Driving Energy Efficiency into North American Electric Vehicle Charging Infrastructure

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ABSTRACT

Electrification, particularly in the transportation sector, presents an opportunity for the use of efficient technologies to reduce energy consumption and related carbon emissions. To enable the transition to cleaner transportation, utilities, manufacturers, consumers, and other stakeholders must work together to build a robust national electric vehicle (EV) charging infrastructure network. Key to the success of this network is ensuring that the increased electrical load from EVs does not compromise grid reliability.

The U.S. Environmental Protection Agency's (EPA) ENERGY STAR® program specification for EV chargers was launched in 2016 to promote energy efficiency, encourage demand-response capability, and verify product safety. After initially focusing on alternating current (AC) chargers, the specification is being revised to include direct current (DC) fast chargers in its scope and to update its demand response criteria by referencing new industry standards.

Utilities play a key role in the future of electric transportation since they are well positioned to make the transition possible. In this paper we discuss the load impacts of EV growth and refer to research on mitigating negative impacts. Here, researchers from the Smart Electric Power Association discuss how utilities are approaching charging technology deployment. This research includes the use of strategies such as electric rates to manage system loads and customer bills, education and outreach, and direct load control.

We conclude that the EV transition can bring significant environmental and financial benefits if policymakers and utilities undertake careful planning and analysis to design effective programs based on existing best practices contained in this paper and from other sources.

Electric Vehicle Chargers and the Opportunity for Energy Efficiency

The number of EVs on the roads is expected to grow leading to an increase in EV charging needs at home, work, destinations, and along travel routes. This growth was caused by both consumers' concern for the environment and by favorable economics, as it costs up to 50 percent less per mile to operate an EV compared to a traditional car (Brown 2019). It is estimated that, by 2030, nearly 19 million EVs will consume approximately 93 terawatt-hours of electricity at millions of charging ports each year (EEI/IEI 2018). With overall growth driven primarily by transportation electrification, widespread electrification could result in up to 38 percent energy load growth (see Figure 1), which needs to be effectively managed to ensure grid reliability and to contain grid upgrade costs (Mai et al. 2018).

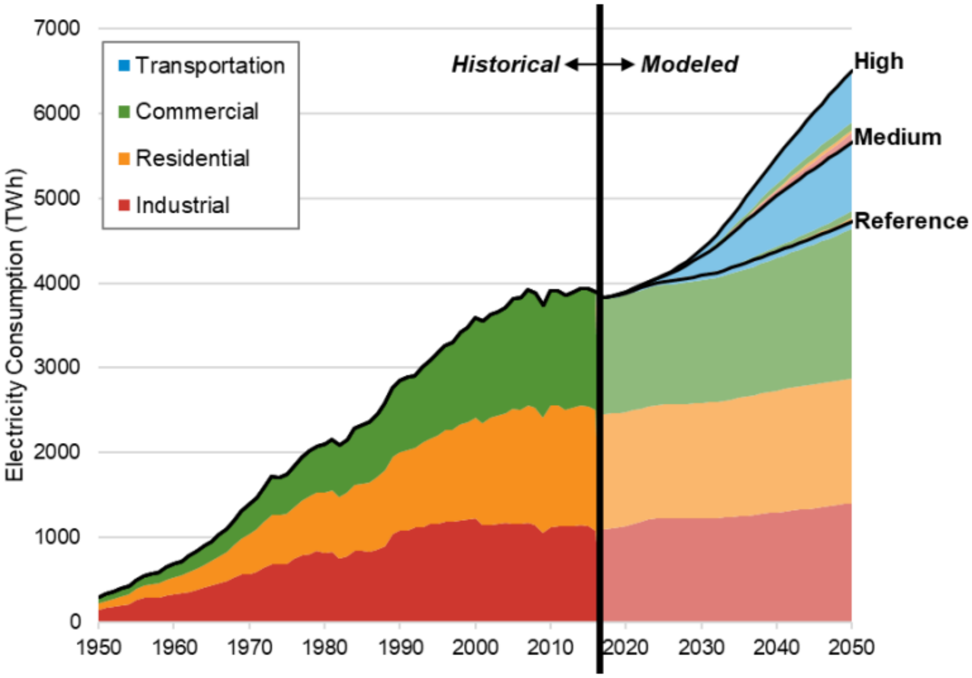

Figure 1. Historical and projected annual electricity consumption by sector.
Source: Mai et al. 2018.

