What are the early experiences in using DC Fast Chargers? August, 2013

When fully deployed, The EV Project will collect usage data on approximately 200 dual-port DC Fast Chargers (DCFC). A DCFC is a type of Electric Vehicle Supply Equipment (EVSE) that is designed to deliver direct current (DC) to an electric vehicle's (EV) on-board battery. DC "fast chargers" are defined for this document to be equipment that complies with the Society of Automotive Engineer (SAE) Rating Terminology of DC Level 2. For reference, DC Level 2 includes power ratings between 36 kW and 90 kW.

The Blink DCFC deployed by The EV Project is designed to deliver up to 60 kW power. The Nissan Leaf battery management system allows acceptance of up to 50 kW DC power. At this rate, the DCFC is capable of restoring a Leaf battery from a 30% state of charge (SOC) to an 80% SOC in about 25 minutes. To accomplish the same recharge, a typical AC Level 1 EVSE (1.6 kW) will require approximately 10 hours, and an AC Level 2 (3.3 kW or 6.6kW) EVSE would take approximately 3 - 5 hours, depending on the Leaf battery's acceptance capabilities. The Nissan Leaf is the only vehicle in The EV Project that is capable of accepting a DC charge.

There has been much written and said about the need for rapid recharging, but before the deployment of DCFC in The EV Project, little was known about how the actual EV drivers might respond to the availability of fast charging. This paper explores the early behavior of EV drivers as it relates to their utilization of the DC Fast Chargers.

Why is this important?

The first DCFC delivered for charging the current offering of electric vehicles was in Japan and provided by Tokyo Electric Power Company (TEPCO). There is an oft-cited anecdote that suggests that the mere deployment of a DCFC instilled greater range confidence in TEPCO employees driving EVs. Apparently, after DCFC units were deployed for use, simply knowing that the DCFC provided a rapid recharge in the event that they depleted their EV battery below their comfort level was sufficient. This conclusion was drawn because the DCFC equipment was rarely used. This prompted the question – will DCFC deployed in The EV Project have a similar effect and also go unused?

At the outset of the study, The EV Project anticipated that DCFC would be used for three primary purposes: 1) a backup for the local AC Level 2 publicly available infrastructure similar to that identified by TEPCO; 2) the primary charge strategy for those with an EV but no designated overnight charging location (for example, those in multi-unit dwellings or on-street parking); and 3) range extension along urban connectors and transportation corridors. All of these purposes could be important in the adoption of EVs by the broader United States population.

Free Charging

In order to encourage use, The EV Project did not charge fees for the use of DC Fast Chargers until June 2013. This provided the EV driver with the opportunity to evaluate the DCFC charging at no cost to see if or how it met their transportation needs. However, just as was true for the AC Level 2 infrastructure, there must be a business case for charging site hosts in order to support the widespread availability of away from home charging. Consequently, usage fees are being deployed throughout the EV Project study markets in late June and July 2013.

This paper considers the usage of DCFC observed up to this point.

DCFC Deployment and Utilization

For the purposes of this report and EV Project infrastructure utilization analysis overall, a plug-in event is defined as an event wherein a DCFC is connected to a vehicle for more than 10 seconds duration, during which energy is delivered to the Leaf. This would typically exclude demonstrations of connector plug-in techniques.

Deployment of DCFC units commenced in 2012, and the units were immediately used by Leaf drivers. Figure 1 shows the total number of plug-in events per week since August 2012. The figure also shows the total number of available DCFC (black dots) that were used during those weeks.

