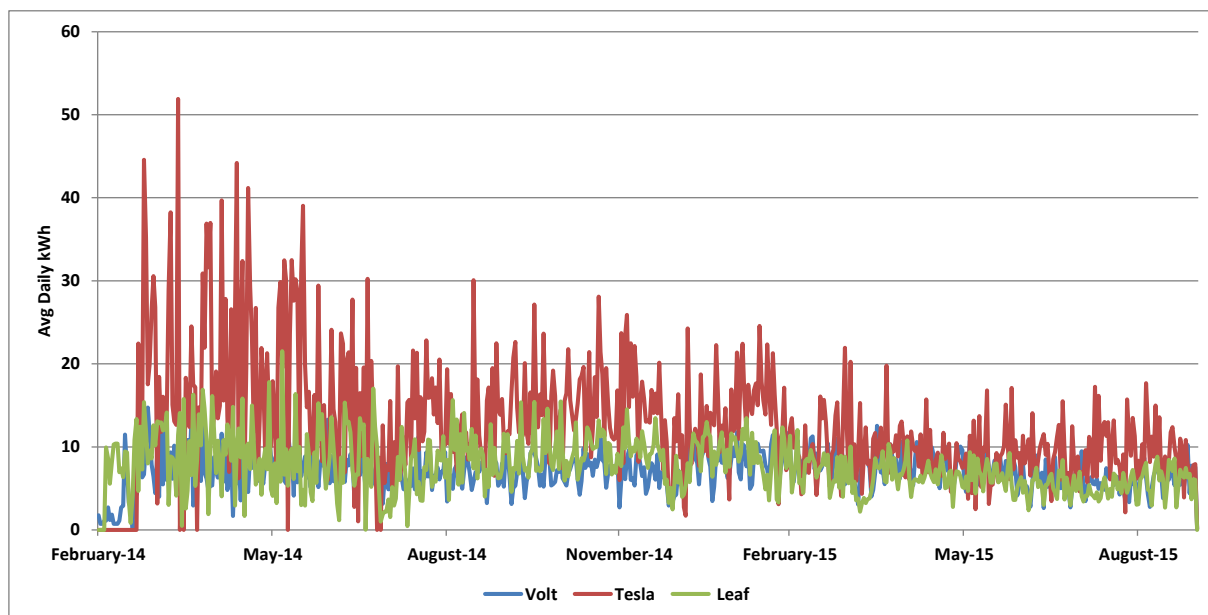


Figure 7: Average hourly kWh from each vehicle type.

As expected, Teslas have the largest kWh/day as well as kW load followed by the Leaf and the Volt. The difference in kWh/day between Leafs and Volts is small. This indicates that Volt owners are mimicking the behaviour of Leaf owners and are probably primarily driving using electricity (assuming that the vehicles are traveling a similar number of miles each day).

3.2.2 Average daily charges and kWh

Volts have the most charges per day, reflecting the small battery size and also that owners are trying to run their vehicles mostly on battery power. Teslas use the most kWh/day followed behind by the Leaf. The average kWh/day of the Volt and the Leaf are not very different again indicating the Volt owners are trying to use their battery as much as possible. Figure 8 shows each vehicle's average kWh/day and average number of charges/day for all the vehicles in the study.

Table 1: Average charges/day and summed kWh/ day divided by vehicle type
taken from only these three vehicle types.

Vehicle Type	Charges/Day	kWh/day
Leaf	0.82	7.34
Tesla S	0.61	11.49
Volt	1.15	6.25
Total Average	0.87	8.36

