CAN DRIVERS OF PLUG-IN ELECTRIC VEHICLE BE PROMPTED TO CHARGE OFF-PEAK?

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Word Count: 6,944 + (1 Figure x 250 words) = 7,194

Submission Date: 26 July 2013
ABSTRACT
Many benefits of plug-in electric vehicles (PEVs) depend on when during the day those vehicles are charged. PEV drivers’ accounts of the effects of demand response management (DRM) on the time of day they charge their PEVs are summarized. Interviews and focus groups were conducted in San Diego County, CA in spring and fall 2012. Three DRM strategies were deployed in the study region. First, pricing included both intentional time-of-use (TOU) prices for home charging and non-TOU prices for away-from-home charging. Second, technology to support PEV drivers’ included timers to control when charging begins and ends. Third, social marketing—in this case, past campaigns incorporated into social narratives—promoted private and social benefits of shifting electricity demand off-peak. The aggregate effect was a story widely told by respondents about their goal to charge their PEV only during the “super off-peak” period between midnight and 5am. However, drivers’ accounts differed as to their adherence to this goal because 1) they use prices other than the TOU tariffs to judge whether an electricity price was high or low, and 2) the TOU price signal may or may not prompt them to incorporate a social narrative about the susceptibility of the electrical grid during periods of peak demand into their behavior. PEV drivers with home photovoltaic systems were the least likely to say they charge their PEV in accordance with the TOU schedule in part because of their mistaken belief their home photovoltaic system insulates the grid from their vehicle charging.
ENLISTING PLUG-IN ELECTRIC VEHICLE BUYERS IN OFF-PEAK CHARGING

Several benefits are touted for plug-in electric vehicles (PEVs) including reduced emissions of pollutants and greenhouse gases (1, 2, 3, 4, 5), lower cost and improved reliability of electricity grids, enhanced integration of renewable electricity (6, 7), and management of local electricity distribution (8). All are affected by when PEVs are charged throughout the day; analytical scenarios range from all PEV drivers charging whenever they arrive home to all strictly adhering to a desired period—typically late night when pre-existing demand is lowest. Charging of PEVs would represent new demand for electricity. Thus, it is desirable to manage the new demand in a way that at least does not exacerbate the present time-of-day distribution and at best utilizes new PEV demand to produce more desirable total demand. The research questions we address are whether the early PEV buyers’ conform their vehicle charging behavior to schedules desired by demand response managers. Why do (or don’t) these early drivers charge their PEVs according to such schedules? Answers help refine estimates of PEV costs and benefits as well as design of demand response management (DRM) programs.

Electricity Demand Response

DRM pricing strategies include time-of-use (TOU), real-time pricing (RTP), and critical peak pricing (CPP). TOU prices vary over a day according to fixed schedules. RTP prices vary according to demand; in practice, customers with RTP may have as little as one hour to adapt to price changes. CPP is essentially TOU with the highest price being variable (as in RTP) rather than fixed (as in TOU). Incentive-based strategies pay customers to participate in, as examples, direct load control or service interruption and curtailment. Technologies to support DRM include information interfaces such as web-portals, information and control technologies such as programmable communicating thermostats, and timers. Social marketing (9) may also be used to exhort users to reduce demand, especially peak demand. Dütschke and Paetz (10) describe how differences in prices guide behavior by combining a private cost signal that incentivizes specific behaviors with an information signal “that demand threatens to override supply in a high-price period.” In this instance, heeding the information signal prompts pro-social behavior: keeping the grid operating.

Demand Response, Households, and PEVs

Of particular interest would be studies describing the effect of demand response on household PEV charging behavior. However, there is as yet scant literature specific to this topic. The more general literature on residential electricity demand response programs reveals a fairly unified approach to measuring electricity demand: the own-price elasticity of electricity, i.e., for a one percent change in the price of electricity, what percentage change is there in the demand for electricity?

