Incentivizing Sustainable Electric Vehicle Charging: Experimental Evidence from UCSD Campus

Ryan Hanna Teevrat Garg Jeffrey Myers
Sebastian Tebbe David Victor*

November 24, 2023

Abstract

To harness emission benefits from electric vehicle (EV) charging, it is essential to shift charging activities to periods of abundant renewable energy. We created an EV charging club on the University of California San Diego (UCSD) campus to answer questions about charging activities at workplaces. Specifically, we conduct a field experiment to measure the effectiveness of informational and financial incentives to shift the share and timing of EV workplace charging sessions. The informational interventions included periodic notifications highlighting the environmental benefits of daytime charging, while the financial interventions involved targeted discounts for on-campus charging. While neither type of incentive affected the overall charging behavior, they induced distinctive temporal shifts. Informational prompts facilitated a transition from early morning to daytime workplace charging, whereas financial incentives prompted an intertemporal substitution towards earlier charging activities.

*Hanna: Center for Energy Research, University of California San Diego (rehanna@ucsd.edu); Garg: School of Global Policy and Strategy University of California, San Diego (tgarg@ucsd.edu); Myers: Center for Energy Research, San Diego (jmyers@ucsd.edu). Tebbe: School of Global Policy and Strategy University of California, San Diego (ytebbe@ucsd.edu); Victor: School of Global Policy and Strategy, University of California San Diego (dvictor@ucsd.edu).

I Introduction

The electrification of transportation, particularly the widespread adoption of EVs, presents a promising opportunity to reduce emissions from electric power systems. However, realizing these benefits requires efficient management of EV charging behavior. One critical challenge is encouraging drivers to shift their charging activities to midday when solar and wind power generation are the most abundant. Charging EVs on campus during the day, when solar power is the primary energy source, can significantly reduce emissions compared to charging at home overnight, when natural gas generators are typically used to power the grid. By strategically influencing when and where drivers charge their vehicles, it is possible to optimize electricity costs, minimize emissions, and enhance the overall sustainability of the electric power grid.

In this paper, we conduct a field experiment at the UCSD campus to assess the willingness of EV drivers to shift to on-campus charging in response to informational treatment and financial incentives. In the informational treatment, we provide information about the emission benefits of charging during daytime versus nighttime, expressed as CO_2 savings, gasoline equivalents, and damages. In the first phase of the financial treatment, participants receive a small ($\$.16/kWh$) and a large discount ($\$.23/kWh$) for all kWh charged on the UCSD campus, resulting in effective rates of $\$.14/kWh$ and $\$.07/kWh$. The small-discount rate corresponds to SDG&E cheapest rate for overnight home charging and the large-discount rate corresponds to UCSD's wholesale cost of electricity. In the second phase of the financial treatment, we test for habit formation in the EV charging behavior on campus by performing a second randomization where half of the large discount group only receives small financial incentives for on-campus charging.

Our empirical findings reveal that neither informational prompts nor significant financial discounts had a statistically significant impact on the charging behavior of EV drivers at the UCSD campus. Individuals who received informational prompts about the environmental benefits of daytime versus nighttime charging displayed no significant change in the share of on-campus charging, the number of charging sessions, total energy consumption, charging costs, session and charging durations, or idle durations. Similarly, substantial financial incentives for on-campus charging did not influence individuals' total charging activities. We document that this may be linked to the occupancy of the charger network and the perceived unreliability of charging sessions, where high utilization rates and glitches potentially deter individuals from modifying their charging behaviors during the experiments.

However, our analysis of the temporal distribution of charging sessions reveals distinct impacts of informational and financial treatments. The informational prompts led to a significant decrease in early morning charging sessions, with a corresponding increase during mid-morning and early afternoon periods. This suggests a pronounced intertemporal substitution effect, indicating a shift from early morning to daytime charging influenced by environmental prompts. Conversely, financial incentives for on-campus charging resulted in a significant increase in early morning sessions and a decrease during mid-morning hours, implying an intertemporal substitution towards earlier charging activities.

These empirical findings offer valuable insights into the determinants influencing EV charging decisions and formulating strategies to align charging practices with sustainability objectives. Although informational and financial incentives do not affect the overall volume of workplace charging activities, they effectively modify the temporal distribution of charging sessions. Informational interventions contribute to a temporal shift in charging behavior, encouraging drivers to align their charging activities with periods of heightened green energy production during the day. Conversely, financial incentives exhibit inefficacy in attracting additional drivers to charge on campus, prompting existing users to charge during periods characterized by lower green energy production in the morning. This suggests a potentially detrimental impact of financial incentives due to their role in inducing intertemporal shifts in charging behavior.

The rest of the paper proceeds as follows. Section II outlines the experimental design and summarizes the data. Section III provides the empirical methodology. Section IV presents the empirical results. Section VI concludes with policy implications

Literature Review

Our research speaks to the literature on price-based and informational intervention to change the charging behavior of drivers. First, price-based interventions have shown promise in influencing charging behavior. Pricing strategies tied to kilowatt-hour (kWh) consumption or charging session duration, such as flat fees per session (Motoaki & Shirk, 2017) or time-of-use (TOU) rates (Davis & Bradley, 2012; Langbroek et al., 2017), have been effective in incentivizing preferred charging behavior (Kacperski et al., 2022). Demand response or "flex" events, where drivers can earn revenues for opting in or face penalties for opting out, have also been successful in shaping charging behavior (Lagomarsino et al., 2022). Monetary prizes and auctions, where drivers can bid on preferred pricing discounts, have further demonstrated their potential in motivating drivers to engage in desired charging practices (Fetene et al., 2017). Furthermore, implementing fees for excessive stall napping or rule-breaking can deter unwanted charging behavior (Asensio et al., 2021). Bailey et al. (2023) show that drivers react strongly to financial incentives to shift the timing of EV charging, but the charge timing reverts to pre-intervention behavior when financial incentives are removed.

Second, informational interventions have proven effective in influencing charging behavior. Etiquette notifications to prompt drivers to move their vehicles once the charging session is completed can help optimize station utilization. Peer comparisons through weekly reports on energy and climate impacts can foster a sense of competition and drive individuals towards more sustainable charging behaviors (Sudarshan, 2017). Additionally, providing personalized and tailored information at the point of charge, such as participation alerts for flex charging events, has shown increasing engagement and influencing charging decisions (Asensio et al., 2021). Information framing about estimated cost savings from joining a program affects enrollment rates (Nicolson et al., 2017). Drivers have also been shown to increase their willingness to pay for charging sourced from renewable sources (Nienhueser & Qiu, 2016). Bailey et al. (2023) documents that nudges do not significantly affect changing EV charge time.

II Experiment

II.A UCSD charging network

The field experiment is conducted with the UCSD Transportation Services Office (UCSD TS). UCSD is San Diego's largest public charging hub with 331 Level 2 and 13 Direct Current (DC) Fast Chargers.[1] They are responsible for setting charging policies and prices for drivers who charge on campus in collaboration with the two leading charging providers, ChargePoint and PowerFlex.[2] These providers collect data on the charging behaviors of drivers, who are mainly members of the EV Charging Club, a subset of UCSD-affiliated drivers (students, staff, and faculty). By joining this club, members receive discounted pricing, and in exchange, they provide UCSD TS with basic demographic information and their PowerFlex and ChargePoint IDs.[3]

We invited members of the EV Charging Club to join a smaller Triton EV Research Club, where they can participate in direct research activities by responding to a survey about their demographics, charging habits, and a series of policy experiments.[4] Appendix A.1 describes the three nested groups of research subjects. Appendix A.2 documents the

[1] UCSD has planned to install an additional 760 Level 2 and 35 DC Fast Chargers by the end of 2025.

[2] ChargePoint operates 250 Level 2 ports and 13 DC fast charging stations around campus. PowerFlex has 72 Level 2 charging stations around campus that are affiliated with Tesla.

[3] Figure B1 displays the delivered charging on campus for various providers. Figure B2 illustrates the UCSD campus charging zones.

[4] To help with recruitment, we randomly select 30 registrants to receive a $50 Visa gift card.

parking permits required in all spaces.[5]

II.B Experimental design

We first collect information on drivers' demographics (i.e., age, gender, ethnicity, income, education, environmental attitudes, university affiliation, and car ownership), charging behavior (i.e., living arrangement, working arrangement, commute, access to charging alternatives, commuting habits, parking habits, charging habits), and charging motivations (i.e., low cost, potential to earn revenue, choice, availability or accessibility, convenience, simplicity, equity, climate stewardship, privacy). Appendix A.4 reports the Triton Club enrollment survey. In addition, we gather data on odometer surveys throughout the experiment to track total driving before and after each intervention phase.

The experimental setting consists of four key interventions aimed at answering essential research questions about workplace EV charging behavior. Firstly, we want to know if informing drivers about the environmental benefits of workplace charging as opposed to home charging motivates them to choose on-campus charging. Secondly, we aim to understand the price elasticity of EV charging by examining the impact of additional discounts for on-campus charging. Thirdly, we test for the presence of habit formation when financial incentives are removed. Finally, we want to understand whether there are interaction effects between receiving financial and informational interventions.

Figure I outlines the experimental design to investigate EV charging behavior on the UCSD campus. In the informational intervention, the treatment and control group consists of a randomly selected half of the Triton Chargers group.[6] Both groups receive a welcome message, but only the treatment group receives three information prompts over three weeks (20 days), explaining the emission benefits of charging during the daytime versus nighttime, including CO_2 savings, gasoline equivalents, and damages.[7] The goal is to educate drivers about the positive impact of charging during daylight hours when solar power generation is most plentiful, but utility residential charging rates are higher than during nighttime.The sample period for the informational treatment runs from October 4 to October 18. Figure A2 displays the experimental schedule during the fall quarter that spans from September to

[5]A valid UCSD parking permit is required to park in campus or medical center EV charging station parking spaces. A vehicle that is parked in an "EV Charging Only" space but is not actively charging may be cited and/or towed. In addition, vehicles parked in "EV Charging Only" spaces must be actively charging. Parked vehicles that exceed the posted time limit and/or are not actively charging will be cited.

[6]We randomize the treatment and control groups using stratified block randomization based on the weekly days of commuting to campus, the charging location, and the motivation behind choosing the charging location.

[7]Appendix A.6 derives the avoided CO2 damaged, the gasoline equivalent, and the global environmental damages when shifting from nighttime to daytime charging.

December 2023. Appendix A.5 reports the text of all intervention prompts.

The financial intervention involves offering drivers additional discounts for workplace charging over the quarter's final eight weeks (55 days). The base rate to charge EVs is set $\$.30/kWh$.[8] In the first phase of the financial intervention, participants receive a small ($\$.16/kWh$) and a large discount ($\$.23/kWh$) for all kWh charged on the UCSD campus, resulting in effective rates of $\$.14/kWh$ and $\$.07/kWh$, respectively.[9] Appendix A.7 documents the calculation of different discount rates.

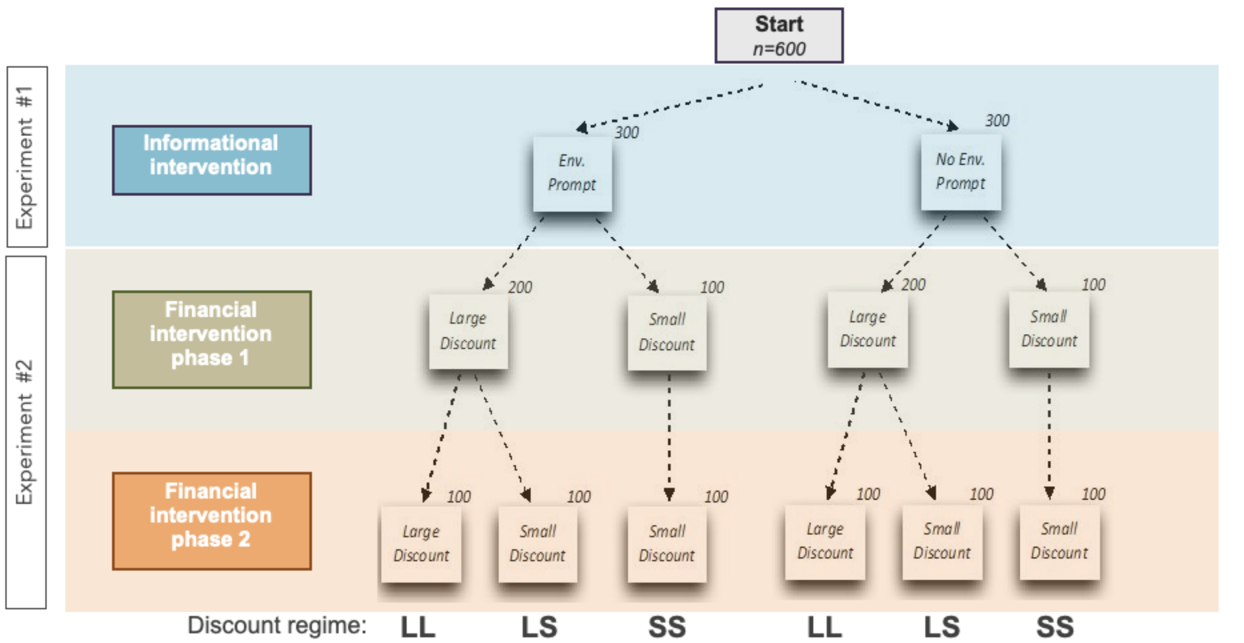


Figure I: Experimental design

Notes: This figure documents the experimental design. The experiment consists of three phases. The first phase, called the informational treatment, will run from October 4 to October 22. The second phase, called the first financial treatment, will run from October 23 to November 4. Finally, the third phase, called the second financial treatment, will run from November 5 to November 18. During the informational treatment phase, the participants will receive the same message prompt three times. These prompts will be sent at 6:30 am on the specified day.

