WHITE PAPER

Electric Vehicles and the Power Grid: Emergence and Convergence

Introduction

Electric vehicles (EVs) were promoted by Thomas Edison as early as 1903.[1]

Electricity is the thing. There are no whirring and grinding gears with their numerous levers to confuse. There is not that almost terrifying uncertain throb and whirr of the powerful combustion engine. There is no water circulating system to get out of order—no dangerous and evil-smelling gasoline and no noise.

Edison and Henry Ford joined forces to develop an affordable EV in 1914.[1] When that vehicle didn't come to market, Ford and Edison diverted paths: Ford to building his auto empire and Edison to becoming a force behind the making of the power grid. Thus, the automobile and the electrical power industry came of age together. Now they are converging again–in ways that will re-make both industries.

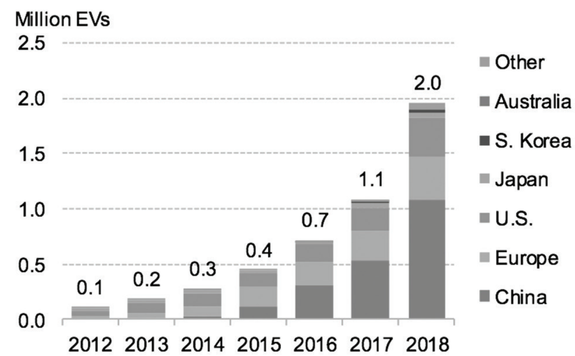
Executive summary

As EV purchase prices drop, public charging stations spread, performance improves, and automakers develop more broadly appealing models with longer ranges, EV adoption will soon hit a tipping point. As EV charging places greater demands on the power system, it also represents a large new source of demand for a U.S. utility industry that has seen flat or declining load growth for a decade.

Many utilities see EVs as a large opportunity, but they are only beginning to explore how to most effectively participate in the emerging electrification of America's transportation fleet. This paper examines what utilities are doing—and what needs to be done—to integrate EVs to facilitate what is an operational challenge, an important revenue stream, and a promising grid management resource.

Where EVs are today

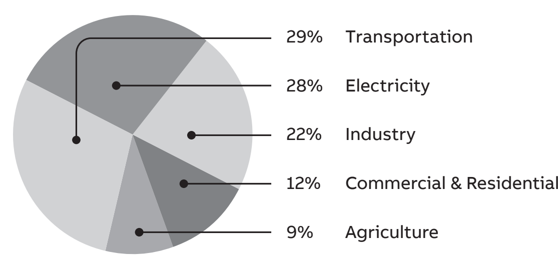
As of June 2019, over 1.3 million EVs have been sold cumulatively in the United States.[2] But what is surprising is not the volume, but the velocity by which EV sales are accelerating in the United States and globally.



—
01 Annual Global Passenger EV Sales by Region Source: Bloomberg NEF. Note: Includes highway-capable passenger vehicles. Excludes low-speed EVs, buses and other commercial vehicles. South Korean and Australian EV sales prior to 2016 have not been included. The excluded data does not have a material impact on the results.[3]

Multiple forces—environmental, societal, economic, and, significantly, the fact that consumers enjoy buying and owning these vehicles—are converging to drive adoption.

The transportation sector is the nation's largest source of climate-warming pollution (see Figure 02).[4] Greenhouse gas emissions in transportation, primarily stemming from burning fossil fuel for cars, trucks, ships, trains and planes, have increased more than any other sector.



—
02 Total U.S. greenhouse gas emissions by economic sector in 2017. Source: Environmental Protection Agency.

80% lower
Today's battery prices have dropped 80% in comparison to 2012 prices.

Many states are now establishing pathways to achieve their greenhouse gas emission reduction goals. “Whether those goals are 40% reduction by 2030 or 80% or even 100% by 2050, the bottom line is there’s growing pressure to reduce emissions,” said Gary Rackliffe, Vice President of Smart Grid North America, ABB. “The two lowest hanging fruits are coal emissions or hydrocarbons related to electricity generation and the internal combustion engine.”

