Effective EV Programs to Make Change Happen

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ABSTRACT

As electric vehicles (EVs) continue their exponential growth curve, utilities across the country are exploring how to tap into these resources to increase revenue and meet climate goals. However, unmanaged increase in peak demand may pose problems for transmission systems at both the macro- and micro-grid level.

This paper will focus on the types of EV load management, both behavioral and active interventions, giving examples and variations of each. We will then share program designs, recruitment, and early findings from a ComEd EV managed charging pilot. This complex pilot relies on both behavioral and managed charging mechanisms to discourage peak-time charging among their residential customers. Next, we'll walk through the program design process: goals of the study, program elements, and reasons why a telematics-based approach is being tested. Then we discuss the most basic of program elements—recruitment—because unlike thermostats or air conditioners, there are only limited EV drivers in any given service territory. We will discuss how ComEd determined customers to target for recruitment, what characteristics they shared, and the results of the recruitment.

Finally, we'll walk through charging patterns and details prior to interventions. Initial charge information will illuminate the true draw of an EV, the types of charger customers are using, locations they charge, and average EV consumption.

Introduction

As EVs continue their exponential growth curve, utilities across the country are exploring how to tap into these resources to increase revenue and meet climate goals. Current growth models predict rapid EV growth. Since 2015, the global share of new passenger EVs has increased at an average of around 50% per year (Dennis 2021). In all likelihood, EV sales won't follow this exponential growth pattern indefinitely, and sales are likely to slow and level off before reaching 100%. Bloomberg New Energy Finance and Morgan Stanley (and others) predict that new global EV sales will outnumber traditionally fueled vehicle sales by 2050, if not sooner (Bloomberg NEF 2021; Morgan Stanley 2017).

EVs are widely regarded as the next step in the evolution of automobiles, partly because of the advanced technology involved and partly because of their potential to significantly reduce greenhouse gas emissions. Transportation is the largest single source of U.S. greenhouse gas emissions, with light-duty passenger vehicles accounting for approximately two-thirds of those emissions (C2ES 2022). According to an analysis by the Union of Concerned Scientists, the average battery powered EV produces greenhouse gas emissions equivalent to a gasoline-powered car that achieves more than 70 miles per gallon; the average new car in the U.S. achieves 25.3 miles per gallon (Reichmuth 2017). Electrification also benefits local populations by reducing tailpipe emissions that can harm the heart and lung health of people living near roads (EPA 2022).

Transportation electrification is also an incredible new revenue stream for electricity providers. According to research from Accenture, EVs will create a $2 trillion revenue opportunity for utility companies (Accenture 2019).

However, with this great opportunity comes real concerns with how to accommodate the new demand within the existing electricity generation, transmission, and distribution systems. Utilities are simultaneously exploring strategies to increase EV adoption while preparing for associated demand surges. Specifically, when a customer charges a car on a Level 2 charger, the car draws the equivalent of several residential air conditioners at once. While that draw is manageable on its own, the draw can be catastrophic to already-strained capacity systems in the heat of the summer or during peak-demand hours. Utilities are tasked with smoothing out the demand of EV charging, also known as EV load management, to ensure that this increased electricity consumption occurs during times of excess generation and/or low customer demand. Combining the increased revenue from EV adoption and the excess generation capacity could be a perfect match for electric utilities.

As utilities, our first impulse is to build upon the successes of traditional demand response (DR) and demand side management (DSM) programs to manage the increased load from EVs. While some of the concepts are similar between EV load management and traditional DR/DSM programs, it is important to note the differences between the measures involved, in terms of cost, risk, and attention.

First, the purchase of an EV, or any automobile, is likely one of the largest single purchases that consumers make. As such, EV owners are more hesitant to offer the utility too much access to the car, especially the battery. Replacing the primary battery in an EV costs $15,000+; owners do not want to be stuck replacing their car battery because of a $25 incentive from their utility.

Second, there can be severe repercussions to not having a car fully charged when scheduled. Unlike a DR event called on an air conditioner where the home increases in temperature by a few degrees, having an empty car battery can result the owner missing work, school, or other required activities. Unlike the discomfort of a warm house, charging a car can take 8 hours and may leave the owner stranded in the meantime.

Finally, there is increased media attention and customer focus on EVs due to the relative newness of the technology. Utilities and auto manufacturers are keen to avoid negative press associated with a poorly-run EV load management system. Similarly, reports of negative customer experiences around EV ownership could spread quickly among communities and thus impact EV adoption in the near term.