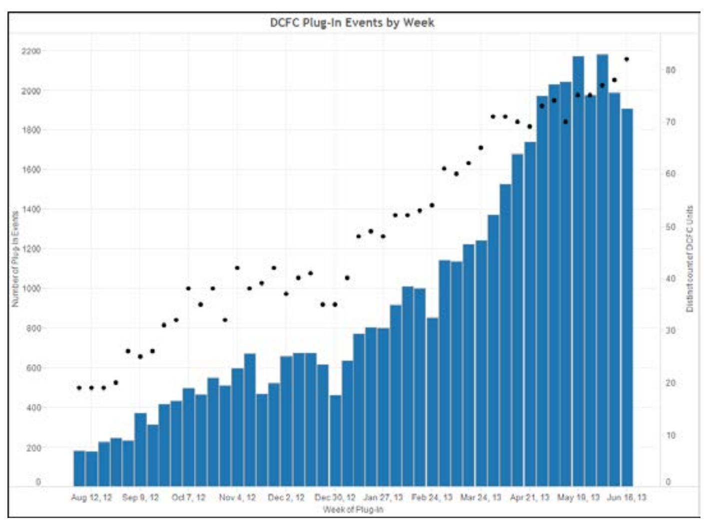

Figure 1. DCFC Plug-In Events

The increase in usage in the most recent months may be due, in part, to the increased deployment of DCFC, the increased enrollment of Leaf drivers in The EV Project, and perhaps a growing utilization by Leaf drivers as their charging experience expands. Leaf sales have also increased in the past six months outside of The EV Project as well, so new drivers are being added. In June 2013, The EV Project was fully subscribed by vehicle participants, so the number of vehicles reporting in the project will be constant from the second calendar quarter of 2013.

The relative contribution to the plug-in events by DCFC in each study region of the EV Project since January 2013 is shown in Figure 2.

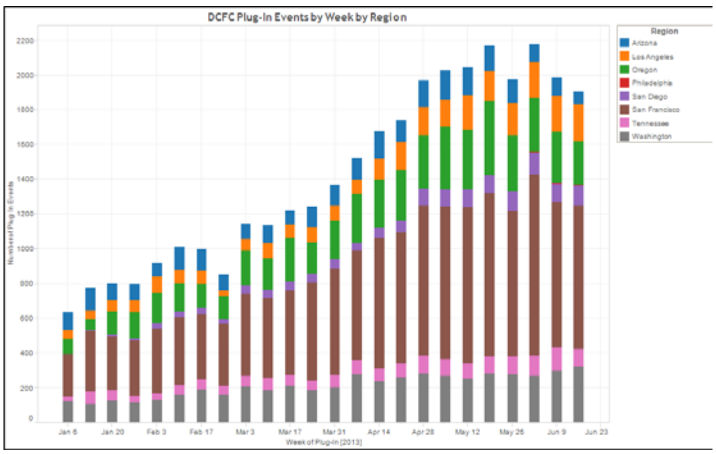

Figure 2. DCFC Plug-in Events by Week and Region

The large contribution by the DCFC in San Francisco is noticeable in Figure 2. This is indicative of the enthusiastic participation by both vehicle drivers and DCFC charging site hosts in this region. Figure 3 shows the number of EV Project DCFC deployed in each of the regions through the end of June 2013.

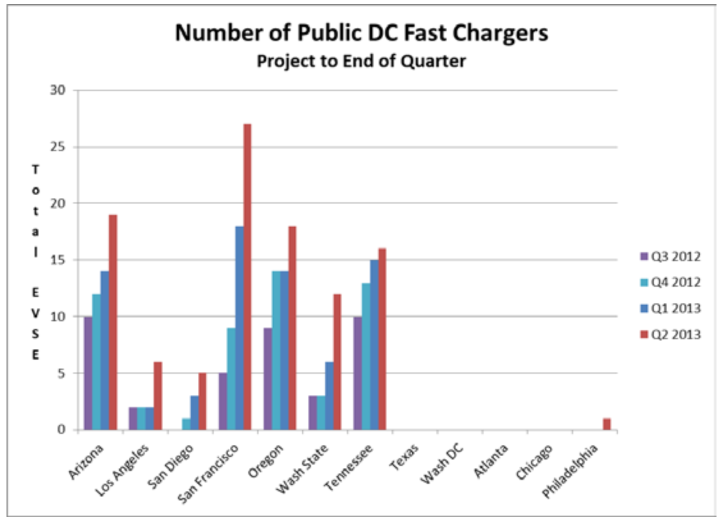

Figure 3. DCFC Deployment by Region

The number of DCFC and the number of plug-in events in each region vary considerably. In order to understand the relative usage in each region, the number of plug-in events between the beginning of April 2013 and the end of June 2013 was divided by the number of DCFC in the region at the end of this period. The results are shown in Figure 4.