Beyond, greenhouse impacts, e-mobility can also help address growing global societal needs to increase the attractiveness and livability of cities. Most of the world’s population now resides in urban areas, compounding multiple problems, including increased traffic congestion and noise, which, in turn, impacts economic and human health (stress, asthma, accidents, etc.).

But the biggest e-mobility driver could arguably be economics. Automakers have committed $300 billion[5] to develop EV models with mass-market appeal, not out of altruism, but out of a desire to gain a competitive advantage. All major manufacturers are now producing or planning to produce EVs, including sports cars, crossovers and pickup trucks.

> “The plummeting cost of batteries enticed manufacturers to explore EVs. Now, as more manufacturers invest at scale across the supply chain, costs are being driven down farther, boosting the value proposition,”

said Heather Flanagan, Marketing Manager of EV Infrastructure, ABB.

Today’s battery prices are 80% lower than in 2012,[3] with estimates dropping below $200 per kilowatt hour,[6] and automakers like General Motors eyeing potential costs dropping to as low as $70/kWh in the future.[7] Mega-factories are currently producing batteries with increasingly higher power densities that don’t take up more space or add weight as vehicles’ ranges between charges increase to well over 200 miles in affordable mass-market models.

Power electronics and battery management systems are being configured to accept charge levels up to 350 kW, which would allow a car to charge 300 miles in 15 minutes, unimaginable just a few years ago. Companies like ABB are providing direct current (DC) fast charging stations that can recharge these increasingly powerful batteries in only a few minutes, removing range anxiety barriers and concerns about long charging times.

High-power chargers are also making large fleet charging like buses, ride-sharing, delivery vans, and trucks feasible, an important advance. While the average consumer often focuses on the sticker price, fleet owners look at total cost of ownership including operating costs, maintenance and longevity. NYC Fleet, as one example, evaluated 2018 maintenance costs and found that servicing costs with its all-electric vehicle models was “dramatically” less than with gas, hybrid, or hybrid plug-in models. [8]

“We may well see the electrification of commercial transportation moving faster than the private sector because it is an easier lift—it makes good economic sense,” said Rackliffe. “However, as more of these bigger EVs and fleets reach the road, the challenges to the grid will grow more complex, even as the potential benefits grow.”

Understanding the grid impact of EVs: Three sample scenarios

Charging a class-8 tractor-trailer, will require an estimated 1-3MW charger per truck.[9] That means a fleet of 50 tractor trailers charging overnight could add up to a load of up to 150MW.

One hundred EVs recharging on 50kW DC Fast Chargers at a supermarket would add a 5MW load.

Most residential transformers serve between 10 and 50kVA of load. [10] A single EV with a 240V (Level 2) charging system consumes approximately 7kVa. Overloading is possible if more than one electric car is charging on the same local transformer, called charge clustering.

—

20 million EVs

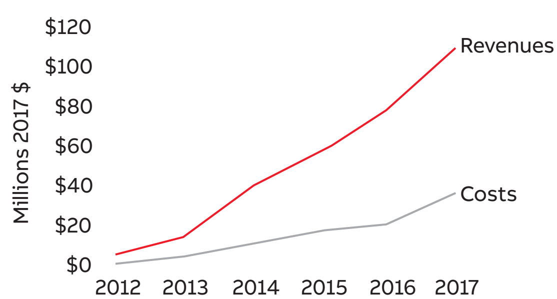
predicted to be on U.S. roads by 2030—the most significant new electric load since the rise of air conditioning in the 1950s.

Increased EV load poses both opportunities and challenges

With 20 million EVs predicted to be on U.S. roads by 2030, electrified transportation will consume the equivalent average annual energy consumption of 5.6 million to 32.3 million U.S. homes.[11] EVs are poised to introduce the most significant new electric load since the rise of air conditioning in the 1950s. For utilities who have faced a decade of flat and declining electric usage, thanks largely to efficiency advances in heating and cooling equipment and LED lighting, this is a welcome opportunity.[12]

As the EV ecosystem develops, the energy industry not only stands to profit from increased consumption of electricity, but electricity customers stand to benefit from decreased costs if more power can be delivered through existing grid infrastructure.