Residential DRM without PEVs

Across decades of research on many electricity DRM program designs in locations around the world, studies indicate household response is inelastic. Faruqui and Sergici (11) reviewed residential DRM experiments from 2001 to 2005, mostly in US states, though also in France, Australia, and Canada. They claim there is “conclusive evidence that households respond to higher prices by lowering usage.” Their estimates of own-price elasticity of demand for electricity were in the inelastic range, i.e., 0 to -1.0. A USDOE (12) review cites studies of voluntary participants in a variety of demand response programs attempting to cut total on-peak
electricity consumption: reported own-price elasticities for three different residential studies range from -0.04 for the least elastic participants in a residential CCP program to -0.21 among those participants with the most elastic response in a TOU program. The California Statewide Pricing Pilot (SPP) from July 2002 to December 2003 reported dozens of substitution and own-price elasticities for different combinations of CCP, TOU, and information across different climate zones, periods of months, years, sequential days, and household characteristics (13). While all elasticities were negative, few exceeded 0.20 in absolute value and none exceeded 0.30. CRA (13) comments on the historical arc of DRM study results, comparing the results from the California SPP to those reported in an earlier review by Caves et al (14). The effects measured in 2002 and 2003 in California indicate less price sensitivity compared to earlier measures. CRA (13) draws the inference that DRM and other conservation efforts in the intervening years may have reduced the potential for households to respond to TOU and CPP pricing and information campaigns. However, even in the early 1980s Faruqui and Malko’s (15) review of twelve experiments concluded that while TOU rates generally reduced peak period and total daily electricity use, estimated short-run own-price elasticities ranged from 0 to -0.45.

Another result from this earlier research foreshadows part of the discussion with PEV drivers we presently report: “if the TOU rates had an effect on usage, the effect was virtually identical for each TOU rate” (16). Similar results are reported in other more recent studies. Herter and Wayland (17) report that while CPP did result in peak demand reductions, differences between $0.50 and $0.68/kWh did not produce statistically significantly different reductions. Thorsnes et al. (18) report there was no significant variation in peak conservation with price across experimental groups of households in New Zealand.

TOU and PEV Simulations
A recent discussion of TOU pricing and PEVs reviews the rational actor rationale for why pricing would affect PEV charging (19). Their simulations suggest an average own-price elasticity of only -0.04. They speculate that early PEV buyers may be motivated by more than the modest private cost savings simulated for any driver adhering to the off-peak charging period. In particular, the value of the convenience of charging whenever a driver arrives home may outweigh the cost savings of waiting. This line of speculation raises the question of the role of supporting technologies such as the timers available to PEV drivers in this study and whether PEV drivers can enjoy both the convenience of plugging in upon arriving home and lower cost of delaying charging to off-peak.

A Practice Theory Approach to Electricity Management by Households
Reliance on elasticities signals the pervasive use of an underlying model of electricity users as rational actors. As an exception, Strengers (20) explores practice theory as a way to reframe peak electricity demand management. Practice theory posits that practices are the source and carrier of meaning, language, and normativity, i.e., what people do and are expected to do. A practice “consists of several elements, interconnected to one another: forms of bodily activities, forms of mental activities, ‘things’ and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge” (21). Individuals are simultaneously constrained and directed by practices even as those same individuals constitute those practices by enacting them. From this perspective, energy consumption patterns arise from the expectations and conventions associated with everyday household energy consuming practices. This theoretical argument elaborates on earlier empirical work in which Strengers (22) examined the
causes behind the impact of a dynamic peak pricing (DPP) on households’ electricity consumption. She acknowledges that households weigh the benefits of electricity-saving practices against the high cost of electricity during DPP but notes that increased cost did not often feature in households’ explanation of why or how they responded to DPP signals.

THE PRESENT STUDY

As so little is known yet about the specific case of DRM and PEV charging, we will break with the tradition of much of the DRM literature; we will not present numeric measures of elasticity of demand. We will convey whether and how a sample of PEV drivers talks about assembling the practice of PEV charging and how their descriptions are shaped by pricing, the enabling technology of timers, and social narratives—stories shared by members of a social group—grounded in a history of social marketing to reduce peak household electricity demand.

Setting

This research focuses on early buyers and lessees of PEVs in San Diego County, CA during the spring and fall of 2012. The electricity utility in the study region, San Diego Gas & Electric (SDG&E), is conducting a large sample, multi-year experiment of PEV TOU tariffs. That experiment is part of the context in which the research reported here was conducted, but the two research efforts are being conducted independently.

