

Plug-in Electric Vehicle Consumer Usage Study

40 Drivers. 40 All-Electric Nissan LEAFs

Workplace Charging

July 2013

Project Insights: Real-World Charging Behavior at the Workplace



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INTRODUCTION

Advanced Energy's Plug-in Electric Vehicle (PEV) Consumer Usage study began in January 2012. This study takes an in-depth look at the consumer driving and vehicle charging trends of 40 all-electric vehicle drivers in the Research Triangle Park, N.C. area over two years to document and evaluate general characteristics and usage trends for the electric vehicle consumer market. The purpose of this study is to identify potential barriers to widespread adoption of PEVs and the Electric Vehicle Supply Equipment (EVSE) infrastructure that supports them and evaluates the impact of external events, such as changes in infrastructure availability, duration of vehicle ownership and seasonal temperature variances.

Each Advanced Energy's *Project Insights* report addresses one specific market variable and identifies and explores opportunities to overcome the associated adoption barriers. This report focuses on Workplace Charging availability and how it may influence PEV driving and vehicle charging behavior. For more information on this report or to explore partnership opportunities with Advanced Energy on the PEV Consumer Usage study, please contact Lisa Poger, Transportation Initiatives Project Manager at Transportation@AdvancedEnergy.org.

BACKGROUND

Concerns of global climate change, U.S. reliance on foreign oil, growing demand for petroleum-based fuels and unpredictable gas prices are clear motivators for driving consumer preference and the transportation industry toward fuel-efficiency and alternative energy vehicles. Several automotive manufacturers have successfully launched a new generation of hybrid vehicles and PEVs while others have announced plans to introduce new models in the coming years. With this in mind, clear understanding of the early consumer PEV adoption model is essential for public and private infrastructure planning and barrier identification and resolution.

Charging stations are the transportation fuel source for PEVs and for PEVs to be fully commercialized; electric charging infrastructure must be deployed. Recent PEV studies suggest that the primary location for PEV charging is at the residential location, with 80- to 90 percent of PEV charging events occurring at the home; however, extension of charging infrastructure beyond the residential location is thought to be vital for wide-spread PEV adoption, as the opportunity to charge in a public location increases the vehicle travel range and improves driver confidence in making it to their destination.

WHY IS THE PEV CONSUMER USAGE STUDY IMPORTANT?

Real-world behavior data on consumer market adoption is important to a number of PEV industry stakeholders. Results of this study will be used to determine best practices and guidelines for vehicle technology and infrastructure deployment, identification of potential impacts to the electric grid, and reduction of barriers to wide-spread PEV adoption for:

- **Original Equipment Manufacturers (OEMs)**
OEMs, otherwise known as vehicle and charging station manufacturers, benefit tremendously from first-hand experience of real-world drivers. Feedback and data from early adopters will help guide manufacturers in the development of their products for wider audience acceptance.
- **Electric Utilities**
Understanding the charging profile of vehicle drivers and the impact of charging to local grid reliability is a key concern for utility providers. Benefits of this study are identifying when and where vehicles are likely to charge under varying conditions and charging scenarios.
- **Municipal Planners**
Results of this study will be used to support a strategic and structured approach to providing public charging infrastructure. Understanding of real-world driving and charging behaviors can guide investment best practices regarding charging infrastructure placement for maximum utilization and public benefit.
- **PEV Consumers**
Understanding the charging behaviors of real-world drivers can reduce consumer concerns about limited vehicle ranges and possibilities of being stranded without available fueling options. Additionally, evaluating charging characteristics and behaviors can provide valuable insight into the optimal charging levels required for home, workplace and public charging.

METHODOLOGY

Project Support

Advanced Energy leveraged a U.S. Department of Energy (DOE) and North Carolina State Energy Office (NCSEO) consumer adoption initiative to offer consumers a \$7,500 per vehicle incentive toward the purchase of an all-electric NISSAN LEAFs in addition to the available federal tax credit of \$7,500. In exchange for this incentive, consumers agreed to participate in Advanced Energy's two year PEV Consumer Usage study.

Additionally, in collaboration with the Triangle Clean Cities Coalition, Advanced Energy administered the electric vehicle infrastructure portion of a DOE grant to work with corporate campus partners to deploy 24 charging stations at workplace locations and also educate workplace employee on the benefits of electrified transportation. Advanced Energy's PEV Consumer Usage Study continues to build on the strong momentum of these earlier consumer adoption initiatives.

Participant Selection

Participants were selected with a goal in mind to cover a range of charging station availability scenarios. Participants were required to live or work in the North Carolina Research Triangle Park area, have a daily commute of 60 miles or less, and be willing to purchase a Nissan LEAF by January 2012.

Workplace Hotspots

Eight workplace "hot-spot" were identified through the participant application process. The "hot-spot" clusters varied in workplace charging availability, with 68 percent having access to Level 2 (240V/40A) charging, seven percent having access to Level 1 (120V/20A) charging, and 25 percent with no available access to workplace charging. Workplace clusters were geographically spread across the Research Triangle Park area. See Figures 1 – 2.

Workplace Charging (WPC) Cluster Name	Total Number of Participants	Charging Stations (#) Level	Charging Station Access Fee
WPC-001	4	(10) Level 2	None
WPC-002	3	(10) Level 2	None (4-hour limit)
WPC-003	7	(8) Level 2	None
WPC-004	9	(8) Level 2	None
WPC-005	4	(3) Level 2	\$1/hour parking fee (8am-5pm, M-F)
WPC-006	3	(3) Level 1	None
WPC-007	3	No Access	NA
WPC-008	7	No Access	NA
Total Participants	40		

Figure 1. Participant availability of workplace charging.

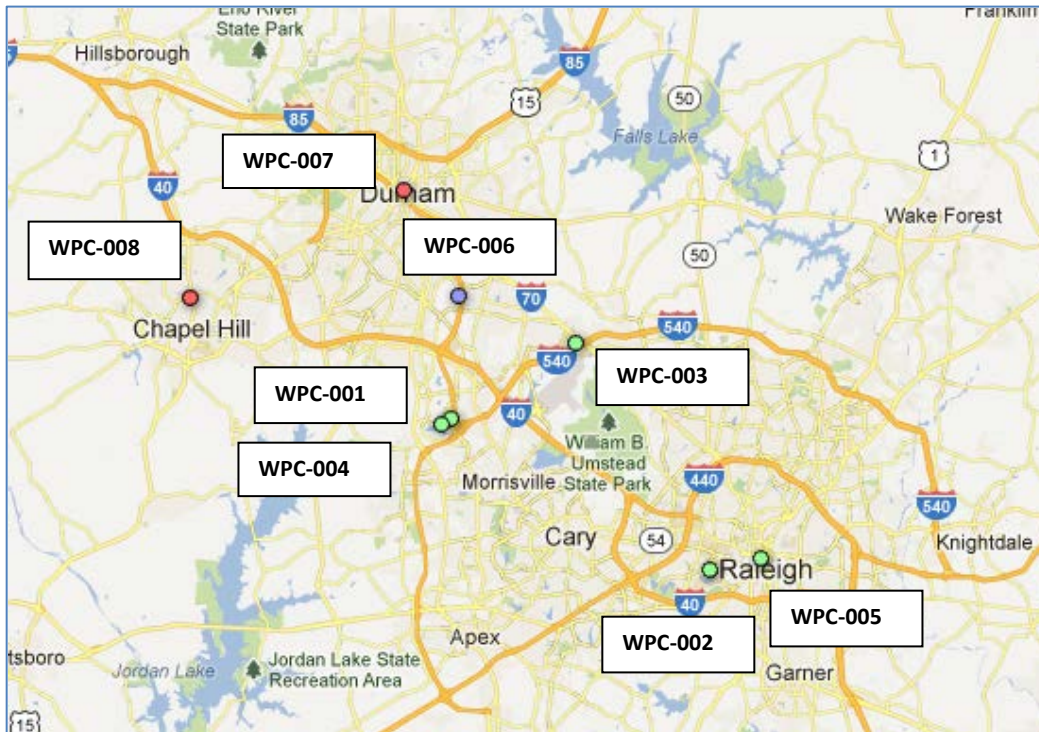


Figure 2. Map of cluster locations in the Research Triangle Area.