In fact, a recent study of EVs in California by Synapse Energy Economics found that between 2012-2017, EV customers put downward pressure on rates for Southern California Edison (SCE) and Pacific Gas and Electric's (PG&E).[13] The analysis found that customers tended to charge during off-peak hours—especially those on time-of-use (TOU) rates—when there is spare capacity on the grid. As a result, through 2017, EVs have not only imposed minimal costs on the grid, they generated new revenues that were returned to customers in the form of lower rates and bills.



—

03 PG&E's Revenues from EVs outweighed the costs[13]

Time-of-use (TOU) rates

With TOU pricing, customers are billed based on the time of day that the electricity is consumed. As one example, PG&E offers its lowest costs from 11 p.m. to 7 a.m. when demand is lowest.[14] Electricity is more expensive during peak (2-9 p.m.) and partial-peak (7 a.m.-2 p.m. and 9-11 p.m.) periods. **Rates can sometimes be more than double based on time of day.**

EVs also offer utilities new opportunities to innovate business models and cultivate new revenue streams. As one example, electric utilities can play an important role in deploying vehicle charging stations. Their form of investment in charging infrastructure can vary. Using the "make-ready" approach, the utility invests in the electrical infrastructure and upgrades necessary at the site, while a site host owns the charging station itself and may also operate or use a third-party network to operate it. In an owner–operator model, the utility not only invests in all the electrical equipment and grid upgrades, it also invests in the charging infrastructure, and takes ownership of the station itself. A hybrid approach may include a rebate the utility can offer to a third-party owner-operator to further enhance investment incentives in their service territory. Investment models will often depend on the regulatory environment for a given utility and how they approach EV charging in their territories.

—

Importantly, with planning and investment, EVs may prove to be more than a revenue source: They may be a significant grid management resource. Potential use cases explored in this paper include soaking up surplus renewable generation, managing peak demand and possibly even serving as a storage solution to provide services back to the grid.

The potential impact to power systems

EVs can, in themselves, consume more electricity than a house. And, of course, this load moves: drivers can charge at home, at work or at public charging stations.

In these early days of EV adoption, quantifying the potential risk that EVs may pose to the stability of power systems has been a source of contention. While headlines around the world—from Texas to Germany to the UK—scream warnings that EVs could pose blackout risks or even "sink the grid," industry analysts largely agree that in the shorter term, with the potential exception of some small local pockets, and unless there is a sudden and unexpected rapid upsurge in the use of EVs, the current power system should be capable of absorbing additional load.

As one test scenario, looking to Germany, whose adoption resembles the United States, ABB conducted an in-depth analysis of multiple scenarios for anticipated power needs in the years 2020, 2030 and 2040. “A gradual shift to e-mobility will not suddenly or dramatically overburden our existing power systems in the short term,” said Alexandre Oudalov, Manager Power Systems of the Future, Power Grids division, ABB.

Longer-term scenarios predict that current power systems would be put under additional pressure by reshaping the electricity load curve by the years 2030-2040. “If sufficient investments and operational adjustments fail to meet new consumption patterns, the different usage patterns associated with EVs are likely to result in spikes that could, at times, overtax current systems,” Oudalov said.

