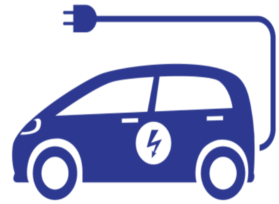
Electric Vehicles Are Not Crashing the Grid:

Lessons from California



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Prepared on Behalf of the Natural Resources Defense Council

Can the Grid Handle Electric Vehicles?

Plug-in electric vehicles (EVs) offer a key opportunity to reduce harmful emissions and save consumers money at the same time. EVs are responsible for far fewer greenhouse gases and local air pollutants than conventional vehicles and become cleaner as more renewable electricity is added to the grid. In addition, EVs are generally much cheaper to operate than conventional vehicles.

However, the recent increase in the popularity of EVs has prompted concerns that the current electric grid may not be able to handle the spikes in household electricity consumption associated with EVs. This would necessitate costly upgrades to electric distribution infrastructure, and possibly even expensive increases in generation and transmission capacity.

Real World Data

Fortunately, starting in 2012, state regulators required California's largest investor-owned electric utilities to publish an annual "load research" report, which contains troves of data:

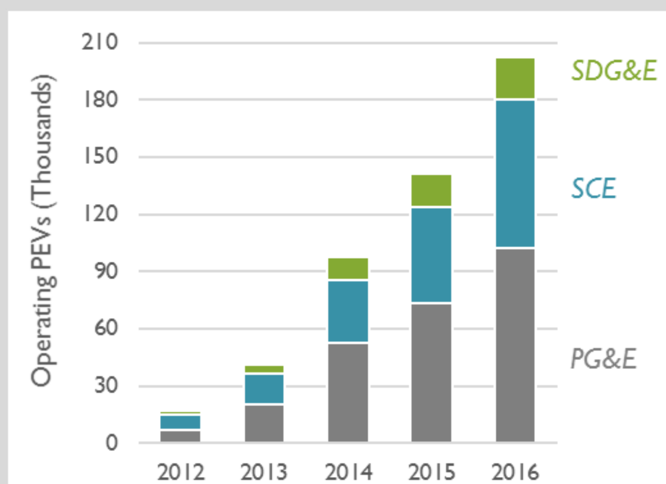
- First, it assesses the degree to which EVs in the utilities' service territories have required costly service line or distribution system upgrades.
- Second, it evaluates the extent to which time-of-use electric rates—which charge customers different energy prices based on the time of day— incentivize EV owners to charge during low-cost, off-peak times.

The results are in. According to the fifth and most recent EV load research report, EV-driven electric system upgrades have been exceedingly rare, and TOU rates have been highly effective at encouraging off-peak charging.

California as the Test Bed

The utility load research reports are particularly useful because they provide data for a region that is at the forefront of the current growth in the EV industry. As of October 2017, there were more than 334,000 EVs in the state, accounting for almost half the U.S. market. During the four years between the publication of the first and most recent load research reports, the utilities' collective estimate of the number of EVs in their service territories grew by a factor of 12 (see Figure 1).

Figure 1. Rapid Recent Growth in EVs in California IOU Service Territories



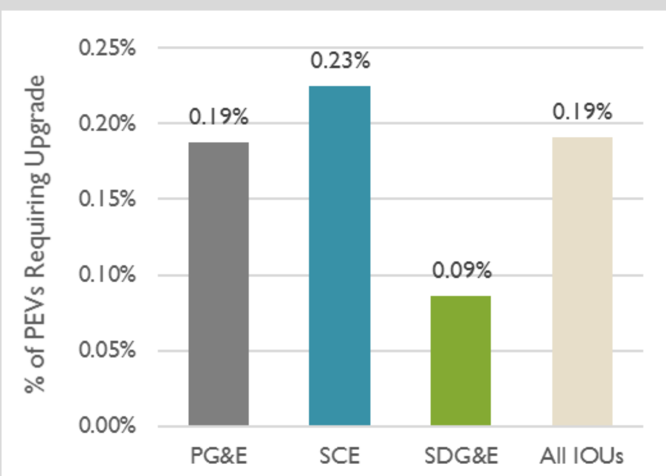
California electric utilities are managing load associated with approximately one car for every 50 residential customers. However, EVs are much more concentrated than that ratio suggests. All three utilities have found that EVs tend to cluster in certain neighborhoods. This clustering would likely exacerbate any tendency for EVs to drive increased distribution system costs.