Vehicle Data

Advanced Energy partnered with the Nissan Corporation Technology Center (Nissan) on vehicle data collection for 15 specific data parameters. Nissan provided and installed the advanced data logging devices and compiles a monthly report of vehicle driving and charging activity. Data collected in this study differs from the CARWINGS-data, utilized in other vehicle studies, as it is collected at one-second intervals and contains nine additional data elements that allow further analysis of vehicle operating conditions and consumer driving styles. See Figure 3.

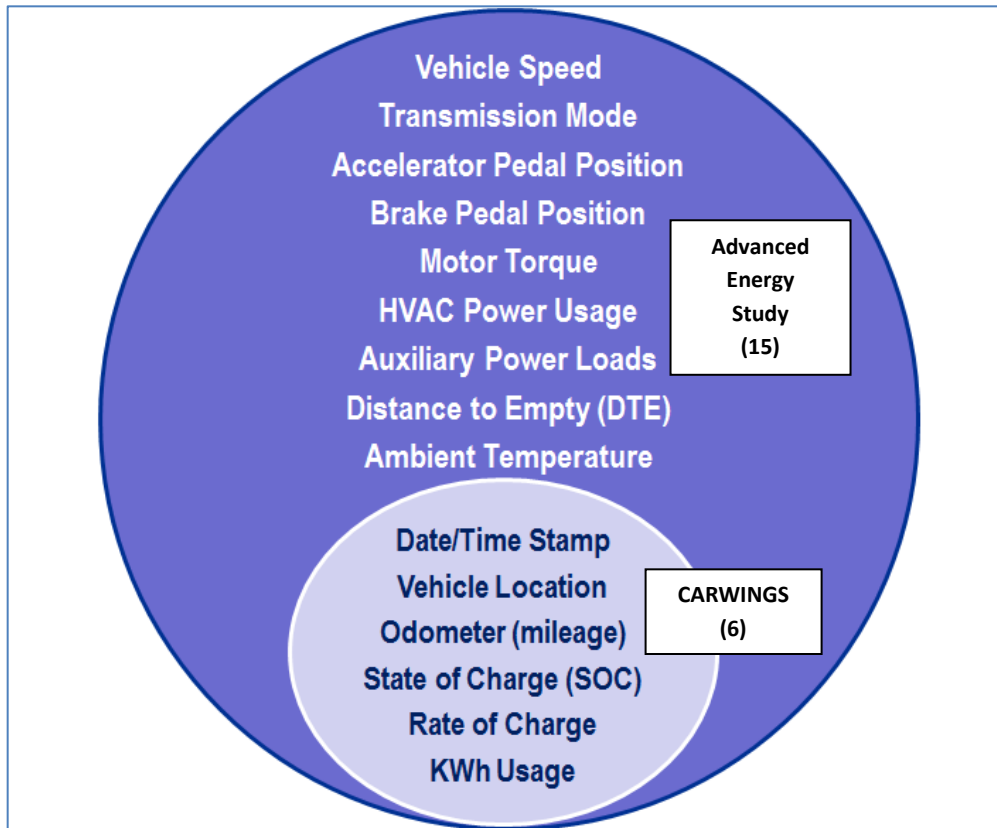


Figure 3. Data parameters for Advanced Energy vehicle study.

Advanced Energy’s PEV Consumer Usage study is also unique in the comprehensive scope and scale of data collection and frequency, with more than 40 million data points logged per vehicle per month. Advanced Energy collects 2,250 data points for each corresponding CARWINGS data point collected. See Figure 4.

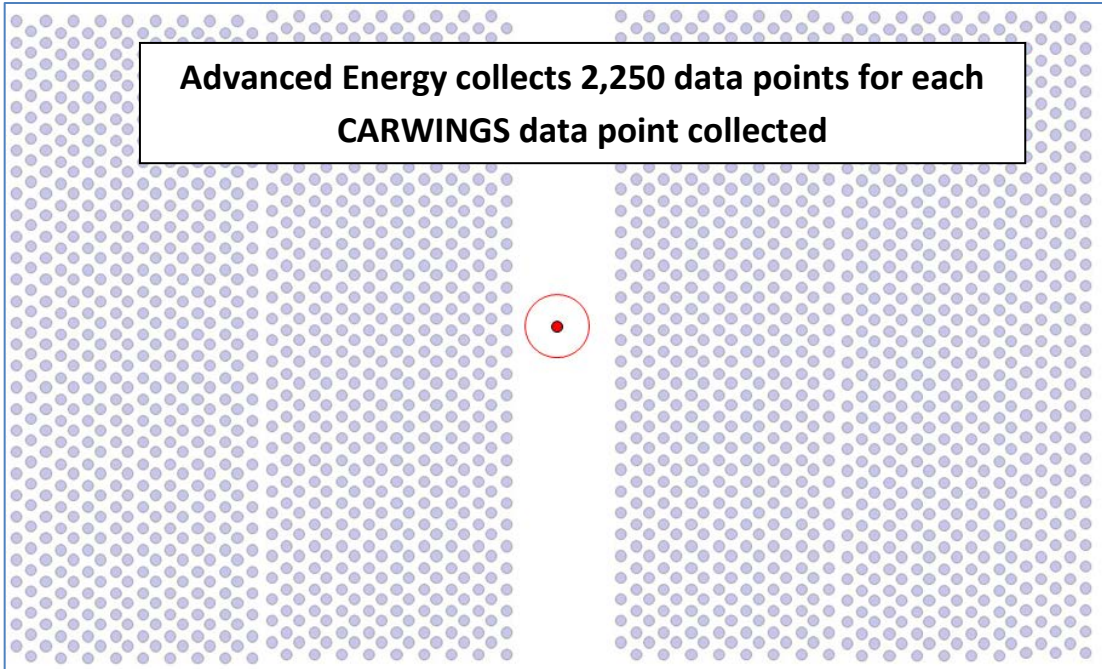


Figure 4. Data points collected for each OEM data point.

Participant Surveys

Quarterly surveys are conducted to obtain subjective data from participants regarding their PEV experiences. Survey questions were developed to discern driver perspective and identify variances that may influence driver behavior. Participant responses also help characterize target markets for early PEV adopters. An example survey question is shown in Figure 5.

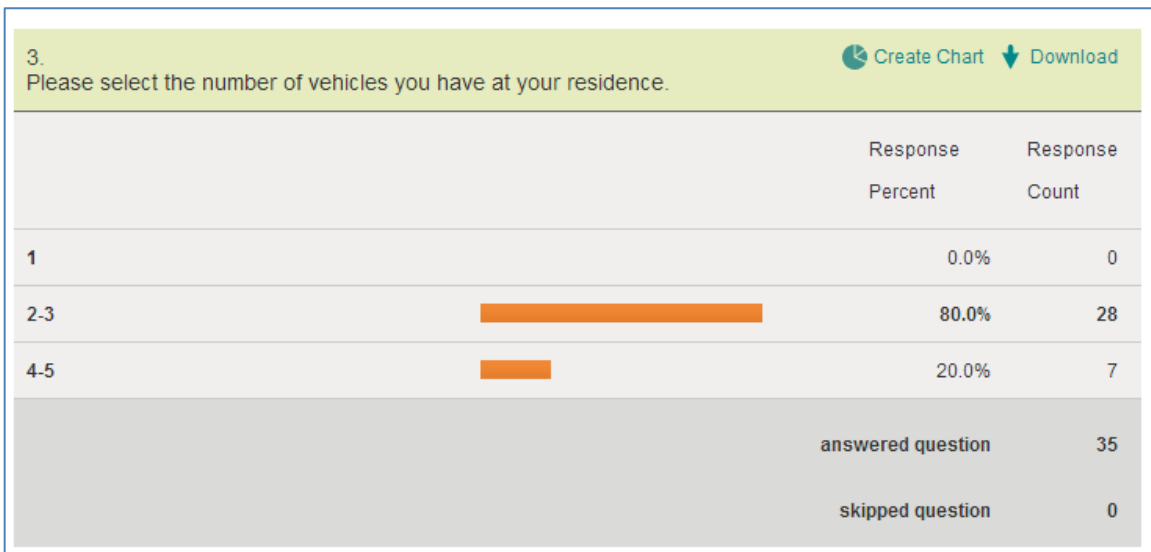


Figure 5. Sample survey questions.