The load impacts from increased EV charging can be evaluated at several levels: residential, commercial, and electricity system. Figure 2 illustrates the anticipated load increase of up to 30 percent for a typical residential feeder circuit of 150 homes when EV penetration hits 25 percent (Engel et al. 2018). Without load management, EVs can add to peak load and become a net cost to the utility. General rules of thumb are not useful when studying the grid impacts of EVs, as each utility, and small areas within each utility territory, need to be evaluated. The Sacramento Municipal Utility District (SMUD) pursued such a study to understand the impact of distributed energy resources (DERs) including EV charging equipment. In a high DER adoption scenario, 17 percent (12,000) of transformers appeared stressed primarily due to EV charging activity (SEPA, Black & Veatch, and SMUD 2017). When problems are identified, solutions can be applied. Consequently, SMUD launched a program that pairs batteries with EV charging in selected transformer stressed locations (Howland 2020).

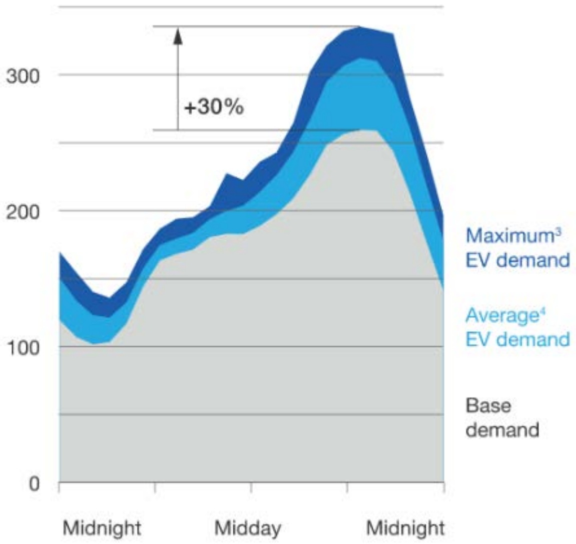

Figure 2. Peak local circuit load growth (in kW) associated with increased EV charging. *Source:* Engel et al. 2018.

Electric Vehicle Chargers and the Opportunity for Reduced Carbon Emissions

Since 1990, increased vehicle miles traveled have resulted in a 29 percent increase of carbon dioxide (CO_2) emissions in the transportation sector (EPA 2019). Because of these increases, by 2017 the transportation sector overtook the power sector and became the primary source of CO_2 in the United States (see Figure 3). To address and reduce CO_2 emissions from transportation, the sector can be electrified while moving towards energy mixes with a greater share of renewable energy sources. Many utilities are already making the transition to renewables and are retiring coal-fired generators. This positive trend is developing quickly and in 2019, renewables grew to account for 18 percent of total generation, with some months when renewables provided more power to the grid than coal (EIA 2019; EIA 2020).

Coupled with the shift towards renewable electricity sources, there are other efficiency gains from EVs. One of the benefits is from more efficient energy conversion, primarily through better motors. Vehicles with internal combustion engines are 18 to 22 percent efficient, while vehicles with electric motors are over 90 percent efficient (DOE 2020). While the overall benefits of electrification are substantial, given the variation in generation sources throughout the country, the scale of CO_2 reduction is related to the carbon mix where the EV charging is occurring. Research has confirmed that influencing the time of charge can provide environmental benefits by reducing CO_2 emissions when the grid is utilizing renewable power sources (Rieves 2020). Some studies have shown over 65 percent reductions (McLaren et al. 2016) but environmental benefits occur throughout the United States, even in areas with the majority of electricity coming from coal.

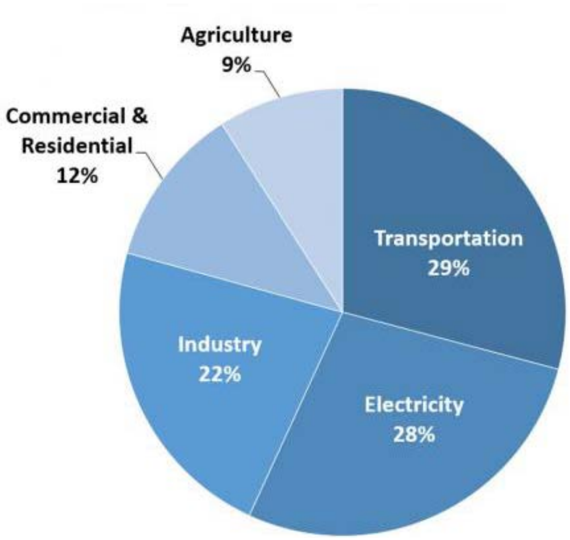

Figure 3. Total U.S. greenhouse gas emissions by economic sector in 2017. *Source*: EPA 2019.