Phase 2 of the financial intervention splits the large discount group into large discounts (LL) and small discounts (LS). One of these subgroups continues to receive the large discount, while the other half is informed that they will now receive small discounts. These participants were in the large discount group in the first phase of the experiment. This serves as our pre-

[8]The residential base rates of SDG&E as of September 2023 are summarized in Table A1. Drivers can, at times, charge at home at lower rates than campus rates.

[9]The small discount rate corresponds to the overnight SDG&E residential rates and the large discount rate to the marginal cost of electricity for UCSD.

treatment period for this phase of the analysis. After November 9, half of the participants' financial incentives for charging on-campus were reduced to small discounts, while the other half continued to receive large discounts. The sample period for the financial treatment to measure the price elasticity and habit formation covers October 24 to November 24. Consequently, we use the small discount group as the "Control" group in this phase to estimate the impact of the large discount intervention.

II.C Descriptive Statistics

Table I summarizes our experimental data on socio-demographic characteristics (Panel A), vehicle attributes (Panel B), and charging characteristics (Panel C), and the outcome variables (Panel D). The average age of participants is 38 years, with around 17 years of education, an average income of approximately $135 thousand, and commutes around three times per week to campus. Moreover, Figure B3 shows that the majority of participants are staff (49%) and faculty (24%), predominantly white (49%) and Asian (36%), and own a house (44%). The average car is 2.4 years old, with an average of 27,709 miles, daily driving of 38 miles, and 76 percent of the cars being battery electric. Around 59 percent of participants have a home charger with an average voltage of 195 volts and are charged at 18 cents per kWh. Participants charge 28 percent of their sessions on campus, which equals 2.18 times during the experiment, with an average session and charging time of 301 and 216 minutes, resulting in around 85 minutes of idle time. The average charge results in a total energy transmission of 19 kWh, and costs around $5.38.

Figure B4 displays charging behavior patterns based on location, time of day, reasons for charging, and motivation to charge on campus. Panel A shows that most drivers charge their vehicles on campus (43%) or at home (39%). Drivers also utilize other locations, such as nearby plazas or their final destinations, for charging. Panel B highlights that nearly 40% of drivers charge their vehicles at night, while less than 20% charge during solar peak hours between 12-16. Panel C illustrates that low prices are the drivers' key factor in the charging decision. In addition, charging around activities, finding a charger, and charging near campus have been stated as additional factors determining charging. Panel D highlights that charging close to the office, open stalls, and having long dwell charge sessions are key reasons to charge on campus. However, environmental concerns are not stated to play a pivotal role in charging decisions.

Moreover, the open-ended questions in the enrollment surveys indicate that drivers have identified several key reasons for not charging their EVs on campus. The primary barriers include the limited 4-hour layover, concerns surrounding rates and rate structures, and difficulties finding available charging stations.

Table I: Summary Statistics

	Mean	Std. dev.	Min	Max	Obs.
A.Socio Demographic Variables					
Age	38.25	12.88	22	80	629
Share Male (in %)	0.53	0.50	0	1	629
Income (′000)	135.73	66.58	25	200	557
Years of Education	17.18	3.09	11	21	629
Days on Campus	3.26	1.75	0	6	629
B.Vehicle Attributes					
Vehicle Age	2.38	2.59	0	22	629
Battery Electric (in %)	0.76	0.43	0	1	629
Odometer Reading	27709.30	28778.80	47	205,069	352
Daily Mileage	37.85	31.76	0	333	241
C.Charging Characteristics					
Home Charger (in %)	0.59	0.49	0	1	629
Charging Price (cents per kWh)	0.18	0.12	0	1	382
Charging Club Member (in %)	0.27	0.45	0	1	629
D.Outcome Variables					
Average Session (in min)	307.25	179.30	23	927	370
Average Charging (in min)	223.04	138.41	21	740	370
Average Idle Time (in min)	84.21	104.21	0	614	370
Average Energy (in kWh)	19.40	12.43	2	69	370
Average Price	5.55	3.60	0	18	370
Number of Charging Session	4.05	5.50	0	35	629
Share Campus	30.13	33.76	0	100	221

Notes: This table reports descriptive statistics on socio-demographic variables (Panel A), vehicle attributes (Panel B), charging characteristics (Panel C), and the outcome variables (Panel D) for the Triton Charging Club.

III Empirical Methodology

To empirically estimate the effect of the information and financial treatment on the charging behavior, we estimate the following equation (1):

$$y_i = \beta Info_i + \delta Reward_i + \eta(Info_i \cdot Reward_i) + \gamma X_i + \alpha_j + \eta_t + \varepsilon_i, \quad (1)$$

where i indexes the driver. y_i refers to the relevant outcome of interest. The primary dependent variable corresponds to the share of total charge in kWhs on campus relative to the expected total charge. In addition, we consider the number of charging sessions, total energy, cost, duration, charging time, and idle time as outcomes. $Info_i$ and $Reward_i$ are dummy variables equal to 1 if the individual received the informational or financial prompts, respectively, and equal 0 otherwise. The vector X_i represents a rich set of individual socio-demographic variables, vehicle characteristics, charging attributes, and motivation about charging.[10] We also include a dummy variable η_t for the the Clean Air Day on October 4th, which reduced rates by 50 percent. We document that the price cut only moderately increased the total charging activities of Triton Chargers (Figure A4), but it resulted in substitution to earlier charging times during the day (Figure A5). The α_j are vehicle fixed effects to control for time-invariant vehicle characteristics. Standard errors are clustered at the individual-level. To filter actual charging sessions, we limit the data to sessions that last a maximum of 16 hours and charged at least 1 kWh.

The coefficients of interest β and δ measure the effect of the information and financial treatment on the outcome of interest. The coefficients η measure the interaction effect between information and financial treatment. We provide power calculations in Appendix D.

For the second phase of the financial experiment, we consider an analogous specification to that in equation (1), with the following exception. First, we add an indicator variable $Reward_{2i}$ denoting 1 if an individual is in the large discount group in the second phase, with small discount as the control. The sample period for this analysis is limited to November 9 to November 24.

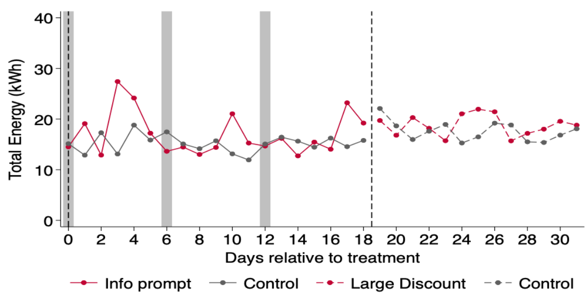
IV Empirical results

IV.A Effect on total charging behavior

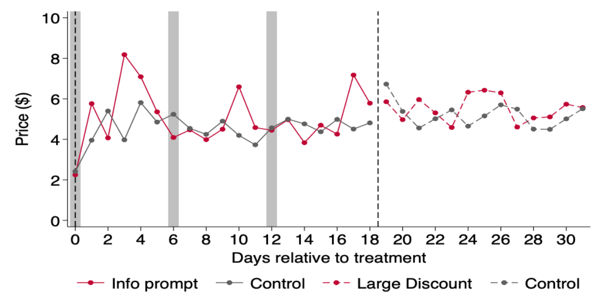
This section reports the empirical estimates of the information prompts and financial discounts on various charging activities. We first display various charging activities of the Triton

[10] The control variables include age, gender, income, years of education, days charged on campus, vehicle age, type of car, odometer reading, an indicator for home charger, charging price, and being a charging club member. In addition, we include a dummy for the preferred charging location, usual charging time, main charging motivation and motivation to charge on campus.

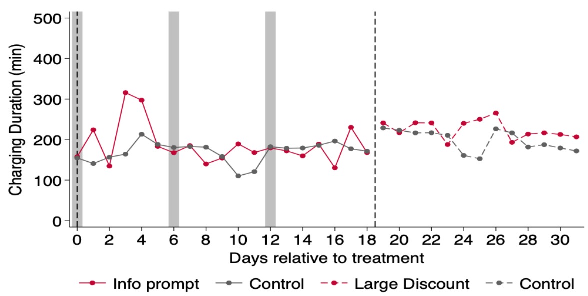
Charger Club after the first day of the informational (left-hand side) and financial treatment (right-hand side). Figure II illustrates the total energy used (Panel A), total price charged (Panel B), charging duration (Panel C), and number of daily charging sessions (Panel D) of the treatment and control group for the first 18 days after the treatment. The raw data shows no striking differences between the charging behavior among individuals who received the informational prompts, a large financial discount, and the control group. There is a slight increase in total energy and charging duration among treated individuals after three days. These descriptive results suggest that the informational and financial treatment did not significantly impact individuals' charging behavior.



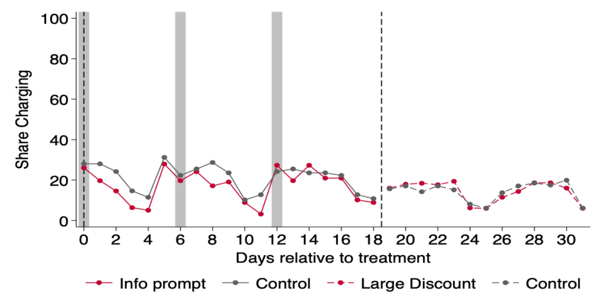
(a) Total energy



(b) Price



(c) Charging duration



(d) Charging sessions

Figure II: Dynamic effects

Notes: This figure shows the charging activities of the Triton Charger Club relative to the first day of the informational (4th of October) and financial treatment (23rd of October). The statistics include the total energy used (Panel A), total price charged (Panel B), charging duration (Panel C), and number of daily charging sessions (Panel D).

Table II provides the regression estimates of the informational prompts (Panel A), the charging discounts (Panel B), and the interaction effect between financial and informational treatment (Panel C). The informational prompts and the large discounts had no statistically significant effect on the treated individuals' share of on-campus charging, the number of charging sessions, the total energy, the price, the session duration, the charging duration, and the idle duration. First, this suggests that workplace charging is not impacted by information about the environmental benefits of charging during the daytime versus nighttime,[11] consistent with the informational treatment effects during the spring trial experiment in June (see Appendix C). Second, financial discounts on workplace charging sessions do not seem to be effective in changing individuals' charging habits. The lack of responses to the financial treatment is consistent with the fact that during the Clean Air Day, our analysis indicates no statistically significant increase in charging activity compared to other Wednesdays.[12]

IV.B Effect on timing of charging behavior

Subsequently, our analysis shifts to the temporal dynamics of charging activities, specifically comparing the average daily charging patterns of the informational (left-hand side) and financial treatment (right-hand side) groups during the initial three weeks following their respective interventions. As depicted in Figure III, the predominant concentration of total energy delivered and charging sessions occurs between 7 am and 9 am on campus, with an additional peak observed around 12 am. On the left-hand side, Figure III indicates a substantial decrease in total energy, pricing, charging duration, and sessions occurring before 6 am within the informational treatment group. Conversely, the right-hand side depicts a shift of charging activities to earlier hours in the morning for the large discount treatment group. Consequently, environmental prompts seem to effectively contribute to a postponed scheduling of charging sessions during later hours of the day, whereas financial incentives appear to stimulate a behavioral response among drivers, inducing an earlier arrival on campus for charging purposes.

Table III presents the regression estimates of the temporal distribution of charging sessions. The informational treatment resulted in a significant decrease in charging sessions occurring prior to 6 am. However, this reduction was counterbalanced by an (insignificant) increase in charging activities between 8 am and 10 am and 12 am and 16 am. Relative to the average number of charging sessions before 6 am, this corresponds to a 100 percent decrease in charging sessions. This indicates a pronounced intertemporal substitution effect, wherein the environmental prompts induced a shift from early morning charging to daytime charging when renewable energy sources are most abundant.

Conversely, financial discounts for on-campus charging yielded a significant upswing in

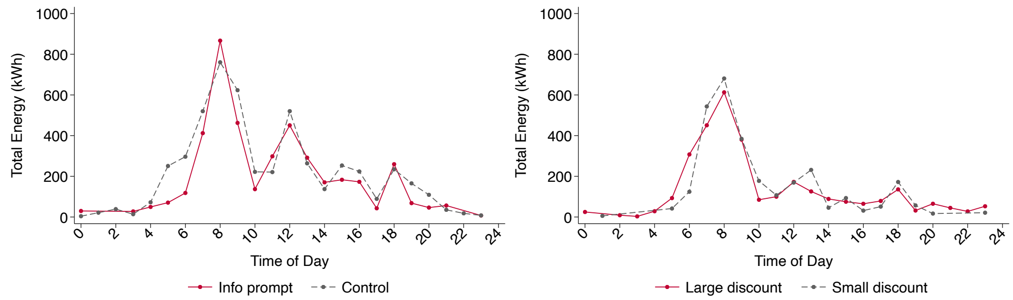
[11] One possible explanation for the non-existing treatment effect may be that the information about environmental benefits diffused from treated to non-treated participants. However, as we do not observe a significant increase in workplace charging immediately after the experiment, we believe that spillover within workplaces is not a potential problem.

[12] During the first three weeks of October, Figure A4 indicates a 10% increase in charging activity on Clean Air Day when compared to other Wednesdays, although this increase does not achieve statistical significance (Panel B). This charge rate discount results in a 50% reduction in the total price of charging (Panel F).