Electricity Pricing

Home At the time of this study there were six possible TOU tariffs for households with PEVs, all varying seasonally; Figure 1 illustrates the summer rates as well as the lowest and highest rates within the (non-TOU) residential tiered tariff. (Peak prices during winter are generally lower.) Electricity for most residences without PEVs is priced according to a tiered system; the more electricity a household uses per month, the more they pay per kilowatt-hour (kWh) as they cross thresholds in monthly usage, i.e., tiers.

All the TOU price structures for households with PEVs divide the day into three periods: high (peak), medium (off-peak), and low (super off-peak). The EV-TOU1 tariff is available to any household with a PEV. The EV-TOU1 rate is a whole house rate (including the PEV). The EV-TOU2 is available to households with a separate meter for the PEV only, leaving the residence on a tiered rate.

The utility is also conducting a TOU rate experiment specifically for households with PEVs. All participating households installed an EVSE at their home and had a second meter solely for their PEV. Further, all had the same brand EVSE and the same make and model of EV. Participating households were randomly assigned to one of three experimental TOU rates—X, Y, or Z. These rates were designed to study the elasticity of PEV drivers’ time-of-day vehicle charging rather than according to the principles of cost-recovery and rate of return on capital used to set non-experimental rates.

Finally, households who had a domestic solar energy system (SES), i.e., a solar photovoltaic system, prior to buying or leasing their PEV were on the sixth possible TOU tariff. Their DR-SES tariff determines both what these households pay for electricity when their SES produces less energy than the household (plus PEV) demand and what these households are paid when they are net electricity producers. This group makes up more than one-third of all the early buyers and lessees of PEVs in the study area.
FIGURE 1  San Diego Gas & Electric summer residential TOU tariffs, cents per kWh.

Away-from-home  Charging PEVs away-from-home was not explicitly priced by any TOU tariff. However, that PEVs are more likely to be driven away from home during the day and early evening means that any price difference between home and away-from-home—and especially free away-from-home charging—carries a TOU signal. When we conducted the household interviews in spring 2012, away-from-home charging was free. This included “public” charging available to any PEV driver as well as employer-provided charging limited to employees. By the time we conducted focus groups in fall 2012, PEV drivers had begun to be billed at some locations for public charging. At present in California, operators of these charging
locations cannot resell electricity; they typically bill for connection time regardless of whether the vehicle is actually drawing power, how much power (as different PEVs charge at different powers), or total energy. Further, prices at away-from-home charging locations are not uniform, but vary by EVSE provider network. All these complicate price comparisons—for PEV drivers and analysts.

Vehicles

Virtually all of the PEVs in this study are Nissan LEAF EVs. At the time of this research, this vehicle had a 3.3KW charger; other PEVs charge at higher power. One of the relevant factors shaping observed charging behavior is that the LEAF will typically charge to “full” within the five-hour super off-peak period. Most drivers of this vehicle reported they routinely charge it to only 80 percent state of charge to promote longer battery life; the driver can set this to be the default “full” charge. Further, few of these drivers nearly deplete the battery before charging. Thus while the LEAFs 24kWh battery might nominally require nearly eight hours to charge from zero to 100 percent, in practice few of our respondents ever require a charge greater than the approximately 16kWh that the 3.3kW charger can supply during the five-hour super-off peak period. Thus, when charging at home at night, few of our respondents must routinely choose between a “full” charge and paying more than the lowest price for electricity. If they do have to make this choice, they can use the timer to both start and stop charging.

Research Methods

Sample

Twenty-eight PEV owners and lessees were interviewed in their homes in April and May 2012. Four focus groups were conducted with a distinct sample in November 2012; a total of thirty-three more PEV drivers participated. All 61 people were drawn from the population of people eligible for a California Clean Vehicle Incentive (CVI) in 2011 and early 2012. Notably this population excludes the earliest buyers and lessees of Chevrolet’s Volt because during its first model year that vehicle was not eligible for the CVI. Thus, these samples of PEV buyers are made up almost solely of buyers and lessees of the LEAF EV; the substantive discussion presented here focuses solely on these EV drivers. These PEV owners and lessees had on average higher incomes, were older, and had more formal education than the general population of San Diego. Previous research identified similar differences between samples of new-vehicle buying households and general populations (23).

The interview sampling covered ranges and varieties of several household and driver attributes: household income, gender of the primary PEV driver, age of the survey respondent, households made up of employed or retired households, and whether the home had a solar photovoltaic systems or not.

