A Plug for Effective EV Rates

By Avi Allison and Melissa Whited *March 2, 2017*

The Case for Supporting EVs

U.S. Department of Transportation (FHWA)

Electric vehicles (EVs) provide a tremendous opportunity to reduce greenhouse gas (GHG) emissions and save money at the same time. In the United States today, EVs generally result in substantially fewer GHG emissions compared to gasoline-powered internal combustion engine (ICE) vehicles.[1] EVs are also typically cheaper to operate than ICEs. A recent Synapse analysis found that replacing ICEs with EVs powered by renewable energy is one of the most cost-effective ways for states in the Northeast to cut GHG emissions.[2]

However, the environmental, health, and economic benefits of EVs are not guaranteed. When powered primarily with coal-fired electricity, EVs can *increase* emissions of GHGs and local air pollutants.[3] And charging EVs during times of peak electricity demand could result in higher electric system costs, potentially outweighing the operational energy savings associated with EVs. It is therefore well worth encouraging EV owners to charge their vehicles at times when electricity is cheap and clean.

The Role of Rate Design

Electricity rates play a crucial role in fostering the adoption of EVs and encouraging existing EV customers to charge their vehicles in an environmentally and economically efficient manner. Unfortunately, standard electricity rates do little to encourage EV adoption or optimal charging times. In fact, current time-invariant rates and demand charges may even directly discourage efficient charging practices.

Rethinking Rates for EVs

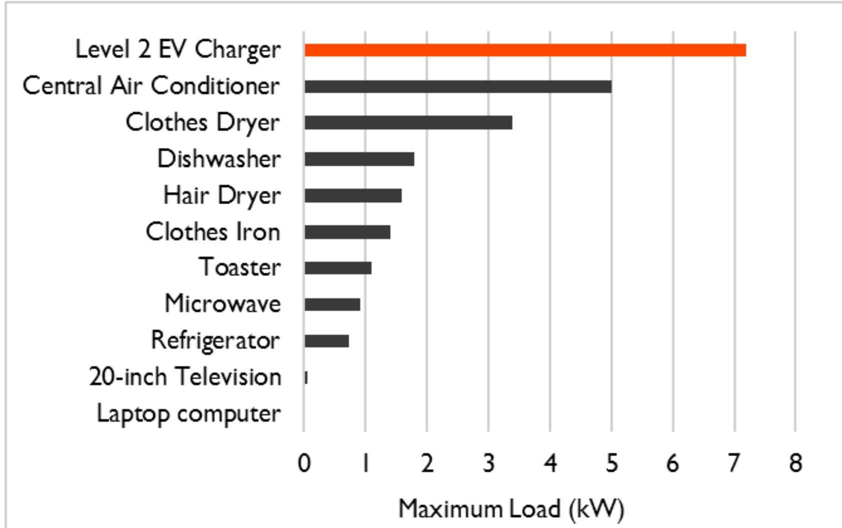
In addition to their potential to cut costs and emissions, EVs have at least two important characteristics that set them apart from most other uses of electricity. First, they represent relatively large loads. As shown in Figure 1, home EV charging systems can draw nearly 50 percent more power than even the most energy-intensive residential appliances. If charged during a time of peak demand with a standard Level 2 charger, an EV's load is roughly equivalent to that of an entire household.[4]

Second, EVs are effectively storage devices. When EVs draw electricity from the grid, that electricity is not immediately used to propel the vehicle. Instead, the electricity is stored in the vehicle's battery for later use. Most people do not care so much about precisely when and where their EV gets charged, as long as the battery works when it is needed. This is very different from most major residential electricity uses (think of air conditioning) and opens up the possibility of encouraging efficient charging without inconveniencing consumers.

Residential Rates Fall Short

Most residential electricity rates include a fixed charge and an energy charge. Fixed charges are applied once a month regardless of the quantity of electricity consumed. The energy charge commonly takes the form of a flat rate or other time-invariant rate, which charges customers the same price per kilowatt-hour (kWh), regardless of when that energy is consumed. Such time-invariant energy rates fail to reflect the fact that the cost to provide a kilowatt-hour of energy may vary substantially from hour-to-hour and month-to-month. Under a flat rate, two customers who use 500 kWh per month would receive the same bill, even if one customer uses electricity only during peak hours when it is most expensive, while the other customer uses electricity at night, when electricity tends to be cheapest.