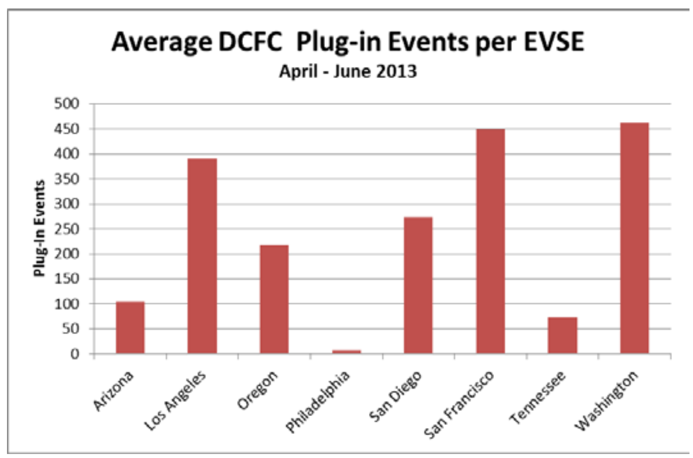

Figure 4. Average Plug-in Events per EVSE by Region

The high utilization per EVSE in Washington State and Los Angeles is interesting because of their relative low DCFC population. The high utilization per EVSE in San Francisco is also interesting because of its high population of DCFC. Approximately 100 of the planned 200 Blink DCFC have been deployed at the time of this writing.

EVSE Utilization

The number of plug-in events observed thus far is significant. Figure 5 provides a scatter diagram identifying for each DCFC, the number of plug-in events recorded vs. the number of weeks deployed. For example, there is a data point representing a specific DCFC near the 20 week horizontal axis and the 500 event vertical axis. This DCFC has received a total of 549 plug-in events since being deployed 21 weeks before this writing. The trend line shows an average of 16 plug-in events per week per DCFC since August 2012.

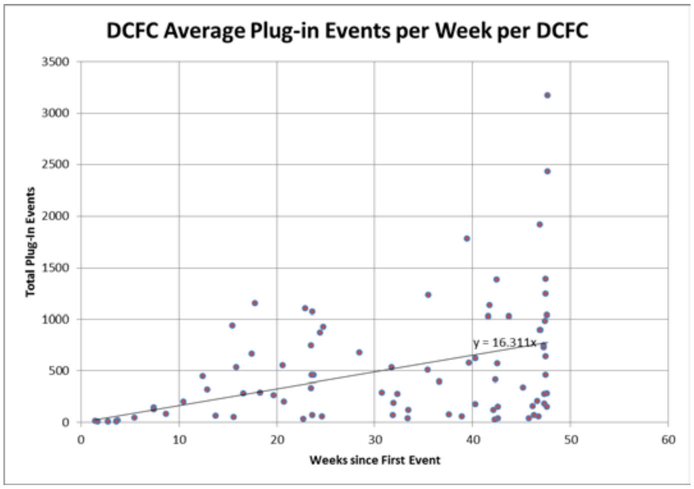

Figure 5. DCFC Average Events per Week

As shown in Figure 5, some DCFC are more highly used than others, and as shown in Figure 4, some regions show higher utilization than others. The same is true for the publicly accessible AC Level 2 EVSE. The factors that may contribute to higher or lower usage will be studied in later reports.

DCFC Connection Times

Figure 6 identifies the time of day when the Leaf was connected to start the charge. It is not surprising that the least-used time of day is the early morning hours between 3 a.m. and 9 a.m.