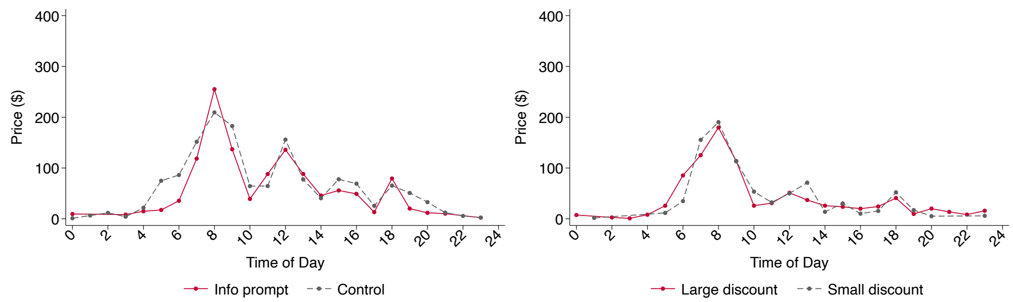
Table II: Effect on charging behavior

	Outcome Variable						
	(1) Share	(2) N(Charging)	(3) Energy	(4) Cost	(5) Duration	(6) Charge Time	(7) Idle Time
A.Informational prompt							
Info Prompt	5.121	-.047	-6.233	-1.813	-125.876	-79.323	-46.554
	(3.897)	(.442)	(8.881)	(2.536)	(161.745)	(108.438)	(78.137)
Mean Dep. Var.	31.56	4.3	76.31	21.87	1282.6	905.88	376.72
B.Financial incentives							
Large Discount 1	-1.393	-.087	3.081	.711	50.797	56.465	-5.668
	(5.537)	(.227)	(4.487)	(1.332)	(72.247)	(52.756)	(29.800)
Mean Dep. Var.	35.43	1.88	34.15	10.01	567.22	406.36	160.86
C.Interaction							
Information x Discount	2.372	-.091	-3.736	-1.275	-102.011	-37.153	-64.858
	(4.203)	(.485)	(9.280)	(2.627)	(167.665)	(115.589)	(80.059)
Observation	221	629	629	629	629	629	629

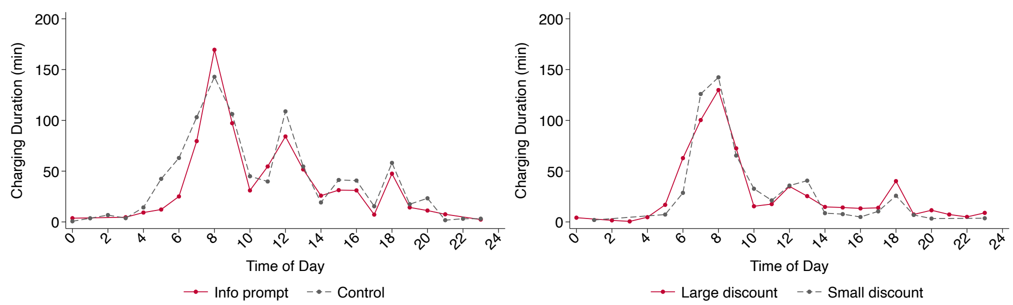
Notes: This table presents the regression estimates of the informational prompts (Panel A), the first financial treatment (Panel B), and the second financial treatment (Panel C). The dependent variables indicate the share of on-campus charging (column 1), the number of charging sessions (column 2), the total energy (in kWh) (column 3), the price (in $) (column 4), the session duration (in min) (column 5), the charging duration (column 6), and the idle duration (column 7). All regressions include individual demographic, vehicle, charging infrastructure, motivational control variables, and vehicle-fixed effects. The mean dependent variable and the number of observations are reported below the coefficients. The time period for the informational treatment reaches from October 4 until November 4, the period for the financial treatment reaches from October 23 until November 4. Robust standard errors, clustered by individuals, are in parentheses. *, **, ***: statistically significant with 90%, 95%, and 99% confidence, respectively.



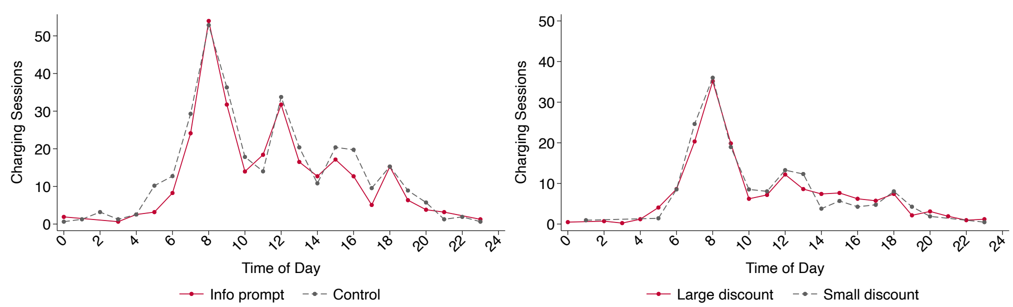
(a) Total energy



(b) Price



(c) Charging duration



(d) Charging sessions

Figure III: Charging time

Notes: This figure shows the charging activities of the Triton Charger Club by the time of the day of the informational and financial treatment. The statistics provided the total energy used (Panel A), total price charged (Panel B), charging duration (Panel C), and number of daily charging sessions (Panel D).

charging sessions before 6 am. Simultaneously, there was a decrease in charging sessions between 10 am and 12 am. This pattern suggests an intertemporal substitution towards earlier sessions due to the financial incentives for workplace charging. One plausible explanation is that the financial discounts intensify competition for charging stations, prompting drivers to arrive at work earlier. This interpretation aligns with observations during Clean Air Day, where drivers tended to engage in earlier charging activities.[13]

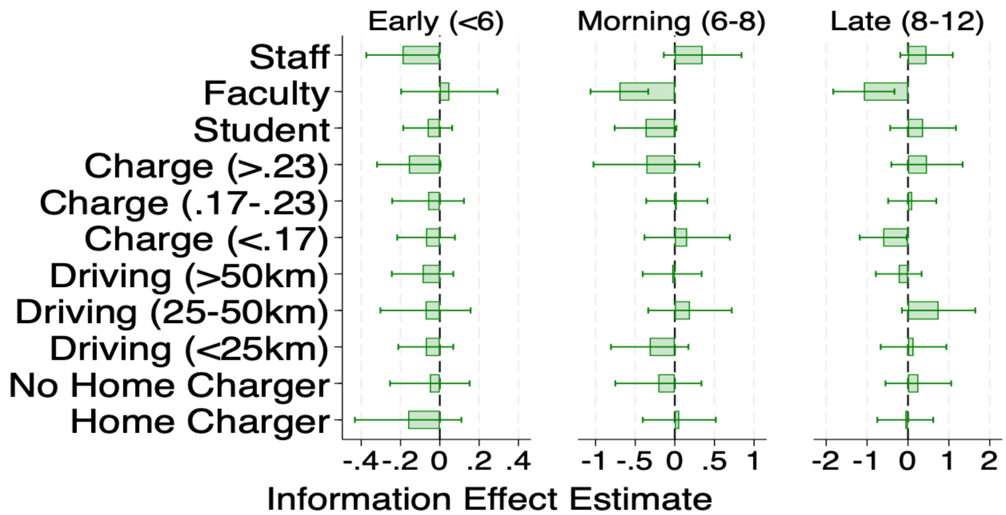
In addition, we conduct a heterogeneity analysis to examine key driver sub-groups based that shift their charging behavior. Specifically, we investigate how home charging access (whether drivers have access to charging infrastructure at home), the commute frequency and distance, the price paid for charging at home, and the profession impacts their charging behavior and response to interventions. Figure IV displays the effect the informational (Panel A) and financial treatment (Panel B) on the number of charging sessions early in the morning (<6am), morning (6 - 8 am), and late in the morning split by demographic characteristics. Particularly, staff and people with home charger reduce their charging sessions early in the morning as a response to the informational prompts. Faculty, people with high low charging prices reduce their charging in the morning. The financial treatment resulted in additional charger sessions for people with high home charger prices and low daily driving.

[13]Figure A5 illustrates the temporal distribution of charging activities during the first week of October. On Clean Air Day, there was a shift in charging sessions from midday to morning (Panel B), indicating that the reduction in charging rates may motivate drivers to arrive at work earlier to secure a parking spot.

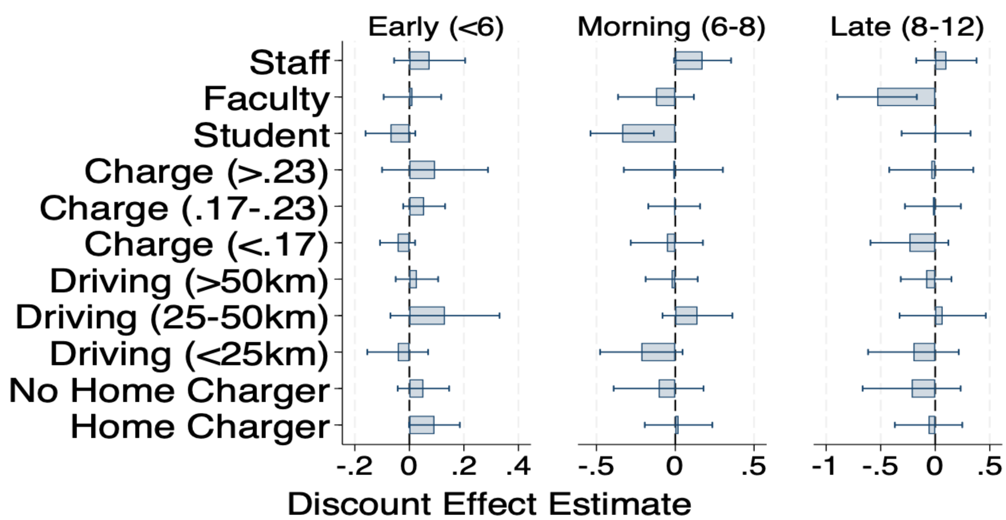
Table III: Effect on charging timing

	Timing of Charging Sessions					
	(1) 0-6	(2) 6-8	(3) 8-10	(4) 10-12	(5) 12-16	(6) 16-24
A.Informational prompt						
Info Prompt	-.134*	-.082	.073	.000	.045	.001
	(.074)	(.116)	(.179)	(.087)	(.165)	(.147)
Mean Dep. Var.	.13	.37	.85	.35	.84	.69
B.Financial incentives						
Large Discount 1	.047**	-.069	-.017	-.085*	-.004	.004
	(.026)	(.060)	(.095)	(.048)	(.084)	(.077)
Mean Dep. Var.	.05	.16	.38	.15	.35	.31
C.Interaction						
Information x Discount	-.152*	-.171	.170	-.009	.003	-.012
	(.079)	(.113)	(.220)	(.089)	(.171)	(.162)
Observation	629	629	629	629	629	629

Notes: This table presents the regression estimates of the informational prompts (Panel A), the first financial treatment (Panel B), and the second financial treatment (Panel C) on the timing of charging sessions. The dependent variables indicate the number of charging sessions between 0-6 (column 1), 6-8 (column 2), 8-10 (column 3), 10-12 (column 4), 12-16 (column 5), and 16-24 (column 6). All regressions include individual demographic, vehicle, charging infrastructure, motivational control variables, and vehicle-fixed effects. The mean dependent variable and the number of observations are reported below the coefficients. The time period for the informational treatment reaches from October 4 until November 4, the period for the financial treatment reaches from October 23 until November 4. Robust standard errors, clustered by individuals, are in parentheses. *, **, ***: statistically significant with 90%, 95%, and 99% confidence, respectively.



(a) Information treatment



(b) Financial treatment

Figure IV: Heterogeneity in temporal shifts

Notes: The figures the effect the informational (Panel A) and financial treatment (Panel B) on the number of charging sessions early in the morning (<6am), morning (6 - 8 am), and late in the morning split by demographic characteristics. The dependent variable indicates the number of charging sessions in the indicated time interval. 95%-confidence intervals are indicated through the error bars.

IV.C Understanding results on charging behavior

This section delves into the underlying reasons for the observed lack of responses to our experiment on charging behavior, exploring the network utilization and the perceived unreliability of charging sessions.

1. *Network utilization.* The absence of responses to informational prompts and financial incentives may be attributed to full occupancy of the charger network at the UCSD campus. Figure V illustrates the network utilization of Powerflex (red) and ChargePoint (blue) chargers throughout the experiment. Powerflex maintains close to 100 percent utilization, while ChargePoint hovers around 80 percent on weekdays, with network capacity not reaching full utilization on weekends. This observation suggests that the near-maximum utilization of both charging operators during the week may account for the lack of additional charging and a shift to earlier charging in response to the financial and informational interventions.

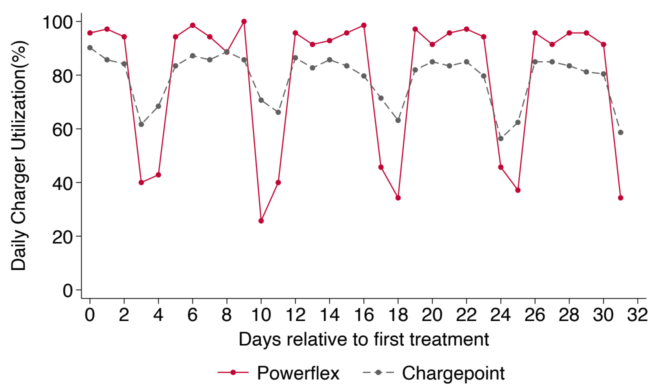
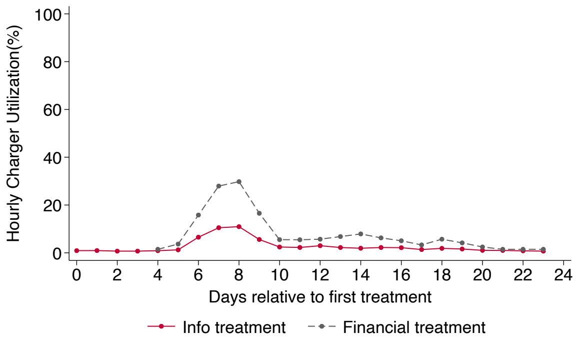
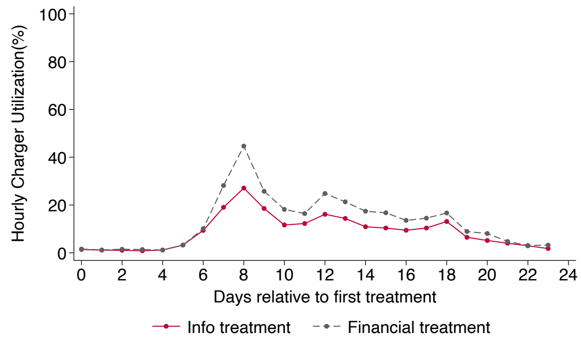


Figure V: Network utilization

Notes: This figure shows the daily charger utilization of the Powerflex (red) and ChargePoint (blue) chargers relative to the first day of the informational treatment. The daily charger utilization corresponds to the fraction of chargers used in a given day relative to all chargers used between October 4 and November 4.