ENERGY STAR Specification for EV Charging Stations

Given the growing role of electricity in the transportation sector, EPA evaluated the vehicle charging technology in beginning in 2015 to determine if there were efficiency opportunities. The results were mixed and showed that, while Level 1 (120 volt) and Level 2 (240 volt) AC power EV chargers were very efficient in the active charging mode, some chargers used 10 times as much power as others when in the standby mode (i.e., no vehicle or when not charging). As a result, EPA established an ENERGY STAR specification that resulted in 40 percent energy savings in standby mode. Table 1 illustrates the lifetime savings if all Level 1 and Level 2 chargers in the United States were ENERGY STAR certified. EV chargers meeting the ENERGY STAR specification will save money, reduce electricity consumption, and avoid greenhouse gas emissions.

Table 1. Savings from ENERGY STAR certified EV chargers

Unit	Amount
Dollars ($)	17,000,000
Electricity (gigawatt-hours)	62
Greenhouse gas emissions (metric tons)	125,000
Gasoline vehicles equivalent	26,000

Source: EPA 2016

In addition to energy savings, EPA sought to promote products that are capable of load management using open communications standards for products that can support utility demand response (DR) programs. DR functionality is especially important given that EV chargers, even at the residential level, represent very large electricity loads, as shown in Figure 4. The optional DR/connected criteria require that any product listed as ‘connected capable’ on the ENERGY STAR website be able to support open communication standards (including system integrators and cloud applications) and allow consumers to override a DR event. All products are tested in EPA recognized third-party laboratories.

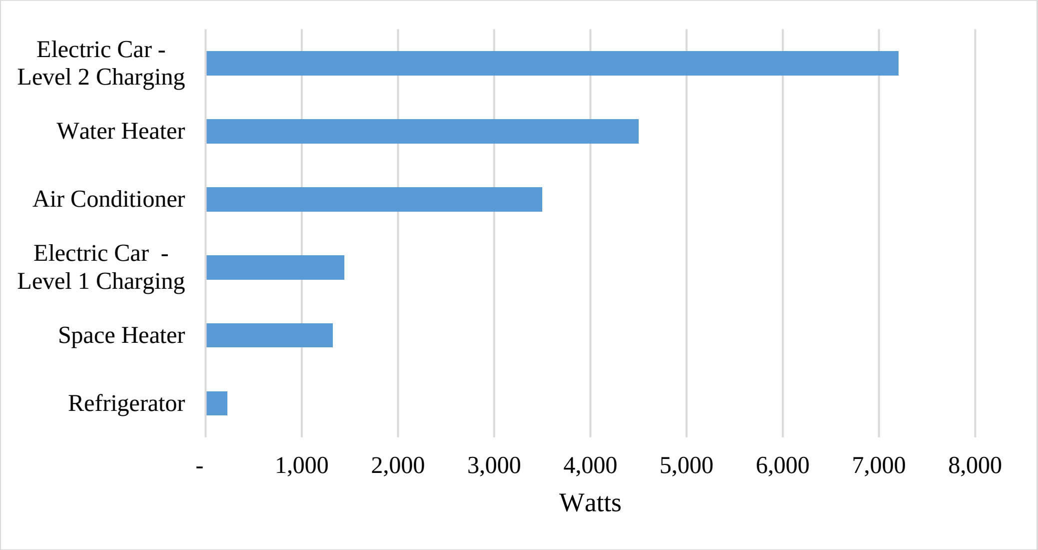

Figure 4. Power draw figures for typical household appliances. *Source*: DOE 2017, adapted by ICF.

To ensure consumer confidence, an important component of the ENERGY STAR required testing focuses on product safety. The Electric Power Research Institute conducted a study in 2019 to examine the issue of product testing and safety certification. The results showed that there were numerous Level 2 EV chargers for sale by large online retailers that were either counterfeit products, made false claims about safety certification, or simply made no safety claims at all (Halliwell 2019). In each of these cases, the products are not in compliance with the National Electrical Code and pose potential safety hazards. Any accidents resulting from the use of these products have the potential to seriously impact the EV charging industry. Accordingly, as part of the third-party certification process, all ENERGY STAR certified EV chargers must be listed by a Nationally Recognized Testing Laboratory for safety, which will help reduce the problem but not eliminate it. As of February 2020, there are still products for sale on the open market that are not safety certified.