Increased costs, risks, and attention puts additional pressure on running excellent EV load management programs out of the gate. Unfortunately, EV load management programs are still in their infancy, and learnings from successfully implemented utility programs are scarce. This paper explains types of EV load management programs, as well as the process, challenges, and early findings of one specific EV program deployed by ComEd in Illinois.

EV Load Management Program Types

In broad terms, there are two types of EV load management interventions: behavioral and active. The primary purpose of both types is to shift the EV charging electricity load toward times where there is excess generation on the electric grid and/or decreased consumer demand. The difference in these types is in who directly controls the EV charge. In behavioral interventions, the owner is in full control of their EV charging but is encouraged to charge during certain hours. In active interventions, the owner gives control of the car charge to the utility or third party, who then schedules or curtails charging as needed. If behavioral interventions are implemented correctly, active interventions are ineffective; customers have already changed their charging schedules away from peak hours, and active curtailment does not yield additional load shifting. Note that either intervention can be deployed with either hardware (such as EV supply equipment, or EVSE) or software (such as telematics connected directly to the car). In this section, we'll detail each of these program types, provide examples and variations, and offer commentary on the tradeoffs.

Behavioral Interventions

Behavioral interventions rely on nudges, incentives, and education to encourage EV owners to shift charging times independently. Generally, there are utility-provided incentives to make this change; however, pure behavioral programs without incentives also exist. Behavioral programs are quite effective in the EV space because of the ease of setting charging schedules for most car Original Equipment Manufacturer's (OEM) EVs. Setting charge schedules is generally required only once, reducing the cognitive load of participation, and can be completed at any time via the OEM app. Once the charge schedules are set, the car will charge only during the designated times unless or until the owner overrides or changes the schedule. Three examples of behavioral interventions are offered below.

Time of Use Rates (TOU): TOU rates are a type of behavioral intervention that rely on tiered rate structures to encourage EV owners to charge during off-peak times. There can be any number of different retail rates throughout the day, but most utilities offer two to three. In this system, customers set their charging schedules to charge their car only during lowest cost electricity hours, resulting the lowest possible cost to charge. TOU rates are most common in communities with advanced meter infrastructure (AMI) that enable electricity meters to report consumption on an hourly basis (or less). However, with the help of software or hardware solutions, utilities can initiate a synthetic TOU rate where utilities apply rates only to the energy consumed by the EV, as determined through the car telematics or EVSE data.

Off-Peak Incentives: Off-peak incentive programs are just that—utilities provide a monetary incentive to avoid charging at peak hours. The two variations on this theme are whether the utility wants to avoid charging on peak capacity days (events) or peak hours every weekday. The first option discourages peak charging a few days a year, usually up to 10, on days of extreme electricity demand. These events are generally called the day ahead and last for a few hours. Customers should be informed of the event the day before, so they have the opportunity to fully charge the car prior to the time of the event. Incentives are provided to customers who do not charge during the called events, as determined through the car telematics or EVSE data.

The second variation is intended to discourage charging during regular everyday peak hours, which can change once or twice a year. In this offering, participants are informed of the daily peak hours and are provided with incentives to avoid those times entirely. Oftentimes, participants are granted a few opt-outs each month, allowing for peak charging a few times each month without losing the incentive. Stated differently, participants receive their incentive every month they charge during off-peak hours; they lose this incentive if they charge on peak more than the allowed amount.

Charge Reports: Similar to home energy reports, charge reports offer feedback and nudges to educate customers on the benefits of charging off-peak to encourage load shifting. These reports can be especially effective in the EV context due to the ease of setting (and forgetting) charging schedules. These reports can be combined with other interventions to encourage participation and applaud achievements.

Active Interventions

Active interventions achieve load shifting by remotely stopping EV charging during times of peak electricity demand or decreased supply. Incentives are usually performance-based and decrease when customers opt-out of curtailed charging hours. Layering active controls with tiered rate structures ensures customers will charge their cars during lowest cost times. Two variations of active interventions are DR event-based and scheduling.

DR Events: Similar to traditional DR programs, utilities call a DR event when electricity demand is expected to exceed supply during a certain time period. These events are often determined the day ahead and last for a few hours. Whenever possible, customers should be informed of the event the day ahead, so they have the opportunity to fully charge the car prior to the time of the event. During the designated event hours, utilities remotely turn off charging through the networked car (software) or charger (EVSE).

