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The SDG&E PEV Rate & Technology Study - One Year Progress Report

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Abstract

To benefit California's understanding of charging time behaviour for plug-in electric vehicle ("PEV"), San Diego Gas & Electric Company ("SDG&E") proposed to the California Public Utilities Commission ("CPUC") a study of consumer time-of-use charging preferences, charging technology use, and other relevant factors. An experiment that includes CPUC approved time-differentiated rates ("Study") was implemented. Insights gained from the Study will provide value to the CPUC's rate making policies for plug-in electric vehicle consumers. With the CPUC's authorization to test experimental PEV rate designs, California will also be able to better understand consumer charge-time decision making. The Study is timely in that it takes advantage of a unique market condition implemented in the SDG&E service territory, coincident with the 2011 launch of the EV Project and Nissan LEAF PEV deployment. The data collection for the Study commenced January 2011 and will continue into 2013. Although the price elasticity results will not be available until late 2013, the purpose this paper is to highlight the Study's initial design and its progress through 2011.

Keywords: California, charging, cost, energy consumption, off-peak, policy

1 Introduction & Background

The San Diego California is one of a number of regions in the United States selected to study customer PEV charging patterns as part of the EV Project. ECOtality manages the EV Project which was funded by the Department of Energy ("DOE") beginning in. This DOE award was announced August 5, 2009 and is providing up to 1,000 home electric vehicle supply equipment ("EVSE") for the first 1,000 Nissan LEAF PEVs purchased in the San Diego region. On August 8, 2009, the California Energy Commission ("CEC") announced that it was awarding $8 million to ECOtality as matching funding for this project, which will result in additional infrastructure being deployed to the San Diego region (please see Section 7 for a summary of Nissan LEAF features, as well as the a description of the EV Project).

The selection of the San Diego region for the EV Project was in part due to Nissan's announcements to target the region for the 2011 launch of the Nissan LEAF deployment in significant volumes. These unique market conditions created an opportunity for SDG&E to propose a research plan that, with approval from the CPUC, allow parties to study PEV consumer time-of-use charging preferences described in this Study. Insights gained from this Study will provide value to the CPUC's rate making policies for a utility's PEV customers.

2 Working Hypothesis

It is expected that time variant pricing and technology use will influence consumer charging behavior. Furthermore, greater price variations are expected to drive more charging activity to off-peak and super off-peak periods. Enabling technology should make charging off-peak more accommodating. In order to design PEV charging rates for the introduction of PEV customers, these suppositions need to be verified and quantified.

Enabling technology is intended to facilitate charging behavior that is convenient and economic to the consumer. It is expected that this enabling technology will be utilized by the consumer at the PEV end-use level (on-board the LEAF and/or via the EVSE) to facilitate charging at desired times and duration. The research design for this Study will examine the relationship between time variant pricing and the consumer's use of enabling technology, while controlling for other consumer factors.

As noted below, the extent to which time variant PEV rates, with the use of enabling technology do not explain charging behavior, alternative hypotheses will need to be considered. For example, PEV consumers may find driving requirements to be a more compelling than electricity pricing in determining PEV charging time of day and duration decisions. In other words, "driving needs" may "trump" the impact of pricing, when decisions are made about the time and duration for charging the PEV. What remains to be seen is how persistent this phenomenon is over time, if at all.

3 Research Objectives

The overall research objective is to examine PEV consumer charging time preferences, use of enabling technology, and other relevant factors by incorporating a controlled study of CPUC-approved electricity rates and consumer use of available technology coincident with the implementation of the EV Project and adoption of the Nissan LEAF in the SDG&E service territory.

With these expectations, the research objectives include:

• Create a customer preferences model that explains time-of-use charging behaviors; including the estimate of the impact of time-varying rates on PEV charging energy use by time-of-day or period (e.g., development of models that can be used to predict impacts under alternative pricing plans).

• Evaluate the importance and use of technology to help enable PEV consumers' responses to time variant pricing.

4 Model of Charging Behavior

The Study was designed to ascertain to what extent the level and structure of the electric retail rates offered to PEV customers influence when he or she charges the vehicle. Each experimental rate is designed in varying degrees to send a price signal to influence the consumer regarding at-home PEV charging. Charging at times when electricity is cheaper to supply may improve the economics of PEV ownership.

