Do electric vehicle charging policies shape driver behavior? Field evidence from a large university charging network

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***Abstract*—Electric vehicle charging policies, e.g. pricing and parking rules, may affect drivers' charging behavior, which in turn may affect the optimal provision of charging services. However, while many such policies have been proposed, there is comparatively little field evidence on their implementation and impact on behavior. Here we analyze two policies—a minimum session fee and an increase in charger dwell-time, or the maximum duration a vehicle can park at a charger, from 4 to 12 h—implemented at the University of California San Diego in 2023–2024 across 530 chargers collectively used by >9,000 drivers. We present evidence of the impact of these policy changes on drivers' session-level energy use, charging duration, and idling duration. Results suggest that policies have significantly altered behavior: driven by the dwell-time increase, together they have led to 41% larger sessions, from 14 to 20 kWh, and 81% longer idling times, as drivers charge for longer but park for much longer, as well as a 38% decrease in small sessions of <10 kWh. We discuss policy interaction effects and heterogeneity in effects by vehicle type.**

***Index Terms*—Electric vehicle, electrification, EV charging network, transportation, workplace EV charging**

I. Introduction

With increasing sales of electric vehicles (EVs) [1], many workplaces and other institutions are installing EV charging networks in their parking lots to support drivers [2]. In addition to installing hardware, workplaces must also set policies, such as prices and parking rules, that govern the use of chargers. This task is potentially complex because the list of available policies is long. At a minimum workplaces must set charging rates, which could be per hour, per kWh, or free, as well as a rate structure, which could be static or time-varying, and flat or tiered volumetrically. More comprehensive programs might include subscriptions, special offers, and rules that govern charger sharing, such as dwell-time limits, reservation systems, and rules against overstay.

A workplace's decisions about infrastructure and policy are important because they implicitly shape drivers' experiences and hence behavior [3]. As drivers go about their days, commute to work, and return home, they make decisions about how frequently to charge, how long to park and charge, and the amount of battery to replenish with each charging session [4]. Even as these decisions are constrained by a driver's commuting patterns [5], they may be shaped by the broader policy environment for charging. For example, minimum session fees and long allowable dwell-times in theory encourage fewer, longer sessions.

Driver behavior is important because it shapes the economics and optimal provision of charging services [6]. Behavior affects network operating costs because it implicitly shapes energy throughput and capacity factor on the network as well as the timing and volume of energy the network operator must purchase and amortize costs over. Behavior also affects the potential for earning revenue: if drivers demand immediate (rather than offer flexible) charging, e.g., they preclude lucrative opportunities for shifting EV load.

The motivation of this work is to improve our empirical understanding of how charging policies interact with driver behavior in the real world. Although numerous policies have been proposed in the literature, only a small subset have been studied in the field where policies alongside other exogenous and unforeseen factors shape behavior. We focus on workplace charging because it is expected to grow second only to home charging [7], enable broader access to EVs, and help cut charging emissions [8].

Four field studies of workplace charging policy closely align with this work. Each of these [9]–[12] assessed how policy causes drivers to change their behavior in preferred ways —e.g. with incentives to charge with green electricity [9], hourly fees that discourage overstay [10], discounts for flexible charging [11], and messaging and incentives for workplace charging [12]. (Other field studies have addressed public charging [13]–[15] and home charging [16], [17]. Numerous others have been set in laboratory and online settings [3], [18], [19].)

This paper contributes to this literature by presenting and analyzing new field data from the real-world implementation of two policies at the University of California San Diego (UCSD) charging network [20]. In 2023–2024 UCSD introduced kWh-equivalent minimum session fees and increased

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charger "dwell-time," or the maximum duration a vehicle can park at a charger, from 4 to 12 h. Although these two policies were changed to improve resource allocation and driver convenience, we assess how each has affected driver behavior by exploiting two distinct quasi-natural experiments [21]. We focus on three session-level behaviors that together capture *how* drivers charge: energy, charging duration, and idling duration. With (anonymized) data on drivers' individual sessions, including location, we isolate and compare charging activity before and after it was treated, i.e. exposed to a policy change.[1] Using interrupted time-series analysis, we identify significant, pervasive changes in charging behavior that coincided with changes to policy. We know of no other coincident phenomena that offer an alternative explanation for these shifts in behavior.