The driver surveys also provide insight into factors independent of vehicle operation and charging. For example, participants provided feedback on the location and level of charging infrastructure they would like to see deployed, as well as how their charging behaviors may change if the infrastructure was made available. See Figure 6.

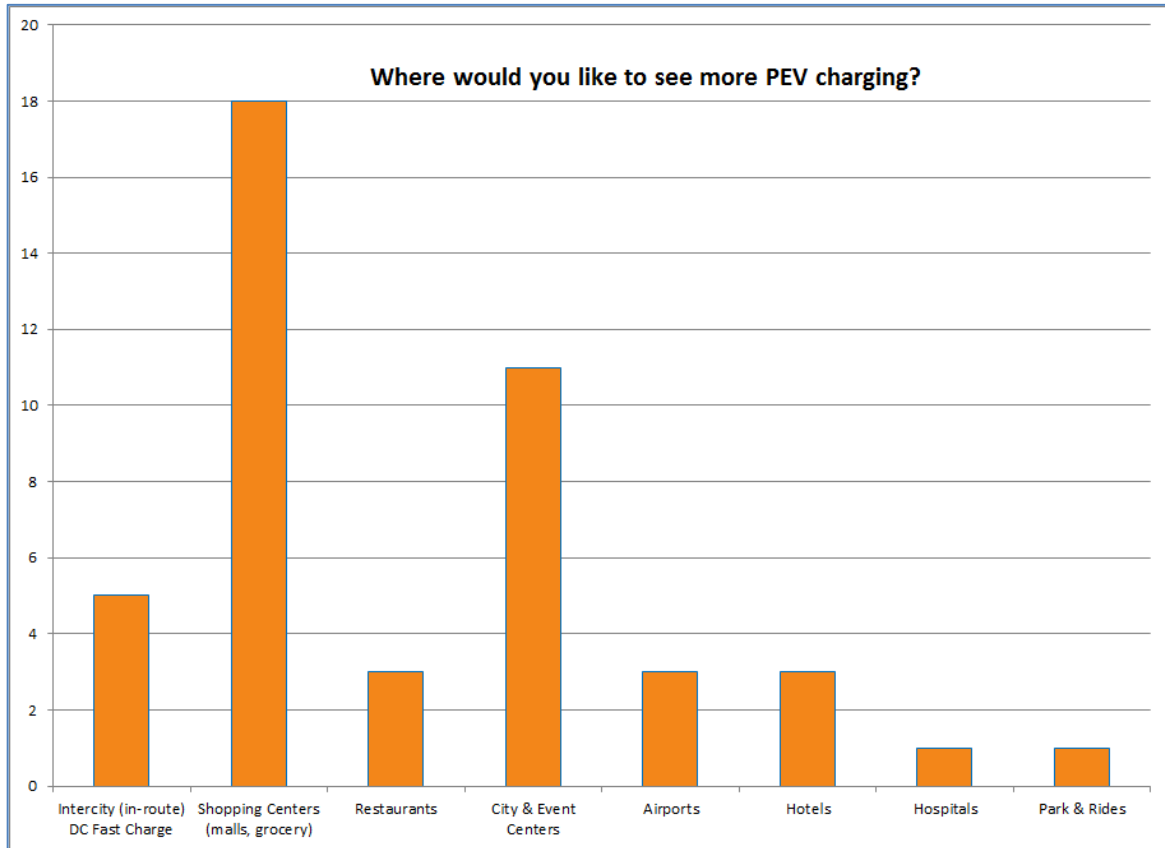


Figure 6. Sample survey questions.

Survey questions relating to workplace charging and accelerated PEV adoption at the workplace addressed participant observations of vehicle adoption outside of the Advanced Energy PEV Usage Study and self-assessment of home and workplace charging behaviors. See Figure 7.

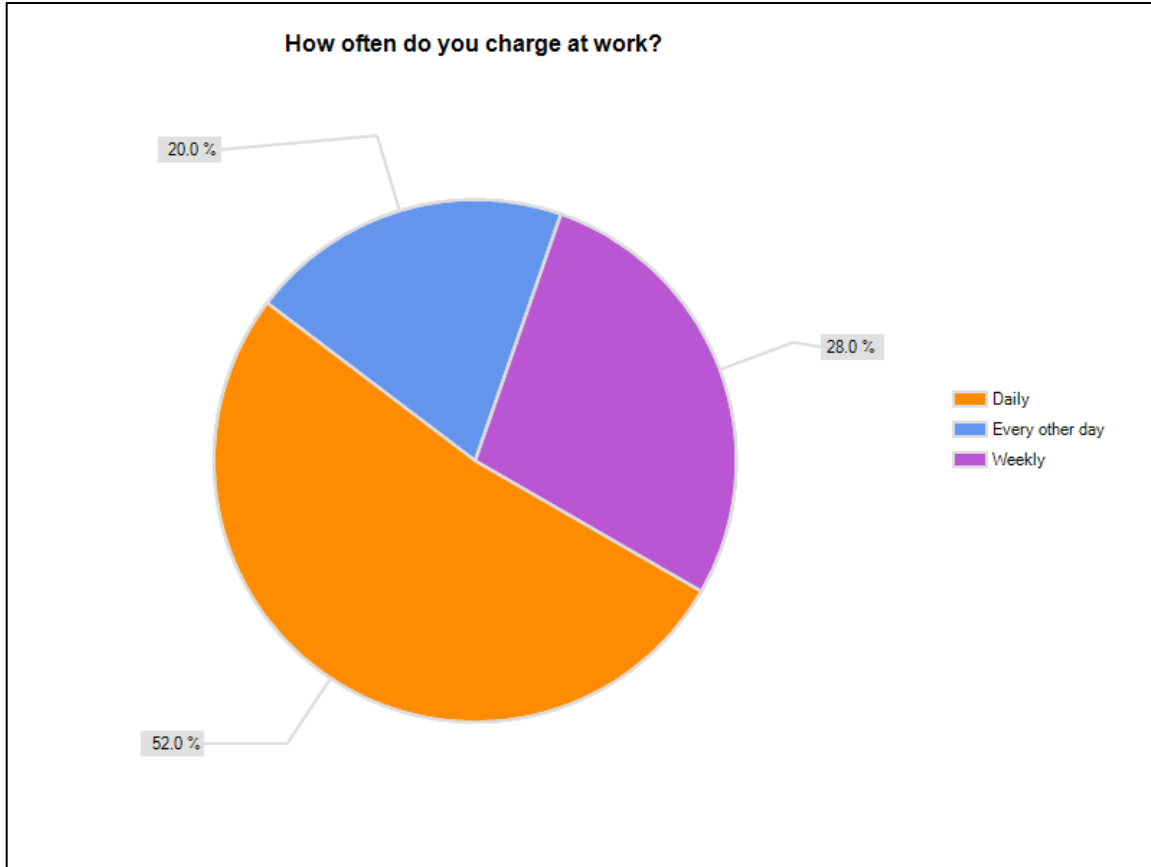


Figure 7. Survey data Q3 2012.

Survey data collected from participants indicated that, of those drivers charging at the workplace location, 52 percent charged daily, while 20 percent charged every other day and 28 percent charge weekly. This subjective data indicates that at least 48 percent of the vehicle drivers within the Advanced Energy PEV Usage Study can complete their daily commute without charging opportunities at the workplace.

Significant opportunities exist for promoting PEV adoption at the workplace. While the majority of vehicle charging is still expected to occur at the driver's primary residence, promotion of PEVs at the workplace takes advantage of the social like-mindedness of the typical workplace and supports the information-exchange between users that is essential to the adoption of any new technology. In some workplace scenarios, employers may also provide incentives toward purchase of a PEV in an effort to promote clean transportation and add to their corporate sustainability portfolio. Survey data collected from participants indicated that nearly 75 percent of drivers have observed adoption of PEVs outside of the Advanced Energy PEV Usage Study. See Figure 8.

