What Use Patterns Were Observed for Plug-In Electric Vehicle Drivers at Publicly Accessible Alternating Current Level 2 Electric Vehicle Supply Equipment Sites?

December 2015

Key Conclusions

- The average battery state-of-charge (SOC) at the start of charging at publicly accessible alternating current (AC) Level 2 electric vehicle supply equipment (EVSE) was 49% for Leaf drivers and 39% for Volt drivers.
- Most charging events at publicly accessible AC Level 2 EVSE concluded with the battery SOC over 80%.
- Charging data from The EV Project support the premise that most away-from-home charging at AC Level 2 EVSE is a "convenience" charge.

Introduction

The EV Project deployed over 4,000 AC Level 2 EVSE for drivers to charge their plug-in electric vehicles (PEVs) when away-from-home. The vast majority of these EVSE stations were installed to be available to all PEV drivers at publicly accessible locations. Some were also deployed for use at workplaces and for fleets. This paper only examines the use patterns of PEV drivers using the EVSE intended to be publicly accessible.

The user-based patterns for use of publicly accessible EVSE evaluated for this paper include the battery indicated SOC at the beginning and end of charge, the day of the week the charge took place, and the time of day when the charge took place. This evaluation is similar to that undertaken for direct current (DC) fast charging in the paper titled, "*What Were the Use Patterns Observed at the Highly Utilized Direct Current Fast Charge Sites?*".[1] However, unlike the DC fast charger (DCFC) used only by Nissan Leaf drivers, the AC Level 2 EVSE charge infrastructure supported both Leaf and Chevrolet Volt EV Project participants.

Data Analyzed

Although the EVSE could be used by PEVs not participating in The EV Project and vehicles participating in The EV Project could use publicly accessible EVSE that were not part of the project, this analysis examines only the user-based conditions when the PEV was a participant in The EV Project and the EVSE was supplied by The EV Project.

This paper will also examine the use of AC Level 2 EVSE "sites." Sites are defined as locations where one or more EVSE units are installed. The average number of EVSE units per publicly accessible site was 2.58.

The Blink AC Level 2 provided by The EV Project provided use data that were collected by The EV Project, evaluated, and analyzed. The data evaluated for this paper were collected over the entire term of The EV Project from installation of the first publicly accessible AC Level 2 EVSE in April 2011 to the end of December 2013.

Discussion of Results

When Were the Publicly Accessible Alternating Current Level 2 Electric Vehicle Supply Equipment Used?

Data collected on charge events in The EV Project provided the time and day the charge took place. Examination of the day of the week the publicly accessible stations were used found that they were used uniformly throughout the work week for the Leaf, with less than 10% variation. The Volt showed more variation between the weekdays, with more charging toward the end of the week (e.g., Mondays were 30% lower than Fridays).

Drivers of both vehicles used publicly accessible charging infrastructure less frequently on weekends.

Figures 1 and 2 show the percentage of charge events occurring each day of the week for each vehicle type in the project, for all charge events that occurred at public EVSE.

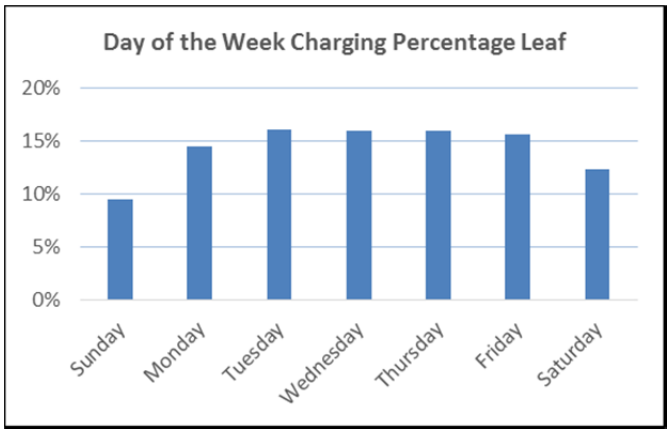

Figure 1. Day of the week when publicly accessible AC Level 2 EVSE were used by Leaf drivers.

