How do PEV owners respond to time-of-use rates while charging EV Project vehicles? July, 2013

The EV Project has enrolled approximately 8000 residential participants. These participants purchased or leased a Nissan Leaf or Chevrolet Volt, and the Blink Electric Vehicle Supply Equipment (EVSE), used to recharge the Plug-in Electric Vehicle (PEV) battery, was installed at their residences. The power required to recharge an EV can be a significant electrical load for the house on the electric grid. Certain electric utilities within the EV Project regions have incentivized the home owners to charge their PEV at specific times to help in managing the overall electrical system load. Does The EV Project driver behavioral data show these incentive programs to be effective?

Why is this important?

A question frequently asked relating to the adoption of EVs is “What is the impact of EV charging on the electrical grid?” The change in transportation fuel from petroleum products to electricity as the PEV transportation segment grows will certainly impact the demand for electrical power, but each electric utility views that impact differently.

The electric utilities serving The EV Project regions have a mixed response to this question. Some have shown little concern as yet for overall power generation and distribution in their service territory while others see the increase in PEV charging demand as an additional challenge to an already challenged system. This is particularly true in the southwestern states where there is a history of power disruptions in the grid - so called “brownouts” and “blackouts”.

Utility System Load Profiles

Figure 1 shows the Southern California Edison (SCE) hourly load profile for the top 12 days of summer (red line), the top 3 days in winter (dashed blue line) and the average of the top 10 days in a normal winter (dashed green line) during 2004.[1]

The notes in the cited report related to this graph indicate the significant load impact of air conditioning during the summer which is absent during a normal winter where the load is more related to lighting and some heating. This same impact can be seen in unusual winter days as well as noted by the dashed blue line.

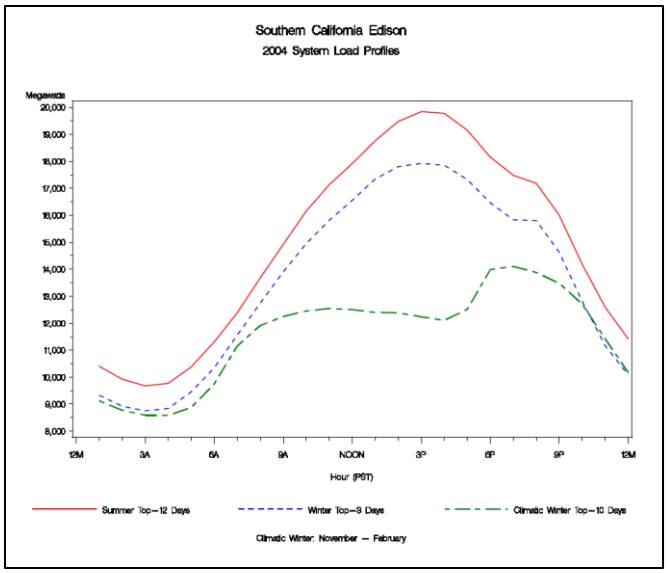

Figure 1 SCE Hourly System Load Profile 2004

Figure 2 from the same report contains the load profiles for the same type of days but shows residential load rather than system load.

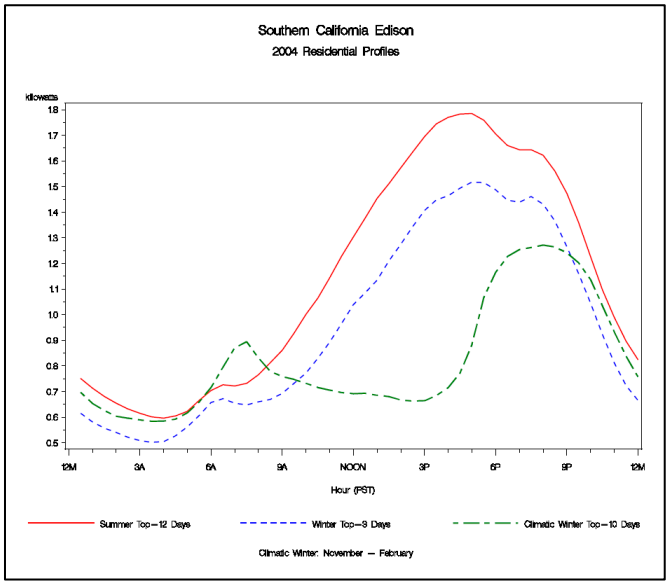

Figure 2 SCE Hourly Residential Load Profile 2004

Figure 1 clearly shows the peaks and valleys in the system wide power demand. Residential air conditioners provide a significant load for the residence, and Figure 2 shows the clear impact of this load on this system load, both in summer and unusually warm winter days. PEV charging is a more significant load than air conditioning, but the impact of PEV charging in the residence was not shown in this 2004 graph. Of course, the system load profile is also

impacted by other loads of businesses and other commercial utility customers.