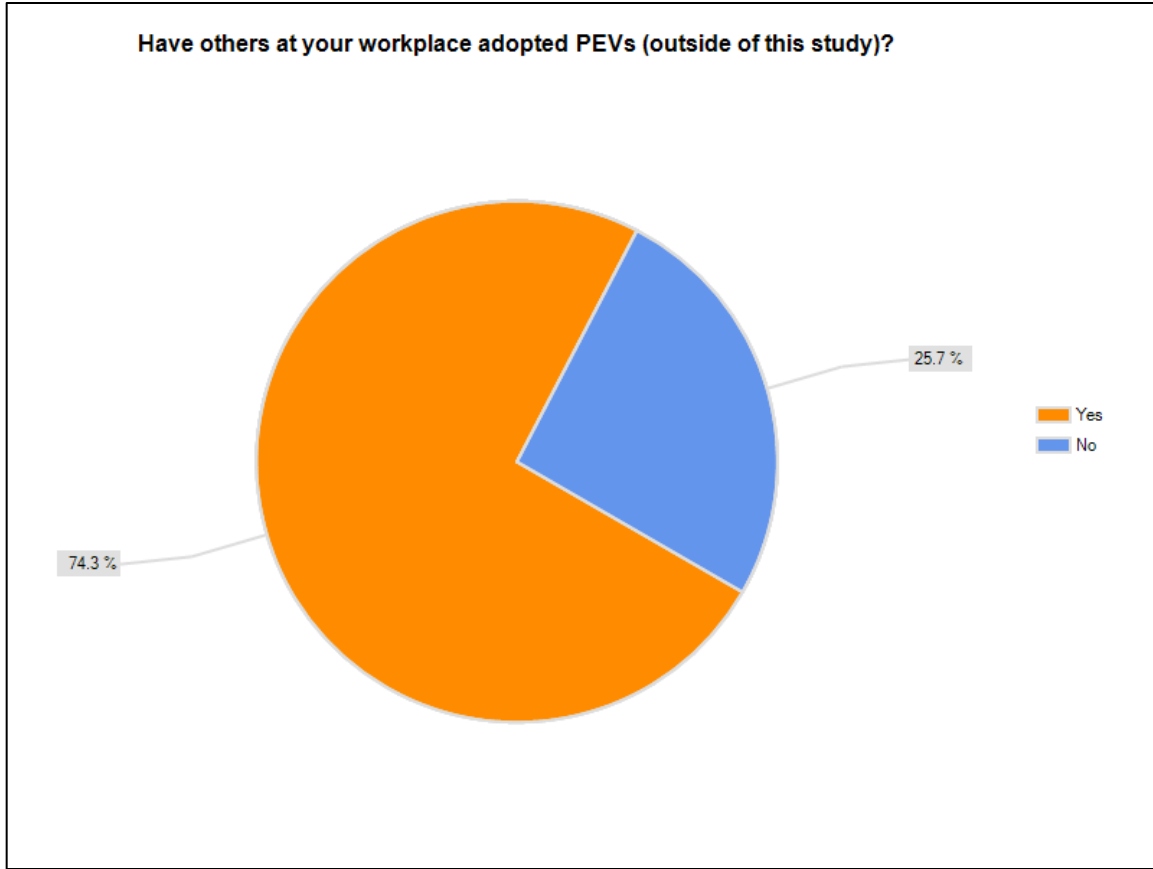


Figure 8. Survey data Q3 2012.

DATA ANALYSIS

Study vehicles were deployed in January 2012. Vehicle data is collected monthly and uploaded to Microsoft Sequel Server. Data trends are analyzed on a monthly basis to identify changes to vehicle charging habits, travel patterns and consumer driving characteristics relative to the baseline.

REPORT TOPIC: Workplace Charging

Workplace charging plays a critical role in America's PEV charging infrastructure. Installing workplace charging is a sign of corporate leadership, showing a willingness to adopt advanced technology as well as increasing consumer exposure and access to PEV charging opportunities. While employer-provided PEV charging also serves as an appealing employee benefit that can help attract and retain a cutting-edge workforce, it also enhances corporate sustainability efforts and can be a valuable complement to employee energy education plans.

The DOE Workplace Charging Challenge is a great example of how employers can help provide their employees with information while enhancing corporate sustainability efforts. In support of employers who undertake the Pledge, DOE will provide technical assistance, informational resources and an information-sharing forum. Additionally, successes made by those who undertake the Pledge will be recognized and the identification of best practices will be disseminated.

The ability to charge at work could potentially double a PEV driver's all-electric daily commuting distance. This untapped resource presents a significant opportunity to expand the country's PEV charging infrastructure. (DOE, 2013)

Aside from at-home and public PEV charging, research strongly supports the need for workplace charging opportunities. The Electric Power Research Institute (EPRI) estimated that 54 percent of non-residential parking occurs at the workplace where layover is often between four- to- eight hours. This extended period where vehicles are sitting in one place is the perfect time to provide EV owners with an extension in range. Workplace charging could provide PEV owners an extra 15- to- 70 miles of range depending on the charging infrastructure available. This matches well with the characteristics of typical commuters today, of which 90 percent drive less than 40 miles one-way to work. (Energy Innovation Corridor, 2013)

One frequently asked question is “What are the optimal charging levels for home, workplace and public charging.” To determine optimal charging levels is it important to identify the differences in infrastructure availability and travel patterns of an individual or group of drivers.

Driver Scenarios

Driver characteristics varied in several key categories; including access to workplace charging, one-way commute distance and home vehicle charging speeds. Participants were grouped across home and workplace charging categories and commute distances were averaged. Groups were analyzed independently and in aggregate to evaluate differences in driving and charging patterns. See Figure 9.

Scenario	Home Charging Level	Workplace Charging Level	Total # Drivers	Average Commute (one-way miles)
A	Level 1	None	2	5
B	Level 1	Level 1 or 2	13	12
C	Level 2	None	8	11
D	Level 2	Level 1 or 2	17	16
Total			40	

Figure 9. Distribution of home and workplace charging levels.

Frequency of Charging Events

An evaluation of the number of charge events initiated each hour of day helps to understand and plan for anticipated power demands on the electric grid. Figures 10 – 14 illustrate the vehicle charging behavior of the Advanced Energy PEV Usage Study vehicles as a percentage of the total number of charge events recorded over a nine month period (January 2012 to September 2012).

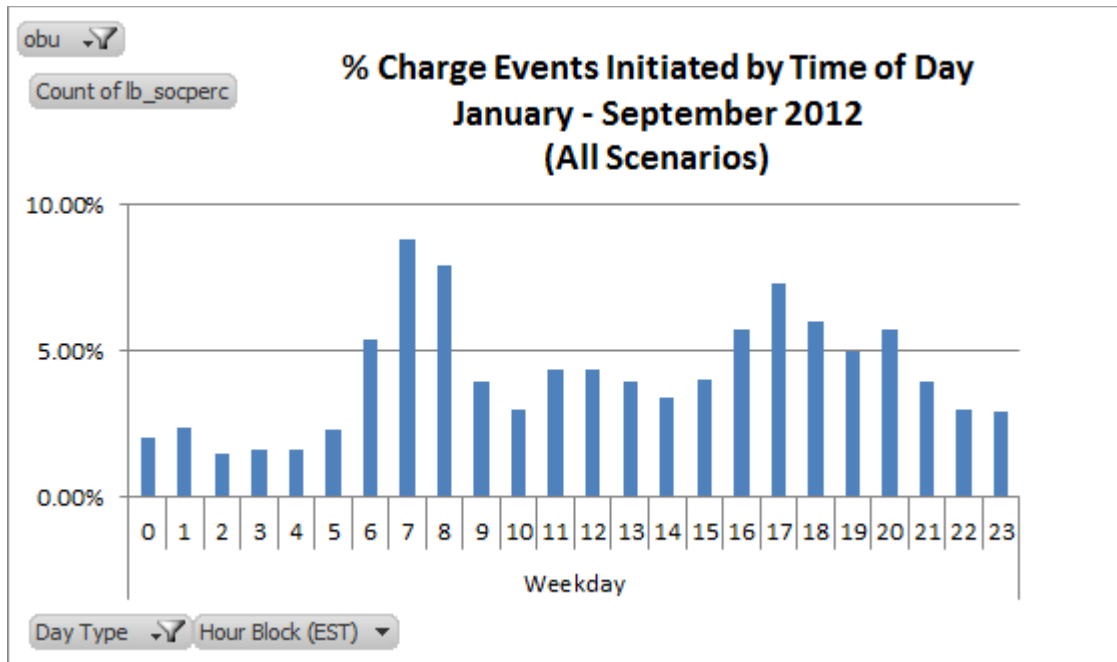


Figure 10. Percent of charging events initiated by time of day (all scenarios).