None of the interview households participated in the focus groups. Each of the four groups had between seven and ten participants. The goal of a focus group is to engage a small number of people in conversation to elicit stories and in-depth explanations. The sampling process of segmenting participants into groups helps to achieve this goal by grouping similar people together. Further, it allows for enhanced comparison and contrast between groups (24). These focus groups were segmented according to gender and interest in technology. Women and men tend to have different social roles and consequently travel behavior and vehicle perceptions. As examples, men’s and women’s travel behavior continues to differ by trip times and distances, the number of non-work trips, vehicle occupancy, and propensity to trip-chain. General interest
in technology and specific interest in PEV technology may both be attributes of early PEV
drivers and affect PEV drivers’ ability to understand PEVs.

Interview and Focus Group Protocols and Analysis

A team of four researchers conducted the interviews: two for each interview. Most interviews
were conducted at the participant’s home and included at least the primary driver of the PEV.
Every attempt was made to include spouses and partners, especially if they drive the PEV, too.
Interviews lasted between one and two hours. The discussion was guided by a list of specific
topics: purchasing (or leasing) the PEV, charging, information sources including vehicle
instrumentation, and any sense of community forming around PEVs. Questions were open-ended
and participants were encouraged to discuss items important to them. Interviews were audio
recorded and supplemented by field notes and observations made during the interviews.

During the interviews, the interview team met every couple days to review. Upon
completion of all the interviews, each researcher reviewed the audio recordings and compiled a
review of the households in which they had been an interviewer. The reviews were then
compared against each other to locate themes across households representing common
experiences, ideas, and valuations across interviews (25).

The focus groups were moderated by one researcher and observed by three others. These
four researchers were the same as the interview team. The focus group protocol was designed by
these four based on the themes developed from the interview data: home charging, away-from-
home charging, how PEV charging has changed with the advent of billing for away-from-home
charging, charging etiquette, social interactions, and information sources. Each focus group
lasted two hours. The moderator provided initial introduction and assured the conversation
covered all the topics in the protocol, but in general allowed the participants to determine the
direction and extent of discussion.

The focus groups were videotaped and transcribed. Additional field notes and
observations made during the focus groups supplemented the recordings. Researchers reviewed
recordings of all four groups and compiled a summary of thematically relevant statements.

RESULTS: EARLY PEV DRIVERS REACTIONS TO DRM

After presenting a summary of the statements about how and why DRM affect their PEV
charging, results are organized according to their emphasis on pricing, technology, or narrative,
though the implied distinction between these three is overstated because of the relationships
between them.

Summary Results

The three PEV charging DRM strategies in San Diego are incorporated by many of these early
PEV drivers into similar accounts of beliefs and behaviors that these PEV drivers say assure very
high percentages of their PEV charging occurs during the “super off-peak” time period,
especially on weekdays. However, differences across TOU rates make very little difference in
these accounts: the existence of any TOU price signal (at least within the observed range of
differences) is enough to prompt an account of late night PEV charging. The exceptions—
households who have an SES-TOU rate—appear likely to ignore the time of day consequences
of charging their PEV.

The role of timers is to make charging between midnight and 5am routine: man of these
PEV owners set a timer once: thereafter, they plug-in their PEV upon arriving home and don’t
think about it again until they unplug the car the next morning. This routine is widely but not universally practiced; nor is it foolproof. Unintended outcomes occasionally occur when the routine is disrupted, e.g., when charging is done somewhere and some time other than its usual setting. The most common unintended outcome is a missed charge: a driver returns to discover the PEV did not charge because they forgot to override the timer.

The effect of TOU tariffs is not solely through the private cost-benefit of lower prices. Rather, the TOU tariffs fit a narrative about electricity in California that the PEV drivers recount: the grid is susceptible to service interruptions during periods of peak demand. The public good behind the TOU pricing is widely accepted and the goal of grid reliability is widely supported among these drivers. The TOU price signals also support another narrative about PEVs: they are inexpensive to drive because electricity is cheaper than gasoline. Part of this narrative is the elevation of cost-effectiveness and frugality to the status of virtues. Thus, the private cost benefits of TOU tariffs will be difficult to entirely disentangle from the social benefits.