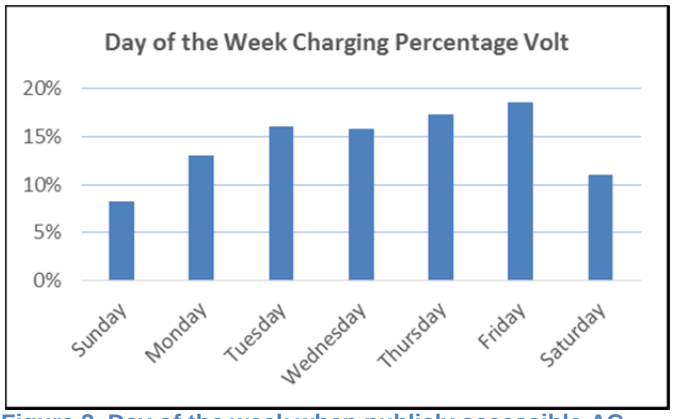

Figure 2. Day of the week when publicly accessible AC Level 2 EVSE were used by Volt drivers.

Further investigation regarding the time of day these EVSE were used shows that the Leaf is most frequently charged at the beginning of the work day (Figure 3). Above average use at lunchtime and at the end of the workday is also indicated. This suggests that the Leaf driver plugs in as soon as they arrive at their destination.

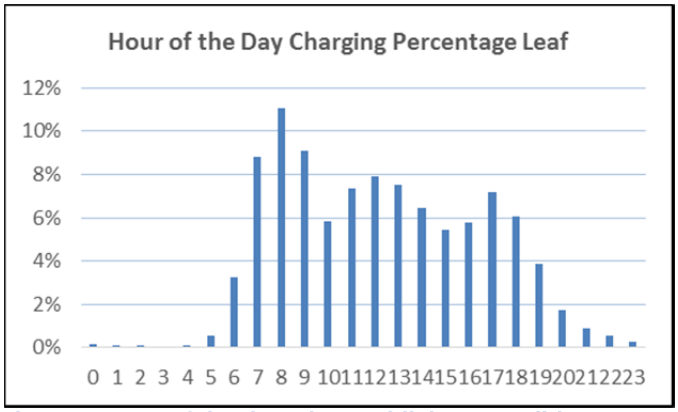

Figure 3. Hour of the day when publicly accessible AC Level 2 EVSE were used by Leaf drivers.

Similarly, Volt drivers charge most frequently at the beginning of the day, but not as distinctly as with the Leaf (Figure 4). Volt drivers charged more uniformly throughout the day (0700 to 1600) and their lunchtime charging frequency was very nearly the same as the early morning.

Drivers of both vehicles rarely initiate their away-from-home charging before 6 a.m. or after 7 p.m.

What was the Battery's State-Of-Charge When the Frequently Used Alternating Current Level 2 Electric Vehicle Supply Equipment Were Used?

As stated in the DCFC use patterns paper (Reference 1), the commonly held assumption is that fast charging is done out of necessity, while away-from-home AC Level 2 charging is done when a charging station is available at or near where the PEV driver parks. Put another way, DCFCs are oftentimes a charging destination, while AC Level 2 charging is done when convenient to a destination.

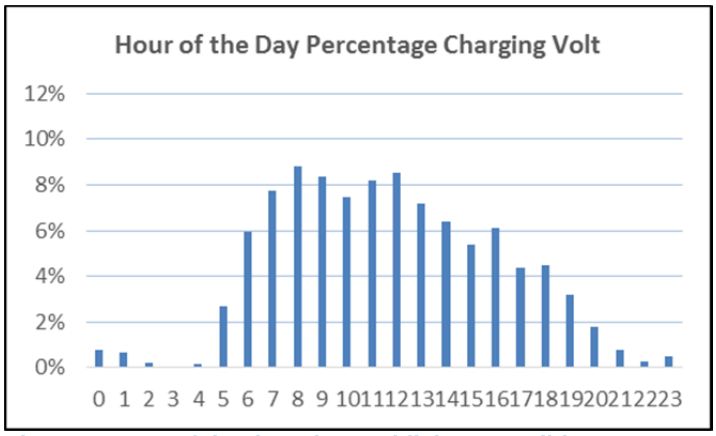

Figure 4. Hour of the day when publicly accessible AC Level 2 EVSE were used by Volt drivers.

Figure 5 shows that this is the case because SOC at the start of AC Level 2 charging (i.e., All Away from Home) is notably higher than it is for DCFC.