(a) Powerflex



(b) Chargepoint

Figure VI: Network utilization by time

Notes: This figure shows the hourly charger utilization of Powerflex (Panel A) and ChargePoint (Panel B). The daily charger utilization corresponds to the fraction of chargers used in a given hour relative to all chargers used between October 4 and November 4.

2. *Charger glitches.* Another plausible factor contributing to the observed lack of responses to the informational and financial interventions is the perceived unreliability of the charger network. In investigating whether issues with the charger network deter individuals from transitioning to workplace charging, Figure VII presents the percentage of charging sessions encountering glitches for Powerflex (red) and ChargePoint (blue) chargers throughout the experiment. Both charging operators exhibit an approximately 20 percent rate of charging sessions experiencing glitches. Furthermore, during a specific period between the 15th and 16th of October, nearly all Powerflex sessions encountered glitches. This notable occurrence of unreliable charging sessions may have contributed to Triton users refraining from altering their charging behaviors during our experiments.

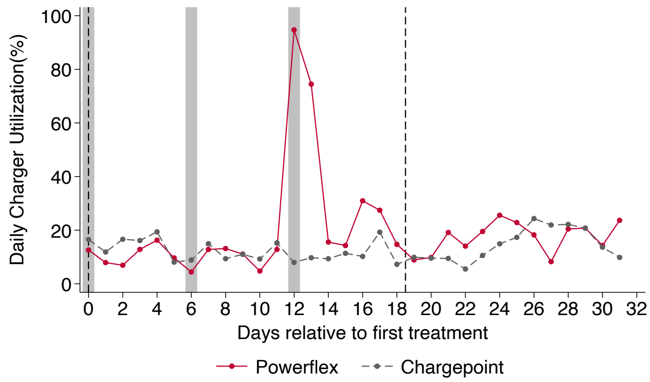


Figure VII: Charger glitching

Notes: The figure displays the percentage of charging sessions experiencing glitches for Powerflex (red) and ChargePoint (blue) chargers from the first day of the informational treatment. A glitched charging session refers to a case where the charging lasts less than 10 minutes and transmits less than 1 kWh of energy.

V Welfare effects

In this section, we combine our experimental findings to perform a back-of-the-envelope welfare calculation. To give an estimate of the net welfare effect of the experiment, we combine the treatment effects presented in previous sections with a set of assumptions and cost estimates. In our calculations, we consider two categories of social benefits (CO_2 emissions, and Low Carbon Fuel Standard (LCFS) credit) and contrast these to the financial inventive costs of the experiment. Focusing on marginal changes induced by the experiment, the net welfare effect (for an average day) can be written as:

$$\triangle W \ = \underbrace{\triangle CO_2 \cdot \triangle MC_{CO_2}}_{Global\ pollutant} + \underbrace{\triangle LCFS\ credit}_{Local\ benefit} - \underbrace{\triangle Incentive\ costs}_{Local\ costs}, \tag{2}$$

where MC indicates marginal cost. Below we give a short summary of the welfare calculations, while more details are provided in Appendix E.

Carbon emission. Calculate the Carbon Emission damage changes from timing. Plot graph that multiplies carbon emission factors with coefficients (2hours) similar to environmental impact in peer effects paper.

$$\triangle CO_2 \ = \sum_{h=1}^{24} (\underbrace{\beta_h^{kWh} \cdot E_h}_{Information} + \underbrace{\delta_h^{kWh} \cdot E_h}_{Discount}) \cdot CI_h \cdot SCC, \tag{3}$$

where the coefficients β_h and δ_h indicate how the informational prompt and the financial discount affect the total energy consumption (kWh) during each hour of the day as illustrated in Figure VIII. E_h is the hourly EV energy consumption (kWh), and $CI_h$is an hourly carbon intensity in gCO_2/MJ per Figure **??**. We multiply this by the social cost of carbon (SCC) of 210 $\frac{\$}{tCO_2}$ following estimates from the Environmental Protection Agency (2022).

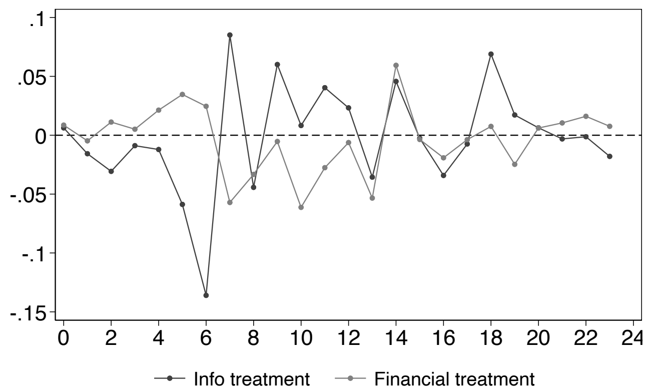


Figure VIII: Effect on hourly charging sessions

Notes: The figure displays the percentage of charging sessions experiencing glitches for Powerflex (red) and ChargePoint (blue) chargers from the first day of the informational treatment. A glitched charging session refers to a case where the charging lasts less than 10 minutes and transmits less than 1 kWh of energy.

LCFS credit. The LCFS is designed to decrease the carbon intensity of California's transportation fuel pool and provide an increasing range of low-carbon and renewable alternatives, which reduce petroleum dependency and achieve air quality benefits. We calculate the hourly LCFS credit as:

$$\triangle LCFS\ credit\ = \sum_{h=1}^{24}(CI_{standard} - CI_h/3.4)\cdot\ E_h\ \cdot\ \bar{P}\ \cdot\ 3.4\ \cdot\ 3.6MJ/kWh\ \cdot\ 10^{-6}MT/g, \tag{4}$$

where $CI_{standard} = 89.5\ gCO_2/MJ$ is the typical carbon intensity from gasoline powered cars, and $\bar{P} = 64.51\ \$/MT$ is the average LCFS price. Multiplying $CI_h$by 3.6 $MJ/kWh \cdot 10^{-6}MT/g$ transforms units of g/MJ into MT. Multiplying the price in $\$/MT$ yields the revenue. $CI_{standard}$ is multiplied by 3.4, which is the Energy Economy Ratio showing the fuel-feedstock combination displacing gasoline with a light-/medium-duty EV shown in the LCFS methodology document.

Cost of incentives. We calculate the costs of the provided financial incentives as follows:

$$\triangle Incentive\ costs\ = (\underbrace{\overline{E^{kWh}}\cdot\ \$.23/kWh}_{Large\ discount}) + \underbrace{\overline{E^{kWh}}\cdot\ \$.16/kWh}_{Small\ discount}), \tag{5}$$

where $\overline{E^{kWh}}$refers to the average total energy consumption per day. We multiply this by the small ($\$.16/kWh$) and a large discount ($\$.23/kWh$) for all kWh charged on the UCSD campus. We assume no financial costs of the informational treatment.

VI Conclusion

As the share of EVs continues to grow, it is essential to understand how to maintain flexibility in EV charging and which policies can help achieve it. Charging EVs during peak hours can strain the electricity supply and require significant investments in grid infrastructure. The field experiment on the UCSD campus sheds light on the complexities of incentivizing sustainable charging practices and estimates how financial and informational incentives affect workplace EV charging behavior.

Our empirical results document that the informational prompts and financial discounts did not influence the overall volume of workplace charging activities but reshaped the temporal distribution of charging sessions. Informational interventions successfully prompted a shift towards daytime charging, aligning with periods of heightened green energy production. Conversely, financial discounts encourage drivers to engage in earlier charging activities. Finally, we highlight the importance of network occupancy and perceived reliability in shaping effective policies for sustainable EV charging behaviors.

References

Agency, E. P. (2022). *Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances.*

Asensio, O. I., M. C. Lawson, and C. Z. Apablaza (2021). "Electric vehicle charging stations in the workplace with high-resolution data from casual and habitual users". *Scientific Data* 8.1, p. 168.

Bailey, M. R. et al. (2023). *Show Me the Money! Incentives and Nudges to Shift Electric Vehicle Charge Timing.* Tech. rep. National Bureau of Economic Research.

Davis, B. M. and T. H. Bradley (2012). "The efficacy of electric vehicle time-of-use rates in guiding plug-in hybrid electric vehicle charging behavior". *IEEE Transactions on Smart Grid* 3.4, pp. 1679–1686.

Fetene, G. M. et al. (2017). "Myopic loss aversion in the response of electric vehicle owners to the scheduling and pricing of vehicle charging". *Transportation Research Part D: Transport and Environment* 50, pp. 345–356.

Kacperski, C. et al. (2022). "Impact of incentives for greener battery electric vehicle charging–A field experiment". *Energy Policy* 161, p. 112752.

Lagomarsino, M. et al. (2022). "Do I need to charge right now? Tailored choice architecture design can increase preferences for electric vehicle smart charging". *Energy Policy* 162, p. 112818.

Langbroek, J. H., J. P. Franklin, and Y. O. Susilo (2017). "When do you charge your electric vehicle? A stated adaptation approach". *Energy Policy* 108, pp. 565–573.

Motoaki, Y. and M. G. Shirk (2017). "Consumer behavioral adaption in EV fast charging through pricing". *Energy policy* 108, pp. 178–183.

Nicolson, M. et al. (2017). "Tailored emails prompt electric vehicle owners to engage with tariff switching information". *Nature Energy* 2.6, pp. 1–6.

Nienhueser, I. A. and Y. Qiu (2016). "Economic and environmental impacts of providing renewable energy for electric vehicle charging–A choice experiment study". *Applied energy* 180, pp. 256–268.

Sudarshan, A. (2017). "Nudges in the marketplace: The response of household electricity consumption to information and monetary incentives". *Journal of Economic Behavior & Organization* 134, pp. 320–335.

Appendix

Incentivizing Sustainable Electric Vehicle Charging:
Experimental Evidence from UCSD Campus

Ryan Hanna *Teevrat Garg* *Jeffrey Myers*
Sebastian Tebbe *David Victor*

A Experimental design

This Section provides additional details about the different charging clubs on the UCSD campus (Section A.1), types of charging (Section A.2), the experimental schedule (Section A.3), the enrollment survey (Section A.4), the treatment assignment texts (Section A.5), the calculations for informational prompt (Section A.6) the discount rate calculation (Section A.7), and the clean air day (Section A.8).

A.1 Campus charging clubs

The charging clubs at UCSD comprise of three different groups.

1. *All EV drivers to campus.* The first club consists of all EV drivers who commute to the UCSD campus. These drivers, including both UCSD affiliates and the general public, have access to the campus network of chargers. The Transportation Office collects charging session data for operational purposes. Additionally, we have access to non-identifiable, aggregate charging session data for all drivers who have charged on campus.

2. *UCSD EV Charging Club.* The UCSD EV Charging Club are exclusively UCSD affiliates (excluding the general public). The club was established by the Transportation Office as part of their transportation electrification efforts. To participate, drivers were given the opportunity to join the club and receive a 5 ¢$/kWh$ discount, equivalent to around a 20% reduction, on all charging activities. During the sign-up process, drivers provided basic demographic information, allowing for further analysis of charging behavior among specific groups. Additionally, each driver links their vehicle and ChargePoint and PowerFlex account numbers in the EV Charging Club registry. This linkage enables us to track and observe the choice of charging stations (either ChargePoint or PowerFlex) made by drivers on a day-to-day basis.

3. *Triton Charging club.* The Triton Charging Club have willingly agreed to participate in research involving a sequence of behavioral experiments. To be eligible, they must be between 18 and 80 years of age, hold a driver's license valid in California and be the primary driver of an EV which they intend on keeping for at least onr year from when they enroll in the study. Members of this club receive additional information and incentives related to EV charging. The club is specifically recruited by the research team for their participation. Prior to the first experiment, drivers are issued a survey to gather information about their charging habits and motivations. During the interventions, drivers receive surveys twice a month that focus on collecting information about their off-campus charging activity. We have access to charging session data that is identifiable by driver ID. All drivers in the Triton Charging

Club have consented to participate in the experiments, complete surveys, and provide access to their campus charging data.

A.2 Types of Charging

Figure A1 displays the three types of chargers on campus. A UC San Diego parking permit or hourly parking payment is required in all spaces.[14]

EV-1 indicates that the parking space has a DC Fast Charger (DCFC) and a one-hour parking limit. The DCFCs range from 50 kW to 125 kW, meaning that they typically add 75 to 185 miles of range in 30 minutes. Chargers at EV-1 spaces have both CHAdeMO and CCS plugs. There is no charging minimum for EV-1 spaces. A charging session must be initiated and vehicles should be moved when the charging session is complete.

EV-4 indicates that the parking space has a Level 2 charger and a four-hour parking limit. Chargers at EV-4 spaces operate at 6.6 kW of power, meaning that they typically add 21 miles of driving range per hour. Chargers at EV-4 spaces use the J1772 plug. EV-4 spaces require a minimum 7 kWh charge. A charging session must be initiated. Vehicles may remain after charging for a total of up to four hours of parking.