California is a bellwether when it comes to EVs. If California is still able to integrate clustered EVs at minimal costs to the electric system, then other areas with lower EV penetration rates likely do not have much reason to worry about near-term EV integration costs.

Substantial EV Charging Can Be Integrated without Substantial Cost

According to the latest load research report, very few EVs in California have required system upgrades. Over the past five years, fewer than 0.2 percent of EVs have resulted in a distribution system or service line upgrade (see Figure 2). When averaged across all EVs in the utilities' service territories, the costs associated with all upgrades have amounted to $21 per vehicle. Notably, that per-vehicle cost declined in 2016 to only $10 per vehicle. This suggests that California has yet to hit a point where distribution system EV integration costs become meaningful.

Figure 2. Very Few EVs Require Distribution System or Service Line Upgrades



The costs of distribution system upgrades associated with EVs appear particularly minor when compared to the total distribution capital budgets of California's utilities. During the year covered by the 2016 load research report, the utilities collectively spent less than $610,000 on EV-driven upgrades out of a collective distribution capital budget greater than $5 *billion.* This puts the costs required by EVs at about *one hundredth of one percent* of total distribution capital expenditures.

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EV Customers on Time-of-Use Rates Charge in Low-Cost Ways

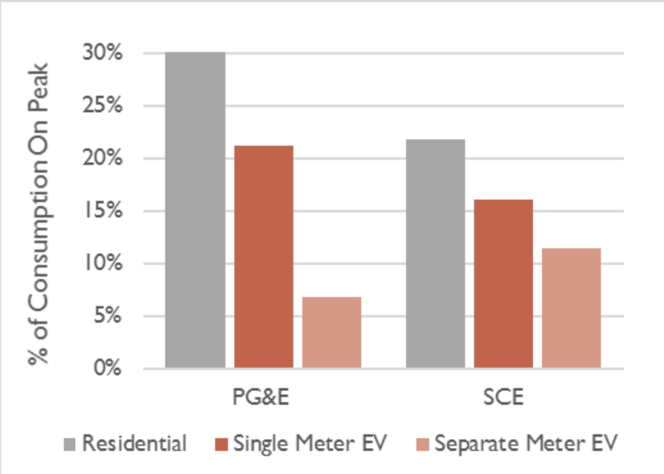
The load research report provides strong evidence that EV owners on time-of-use (TOU) rates charge in ways that minimize harmful impacts on the electric grid. The report generally examines the charging behavior of EV customers on two types of TOU rates. Customers on "single meter" rates have their entire household electricity consumption recorded by a single meter, so that all of their electricity usage is affected by the TOU structure. "Separate meter" rates, in contrast, apply only to a customer's EV charging. Both rate structures generally include an expensive "on-peak" period centered around weekday afternoons, a cheap off-peak period that mainly covers night and early-morning hours, and an in-between "mid-peak" period. It turns out that both metering configurations are effective at encouraging customers to shift their electricity usage to lower-cost hours. Utilities in California and beyond should ensure more EV customers take service on TOU rates.

EV Customers on TOU Rates Charge Off Peak

EV customers on TOU rates consistently consume a far lower percentage of their electricity during on-peak hours compared to standard residential customers. Figure 3 shows that such EV customers (red bars on the right) consume a much smaller percentage of energy during on-peak hours than residential customers without EVs. Customers with separate meters for their EVs only consume 5 to 10 percent of their energy during on-peak periods, meaning that charging primarily occurs outside of the on-peak periods.

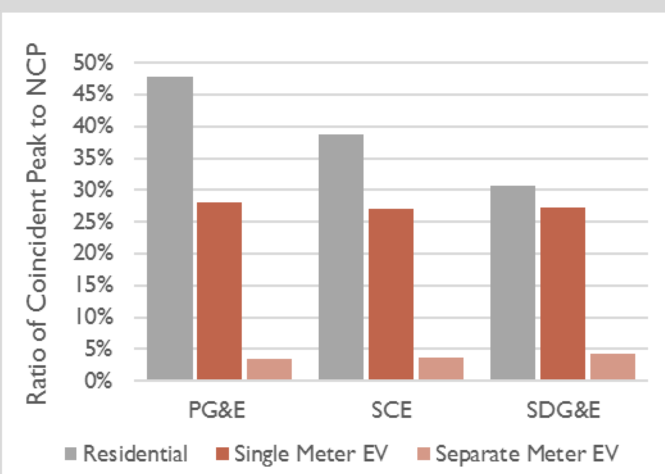
TOU on-peak and off-peak periods are a rough

