Union of Concerned Scientists

EXECUTIVE SUMMARY

Charging Smart

Drivers and Utilities Can Both Benefit from Well-Integrated Electric Vehicles and Clean Energy

HIGHLIGHTS

Electric vehicles powered by renewable energy are a win-win for reducing emissions in both the transportation and energy sectors. Maximizing these benefits depends on aligning vehicle charging with electricity generation and consumption patterns through the use of appropriate technologies and policies.

There are a number of ways in which utilities, automakers, governments, and other stakeholders can better integrate both electric vehicles and renewable energy (particularly solar power) into the grid. From workplace charging programs to electricity rate structure changes, these solutions can help encourage electric vehicle owners to charge when it is best for the grid and for the environment, thus supporting the wider use of renewable energy in the United States.

Electric vehicles (EVs) provide both an opportunity and a challenge for the nation's electricity grid. EVs hold promise for reducing pollution, but unless their demand for energy is managed, owners may start high-powered charging the moment they get home from work, whether they need to or not. Eventually, uncontrolled charging of EVs at maximum power would require substantial, costly investments in the nation's electricity system. Meeting increased evening peak demands would lead to new generating capacity that would sit idle most of the day.

Solar photovoltaic (PV) power has a similar potential to reduce pollution—and its own set of challenges. High levels of PV generation can supply power in locations and amounts that would overwhelm today's electricity infrastructure.

Solutions are at hand, however, and integrating EVs and PV with the electric grid can support the wider use of renewable energy in the United States.

Managing EVs could substantially limit any negative impacts, requiring only modest infrastructure upgrades. EVs already can schedule charging. With price signals, utilities could encourage drivers to charge when best for the grid. This flexibility could improve the performance of power systems under many operating conditions. Utilities could reduce the costs of integrating variable resources like wind and solar and spread the costs of maintaining the grid more broadly, reducing electricity rates for non-EV owners. EV users could provide utilities with consistent, predictable energy demand and grid operators with abundant and precise data on local conditions.

Department of Energy

This home built by the University of Texas uses solar panels to meet all of the occupants' needs and also to charge an EV. Recent advances allow these technologies to work together to improve electricity grid performance and reduce pollution.

The California Public Utilities Commission summarized the issues in a 2014 report: "At a minimum, managed or smart charging strategies are needed to ensure that EVs do not increase peak load, requiring additional generation or capacity expansions. Ideally, charging is coordinated with grid conditions and the ability for aggregation of EVs to respond to grid operator signals."

Two years later, Bloomberg New Energy Finance noted that "a large installed base of EVs means a huge potential increase in demand-response capacity—electric vehicles can be charged when the power price is low, when solar and wind energy are generating strongly, and they can . . . discharge back into the grid when the network is short of generation."

Policies and practices that smooth the impacts of EVs and PV have already begun as part of a larger grid modernization. These efforts include the expanded use of distributed energy resources (including rooftop solar power), new forms of energy storage, and advanced metering infrastructure (also called "smart metering"). It also includes rethinking the design of rate structures and even the utility industry's business model. All of these developments affect what makes charging "smart."

Electric vehicles are particularly important to consider when thinking about energy storage. They can represent a *form* of energy storage, a *competitor* to stationary energy storage, and an *application* for energy storage:

- EVs' storage—their batteries—can be flexible in when they draw power from the grid. An owner might park at work for nine hours but only need two hours to charge. By varying the time of day for charging, a workplace can manage its peak load. In vehicle-to-grid (V2G) configurations, vehicles can take power from the grid and discharge it back when the grid most needs it.

- EVs and other flexible loads like electric water heaters can address many of the problems that grid-scale batteries are intended to address.

[***Managed charging lowers costs and reduces the need for new generation capacity. Properly implemented, it can also reduce emissions compared with unmanaged charging.***]

Steve Fecht/General Motors

Solar-powered charging stations (such as this one in Detroit, MI) are popping up around the country. Smart charging could enable EVs to draw power from the grid when it is cleanest, and with vehicle-to-grid technology feed surplus clean power back to the grid when electricity demand is higher.

- EVs can be plugged into wall outlets but often use electric vehicle supply equipment (EVSE) that includes chargers, safety features, communication capabilities, and other attributes. It may be advantageous to integrate batteries into the chargers to reduce the infrastructure cost of installing high-powered systems, mitigate demand charges, or even allow off-grid, solar-powered EV chargers.

The Union of Concerned Scientists (UCS) asked, "How can electric vehicles support increased utilization of renewable energy?" Based on reviewing the literature, talking with experts, convening conferences, and conducting modeling, we offer several conclusions for states, utilities, automakers, and charging providers to consider as they make plans to deploy charging infrastructure.

- **Smart charging is viable.** Since the 1990s, researchers have explored the value of managed charging of EVs to a renewables-heavy electricity grid; pilot projects began as early as 2001. Commercial systems employ smart charging to respond to time-of-use price signals, provide demand response during critical peak periods, or selectively charge when the "greenest" power is on the grid. Some projects use smart charging or V2G configurations to provide frequency regulation, a short-term balancing of supply and demand.

- **The needs of transportation users take priority.** Automakers, utilities, charging providers, and regulators all stress the overriding importance of respecting the needs of transportation users—in particular, their anxiety about the range of EVs on a single charge. No stakeholder wants to inconvenience drivers by having their vehicles uncharged when needed. This concern will diminish as more EVs are deployed. With millions of EVs aggregated as a resource, negligible adjustments in charging speed for each could provide all the flexibility the grid would require.