**Charging in response to TOU tariffs**

Descriptions of PEV charging by almost all respondents who were on any TOU tariff other than an SES-TOU tariff were similar: “Super-off peak is cheapest. Why wouldn’t I charge then?” In short, that there was any time-of-use price signal was enough for almost all PEV drivers not on an SES-TOU tariff to report that most of their home PEV charging was done during their least expensive period. Their motivations were linked to both the direct effect of pricing on private costs and social or system benefits. Deviations from this behavior were due to the use of some other standard than the home TOU tariff for the comparison or a “broken” mental model that a PEV driver’s home SES (should they have one) insulated the grid from their PEV charging behavior. A notable exception is among PEV drivers who can charge at work for free during the day: we take up such examples in the section on away-from-home charging.

Households who had SES were more mixed in their time-of-day charging behaviors. Some believed their SES insulated the grid from their behavior. This can only be true if the home-SES includes energy storage to act as a buffer; none of these households had storage. Thus, they would plug their PEV in at any time of day they returned home. “When you have solar, you’re generating power during the day so you’re always paying the lowest per-kilowatt rate no matter because you pay based on how much you use and if you’re never using more than the minimum you’re never paying more than the minimum.” However, some other PEV drivers with SES reasoned that they generated the most revenue by producing as much net power during the peak period as possible, thus they would delay their PEV charging until their cheapest price period, beginning at 10pm (Figure 1).

Two features of residential SES and SES-TOU rates complicate this discussion. First, households may or may not have sized their SES in anticipation of charging a PEV. If they did, then the comparatively larger SES power production capacity further reduces the chance they will be net consumers no matter when they plug in their PEV. Second, households on SES-TOU rates only settle their bill with the utility once per year. Thus the incentive for daily adherence to a time of day schedule is blunted by the fact that, metaphorically and actually, today’s net peak consumption can be balanced by tomorrow’s net peak production.

**Comparative prices**

Different PEV drivers use different comparative prices, i.e., what is inexpensive or expensive may not be judged based on electricity’s own price, but in comparison to some other price. These
other prices may be specific, e.g., the price of gasoline, or more generalized, e.g., time and convenience.

For some people, a comparison to gasoline prices reinforces their super off-peak charging behavior. Typical among people who thought in terms of their TOU tariff and the price of gasoline, one of the respondents said, “[You] start thinking about if the EV is really so much cheaper with electricity compared to gasoline, and it may not be, unless you charge at home for the very low rate time, which is midnight to the morning.” Another, Harold, has prepared his interview by writing out for us his total PEV miles and total electricity cost: 3,500 miles and $79.68. He compares the latter to the cost of gasoline for the vehicle his PEV replaced. Using 20 mpg and $4.40 per gallon of gasoline, he makes the comparison: “It’s roughly $80 vs. $800. It’s like ten-to-one…It’s huge. It’s more than I ever thought it would be.” He thinks that over the course of a full year he may be saving closer to $1,500. He thinks his savings are due to his TOU tariff: he starts charging at midnight to “get those more favorable rates.” He says that even if he didn’t, at the worst case it would have been $200 to charge his EV. While that is still favorable to the PEV, he summarizes, “Four-to-one vs. ten-to-one. That’s an incentive to charge at midnight.”

Some drivers bear non-price costs as part of their response to TOU electricity prices. Martin complains that he is only able to get 80 miles driving range, “85 on a good day,” using the 80% battery charge threshold. Yet he adheres to this threshold and sets the cars timer to start charging at midnight and stop at 5am despite the fact it won’t charge to 80% in that interval because he arrives home with the battery nearly depleted. He is only able to make his round-trip commute on this “partial charge” because he drives slower than he would like to and slower than he says he does in the household’s gasoline-powered car. In his case, the TOU price of electricity and the availability of the timer so strongly motivate and facilitate his behavior to charge only during the super-off peak period that he is willing (for now) to pay the daily price of his frustration at driving slower freeway speeds and his trade-offs with TOU pricing include his uncertainty about battery life—his motive for adhering to the 80% SOC limit.