Scheduling: In contrast to DR events, the utility can also remotely schedule daily charging times for the customer through scheduling programs. This variation is the opposite of a DR event; utilities schedule charging to occur when there is an excess of supply on the grid, treating EVs as a type of battery bank in their territory. These programs are especially useful for utilities high in renewable energy sources that may peak at inopportune times, such as high wind generation in the middle of the night. Scheduling also allows for staggard start times, avoiding a surge of charging immediately after low rates commence.

Choices, Choices

As we've discussed before, EVs are not thermostats; They are costly, heavily relied-upon, high-stakes measures. With that in mind, program administrators need to be thoughtful in designing EV load shifting programs. EV behavioral programs have the advantage of easy acceptance; customers are fully in control of their charging behaviors and are encouraged to charge in line with utility needs. There is little customer risk in enrolling in one of these programs and, if designed correctly, meaningful motivation to comply. EVs are especially ripe for behavioral programs due to the ease of setting and changing charge schedules on the car. However, behavioral programs offer less guaranteed load control because the customer retains the power to charge as they see fit. Active load control reduces that uncertainty but runs the risks of customer pushback and lower adoption. In the end, utilities need to balance the need for grid certainty with that of customer acceptance. What works in one territory would be ineffective in another; utilities should design programs with a clear understanding of their goals and implement accordingly.

ComEd Deployment

This next section describes a recent EV technology assessment implemented by ComEd in Illinois. The deployment, branded EV Companion, primarily assesses behavioral interventions without incentives and tests the feasibility of active load control using telematics. ComEd contracted with Rolling Energy Resources (RER) as the telematics partner and Calico Energy to assist with implementation and project management. ComEd recruited and enrolled customers in February and March 2022, and initiated behavioral interventions in June of the same year. The sections below describe the decision process, goals, recruitment, and initial EV loads collected through the platform.

This deployment used a single provider, RER, to connect via telematics to 14 OEMs and offer demand management services. ComEd has other pilots that include EVSE equipment, TOU scheduling, and grid reliability integrations.

Not surprisingly, ComEd decided to explore a telematics platform for EV load management based on their experiences with thermostat optimization programs. In that instance, they struggled with how to achieve the highest participation considering customers may already have an existing advanced thermostat that is not connected to ComEd load control programs. In the exploration of EVSEs and managed charging, there was a similar problem with people wanting to participate in programs but having their own charger. In particular, Teslas often ship to the customer with a Level 2 charger included. Teslas comprise more than 70% of EVs sold (Loveday 2022) and would create a major gap in EV program adoption if ComEd relied solely on incentivizing EVSEs. The telematics option also did not bear the burden of high incentive costs and slow rollout timeframes of EVSE-based programs.

From a customer perspective, ComEd staff were apprehensive about curtailing charging through EVSEs without having visibility into the battery state on the car. Similar to the discussion around risk, ComEd was concerned at the potential for a negative customer experience if a customer went to drive their EV (or possibly even have an emergency need of it) and not have the battery remaining to use their car due to ComEd curtailments. Since vehicle telematics transmits data in real time on battery percent and range remaining, curtailments via software could overcome this concern by setting a minimum battery percent required prior to stopping the charge.

Planning

With these concerns and experiences setting the stage, the ComEd team offered three research questions for this technology assessment:

- How viable is a software-based solution? What are the strengths and limitations?
- What value do these offerings provide for customers and for ComEd? Does the value of EV interventions outweigh the costs?

- What advantages, if any, are there for this solution compared to others?

The team chose a hybrid of interventions, including personalized charge reports (branded MyCharge reports), peak charging alerts, and active load control testing. After recruitment and enrollment, ComEd monitored all cars without any load management interventions during the winter and spring months, prior to summer peak load constraints. This monitoring period serves as a "pre" loadshape to compare against subsequent load management interventions.

Once the monitoring period has concluded, all participants will start receiving MyCharge Reports. These reports are based on behavioral science techniques intended to both encourage the use of their EV and reduce strain on the grid. They offer information on charging costs and emission savings, tips on how to save money and/or reduce emissions, and feedback on their charging patterns. The MyCharge report was the only incentive offered for participants.

During the summer, ComEd's season of peak electricity demand, participants will receive alerts when they charge their car during peak capacity events. These alerts are emailed to participants within 30 minutes of initiating a peak-time charge and serve as immediate feedback to cease charging, because charging during peak times costs significantly more than at other times. ComEd notified participants of the peak event times the day before the event to allow customers to charge prior.