EV-12 indicates that the parking space has a Level 2 charger that operates at a reduced power level, allowing for all-day parking up to 12 hours. There are a few chargers that leverage circuit-sharing, operating at a continuous 3.3 kW. However, most EV-12 spaces leverage chargers with variable power between 1.2 kW and 6.6 kW. These chargers consider the planned time of departure and miles of range to be added and then optimize the delivery of electricity to meet the vehicles' needs and the needs of nearby vehicles while limiting demand on the electrical grid. Chargers at EV-12 spaces use the J1772 plug. EV-12 spaces require a minimum 10 kWh charge.

[14] For more information about electric vehicle charging station at UCSD, see EV charging station.

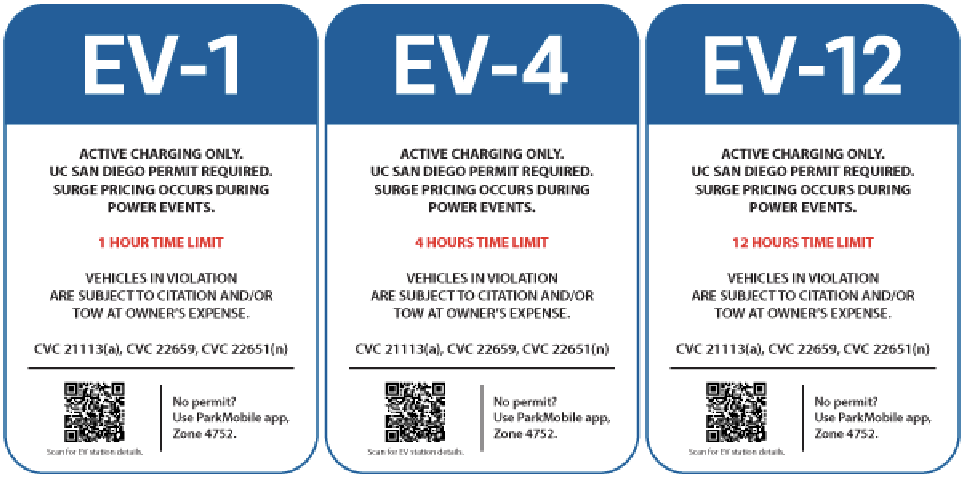


Figure A1: Type of chargers

Notes: This figure displays the three types of chargers on campus. ChargePoint operates EV-4 chargers, and PowerFlex EV-12 chargers.

A.3 Experimental schedule

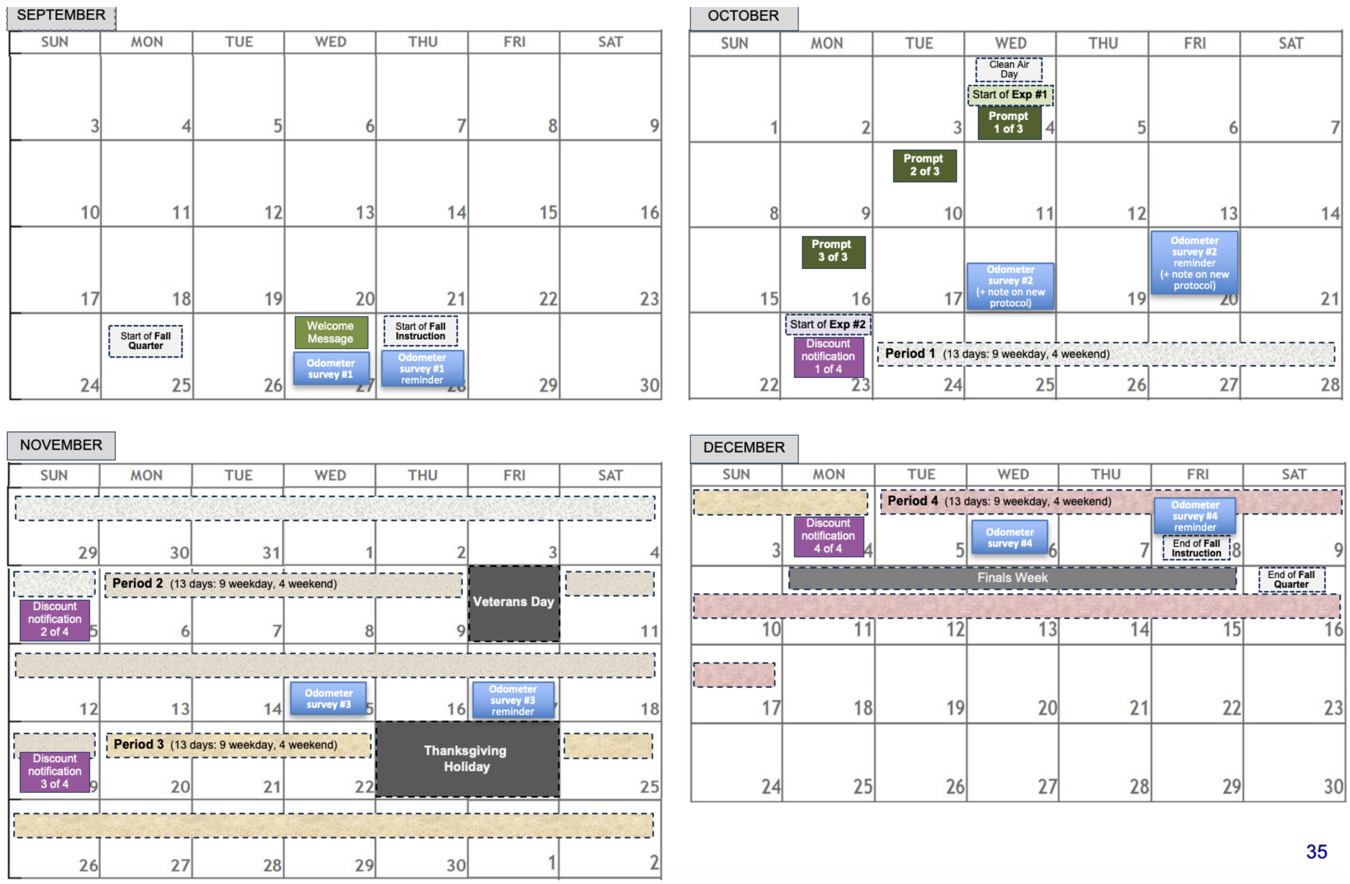


Figure A2: Experimental schedule

Notes: This figure documents the experimental schedule. The experiment consists of three phases. The first phase, called the informational treatment, will run from October 4 to October 22. The second phase, called the first financial treatment, will run from October 23 to November 4. Finally, the third phase, called the second financial treatment, will run from November 5 to November 18. During the informational treatment phase, the participants will receive the same message prompt three times. These prompts will be sent at 6:30 am on the specified day. October 4th refers to the Clean Air Day.

A.4 Triton club enrollment survey

The following is our question list for the Triton Chargers Enrollment Survey.

Intro & Contact

1. Please fill out your contact information

- First Name [Open response]
- Last Name [Open response]

- UCSD email address [Open response]
- Cellphone number [Open response]

2. [Consent form to act as a research subject]

Work/School

3. What is your UCSD status? (If you are a student employee, choose student.)
   - a. Undergraduate student
   - b. Graduate or post-graduate student (Master's, PhD, post-doc)
   - c. Faculty
   - d. Staff
   - e. Other
4. While on campus for work or school, which building(s) are you primarily located in?
   - a. [Drop-down list]

Residence

5. Please enter the 5-digit zip code where you live.
   - a. [Open response]
6. Which of the following best describes your home living arrangement?
   - a. I own a single-family house
   - b. I rent a single-family house
   - c. I own a condo
   - d. I rent a unit in an off-campus, multi-unit complex (e.g. an apartment, condo)
   - e. I live in UCSD campus housing, (e.g. undergraduate, graduate, faculty)
   - f. Other [open response]

6a. [If 6 == e] If you live on campus, which building/complex do you live in?

- a. [Drop-down list]

7. Do you have access to EV charging at your residence?

- a. [Yes / No / I don't know]

7a. [If 7 == yes] If you have access to charging at your residence, what type of charger do you have access to?

- a. Level 1 (110V or 120V—requires no specially installed hardware)
- b. Level II (240V—uses a small box attached to the wall, typically installed by an electrician, and can charge the car overnight)
- c. DC Fast Charger (480V or 500V—uses a large box installed by an electrician that can charge the car in an hour or two; rare at residences)
- d. One of these, but I am not sure which one 7

b. [If 7 == No] If you do not have dedicated charging at your residence, how likely are you to purchase a home charger in the next 12 to 18 months (assuming such an option is available to you)?

- a. Extremely unlikely
- b. Somewhat unlikely
- c. Neither likely nor unlikely
- d. Somewhat likely
- e. Extremely likely

Car

8. What is the primary vehicle or plug-in hybrid that you drive? (If your specific make-model- year-type is not shown, please select "other" for all four dropdowns.)

- a. Year [Drop-down list]
- b. Make [Drop-down list]
- c. Model [Drop-down list]
- d. Type [Drop-down list]

Commuting and Charging Habit and Preferences

9. During the **Spring 2023 academic quarter,** how often per week do you expect to commute to campus from offsite using your electric vehicle or plug-in hybrid?

- a. Less than once per week
- b. 1 day per week
- c. 2 days per week
- d. 3 days per week
- e. 4 days per week
- f. 5 days per week
- g. More than 5 days per week
- h. I don't commute because I live on campus

10. In a typical week, what percentage of your charging do you do at the following locations?

- a. My residence [0–100% slider]
- b. Neighborhood charging plaza within half a mile from my residence [0–100% slider]
- c. Someone else's home or residence [0–100% slider]
- d. Destinations (e.g., malls, restaurants, etc.) [0–100% slider]
- e. UCSD campus [0–100% slider]
- f. Other (e.g., freeways, dedicated charging plazas) [0–100% slider]

[Implemented with sliders and a permissive checksum.]

11. On a typical weekday (Monday–Thursday), what percentage of your charging do you do at the following times of day?

- a. Morning (6am–12pm) [0–100% slider]
- b. Afternoon (12–4pm) [0–100% slider]
- c. Evening (4–9pm) [0–100% slider]
- d. Night (9pm–5am) [0–100% slider]

[Implemented with sliders and a permissive checksum.]

12. At the place and time where you most commonly charge, what rate do you pay?

- a. I don't know
- b. I have free charging
- c. \$0.01–\$0.04 cents per kilowatt hour
- d. \$0.05–\$0.09 cents per kilowatt hour
- e. \$0.10–\$0.13 cents per kilowatt hour
- f. \$0.14–\$0.17 cents per kilowatt hour
- g. \$0.18–\$0.21 cents per kilowatt hour
- h. \$0.22–\$0.24 cents per kilowatt hour
- i. \$0.25–\$0.29 cents per kilowatt hour
- j. \$0.30–\$0.39 cents per kilowatt hour
- k. \$0.40–\$0.49 cents per kilowatt hour
- l. \$0.50–\$0.59 cents per kilowatt hour
- m. \$0.60–\$0.69 cents per kilowatt hour
- n. \$0.70 or more per kilowatt hour

13. When contemplating when and where to charge in the city (ie. at home, on campus, elsewhere), consider the factors that have the biggest impact on your decision. Which of the following most apply to you? Drag the bars or type in the boxes at the end to allocate 100 points among the options below.

- a. I charge when or where charging rates (i.e. prices) are the lowest
- b. I charge where and when I think I am most likely to find an open and working charging stall.
- c. I charge where and when it helps me get more convenient parking.
- d. I charge at stations closest to my daily activities.
- e. I charge when and where I know charging will be quickest (e.g., at DC Fast Chargers).
- f. I charge when and where I think the environmental impact will be the lowest.

- g. I don't have much choice; I charge on campus because it's the only convenient charging option available to me

14. When you charge on the UCSD campus, independent of where you actually end up charging, what is your preferred on-campus charging location?

- a. Central campus (Gilman parking garage, School of Medicine)
- b. East campus (Athena parking garage, Medical Center, Skaggs)
- c. Graduate housing (One Miramar, Mesa Nuevo, Nuevo West, South Mesa, etc.)
- d. North campus (Hopkins parking garage, Pangea parking garage, Rady School of Management)
- e. Scripps Institution of Oceanography campus
- f. South (Osler) parking garage
- g. None; I prefer not to charge on campus
- h. Other

15. If/when you decide to charge on campus, consider the factors that have the biggest impact on your decisions about when and where at UCSD to charge. Which of the following most apply to you? Drag the bars or type in the boxes at the end to allocate 100 points among the options below.

- a. I charge where and when I think I am most likely to find an open charging stall (e.g. I arrive early in the morning when there are more open stalls).
- b. I charge wherever is closest to my office, lab, or classroom.
- c. I perfer to charge at stations where the allowed stall dwell time is longest, to reduce the need to move my car or get a ticket for exceeding the limit.
- d. I prefer to charge for a short period of time (e.g. using fast charging) and then depart
- e. I prefer to charge when and where I think the environmental impact will be the lowest

Demographics

16. Choose one or more races that you consider yourself to be

- a. White or Caucasian
- b. Black or African American
- c. American Indian/Native American or Alaska Native
- d. Asian
- e. Native Hawaiian or Other Pacific Islander
- f. Other
- g. Prefer not to say

17. Are you of Hispanic or Latino origin?

- a. [Yes / No]

18. What was your total household income before taxes during the past 12 months?

- a. Less than $25,000
- b. $25,000–$49,999
- c. $50,000–$74,999
- d. $75,000–$99,999
- e. $100,000–$149,999
- f. $150,000 or more
- g. Prefer not to say

19. What is your age?

- a. 18–25
- b. 26–35
- c. 36–45
- d. 46–55
- e. 56–65
- f. 66–75

- g. 75+ 20.

What is your gender?

- a. Female
- b. Male
- c. Other/Non-binary

21. What is the highest level of education you have completed?

- a. Some high school or less
- b. High school diploma or GED
- c. Some college, but no degree
- d. Associates or technical degree
- e. Bachelor's degree
- f. Master's degree (MA, MS, MBA)
- g. Advanced professional degree (PhD, JD, MD, etc.)