Looking to California

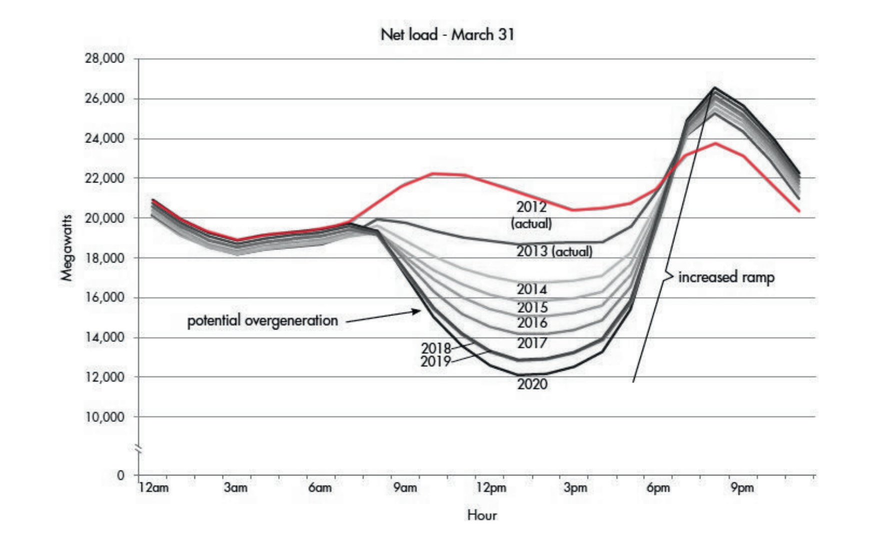
With about half of the EVs in the United States on its roads as of the close of 2018, California is the nation’s largest EV market.[15] The state’s goal of getting 1.5 million zero-emission vehicles on California roads by 2025 and 5 million zero-emission vehicles on the road by 2030 appear to be tenable based on current adoption trends and an aggressive build-out of charging infrastructure.

Research from the California Energy Commission evaluating load impacts, which include a bump in workplace charging in morning and a steep ramp up in the evening, estimate that EV charging could add 1 GW of peak demand to the grid by 2025.[16]

The National Renewable Energy Laboratory (NREL) does not anticipate that an EV market share of up to 3%—about 7.5 million EVs— would significantly impact aggregate residential power consumption.[17] However, if charging continues to happen largely at the home, even a few EVs in the same neighborhood, could make delivering that power a challenge on certain neighborhood circuits.[18] In these cases, present-day feeder systems may become over-stressed, either by transformer

EVs can perform a grid service—or a disservice—depending upon when they charge. California is not only leading the nation in EV adoption, it is also the largest solar power market.[11]

Figure 04, the California "duck curve," a load shape over a 24-hour period, highlights supply/demand timing imbalances that increase with growing deployment of solar power.[20]



How could EVs impact the curve? If customers recharge their EVs during the middle of the day, they can perform a grid service, by soaking up excess solar generation, helping utilities integrate more renewables. On the other hand, if customers recharge their EVs as the evening peak spikes, generation resources may be challenged to accommodate the ramp rate and range required to meet the peak demand.

Managed charging (also called V1G, controlled charging, intelligent charging, adaptive charging, or smart charging) uses a variety of mechanisms and technologies to ramp up or ramp down EV charging to help align charging demand with the needs of the grid.

—
04 EVs can perform a grid service—or a disservice—depending upon when they charge

overloading or under-voltage conditions. And longer term, as EV adoption becomes more mainstream, second-wave EV owners may not be as interested in energy management as early adopters. As a result, NREL reports, distribution transformers may need to be sized up and replaced more frequently, and peak demand may become an issue in some areas.[17]

In 2017, as a prominent real-life example, the Sacramento Municipal Utility District (SMUD) released a report forecasting that EV-related overloads could require replacing 17%, or 12,000, of its distribution transformers at an average cost of $7,400 each.[19]

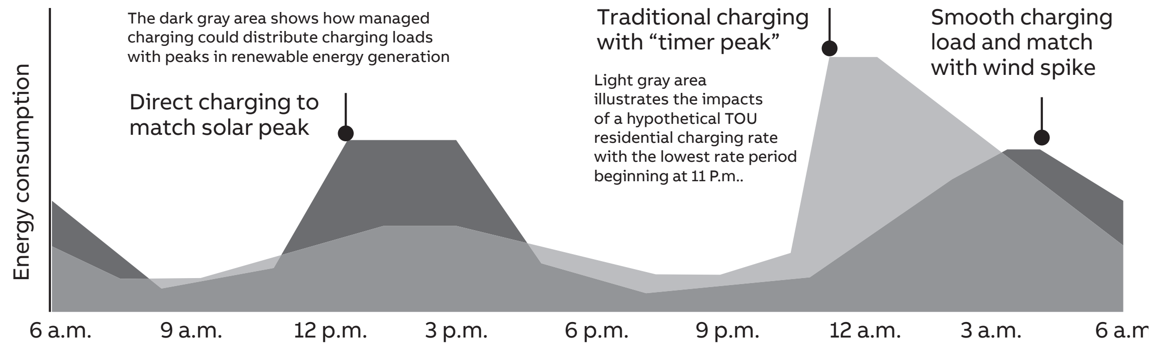
"This report was used by SMUD and other utility stakeholders as a policy example of why utilities should be allowed to rate-base their EV make-ready investments as well as promote managed charging to mitigate the effects of overloads," said Flanagan.