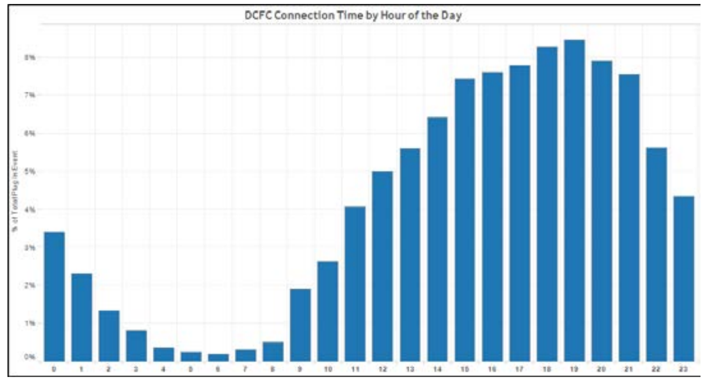

Figure 6. DCFC Connection Time by Hour of Day

There is substantial usage during the peak power times of day between noon and 7 p.m. It is also noted that the highest peak occurs at 7 p.m. This would typically be during or after the work commute and may indicate higher utilization of corridor DCFC. Utilization of DCFC in transportation corridors is also the subject of a later analysis.

Figure 7 shows the DCFC plug-in event by time of day and by region of The EV Project. It is interesting to note that Arizona, Tennessee, and Los Angeles peak earlier in the evening (between 4:00 and 6:00 p.m.) and San Francisco, San Diego, Oregon and Washington State peak later in the evening (between 7:00 and 9:00 p.m.). Several regions show a local peak between the hours of 2:00 and 4:00 p.m.

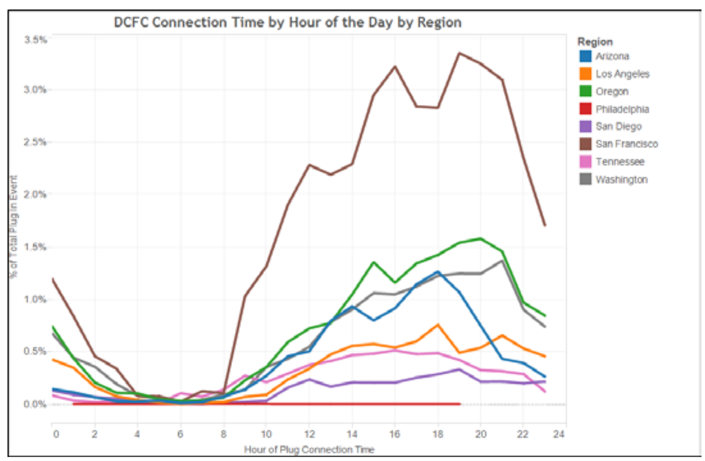

Figure 7. DCFC Connection Time by Region

When connected, Figure 8 shows the distribution of the amount of time (in minutes) a vehicle remains connected.

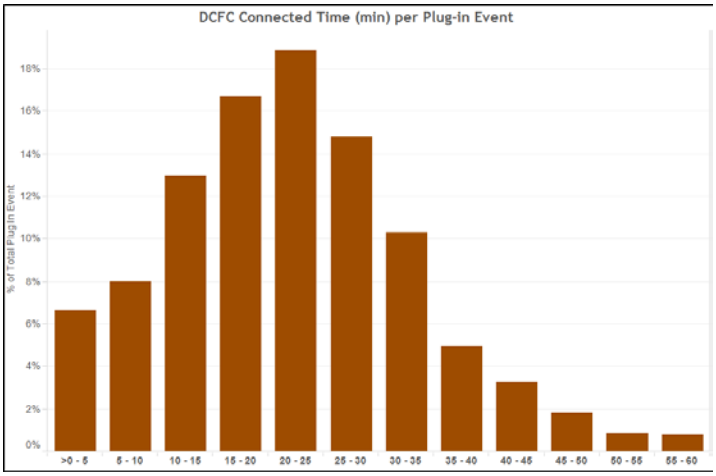

Figure 8. DCFC Connection Duration Per Plug-in Event

As was anticipated, charging at a DCFC is a short time event. With the rapid recharge capability to be able to restore a Leaf battery to approximately 80% in 25 minutes, a long stay would appear to be unnecessary. The longest stay recorded since August 2012 was just under 61 minutes. Access fees are likely to have an impact on connected duration.

