PENINSULA CLEAN ENERGY

March 2025

PCE EV Managed Charging Pilot Results

About Peninsula Clean Energy

Peninsula Clean Energy (PCE) is the locally led, not for profit agency that provides clean electricity to San Mateo County and the city of Los Banos. Our mission is to provide electricity at lower rates to our local community while helping California build a more resilient, carbon-free power grid. We hold ourselves accountable to keep our energy rates stable and competitive, and we're committed to a larger goal: provide our customers with 100% renewable electricity by 2030, every hour of the day.

By encouraging our customers to charge their EVs when the grid has more renewable energy, like when the sun is shining, we can advance our clean energy goals and reduce pressure on the grid. Our EV managed charging pilot sought to put this principle into practice, testing advanced telematics systems to optimize home charging, further reducing costs to customers and maximizing clean energy in local EVs.

Lead Author

Phillip Kobernick, Peninsula Clean Energy

With support from:

Leslie Brown, Peninsula Clean Energy

Kim Le, Peninsula Clean Energy

Brooke Morales, Peninsula Clean Energy

Connor Prince, Peninsula Clean Energy

Rafael Reyes, Peninsula Clean Energy

Cassandra Tang, Peninsula Clean Energy

Andy Wang, Peninsula Clean Energy

Special thanks to:

Fiona Burlig, University of Chicago

Jim Bushnell, University of California, Davis

Addie Melvin, ev.energy

David Rapson, University of California, Davis

Executive Summary

As Peninsula Clean Energy transitions to 100% renewable energy, a critical challenge will be to manage electrical loads such as EV charging, ensuring that clean energy is available for these new energy demands. The evening ramp-up period (5-7 PM) is particularly difficult and costly because energy usage surges while solar generation declines. To address this, PCE launched the EV Managed Charging Pilot to test whether a scalable, vehicle telematics-based smart charging system, which allows EVs to optimize their charging times, could effectively shift large-scale, residential, EV charging away from these peak hours.

The pilot recruited 698 EV owners from a pool of 13,000 targeted customers, testing different financial incentives and pricing strategies. However, despite relatively simple enrollment (since no special hardware, such as a smart home charger, was needed for a customer to participate) and incentives of up to $40 per month, only 4% of invited customers participated, highlighting the difficulty of scaling voluntary programs. Additionally, a significant self-selection bias emerged. Most participants who enrolled were already using PG&E's optional EV2 rate, meaning they were already avoiding peak-hour charging. This dramatically limited the program's ability to further shift charging behavior and reduce evening demand.

Major takeaways

- **Recruitment is a major challenge:** Despite offering various financial incentives, the pilot struggled to achieve broad participation. Even the highest incentive group ($40/month) only reached a **10.6% enrollment rate**. This suggests that voluntary opt-in programs will require significantly different engagement strategies to scale effectively.
- **Self-selection bias limits managed charging effectiveness:** Most enrollees were already avoiding peak hours when charging at home**.** This resulted in lower-than-expected load shift potential because participants did not represent the full spectrum of EV drivers, particularly those who charge during peak hours. **Without addressing this selection bias, managed charging programs risk overestimating their impact.**
- **Managed charging was effective at smoothing "timer peaks" but had minimal impact on peak demand:** While the smart charging system successfully reduced the "timer peak" effect (the surge of charging demand that occurs when off-peak rates begin), its impact on shifting evening ramp-up demand was minimal**.**

Key metrics

698	4%	~0.15 kW
Customers recruited	**Avg. enrollment rate**	**Daily avg. load shift, per EV, 7 PM hour, TOU-C customers**

PCE EV Managed Charging Pilot Results

Table of Contents

Project background

EV charging is a major flexible residential load that has the potential to add significant load when drivers plug in between 5-7 PM after commuting home from work. These hours are particularly challenging and costly to serve with 100% renewable energy. So, if this load can be optimized by shifting from on-peak to off-peak hours, PCE can better provide clean energy at lower rates. See “Projected 2025 hourly average emissions intensity” graphic below.