EVCC member
22. Are you already a member of the campus EV Charging Club?

- a. [Yes / No / I'm not sure]

Charging Accounts
23. Click here to set up your ChargePoint account if you don't yet have one or to log in if you do. Enter your ChargePoint ID below.

- a. [Open response]

24. Click here to set up your PowerFlex account and download the Smartphone app if you haven't yet. Enter the email address associated with your PowerFlex account below.

Open Response
Do you have any final comments on the EV charging experience at the UCSD campus? [Open response]

A.5 Treatment assignment texts

In this section, we present the text from the prompts sent to the participants during Phase 1 and Phase 2 of the experiment.

- [Welcome Message]: Dear Triton Charger, Welcome back to campus. We write because you have joined the Triton Chargers EV Research Club—are a "Triton Charger"—and agreed to participate in research on EV charging. Starting next week, you will receive another message from us about our first set of research activities for this fall. As you may have seen, there have been a number of changes on campus with parking, EV policies, and costs. Information on UCSD's EV network is maintained here. One of the benefits of being a Triton Charger is that you will have access to additional charging discounts and other information about the benefits of charging on campus. During the fall, you will also receive a few surveys that request odometer readings as well as opportunities to earn prizes. These surveys—one of which we sent today—are very brief (2 questions) but extremely important for our research. We thank you for your participation. If at any time you have questions about this research study or EV charging on campus, please do not hesitate to contact us. Learn more about the Triton Chargers club here.

The following text is sent to the control group:

- [Control message]: No message.

The following text and the content of Figure A3 is sent to the treatment group about information on CO_2 savings, gasoline equivalent, and damages:

- [Informational prompts]: In San Diego in fall, charging a typical EV during daytime, when solar power is plentiful, avoids **29** pounds of CO_2 emissions compared to charging during nighttime when California relies heavily on burning natural gas to generate electricity. This is equivalent to avoiding burning **1.5** gallons of gasoline with every charge; scientists estimate that these avoided CO_2 emissions prevent **$2.75** in costs to human welfare and the global economy.

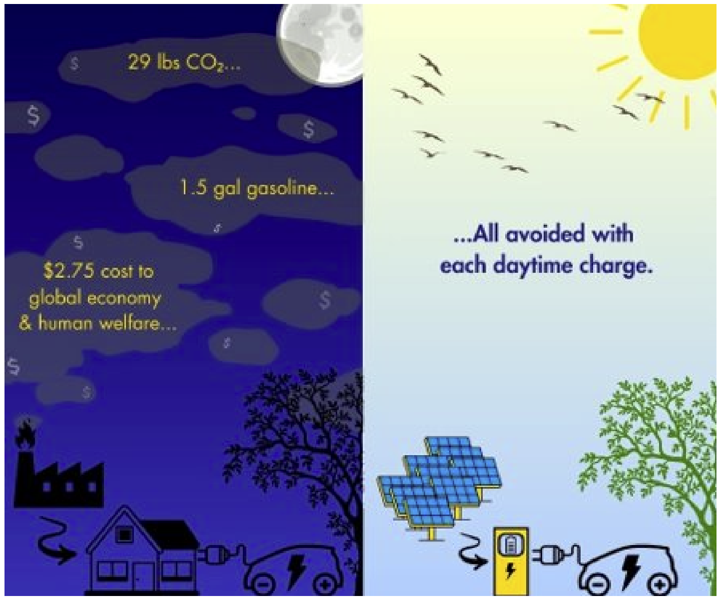


Figure A3: Environmental prompt

The following text is sent to the small and large financial discount group on about information on October 23:

- [Large financial prompt 1]: **From October 24 through November 5**, we will offer a >**75%** discount on all Level-2 charging you do on campus. We are providing a **$0.23/kWh** discount on the base campus price of $0.30/kWh. That means you pay just **$0.07/kWh**. After November 5, these discounts will continue, but they may change in size. We will tell you of all changes ahead of time.
- [Small Financial prompt 1]: **From October 24 through November 5**, we will offer a >**50%** discount on all Level-2 charging you do on campus. We are providing a **$0.16/kWh** discount on the base campus price of $0.30/kWh. That means you pay just **$0.14/kWh**. After November 5, these discounts will continue, but they may change in size. We will tell you of all changes ahead of time.

The following text is sent to the small and large financial discount group on about information on November 23:

- [Large, large financial prompt 2]: In October, we announced discounted campus charging through November 5. **From November 6 through November 19, your discount will remain the same.** The Triton Chargers research team will continue to provide a >**75%** discount (\$0.23/kWh) off the base campus price of \$0.30/kWh. That means you will continue paying just **\$0.07/kWh**. After November 19, these discounts will continue, but they may change in size. We will tell you of all changes ahead of time.

- [Large, small financial prompt 2]: In October, we announced discounted campus charging through November 5. **From November 6 through November 19, your discount will now be smaller.** It will decrease from about 75% to **50%** off the campus's base price of \$0.30/kWh. That means you will now pay just **\$0.14/kWh**. After November 19, these discounts will continue, but they may change in size. We will tell you of all changes ahead of time.
- [Small, small financial prompt 2]: In October, we announced discounted campus charging through November 5. **From November 6 through November 19, your discount will remain the same.** The Triton Chargers research team will continue to provide a >**50%** discount (\$0.16/kWh) off the base campus price of \$0.30/kWh. That means you will continue paying just **\$0.14/kWh**. After November 19, these discounts will continue, but they may change in size. We will tell you of all changes ahead of time.

The odometer survey:

- [Odometer survey]: As part of ongoing EV research at UCSD, please help us by completing a very brief 2-question survey on your current odometer reading. Odometer readings are important because they help us better understand how you are using the campus EV network to meet your charging needs. As a reminder, we are sending a few surveys over the Fall quarter. By responding to at least two, you will be entered into a raffle for one of three \$1,000 Visa gift cards, drawn at the end of the quarter. For each additional survey returned beyond the two, you will receive an additional two raffle tickets.

A.6 Calculations for informational prompt

1. *CO_2 avoided.* We calculate the avoided emissions (in kilogram CO_2) as the emission factor (in $\frac{kgCO_2}{kWh}$) multiplied by the energy consumed (kWh) as follows:

$$Emissions\ avoided\ =\ Emission\ factor \cdot Energy\ consumed,$$

where the emissions factor come from CARBs grid carbon intensity methodology, which is used to calculate LCFS revenue for flex charging and uses average emission factors. We then calculate the energy consumed as a 75% fill-up of a Tesla Model 3 with a 68 kWh battery over a 4 hour charging session. This charge session requires 51 kWh. We refer to night time between 12-4am and daytime between 8am-12pm. We multiply this by the average daytime and nighttime MEFS of 0-18 gram $\frac{CO_2}{MJ}$, and 81-87 gram $\frac{CO_2}{MJ}$. The average effect when shifting from nighttime to daytime electric vehicle charging expressed in avoided CO2 damages for each quarter equals:

$$Q1: \ (82 - 0) \ \frac{gCO_2}{MJ} \ 51kWh \ = \ 15kg$$

$$Q2: \ (81 - 14) \ \frac{gCO_2}{MJ} \ 51kWh \ = \ 12kg$$

$$Q3: \ (83 - 18) \ \frac{gCO_2}{MJ} \ 51kWh \ = \ 12kg$$

$$Q4: \ (87 - 15) \ \frac{gCO_2}{MJ} \ 51kWh \ = \ 13kg$$

2. *Gasoline equivalent.* We calculate the gasoline equivalent (in gallon) as the emissions avoided when shifting from nighttime to daytime electric vehicle charging (in kilogram CO_2) divided by the co2 content of gasoline (in $\frac{kgCO_2}{gal}$) as follows:

$$Gasoline\ equivalent \ = \ Emissions\ avoided \cdot CO_2\ content\ gasoline,$$

where we assume that one gallon of gasoline equals 8.8 kilogram of CO_2. The average effect when shifting from nighttime to daytime electric vehicle charging expressed in gasoline equivalent (in gallon) for each quarter equals:

$$Q1: \ 15\ kgCO_2 \cdot \frac{1}{8.8\frac{kgCO_2}{gal}} \ = \ 1.7$$

$$Q2: \ 12kgCO_2 \cdot \frac{1}{8.8\frac{kgCO_2}{gal}} \ = \ 1.4$$

$$Q3: \ 12kgCO_2 \cdot \frac{1}{8.8\frac{kgCO_2}{gal}} \ = \ 1.4$$

$$Q4: \ 13kgCO_2 \cdot \frac{1}{8.8\frac{kgCO_2}{gal}} \ = \ 1.5$$

3. *Global environmental damages.* We calculate the damages avoided (in \$) as the emissions avoided when shifting from nighttime to daytime electric vehicle charging (in

kilogram CO_2) multiplied by the social cost of carbon (SCC) (in $\frac{\$}{tCO_2}$)

$$Damages\ avoided \ = \ Emissions\ avoided \cdot \ SCC,$$

where we assume a social cost of carbon of 210 $\frac{\$}{tCO_2}$ following estimates from the Environmental Protection Agency (2022). The average monetary damages when shifting from nighttime to daytime electric vehicle charging expressed for each quarter equals:

$$Q1: \ 15\ kgCO_2 \cdot 210\frac{\$}{tCO_2} \ = \ \$3.15$$

$$Q2: \ 12kgCO_2 \cdot 210\frac{\$}{tCO_2} \ = \ \$2.5$$

$$Q3: \ 12kgCO_2 \cdot 210\frac{\$}{tCO_2} \ = \ \$2.5$$

$$Q4: \ 13kgCO_2 \cdot 210\frac{\$}{tCO_2} \ = \ \$2.75$$

A.7 Discount rate calculation

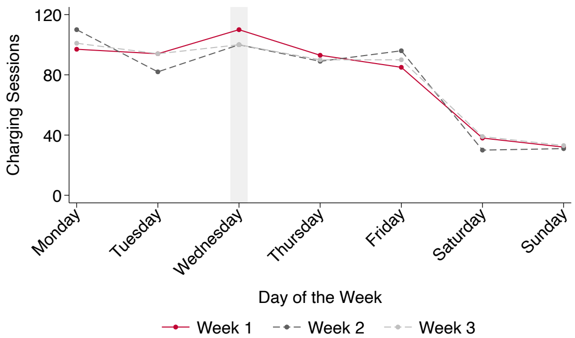
The base rate is set to $.30/$kWh$ by the Transportation Office. Our goal is to provide discount that lead to plausible rates that reflect the costs of generating electricity. Setting the small and large discount rates to $.16/$kWh$ (53% of base price) and $.23/$kWh$ (77% of base price) results in effective rates of $.14/$kWh$ and $.07/$kWh$.

Table A1: SDG&E residential rates in September 2023

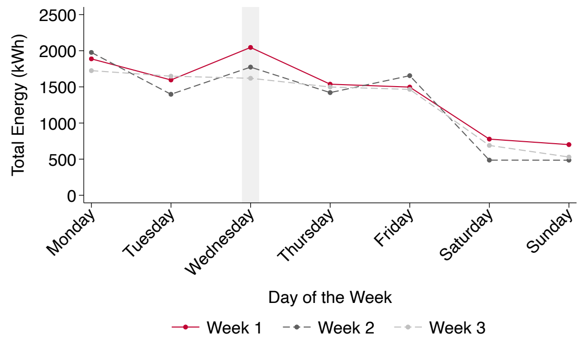
	Time of day ($/$kWh$)		
Plan	Super-Off-Peak	Off-peak	On-peak
TOU-DR1	.41	.435	.519
TOU-DR1		.423	.519
TOU-DR-P	.41	.435	.52
Standard	.452	.452	.452
EV TOU 5 Winter	.145	.448	.511
EV TOU 2 Winter	.276	.464	.527
EV TOU	.276	.464	.527

Notes: This figure documents SDGE residential rates in September 2023. EV-TOU requires a separate EV meter, installed by an electrician at the homeowners expense, that tracks the EVs electricity use separately, while the house remains on a tiered rate. EV-TOU-2 uses existing household smart meter to track both home and EV electricity usage. EV-TOU-5 uses your existing household smart meter to track both your home and EV electricity usage, differentiated by lower volumetric rates and a fixed monthly fee of $16. In exchange for a basic service fee, this schedule provides the lowest rates for overnight EV home charging. Drivers who have home solar PV and/or batteries have different rates.