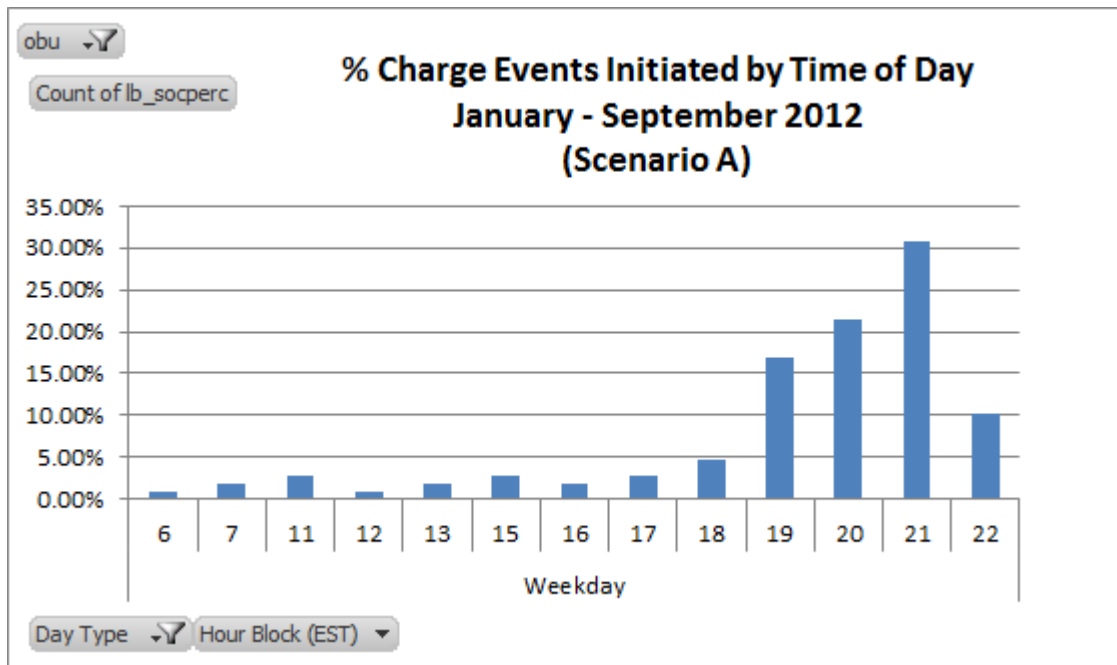


Figure 11. Percent of charging events initiated by time of day (scenario A).

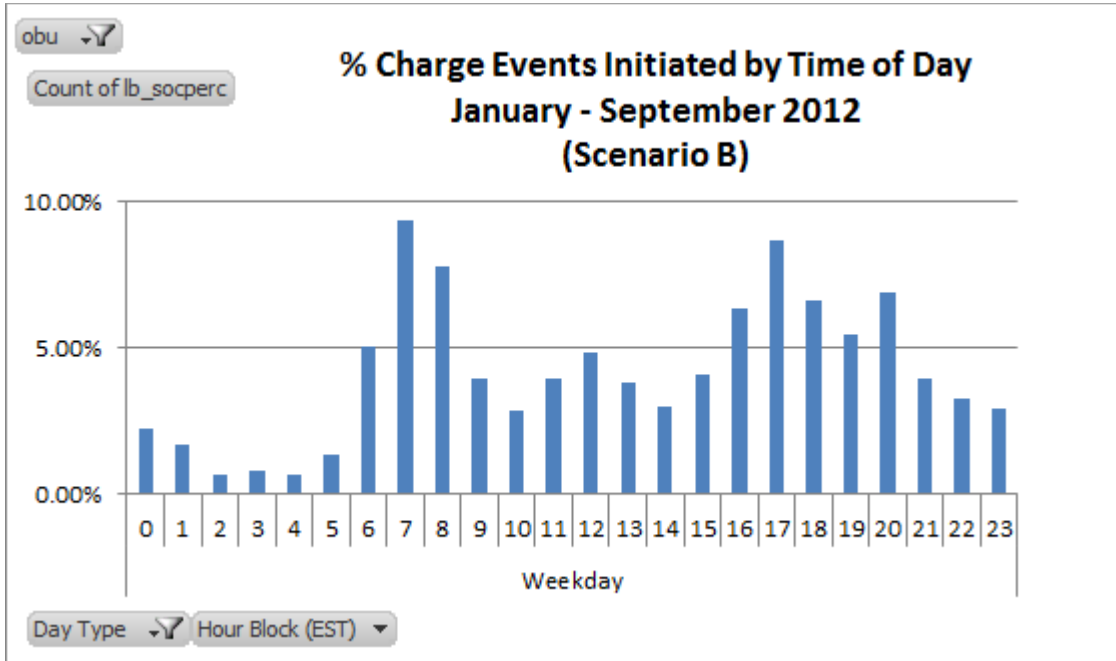


Figure 12. Percent of charging events initiated by time of day (scenario B).

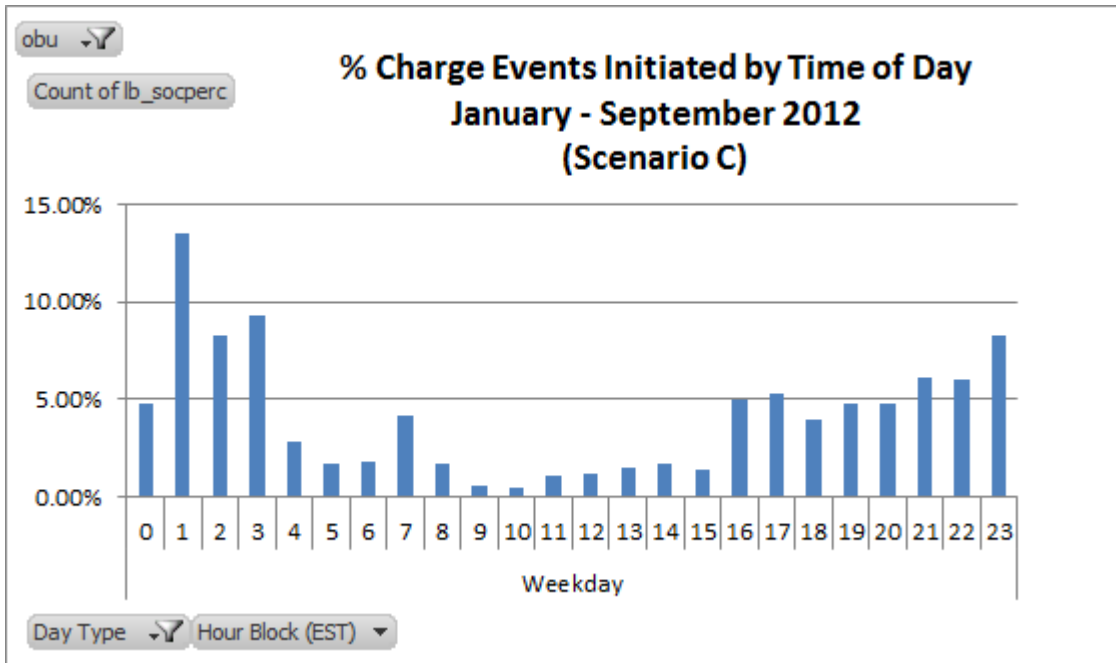


Figure 13. Percent of charging events initiated by time of day (scenario C).