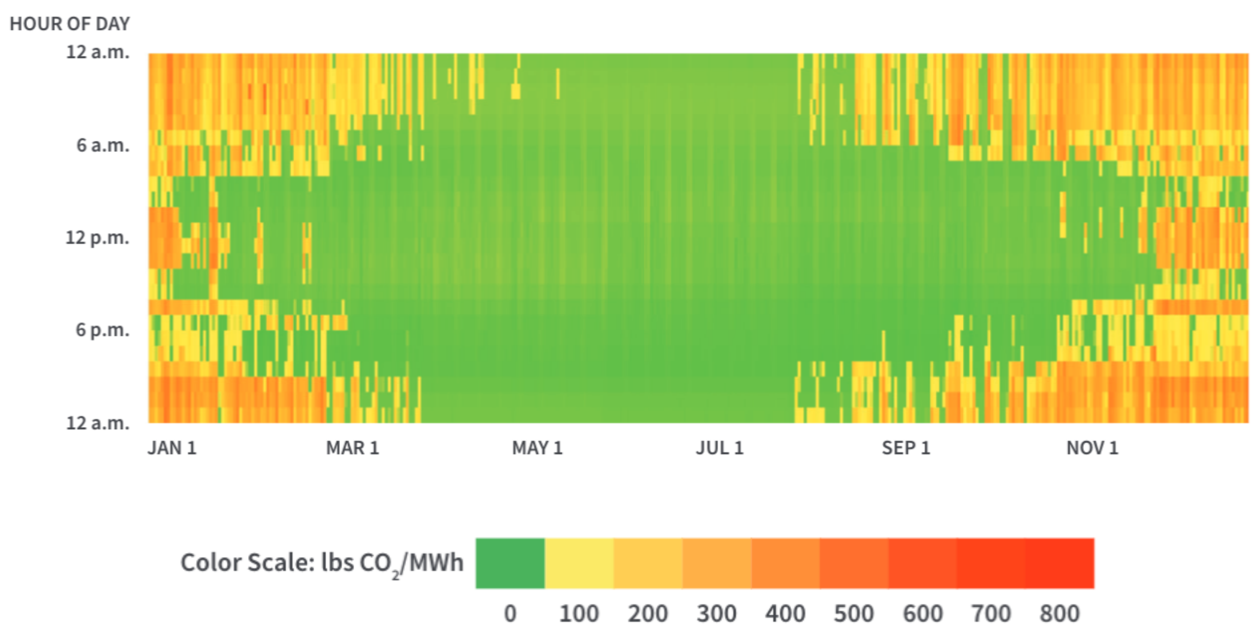
PCE focused on EV managed charging systems that utilize vehicle connected car systems. These systems allow for easier and more scalable customer enrollment compared to systems that utilize internet-connected home chargers. Most EV drivers plug in an outlet or use a non-internet connected home charger. Since an estimated fewer than 10% of people use an internet-connected EV charging at home, telematics systems allow for widescale enrollment.

PCE began evaluating EV managed charging options in 2020, seeking opportunities to demonstrate scalable load shift in support of providing 100% renewable energy in all hours of the day. After a successful proof of concept test with FlexCharging, PCE conducted a competitive solicitation and selected ev.energy for phase 2 of the pilot, which launched in the summer of 2023 and ran for approximately 9 months.

In addition to further validating the technology, PCE had the following learning objectives:

- How much load shift is achievable through telematics systems?
- How much and what types of incentives are important for customer recruitment and retention?
- How will EV drivers charge differently if their rate is adjusted? Will we see similar load shift through rates as through smart charging?

PCE projected 2025 hourly average emissions intensity, 90% time-coincident renewables



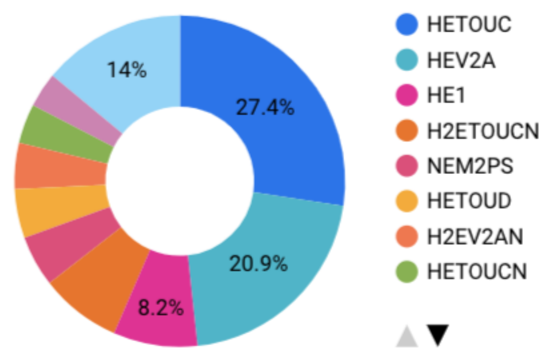
Who are San Mateo County's EV drivers?

EV community analysis

By combining 2023 DMV registration data with home energy consumption data from PG&E, PCE was able to learn more about EV drivers and how they use energy at home.

- A plurality of EV drivers (27%) are on the default TOU-C rate, 21% have opted into the EV rate, and 8% have opted back to the non-time of use E1 rate.
- About 33% of EV drivers are on a solar rate.
- 15% of EV drivers responded that they didn't know what rate they were on.
- EV drivers on the EV2A rate are highly responsive to their rate, with a significant spike in home energy use at midnight, at the start of the off-peak window (see home energy data below)