Electricity generating costs to the utility can be reduced if the peak demand is lowered by shifting some demand to the other times of the day. To do this, the electric utility, through approved rate designs, may provide time-of-use (TOU) rates that incentivize power users to shift their loads if possible. This paper focusses on the incentives to home owners relating to their PEV charging needs and how they respond to those incentives.

How do utilities use TOU rates?

Electric utilities may seek to shift the peak loads to times of typically lower demand through TOU rates. These rates generally classify times of the day as "On-Peak" and "Off-Peak" and in some cases, a "Shoulder", "Partial-Peak" or "Mid-Peak". For example, for its Time-of Use Tiered Domestic rate, SCE identifies the residential hours as:

On-Peak: 12 – 6 PM weekdays
Off-Peak: All other hours[2]

Note how this on-peak time fits with the maximum demand shown in the load profile of Figure 1.

Pacific Gas and Electric (PG&E) defines summer weekday times on Electric Schedule E-9 as:

On-Peak: 2- 9 PM
Partial-Peak: 7 AM – 2 PM and 9 PM– 12 AM
Off-Peak: All other times[3]

Portland General Electric (PGE) defines summer weekday times as:

On-Peak: 3 – 8 PM
Mid-Peak: 6 AM – 3 PM, 8 – 10 PM
Off-Peak: 10 PM – 6 AM[4]

The price charged for power is typically lower for the off-peak times than for the on-peak times, in order to incentivize the residential customer to shift loads to off-peak times. While it may not be possible to shift all loads (such as air conditioning), it is possible to shift power to operate swimming pool pumps, clothes dryers, etc. to these off-peak times. The same is true for PEV charging. Some electric utilities have also implemented special EV Rates to further incentivize the shifting of PEV charging loads to off-peak times.

Within the regions of The EV Project, the electric utilities that provide TOU rates include the following:

Arizona Public Service
Georgia Power
Los Angeles Department of Water and Power
Pacific Gas & Electric
Portland General Electric
Salt River Project
San Diego Gas & Electric

EV Charging Loads

The Blink EVSE provided to The EV Project participants can supply up to 7.2 kW power to a connected PEV. The actual energy transferred depends upon the capability of the vehicle's onboard charger and the charge acceptance rate dictated by the PEV's battery management system. While most PEVs currently accept up to 3.6 kW, model year 2013 Nissan Leafs and other vehicle models coming to market will accept up to the EVSE's 7.2 kW rating. The peak load shown in Figure 2 for a residence is about 1.8 kW. If charging the PEV occurs simultaneously with the peak household loads, the new peak could be as much as 9 kW. As such, it is possible that charging the EV will increase the household demand by a factor of 5.

PEV charging will significantly impact household demand at any time of day. Adding a 7.2 kW load at 3 AM in summer could increase the household load by over 10 times. However, this occurs when the rest of the utility system is off-peak and thus helps to flatten the overall system load curve.

How then do PEV owners respond to TOU rates while charging The EV Project vehicles?

Analysis Methodology

This topic was first addressed by The EV Project in 2012. The methodology and initial results were published on The EV Project website (www.theevproject.com) and presented at EVS26 (Electric Vehicle Symposium) in Los Angeles.[5] That methodology illustrates the importance of "Charging Availability" and "Charging Demand".

Charging availability at a point in time is the percentage of EVSE in a geographical area that are connected to a vehicle. Charging demand at a point in time is the total amount of power being drawn from the electric grid by a group of EVSE in a geographical area. These are represented by time-of-day plots. For The EV Project, these plots have been included in the quarterly reports since first quarter 2011 and posted on the website. They are prepared by geographic area and show the hourly percentage of EVSE connected and hourly charging demand for all weekdays and weekends for the quarter evaluated. In addition, these plots are prepared for each of the electric utilities in The EV Project areas.

Figure 3 shows the weekday residential charging availability for EV Project vehicles in the Nashville Electric Service (NES) territory during the first quarter 2013. Figure 4 shows the weekday residential charging demand in the

same service territory for the same time period. Note that the plot shows the maximum, minimum, median, and inner quartile values for all the days of the quarter. NES does not incentivize PEV drivers to shift charging times and the plots show that a typical PEV driver commences the charge when the vehicle is connected to the EVSE.