The evolution of the grid
Longer-term scenarios predict that many power systems would be put under additional pressure by EV charging, which may, in turn, reshape the electricity load curve, potentially creating new peaks which may overstretch capacity at the generation, transmission and distribution levels.

Today's grids are primarily managed by evaluating the load and then dispatching generation to meet demand. A core problem is that most baseload generating plants are not built to ramp up and down to handle demand spikes. Coal-fired plants and combined-cycle gas-turbine plants were designed to be operated continuously and are not flexible enough to be brought online quickly to close the supply gap at times of peak demand. While solar PV and wind generation resources can be curtailed—an undesirable outcome both economically and environmentally—they are variable resources with limited dispatchability.

To meet increases in peak demand, utilities may need to 1) add generation resources required to increase or shift generation load timing, 2) Add storage to discharge at peak, or, 3) manage charging to shift the load—or employ some combination of these three approaches.

We believe the grid of the future will lean primarily on the last approach. Instead of building out more generation, equipment and wires to meet the highest possible load, the focus will shift to better manage the load—to eliminate, or at the very least, dramatically reduce peak requirements and shape load to match available renewable generation. EVs, as a flexible load, offers multiple opportunities to distribute charging as illustrated in figure 05.[11]



05

05 Opportunities for EV managed charging to meet grid needs (illustrative) Source:BMW of North America, 2016 with edits by Smart Electric Power Alliance, 2017.

Notably, industry discussions around this shift are now evolving beyond how to manage load and moving toward a systems-level vision that considers vehicles and the grid as a part of an integrated network. SEPA put it well in its 2019 paper on managed charging:

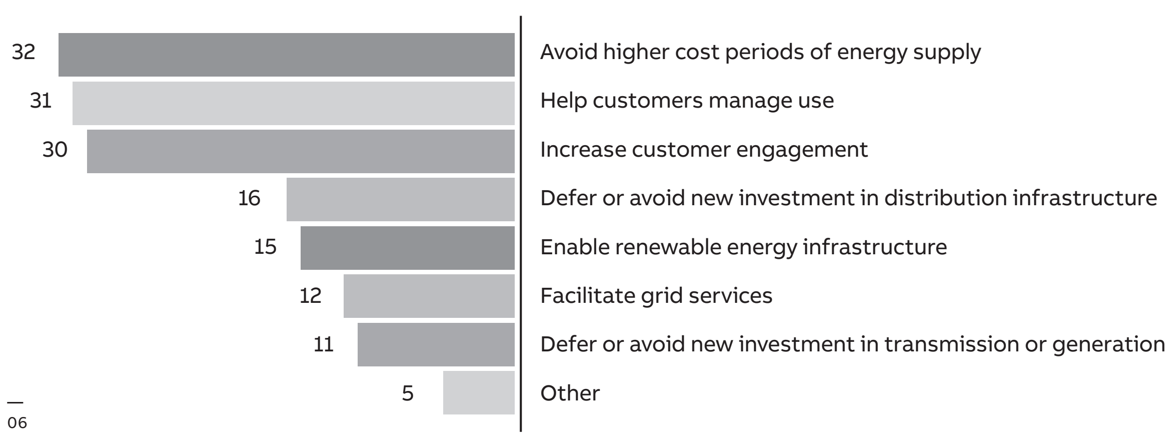
“With a growing charging load that can be flexible and intelligent, EVs are part of the larger discussion around the evolution of the grid and the future of the electric utility industry. Most industry analysts treat EVs as a way to increase load in an era of flat or declining electricity sales. However, managed EV charging can also be a useful means to better align and balance a power supply that is increasingly diverse, decentralized, renewable and intermittent with flexible demand. By integrating more renewables and avoiding dispatch of peaker plants, managed charging can reduce emissions in the transportation and utility sectors and improve grid economics.”[11]

