Analyzing Public Charging Venues: Where are Publicly Accessible Charging Stations Located and How Have They Been Used?

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Key Conclusions

- The majority of the alternating current (AC) Level 2 charging stations discussed in this paper was located at retail locations and parking lots/garages.
- Direct current (DC) fast chargers (DCFCs) were not broadly distributed across venue categories; they only existed at eight types of venues. Most of the venues showed similar use ranges. This indicates that the venue may not be drawing the customers to DCFCs.
- The workplace venue was the most utilized venue for Level 2 electric vehicle supply equipment (EVSE). People are likely to use Level 2 charging infrastructure for longer periods of time while they are working.
- All DCFC venues had a median average of 4 to 7 charging events per week per site. All Level 2 EVSE had a median average of 9 to 38 charging events per week per site. DCFCs only require approximately 30 minutes to charge a vehicle; therefore, it's expected that they would have a higher number of daily charging events.
- EVSE sites were not evenly distributed across venues. If a venue contained a small number of EVSE sites, there may not have been enough data to accurately describe potential usage.
- Data presented in this paper were collected at the beginning of electric vehicle adoption across the United States. Also, charging infrastructure was being deployed throughout the data collection effort. Because the number of vehicles increased as the number of available EVSE increased, this paper demonstrates the potential for each venue, but it may not accurately describe a mature market.

Why Venues?

Stakeholders interested in providing AC Level 2 EVSE units and DCFC are looking to Idaho National Laboratory (INL) to analyze data collected from Blink, ChargePoint, and AeroVironment EVSE installed around the United States as part of plug-in electric vehicle charging infrastructure demonstrations. Many stakeholders are considering supporting the emerging electric vehicle market by installing or funding EVSE. They have asked where the best locations are to install public charging stations and how the EVSE will be used in those locations. Data collected by INL can provide insight regarding real-world usage of EVSE at various locations.

Defining the "best" location for EVSE is a complex undertaking. Businesses, government agencies, and other organizations have many reasons for providing EVSE; therefore, their definition of the "best" location for EVSE varies. Some are concerned with installing EVSE where it will be highly used and provide a return on investment. This return may come in the form of direct revenue earned by fees for EVSE use, or indirectly by enticing customers to stay in their businesses longer while they wait for their vehicle to charge, or by attracting the plug-in electric vehicle driver customer demographic. Other organizations have non-financial interests, such as supporting reduction of greenhouse gas emissions or petroleum reduction or furthering other sustainability initiatives. Others install EVSE to boost their public image. Additionally, employers provide them as a benefit to attract employees [1].

Furthermore, characterizing an EVSE location is not straight forward. First, the immediate vicinity surrounding the EVSE, referred to in this paper as the venue, may influence EVSE usage. Other aspects of location may also contribute to an EVSE site's popularity (or lack thereof), such as the site's geographic proximity to a large business district or an interstate highway. The general location of the EVSE site, such as the part of town, city, or region where it is located, may also influence its use.

To begin addressing these factors, this paper presents a simple analysis of EVSE usage by venue to provide a basic comparison of how public charging units are used in different locations. This paper uses two simple metrics to quantify EVSE usage at different venues and identifies whether EVSE at some venues were consistently used more than EVSE at other venues.

Venues Described

Blink, ChargePoint, and AeroVironment's publicly accessible charging sites containing EVSE that reported usage data to INL were given a primary venue classification. This venue classification is a coarse classification that gives a broad definition of the site location and provides a general perspective on the reason a plug-in electric vehicle driver would be utilizing that location. Primary venue categories were chosen to be compatible with other plug-in electric vehicle charging infrastructure demonstrations [2]. Future white papers will subdivide the primary venues into sub-venues that provide more detail about each primary venue. Descriptions of the primary venue and sub-venue classifications are provided in the whitepaper "Categorizing EVSE Venues: Describing Publicly Accessible Charging Station Locations" [3].

Which EVSE are Being Studied?

This report presents findings from data reported to INL by publicly accessible Blink AC Level 2 EVSE and DCFC in The EV Project, ChargePoint Level 2 EVSE in the ChargePoint America Project, and AeroVironment Level 2 EVSE and DCFC on The West Coast Electric Highway in Washington State and Oregon. EVSE were grouped by site to facilitate analysis by venue. An EVSE site is a location where one or many EVSE were available for use. Sites discussed herein were comprised of as few as one and as many as 18 EVSE. EVSE sites were not evenly distributed geographically across the United States.

This study only included EVSE sites that averaged more than three charging events per week and were publicly available. There were many reasons a site averaged less than three charging events per week. EVSE at underperforming sites may have had erroneous location data, were broken, logged data incorrectly, or were poorly located.