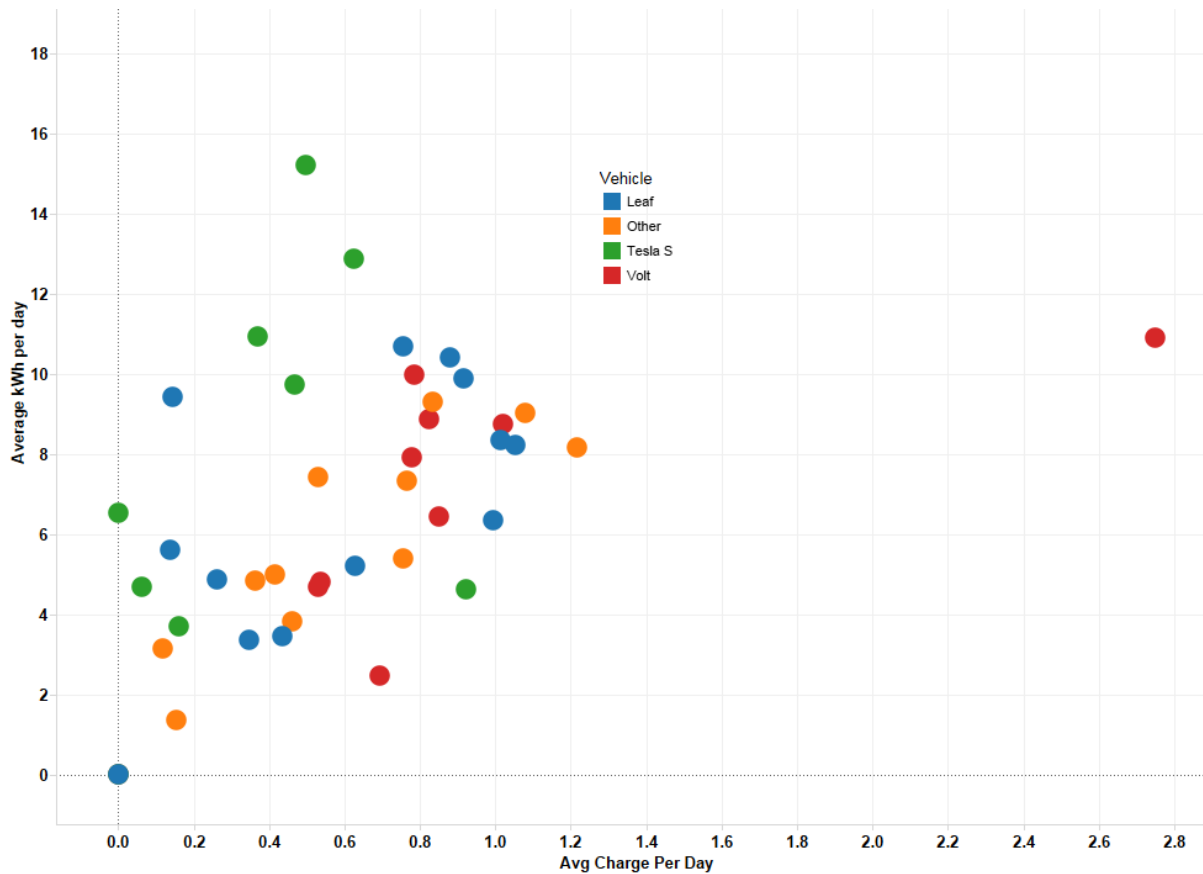


Figure 8: Average charge per day vs. average kWh per day colored by vehicle type.

3.4 Program Costs

As shown before, customers shifted most of their charging to off-peak times, which is reflected in the total costs below. Customers saved money by charging during off peak times. As one might expect, Tesla owners spent the most on energy while Leaf and Volt owners spent similar amounts. Most customers charged primarily at home and therefore their home meter captures almost all of their vehicle energy used.

Table 1: Average spent per customer per month for each vehicle type (September 2015 was chosen). 'If flat rate charge was used' is the total amount that would have been spent if no off-peak rates were available. Savings is the savings per customer per month that the customers saved through the PIV TOU rates.