Finally, a small pool of employees will enroll in the active load management component. This intervention was purely to test functionality (i.e., whether or not a software-based solution could curtail charging on demand and what that experience looked like for EV owners).

Recruitment

Recruitment for EV programs can be challenging due to the relatively small number of EVs on the road today; EV owners in the territory can be hard to find and target for program options. One option available to utilities with AMI infrastructure is to analyze billing data, isolate the spike in usage generally associated with the addition of EV charging load, and target those homes for EV program marketing efforts. ComEd chose against this route due to concerns about perceived invasion of privacy. Specifically, ComEd was concerned that customers would feel their utility knows too much about their habits and purchases—the "big brother" surveillance concern (Zittrain 2014). As such, ComEd chose to roll out this deployment among a small number of customers who had informed ComEd that they owned an EV, had opted in to EV-related marketing efforts, and were not already participating in other EV-related pilots (ComEd 2022a).[1] The final number of customers recruited to the program was 4,525.

ComEd released recruitment emails to the self-identified EV owners advertising EV Companion as a tool to help participants understand their EV charging habits, costs, and ways to save money on their bill (Figure 1). The EV Companion monthly reports are designed and deployed by RER and aim to bridge the gap between fuel costs and energy bills. The reports offer information on when the customer charges their EV, how the charging time of day connects to electricity costs, and how much the customer would have paid for a gas equivalent vehicle. The reports utilize vehicle data from the participant EV telematics, localized gasoline prices,

[1] As noted earlier, ComEd runs a number of other EV initiatives such as TOU and EVSE pilots. The team did not want to impact the other efforts due to interventions from EV companion.

hourly electricity prices, and other information to create salient, actionable insights for the participants.

Figure 1. EV companion recruitment email

Connected EVs from the following 14 OEMs are eligible to participate: Audi, BMW, Cadillac, Chevrolet, Chrysler, Ford, Hyundai, Jaguar, Land Rover, Lincoln, Nissan, Tesla, Volkswagen, and Volvo. In order to enroll their car, recruited customers click on a unique URL embedded in the email to connect their car to the RER telematics platform. From there, they legitimize RER access to the vehicle's data through their OEM account and receive a confirmation of registration email. The enrollment flow is designed to require minimal customer input; the process is offered below in Figure 2.