- **Time-of-use pricing is a near-term option for integrating electric vehicles with the grid.** Using price signals to align charging with grid needs on an hourly basis—a straightforward implementation of smart charging—can offer significant benefits to renewable energy utilization. As more solar power comes onto the grid, it will be important to shift electricity loads to the middle of the day. Areas with abundant solar power will want to encourage daytime workplace charging of EVs. Regions with abundant wind power may choose to encourage smart charging overnight at homes.
- **Smart charging can play a role in ancillary services markets.** Smart charging can and does provide grid services. It costs relatively little to add communication and control capability to a charger. Smart charging systems can provide moderate economic benefits to the grid for renewables integration and other purposes. The value is fairly low because renewable energy has proven easy to integrate at current levels. While this may be a problem for EVs trying to earn revenue from grid services, overall it is a good problem to have. Storage or flexible loads may become more necessary at higher levels of renewable energy penetration.

Anne G. Blair

Well-planned incentive programs can encourage EV owners to charge their vehicles when it is best for the grid and for the environment. Smart EV charging can not only reduce electricity- and transportation-related emissions, but it can also reduce electricity costs for all consumers (including those who do not own EVs).

- **Utilities need a plan to use the data.** The sophisticated electronics built into an EV or a charger can measure frequency, voltage, and more complex attributes of the electric grid. EVs and chargers can automatically correct some small local problems in "power quality," and they can report back to a utility or grid operator about conditions requiring attention. Further, solar power systems, batteries, and smart meters can provide data on grid conditions; utilities could provide rebates in recognition of the value of this service—if the utilities have the means to handle the data.

Infrastructure for EVs is at an early stage in the United States, and UCS hopes that this research can inform ongoing deployment across the country. We offer several recommendations for maximizing EVs' benefits to the electricity grid immediately:

- **Support workplace charging.** This is an excellent option for addressing solar over-generation and matching electricity demands to variable supply. It also can raise awareness of EVs and establish confidence that their range and recharging options will meet drivers' needs. To improve the use of this option, utility regulators should reevaluate the design of peak demand charges.
- **Consider greater use of time-varying rates for EV charging to avoid charging at peak demand times.** Shifting more utility rates from peak demand charges to hourly rates would better align demand with system needs. Regulatory flexibility to enable the use of the meters embedded in EV chargers would make it easier to enroll EVs in time-varying rates.
- **Align regulatory incentives to benefit the electricity distribution system.** Distributed energy resources can be managed to reduce strain on the distribution system—given incentives to do so. One solution is to allow utilities to earn a higher rate of return when they meet specific goals for limiting system costs, reducing pollution, or improving reliability. This would give utilities a reason to offer their customers incentives to adopt smart technologies that can benefit the grid.
- **Enable EV chargers to participate in the market for electricity grid services.** Costs of market access that are independent of resource size make it difficult for small projects to participate. With aggregation, hundreds or thousands of EV chargers could enter the market as one larger resource to provide demand response or other services.

Smart charging can lessen the impact of electric vehicles on the nation's electricity grid and help the grid better accommodate renewable energy.

- **Consider flexible loads and vehicle-to-grid in storage proceedings and procurements.** Flexible loads and V2G can provide many of the same benefits as dedicated storage, such as enabling increased market penetration by renewables. States seeking to deploy storage should consider the extent to which flexible loads can help meet their goals.
- **Define "smart" to include pollution.** To a limited degree, the impact of smart charging can be quantified. UCS modeled both managed and unmanaged charging nationally, estimating some of the impacts of shifting EV charging demand throughout the day. Managed charging yields cost savings for all consumers due to reductions in electric system costs, and EV deployment reduces carbon emissions in the models compared with internal combustion engines. However, managed charging increased emissions from the power sector relative to unmanaged charging because energy prices do not fully incorporate the costs of pollution, and certain regions have off-peak power characterized by low cost but high emissions. Smart charging strategies must consider the impact of pollution. Fortunately, some EV chargers can already estimate pollution impacts and schedule charging appropriately. In the long term, putting a price on pollution is economically sound. The estimated benefits of managed charging are larger in studies that consider very high levels of renewable energy (50 percent or more).
- **Accelerate learning from pilot projects to develop local expertise in smart charging.** Such research should specify the types of EV charging to be employed, the vehicle-grid integration issues to be addressed, the existing knowledge base, the uses of project data, the rationale for selecting specific communication options, and the benefits of emissions reductions.

A future with many EVs, each one idle most of the time, would enable these vehicles to play a major role in the grid integration of renewables. Yet there is another possible future to consider, one with shared vehicles and autonomous vehicles. The business case for smart charging to provide grid services would change with fewer vehicles on the road and each used much more often. Even then, flexible charging would provide grid benefits during the idle periods for fleets.

The best near-term option for smart charging is likely time-of-use pricing structured to reflect the costs of energy, system capacity, and pollutant emissions. Done well, this should reduce curtailment of renewable energy. More sophisticated smart-charging models can be implemented if the costs are low. In a future of high market penetration by renewables, flexible loads such as EVs may be of great value to the grid. In a transition to shared autonomous vehicles, smart charging would face competing pressure to maximize vehicle utilization, but price signals could convey the costs of unmanaged charging accurately.

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FIND THE FULL REPORT ONLINE: www.ucsusa.org/smartcharging

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