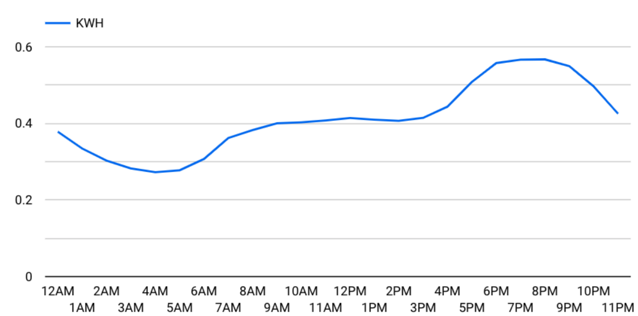
San Mateo County EV Drivers, by Rate



Hourly Home Energy Usage of Known EV Drivers, by Rate

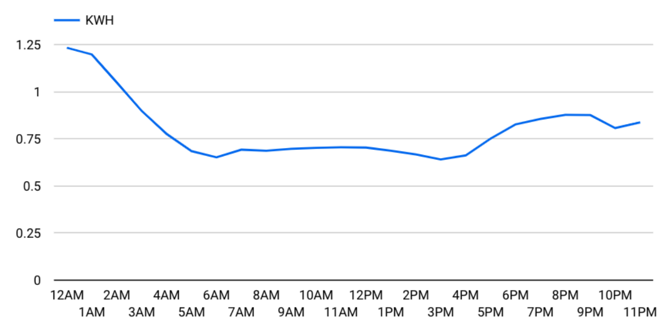
TOUC

Hourly Average kWh Usage



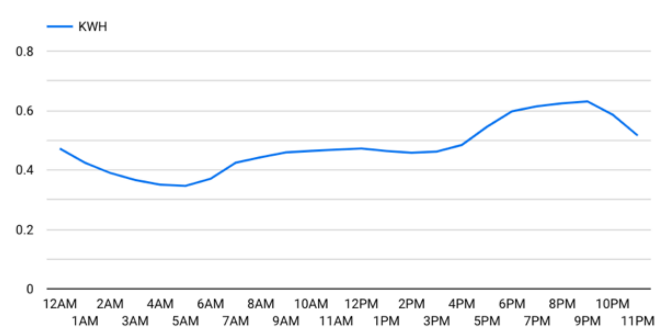
EV2A

Hourly Average kWh Usage



E1

Hourly Average kWh Usage



Pilot overview

PCE decided to focus on residential customers for this pilot. If unmanaged, home charging that begins during the evening ramp up hours, when commuters came home and plug in, represents the most significant and potentially impactful load pressure. To simplify the pilot, only known EV drivers in the default TOU-C rate or the EV opt-in EV2-A rate were invited to participate. EV drivers on all other rates were initially excluded, including solar customers. EV drivers at multi-family properties were also omitted due to the complexities of using third-party chargers.

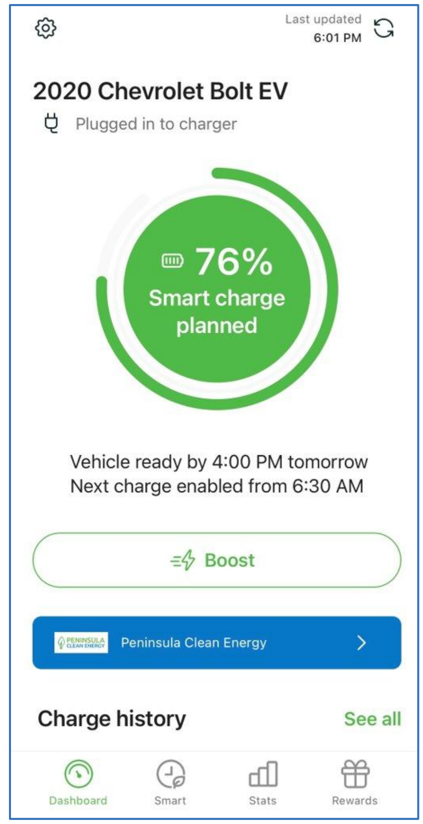
Residential EV drivers were sourced from local DMV registrations. These customers were randomly split into various control and treatment groups. These groups were designed to study the various load shift, recruitment, and retention impacts of different incentives and approaches. Customers were given an incentive offer via email recruitment, further outlined in the outreach section below.

These randomly assigned groups received different charging interventions.

First, customers were generally split into "smart charging" or "monitor" groups. EV drivers in the smart charging groups needed to download the ev.energy app, sync their vehicle, and enter their "smart charging" schedule. The schedule allowed them to select by what time they needed their car charged each day. The ev.energy system would delay charging until off-peak hours and during hours of lowest grid emissions, while ensuring the EVs were charged by the indicated departure time (see photo to the right for a screenshot of the app demonstrating this feature).

Other customers were enrolled into "monitor" groups. These customers did not receive smart charging features in the app. Instead, their charging was monitored through the ev.energy system for data collection. These drivers received other incentives, such as rate adjustments further described below, to test the impact of behavioral load shift instead of through an automated system.

Incentives were also applied in several ways. Some customer groups received smart charging through the ev.energy system and monthly incentives ranging from $0 to $40 per month. Other drivers received rate adjustments that increased the cost of on-peak charging and decreased the cost of off-peak charging. In these groups, drivers would need to manually adjust their charging behavior since the app would not do this for them.



Screenshot from the ev.energy app, showing a user's smart charging schedule in use. Although the vehicle is plugged in at 6:01 PM, the vehicle won't start charging until 6:30AM and will be ready by the targeted departure time of 4 PM. The app is also factoring in that this driver uses Level 1 charging at home.

In addition to the incentive offer that corresponded with their randomly assigned group, all customers (except for control group 1) were also entered into a raffle to win a $500 bill credit.

Customer group assignments

As noted above, customers were generally assigned to "smart charge" and "monitor" groups. EV drivers in smart charge groups received the full smart charging functionality provided by the ev.energy app. Many of these groups also received various incentives to test enrollment potential, further described below. EV drivers enrolled into the monitor groups received various price interventions, such as changes to their electricity pricing, but no smart charging functionality, to test the impacts of behavioral modifications.

Control groups (C1 and C2)

The pilot used two control groups: a pure control and a Hawthorne control. The pure control (C1) were randomly assigned EV drivers that were never invited to participate in the pilot and used as a baseline. EV drivers in the Hawthorne control (C2) were invited to participate and didn't receive either an incentive of any kind nor smart charging. They were a monitor-only control to analyze the baseline energy use of EV drivers who opted into the pilot, compared to the C1 group.

Smart charge groups (T1 – T4)

These four groups were designed to test both the app's automated load shift potential and the impact of incentives. All four received smart charging. The first group, T1, received no incentive. Participants in groups T2-T4 received flat, monthly incentives of $5, $20, and $40, respectively.

