Title

Shifting a Portion of Plug-In Electric Vehicle Travel Patterns Could Significantly Cut Peak Power Demand

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Shifting a Portion of Plug-In Electric Vehicle Travel Patterns Could Significantly Cut Peak Power Demand

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Issue

Plug-in electric vehicles (PEVs) are among the most promising strategies for reducing transportation-related emissions and mitigating their impacts on both the environment and public health. Historically, PEV adoption has been slowed by three key barriers: range anxiety, limited charger availability, and high purchase costs. Recent advances — including improvements in battery technology, tax incentives, and subsidized charging programs — have begun to ease these challenges, leading to steadily increasing adoption rates.

Planning for the mobility needs of PEVs is particularly important due to the vulnerability of the power grid to outages that can cascade drastically. Yet a common limitation in current PEV analyses is their narrow focus on mobility patterns, often restricted to estimating simple variables like arrival or departure times. Few studies have incorporated individual mobility needs at a metropolitan scale into planning for electricity demand management.

To address this gap, we simulated daily travel patterns for the entire Bay Area population using TimeGeo[1], a mobile phone-based urban mobility model. TimeGeo identifies home, work, and other activity locations for individuals based on the timing and frequency of their phone calls. These data can be used to simulate the travel behavior of PEV owners, combined with vehicle usage rates drawn from U.S. Census data and the California Plug-in Electric Vehicle Driver Survey[2] (Figure 1A).

Key Research Findings

Adoption rates of PEVs depend on income and distance travelled. PEV drivers tend to have higher incomes than owners of conventional gasoline vehicles. Only 15% of gas vehicle owners have average annual incomes above $150,000, compared with the 47% of PEV drivers. PEV drivers also travel less; 64% drive under 30 miles per day. This information was used to generate a subsample of PEV trips from all vehicular trips in the Bay Area using a Bayesian sampling procedure as shown in Figure 1C.

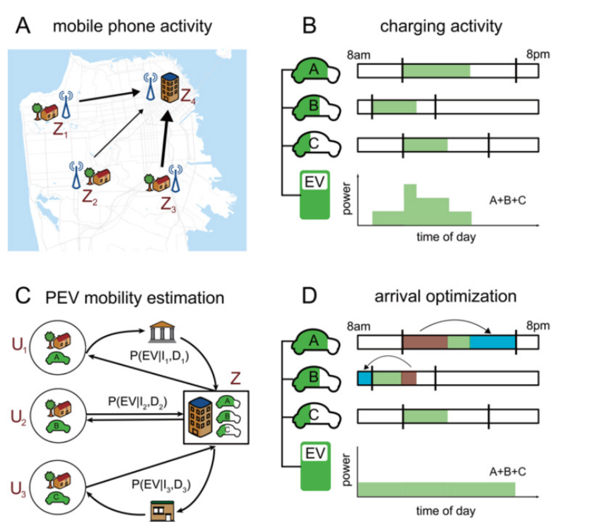

Figure 1. Coupling PEV charging with urban mobility. (A) Mobile phone data are used to model individual mobility. (B) Charging session data are used to characterize individual and total electricity demand curves. (C) The Bayesian inference method is used to find the probability that the vehicular trip is made by a PEV. (D) Charging activity is shifted to relieve peaks in demand.

Electric vehicle charging mostly takes place at work. About 98% of all charging sessions are completed during the work day. Given the variation in battery capacity and mobility patterns, it appears that each charging session serves a number of commuting trips. The actual charging activity does not last the whole charging session, rather the most intensive charging occurs during the morning peak period as shown in Figure 1B. As faster charging technology becomes more prevalent, the peak loads for PEV charging will be even higher.

Shifting some PEV travel can help shift peak demand for power. Figure 2A illustrates an instance where 40 charging sessions are rearranged in one day to minimize peaking. Some users are asked to charge earlier (blue) and others later (red) than their actual requested times. Figure 2B depicts how the power curves change under the flexible strategy by shifting charging times in 15-minute increments. A flexible strategy reduces the power peak down 47% from 1,019 kW to around 479 kW for a shift of one hour. In contrast, a charging-shift strategy reduces the peak load by 66% as there are more available PEV charging openings. Mobility constraints are introduced via the four types of daily trips, called here motifs. More than 30% of PEV drivers have other activities before or after work. The optimal results are the best case scenario because all sessions can be shifted (Figure 2C). The motif aware scheme represents the more feasible gains by coupling the charging strategies with the constraints of the drivers. The motif blind scheme shows how optimization strategies based on charging data only overestimate the benefits of the savings from 3% to 15%, while this loss can be overcome with the mobility information (Figure 2D).

More Information

This policy brief is drawn from the research paper published in Nature Energy which can be found at https://www.nature.com/articles/s41560-018-0136-x and https://its.berkeley.edu/node/13223.

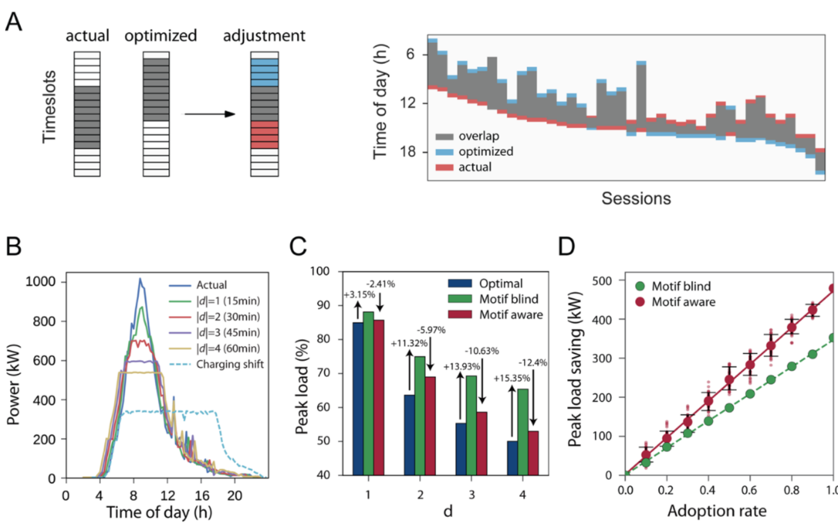

Figure 2. Assessing the benefits of minimizing peak power. (A) An illustration of 40 sessions during one day in the flexible strategy. The sessions are shifted earlier (blue) or later (red) such that the overall peak power is minimized. (B) Decrease in peak power measurements for the varying d of the flexible and charging-shift strategy. (C) Percentage peak load of the three options "optimal," "motif blind" and "motif aware." (D) Peak-load saving versus PEV driver's adoption rate of the time-shift recommendations, for the motif blind and motif aware options when the time shift is d = 4, or 1hr.

[1]Jiang, S. et al. The TimeGeo modeling framework for urban mobility without travel surveys. Proc. Natl Acad. Sci. USA 113, E5370–E5378 (2016).

[2]California Plug-in Electric Vehicle Driver Survey Results: May 2013 (California Center for Sustainable Energy, 2013).

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