Increased Energy Savings in Direct Current Fast Charging.

As EV battery capacities and all-electric ranges increase, so has the need for higher-powered, faster charging stations. EPA is in the process of establishing program requirements for this product category. DC charging technology has evolved significantly in recent years to provide considerably faster charging times and higher power relative to Level 2 chargers. Whereas a 30-ampere Level 2 product typically draws 7.2 kilowatts (kW) to power an EV, DC EV chargers draw up to 350 kW. DC fast chargers are also more complex and contain more functions and features, such as internal heating and cooling, and liquid cooling of the charging cable. Table 2 illustrates the potential losses from different types of EV chargers and demonstrates that DC chargers on the market have varied levels of efficiency, along with significantly higher annual losses when compared with Level 2 models. This presents an opportunity for ENERGY STAR to be an effective tool in identifying efficient models and ultimately influencing the market toward more efficient design.

Table 2. Potential losses from different types of EV chargers

Charger type	Efficiency levels	Estimated annual energy losses
AC Level 2 charger (7.2 kW)	98%	41 kWh (standby mode)
DC fast charger (50 kW)	92-97%	3.8 MWh (operation mode)
DC high power charger (350 kW)	92-97%	27 MWh (operation mode)

Source: EPA 2018.

In addition to establishing efficiency criteria for DC charging stations, EPA is updating the optional connected criteria for products that are DR-capable. These revised criteria are designed with long dwell-time applications in mind, which provide the most load flexible resources, while maintaining a focus on the use of open standards-based communication between the charging station and external applications. The updated criteria include new requirements for scheduling and remote management capabilities, as well as defining DR signals that the EV charger would need to support, such as *delay charging*. These prescriptive criteria will be useful to utilities interested in implementing programs to manage EV charging in their service territories.

Building Out Electric Vehicle Charging Infrastructure

Electric Vehicle Ready Buildings: Retrofit versus New Construction

Policymakers and planners understand the need to build out EV charging infrastructure to accommodate the increasing numbers of EVs on the road and to overcome consumer hesitations about sufficient access to charging. When developing strategies for this deployment it is important to recognize that new construction offers a very time-limited window for the best opportunity to add infrastructure. Incorporating the necessary conduit, wiring, and even EV charging equipment into the planning and construction phase can help to reduce costs compared to installations done after construction is complete.

Retrofitting typically requires parking lot trenching and adding electric service or panel upgrades (CARB 2018), which drives up the cost of the project. One study found that the average cost of an EV-ready parking space was around $900 when incorporated into initial construction, whereas a retrofit cost nearly $4,000 per parking space (City and County of San Francisco 2016). The charger installation experience for Los Angeles County (L.A. County) is another example that illustrates the high costs associated with building retrofits. According to its 2019 sustainability plan, L.A. County plans to install 5,000 EV charging stations at County facilities for public, employee, and fleet use by 2025. Most of the EV chargers will be installed at existing sites throughout the county. These installation costs can vary widely depending on the amount of site work needed. Trenching for cables and conduit is particularly expensive in addition to costs required to make sites code compliant and accessible. In some cases where these high retrofit costs are combined, L.A. County has paid $25,000 per unit for a Level 2 EV charger, for small sites that only require a couple of chargers (M. Le, general manager, Energy and Environmental Services, Los Angeles County, pers. comm., March 5, 2020).

There are additional examples from the commercial sector where the lost opportunity of making facilities EV ready at the outset is evident. In the Washington, D.C. metropolitan area, a new luxury apartment building was constructed and the limited number of EV chargers was immediately found to be inadequate for the residents' needs. As a result, the developer needed to go back and perform expensive retrofits to the site (Fogerty 2019).

Given the high retrofit costs, ensuring buildings are EV ready during construction is a recommended practice. International, state, and local standards are in place to help ensure additional EV charging build-out is done effectively. The following are examples of some of the codes and practices that are being implemented to take advantage of the best opportunity during new construction.

Examples of Policies Encouraging EV Infrastructure in New Construction

- National Model Energy Code Update. The International Energy Conservation Code (IECC) amendments approved for the 2021 IECC included requirements for EV readiness in residential and commercial buildings. More specifically, certain quantities or percentages of parking spaces will be wired for future EV charging stations.