Average Cost Per Customer Per Month							
Category Type	Rate type	Total kWh	\$ Spent (off-peak)	\$ Spent (peak)	Total \$ (off-peak & peak)	If flat rate charge was used	Savings (flat rates- peak/off-peak rates)
Volt	PIV	189	\$14.08	\$3.60	\$17.68	\$25.81	\$8.13
	PIVGreen	203	\$17.51	\$5.84	\$23.35	\$27.66	\$4.30
Tesla	PIV	272	\$21.28	\$2.52	\$23.80	\$37.04	\$13.24
	PIVGreen	288	\$28.40	\$0.89	\$29.29	\$39.27	\$9.98
Leaf	PIV	187	\$13.52	\$4.44	\$17.96	\$25.50	\$7.54
	PIVGreen	187	\$16.72	\$4.23	\$20.95	\$25.55	\$4.60
Other	PIV	159	\$11.72	\$3.24	\$14.96	\$21.65	\$6.69
	PIVGreen	204	\$18.15	\$4.68	\$22.82	\$27.77	\$4.94
Average	PIV	202	\$15.15	\$3.45	\$18.60	\$27.50	\$8.90
	PIVGreen	221	\$20.20	\$3.91	\$24.10	\$30.06	\$5.96
	total Average	211	\$17.67	\$3.68	\$21.35	\$28.78	\$7.43

3.5 Utility Costs

The total utility electricity revenue throughout the program was almost \$16,000 dollars. Per customer per month average value of \$21.35 can be used to project potential revenues based on EV adoption.

3.6 Transformer Loading

EPRI's 'Hotspotter' tool was used to determine the grid impacts of increased EV charging. Using a probabilistic model, the Hotspotter tool uses information about miles driven, charge start time, EV type (and battery size), EV adoption probability in a specified region and existing transformer peak load to determine the overloading of transformers. This analysis provides statistics on the number of transformers that could potentially be overloaded due to EV charging. The number of transformer overloads can then be used to calculate the transformer upgrade costs each year. This cost estimates in this analysis should be used to show general trends and not exact monetary values as there are many assumptions and unknowns included.

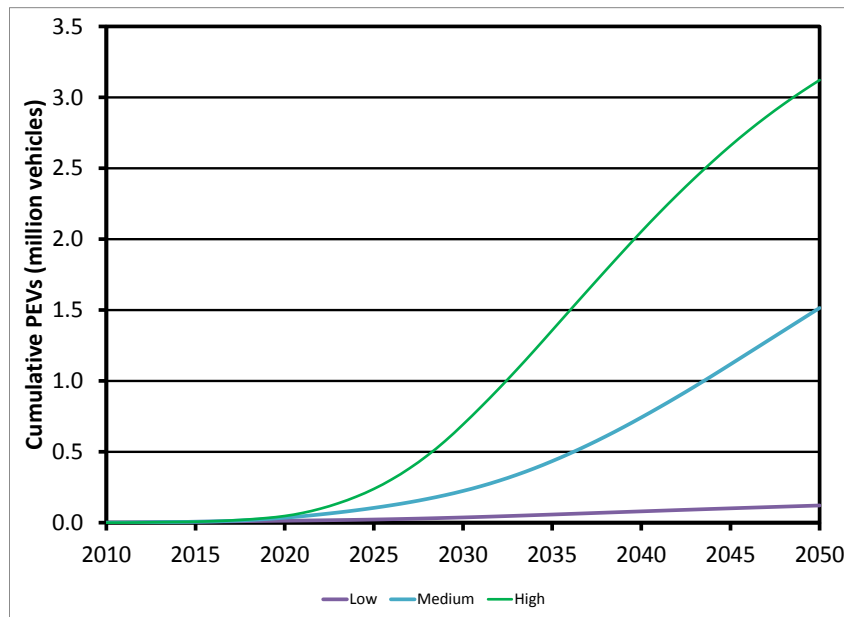


Figure 9: EPRIs Cumulative PEV projections for the state of Maryland. Three different scenarios are shown.

Using three different vehicle projection scenarios (Figure 9), and a changing mix of EVs, analysis showing upgrade costs, and transformer overloading was performed out to 2025. Representative values were chosen for:

- Miles driven before a charge: Varied between 100 and 200 miles.
- Number of EVs per residence: Maximum is 3.
- Time that EV owners plug in: This is based on home arrival time and then can be shifted if a TOU rate is used.
- Emergency transformer status: 150% of transformer capacity.
- Transformer upgrade costs: Average cost \$7,691. This is an average of overhead and underground.