Figure 1. Load of Level 2 EV Charger Relative to Other Household Loads



Sources: Consumer Reports Wattage Calculator; Bosch Electrical Vehicle Solutions.

The misleading equivalence of time-invariant rates is significant for an EV owner who is equally happy to charge her vehicle during peak or off-peak periods so long as her EV is charged when she needs to use it. Even the slightest price differential is generally enough to incentivize more efficient charging practices, such as charging overnight when demand is low and low-cost wind energy may be abundant.[5] Flat rates and other time-invariant rates provide no such incentive.

Standard electricity rates do little to encourage EV adoption or optimal charging times.

Pitfalls in Commercial and Industrial Rates

In addition to a fixed charge and an energy charge, most commercial and industrial electricity rates also include a demand charge. A demand charge is typically based on a customer's maximum hour, 30-minute, or 15-minute period of electricity demand over the course of a month, regardless of when that peak demand occurs.[6] This type of "non-coincident" demand charge incentivizes customers to smooth out their energy usage to avoid significant spikes in consumption in order to avoid the need to increase the capacity of the distribution system serving the customer. For example, if a customer's peak load increases, the transformer serving that customer may need to be replaced with a larger capacity transformer. Other costly upgrades may also be required, such as expanding the capacity of the power lines or substation serving that customer. For this reason, a demand charge can play an important role in helping to avoid unnecessary distribution system costs.

Unfortunately, a demand charge may have perverse impacts when it comes to EVs. First, the mere presence of a demand charge may lead businesses to resist installing EV chargers for their employees or customers in order to avoid the possibility of higher demand charges. Second, while a non-coincident demand charge may smooth demand spikes, it does not provide any information regarding the hourly cost to generate electricity or the emissions associated with electricity. Because of this, a demand charge may encourage customers to charge EVs during periods when energy is produced in costlier, more polluting ways. For example, a demand charge might compel a business customer to institute a policy that staggers EV charging over the course of the day. While such a policy would minimize the business's demand charges and possibly avoid distribution system upgrades, it may increase wider utility system costs if it leads to customers charging their vehicles more during system peak hours.

A demand charge may have perverse impacts when it comes to EVs.

To harness the full economic and environmental benefits of EVs, conventional rate designs must be reconsidered.

Options for Improved Rate Design

The good news is that there are a variety of EV rate design alternatives that would encourage much more efficient charging practices. What's more, many utility companies have already adopted some of these alternative rate structures for EV customers.

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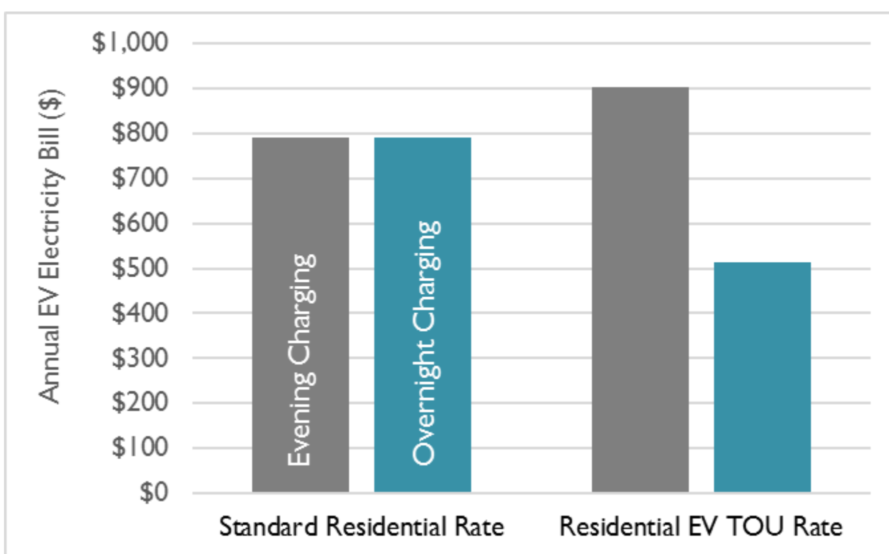
Residential Time-of-Use Pricing