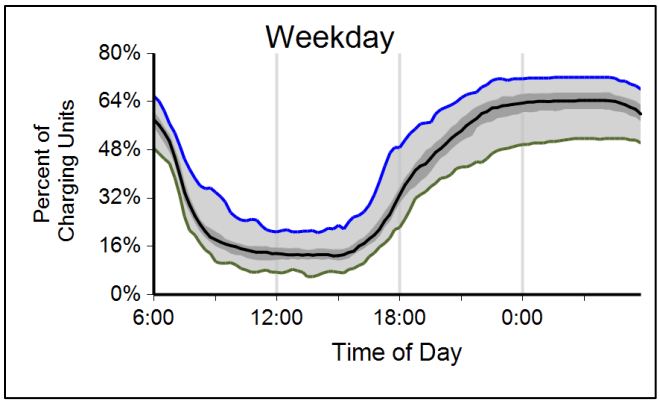

Figure 3 Weekday Residential Charging Availability in NES Territory, Q1 2013

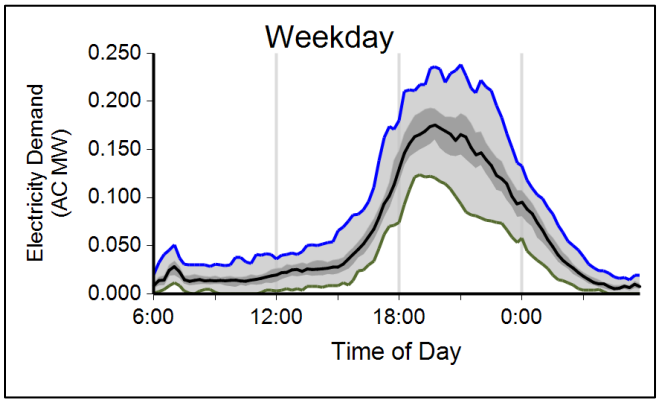

Figure 4 Weekday Residential Charging Demand in NES Territory, Q1 2013

Figures 5 and 6 show the same plots for Pacific Gas & Electric (PG&E) for the same time period of the first quarter 2013.

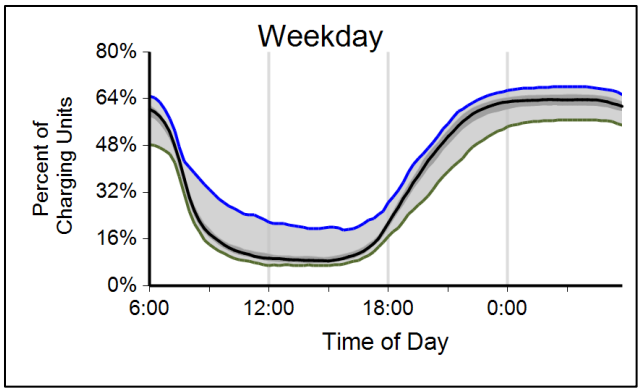

Figure 5 Weekday Residential Charging Availability in PG&E Territory, Q1 2013

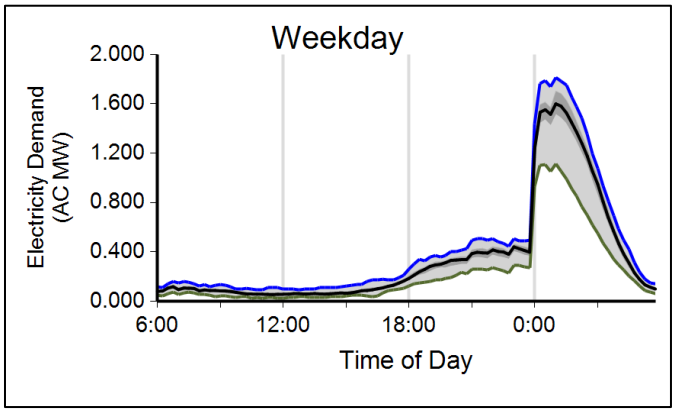

Figure 6 Weekday Residential Charging Demand in PG&E Territory, Q1 2013

While the general behavior of PEV drivers to connect their PEV to the EVSE is the same in PG&E service territory as that in NES territory, drivers in PG&E service territory generally delay the start of the charge until midnight – which coincides with the beginning of the off-peak PG&E rates. Both the PEV and the EVSE provide programming features that allow the vehicle to be connected to their EVSE, but delay the start of the charge until the time set.