Whole-home rate adjustment (T5)

This group was intended to test a rate-based intervention compared to smart charging. Participants in this group did not receive smart charging. They were "monitor only" and only provided charging data in the app. This group also temporarily opted into an experimental new rate, that was applied to their entire home's energy usage, not just EV charging. The price of energy was adjusted so that on-peak hours increased by $.05/kWh and off-peak hours decreased by $.05/kWh.

Whole-home rate adjustment, no app (T6)

Like T5, participants in this group also temporarily opted into an experimental home energy rate with the same price adjustments. However, this group was never asked to download the ev.energy app. Since charging data wasn't available, only home energy usage was analyzed. The intent of this group was to evaluate if behavior load modifications are consistent between those willing to download a connected car app and participants who are unwilling to do so.

Vehicle-only rate adjustment (T7)

This group received a similar rate adjustment as T5 and T6, however the new pricing was only applied to EV charging energy, when charging at home. This is different than the T5 and T6 groups, in which the pricing adjustment was applied to whole-home energy use; adjusted prices in the T7 group only applied to the energy used to charge their EV. EV drivers paid an extra $.05/kWh when charging on peak and a discount of $.05/kWh when charging off peak, applied as a bill credit or charge on their following month's electricity bill.

Reverse auction (T8)

This small group was intended to test incentive designs, such as one-time upfront and monthly incentives. A reverse auction style platform was developed to test how much one-time incentive would encourage participation. Upon enrollment, EV drivers received smart charging.

Customer recruitment

Roughly 13,000 EV drivers were targeted for recruitment. These EV drivers were identified through DMV registration data and successfully synced with the address on their PG&E bill so that their home energy usage and rates could be identified. Only EV drivers on the TOU-C (default time of use) and EV2-A (opt in EV rate) were included in recruitment.

Enrollment marketing began in May 2023 and was conducted in several phases through August 2023. Each customer received 3 emails with varying messaging approaches.

Recruitment proved harder than expected. This was despite having high email campaign engagement with email open rates regularly exceeding 50% and utilizing a telematics platform that allowed for relatively easy customer enrollment. The overall enrollment rate was 4%. Aside from the high-value T4 group, no recruitment group exceeded a 6% enrollment rate. Some customers failed to enroll because of technology issues. For example, some never completed onboarding in the ev.energy app by fully connecting their vehicle, reducing the number of customers that successfully sent home charging data. This was due to technical limitations or a frustrating connection process with their vehicle make. Others already had home energy management systems (solar and storage customers in particular) and didn't want to add a possible interference.

Self-selection bias among customers who chose to join the pilot was a major challenge. For example, customers who opted in the optional EV2-A rate (PG&E's EV rate) were significantly more likely to join the pilot than EV customers on the default rate. **75% of everyone who joined the pilot was on the EV rate, despite representing less than half of the target recruitment audience**. As described later in this report, the customers who opted in also used energy differently than similar EV drivers who did not end up joining the pilot.

Enrollment summary

PCE tested the recruitment potential of various incentives. Groups offered relatively high incentives for participation enrolled at only moderately higher numbers than the control group.

Group	Customers emailed	Enrollment total	Enrollment rate
Control 2 (Hawthorne)	2,570	88	3.4%
T1 ($0 incentive)	2,461	35	1.4%
T2 ($5/mo incentive)	1,780	56	3.1%
T3 ($20/mo incentive)	1,027	51	5%
T4 ($40/mo incentive)	585	62	10.6%
T5 (rate change)	1,531	64	4.2%
T6 (rate change, no app)	1,379	74	5.4%
T7 (rate change, car only)	1,529	75	4.9%
T8 (reverse auction)	441	9	2%

Given the challenges in initial recruitment, PCE expanded the scope of the pilot, adding a generic group in addition to the control and treatment groups described above. Eligibility for this new group was broadened to include all EV customers who were not previously contacted in prior rounds, including customers on solar rates and the non-time of use E1 rate. These customers were not offered any incentives and only received smart charging interventions (no rate modifications). About 4,000 customers were targeted in this secondary phase and roughly an additional 200 joined, a 5% enrollment rate, consistent with the first round. These customers were nearly entirely residents who had installed solar at their homes.

Results and insights

Key takeaways

- **Recruitment is a challenge.** Even with generous incentives, enrollment is generally less than 10%, making even lower friction options like telematics difficult to scale.
- **Self-selection bias limits load shaping potential.** EV drivers that are more likely to enroll in managed charging programs are more likely to be mindful of their charging and already charging off peak. They also use less energy overall than similar EV drivers who didn't opt in to the program. Both these factors limit load shape potential.
- **Residential slow charging is common.** Less than half of pilot participants charge at full Level 2 charging speeds (6+ kW), challenging the notion that Level 2 charging is ubiquitous. About 1/3 of EV drivers use Level 1 charging.

Customer retention

Incentive amounts or structures didn't have a significant impact on customer retention. Nearly everyone who joined remained in the pilot for its full duration. This was bolstered by messaging and app features that encouraged a "set it and forget it" approach to EV managed charging. Notably, some EV drivers in the control group (C2) left because they had assumed the app would provide managed charging, which they wanted, but were only in a monitor-only group.