Eight model runs were performed to answer the questions:

- How does different size EV vehicle fleets affect transformer overloading and costs over time?
- How do TOU incentives help shift peak loading and potentially costs?
- Does a time shift of two hours to the TOU rates result in any differences?

The peak hour over a year's worth of data was 7 PM. The peak day for each transformer was used as the baseline for adding increased PEV charging load.

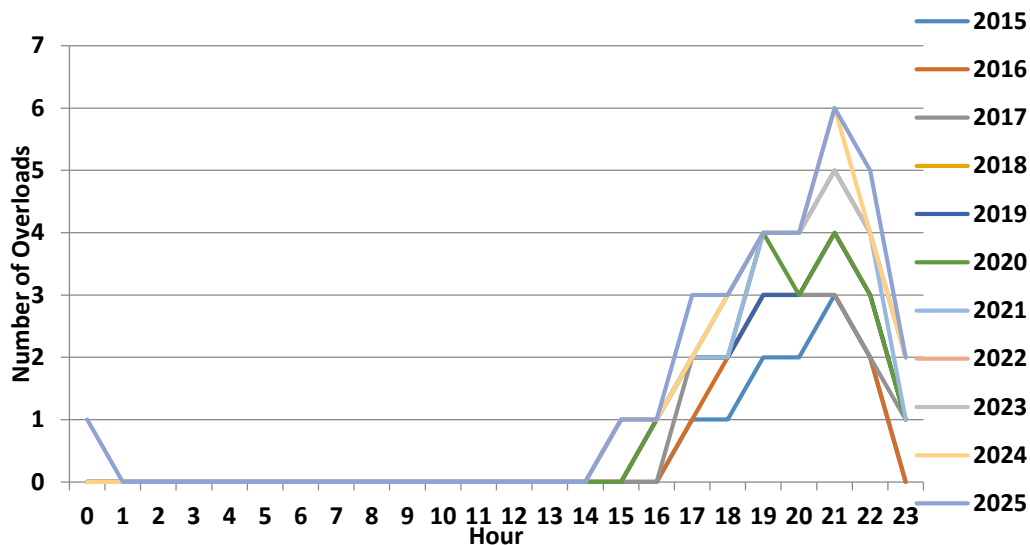


Figure 10: Number of transformer overloads for one of the scenarios (medium EV penetration, TOU rate 8PM, 100 miles driven between charges).

Using a medium EV penetration scenario, and a TOU time of 8 PM, and 100 miles driven between charges, Figure 10 shows the projected number of overloads by year out to 2025. Note that once a transformer is upgraded, it is assumed to be capable of handling all future loads on the system.

The transformer overloads in Figure 10 can be used to estimate the costs associated with upgrading the system. Three medium vehicle adoption scenarios were tested, 8PM TOU, 10 PM TOU and a no TOU rate. All three scenarios assume medium PEV adoption scenario and that all vehicles drive 100 miles before being charged. Both TOU cases save money in the long run over the non TOU rate. Furthermore the TOU case beginning at 10 PM saves more money in the long run than the 8PM TOU case as there is still coincident load on the grid at 8PM which drops off by 10 PM.

During this program, Pepco conducted 7 demand response (DR) events. Customers were alerted by email the morning of the event that they would be asked to reduce their level of charging (from level 1 to level 2) for 4 hours in the afternoon. Over all DR events, only 3 people were effected. 2 reduced their load, and one opted out. This indicates that DR events are very effective at reducing load on the grid. The transformer loading analysis did not take DR capabilities into account and it could be another way to help reduce costs.

4.0 Satisfaction with the program

Customers completed a survey one year after enrolment in the program. In general, customers were very satisfied with the program. A maximum of 11% were 'Not Satisfied' with the regard to the 'Communications with Pepco regarding the program'.