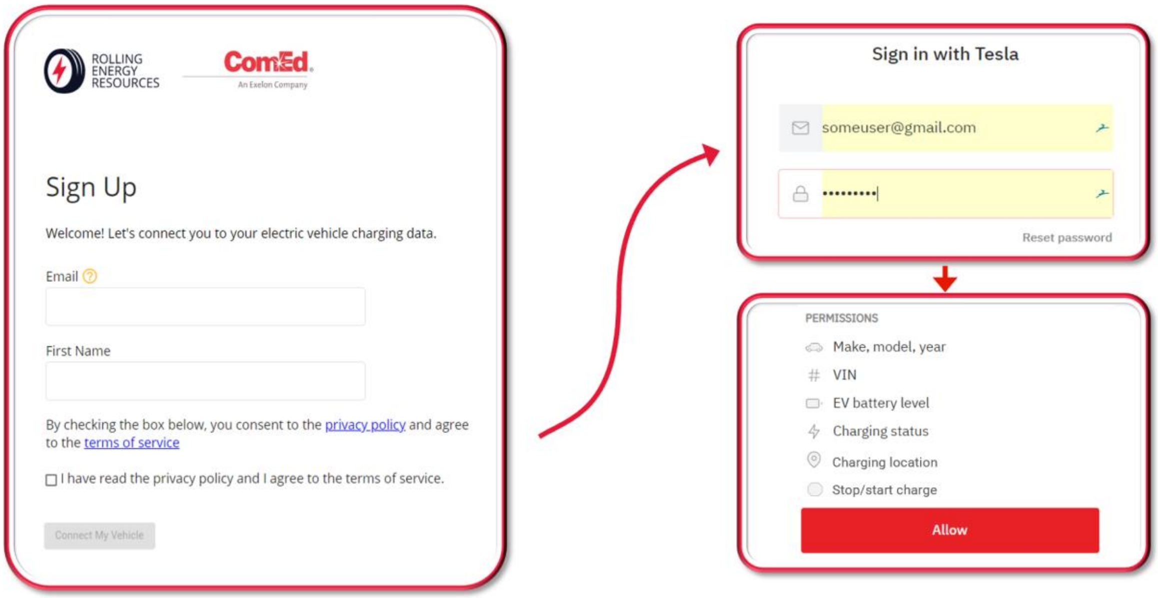

Figure 2. EV Companion Enrollment Flow

An important distinction in this participant group is that this is not an unbiased sample of EV owners. Nearly all (88%) of the recruitment pool was already involved in at least one load-shifting initiative—an hourly pricing (HP) rate structure (ComEd 2022b). This rate structure mimics the true cost of electricity during the day, resulting in large pricing variability. Customers who chose this rate structure are already attuned times of peak demand and when to charge their car to avoid high price spikes. Similarly, many also participated in the peak times savings (PTS) program (ComEd 2022c). This program offers monetary incentives to reduce electricity consumption during peak summer events, between May 1 and October 31, usually three to six days each summer. Both HP rate structures and PTS program structures incentivize customers to charge off-peak, resulting in shifted loadshapes for the EV Companion participant pool. ComEd did not limit the recruitment to specific OEMs and did not offer incentives to participate.[2] The goal number of participants was 100 cars. Recruitment was conducted solely via email, and the initial recruitment email deployed February 2, 2022.

Recruitment Results

Within 24 hours of the initial recruitment release of 4,525 emails, 237 cars had successfully registered through the telematics platform. Registrations trickled in throughout the

[2] There was discussion about adding incentives, which ultimately proved unnecessary due to a high response rate.

following weeks, resulting in 272 cars enrolled from the initial email recruitment (without reminder emails) from 264 customers. In March, the team considered sending reminder emails to this group; however, the program significantly exceeded their 100-car target and additional cars were of limited value to assess the identified study goals.

Enrolled cars represented a wide range of EVs and OEMs. As expected, participants in EV Companion primarily owned Teslas, likely because Tesla represents the majority of EVs sold (as noted above). Table 1 provides the distribution of cars enrolled in the program.

Table 1. EV Companion enrolled cars by OEM

OEM	Participant car count
Audi	5
BMW	7
Chevrolet	26
Chrysler	2
Ford	8
Hyundai	1
Jaguar	3
Jeep	1
Nissan	4
Tesla	212
Volkswagen	2
Volvo	1
Total	**272**

The distribution of participants was similar to that of the recruitment in terms of their choice in rates and program participation. Namely, 92% of EV companion participants were also part of the HP rate structure, and 40% participated in the PTS program (Table 2).

Table 2. EV participants by rate structure and PTS participation

Rate (Rate Class)	PTS participant		Total
	Yes	No	
Flat Rate (BES, RDS)	3	6	9
Hourly Pricing (HP, BESH)	98	145	243
Time of Use (TOU)	7	5	12
Total	**108**	**156**	**264**

Initial Charging Findings

As of the time of this paper, the implementation team had one month of car charging on the system. This next section discusses the loadshapes, draw, and charging patterns of 255 enrolled cars.

Average demand of vehicles enrolled in monitoring peaks around 2 AM and predominantly falls between midnight and 5 AM, on both weekends and weekdays, as shown in Figure 3. This pattern of night charging is likely attributable to the vast majority of vehicles either receiving rewards through the PTS program or avoiding charging during times of higher cost on the HP and TOU rates. Weekday demand peaks at 2.4 kW while weekend demand peaks at 2.8 kW, suggesting a slightly higher propensity to charge on the weekends. Figure 4 shows that the percent of vehicles charging at a given time aligns strongly with the average demand.