Two rate design factors are under examination. First, is the effect of the level of nominal and relative electricity rates ($/kWh) assessed for charging a PEV at home under a residential tariff. The Study charges different rates for charging at different times of the day that correspond to electricity supply costs (referred to as "On-Peak," "Off-Peak" and "Super Off-Peak"). Rates during the On-Peak time of day (i.e., noon to 8 PM) are higher than those at the Super-Off-Peak times (i.e., midnight and to 5AM). It is assumed that consumers are induced by these price differences to charge the PEV during the lowest cost periods of the day. It is important then to determine how large a rate differential is needed to accomplish this, as well as what factors, other than the rates, influence charging behavior.

A related issue is how day (On-Peak) and evening (Off-Peak) are defined in terms of hours of the day. It is assumed that the earlier the lower rates are available in the evening, the easier it is for PEV owners to fully charge their vehicle. However, because San Diego regional electricity usage (and therefore marginal supply cost) is high in the evenings (e.g., from 5 PM to 10 PM), charging rates have to be higher to reflect the cost of supply during those time periods).

This Study intends to sort out these effects to the extent to which prices and the specification of when they are low and high influence at-home charging. The Study therefore includes temporary, CPUC-approved experimental rate schedules (or rate treatments) that vary according to the daily prices for charging and the hours to which they apply. The observed charging patterns will provide data needed to better understand these influences and contribute to the design of PEV rates in the future.

Time-of-Use ("TOU") Charging behavior will be characterized by a specification of the demand for electricity. This demand formulation has been used elsewhere to characterize household electricity demand under conventional time-of-use pricing, and more recently to estimate the substitution effect for more dynamic time-varying rates like Real-Time Pricing, Critical-Peak Pricing and Variable-Peak Pricing [1]. Notably, a variation of this formulation has been used to estimate substitution elasticities using the data gathered during the California pricing experiment in 2003 to 2004[2].

5 Methodology & Operational Definitions

5.1 Dependent Variable

Time-of-Use Charging is defined as the ratio of on-peak charging kWh to non-peak charging kWh per unit of time (e.g., day, month, season and year). Each participant (i.e., LEAF customers screened into the EV Project) is randomly assigned an experimental PEV rate whereby vehicle charging usage is separately metered, from other household energy use. Where possible, TOU Charging data will be gathered on a 15 minute interval or hourly basis (aggregated to TOU periods) using an Interval Data Recorder ("IDR"). For example, on a per day basis, this variable can be measured as the follows ratios:

- On-Peak kWh / Off-Peak kWh,
- On-Peak kWh/ Super Off-Peak kWh, and
- Off-Peak kWh / Super Off-Peak kWh.

These values are aggregated by TOU periods and by any aggregation of time (e.g., week day, week-end, and season).

5.2 Independent Variables

Time-Varying PEV Charging Rates are the Pricing Treatment. One of three experimental PEV charging rates with varying on-peak to off-peak pricing differentials, for two seasons (Summer & Winter) and the same TOU periods for each season (Summer & Winter), and the same TOU periods for weekdays and weekend days, will be randomly assigned to each Study participant.

The proposed experimental time-varying PEV charging rates for this Study were developed following these guidelines:
- The definition of TOU periods is consistent with current rate Schedule EV-TOU
- Current TOU periods approximate periods of differing system demand (e.g., the Super Off-peak period of midnight to 5 AM reasonably approximates SDG&E's period of lowest system demand, and lowest cost; this TOU period creates the greatest opportunity for PEV drivers to charge the vehicle at the lowest possible cost).
- The experimental PEV rates include 3 TOU periods, 7 days per week, with no seasonal variation are
- The experimental PEV rates may not be indicative of future rate proposals
- The experimental PEV rates for this Study are temporary and intended to provide data for analysis of the price elasticity of demand
- Super-Off-Peak rates should not be less than the sum of the rate components: transmission, distribution and non-bypassable costs, and generation marginal energy costs
- On-Peak rates should not greatly exceed residential customer rates for Tier 4 usage under their otherwise applicable tiered (inclining block) residential rate
- No "bill protection" (i.e., to "true up" the PEV customer's bill against an otherwise applicable PEV rate) should be provided since each proposed rate offers an opportunity for PEV customers to achieve savings above the current applicable EV-TOU rate. This requirement is essential to the Study in order to maintain the integrity of the research design and maintain the "pricing treatment" effectiveness.