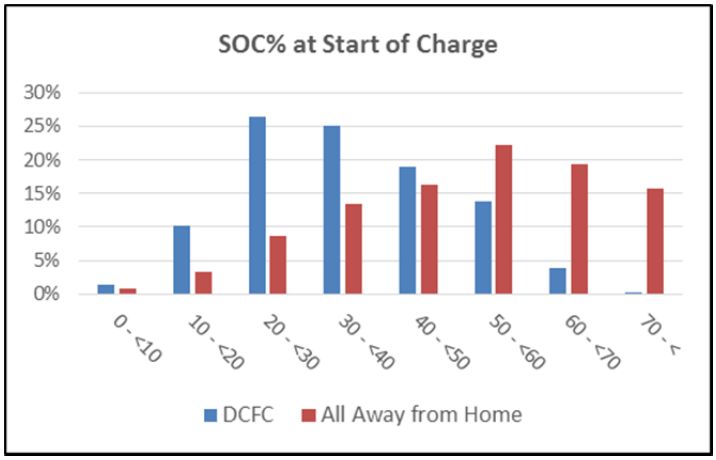

Figure 5. Percentage of away–from-home charging (y-axis) that takes place at SOC% range (x-axis).

The y-axis in Figure 5 is the percentage of all charging represented by the range of SOC% at the start of the charge. In fact, the average SOC at the start of AC Level 2 charging at publicly accessible sites is 49% for Leafs and 39% for Volts. The 50% larger battery capacity for the Leaf, as well as the shorter average daily distance they are driven, will account for most of this difference in initial SOC.

Another factor in understanding how publicly accessible EVSE are used is the battery SOC at the end of the charge. A PEV driver who is truly charging when convenient may choose to charge even when getting just a partial re-charge. Figures 6 and 7 show the SOC% at the end of charge for Leafs and Volts.

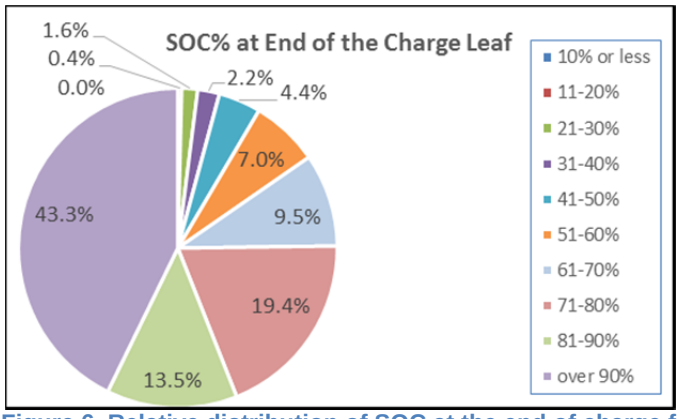

Figure 6. Relative distribution of SOC at the end of charge for AC Level 2 charging of a Leaf.

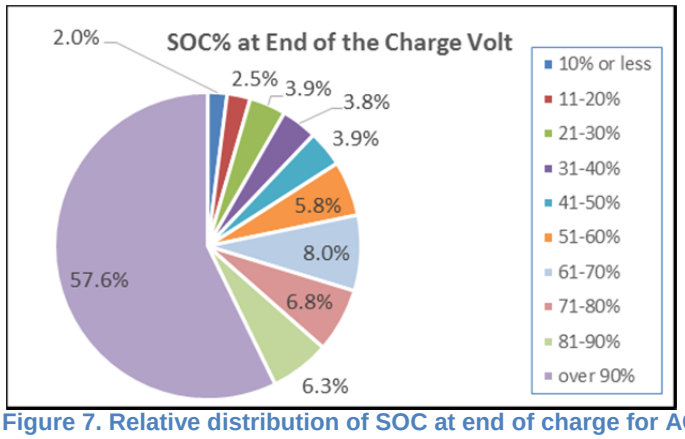

Figure 7. Relative distribution of SOC at end of charge for AC Level 2 charging of a Volt.

Data suggest that the majority of vehicles charge to a full charge when using the publicly accessible EVSE. The large percentage of Leafs charging to 80% SOC is most likely due to the vehicle's full charge default being set to 80, which the Leaf driver must change to 100% if desired.

Although the majority of charges go to full charge, nearly half of the charge events end below a full charge, supporting the convenience aspect of away-from-home charging at publicly available sites.