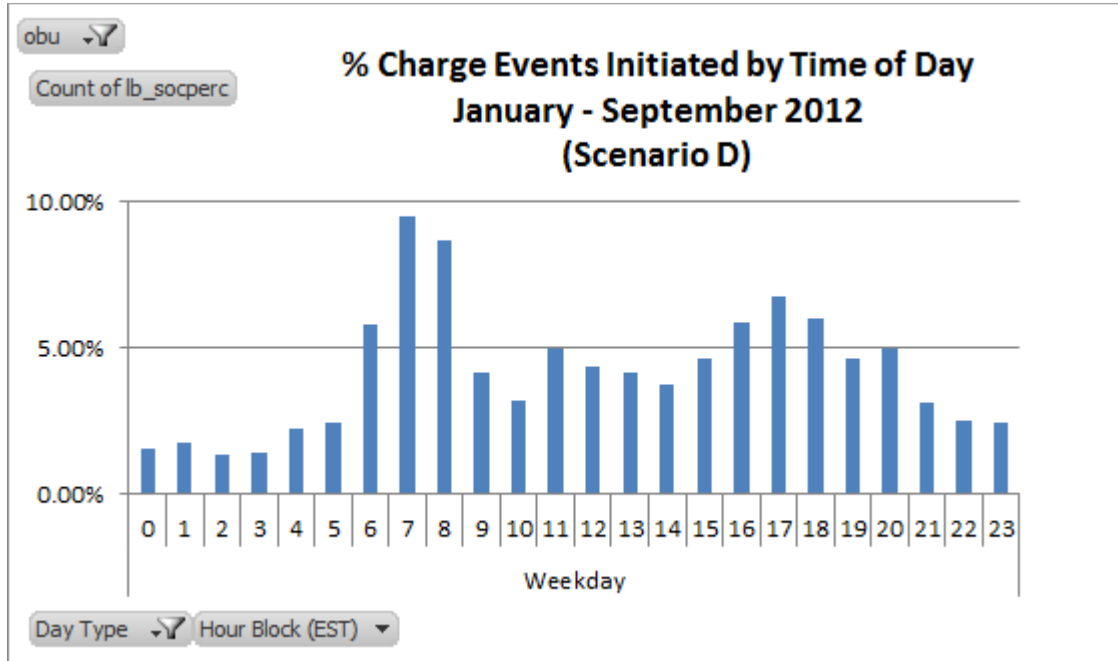


Figure 14. Percent of charging events initiated by time of day (scenario D).

The observed charging patterns of the different driver scenarios indicate that drivers with Level 1 or Level 2 charging at the workplace (scenarios B and D) initiated charging sessions more often in the early part of the day, 6am to 9am, when drivers are expected to be arriving at the workplace. Approximately 25 percent of charging incidences were initiated between these times for these groups. Conversely, less than five percent of charging incidents were initiated between the hours of 6am and 9am for drivers with no available access to workplace charging (scenarios A and C). These observations suggest that, where available, employees are utilizing workplace charging.

Battery State of Charge

An evaluation of the state of charge or “distance to empty” (DTE) displayed to the driver at initiation of each charge event helps identify the full vehicle miles needed for recovery and can indicate the level of confidence of drivers in maintaining an adequate charge. Figures 15 – 19 illustrate the charging behavior of Advanced Energy PEV Usage Study vehicles as an average DTE at charge start for the month of September 2012.

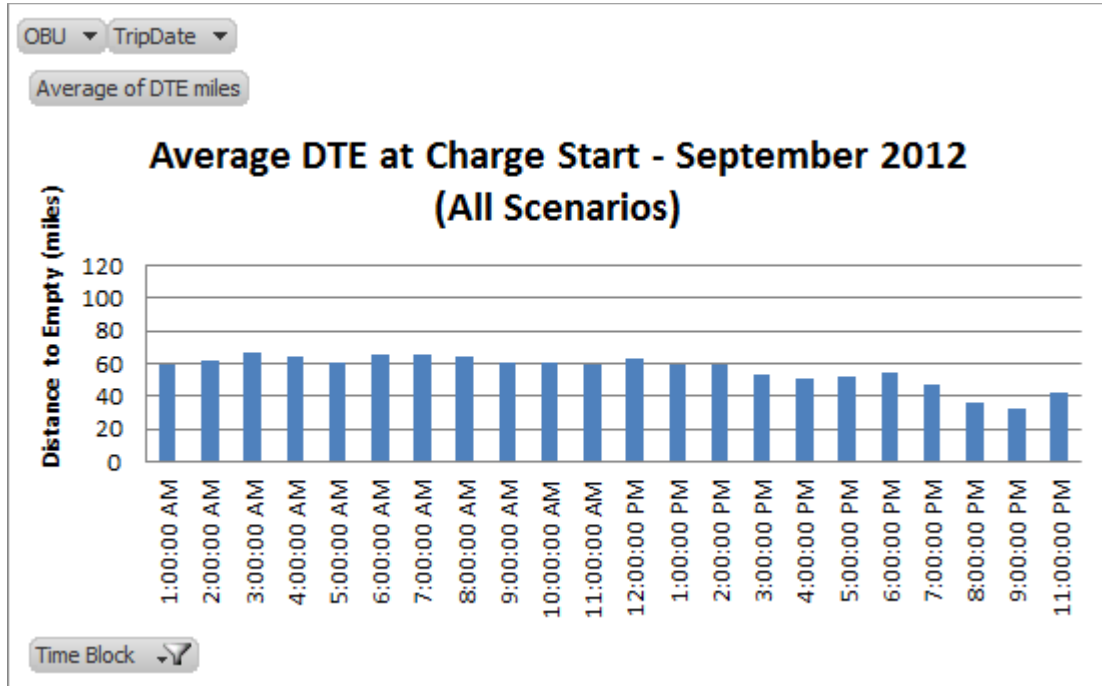


Figure 15. Average distance to empty (DTE) displayed at time of charge initiation (all scenarios).

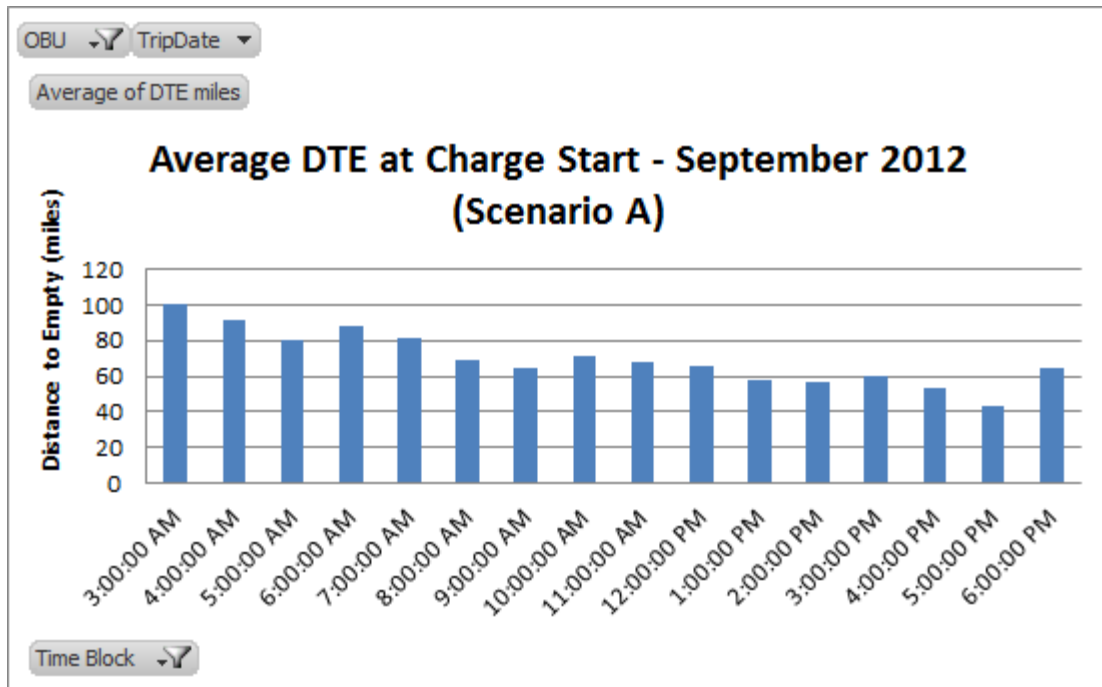


Figure 16. Average distance to empty (DTE) displayed at time of charge initiation (scenario A).