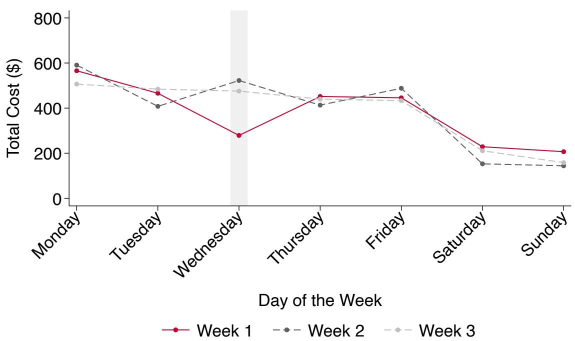
A.8 Clean air day



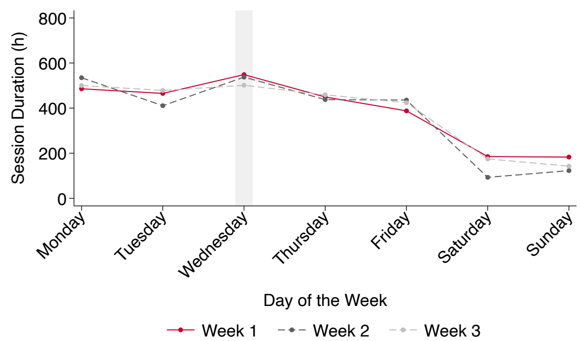
(a) Number of charging sessions



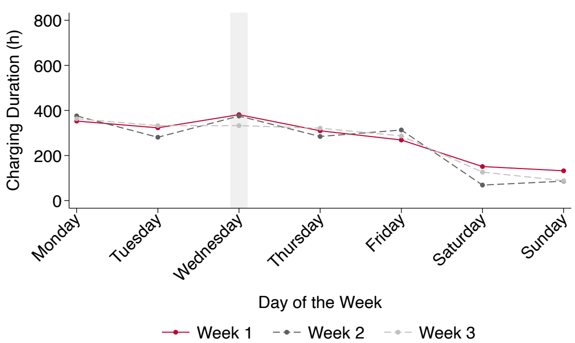
(b) Total energy



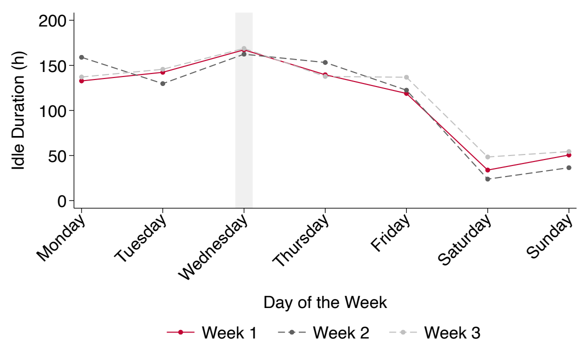
(c) Total costs



(d) Charging duration



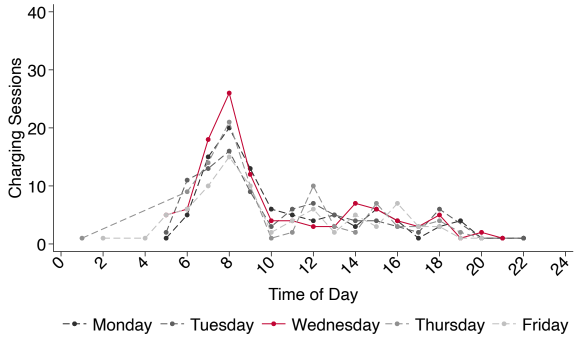
(e) Charging duration



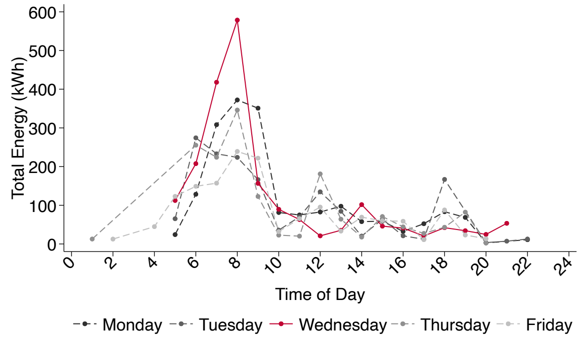
(f) Idle duration

Figure A4: Triton charging on clean air day by weekday

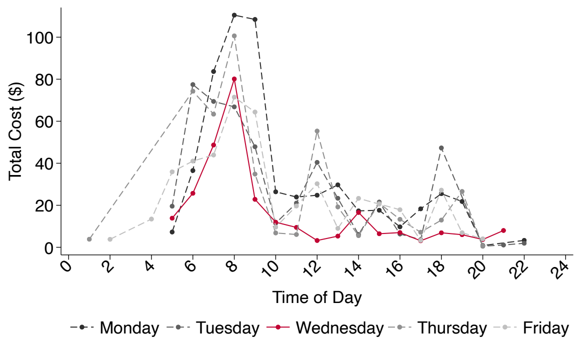
Notes: This figure shows the charging activities of the Triton Charger Club during the first three weeks of October, broken down by day of the week. The statistics provided include the number of daily charging sessions (Panel A), total energy used (Panel B), total price charged (Panel C), session duration (Panel D), charging duration (Panel E), and idle duration (Panel F). The periods covered are as follows: week 1 refers to October 2-8 (red), week 2 refers to October 9-15 (gray), and week 3 refers to October 16-22 (light gray). The clean air day was on Wednesday in week 1.



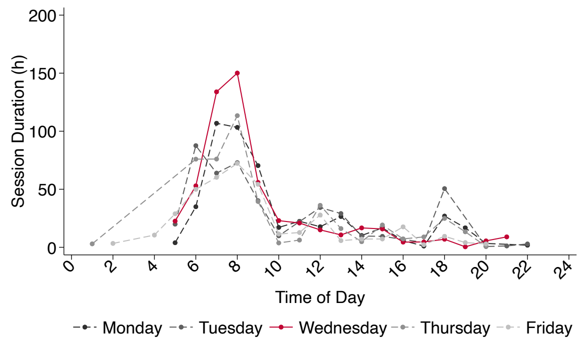
(a) Number of charging sessions



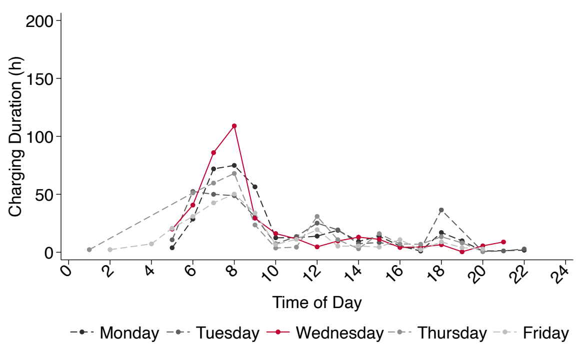
(b) Total energy



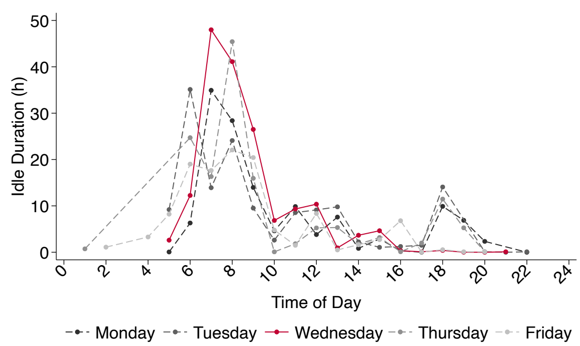
(c) Total costs



(d) Charging duration



(e) Charging duration



(f) Idle duration

Figure A5: Triton charging on clean air day by time of day

Notes: This figure shows the daily charging activities of the Triton Charger Club during the first week of October 2-8, broken down by time of the day. The statistics provided include the number of daily charging sessions (Panel A), total energy used (Panel B), total price charged (Panel C), session duration (Panel D), charging duration (Panel E), and idle duration (Panel F). The clean air day was on Wednesday (red).

B Descriptive Statistics

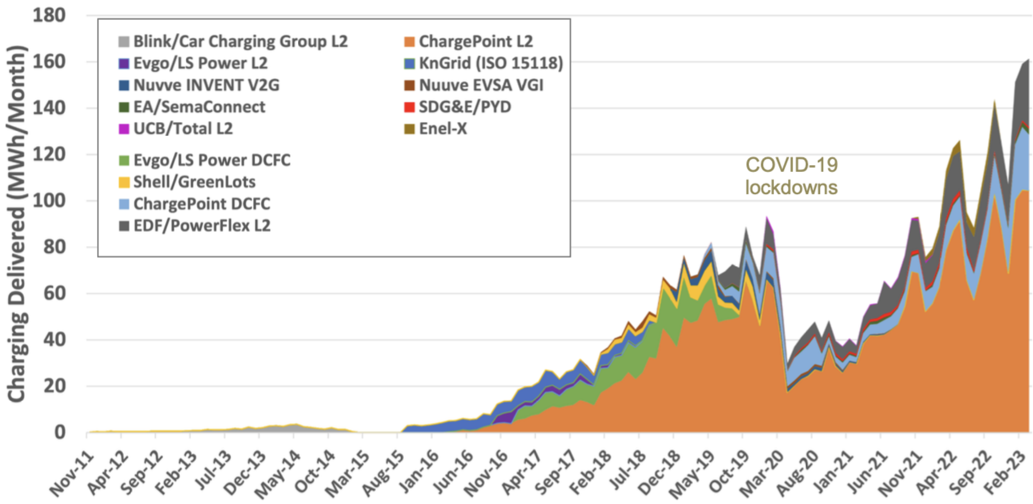


Figure B1: UCSD campus network

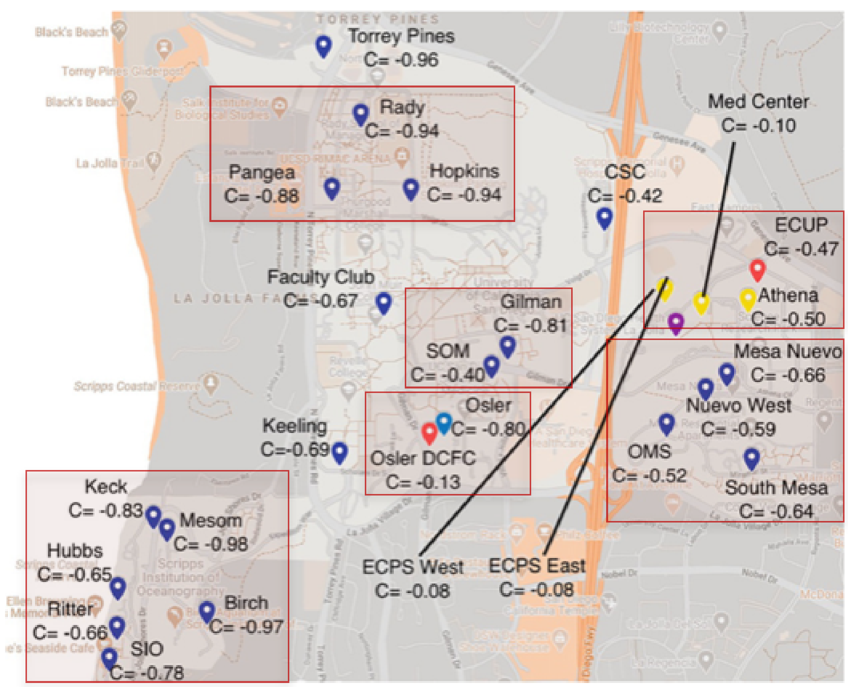
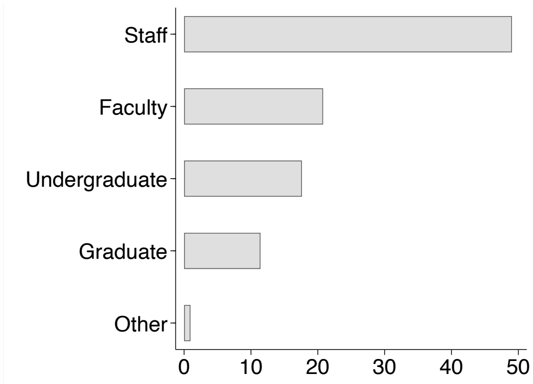
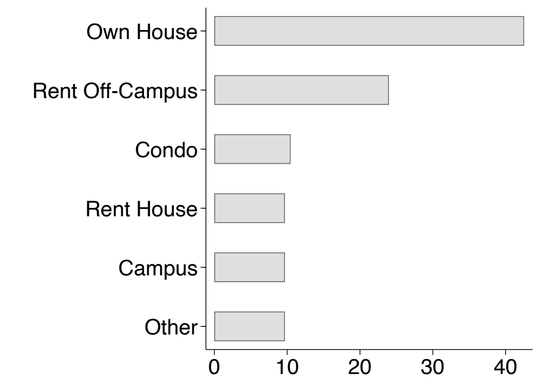


Figure B2: UCSD campus charging zones

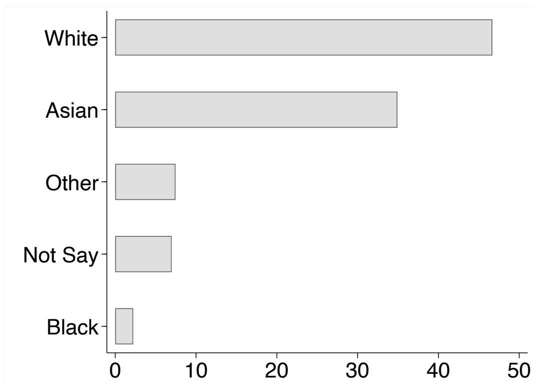
Notes: The purple markers correspond to the UCSD medical center. Yellow markers correspond to medical center plazas, orange markers correspond to DCFC plazas, and blue markers correspond to other plazas. "C" refers to the percent change in dispatched energy from prior to the shutdown to during the shutdown.



(a) Profession



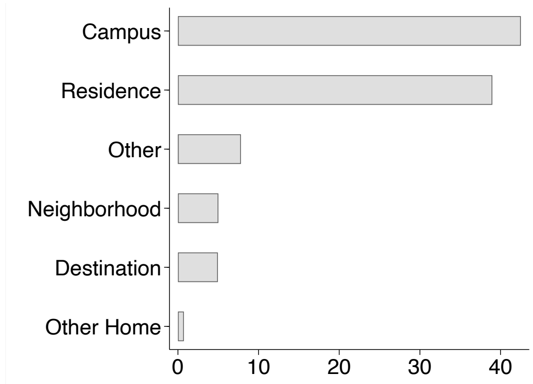
(b) Living Arrangement



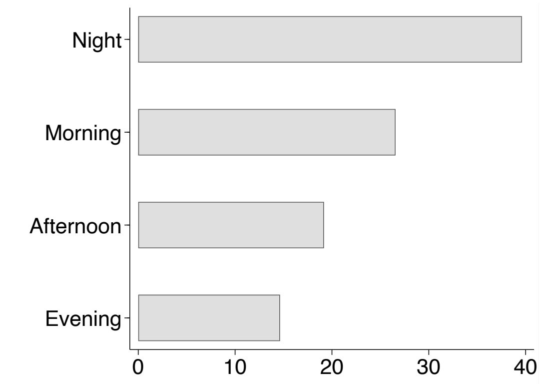
(c) Race

Figure B3: Demographics

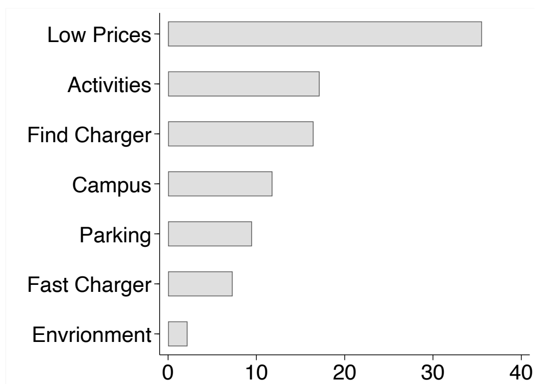
Notes: The figure presents summary statistics for demographic variables of the Triton Charger Club.