DCFC Energy Dispensed

Figure 9 shows the distribution of energy dispensed (kWh) per plug-in event.

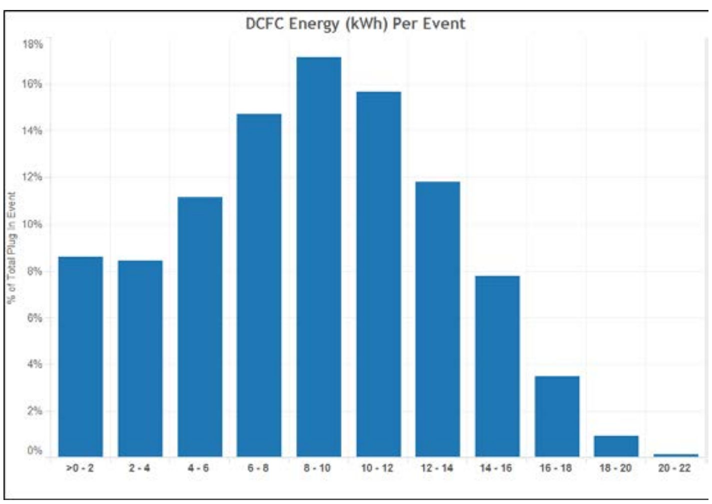

Figure 9. DCFC Energy Dispensed per Plug-In Event

Not surprisingly, the bar graph in Figure 9 looks similar to the connection duration graph in Figure 8. However, as noted above, the actual charge acceptance by the Leaf is controlled by the on-board battery management system. Several factors can affect the energy acceptance by the Leaf. Figure 10 shows a scatter plot of energy delivered vs. time connected for each plug-in event. The highest rate of power acceptance is approximately 50 kW and is shown by the smooth edge on the left. However, there are a significant number of charge events where the power acceptance (and thus the energy delivered) is well below the maximum 50 kW capability of the Leaf.

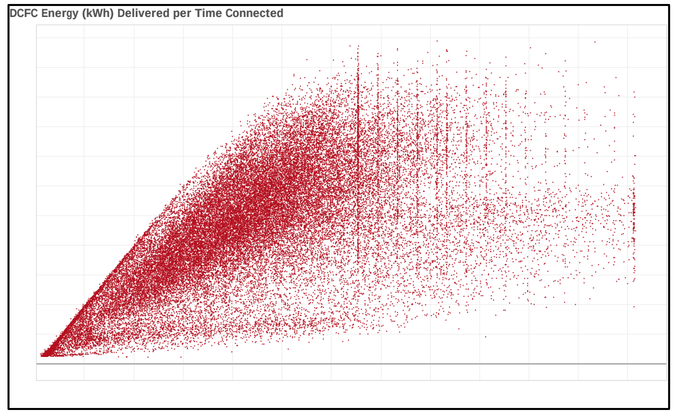

Figure 10. DCFC Energy Delivered per Time Connected

Figure 10 shows that at about 25 – 30 minutes into the charge, the highest power delivered begins to decrease. When the energy delivered is divided by the duration of the plug-in event, average power delivered during the event is obtained. If only the plug-in events of less than 30 minutes are considered, Figure 11 provides the distribution of plug-in events at the specified range of average delivered power.