- CALGreen Standards. California has been a leader in state-level standards. New regulations currently require 6 percent of parking spaces in new non-residential buildings to be "EV capable." CALGreen defines EV capable parking spaces as: equipped with conduit and electrical panel capacity for 40-ampere, 208/240-volt circuit(s) to support the future installation of wiring and EV charging stations.[1]

- Municipal Codes. EV-ready buildings are becoming more common across the country. Atlanta, Georgia, for example, established requirements for newly constructed residential buildings, public parking facilities, commercial and multifamily parking structures, and single-family homes.[2] In Denver, Colorado, the requirement applies to new and significantly altered single-family homes, duplexes, townhomes, multi-family properties, and commercial developments.[3]

Role of Utilities

Utilities fill a unique role in the future electrification of the U.S. transportation sector. As trusted energy providers, they have the attention of customers, they also own the electrical infrastructure, and many have a financial incentive to sell more electricity. As of June 2020, there were more than 80 approved utility filings across 45 utilities focused EV charging infrastructure, and another 32 pending filings for 23 utilities, with a total potential investment of more than $2.9 billion (Atlas Public Policy 2020). Finding an appropriate and fair role for utilities in the EV space has been on regulatory dockets for years, resulting in decisions and other actions from some utility commissions to significantly cut back on plans for the deployment of utility-owned EV infrastructure (Pyper 2015; NCUC 2020). While this debate will continue nationwide, there has been consensus in some areas that utilities should be permitted to facilitate and fund hardware, wiring, and construction investments up to, but in some cases not including the EV charger itself for workplace and public charging sites. This is referred to as a 'make

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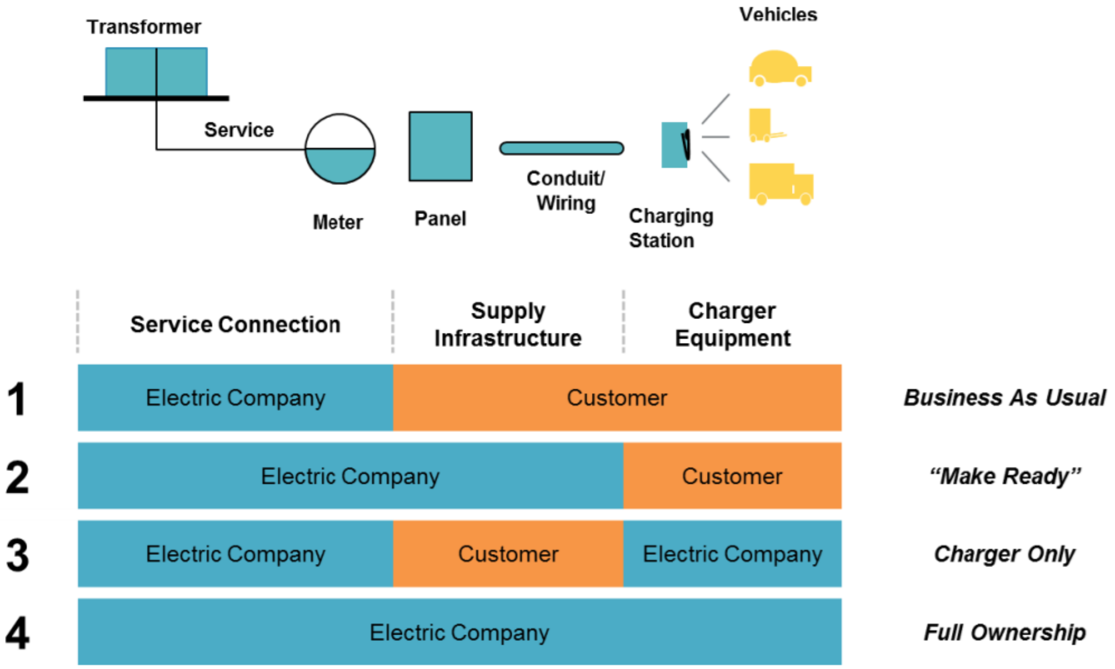
[1] California Green Building Standards Code or "CALGreen" (California Code of Regulations, Title 24, Part 11). §5.106.5.3 (enacted July 2019)

[2] Atlanta City Council Code of Ordinances, §17-0-1654

[3] 2019 Denver Building and Fire Code, §N1104.2 and §C405.10

ready' investment, and examples include the Eversource EV Charging Station program in Massachusetts and the Pacific Gas and Electric Company's EV Charge Network program in California. Figure 6 illustrates the various models of utility investment in EV charging infrastructure.