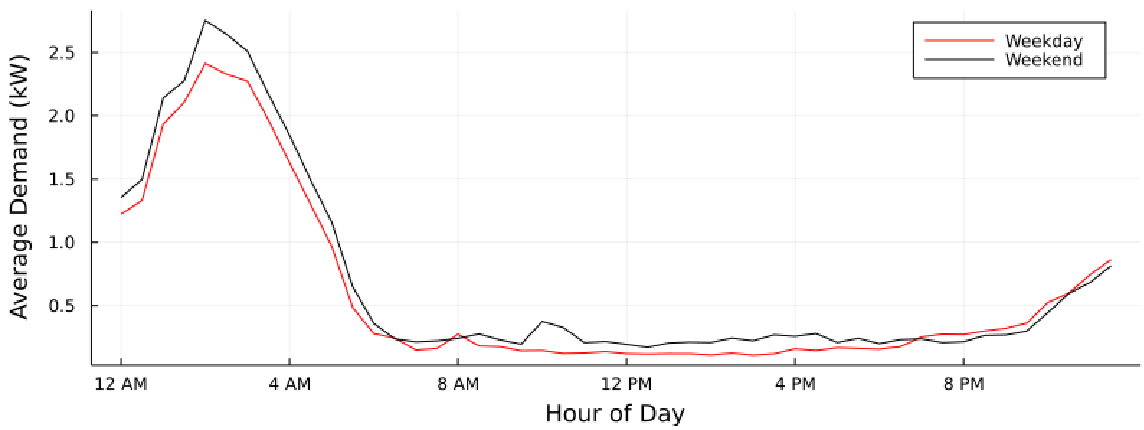

Figure 3. Average weekend and weekday loadshapes for home charging from enrolled vehicles, across February 2022.

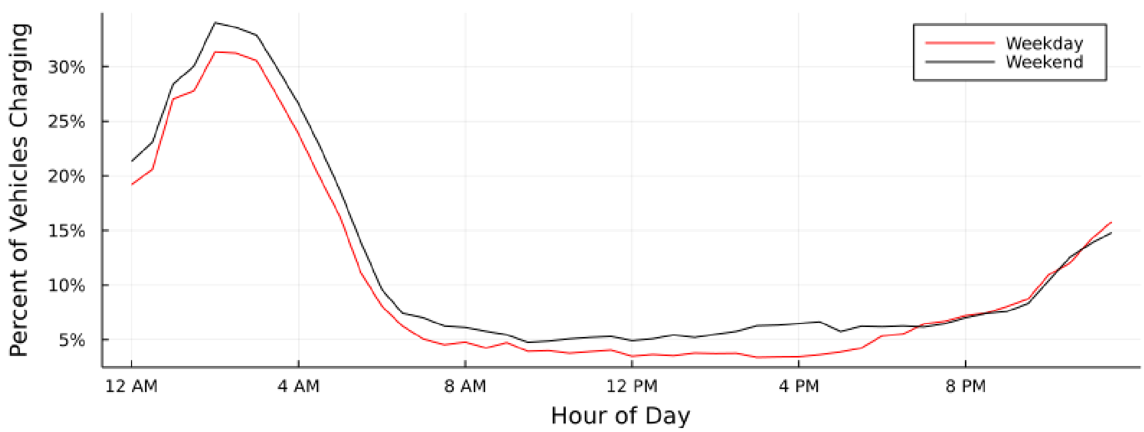

Figure 4. Percent of enrolled vehicles charging at home on weekdays and weekends, by hour of day, across February 2022.

Enrollees were not required to have a specific model of home charger, but virtually all of detected charging at home came from Level 2 chargers[3], as shown in Figure 5. The figure demonstrates that among enrollees, most of the aggregate demand on the grid was from Level 2 chargers. Most of the participants owned Teslas which come with Level 2 chargers and can be scheduled to charge off peak through the Tesla app. The remainder likely use smart chargers, which are usually also Level 2 chargers, to charge off peak.

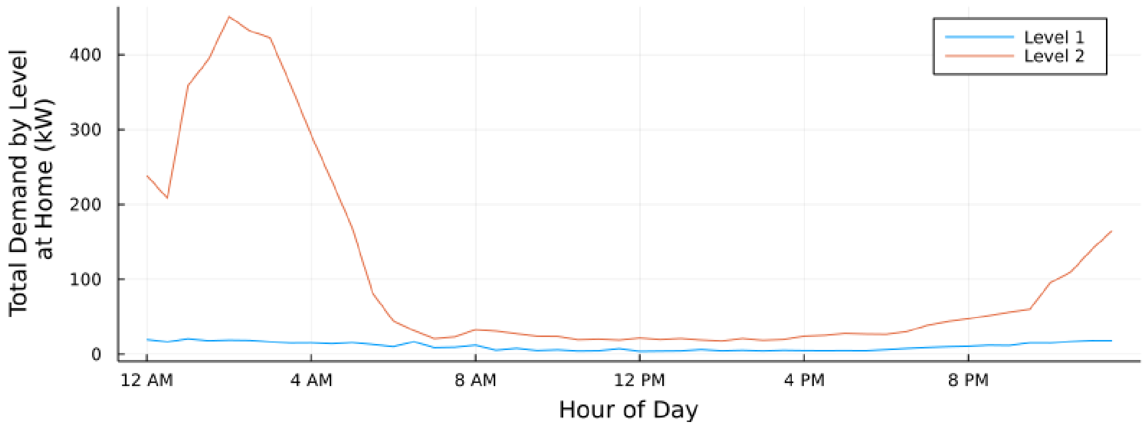

Figure 5. Total weekday demand for home charging, by charger level and hour of day, across February 2022.