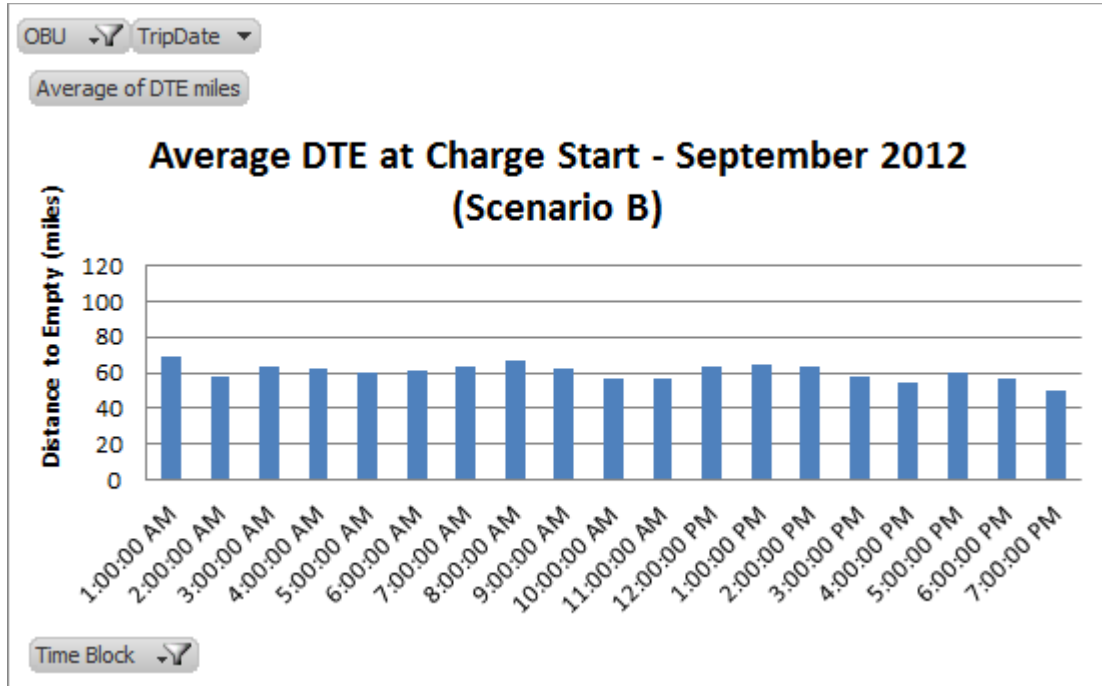


Figure 17. Average distance to empty (DTE) displayed at time of charge initiation (scenario B).

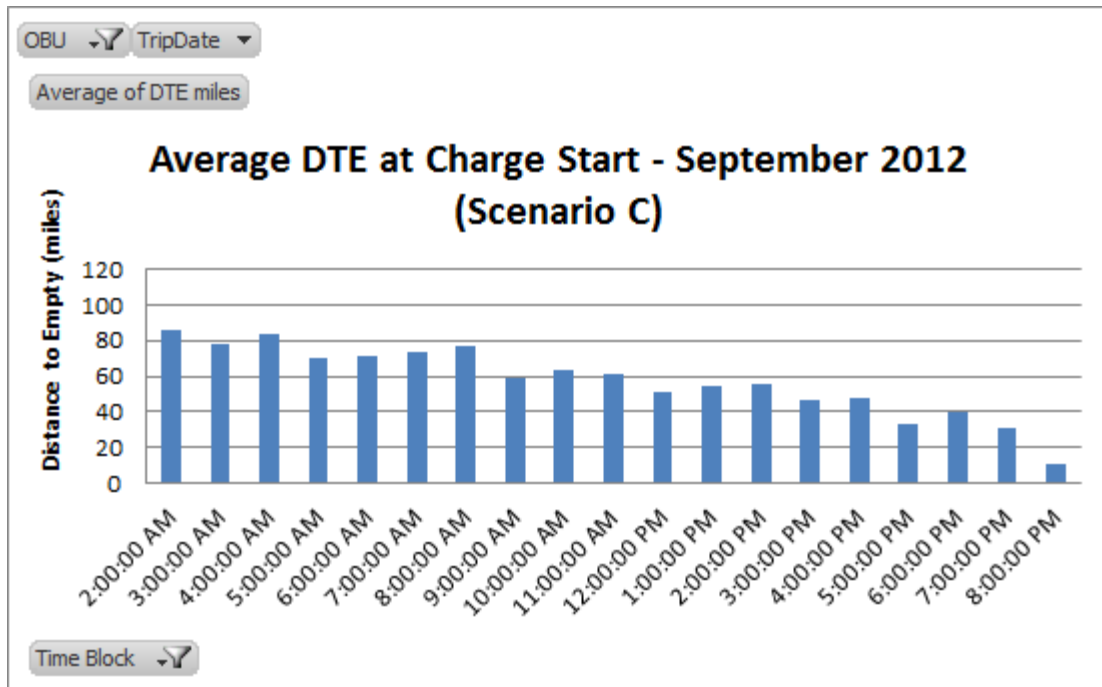


Figure 18. Average distance to empty (DTE) displayed at time of charge initiation (scenario C).

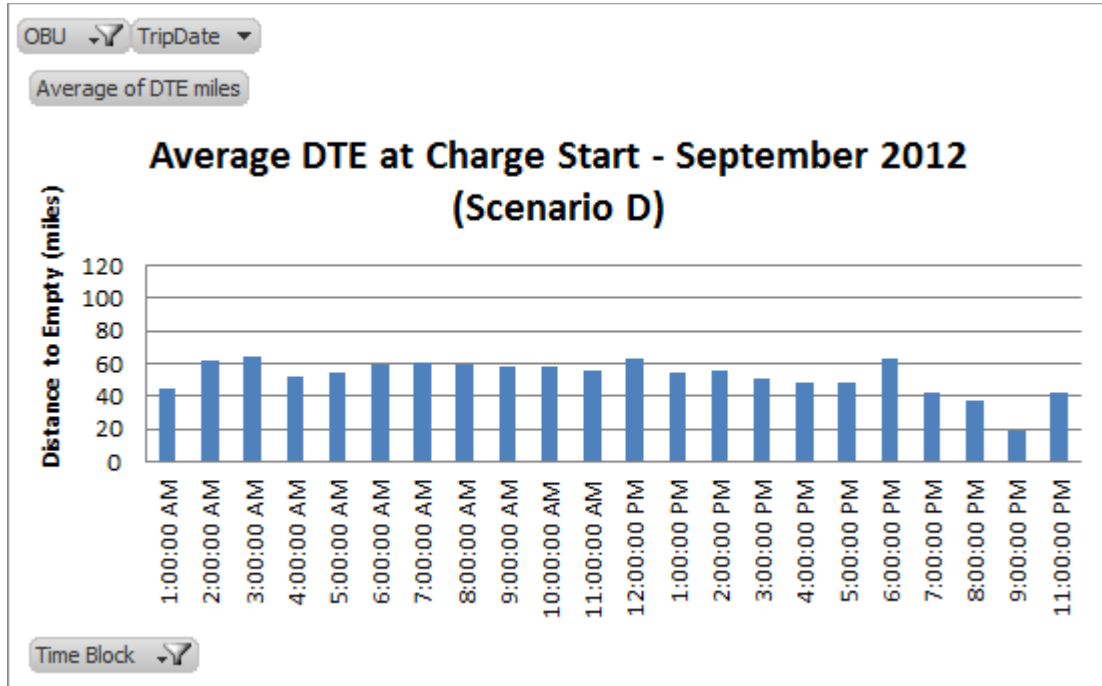


Figure 19. Average distance to empty (DTE) displayed at time of charge initiation (scenario D).

The recorded DTE displayed to drivers at the time of charge event initiation indicates that the average remaining miles for all vehicles was approximately 40. This equates to about 50 percent of the battery charge given a vehicle range of 76 miles per full charge. For all driver scenarios, the average DTE at the time of charge initiation between the timeframe of 6am to 9am was approximately 60 miles. This observation suggests that charging sessions initiated between the hours of 6am and 9am, the times when employees are expected to arrive at work, are opportunity charging events. Opportunity charging is giving the vehicle a (partial) charge whenever there is access to an electric outlet. For these vehicles, two- to- four hours of charge will fully replenish their battery; however, these charging events may not be necessary to complete their daily commutes. At the time of this report, drivers in scenario groups B and D had access to Level 1 or Level 2 charging at the workplace at no additional cost.

Instantaneous Demand

Understanding the charging profile of vehicle drivers and the impact to local grid reliability is a key concern for utility providers. Figures 20 – 21 identify the cumulative demand of Advanced Energy PEV Usage Study vehicles as maximum kW demand at each 15 minute interval over the course of one day.