In what follows, Sec. II presents data and methods; Sec. III presents key findings; and Sec. IV concludes with directions for future research.

II. Setting, Methods, and Data

Setting. Our analysis is based at the UCSD charging network of >600 (as of writing) Level 2 chargers. Over 8 months in 2023–2024, UCSD gradually changed two polices: in 11 parking lots it replaced old chargers and, at the new chargers, increased the allowable dwell-time from 4 to 12 h; and shortly thereafter introduced 7 and 10 kWh-equivalent minimum session fees at all 4-h and 12-h chargers, respectively (Fig. 1).[2] We refer to these 31 weeks of policy change as the *policy period*. During the 21 weeks before and 37 weeks after the policy period—what we call the *pre* and *post* periods—network infrastructure and policy were stable.

Of the 28 parking lots in our analysis (Table I), chargers in 11 were replaced and converted to 12-h dwell-time; we refer to these as *converted* lots. The other 17 lots retained either fully 4-h or 12-h chargers; we refer to these as *stable 4-h* and *stable 12-h* lots.[3] All lots received the minimum session fee.

TABLE I
Summary of charging activity in the 3 parking lot types during the pre-policy and post-policy periods

Lot Type	# Lots	Period	Charging Ports	Sessions	Drivers
Converted	11	Pre	105	29 721	3296
		Post	199	23 375	3065
Stable 4-h	12	Pre	49	12 756	2222
		Post	34	9476	1437
Stable 12-h	5	Pre	24	3819	608
		Post	140	4471	901

[1]This study used de-identified charging data that is collected by the campus for operational purposes, contains time-stamped charger-level telemetry, and does not contain personally identifiable information. Our work nevertheless has IRB approval at UCSD (#805222)

[2]With a y-kWh minimum fee, drivers are billed for y kWh when they draw $< y$ kWh.

[3]Included among these are two stable 4-h lots that were decommissioned in the post period but have sufficient activity to characterize behavior and three stable 12-h lots that were newly opened in the post period. Behavior in these lots resembles that of other stable lots.

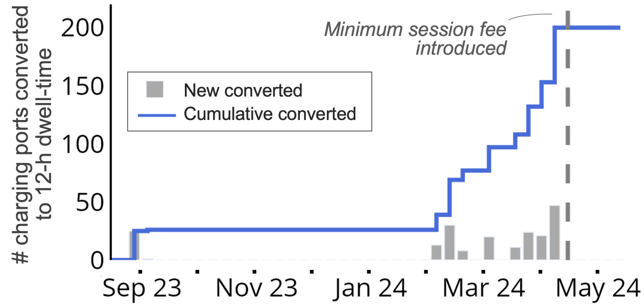

Fig. 1. The policy period and its two policy changes: conversion of charger dwell-time from 4 to 12 h in converted lots and introduction of kWh-based minimum session fees campuswide.

Methods. The nature of the policy changes at UCSD provides a quasi-natural experiment [22] that allows for assessing the effects of each policy treatment. (Quasi-experiments are common and used to study naturally occurring phenomena, like policy, where random assignment is not possible [21].) First, the minimum session fee can be assessed by comparing behavior in stable lots before and after the policy change using single-group interrupted time series (ITS) analysis, since these lots received only this one policy change [23]. Second, the dwell-time increase can be assessed by comparing behavior in converted lots (which received both policies) before and after the policy change and deducting the analogous change in behavior in stable lots (which received only the session fee). Formally this is known as controlled ITS analysis, which, with its use of a control group, adds robustness to findings because it controls for secular trends [24].