Away-from-home charging: The role of implicit price and non-price signals

By the fall 2012 focus groups, some away-from-home charging locations were billing users, but for the duration of time their PEV was plugged-in, not for kWh of electricity. These prices don’t vary by time of day. Thus away-from-home charging went from an implicit signal that conflicted with the goals of the home TOU tariff, i.e., free charging away-from-home, even during peak periods, any reduction in their away-from-home charging has the effect of reducing peak or off-peak charging, whether or not it increases their super off-peak charging.

When and where it was available, free away-from-home charging presented a powerful price signal. Several respondents revealed using public charging stations because they were free even when their vehicle did not need a charge: “Even if it only took [approximately 20% of the battery capacity] to get down there, I’m plugging in. Because it’s free…” One focus group
participant explained his response to now being billed for connection time at PEV chargers, “A dollar an hour isn’t that big of a deal, but there’s a big gap between $1 an hour and free. You know, $1 to $2 is not that big of a deal, but $1 to free that’s what motivates people: free.”

Comparisons between gasoline and electricity costs and between home charging and public charging constituted the primary comparisons conducted by respondents. One driver discussed how the expense of paid public charging compared to the cost of charging at home causes him to limit his PEV charging to home and thus, largely to super off-peak, “I’m not going to rely on [away-from-home] charging at all. I will not take the [EV] out of the driveway unless I know perfectly well I can come back.” Several other drivers shared this sentiment, “As far as relying on the infrastructure to charge, it really is not economically viable to charge any place that charges more than twice as much as what you would pay at home.” In contrast, others expressed the opinion that so long as public charging remained cheaper than gasoline they would be willing to pay for public charging. One driver made the difference between comparative prices explicitly, “It depends on how you did the comparison. If you’re comparing the charging at home on the super cheap rate – midnight to five – [away-from-home charging is] probably four times as much. But it is still…half as much as buying gas.”

Charging behavior in response to DRM-supporting technology: timers

Some PEV drivers related how establishing a routine helped them adhere to a schedule of PEV charging. The primary role of timers was to enable this routine. One respondent said, “I just set the timer for midnight…it charges up the next morning and I get in and go.” Another adds, “You plug it in when you get home and you don’t think about it until you get out the next morning.”

However, other households established more flexible behaviors; they were more likely to make decisions on an ongoing basis about when to charge. Though these drivers also generally tried to charge during off-peak times, they cited possible emergencies and disruptions in daily routine as reasons for charging during peak periods. One driver explains, “Too many things come up unexpectedly, but, yeah, usually we plan. And sometimes I forget to hit the ‘don’t charge during the day’ button.”

The downside of using the timer technology to establish and sustain a routine of charging at home after midnight is that the routine separates the driver from the actual vehicle charging. The driver merely connects the EVSE to the car: the timer starts (and in some cases, stops) the charging. This is problematic when the drivers want to charge their PEVs at a place or time that is not the primary place and time of the routine. Charging anywhere else or at any other time—both in the sense of clock time and in the sense of the flow of events in their day—is a break in the routine. In the non-routine situation they may connect the EVSE to their PEV—and walk away forgetting to override their timer. The usual consequence is a missed charge. Several people offered such examples, “We forgot to push the timer button to turn the timer off so we were [billed] for two hours and didn’t get any electricity at all.”

Charging behavior in response to social marketing

Several PEV drivers recount reasons why charging their PEV during the super off-peak period provides social benefits to all electricity users in addition to private cost reductions to themselves. In the absence of concurrent social marketing to promote PEVs, these PEV drivers recount past social marketing campaigns, providing evidence that the message to moderate peak use has become part of a social narrative about electricity. As Jane says, “Ever since I have been
in California, I’ve been conditioned that between 11[am] and 6pm are flex hours and that’s when they have the blackouts….”

Some drivers explained their choice to charge their PEVs during super off-peak periods as a civic duty. One driver discussed his belief that charging his PEV at night not only supports the grid, but the local economy, too:

“Well, electricity is so much cheaper if you’re charging at night, you have more money to spend on the local economy, and you’re not sending money overseas. So it’s good for the local economy…it’s also we’re supporting the infrastructure because we’re paying the infrastructure cost, so we’re bringing the cost down for the system for everybody else.”

This civic-mindedness was present even among drivers with home SES: “Charging during off-peak times reduces emissions and infrastructure costs, it’s just better for society. It’s the right thing to do…it’s just being a good citizen.”