Charging availability and charging demand plots for the Portland General Electric service territory from the first quarter 2013 report are shown in Figures 7 and 8 below.

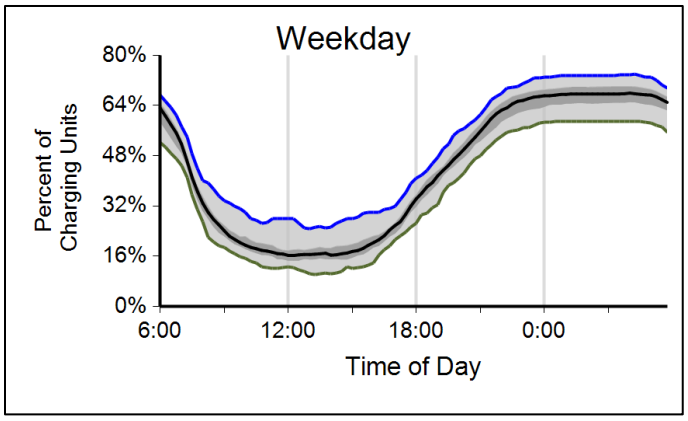

Figure 7 Weekday Residential Charging Availability in PGE Territory, Q1 2013

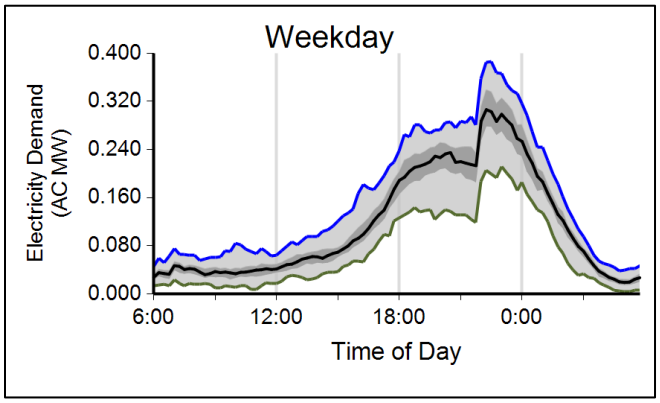

Figure 8 Weekday Residential Charging Demand in PGE Territory, Q1 2013

Figure 8 shows that there is an effect of PEV drivers in PGE service territory programming their PEVs or EVSE to commence the charge at 10 pm at the beginning of the off-peak times. However, there are a significant number of PEV drivers who do not appear to be taking advantage of off-peak charging, as reflected by the rise in demand with the increase in charging availability. This rise occurs during the PGE declared on-peak times.

Observations

The first quarter 2013 driver behavior data clearly show, as it also did in the initial 2012 report on this topic[6], that the financial incentives appear to successfully shift PEV charging demand to off-peak hours. However, it also appears that TOU incentive was more effective in the PG&E service territory than in the PGE territory.

TOU Survey

A survey of The EV Project participants was conducted on this topic in these two regions providing TOU rates: PG&E in the San Francisco Bay area and Portland General Electric (PGE) in the greater Portland area. Because all participants reside in the region where TOU rates are available, the survey asked whether the participant was aware of the rates, how they became aware, whether they subscribed to the rate, and if the purchase or lease of the PEV caused them to change their rate choice.

Survey Results

A total of 356 responses were received from 1088 EV Project participants, at that time representing a 33% response rate. These included 93 from PGE service territory and 264 from PG&E territory.

1. **To which utility rate structure are you currently subscribed?**

	PG&E	PGE
Basic	16%	68%
TOU	53%	26%
EV	28%	5%
Solar	3%	1%

The high percentage of respondents in PGE territory opting for the Basic rate is a possible reason for the shape of the charging demand curves seen in Figure 8. The Basic rate has no incentive for delaying the charge. Thus, the EV driver would be expected to commence the charge immediately upon connecting the vehicle to the EVSE, such as after the evening commute home. This is similar to the PEV driver behavior seen in NES service territory.

2. **Are you aware of the availability of the TOU rate?**

Until this survey was distributed, 3% of the PG&E responders said that they were not aware their utility provided TOU rates and 13% of the PGE customers said that they were likewise not aware.

3. **Did you change your rate during or after acquiring your PEV?**

Sixty-seven percent of the PG&E responders indicated that they changed rates during or after they acquired the PEV. Only 31% of the PGE responders indicated that they changed.

4. **How did you become aware of the availability of the TOU rate?**

For those who were aware of the TOU rate, the responses are identified below.