Perhaps the most straightforward and common alternative to standard residential flat rates is time-of-use (TOU) pricing. Under a TOU rate design, customers face different energy prices based on the time of day. Often a TOU rate will have high prices during summer afternoons and low prices at night, although the definition of peak hours may vary considerably from place to place depending on local conditions.

Figure 2 illustrates how the savings from TOU rates can incentivize residential customers to charge during off-peak periods (such as overnight) rather than during peak demand times. In this example, based on Southern California Edison's (SCE) rate structure, an EV owner facing a TOU rate can save nearly $400 per year by charging during off-peak periods rather than during the evening peak. Under a flat rate, the EV owner incurs the same bill regardless of when the EV is charged.

Electric utilities in states as far flung as Alaska, Hawaii, New York, and Georgia offer TOU rates to residential EV customers, and researchers have repeatedly found these rates to be effective at reducing costs and emissions. A pilot study in San Diego concluded that TOU rates are very effective at encouraging customers to charge during low-cost times, with up to 90 percent of customers choosing to charge during "super off-peak" periods.[7] Another study estimated that EV TOU rates would save California $1.2 billion between 2015 and 2030 compared to a flat rate.[8] Meanwhile, a report focused on New York State estimated that switching to TOU rates for EV owners could save up to 755 metric tons of carbon dioxide and 196 metric tons of nitrogen oxides annually by 2030.[9] These studies indicate that, by incentivizing EV owners to charge their vehicles when electricity production is less costly and less polluting, EV TOU rates can generate benefits for both EV owners and non-EV owning electric customers.[10]

Figure 2. Residential TOU Rates Incentivize Off-Peak EV Charging



Sources: SCE; U.S. Department of Energy.

TOU rates for EVs can have drawbacks. For example:

- By incentivizing all EV owners to charge at the same time, TOU rates may result in new local peaks in neighborhoods with high EV penetration, thereby potentially increasing distribution system costs.

- TOU rates for EVs either require the installation of a new, advanced meter for measuring EV electricity consumption alone or require that an entire household face TOU rates. New meters can be expensive, and households may be reluctant to switch to TOU rates for all household electricity consumption.
- Finally, TOU rates are only effective to the extent they are designed to incentivize charging when electricity generation is less costly. If rates are structured poorly, or fail to keep up with changing electricity generation cost profiles (such as increased solar generation causing mid-day electricity costs to drop in California), they may be counter-productive to efficient EV charging.

Hourly Pricing

Hourly rates may provide the strongest incentives to charge EVs when electricity is relatively cheap and clean. Under this rate design, customers face a different variable rate for every hour of the year. The rate is typically based in large part on wholesale electricity prices set in day-ahead markets. These prices depend directly on the cost of producing electricity at a given time, rather than roughly approximating cost patterns, as TOU rates do.

Hourly rates may provide the strongest incentives to charge EVs when electricity is relatively cheap and clean.

Though less common than TOU rates, hourly rates are available to EV owners in a few utility service areas. Commonwealth Edison, the utility that serves Chicago, offers the option of hourly pricing to all residential customers.[11] An analysis of 2013 prices found that EV owners on the hourly pricing plan could cut their annual EV energy supply costs by 45 percent relative to the standard fixed rate, and 38 percent relative to TOU rate, by charging their cars during the low-cost overnight hours.[12]

Both of southern California's largest investor-owned utilities have hourly pricing programs targeted at workplace EV charging. San Diego Gas & Electric's hourly pricing pilot rate is also available to certain residential customers. It has the unique feature of containing an hourly distribution component as well as an hourly wholesale price component. This distribution component accounts for the costs associated with charging at times of neighborhood-level peak demand, and it can help mitigate the local peak concerns associated with TOU pricing. This innovative rate design can help combine the best features of time-varying energy rates with the incentives embedded in a demand charge that help to avoid overloading the distribution system.

