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DISTRIBUTED SOLAR PHOTOVOLTAICS FOR ELECTRIC VEHICLE CHARGING

REGULATORY AND POLICY CONSIDERATIONS

ABSTRACT

Increasing demand for electric vehicle (EV) charging provides an opportunity for market expansion of distributed solar technology. A major barrier to the current deployment of solar technology for EV charging is a lack of clear information for policymakers, utilities, and potential adopters. This paper introduces the pros and cons of EV charging during the day versus at night, summarizes the benefits and grid implications of combining solar and EV charging technologies, and offers some regulatory and policy options available to policymakers and regulators wanting to incentivize solar EV charging.

BACKGROUND

Increasing demand for EV charging provides an opportunity for market expansion of distributed solar. A main hindrance to this growth is a lack of clear information on the economic, environmental, and utility infrastructure impacts of daytime EV charging with solar.

Utilities that currently provide special time-of-use electricity rates for EV charging incentivize owners to charge their vehicles at night (see Text Box 1 at the end of this document). This approach takes advantage of inexpensive base load generation and avoids adding load to the utility system during daytime peak periods.

Charging EVs during the daytime, however, can provide a number of benefits, as summarized in the table. Daytime charging can increase the total number of miles that can be driven daily. If a driver is limited to charging at night, the range of the vehicle is limited to the miles that can be driven on one charge. If daytime charging was feasible, a driver could commute to work and recharge before taking the vehicle to lunch. After lunch, the vehicle could be charged again, allowing for errands as part of the commute home. Daytime charging, thus, leads to more petroleum displacement and reduced range anxiety for drivers. The ability to charge away from home during the daytime also opens EV ownership to individuals that cannot, or do not want to, install charging infrastructure at their residences. Overall, daytime charging increases the utility of EVs and may contribute to increased adoption. Other pros and cons of the two charging paradigms are summarized in the table above.

EV Charging at Night vs. Day

	Pros	Cons
Nighttime or Off-peak Charging	• Makes use of low-cost base load generation • Few or limited balancing and capacity challenges	• Limits potential daytime travel • EV ownership requires investment in charging infrastructure at residence
Midday or On-peak Charging	• Increased mileage potential and petroleum displacement • Reduced driver anxiety • Potential for increased EV adoption	• May increase peak load • May cause spikes in demand curve • Demand charges could be triggered

> Daytime charging increases the utility of EVs and may contribute to increased adoption.

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Plug-in hybrid EVs charge at the rapid charging system powered by a solar canopy at the Vehicle Testing and Integration Facility at the National Renewable Energy Laboratory.
Photo by Dennis Schroeder, NREL 26238

INDIVIDUAL CHALLENGES OF SOLAR AND EV TECHNOLOGIES

Considered individually, both solar PV and EV technologies have challenges to overcome. The variable nature of distributed solar technology creates challenges for grid integration. The current high cost of batteries used in EVs limits the economic viability of EVs and constrains the number of miles that can be driven on a single charge.

> Combining solar PV with controlled EV charging can be expected to result in a smoother net demand profile than can exist through the implementation of either technology alone.

BENEFITS OF COMBINING SOLAR AND EV CHARGING TECHNOLOGIES

Combined deployment of solar and EV technologies can address the individual challenges of both. EVs can assist with the integration of higher levels of solar generation on the utility grid by smoothing the solar supply curve, reducing the need for curtailment, and increasing the efficient use of transmission and distribution resources.[2] Installing solar in proximity to EV charging infrastructure can reduce or eliminate demand spikes and increases in peak load caused by daytime charging. In some locations, encouraging daytime charging with solar may displace fossil fuel generation. In all cases, the use of controlled charging, which synchronizes the timing of EV charging to match the production of the solar system, increases the benefits for both technologies. Controlled charging schedules can be designed to minimize restrictions on drivers and maximize the benefits to the grid.

Controlled charging technology can be employed in the absence of solar, as well as when EV charging stations are combined with distributed solar technology. Modeling and limited in-field experience indicate that the grid implications of the various technology combinations are distinctly different from one another.[1] The observations for each case are summarized in the bulleted sections below.

In sum, these observations indicate that combining solar PV with controlled EV charging can be expected to result in a smoother net demand profile than can exist through the implementation of either technology alone.

Uncontrolled EV Charging (No Solar)

- There is a spike in the load and an increase in electricity system ramping rates as a result of EV charging immediately after the morning commute.
- Charging immediately after the evening commute contributes to demand during the system peak, requiring increases in total capacity availability.

Controlled EV Charging (No Solar)

- Staggered charging during morning hours can smooth the peak otherwise caused by charging after the morning commute, but requires more expensive smart-charging technology and coordination.
- Deferring charging that would normally occur between 3 p.m. and the end of the peak period reduces the impact of post-work charging on the cumulative amount of energy needed during the peak period. It also reduces the length of the peak period. Deferring evening charging does not reduce the maximum peak level, however, which occurs prior to 3 p.m.
- Restricting charging to morning hours reduces the effects of EVs on peak demand, but limits the benefits of midday charging.

Uncontrolled EV Charging (With Solar)

- PV production overlaps with demand from EV charging after the morning commute, but is not optimally aligned.
- A spike in demand occurs immediately after the morning commute, when EVs are charging and PV production is still ramping up.
- EV charging reduces the curtailment of PV generation in mid-morning hours, and may displace fossil fuel generation in some locations.