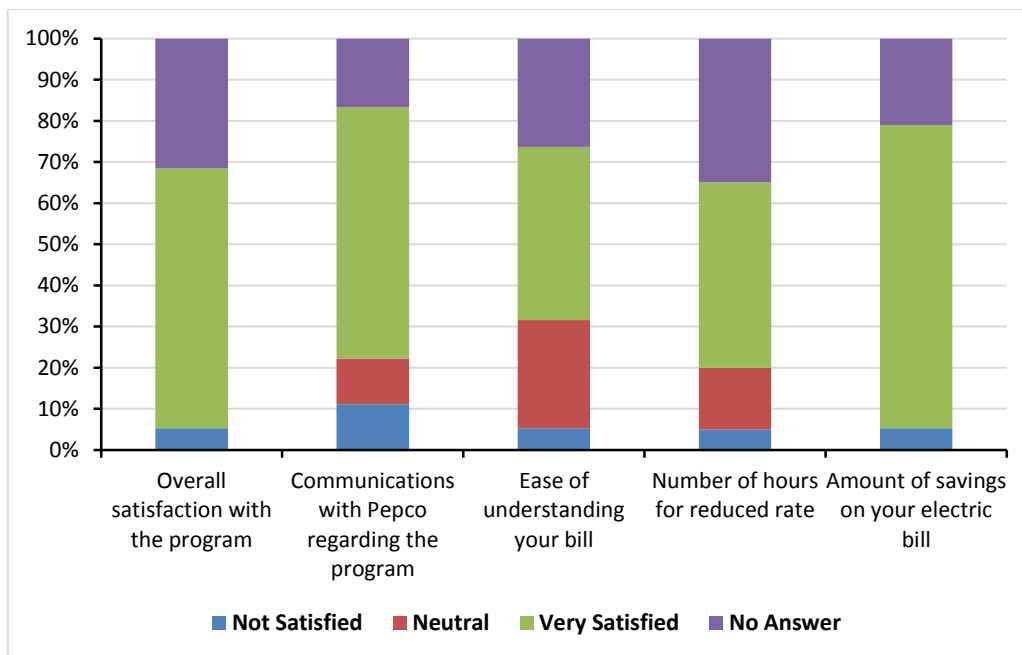


Figure 13: Overall satisfaction with the program

5.0 Conclusion

This Pilot Program showed that EV customers, regardless of vehicle type, mostly charged at off peak charging times, confirming that TOU rates are an effective way of shifting load off peak. Furthermore, almost no customers were charging during demand response events which shows that just planning a DR event incentivizes customers not to charge during that time or that customers were not plugged in at that time anyway. EPRI's Hotspotter tool showed that utility infrastructure upgrades are needed regardless of EV penetration scenario; however, with more EVs on the road, more upgrades are needed. The tool confirmed that shifting charge times to off peak times saves costs due to avoided or delayed infrastructure upgrades. More costs savings were identified when the off peak time was shifted two hours later.

Authors



Jamie Dunckley is a Data Analyst/Scientist at the Electric Power Research Institute (EPRI). She received her BS in Environmental Engineering at MIT and her Masters and PhD in Civil and Environmental Engineering at Stanford University. Her current projects include transformer loading analysis, electric vehicle tracking studies and mapping current and future electric vehicle charging infrastructure.



Barbara M. Gonzalez is an experienced project manager and engineer with more than 30 years of experience in providing leadership in power generation, fleet management, human resources, business performance and other corporate initiatives at Pepco. Since 2011, Ms. Gonzalez has served as Manager of Special Projects which includes Pepco's Plug in Vehicle Charging and other energy projects. In this role, she is responsible for ensuring that these projects adhere to safety, scope, timeliness and budgetary requirements.



Dan Bowermaster is the Program Manager for Electric Transportation at EPRI. His program's research focuses on the development, deployment, and analysis of plug-in electric vehicles and charging infrastructure and collaborates heavily with the automotive and technology industries. Bowermaster has a master's in business administration from the Wharton School of Business and a master's in international studies from the University of Pennsylvania. He also holds bachelor's degrees in mechanical engineering and in international relations from the University of California, Davis.