The fundamental role of managed charging
Bearing in mind that the average American drives less than 40 miles per day in somewhat predictable patterns, there is plenty of room for charging flexibility.[21] As illustrated in a SEPA survey, utilities see a wide range of uses for managed charging.[11]

At its most basic level, passive managed charging, relies on customer behavior to affect charging patterns. For example, EV time-of-use rates provide predetermined price signals to customers to encourage EV owners to charge their vehicles during off peak times when rates are cheaper. “Every EV has a setting for starting and stopping time of charge, so this first step can easily be done by the consumer with zero extra investment,” said Flanagan. “Smart, networked chargers take this a step further, introducing a set of enhanced capabilities to optimize charging at the lowest rates.”

More than 25 U.S. utilities have already introduced or are trialing EV-specific TOU rate structures, typically incorporating a significant gap between off-peak and peak prices, to incent customers to charge off peak and to avoid charging during peaks.

Studies have demonstrated that TOU rates can influence behavior, even outside highly eco-aware areas like California. Arizona-based utility Salt River Project (SRP), as one example, worked with the Electric Power Research Institute (EPRI) on an 18-month study of the charging habits of EV drivers to understand the impact on the grid.[22] The study found that TOU price plans incented EV drivers to



06

06 How utilities are using or planning to use managed charging. Source: Smart Electic Power Alliance, 2019. N=48. Note: Utilities selected all that applied.

charge later, which SRP reported would help meet demand without needing to add power generation.

At the next level of managed charging is active managed charging, also called direct load control or smart charging, which allows a utility or third-party to remotely control vehicle charging by turning it up, down, or even off to align with the needs of the grid.

How might this work? Imagine Alice, Bob, and Carol all arrive home from work by 6p.m.. They plug-in their EVs right away, as is most convenient for them. Each EV owner has previously specified in their app that they require a full charge by morning. To avoid charging in the peak hour, the utility shifts Alice's charging to 10p.m., Bob's charging to 11p.m., and Carol's charging to 12 a.m.. In this manner, Alice, Bob, and Carol each pay off-peak prices and have a fully charged EV by the time they drive to work. The utility has thus shifted demand off-peak without creating a new peak period.

The utility also can take load off the grid as needed. Say, for example, while Alice's car is charging, another car on her street also begins charging, straining a distribution transformer. The utility's software can interrupt the process to stagger the load. In this way, managed charging can smooth unintended TOU timer peaks, potentially avoiding costly grid upgrades to distribution equipment including additional transformers/switchgear and lines/cables.

Although managed charging is in its early stages, it is more than theoretical. A SMUD report, for example, reported that managed charging reduced almost all its cost impacts of higher residential charging levels, even at loads up to 19.2kW, potentially saving significant transformer upgrades.[11] (Note: the impact to transformers may

vary based on distribution design, capacity, age, other customer loads, and the degree of clustering and overlap of EV charging.)

A variety of technologies and methodologies are emerging to enable managed charging. Between January and April 2019, SEPA surveyed 84 utilities to gauge their interest in utility-run managed charging programs.[11] Respondents indicated greater interest in direct load control via the charging infrastructure rather than through automaker telematics. See figure 07.