<table>
<tr><th></th><th>Service Connection</th><th>Supply Infrastructure</th><th>Charger Equipment</th><th></th></tr>
<tr><td>1</td><td>Electric Company</td><td colspan="2">Customer</td><td>Business As Usual</td></tr>
<tr><td>2</td><td colspan="2">Electric Company</td><td>Customer</td><td>“Make Ready”</td></tr>
<tr><td>3</td><td>Electric Company</td><td>Customer</td><td>Electric Company</td><td>Charger Only</td></tr>
<tr><td>4</td><td colspan="3">Electric Company</td><td>Full Ownership</td></tr>
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Figure 6. Utility EV Charging Infrastructure Investment Models. *Source*: EEI 2018.

The Role of the Smart Electric Power Alliance

Given the numerous and complex issues surrounding clean electrification and EV charging, SEPA has taken a leadership role in working with multiple stakeholders, including utilities. ENERGY STAR has partnered with SEPA to better understand utility EV programs and identify best practices, leveraging SEPA's research and member network. SEPA has become an advocate of managed charging, which focuses on the alignment between charging activity and the needs of the grid. SEPA has determined that, to effectively manage charging, utilities may apply both *passive strategies* and *active strategies*, detailed in the following section.

SEPA Framework

SEPA has developed a framework to categorize utilities based on EV program development. This framework ranges from utilities that are just starting to think about and experiment with EVs and charger programs, to sophisticated programs with active customer engagement to manage large EV fleets and thousands of EV chargers. By grouping utilities in such a way, SEPA can facilitate more effective peer-to-peer sharing and collaboration, as well as target its research and resources.

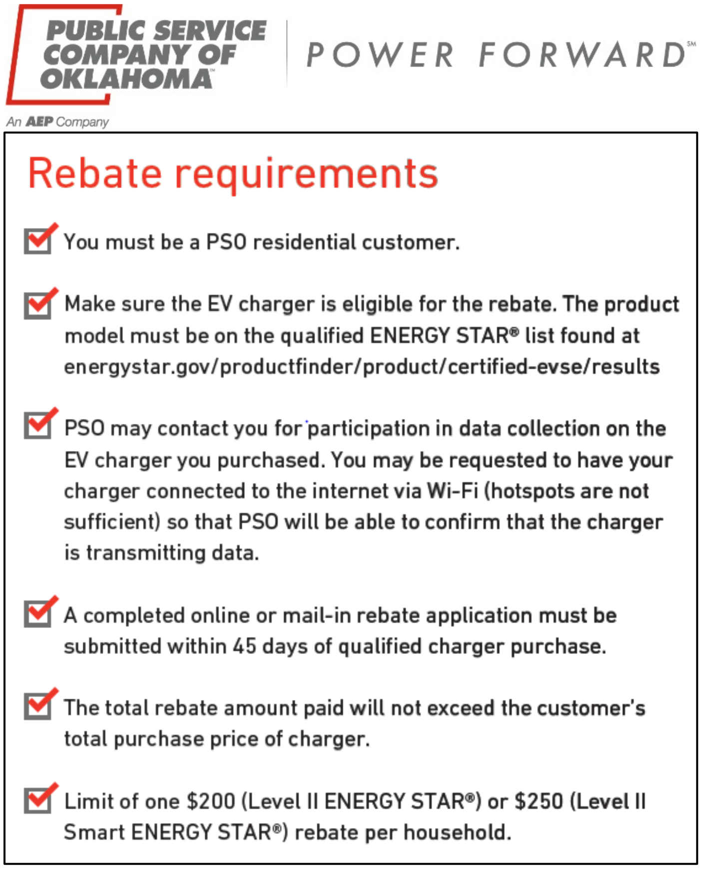
Early Stage: Customer Awareness

Utilities have emerged as a trusted advisor for consumers looking to learn about, purchase, and charge EVs. For utilities that recognize the benefits of EVs but are not in the position to implement a pilot or program, utilities can provide customers educational content of the benefits of EVs and integrate such resources onto their web platforms.

Intermediate Stage: Programs and Incentives for Electric Vehicle Chargers

A more hands-on approach that SEPA defines as the intermediate stage is for utilities to offer financial incentives for EV charging equipment and installation. These incentives could include rebates for charging equipment or reduced rates on electricity used during off-peak periods. EV rates have been shown to be effective in influencing customer behavior, when the programs are properly designed (Myers 2020).

As an example, to promote the adoption of smart EV chargers, the Public Service Company of Oklahoma (PSO) offers incentives for Level 2 chargers, with a higher rebate amount for "smart chargers," as shown in Figure 7.



PUBLIC SERVICE COMPANY OF OKLAHOMA
An AEP Company
POWER FORWARD℠

Rebate requirements

☑ You must be a PSO residential customer.