The key assumption in ITS is that behavior in the treated group (converted lots) would have resembled behavior in the control group (stable lots) without the incremental policy change (the dwell-time increase)—what's called *parallel trends*. (We do observe parallel trends in the pre period—e.g., absolute changes in kWh/session in converted, 4-h, and 12-h lots are <0.5%/week.) Our setting meets other key validity criteria for quasi-experiments: treatment was exogenous because dwell-time conversions followed engineering and logistical constraints, not behavior or demand patterns; drivers (and hence sessions) did not select into treatment, as we observe that drivers do most of their charging in a single lot; and drivers were not informed of treatment ahead of time in a way that could bias treatment.

To assess significance in pre-to-post period changes in behavior, we run the ordinary least squares model $y_i = \beta_0 + \beta_1 \times \text{Post}_i + \varepsilon_i$, where outcome $y \in \{\text{energy, charging, idling}\}$ and Post_i is a binary indicator equal to 1 if session i occurred in the post period. We report two-sided p-values for β_1 using conventional standard errors.

Data. Our dataset contains minute-level session data on every instance of a vehicle connecting to the UCSD network, including the (anonymized) driver, location, energy received, vehicle, and the time it plugged in, stopped charging, and unplugged from the charger. We focus on three session-level charging attributes that define *how* drivers charge: energy (kWh), charging (h), and idling (h), where the sum of time

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spent charging and idling is the total session duration.

In total, our analysis comprises 91,663 sessions over 58 weeks (the pre and post periods) at 530 Level 2 chargers. Table I summarizes charging activity by period and lot type.

III. Results

We first present broad trends (Sec. III.A) and variation (III.B–C) in charging behavior by lot and vehicle type, and then report the effects of policy on behavior (III.D).

A. Trends in charging behavior over time

Fig. 2 shows weekly session level charging (energy use, charging duration, and idling duration) among all vehicle types in the months before, during, and after policies were changed. Activity is separated by lot type (see Table I). Across all 3 measures we observe substantial noise but also predictable patterns of variation that follow seasonal holidays in the academic quarter system. We note two important trends.

First, drivers typically initiate deeper sessions and spend more time charging and idling in stable 12-h lots (which permit 12 h of parking and charging) than they do in stable 4-h lots. With greater convenience afforded by the longer 12-h dwell-time, mean session energy is 17 kWh, 21% larger than the 14 kWh mean in stable 4-h lots.

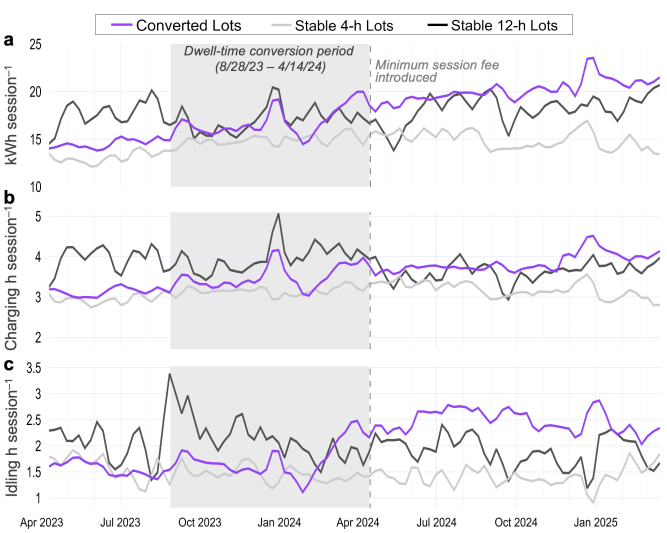

Fig. 2. Session level behavior among all drivers: *(a)* energy (kWh/session), *(b)* charging duration (h/session), and *(c)* idling duration (h/session) in the 3 parking lot types in the months before and after the policy period. Shading and the dashed vertical line denote the policy period (cf. Fig 1). Data are plotted by week with a 2-week rolling average. See Table I for a summary of the charging ports, sessions, and drivers that compose each time series.