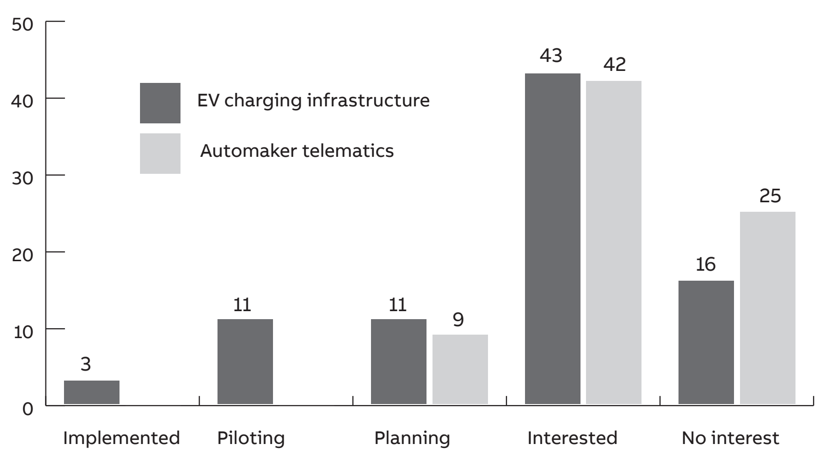
Utilities are also exploring a range of workplace partnerships and other incentives to drive mid-day charging when the electric system is coping with oversupply risks driven by solar generation. Some employers have even come to promote workplace charging as an employee benefit, for example.[23]

Smart charging is also critically important in commercial use. Charging systems for electric buses, as an example, are already capable of managing overnight charging to avoid spikes. Buses at the depot are connected by a plug or an overhead connector, and, for example, three buses on the same connection are charged successively to spread the charging process through the night. This process is optimized to leverage off-peak rates, fully utilize the charging infrastructure during the charging window to minimize demand charges, and have sufficient charging infrastructure to complete charging of the bus fleet.

Energy storage

Energy storage systems are likely to play a growing role in our power systems, particularly as pressure mounts to develop methods to store power generated by renewable sources. Energy storage systems can be charged or discharged quickly in response to increases or decreases in load, balancing supply and demand.

—
07 Utility interest in managed charging programs by technology type



—
07

EV charging infrastructure owners are already starting to deploy battery storage at charging sites to alleviate demand charges, which helps the grid. The batteries charge when rates are cheapest and then use the stored energy to supplement the grid at peak. The batteries can also smooth the site's demand to avoid spikes and higher demand charges.

Vehicle-to-grid (V2G)
Because EVs are stationary for more than 23 hours each day on average, V2G leverages their battery packs as sources of reserve energy that together act as one collective battery fleet to send power back to the grid when demand is high and charge when demand is low. More than serving to mitigate the impact of EV charging, V2G could potentially help to buffer the effects of uneven production of electricity from future renewable sources by providing voltage and frequency support to the grid, contributing to the grid's overall stability.

V2G would require a bi-directional charging interface, managed by a cloud-based software system, and connected to a mobile application. The approach could reduce the EV total cost of ownership by enabling owners to sell power from the vehicle to the grid. Once an EV has come to the end of its useful life, its batteries could also serve a secondary purpose in stationary applications to provide power storage. Moreover, the lithium-titanate batteries found in the electric bus segment can be used for bus-to-grid purposes without causing premature aging.