☑ Make sure the EV charger is eligible for the rebate. The product model must be on the qualified ENERGY STAR® list found at energystar.gov/productfinder/product/certified-evse/results

☑ PSO may contact you for participation in data collection on the EV charger you purchased. You may be requested to have your charger connected to the internet via Wi-Fi (hotspots are not sufficient) so that PSO will be able to confirm that the charger is transmitting data.

☑ A completed online or mail-in rebate application must be submitted within 45 days of qualified charger purchase.

☑ The total rebate amount paid will not exceed the customer's total purchase price of charger.

☑ Limit of one $200 (Level II ENERGY STAR®) or $250 (Level II Smart ENERGY STAR®) rebate per household.

Figure 7. Excerpt, PSO rebate form for ENERGY STAR certified Level 2 EV chargers. *Source*: PSO 2019.

Utilities interested in active managed charging programs can point to the ENERGY STAR specification and require customers to purchase connected-capable chargers to facilitate the use of open protocols in managed EV charging.

Late Stage: Managed Charging Programs

As of 2019, utilities across the country had completed or were running 38 managed charging pilot and demonstration projects (SEPA 2019). In Figure 8, projects have been segmented by load control via the charging device (active), load control via the vehicle (active), and behavioral load controls (passive). The figure showcases the prominence of active managed charging programs.

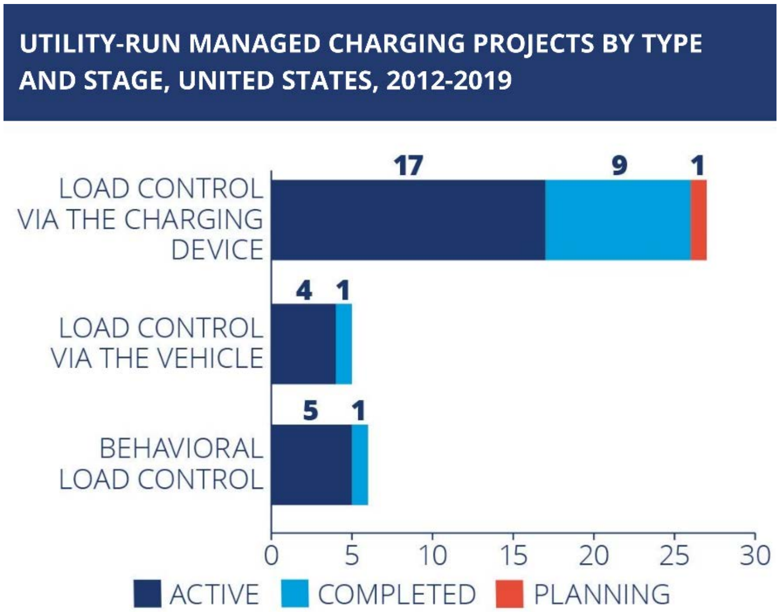


Figure 8. U.S. utility-run managed charging projects by type and stage, 2012-2019. *Source:* SEPA 2019.

Managed charging programs offer opportunities to meet grid needs and reduce costs. Other motivations for utility deployment of managed charging programs are summarized in Figure 9.

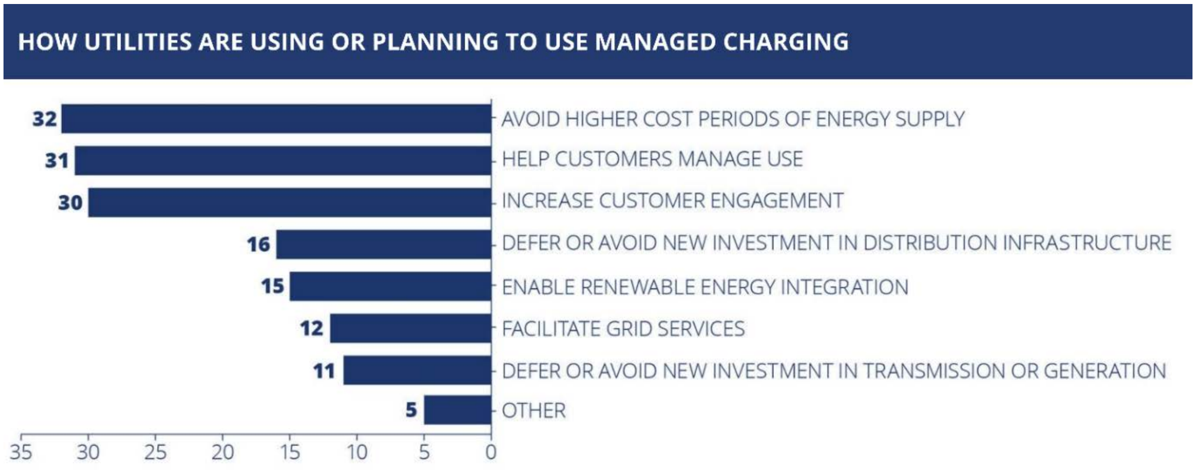


Figure 9. Utility plans for managed charging programs. *Source:* SEPA 2019.