In the design of this program, the drivers that motivate charging behaviors help inform messaging to customers. Of particularly interest is how vehicle state of charge drives customers to plug in, and what final charge is desired by drivers. This preliminary data shows a wide range of starting state of charge values, with an average of 53% remaining and an interquartile range of 40%-68%. Final state of charge values are skewed to the right as expected, with notable peaks at 80% and 90%, which are common limits suggested by manufacturers to preserve battery life. Figure 6 shows histograms of these values that include all charging sessions.

[3] Level 2 charging systems operate on 240V circuits, whereas Level 1 charging systems operate on 120V circuits. Level 2 systems deliver both a higher amperage and voltage, resulting in greater than 3-17 kW of power delivered to the vehicle, compared to 1.8 kW for Level 1 chargers.

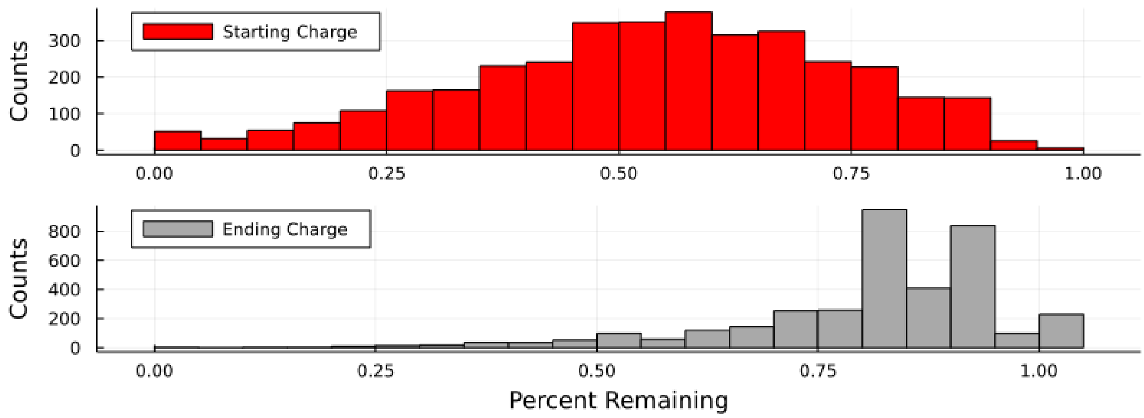

Figure 6. Histograms of battery charge percentage at the start and end of charging for all home charging sessions of enrolled vehicles, across February 2022.

A slight majority of cars charged exclusively at home (55%), and the charge sessions were longer at home than away. Eighty-four percent (84%) of energy consumed by the participant cars was from the home charger. Cars charged an average of 17 times during our 30-day monitoring period and consumed an average of 408 kWh (Figure 3).

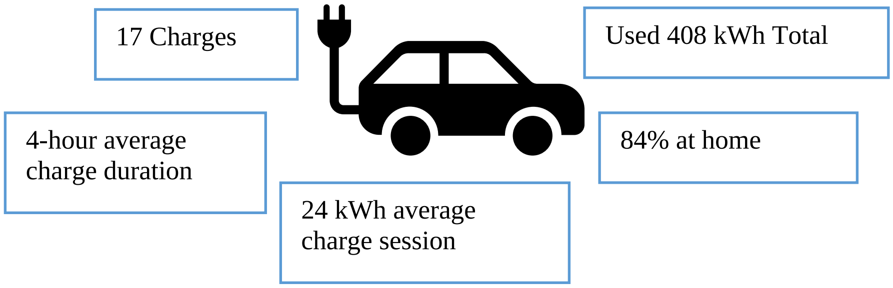

Figure 3. Average Car Charging Habits (n=264)

As noted previously, loadshapes for this group should not be considered that of an average EV owner. The customers had opted into EV Companion without incentives and most (98%) are already enrolled in another load shifting program, such as the HP rate or PTS program.

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