Controlled EV Charging (With Solar)

- Controlled charging allows optimal use of PV to smooth the load curve caused by daytime EV charging.
- Controlled charging reduces the potential need for curtailment of PV generation throughout the day.
- Controlled charging could reduce the need to keep thermal generators online to provide operating reserves for PV generation, and may increase opportunities to displace fossil fuel generation.

REGULATORY AND POLICY METHODS TO INCENTIVIZE SOLAR EV CHARGING

Regulators and policymakers have the opportunity to influence the extent to which solar is employed for EV charging. Although EV use is still relatively low, the number of charging stations being installed is rapidly increasing. But the installation of solar technology in conjunction with these charging stations is limited. Most of the cases involve commercial or industrial customers for which environmental responsibility and employee satisfaction are main drivers. (See Text Box 2 on Sierra Nevada Brewing Company.)

Some regulatory and policy options for incentivizing the combination of solar and EV charging are given in the following bulleted sections.

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Regulatory and Rate Options to Incentivize Solar for EV Charging

- Provide rebates for co-location of EV charging and solar technologies; offer higher rebates when controlled charging is employed.
- Provide special rate structures or bill credits for customers that have co-located EV charging and distributed solar technologies. This would be similar to the incentives provided for customer participation in utility-controlled demand site management programs. (See Text Box 1 for examples of special rates for EV owners that are currently offered by utilities.)
- Incent utilities to encourage solar EV charging by allowing them to count the EV charging load that is off-set by co-located distributed solar as eligible under utility energy efficiency requirements. The rationale is that the solar technology off-sets the EV charging load, which could qualify the use of a co-located solar system as an efficiency measure.
- Streamline interconnection applications that involve co-located solar and EV charging infrastructure.
- Identify locations on the grid where including solar with EV charging infrastructure can provide the greatest benefit; use targeted incentives in these locations.
- Waive demand charges associated with increased demand from EV charging on days when the solar systems are not producing above a certain threshold (due to clouds or snow), for customers who co-locate solar with EV charging.

Policy Options to Incentivize Solar for EV Charging

- Provide special recognition for companies that co-locate solar with EV charging at the workplace or in public parking lots.
- Provide unbiased information to raise awareness of the benefits of combining solar and EV charging technologies and assist potential project developers.

Text Box 1: EV Time-of-Use Rate Options

The three investor-owned utilities in California, as well as some municipal utilities, offer residential customers special EV Time-of-Use Rates.[3] Two options are often available, both of which require smart-metering. One option applies a single time-of-use rate to the total electricity load from all sources (both home and vehicle). This option is cost effective if the majority of the total load is during off-peak hours. The second option uses a separate meter, paid for by the customer, to track the electricity used only for charging the vehicle. In both cases, electricity is least expensive between midnight and 3 a.m.

Customers with solar systems can either retain standard electricity pricing or choose a special EV rate. If their solar generation is sufficient to cover the load of both their residence and their vehicle, the standard rate structure is most cost-effective. If their solar system does not meet their full load requirement, the single meter time-of-use rate can be chosen so that solar generation can off-set a portion of the load from the vehicle. If a separate meter is used for the vehicle, solar production cannot off-set the load from the vehicle (e.g., meter aggregation, in this case, is not allowed).

Text Box 2: Sierra Nevada's Solar EV Charging Stations

In 2009, Sierra Nevada Brewing Company installed two EV charging stations at their brewery in Chico, California. The chargers are combined with a 1.5-MW solar system, one of the largest privately owned distributed solar systems in the country. The key motivation behind Sierra Nevada's investment, which was made from the company's operating budget, was to support their sustainability goals and assist in the build-out of the EV infrastructure in California. EV charging is offered at no cost to employees and guests at the site.[4]

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For additional information and questions, please contact Joyce McLaren (NREL) at *joyce.mclaren@nrel.gov*

REFERENCES AND RESOURCES

1. Denholm, P.; Kuss, M.; Margolis, R. M. "Co-Benefits of Large Scale Plug-In Hybrid Electric Vehicle and Solar PV Deployment." *Journal of Power Sources* (236), 2013; pp.350-356. dx.doi.org/10.1016/j.jpowsour.2012.10.007

2. Lowenthal, R. "You've Got to Charge Your EV While the Ducks Are Quacking." Greentech Media, April 21, 2014. Accessed 2014: *http://www.greentechmedia.com/articles/read/Youve-Got-to-Charge-Your-EV-While-the-Ducks-Are-Quacking*

3. See the following for more information on the utility rate options:

   "New Electric Vehicle Rate Options." Pacific Gas & Electric, 2014. Accessed 2014: *http://www.pge.com/myhome/environment/whatyoucando/electricdrivevehicles/rateoptions/*

   "EV Rates." San Diego Gas and Electric, 2014. Accessed 2014: *http://www.sdge.com/clean-energy/ev-rates*

   "Get a Charge Out of Your Electric Vehicle." Southern California Edison, 2014. Accessed 2014: *https://www.sce.com/wps/portal/home/residential/rates/residential-rates*

   "PEV Pricing Plans." Sacramento Municipal Utility District, 2014. Accessed 2014: *https://www.smud.org/en/residential/environment/plug-in-electric-vehicles/PEV-Rates/*

   "Residential Rates." City of Palo Alto, 2014. Accessed 2014: *http://www.cityofpaloalto.org/gov/depts/utl/residents/rates.asp*

4. *The Toast of the Town: Sierra Nevada Brewing Co. Becomes First Corporation to Install Networked Charging Stations for Electric Vehicles*. Chico, CA: ChargePoint, 2009. Accessed 2014: *http://www.chargepoint.com/press-releases/2009/0423*

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