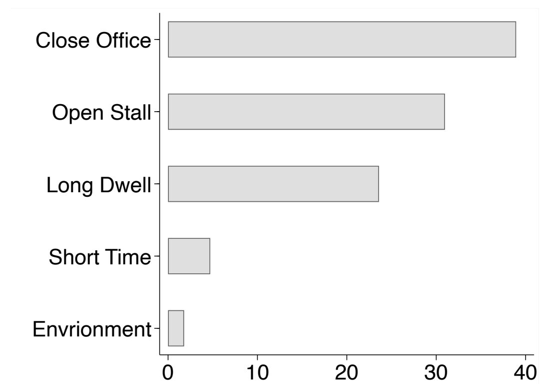
(a) Charging Location



(b) Charging Time



(c) Charging Motivation



(d) Motivation Campus Charging

Figure B4: Charging Motivation

Notes: The figure present the the motivation for charging.

C Spring trial

This Section provides additional details about the experimental schedule (Section C.1), descriptive statistics (Section C.2), and the empirical results (Section C.3) of the spring trial experiment.

C.1 Experimental schedule

During the June spring trial, we conducted the first of four planned experiments. To assign participants to either the Information or Control group, we used stratified black randomization, leveraging data collected during the pre-period.

The experimental schedule of the spring trial experiment is documented in Figure C1. On May 31, 2023, all participants received a welcome message to the Triton Charging Club. The Information group received four informational prompts between June 6 and June 14, as follows:

- [Information]: Thank you for being a Triton Charger and supporting research aimed at improving the quality of charging services offered at UCSD. We are working to grow our charging network and reduce automobile emissions as we transition to an electric vehicle future. In San Diego in spring, charging a typical EV during daytime, when solar power is plentiful, avoids **26** pounds of CO2 emissions compared to charging during nighttime. This is equivalent to avoiding burning **1.4** gallons of gasoline with every charge. In addition, scientists estimate that these avoided CO2 emissions prevent **$2.50** in costs to human welfare and the global economy.

The Control group received a prompt without any informational content as follows:

- [Control] Thank you for being a Triton Charger and supporting research aimed at improving the quality of charging services offered at UCSD. We are working to grow our charging network as we transition to an electric vehicle future.

We conducted two odometer surveys on June 9 and June 16 to calculate the average daily driving and charging demand.

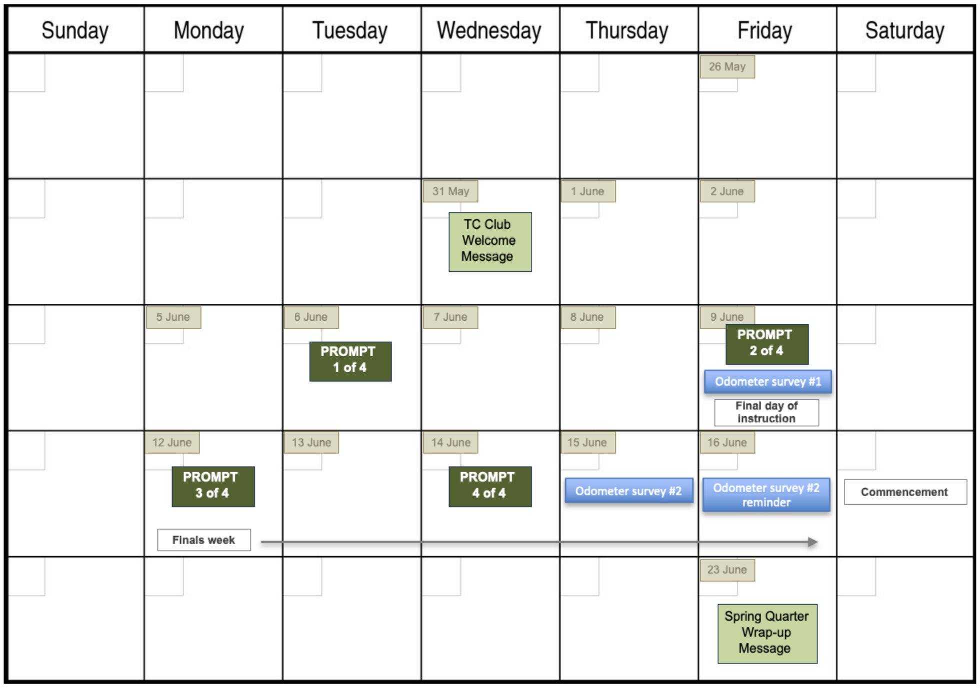


Figure C1: Experimental schedule spring trial

Notes: This figure documents the experimental schedule of the spring trial. The treatment groups receives the same message prompt four times over the course of the experiment. Prompts are sent at 6.30 am on the stated day. All participants receive two odometer surveys.

C.2 Descriptive statistics

Table C1: Summary statistics of spring trial

	Mean	Std. dev.	Min	Max	Obs.
A.Socio Demographic Variables					
Age	38.00	12.95	22	80	419
Share Male (in %)	0.51	0.50	0	1	419
Income ('000)	143.24	64.60	25	200	333
Years of Education	17.02	3.03	11	21	419
Days on Campus	3.29	1.68	0	6	419
B.Vehicle Attributes					
Vehicle Age	2.59	2.60	0	22	419
Battery Electric (in %)	0.76	0.43	0	1	419
Odometer Reading	26197.98	24283.40	188	149,320	227
Daily Mileage	49.57	53.89	0	333	88
C.Charging Characteristics					
Home Charger (in %)	0.61	0.49	0	1	419
Charging Price (cents per kWh)	0.19	0.12	0	1	272
Charging Club Member (in %)	0.34	0.47	0	1	419
D.Outcome Variables					
Average Session (in min)	307.42	196.14	1	902	208
Average Charging (in min)	206.20	142.10	0	750	208
Average Idle Time (in min)	101.22	144.06	0	735	208
Average Energy (in kWh)	18.10	13.67	0	66	208
Average Price	3.79	2.96	0	20	208
Number of Charging Session	1.73	2.52	0	18	419
Share Campus	0.26	0.34	0	1	73

Notes: This table presents the summary statistics of the spring trial experiment.

We use the data collected through the enrollment survey to evaluate the effectiveness of the randomization process. To ensure that the three groups are balanced on pre-treatment observables, we compare the means of various socio-demographic, vehicle, and charging characteristics in Table C2. Using a one-way ANOVA test, the table shows there are no statistically significant differences in means of each variable across the two groups.

Table C2: Balance tests

	Treated		Control	
	Mean	Std. Dev.	Mean	Std. Dev.
A.Socio Demographic Variables				
Age	37.88	12.94	38.13	12.99
Share Male (in %)	0.54	0.50	0.49	0.50
Income ($'000$)	145.39	66.26	141.06	62.98
Years of Education	16.97	3.07	17.08	3.00
Days on Campus	3.31	1.75	3.28	1.61
B.Vehicle Attributes				
Vehicle Age	2.46	2.35	2.71	2.82
Battery Electric (in %)	0.74	0.44	0.78	0.42
Odometer Reading	26772.07	23878.33	25761.84	24670.43
Daily Mileage	49.60	55.44	49.53	53.00
C.Charging Characteristics				
Home Charger (in %)	0.60	0.49	0.62	0.49
Charging Price (cents per kWh)	0.18	0.11	0.19	0.12
Charging Club Member (in %)	0.34	0.47	0.34	0.48
N(Observation)	210		209	

Notes: This table compares pre-treatment average socio-demographic (Panel A), vehicle (Panel B), and charging infrastructure characteristics (Panel C) of the Information and Control group.

C.3 Empirical results

To empirically estimate the effect of the informational prompt on the charging behavior at the workplace, we estimate the following equation:

$$y_i \ = \ \beta Treatment_i \ + \ \gamma X_i \ + \ \alpha_i \ + \varepsilon_{it}, \tag{1}$$

where i indexes the individual. y_i refers to the relevant outcome of interest. The primary dependent variable corresponds to the share of total charge in kWhs on campus relative to the expected total charge. In addition, we consider the number of charging sessions, total energy, cost, duration, charging time, and idle time as outcomes. $Treatment_i$ is a dummy variable equal to 1 if the individual received the informational prompts. The vector X_i represents a rich set of individual socio-demographic variables, vehicle characteristics, charging attributes, and motivation about charging. The α_j are vehicle fixed effects to control for time-invariant vehicle characteristics. The sample period for the spring trial experiment covers June 6 to June 16.

Table C3: Regression analysis of spring trial

	OLS						
	(1) Share	(2) N(Charging)	(3) Energy	(4) Cost	(5) Duration	(6) Charge Time	(7) Idle Time
A.Spring Trial Experiment							
Info. Prompt	-.020	-.467	-4.418	-1.525	-400.533*	-112.891	-287.641*
	(.153)	(.313)	(8.903)	(1.851)	(213.941)	(111.904)	(153.761)
%-Effect	-7.7	-26.98	-8.09	-13.43	-36.72	-17.2	-66.23

Notes: This table presents the regression estimates of the informational prompts (Panel A), the first financial treatment (Panel B), and the second financial treatment (Panel C). The dependent variables indicate the share of on-campus charging (column 1), the number of charging sessions (column 2), the total energy (in kWh) (column 3), the price (in \$) (column 4), the session duration (in min) (column 5), the charging duration (column 6), and the idle duration (column 7). All regressions include individual demographic, vehicle, charging infrastructure, motivational control variables, and vehicle-fixed effects. The %-effects and number of observations are reported below the coefficients. The time period reaches from June 6 until June 16. Robust standard errors, clustered by individuals, are in parentheses. *, **, ***: statistically significant with 90%, 95%, and 99% confidence, respectively.

D Power calculations

In this section, we calculate the statistical power of our information treatment and two financial treatments. Under several simplifying assumptions, List et al. (2011) show that the minimal detectable treatment effect ($\hat{\delta}$) from a design with two treatments, significance level α and power $1-\beta$ is

$$\hat{\delta} = (t_{\alpha/2} + t_{\beta})\sqrt{\frac{\sigma_0^2}{n_0} + \frac{\sigma_1^2}{n_1}}. \tag{1}$$

where n_0, n_1, σ_0^2 and σ_1^2 refer to the sample size and the variance of the control and treatment group. δ is the minimum average treatment effect that the experiment will be able to detect at a given significance level and power. Based on a significance level of $\alpha = 0.05$ and setting statistical power to $1-\beta = 0.80$, we have $t_{\alpha/2} = 1.96$ and $t_{\beta} = 0.84$ using standard normal tables. We can also use the equation (1) to back out the statistical power of our experiment for effect size δ:

$$t_{\beta} = \frac{\delta}{\sqrt{\frac{\sigma_0^2}{n_0} + \frac{\sigma_1^2}{n_1}}} - t_{\alpha/2}. \tag{2}$$

To calculate the statistical power of our experiment, we calculate the standard deviations of charging on campus for the treated and non-treated groups in the informational and financial treatment. In addition, we retrieved data on the estimated treatment effects for off-peak home charging for the financial ("rewards") and informational intervention ("nudge") from Table 1 in Bailey et al. (2023). The relevant data and our power calculations are displayed in Table D1. We refer to 1 as the treatment group and 0 as the control group.

Given the sample sizes and standard deviations in our experiments, Table D1 shows the minimal effect size we can detect with 80% power. The minimal detectable effect size equals .0838 and .091 for the information and financial treatment effects. This corresponds to a percentage change of around 20 percent in each treatment. In addition, we can detect the effect sizes from Bailey et al. (2023) for the information and financial treatment effects with .9975 and .78 power, implying that our experiment is sufficiently powered. However, this assumes that the substitution to off-peak hours for household charging equals the substitution from household to workplace charging.

Table D1: Summary of statistical power calculations

	Informational Treatment	Financial Treatment	
	Charge Indicator	Price Elasticity	Habit Formation
Own Data:			
Participants n_0	315	200	200
Participants n_1	315	400	200
Mean $\mu_0 = \mu_1$	.4251	.4251	.4251
St. Dev. $\sigma_0 = \sigma_1$	.3755	.3755	.3755
Minimal detectable effect size $\hat{\delta}$	.0838	.091	.1051
[in %]	19.71	21.4	24.72
Data from Bailey et al. (2023):			
Effect δ	-.0225	.0958	0
Statistical power $1 - \beta$	.9975	.78	.88

Notes: Charge Indicator equals 1 if the vehicle was charged on campus, and 0 otherwise. The statistical power follows from equation (2), the minimum detectable effect size from equation (1).

E Policy Implication

References

Agency, E. P. (2022). *Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances.*

Bailey, M. R. et al. (2023). *Show Me the Money! Incentives and Nudges to Shift Electric Vehicle Charge Timing*. Tech. rep. National Bureau of Economic Research.

List, J. A., S. Sadoff, and M. Wagner (2011). "So you want to run an experiment, now what? Some simple rules of thumb for optimal experimental design". *Experimental Economics* 14, pp. 439–457.