	PG&E	PGE
General	35%	48%
Contacted	27%	15%
Internet	8%	2%
Read	6%	6%
Friend	8%	3%
Utility	1%	8%
Installer	2%	0%
Dealer	8%	4%
Other	6%	13%

"General" means the responder had general knowledge of the rate availability and couldn't pinpoint how they became aware. "Contacted" means the responder contacted the utility to inquire. Some researched the rate structure on the internet or read information on the rates. Some were made aware of the rate from a friend. For some, the EVSE installer or the vehicle dealer provided the information. The electric utility also made contact with the responder in some cases and some didn't fit into any of these categories.

Combining the "General", "Contacted", "Internet", and "Read" categories indicates efforts by the individual to identify the rate. Therefore 75% of the PG&E and 72% of the PGE responders found the rate for themselves.

5. Do you program your EVSE, your EV, both or neither for charging?

	PG&E	PGE
EVSE	25%	18%
EV	53%	45%
Neither	9%	29%
Both	14%	8%

A significantly larger percentage of responders in the PGE service territory programmed neither the EV nor EVSE, compared to PG&E customers responding to the survey. This is consistent with the different charging demand shapes in Figures 6 and 8. This topic was explored further in the *EVSE Programming* lesson learned also posted to The EV Project website.

Even though 68% of the responders in PGE service territory indicated they subscribed to the Basic or Standard utility rate, 57% of these responders indicated that they indeed had programmed their EV or EVSE or both. This suggests that EV drivers schedule charging for reasons other than financial incentives.

3% of the TOU subscribers noted that they programmed neither the PEV nor the EVSE even though 2 of these 8 responses indicated that they changed to the TOU rate as a result of obtaining the PEV.

6. Comments

Other than those who were not aware of the special rate structures, some elected not to adopt the TOU rate because their PEV needs made it inconvenient to charge off-peak. Others reported they could not realize any savings with TOU rates.

Observations

The data indicate the effectiveness of the TOU incentive rates in PEV drivers initiating their charge during the off-peak periods. The survey indicates that the TOU program does indeed influence PEV driver charging patterns. Overall, 57% of the respondents did change their utility rate subscription as a result of obtaining the PEV.

The charging demand and survey data from the PG&E service territory indicate that PG&E TOU rates effectively incentivize PEV drivers to both select a TOU rate plan and to delay their charging until off-peak periods. However, data from the PGE service territory suggest that PGE's TOU rate plans are not as effective an incentive, in that only 31% of responders chose a TOU rate plan. This could be due to lack of awareness – the survey indicates that many PEV owners were not aware that these programs exist. Furthermore, over 70% of the responders learned about TOU rate options on their own.

The shift in charging demand to the TOU period is very obvious in the demand curve of Figure 6 for PG&E. This shift causes a demand spike at or shortly after the beginning of the TOU period. This spike is not as pronounced in the demand curve of Figure 8 for PGE. It is possible that either or both electric utilities have indeed created enough of a change in demand that their system load objectives are being met with the current enrollments.

Two factors that will influence the level of awareness and ultimately TOU program enrollment are the perceived value of the incentive and the program's outreach and education efforts. Both of these are important factors that the utilities manage to meet their own objectives for affecting demand.

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 United States (U.S.) Department of Energy (DOE) through the American Recovery and Reinvestment Act and ECOtality and its partners. The EV Project will deploy and study approximately 13,000 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™ and 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 DOE 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 U.S. DOE, state and municipal governments, and international research institutes to implement and expand the presence of this technology for a greener future.

Idaho National Laboratory (INL) is one of the U.S. 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 (BEA).

References

[1]Southern California Edison, Rebuttal Testimony Supporting Edison Smartconnect™ Deployment Funding and Cost Recovery: demand Response, Rosemead, CA, February 19, 2008
[2]Southern California Edison, Schedule TOU-D-T Time-of-Use Tiered Domestic, Effective Apr 1, 2013
[3]PG&E Electric Schedule E-9 http://www.pge.com//myhome/environment/whatyoucando/electricdriveveh icles/rateoptions/, accessed 7-17-2013
[4]Portland General Electric site: http://www.portlandgeneral.com/residential/your_account/billing_payment/t ime_of_use/pricing.aspx, accessed 7-17-2013
[5]A *First Look at the Impact of Electric Vehicle Charging on the Electric Grid in The EV Project*, Schey, Scoffield, Smart, 2012
[6]ibid

For more information, visit www.theevproject.com

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