As noted about, Study participants (LEAF customers) will be randomly assigned to one of the experimental rates or pricing treatments. Random assignment of participating customers to pricing (rate) treatments (vs. customer self selection) is critical to the Study to reduce or eliminate bias associated with a consumer selecting a rate that matches their driving needs and lifestyle. Randomization provides the means for understanding if charging behavior is due to pricing, driving needs, or other factors.

The CPUC approved, temporary experimental residential rate schedules for PEV charging are as follows:

• Schedule EPEV-L (Low Price Ratio), representing a 1 to 2 price differential between super off-peak to on-peak periods (and most indicative of SDG&E's current EV TOU);

• Schedule EPEV-M: (Medium Price Ratio), representing a 1 to 4 price differential between super off-peak and on-peak periods; and,

• Schedule EPEV-H (High Price Ratio), representing a 1 to 6 price differential between super off-peak and on-peak periods.

As noted above, these temporary experimental PEV rates do not reflect any rate design principles. Instead, they were created for the sole purpose of creating experimental pricing treatments designed to have varying degrees of price differences between super off-peak and on-peak pricing.

During 2011, because of the limited public access charging facilities in the San Diego region, the majority of PEV consumers charged at home. Because of this it is important to measure charging patterns during the shoulder peak period ("Off-Peak" period of 8 PM to Midnight), in addition to the "Super Off-Peak" period of Midnight to 5 AM.

If the vehicle battery is about 50% to 65% depleted, the Super Off-Peak period should be sufficient time to achieve a full charge. And, if the vehicle battery is depleted more than this level, it will be important to learn how much of the On-Peak and Off-Peak rate the customer is willing to pay for additional "full or sufficient charge" assurance. For example, when faced with insufficient time in the Super Off-Peak to charge the vehicle to the desired charge level, do participants use the vehicle's timing devices (enabling technology) to add the needed hours just before the Super Off-Peak period starts or ends, or do they ignore the value of the low cost Super Off-Peak charging period in favor of the assurance of a full charge by initiating charging when they arrive home or at a time that is most convenient to charging needs?

5.3 Conditioning Variables

Other factors can influence the charging substitution elasticities, in particular household demographics regarding who uses the PEVs, the purpose of the PEV use, and other external influences. To account for these factors, the following data will be collected from participants:

5.3.1 Charging Enabling Technology

Two types of charging time enabling technology were available to all Study participants: on-board LEAF technology and those available through the EVSE. The on-board LEAF technology (with a remote app option) allows the PEV customer to set start and/or end times for charging, as well as percent of charge (80% or 100% of the battery charge). The EVSE offers similar options. The LEAF also has a charge time override option should the PEV customer decide to charge during other times of day outside of the charge time settings. All customers were given the same amount of information on their PEV TOU rate through direct discussions with SDG&E staff, through the web, and with printed collateral. The content of the information was timely, educational and relevant, and is refreshed at regular intervals. Of interest will be learning which of these technologies are used and useful and why.

5.3.2 Driving Requirements

Other participant data will be gathered that will help explain driving requirements. To the extent to which time variant PEV rates do not explain charging behavior, alternative hypotheses may need to be considered. For example, it may be that PEV consumers may find driving requirements to be a more compelling than electricity pricing in determining PEV charging time of day and duration decisions. To help determine driving requirements, combinations of qualitative and quantitative variables are considered in the analysis. For example, these variables may include miles driven per weekday and per weekend day, and driving geography (surface streets, freeway and terrain).

5.3.3 Participant/Driver Characteristics

These variables include household energy consumption data (historic and through the duration of the study) and data gathered through self-reported survey instruments. These data include demographics (e.g., education, income, age), household occupancy, home characteristics (e.g., size, location) and appliance stock.

Photovoltaic ownership and range of energy efficiency investments and practices will also be assessed. In addition to studying the relationship of these data with time-of-use charging, these data will be used to profile this population and sample against SDG&E system wide customer characteristics. These data will also be useful to track and quantify or qualify differences in early PEV adopters vs. those who adopt or purchase and PEV later in market.