The first 4 weeks of usage of EVSE at a site were not included in the calculation of performance metrics for that site. This provided a grace period to allow plug-in electric vehicle drivers time to discover the charging site. The subset of data chosen for this research was restricted between September 1, 2012, and December 31, 2013. This period of study was chosen because much of the infrastructure was in place by September 1, 2012, and data collection ended for two of the EVSE brands on December 31, 2013.

The results presented within this paper are divided into two sections based on EVSE type: (1) AC Level 2 and (2) DCFC. Normally, plug-in electric vehicles connected to AC Level 2 EVSE have a charge rate of 3.3 to 6.6 kW. Most DCFC are designed to provide a charge rate up to 50 kW. This results in dramatically different charging times. Because usage of the two EVSE types varies, it is necessary to analyze their usage separately.

Which Venues Have the Most Highly Used EVSE?

Alternating Current Level 2 EVSE

AC Level 2 EVSE are less expensive to produce, install, and operate than DCFC. As a result, there are more Level 2 EVSE sites than DCFC sites. Also, most Level 2 EVSE sites were installed before DCFC in the infrastructure demonstrations being studied; therefore, they had more opportunity to be discovered and utilized. Conceptually, Level 2 EVSE are more likely to be used in places where people park for significant amounts of time. People charging at Level 2 sites likely utilize the amenities that the venue has to offer. In fact, it is expected that they park at that venue with a primary purpose other than charging their vehicles, such as visiting a business or facility at that location.

Figure 1 categorizes the 774 public AC Level 2 sites in this study into primary venues. Over 89% of the sites were contained within six venue types, including retail, parking lots/garages, workplace, public municipal, education, and medical. The retail and parking lots/garages venues contained over 45% of all Level 2 sites.

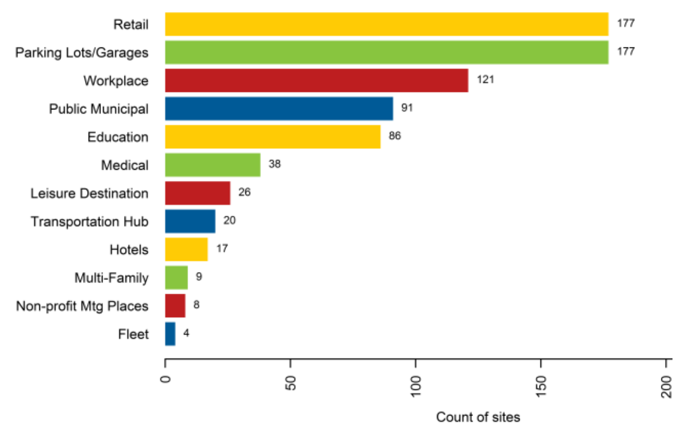

Figure 1. Level 2 EVSE sites categorized by their primary venue. The number at the end of the bar indicates the number of sites within that venue type.

The average number of charging events performed per week at each site was calculated as a measure of site usage frequency over the study period (excluding the first 4 weeks of operation). Figure 2 shows the distribution of the average number of charging events per week per site for each venue category.

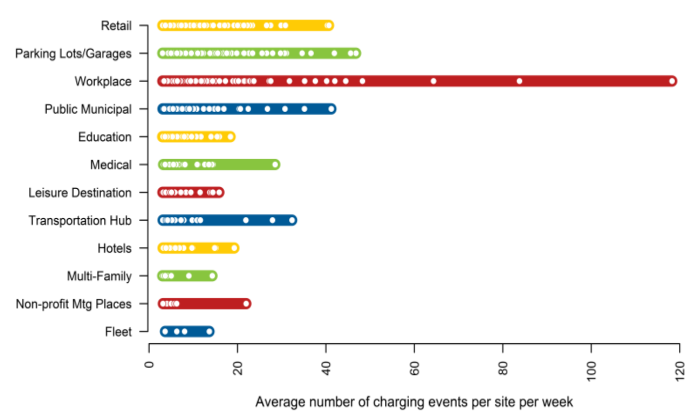

Figure 2. The distribution of average charging events per week per site. Each site's average number of charging events is displayed using a white circle. This figure depicts the range and distribution of usage frequency at sites within each venue type.

The white circles in Figure 2 represent each site's average charging frequency. The range is shown by the colored bar. For example, the site with the greatest number of average charging events per week at retail venues averaged 40 average events per week. Alternatively, the site with the lowest number had three average charging events per week. This means the range in the retail venue was 3 to 40 average charging events per week.

All charging events performed using any EVSE installed at a charging site were included in the calculation of average charging frequency for a site. For example, the top seven workplace sites averaged over 40 charging events per week or over six events per day. These sites all have at least four Level 2 EVSE. On many days, multiple EVSE at each site were used on the same day. It would have been difficult to achieve such high usage frequency at these Level 2 sites if they only contained one EVSE.