Second, although for long periods the 3 measures are relatively stable (albeit with noise; e.g., see session energy in 12-h lots in 2023 and early 2024, and idling in 4-h lots), over short periods behavior changes rapidly. The most salient of these are increases in session energy and idling of 26% and 59% in converted lots over 13 weeks from February through April 2024. These rapid shifts coincided with the end of the policy period when most lots received the new 12-h dwell-time and all lots received the minimum session fee (see Fig. 1). Prior to these 13 weeks, behavior in converted lots generally resembled that in 4-h lots; afterward, it more closely matched behavior in 12-h lots.

B. Charging behavior by parking lot type

Fig. 3 compares the distribution of session energy in the pre- and post-policy periods for each parking lot type as well as the 11 converted lots. Between the pre and post periods, we find a significant, ubiquitous increase in kWh/session in converted lots (Fig. 3a,d–n), with no sign of an analogous change in stable lots (Fig. 3b–c). Increases of 5–80% (41% mean) far exceed the increase of 4.4% and 6.5% in stable 4-h and 12-h lots. Although UCSD's parking lots vary in size, location, and typical user, and each lot's dwell-time conversion varied in timing and scale, we find that kWh/session universally increased in converted lots in the post-policy period. This increase is marked in particular by a pronounced decrease in small sessions of <15 kWh and increase in larger sessions of 20–60 kWh.

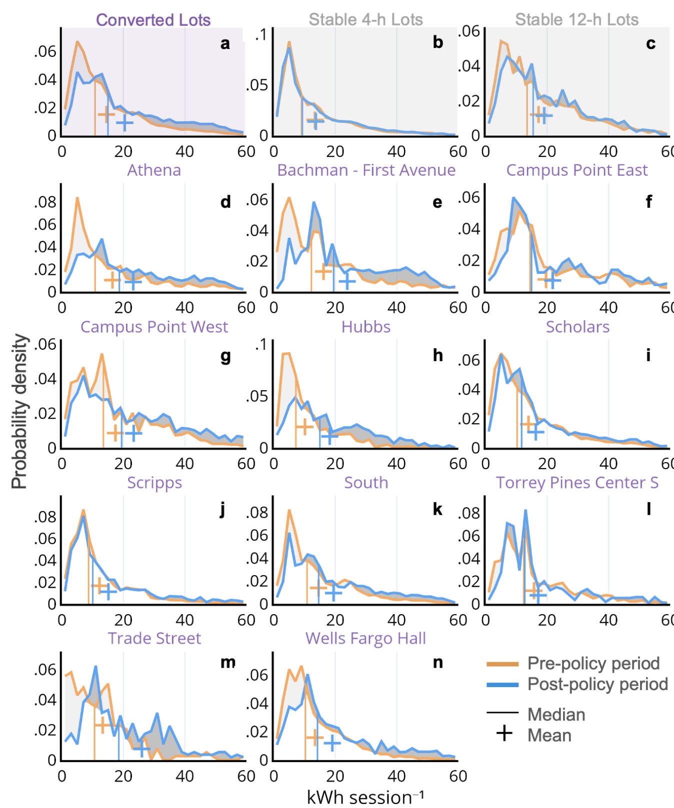

Fig. 3. Distribution of session energy (kWh/session) in the pre- and post-policy periods in the *(a–c)* 3 parking lot types and *(d–n)* 11 converted lots. Vertical lines denote median; plus-marks, mean. Shading shows differences between periods.