Figure 3. EV Customers on TOU Rates Use Little Energy During On-Peak Hours



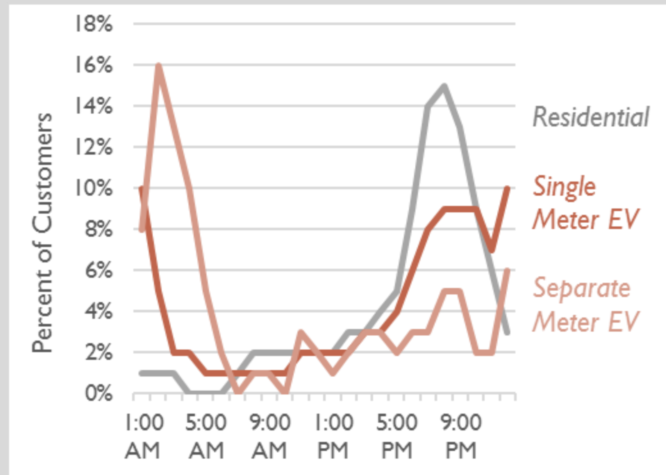
approximation of actual system conditions. But what happens during the few hours of the year when the electric system hits its peak demand? It turns out that customers on EV rates avoid charging their vehicles during those hours, too. By comparing the annual average peak demand of EV customers (also known as a non-coincident peak, or NCP) to that group's average demand during the system peak (also known as coincident peak demand), we can estimate how much EV customers contribute to system coincident peak demand. On average, separately metered EVs consume less than 5 percent of their peak levels during system peaks, which is much lower than standard residential customers (see Figure 4).

Figure 4. EV Customers on TOU Rates Consume Little During System Peak Hours



Rather than increasing demand on the system, EV customers on TOU rates typically hit their monthly maximum demand when the system is least taxed—typically between 11 p.m. and 2 a.m. (see Figure 5).

Figure 5. Percent of PG&E Customers with Peak Demand in Each Hour of the Day



EV Customers on TOU Rates Peak in Beneficial Patterns

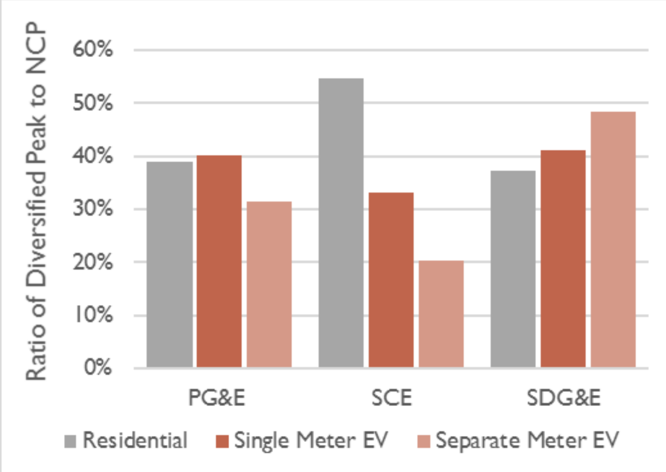
Although EV customers charge during off-peak hours, concerns have been raised that these customers will create new peaks on the distribution system by charging at the same time during off-peak hours.

However, real-world data show that the peaks of EV customers are reasonably diverse, indicating that EV customers do not charge at the same time. In fact, the data show that EV customers tend to have more diversified peaks than the residential class (see Figure 6). Diversity of demand is measured by comparing the class peak demand to the sum of the individual customers' peak demands. If all individual customers peaked at the same time, then the class peak demand would be the same as the sum of the individual customers' peak demands. If individual customers peak outside of the class peak hour, then the class peak demand will be lower than the sum of the individuals' peak demands.