Retention summary

For the most part, customers didn't unenroll from any of the experimental groups.

Group	Enrolled	Unenrolled	Retention Rate
Control 2 (Hawthorne)	88	7	92%
T1 ($0 incentive)	35	0	100%
T2 ($5/mo incentive)	56	3	95%
T3 ($20/mo incentive)	51	3	94%
T4 ($40/mo incentive)	62	1	98%
T5 (rate change)	64	4	94%
T6 (rate change, no app)	74	8	87%
T7 (rate change, car only)	75	0	100%

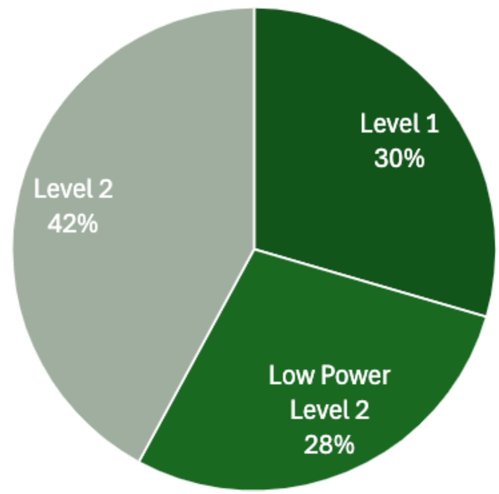
Home charging behavior

Among the more valuable insights provided by the telematics platform was data on how EV drivers are charging their vehicles at home.

For instance, PCE calculated average home charging speeds to quantify the power levels at which EV drivers were charging at home.

While Level 2 charging is often referred to as the norm for residential EV charging, the data show that less than half of residential EV drivers are using Level 2 (a minimum of 6+ kW) when charging at home. About ¼ are using low-power Level 2 (between 2-4 kW) and about 1/3 use Level 1 charging (less than 2 kW).

Home-based EV charging, amount of EV drivers by charging speed



In a survey of participants, 85% of EV drivers that primarily charge at home responded that they were already using technology to charge off peak regularly, either through their vehicle settings (71%) or a timer in their home charger or smart outlet (14%). Other respondents indicated that they manually plug in when off-peak hours begin.

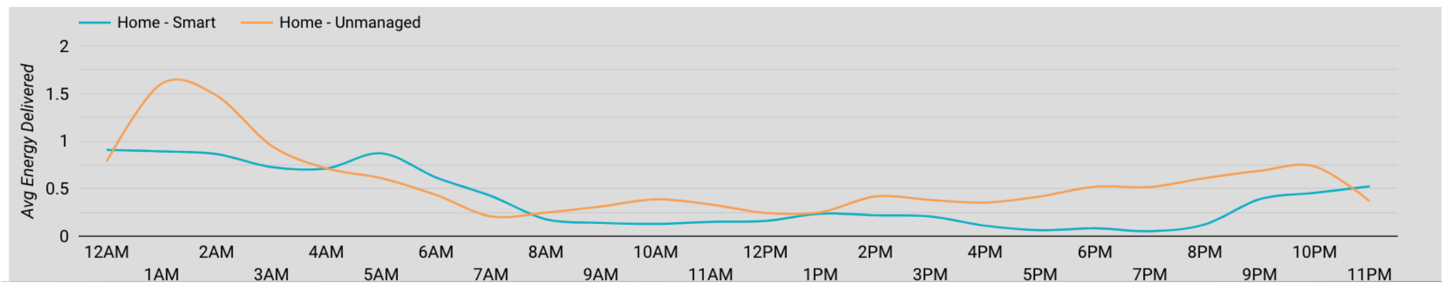
Another unexpected result was that many EV drivers who joined the pilot used about 15-20% less energy at home overall than similar EV drivers, even in control groups. For example, customers on the EV2A rate and in the Hawthorne control group (C2), a monitor only group with no smart charging, used about 13.4 kWh per day in their homes. EV drivers on the same rate in the pure control (C1), residents who never downloaded the app or knew about the pilot, used about 16 kWh per day in their homes, about 16% more. The same was true for EV drivers on the default TOUC rate, with those joining the C2 control using 8.5 kWh per day at home, compared to 10.5 kWh per day for EV drivers on the pure C1 control that never joined, about 20% difference.

EV charging load curves

Data from the ev.energy platform is presented below. These data are from the connected vehicles in the pilot and show EV charging load curves only. It's also important to note that these load curves are not true daily usage averages because they don't include data from null events (days in which the vehicles were not charging) and are thus meant to be illustrative only. True load shift is calculated from the home energy meter data, detailed in the following section.