C. Charging behavior by vehicle type

Fig. 4 further disentangles session energy by vehicle type—i.e. battery EV (BEV) and plug-in hybrid EV (PHEV)—and reveals three important trends. First, the trend toward deeper sessions in converted lots in the post period, shown in Fig. 3, exists for both BEV and PHEV drivers. In converted lots, BEV drivers consumed an additional 6.9

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kWh/session (a 38% increase), while PHEV drivers took 1.4 kWh/session more (an 18% increase). Differences between the two increases are partly explained by differences in battery capacity: in our data set, the median BEV (PHEV) has a 75 (12) kWh battery. For both vehicle types, the increase in kWh/session was marked by a prominent decrease in small sessions and increase in large sessions. Second, by comparison, pre-to-post period changes in stable 4-h lots were negligible: BEV and PHEV session energy fell by 4% and 1%, respectively. Third, in stable 12-h lots, the magnitude of pre-to-post period changes diverge by vehicle type: BEV drivers increased kWh/session by 5% (1 kWh), but PHEV drivers increased it by 15% (1.1 kWh). (All results, with the exception of the negligible change in kWh/session among PHEVs in stable 4-h lots, are statistically significant at $p < 0.01$.) These two areas of divergence (among lot types and vehicle types), as we elaborate in Sec. III.D, indicate that policies may be interacting and that interaction effects vary depending on EV type.

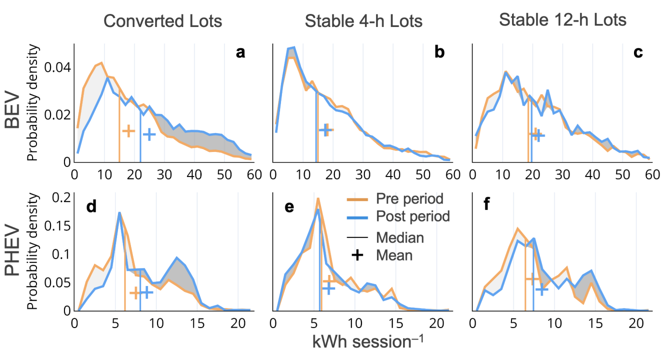

Fig. 4. Distribution of session energy (kWh/session) in the pre- and post-policy periods in converted and stable lots among *(a–c)* BEV and *(d–f)* PHEV drivers. Vertical lines denote median; plus-marks, mean. Shading shows differences between periods.

Fig. 5 disentangles charging and idling duration by period and vehicle type. We observe that BEV and PHEV drivers have similar parking patterns independent of lot type and period (e.g., the two groups plugged in for 4.5 h and 4.2 h, respectively, in converted lots in the pre period). Yet they differ in their charging patterns: because BEVs have much larger batteries, they do substantially more charging while parked.

How have parking and charging patterns changed in the post period? Among BEV drivers, there is virtually no change in stable lots (absolute changes in charging and idling are <6%) but large increases in converted lots: a 28% increase in charging, from 3.5 to 4.5 h, and a 106% increase in idling, from 1 to 2.1 h. The same pattern of increases exists for PHEV drivers (9% and 88% for charging and idling, respectively). In addition, in stable 12-h lots there is a 6.3% increase in charging, which is two-thirds the size of the 9% increase in converted lots. (All results are statistically significant at $p < 0.01$.) As with session energy, pre period charging and idling in converted lots closely resembled that in 4-h lots, while in the post period it closely matched that in 12-h lots.

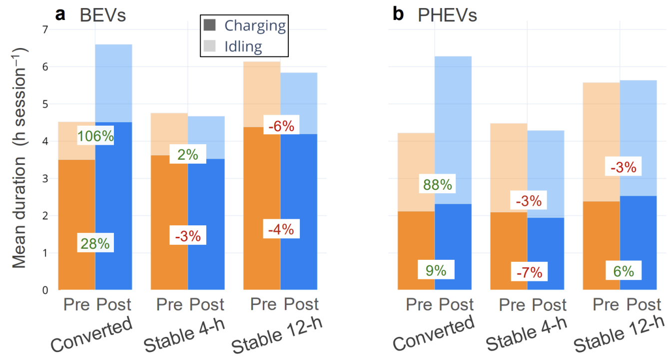

Fig. 5. Mean session duration decomposed into charging (dark bars) and idling (light bars) in the pre- and post-policy periods in converted and stable lots among *(a)* BEV and *(b)* PHEV drivers. Bar height indicates the mean total session duration. Labels indicate the pre-to-post period percent change in charging and idling.