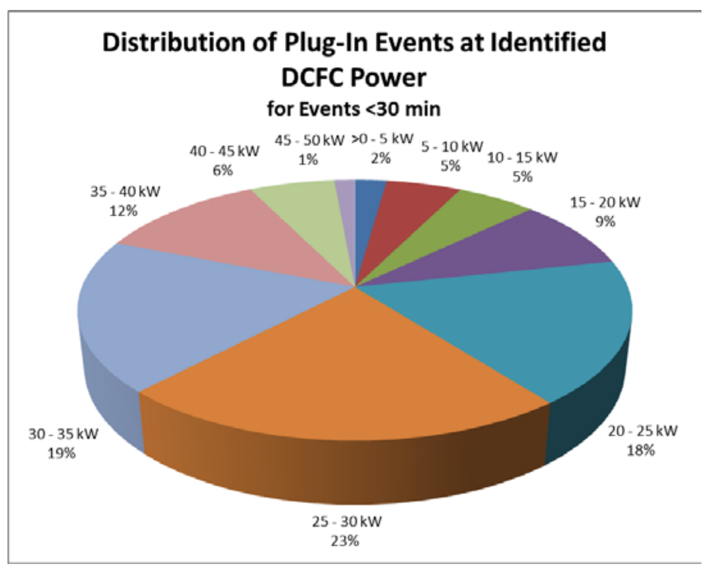

Figure 11. Charge Power Distribution

While the smooth left edge of the Figure 10 scatter diagram shows the highest rate of power acceptance of the Leaf to be 50 kW, Figure 11 shows that for plug-in events of less than 30 minutes duration, the Leaf's battery will accept its full power designed capability only 1% of the time. In a similar manner, Figure 10 shows some charge events of long duration where minimal energy is delivered. Figure 11 show that for only 7% of the events is the average power delivered less than 10 kW.

60% of the time, the power accepted by the Leaf's battery will be between 20 kW and 35 kW. This can also be visualized as the areas of highest density in Figure 10.

A Leaf driver may expect a significant increase in battery state of charge using the DCFC but depending on the Leaf's charge acceptance condition, they may actually experience a recharge less than expected. The vehicle, not the DCFC, dictates the charge rate, and it may also terminate the charging session before the driver's expected end of charge. The DCFC reports to the vehicle the rate of power transfer that it can provide, and it is up to the battery management system on the vehicle to determine how much energy to take and for how long.

Conclusion

Generally speaking, the utilization of DCFC has exceeded expectations, and the initial use appears to dispel the contention that the purpose of DCFC is just a "confidence builder" response to driver range anxiety. More study is needed to specifically address regional differences in DCFC utilization and utilization based upon the venue where the DCFC is located. Specific studies related to utilization in urban connectors and transportation corridors and the effect on BEV travel distances are also warranted.

Revenue models for DCFC access fees may include fees per a connected session, fees for a specific connected time, fees based on a subscription allowing a limited or unlimited number of charges in a period, fees related to the amount of energy dispensed, or some other method. The information presented in this paper may be of use in designing these various rate models. An analysis of the utilization of DCFC after access fees have been implemented and the differences in use based on these fees will be conducted.

The EV driver's expectation of a high energy transfer when using the DCFC may cause him/her to fault the DCFC if total energy is less than expected. In fact, the issue is most likely to be the decision of the vehicle's battery management system not to accept the charge rate available. The EV driver should become aware of his/her own vehicle's design characteristics. EV Project participants' use and attitude toward DC Fast Charging will be surveyed and reported separately.

About The EV Project

The EV Project is the largest electric vehicle infrastructure demonstration project in the world; designed and managed by ECOtality North America (ECOtality), with a budget of over $230 million USD, equally funded by the U.S. Department of Energy through the American Recovery and Reinvestment Act and ECOtality and its partners. The EV Project will deploy and study approximately 13,000 AC Level 2 EVSE charging stations for residential and commercial use, as well as 200 dual-port DC Fast Chargers in conjunction with the usage data from 8,000 Nissan LEAF™, Chevrolet Volts. This project will collect and analyze data, and publish lessons learned on vehicle and EVSE use, and driver behavior. This material is based upon work supported by the Department of Energy under Award Number DE-E0002194.

Company Profile

ECOtality, Inc. (NASDAQ: ECTY), headquartered in San Francisco, California, is a leader in clean electric transportation and storage technologies. Its subsidiary, Electric Transportation Engineering Corporation (eTec) dba ECOtality North America (ECOtality), is a leading installer and provider of charging infrastructure for PEVs. ECOtality has been involved in PEV initiatives since 1989 in North America and is currently working with major automotive manufacturers, utilities, the United States (U.S.) Department of Energy (DOE), state and municipal governments, and international research institutes to implement and expand the presence of this technology for a greener future.

For more information, visit www.theevproject.com

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