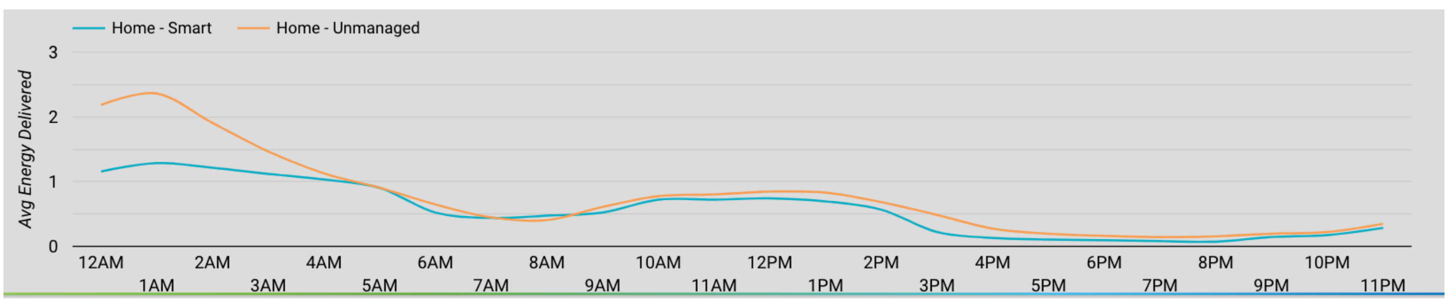
TOU-C (Default rate)

These load curves compare the EV charging data from TOU-C EV drivers in the C2 control group to an average load curve of TOU-C EV drivers in smart charge groups T1-4. Modest load shift was observed during the evening ramp up. There is also evidence of "timer peak" mitigation. EV drivers in monitor-only groups set their vehicle or home charger settings to begin charging during off-peak hours, between midnight and 1 AM. The active charge management system smoothed this timer peak out in the overnight off-peak hours.



EV2A

Like TOU-C EV drivers above, the charge management system successfully smoothed the middle of the night timer peak, in comparison to EV2A drivers in the C2 control group. However, EV2A customers were already highly responsive to their rate, with nearly all drivers avoiding on-peak charging, leaving little load management potential.



Load shift with home meter data

For a true "apples to apples" comparison of load curves and calculation of load shift potential, PCE used whole-home energy data, comparing EV drivers enrolled in the pilot in various treatment groups to EV drivers in the two control groups.

Load shift averages are summarized in the two tables below, sorted by EV drivers on the TOU-C rate and the EV2A rate. Smart charge groups (T1 – T4) and rate modification groups (T4 – T7) have been averaged together. Hours in which the treatment groups reduced load, compared to the corresponding control groups, are indicated as a negative number. Hours in which the EV drivers in the treatment groups increased load, in comparison to the corresponding control groups are indicated as a positive number.

As a reminder, EV drivers in pilot, including the C2 group generally used less energy at home than EV drivers who didn't join the pilot, including those in the C1 group. This is reflected in the data below. Therefore, the comparisons to the C1 group could be thought of as load shifting potential, if recruitment was able to entice a more representative sample to join. And comparisons to the C2 group are load shift potential among the types of EV drivers who actually did join the pilot.

Summary load shifting potential, using home energy data, TOUC customers

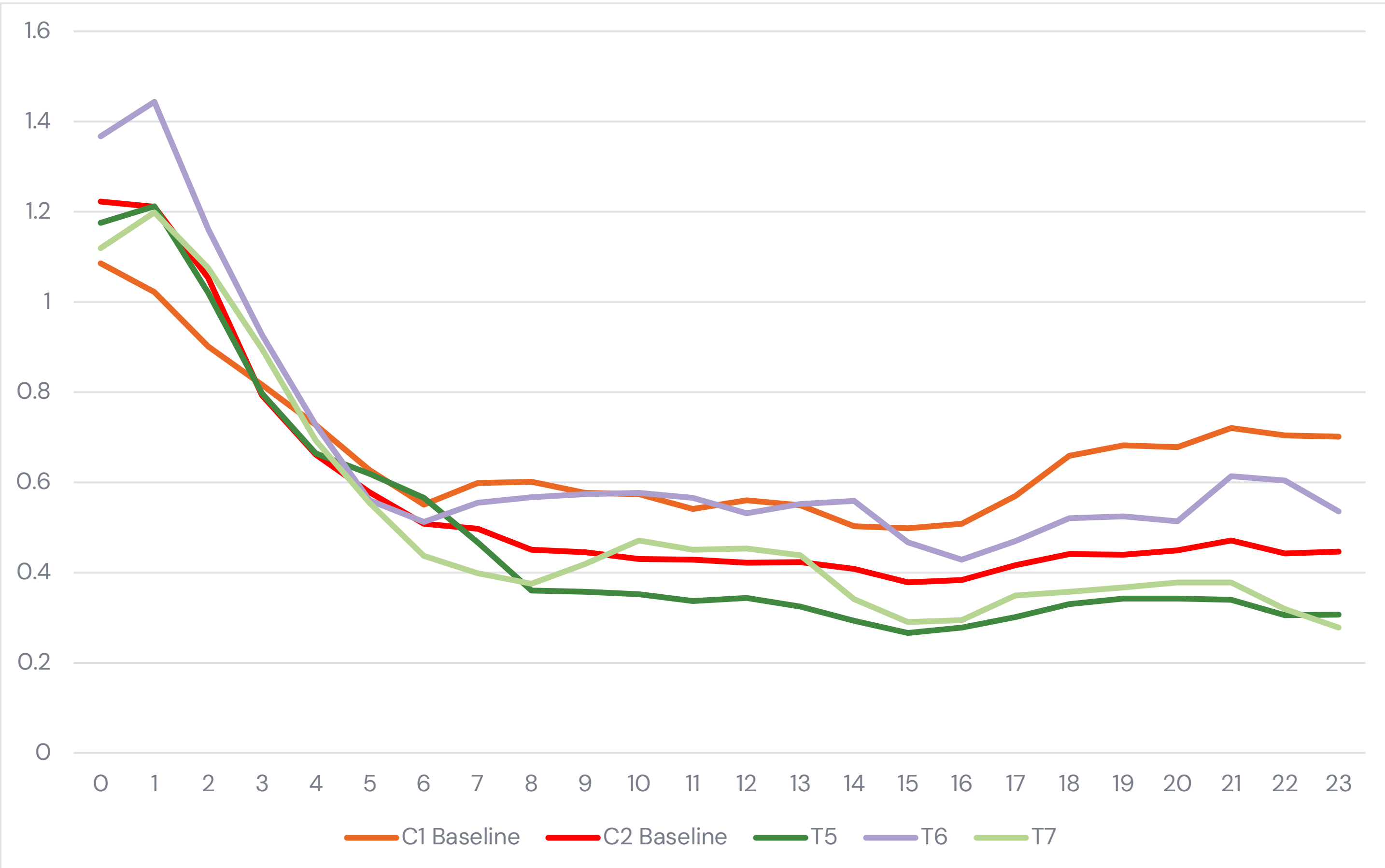
Hour	Smart charging average, compared to C1 group	Smart charging average, compared to the C2 group	Rate modification average, compared to the C1 group	Rate modification average, compared to C2 group
5 PM	-.114 kW	+.08 kW	-.107 kW	+.087 kW
6 PM	-.114 kW	+.08 kW	-.158 kW	+.036 kW
7 PM	-.153 kW	+.022 kW	-.184 kW	-.009 kW
8 PM	-.194 kW	-.007 kW	-.177 kW	+.010 kW