For each venue type, the distribution of site average charging frequency was skewed to the left, meaning that most sites did not experience much usage. The median average number of charging events ranged from four to seven events per week. This means that more than 50% of all charging sites averaged less than seven events per week. Also, 75 to 100% of the sites for each venue type had usage frequency that fell between three and 14 charging events per week. Because there was so little difference in median usage frequency from venue type to venue type and the bulk of the sites all fell within the same range, it is not possible to say that charging sites of a certain venue type were consistently used more than sites at other venue types.

Another way to measure charging site usage is by calculating the average energy consumed per week per site. Figure 3 details the distribution of the average energy consumed per week per site for each venue type.

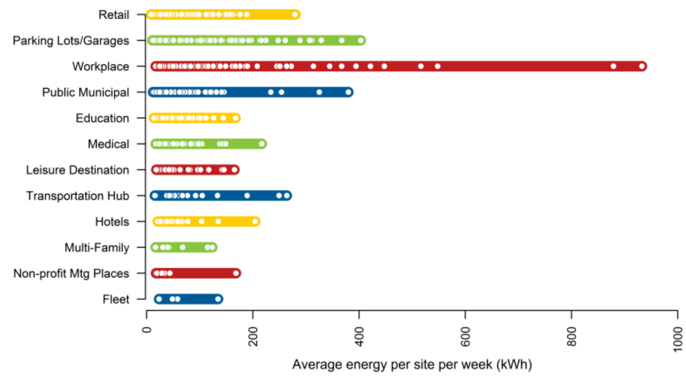

Figure 3. The distribution of average energy used per week per site. Each site's average energy value is displayed using a white circle. This figure demonstrates the range and distribution of energy consumed at sites within each venue type.

Figure 3 provides the range of average charging energy used per week per site. The white circles represent each individual site's average energy per week. Both the number of charging events and the energy used at sites are important measures of usage. However, Figures 2 and 3 show that the overall distribution does not change between the two different metrics. Therefore, in this paper it is reasonable to use either energy or charging frequency to represent usage.

Figures 2 and 3 both show a relatively small number of sites that are highly used. These outliers demonstrate the potential for high usage at sites in numerous venue categories, namely, retail, parking lots/garages, workplace, and public/municipal. Similar potential may exist at sites within other venue types, but it is not possible to determine in this study because of the low number of sites within several venue types. The top 10 sites with respect to charging frequency were located at workplace and parking lots/garages venues.

Direct Current Fast Chargers

DCFC typically can charge an electric vehicle (such as the Nissan Leaf) to 80% state of charge in about 30 minutes. In this way, DCFC are useful for quickly extending the range of battery electric vehicles. Individuals charging via DCFCs may be parking at the location specifically to charge at the DCFC and are not necessarily using the amenities offered by the DCFC venue. Many DCFC have repeat daily and weekly users.

DCFC technology was introduced to market later than AC Level 2 EVSE in the demonstrations being studied. They were also more expensive to deploy than Level 2 EVSE. Site selection was more difficult because high-power DCFC has electrical service requirements that cannot be met at some facilities. As a result, during the study, there were significantly fewer DCFC and their venue distribution was less varied than that of the Level 2 EVSE.

DCFC data in this study were collected from AeroVironment and Blink units. There were 102 DCFC sites containing more than three average charging events per week. Similar to Level 2 EVSE, there were not an equal number of DCFC sites within each venue category. Figure 4 shows the distribution of DCFC sites with respect to venue. The retail venue contains 62% of all deployed DCFC.

Figure 5 shows the average number of charging events per week per site for DCFC sites by venue. The site with the most usage is at a workplace venue. However, the ranges of charging frequency between sites for venue types having more than two sites are similar.

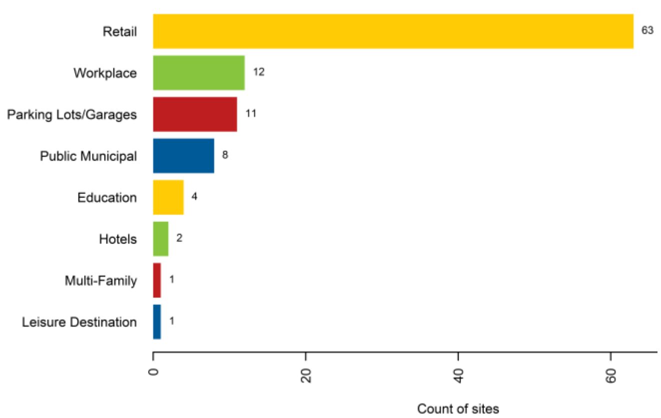

Figure 4. The number of DCFC sites per primary venue. The number at the end of the bar indicates the number of sites within that venue type.