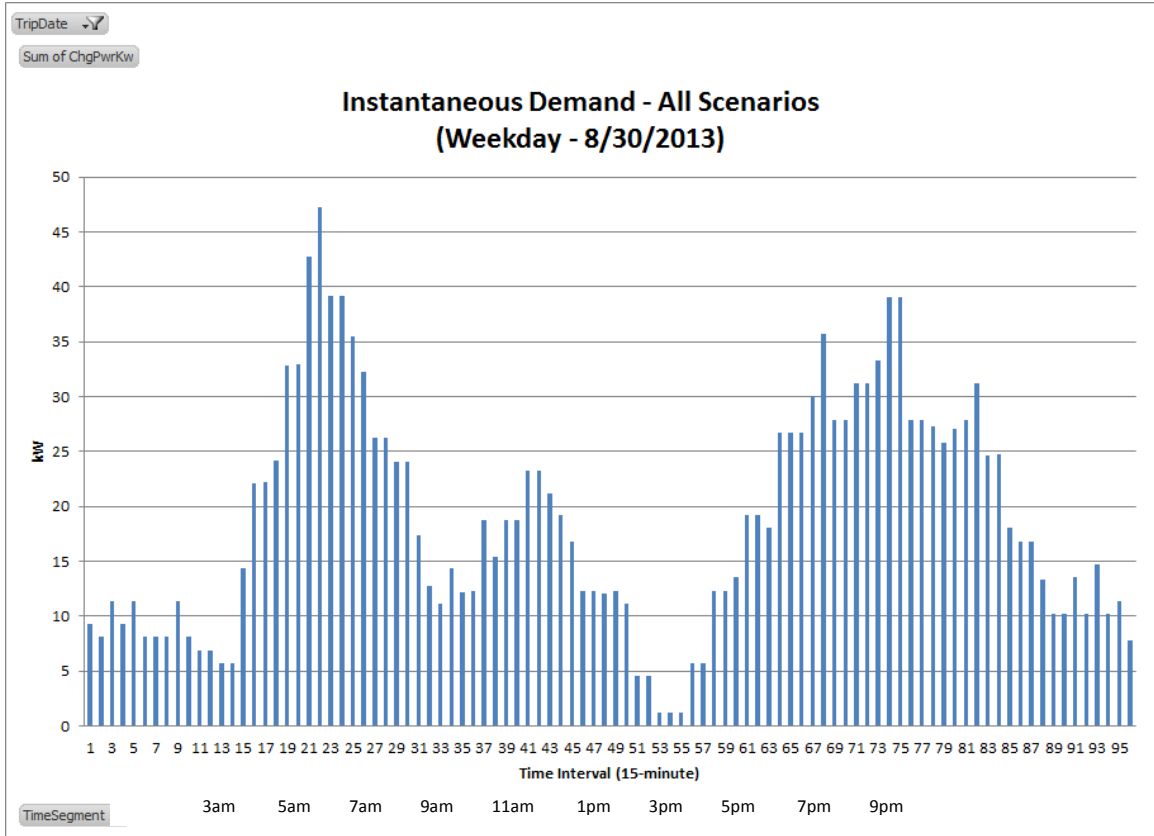


Figure 20. Instantaneous power demand of weekday charging events (all scenarios).

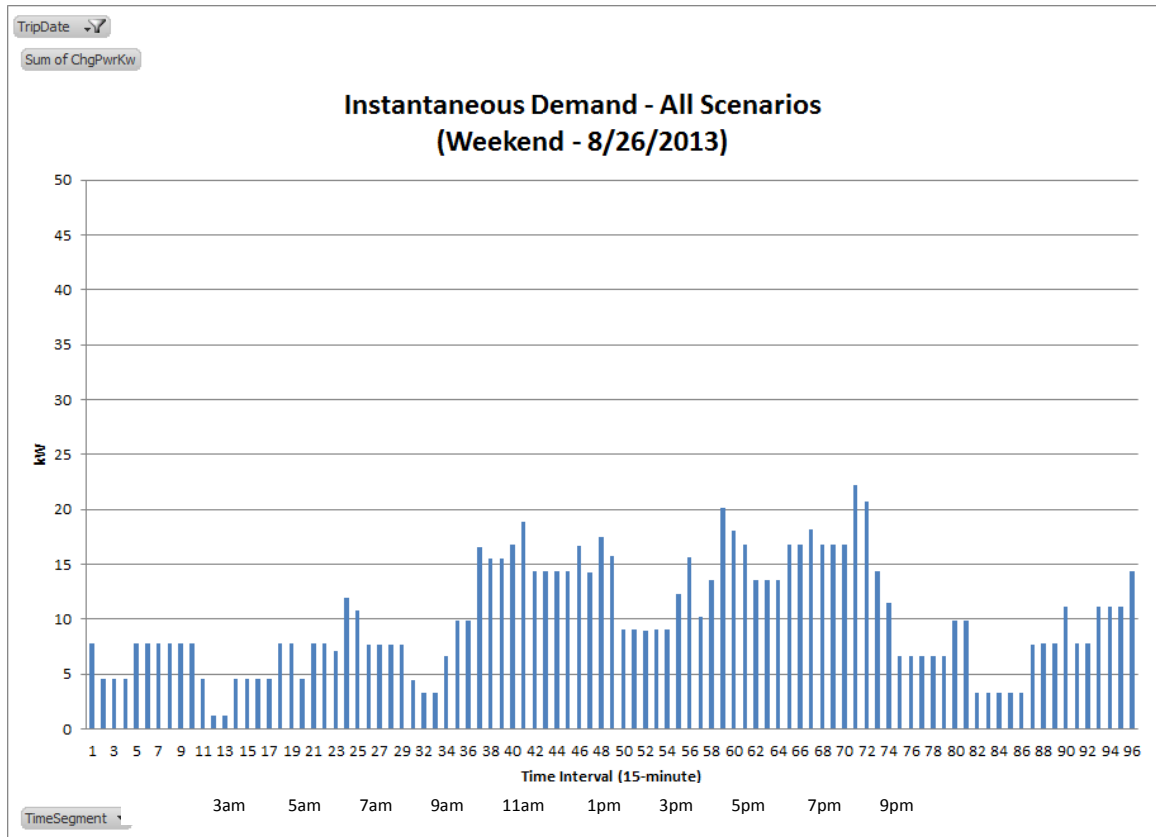


Figure 21. Instantaneous power demand of weekend charging events (all scenarios).

Evaluation of the instantaneous power demands of vehicles during weekday scenarios indicates a peak power demand of 47 kW between the hours of 5am and 6am, a second peak (23 kW) between 10am and 11am, and third peak (approximate 30 kW) between the hours of 5pm and 8pm. These observations indicate that, while a good percentage (25 percent) of charging sessions are initiated between the hours of 6am-9am (see Figure 20); simultaneous charging of vehicles occurs outside of this timeframe with demands above 30 kW occurring before and after the typical work hours (8am to 5pm). Conversely, weekend data indicates a more variable charging pattern with simultaneous charging occurring primarily between the hours of 9am and 5pm (Figure 21).

SUMMARY OF FINDINGS

Where available, employees are utilizing workplace charging. And, although workplace charging may not be essential for employee commutes to and from home, it does allow variability in travel patterns and can help alleviate range anxiety for new adopters of all-electric vehicles. Additionally, workplace charging can be a good way to promote PEV adoption, as vehicle clusters have already been noted. While instantaneous power demand appears to shift to the early morning hours for drivers with workplace charging, demand peaks are occurring outside of typical work hours and are less likely to impact utility demand charges. Defining a value proposition for employers may help overcome barriers to adoption of workplace charging infrastructure.

RECOMMENDATIONS FOR EMPLOYERS

As the PEV market continues to expand, employees will start to expect opportunities to charge at the workplace. Offering vehicle charging opportunities to employees not only benefits current employees, but can distinguish your company from competitors to attract and retain new employees. Additionally, providing alternative fueling opportunities can lend to Leadership in Energy and Environmental Design (LEED) points and add to your corporate sustainability efforts to highlight your commitment to social responsibility.

Through its work with the Blue Skies Corporate Campus project, Advanced Energy worked with corporate campuses in the Research Triangle Park, N.C. area to install workplace charging stations for employees. Case studies highlighting these efforts, from a corporate campus linking its corporate sustainability goals beyond direct business inputs and outputs by encouraging PEVs for its employees to how one company, by installing plug-in electric vehicle charging stations for employee use, demonstrated that employees, even those with longer-than-average commutes, can contribute to emissions reductions and decreased petroleum use through use of electric fuel, are available at Advance Energy's website.

For additional information on PEV readiness and workplace charging, please visit:

www.AdvancedEnergy.org/transportation/resources.

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