Passive Managed Charging Programs

Behavioral load-control managed charging programs can result in cost savings for participants in addition to more favorable loads for utilities. A study found that Ameren Illinois' hourly pricing program, Power Smart Pricing, could reduce a customer's annual EV charging costs by almost 90 percent. As of February 2020, more than 13,000 customers were enrolled in the hourly pricing program, resulting in $12 million savings (Kolata, Makhija, and Zethmayr 2020). Consolidated Edison in New York has implemented a different type of behavior load control program that leverages in-vehicle tracking devices. In partnership with FleetCarma, Con Edison's SmartCharge New York program incentivizes customers to reduce charging during on-peak periods using gamification, rewarding good performance with financial incentives (FleetCarma 2020; SEPA 2019).

Active Managed Charging Programs

In active managed charging programs, the utility or aggregator working with charging networks can determine or control charging time, scale, and location to manage peaks. Active managed charging relies on a reliable two-way flow of information via a variety of communications technologies (SEPA 2019). Customer buy-in and adoption of connected or "smart" EV Chargers is important to the success of managed charging programs.

Avista Pilot Program. From 2016 to 2019, Avista Utilities conducted a pilot program to determine the impact (load profile, grid impacts, costs and benefits) of EV charging activities. A total of 439 charging ports were installed at a diverse set of locations including residential, workplace, fleet, multi-family, and DC fast charging sites (Avista 2019).

Avista designed the pilot to own, maintain, and install EV chargers and rate-base the assets for the customers while utilizing load control via the charging devices. Participating customers allowed Avista to collect charging data and run DR events. Customers had the option to be notified about upcoming DR events the day before and to opt-out of an event. To have a diverse sample, Avista recruited individuals with a variety of driving patterns (e.g., commuters vs. non-commuters) and vehicle types (e.g., long and short-range battery electric vehicles, plug-in hybrid electric vehicles) (SEPA 2019).

One of the goals of the pilot was to determine how to deploy managed charging without inconveniencing customers. One of the weaknesses identified and a lesson learned from the pilot was that the communications infrastructure from the utility, through the EV charger, to the car, was an unreliable link. In particular, wireless (Wi-Fi) connections to the home were particularly problematic, though even in cases where Wi-Fi was avoided and dedicated modems were used, the level of connection was unreliable (M. Vervair, E-mobility engineer, Avista Corporation, pers. comm., March 12, 2020). Despite this issue, overall, the program managers concluded that the pilot successfully shifted EV charging to off-peak hours without disrupting customers.

Telematics-based Programs. The future of managed charging may lean on vehicle telematics. Most vehicles sold today are considered "connected" vehicles and have built-in capabilities, such as GPS location software, which can be managed according to the local grid circuit. Many EVs can be programmed for a charging window, allowing the vehicle driver to align charging with TOU or other off-peak rates. A more sophisticated way to leverage these vehicles would be for the utility or aggregator to send price, emissions, or grid stress signals directly to the vehicle to capture the optimal value and decide when to charge the EVs based on this data. Utilities including Xcel Energy and DTE are planning or pursuing telematics-based managed charging programs in pilot stages. Given the unreliability of the current home and business Wi-Fi and standard LAN connections, as compared with the built-in communications/software systems from EVs, some utilities see telematics as a possible big step forward (M. Vervair, E-mobility engineer, Avista Corporation, pers. comm., March 12, 2020).

Conclusion

In this paper, we have shown that the pathway to successful electrification of the transportation sector has clear environmental and economic benefits, but that the transition must be carefully planned with respect to electric grid impacts. Electric utilities sit at the intersection of the issue, with both the motivation and the capacity to accelerate this trend. Examining utility programs, we have shown that best practices in program management are emerging, including the use of managed charging and communications, the use of batteries in critical areas to level loads, and the use of ENERGY STAR EV chargers, can improve grid impacts and lead to a cleaner more economical transportation future.

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