Summary load shifting potential, using home energy data, EV2A customers

Hour	Smart charging average, compared to C1 group	Smart charging average, compared to the C2 group	Rate modification average, compared to the C1 group	Rate modification average, compared to C2 group
5 PM	-.187 kW	-.033 kW	-.226 kW	-.073 kW
6 PM	-.247 kW	-.030 kW	-.293 kW	-.076 kW
7 PM	-.272 kW	-.030 kW	-.306 kW	-.064 kW
8 PM	-.263 kW	-.035 kW	-.297 kW	-.069 kW

The graph below provides a closer look at the individual rate modification groups (T5 – T7), which relied on behavioral load shift, in comparison to the two control groups, for customers on the EV2A rate. Notably, every group that joined the pilot used less energy overall than the C1 pure control group (in orange), which is comprised of EV drivers that did not join the pilot. The overall differential in energy use between the 3 treatment groups was minimal during the evening ramp up hours. Of the 3 treatment groups, the T6 group, which was rate modification only and didn't download the app, used more energy overall and during the evening ramp up hours, in comparison to the other groups. This provides more evidence to support the conclusion that EV drivers who are inclined to participate using smart charging apps are more likely to take behavioral actions to change load than EV drivers who don't want to download an app.

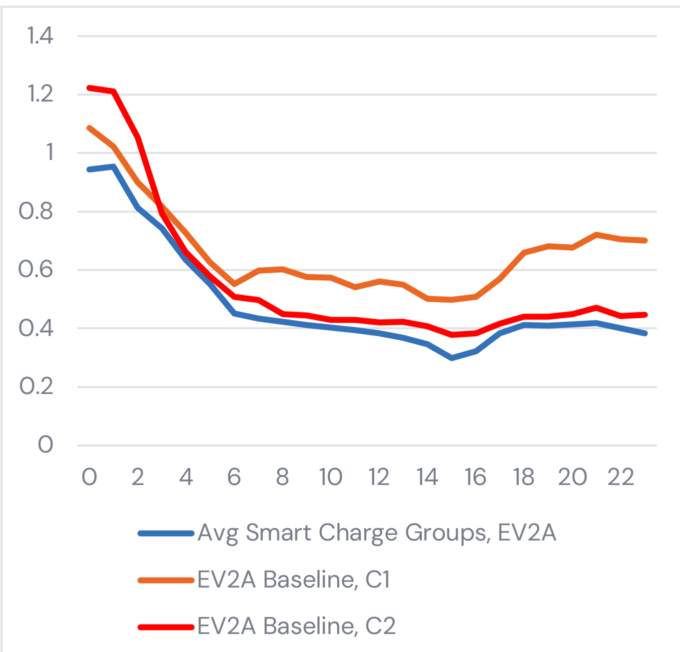
Hourly home energy data for control and rate modification groups, EV2A only