Figure 8 shows the same data as seen in Figures 3, 4, 6, and 7, but on a single bar chart. The 80% SOC for Leafs can be seen, as well as the distribution of initial SOC%, which, although averaging nearly 50%, has many occasions greater than 50% SOC at the start of the charge events.

How Did Use Patterns for Alternating Current Level 2 Electric Vehicle Supply Equipment Compare to How the Direct Current Fast Chargers Were Used?

A similar analysis of use patterns was done for DCFC. The results of these analyses reinforce the premise that the AC Level 2 chargers available to the public are used when convenient to other activities.

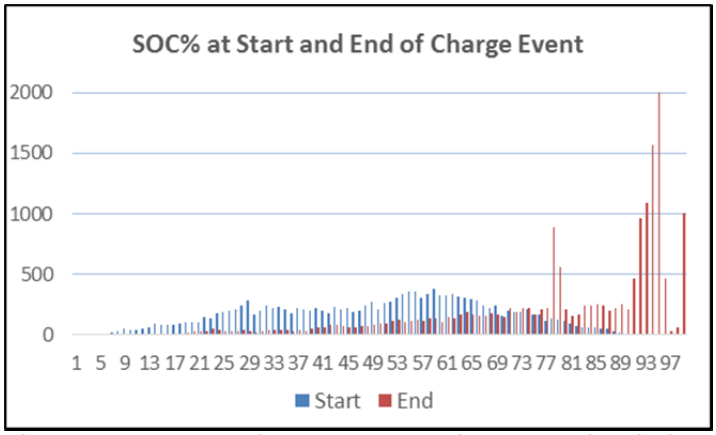

Figure 8. Frequency of percent SOC at the start and end of Leaf AC Level 2 charge events.

When compared to DCFC use patterns, AC Level 2 use occurs most often early in the work day, while DCFC use is done more frequently at the end of the work day. When charging with publicly accessible AC Level 2 EVSE, the SOC% at the start of the charge is significantly higher than it is for DCFC. This can be best demonstrated with SOC% data on the Nissan Leaf, because it can be charged with either AC Level 2 EVSE or DCFC. The average SOC% of the Leaf battery when a charge is initiated at an AC Level 2 EVSE is about 40% higher than the average SOC% at the start of DCFC use (i.e., 49% SOC for AC Level 2 and 35% for DCFC).

Conclusions

The patterns of use for The EV Project's publicly available AC Level 2 EVSE demonstrated that PEV drivers charge their vehicles in locations where it is convenient to their other activities and they begin charging as soon as the destination is reached. AC Level 2 charging is also initiated regardless of battery SOC.

About The EV Project

The EV Project was the largest PEV infrastructure demonstration project in the world, equally funded by the United States Department of Energy (DOE) through the American Recovery and Reinvestment Act and private sector partners. The EV Project deployed over 12,000 AC Level 2 charging stations for residential and commercial use and over 100 dual-port DCFCs in 17 U.S. regions. Approximately 8,300 Nissan LEAFs™, Chevrolet Volts, and Smart ForTwo Electric Drive vehicles were enrolled in the project.

Project participants gave written consent for EV Project researchers to collect and analyze data from their vehicles

and/or charging units. Data collected from the vehicles and charging infrastructure represented almost 125 million miles of driving and 4 million charging events. The data collection phase of The EV Project ran from January 1, 2011, through December 31, 2013. Idaho National Laboratory is responsible for analyzing the data and publishing summary reports, technical papers, and lessons learned on vehicle and charging unit use.

Company Profile

Idaho National Laboratory is one of DOE's 10 multi-program national laboratories. The laboratory performs work in each of DOE's strategic goal areas: energy, national security, science, and the environment. Idaho National Laboratory is the nation's leading center for nuclear energy research and development. Day-to-day management and operation of the laboratory is the responsibility of Battelle Energy Alliance.

For more information, visit avt.inl.gov/evproject.shtml and avt.inl.gov/chargepoint.shtml.

References

1. "What Were the Use Patterns Observed at the Highly Utilized Direct Current Fast Charge Sites?" http://avt.inel.gov/evproject.shtml.

2. "What were the Cost Drivers for Publicly Accessible Charging Installations?" http://avt.inel.gov/evproject.shtml.