Weather data is gathered from 10 regional weather stations to determine the degree to which weather explains time-of-use charging usage (e.g., Use of the LEAF AC on hot summer days, and use of the heater on cold winter days will increase the demand on the battery, which will results in increased electricity usage, for the same miles driven).

5.3.4 Access to and Use of Charging Facilities

The Study survey work includes inquiry about the participant's access to and use of charging facilities at home, at work (during work day), and any other non-home charging facilities, such as Level 2 (240V) Public/Commercial, and DC (480V) Fast Chargers, which could explain changes in home charging patterns.

5.4 Population & External Validity

The population of participants are those SDG&E and LEAF customers who are screened into the EV Project. These participants will be randomly assigned to one of three experimental PEV rates, as described below. A homogeneous Study sample is expected (improving the Study's internal validity). The sample is characterized through variables noted above and contrasted with the SDG&E's residential customer population.

However, such a contrast may not be relevant when considering the generalizability of these results. Vehicle marketing practices may be more relevant to the Study's external validity. Automotive OEMs are not generally focused on the mass marketing of a specific vehicle, especially during the early model launches. It's reasonable to assume that at a minimum, there is an interest in generalizing these results to the next generation of PEV buyers, and not all future automobile buyers (certainly not all utility rate payers). It is reasonable to assume that this population of PEV drivers / owners is probably similar to near-future PEV drivers / owners. The findings from this Study, then will examine price elasticity within a very relevant population of customers, that may better represent future or at least near term PEV buyers/owners. This study does not attempt to generalize its findings beyond this population of PEV consumers.

5.5 Analysis

The econometric modeling and other multiple regression analyses used for determining price elasticity is not described and presented in this interim report. The data collection for the Study commenced January 2011 and is expected to continue into 2013, and hence the price elasticity results will not be available until late 2013.

6 Interim Findings – 2011

The findings and lessons learned from this Study presented at EVS26 summarize descriptive statistical information to date for 2011. This presentation will include an interpretation of the findings, including a statistical description of the makeup of the customer population in the Study compared to the total SDG&E customer population. Also presented will be kWh use by TOU period and by each of the 3 rate groups.

7 Background Information

7.1 Nissan LEAF Features

• Five Passenger Hatchback
• About 100 miles/charge
• 100% Electric - Zero Emission Vehicle
• Accepts Level 1, Level 2 and DC Fast Charging
• Lithium Ion Battery (24kWh capacity)
• About 8 hours for full charge – Level 2 (240v, 3.3 kW charge power)
• Displays SOC in "distance to empty", GIS Map of area reachable
• Has on-board charging time and duration settings and remote applications

7.2 The EV Project Background

The EV project is an ECOtality, USDOE and Nissan collaboration to carry out the largest deployment of EVs & charging infrastructure in US history under ARRA Stimulus Funding (FOA–28). The following cities make up the scope of participation: San Diego, Phoenix, Tucson, San Francisco, Los Angeles, Portland, Eugene, Salem, Corvallis, Seattle, Nashville, Knoxville, Memphis, Chattanooga, Washington D.C., Dallas, Fort Worth, and Houston.

$200 million in project funding was secured to deploy charging infrastructures in US (about $100 million ARRA); plus, an additional $8 million grant from CEC to eTec was awarded for installing additional infrastructure. San Diego Region infrastructure planned includes:
• Up to 1,000 "Free Allowance" Level 2 (240V) EVSE – Residential Charging Installations
• Up to 1,000 Level 2 (240V) EVSE – Public and Commercial Chargers
• Up to 30 DC (480V three phase) "Fast Chargers"

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Greg Haddow, Clean Transportation Manager at the San Diego Gas & Electric Company, leads the company's efforts in developing On-Road and Non-Road electric transportation services for its residential and business customers. Greg has spent over 30 years serving various leadership roles in utility and non-utility energy businesses including: strategic planning, marketing, market and load research, and energy program development and management. During his role as director of sales and marketing at SDG&E he played a key role in the growth of energy efficiency and clean transportation in California. Prior to joining Sempra Energy he served as Supervisor of Market Research at Pacific Gas and Electric.