Part of the focus group discussion centered on several challenges to home charging during off-peak time periods in the context of this social narrative. Participants offered suggestions that would improve the ease of charging and encourage drivers to take advantage of the TOU rates. One driver said,

“It really should all be done in a way that encourages [super off-peak charging], because in the long run, like he said, if we’re plugging in at night and we’re paying something, we’re helping support the grid, you know, the overhead, and all the other positive things that are happening.”

DISCUSSION AND CONCLUSIONS

The primary finding from our conversations with PEV drivers is that the suite of DRM strategies in effect in the study region at the time of the study appears to shift behavior in the intended direction: most drivers describe themselves as attempting to shift home PEV charging to the super off-peak period between midnight and 5am. The accounts of these drivers describe their efforts to assemble new charging practices as part of being a PEV driver. The stories told about assembling these practices confirm the roles of pricing, technology, and social marketing in shaping PEV charging. What this study provides is an understanding of why most PEV drivers believe they should adhere to an off-peak charging schedule and, perhaps more importantly, why some do not.

Their accounts complicate the easy causality suggested by the own-price elasticity of demand for electricity. These PEV drivers are not considering electricity prices only, but compare them to a variety of reference prices and costs that include non-monetary costs. TOU pricing has commonly been analyzed within a narrow calculus of private cost savings. Indeed, many of our respondents tell us the cost savings that accompany super off-peak pricing are important to them. However, TOU prices also fit a social narrative that these PEV drivers recount: the electricity grid in California is susceptible to outages during periods of peak demand. Thus many PEV drivers feel they are acting within a framework of civic duty when shifting their PEV charging to after midnight. This is consistent with Dütschke and Paetz’s (10) contention that prices carry both a cost and an information signal. If the PEV drivers (without SES) in San Diego are responding as much or more to the information about this social narrative as they are to the private cost implications, this would explain for why different TOU price structures don’t produce different stories about responses to those structures: the information content is the same even if the specific price signals differ. In this sense, many of the PEV
drivers in this study connected past social marketing to limit peak use of electricity to the present deployment of PEVs, TOU pricing, and supporting technology.

Timers can aid PEV drivers to make charging off-peak a routine. There are occasional negative consequences to this routine; failure to override the timer when a charge is desired at another time of day has resulted in missed charges. Whether PEV drivers will successfully develop multiple charging routines given more opportunities to charge at more times and locations—and whether technologies such as timers hinder or aid multiple routines—remains to be seen.

The PEV drivers who have made the largest financial commitment to both electric transportation and renewable electricity are the most likely to report charging their PEV throughout the day. This behavior most often seemed based on a mistaken belief that their SES insulated the electrical grid from their PEV charging. Thus people who might be the most committed to clean energy and electric mobility were likely to decrease the private and public benefits of both their SES and PEV.

As the findings reported here are specific to a time, a place, and a more limited variety of PEVs than are already available to consumers, questions about the generalizability (across electricity infrastructure and pricing, households, vehicles, and time) and durability (within households over time) require ongoing research to inform robust policy making and DRM program design. However, this study offers guidelines and hypotheses for further research. Along with past work, these interviews and focus groups prompt the question whether there is any price difference too small to encourage widespread and frequent—if not universal—compliance with off-peak charging. The accounts of these early PEV drivers suggest the answer will not be straightforward. Any difference between the price of PEV charging at home and away-from-home carries an implicit TOU price and information signal given the diurnal patterns of most people’s lives. Use of different comparative prices by different households further complicates questions of why, whether, and how much PEV drivers respond to electricity pricing. These early PEV drivers’ accounts suggest that perfect adherence to off-peak charging is not to be expected even among motivated PEV drivers. Even if past analyses typically use 100% off-peak compliance scenarios to create a bounding case, this research suggests the importance the question of what kinds of signals will large populations of PEV drivers require to assure high enough compliance to achieve the touted benefits of PEVs?
ACKNOWLEDGMENT

The California Energy Commission’s Public Interest Energy Research Program and ECOtality, Inc. funded this research. We thank the participating households, Justin Woodjack for his contributions to the data collection and analysis, Gil Tal for his assistance with sampling and descriptive statistics, and representatives from San Diego Gas & Electric for their comments on this work. The authors bear the sole responsibility for anything said here.
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