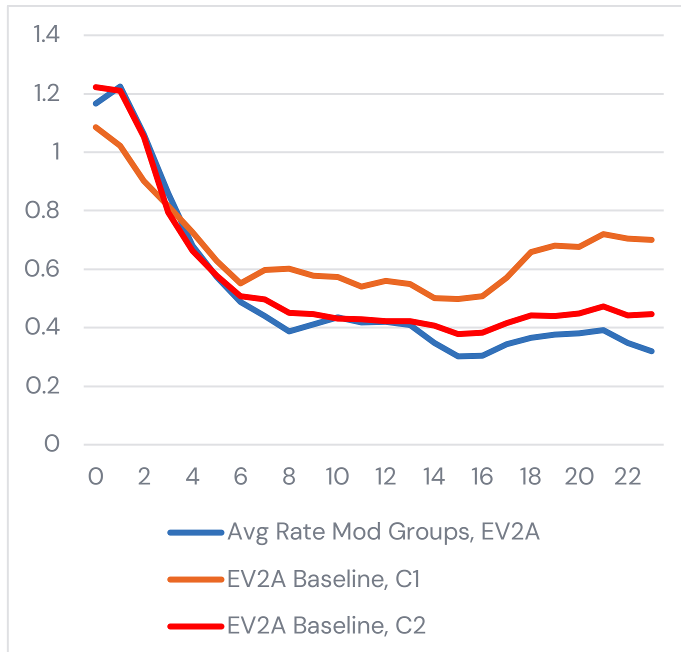
Home energy load curves, on a 24-hour cycle, by experimental of control group. The vertical axis is kW and the horizontal axis is the hour of the day.

The graphs below provide a deeper dive on home energy usage for EV drivers in the experimental smart charge and rate modification groups, in comparison to the two control groups, for customers on the EV2A rate. Most notable is the nearly identical home energy load curves for an average of rate modification groups and the C2 control at nearly all hours of the day. This demonstrates that the pricing interventions had essentially no impact. Smart charging (chart to the left) had a minor impact in reducing timer peaks, compared to the two control groups and nearly no impact in evening ramp-up load shift, especially when compared to the C2 control.

Hourly home energy data for control and smart charge groups, EV2A only



Hourly home energy data for control and rate modification groups, EV2A only



Home energy load curves, on a 24-hour cycle. The vertical axis is kW and the horizontal axis is the hour of the day. “Smart Charge” is a combined average of all smart charge groups (T1-T4) and “Rate Mod” is a combined average of all rate modification groups (T5 – T7). Control group 1 (C1) is the pure control. Control group 2 (C2) is the Hawthorne control, EV drivers who opted into the pilot in a monitor-only group.

This demonstrates that these pricing interventions, on top of existing TOU rates like the EV rate, do little to influence actual day to day charging behavior. The EV drivers who opted into the pilot, in the monitor-only C2 control group, charge nearly identically as the groups who received price modifications to their EV rate.

Conclusions

The telematics-based managed charging system operated by ev.energy provided PCE with valuable insights into home charging, including confirmation of widespread slow charging at home. Timer-peak mitigation was successfully validated, however this primarily benefits the distribution utility by relieving local congestion and mitigating distribution upgrades. These benefits only indirectly impact load serving entities like CCAs that are not responsible for the electrical grid. Load shift during evening ramp up hours was highly limited, mostly driven by self-selection bias among enrollees. Given the limited near-term value, PCE has decided not to pursue active charge management through telematics at this time. Instead, behavioral approaches will be explored, such as targeting high on-peak energy users with education on the opt-in EV rate.

Challenges

Self-selection bias: EV drivers who opted into the pilot used about 20% less energy than similar EV drivers who didn't enroll. Experimental participants were also much more likely to already be charging off peak, providing limited load shift results. Without factoring this in, managed charging pilots may be overestimating load shift potential.

Limited Enrollment: On average, only about 4% of the targeted audience ended up joining the pilot. Customers given high incentives only enrolled at moderately higher rates.

Connected car enrollment challenges: Some customers had challenges completing enrollment by successfully connecting with their vehicle. Chevrolet (General Motors) was a particular challenge. Many Chevrolet customers had a limited time free subscription to OnStar, which is necessary for data transfer, and had challenges connecting after the trial ended. Tesla vehicles were especially easy and seamless to connect.

Telematics technology limitations: The telematics system only has limited access to functionality and insights within the vehicle. For instance, if a vehicle stops charging at the start of the on-peak window, it's impossible to know if it was the telematics system or a vehicle setting that the driver already programmed that stopped the vehicle from charging.

Opportunities

Standardized vehicle communications: Standardized communications and charging interfaces between different vehicle makes would greatly assist third-party telematics charging providers with easier and up to date integrations.

Better recruitment: Since enrollment led by the utility leads to self-selection bias, other recruitment strategies, such as from the automakers to customers, may capture a broader selection of EV drivers.

Virtual submetering: Virtual submetering that allows for billing-quality data to be sent from the EV straight to the utility allows for potentially highly impactful applications. For example, utilities could, in theory, bill customers on EV rates, even if they a parking on a different meter than their home, such as in multi-family housing. This would negate the need for chargers with billing systems and provide potentially significant cost savings to EV drivers.

Grid Benefits: A primary benefit of telematics-based managed charging can be to reduce local electrical grid impacts by smoothing the off-peak surges in energy that occur at the start of off-peak hours. This can help avoid significant infrastructure upgrade costs for distribution utilities, reducing pressure on ratepayers who would otherwise bear these costs in their rates. Distribution utilities that can recruit significant numbers of EV drivers that are representative of the overall EV population, can benefit the most from these systems.

Contact us

Phillip Kobernick
Associate Director of Energy Programs
1-866-966-0110
info@PenCleanEnergy.com