Longer Off-Peak Periods Enable More Diverse Peaks

Figure 6 shows that the diversity of demand varies considerably by utility, but that EV customers tend to have relatively diverse peaks as compared with the

Figure 6. Diversity of Customer Peaks

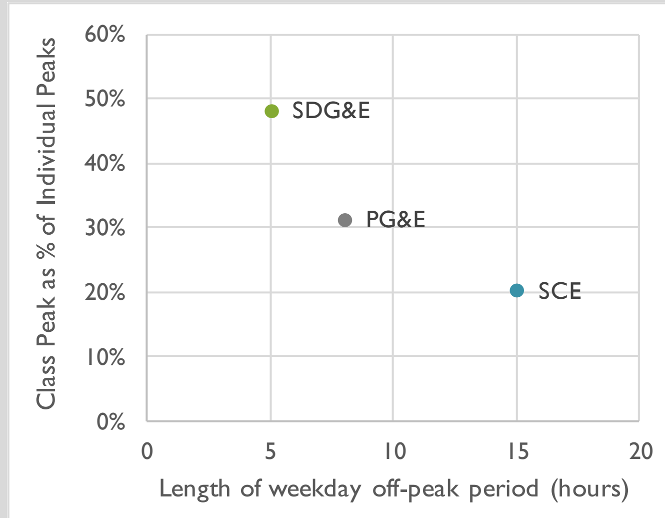


residential class as a whole.

The fact that EV load diversity varies by utility is partly a result of how the TOU rates and off-peak periods are designed. The number of hours in the off-peak period is likely the primary factor driving the difference in EV customer peak diversity across the California utilities. SCE's 15-hour off-peak period provides the greatest diversity of demand, while SDG&E's 5-hour off-peak period encourages customers to charge at more or less the same time.

Figure 7 shows that there is greater coincidence of individual peaks (and less diversity of peaks) with shorter off-peak periods. Thus, expanding the number of hours covered by an off-peak period would likely result in increased peak diversity among customers on TOU rates. Likewise, encouraging drivers to set their EVs to complete charging by the end of an off-peak period, rather than starting to charge at the beginning of an off-peak period, would further diversify EV load.

Figure 7. Relationship Off-peak Period and Coincidence of Peaks



Sources

Energy Information Administration. Annual Energy Outlook 2017. Available at https://www.eia.gov/outlooks/aeo/.

Energy Information Administration. Form EIA-861: Annual Electric Power Industry Report. Available at https://www.eia.gov/electricity/data/eia861/.

Pacific Gas and Electric Company. October 31, 2016. Late Filed Exhibit on Calculation of Imputed Regulatory Values for the Post-Test Years. Application 15-009-001, Exhibit PG&E-46.

Pacific Gas and Electric Company. September 1, 2015. Introduction and Summary of PG&E's 2017 General Rate Case. Application 15-009-001, Exhibit PG&E-1.

Plug-in Electric Vehicle Collaborative. PEV Sales Dashboard, last accessed August 23, 2017. http://www.pevcollaborative.org/pev-sales-dashboard

San Diego Gas & Electric Company. November 2014. Direct Testimony of John D. Jenkins: Electric Distribution Capital. 2016 General Rate Case: Application A.14-11, Exhibit SDG&E-09.

Southern California Edison Company. September 1, 2016. 2018 General Rate Case Overview. Available at https://www.edison.com/content/dam/eix/documents/investors/sec-filings-financials/2018-SCE-general-rate-case-overview.pdf.

Southern California Edison Company, Pacific Gas and Electric Company, and San Diego Gas & Electric Company. December 30, 2016. Joint IOU Electric Vehicle Load Research Report: 5th Report.

Southern California Edison Company, Pacific Gas and Electric Company, and San Diego Gas & Electric Company. December 24, 2015. Joint IOU Electric Vehicle Load Research Report: 4th Report.

Southern California Edison Company, Pacific Gas and Electric Company, and San Diego Gas & Electric Company. December 2014. Joint IOU Electric Vehicle Load Research Report: 3rd Report.

Southern California Edison Company, Pacific Gas and Electric Company, and San Diego Gas & Electric Company. January 31, 2014. Joint IOU Electric Vehicle Load Research Report: 2nd Report.

Southern California Edison Company, Pacific Gas and Electric Company, and San Diego Gas & Electric Company. December 28, 2012. Joint IOU Electric Vehicle Load Research Final Report.

Veloz, 2017. http://www.veloz.org/sales-dashboard/

Synapse Energy Economics, Inc. performed this analysis on behalf of the Natural Resources Defense Council. Synapse is a research and consulting firm specializing in energy, economic, and environmental topics. Since its inception in 1996, Synapse has grown to become a leader in providing rigorous analysis of the electric power sector for public interest and governmental clients.