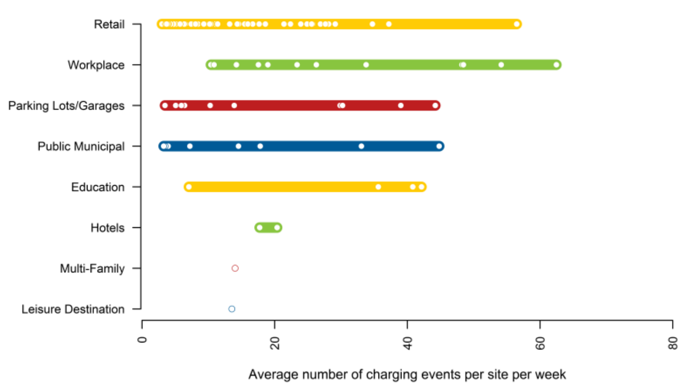

Figure 5. The distribution of average charging events per week per site. The white circles represent each site's average number of charging events per week. This figure depicts the range and distribution of usage frequency at sites within each venue type.

DCFC utilization ranged from three charging events to just over 60 per week. Workplace DCFC saw the greatest number of charging events per week. Median values for Figure 5 range from 9 to 38 events per week. This is a much larger spread than was seen for Level 2 EVSE sites. Workplace and education venues had the highest median charging frequency at 25 and 38 events per site per week, respectively. However, there is still considerable overlap between the range of average charging frequency at these sites and sites within other venue types.

Figure 6 presents the average energy usage per week per site for each venue type. When measured by energy use, the top retail venue used nearly as much energy as the top workplace venue. This demonstrates that the two venues have similar potentials for usage.

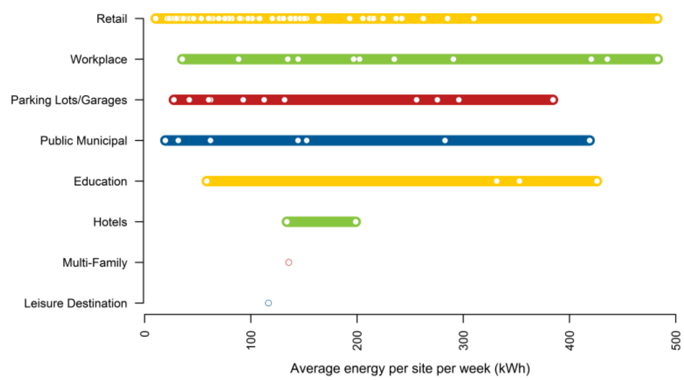

Figure 6. The distribution of average energy used per week per site. The white circle represents each site's average energy used per week. This figure demonstrates the range and distribution of energy consumed at sites within each venue type.

Future Work

This paper provides a simple description of usage across venues. Future papers will provide more detailed analysis regarding each specific EVSE site venue type. To understand how EVSE might be used at a venue, it is necessary to look at more specific metrics, such as total time used, time of day used, and more information about the site locations. Another future topic will determine if sites that contained both AC Level 2 and DCFC EVSE were utilized differently than those with only one type of EVSE available.

About The EV Project

The EV Project was the largest plug-in electric vehicle 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 public use, as well as over 100 dual-port DCFCs. Approximately 8,300 Nissan LEAF™, Chevrolet Volts, and Smart ForTwo Electric Drive vehicles were enrolled in the project.

Project participants gave written consent for The EV Project researchers at INL 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. INL is responsible for analyzing the data and publishing summary reports, technical papers, and lessons learned on vehicle and charging unit use.

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About ChargePoint America

ChargePoint America was led by ChargePoint, with American Recovery and Reinvestment Act funding support from DOE. The project deployed 4,700 residential and commercial charging stations in nine U.S. regions. The data collection phase of ChargePoint America ran from May 1, 2011, through December 31, 2013, and captured over 1.5 million charging events. INL is responsible for analyzing the data collected and publishing results.

About the West Coast Electric Highway

The West Coast Electric Highway is a network of electric vehicle AC Level 2 and DCFC located every 25 to 50 miles along Interstate 5 and other major roadways in the Pacific Northwest (i.e., Washington, Oregon, and California). It contains a large electric vehicle charging network with thousands of AC Level 2 stations and dozens of DCFCs [4].

Company Profile

INL 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. INL 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.

References

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3. "Categorizing EVSE Venues: Describing Publicly Accessible Charging Station Locations," http://avt.inl.gov/pdf/EVProj/CategorizingEVSEVenuesSept2014.pdf.

4. See the West Coast Electric Highway website at www.westcoastgreenhighway.com/electrichighway.htm