D. The effect of policies on behavior

As Sec. III.A–C show, there are significant, ubiquitous changes in behavior in converted lots between the pre- and post-policy periods. To what extent are these attributable to the introduction of minimum sessions fees and increase in charger dwell-time? The key results are summarized in Table II.

Minimum session fee. For the minimum session fee, effects are observed in stable lots (since these lots received only this one policy change) as the difference in charging between the pre and post periods. We find that effects vary depending on charger dwell-time.

In stable 4-h lots, the effect of the minimum session fee on behavior is small and mixed. For example, it led to absolute changes of <3% in small sessions of <7 kWh and a 4% and 1% *reduction* in kWh/session among BEV and PHEV drivers, respectively (Table II).

In stable 12-h lots, by contrast, effects on behavior are larger. These include: among BEVs, a 5% increase in kWh/session and 10% decrease in small sessions of <10 kWh; and among PHEVs, a 15% increase in kWh/session and 10% decrease in small sessions (Table II). These changes in 12-h lots, and lack of them in 4-h lots, indicate that the two policies interact: only when paired with the longer dwell-time do minimum session fees lead drivers to increase session energy. These changes are rooted in behavior, since the shorter 4-h dwell-time does not preclude deeper sessions: with 4 h of parking at UCSD's Level 2 chargers, drivers could draw at least 13 kWh, yet PHEVs take just 6.9 (6.8) kWh in the pre (post) period.

Dwell-time increase. For the dwell-time increase, effects are determined by quantifying pre-to-post period differences in charging in converted lots (which received both policy changes) and deducting the same difference in stable lots (which received only the minimum session fee).

In contrast to the minimum session fees, the dwell-time increase has had a pervasive effect on behavior: among BEVs, a 44% increase in session energy, 102% increase in idling, and 57% drop in small sessions of <7 kWh; and among PHEVs,

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TABLE II
ENERGY, IDLING, AND FREQUENCY OF SMALL SESSIONS BY PARKING LOT TYPE, PERIOD, AND VEHICLE TYPE

		BEVs				PHEVs			
		Energy (kWh)	Idling (h)	% Small Sessions		Energy (kWh)	Idling (h)	% Small Sessions	
Lot Type	Period			<7 kWh	<10 kWh			<7 kWh	<10 kWh
Converted	Pre	18.1	1.0	20	33	7.5	2.1	60	76
	Post	25.0	2.1	9	17	8.9	4.0	42	61
	% Change	38%	106%	–56%	–48%	18%	88%	–30%	–20%
Stable 4-h	Pre	18.1	1.1	23	34	6.9	2.4	65	81
	Post	17.4	1.2	24	36	6.8	2.3	64	80
	% Change	-4%	2%	3%	5%	-1%	-3%	–2%	–1%
Stable 12-h	Pre	21.0	1.8	13	22	7.3	3.2	55	75
	Post	22.0	1.6	12	20	8.5	3.1	42	68
	% Change	5%	-6%	–9%	–10%	15%	-3%	–24%	–10%

an increase in energy and idling of 19% and 93%, respectively, alongside a 29% drop in small sessions. While these increases are larger, they are also more robust because analysis of the dwell-time includes stable lots as a control.

Beyond these policy changes, we know of no other phenomena at or outside the university that plausibly caused such sharp widespread shifts in behavior.

IV. Conclusion

This paper presented new data and analysis of the real-world implementation of two workplace charging policies—a minimum session fee and maximum charger dwell-time. Results indicate that policies, which workplaces have control over, have led to broad shifts in driver behavior, principally deeper sessions. Furthermore, we find evidence that these policies interact and that their effects vary depending on vehicle type.

Shaping charging behavior is important because better behaviors can improve network, grid, and societal outcomes. In future work, we plan to quantify the impact of these behavioral changes on EV load flexibility and on opportunities to reduce grid congestion and emissions from charging.

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