Figure 3 on the next page compares an EV customer's bill under three hypothetical commercial rate structures:

- The standard structure includes a demand charge of $15.11/kW and a time-varying energy charge that varies from $0.05/kWh during off-peak hours to $0.27/kWh during peak times.
- The EV TOU rate does not include a demand charge, and features a variable energy charge that ranges from $0.09/kWh to $0.36/kWh.
- The hourly pricing scheme features an energy charge that varies across all hours, from a low of $0.02/kWh during the middle of the night to a high of $0.48/kWh during the evening peak.

In this example, the standard commercial rate, featuring a large demand charge, incentivizes a company with four EVs to spread the charging of vehicles out over the course of a work day, including into periods that overlap with the system peak. By avoiding setting a new peak, the company reduces its EV-related electric bill by 23 percent.

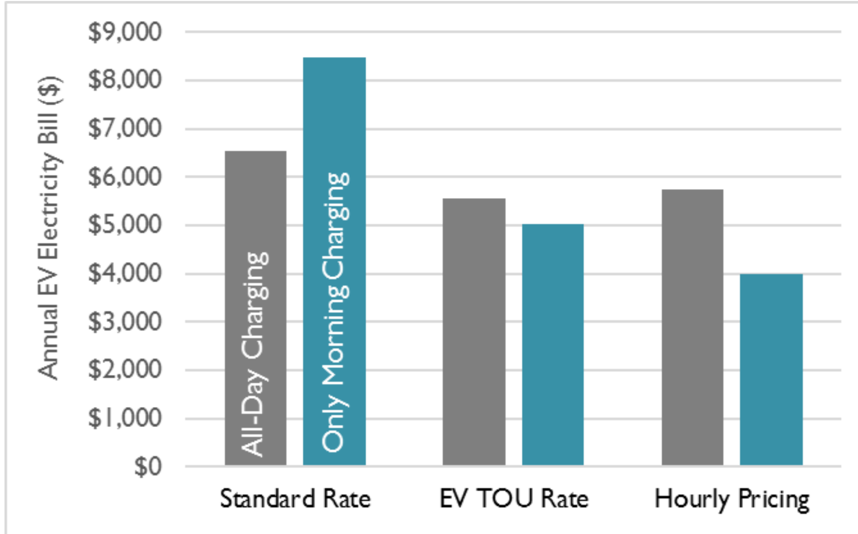
An EV TOU rate reverses this incentive by making it 9 percent cheaper to charge all the vehicles during off-peak morning hours.

The incentive to charge during off-peak hours is strongest under the hourly pricing structure. This rate design makes it 30 percent cheaper to charge all the EVs during the morning.

Importantly, if hourly pricing includes a distribution component (as in SDG&E's pilot), the hourly pricing option can also help to avoid increasing distribution system costs.

Hourly pricing makes the most sense for sophisticated consumers who have the ability to easily access and understand day-ahead electricity prices or who are able to engage a third party to optimize charging for them. Like TOU pricing, hourly pricing requires the installation of advanced electricity metering technology. However, such technology is already widespread in many areas,[13] and the cost of its installation potentially could be offset by electricity savings for EV owners who charge their vehicles overnight.

Figure 3. TOU Rates and Hourly Pricing Encourage Efficient Business EV Charging



Sources: SCE; U.S. Department of Energy.

Rebates for Direct Utility Management

Rather than offering rates that encourage EV owners to charge their vehicles efficiently, some utilities are exploring the idea of paying EV customers to allow a utility to directly control EV charging on its system. The key advantage of this approach is that it allows utilities to manage the potential distribution system costs associated with EV owners in the same neighborhood all charging their vehicles at the same time. If a utility is allowed to directly manage EV charging, it can stagger charging over the course of a day or night, thereby keeping electricity generation costs low while also eliminating the need for distribution system upgrades.

Large utilities including Eversource and Pacific Gas & Electric have experimented with offering rebates for the right to directly manage EV charging.[14] Expanded versions of these pilot programs would involve high technology costs and potentially problematic security and privacy concerns. However, they could also offer substantial benefits. One study estimated that using direct control programs to mitigate EV clustering costs in New York State could avoid infrastructure upgrade costs totaling $103 million by 2030.[15]

Distribution Demand Charges

Although large demand charges are generally at odds with efficient price signals, small demand charges could reduce distribution system costs by incentivizing more gradual EV charging. EV owners generally can choose between various types of chargers, which draw electricity from the grid at different rates. More powerful chargers enable EVs to charge faster, but can result in large local peak loads. Even a relatively small demand charge, when combined with TOU rates, could encourage EV owners to use a less powerful charger and spread their electricity consumption out over the course of an off-peak period.

General EV Rate Design Considerations

The general considerations below can help guide the development of EV rates:

- More sophisticated and high-usage customers, such as EV owners, should face prices that increasingly reflect the cost of consumption at a given time and place.
- TOU pricing is an improvement over flat rate pricing. However, hourly pricing may make the most sense for sophisticated EV customers, as it can help customers to achieve the lowest bills while charging when costs on the system are lowest.
- When combined with a distribution component, innovative hourly pricing can help to avoid increasing distribution costs.
- Demand charges should be used cautiously, as they can create perverse incentives. Where they exist, residential demand charges should only apply to sophisticated, high-load customers (such as EV owners).

Endnotes

1 U.S. Department of Energy Alternative Fuels Data Center. 2015. "Emissions from Hybrid and Plug-In Electric Vehicles." Available at: www.afdc.energy.gov/vehicles/electric_emissions.php.

2 Stanton et al. 2016. "The RGGI Opportunity 2.0: RGGI as the Electric Sector Compliance Tool to Achieve 2030 State Climate Targets." Available at: www.synapse-energy.com/sites/default/files/RGGI_Opportunity_2.0.pdf.

3 Tessum et al. 2014. "Life Cycle Air Quality Impacts of Conventional and Alternative Light-Duty Transportation in the United States." PNAS 111(52). Available at: www.pnas.org/content/111/52/18490.full.pdf.

4 Nexant. 2014. "Final Evaluation of SDG&E Plug-in Electric Vehicle TOU Pricing and Technology Study." Available at www.sdge.com/sites/default/files/documents/1681437983/SDGE%20EV%20%20Pricing%20&%20Tech%20Study.pdf.

5 Nexant, 2014.

6 Frequently measured over 15-minute, 30-minute, or 60-minute intervals. Demand charges can also be structured such that they only apply to hours that fall within system-wide peak periods.

7 Nexant, 2014.

8 Energy and Environmental Economics, Inc. 2014. "California Transportation Electrification Assessment Phase 2: Grid Impacts." Available at http://www.caletc.com/wp-content/uploads/2016/08/CalETC_TEA_Phase_2_Final_10-23-14.pdf

9 New York State Energy Research and Development Authority (NYSERDA). 2015. "Electricity Pricing Strategies to Reduce Grid Impacts from Plug-in Electric Vehicle Charging in New York State." Prepared by M.J. Bradley & Associates LLC. Available at www.mjbradley.com/sites/default/files/NYSERDA-EV-Pricing.pdf.

10 Any net cost impact on non-EV owners would depend on the structure of the rates faced by EV owners, as well as on cost characteristics specific to the local electric generation and distribution system.

11 ComEd. "Hourly Pricing Program Overview." Available at https://hourlypricing.comed.com/. Last accessed 2/24/2017.

12 Elevate Energy. 2014. Hourly pricing and electric vehicles. Available at: www.elevateenergy.org/wp/wp-content/uploads/Hourly-Pricing-and-EVs-050714.pdf

13 For example, approximately 86 percent of electric customers in Georgia and 80 percent of California customers have advanced metering infrastructure technology. See U.S. Energy Information Administration. 2016. Form EIA-861 and Form EIA-861-S Data. Available at: www.eia.gov/electricity/data/eia861/index.html.

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