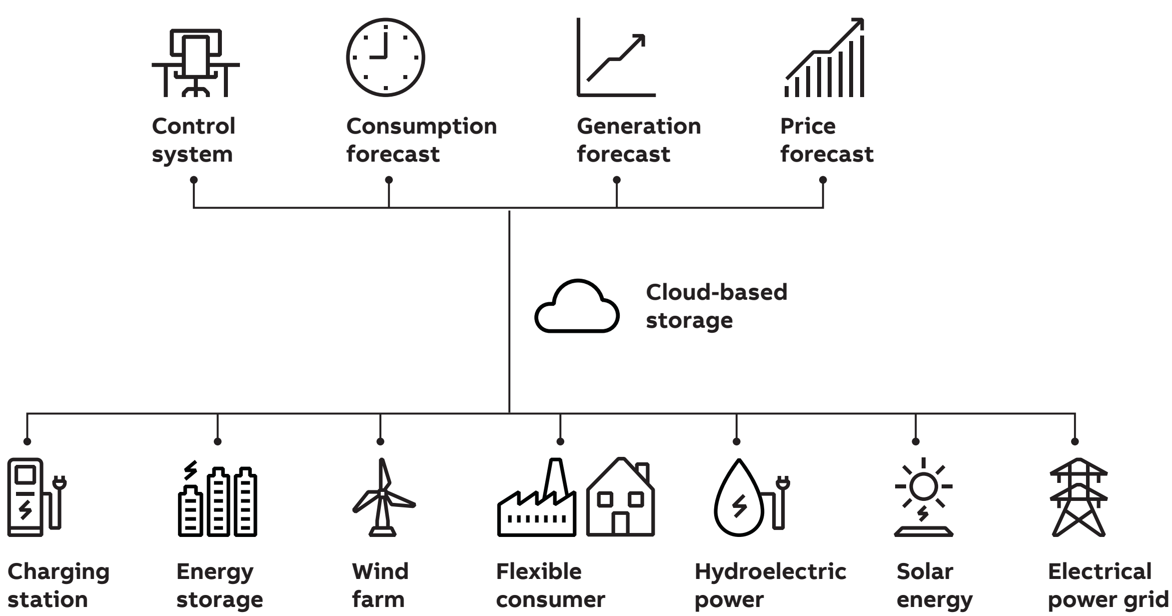
—

Though there are several V2G demonstration projects around the country—perhaps most compellingly in school buses which remained parked most of the day—the standards, commercialization and policy making are still emerging.

Virtual power plants
Yet another technique to spread out the charging of vehicles relies on the centralized management of charging stations. Here, a virtual power plant (VPP) centralizes and optimizes the operation of assets. A VPP can integrate charging stations, consumption sites, power generation sites and energy storage systems, and then optimize and prioritize consumption among assets.

We expect further technological solutions to continue to emerge. To bring the pieces of this puzzle together, the development of adequate standards will require large-scale cooperation between utilities, policymakers, technology firms, automakers, and local authorities to ensure that the challenges of mass e-mobility are addressed in a timely, effective and harmonized manner. An ongoing dialogue must continue and expand to include all key stakeholders—as early as possible—and further steps should be taken to promote innovation and investment in the field.

—
08 Using a VPP to optimizie complex operations



—
08

Conclusion

EVs are here, in part driven by environmental concerns, and in part driven by economic opportunities and keen consumer interest. EVs—in concert with the integration of renewables—are poised to re-make the power grid, offering enticing revenue streams and grid services. Solutions are now being developed to build in the flexibility as well as efficiency and cleanliness required to meet the new demand that is expected to arise from EV use.

Key takeaways include:

1

The current power system is expected to be largely capable of handling additional load over the short term. Looking ahead to 2030 and 2040, grid systems could be overtaxed by unmanaged EV charging. Approaches will need to be implemented to build in flexibility as well as efficiency. This has as much to do with the integration of renewables and distributed generation as with the new demand spikes that could arise from EV charging.

2

The grid of the future must take advantage of EV charging as a flexible, intelligent load. Managed charging holds the key to allow the grid to deliver increased electricity within the existing infrastructure, maximizing renewable generation and reducing the cost of electricity power for everyone.

3

Collaboration between all stakeholders will be essential to ensure that challenges are addressed in a timely, effective and harmonized manner, including further development of standards and the integration of innovative technological solutions.

4

All of these changes represent a substantial increase in system complexity. Yet this complexity will be implemented in conjunction with increasingly sophisticated interconnected technologies. The end result will be a highly adaptable and integrated grid that maximizes our ability to rely on renewables and emission-free mobility.

Endnotes

[1] "Ford, Edison and the Cheap EV that Almost Was," Wired. https://www.wired.com/2010/06/henry-ford-thomas-edison-ev/

[2] "Electric Drive Sales Dashboard," the Electric Drive Transportation Association. https://electricdrive.org/index.php?ht=d/sp/i/20952/pid/20952

[3] "Electric Vehicle Outlook 2019," Bloomberg NEF. https://about.bnef.com/electric-vehicle-outlook/

[4] "Source of Greenhouse Gas Emissions," EPA. https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#main-content'

[5] "Exclusive: VW, China spearhead $300 billion global drive to electrify cars," Reuters. https://www.reuters.com/article/us-autoshow-detroit-electric-exclusive/exclusive-vw-china-spearhead-300-billion-global-drive-to-electrify-cars-idUSKCN1P40G6

[6] "23 Big EV Battery Stories – #NewsBonanza," Clean Technica. https://cleantechnica.com/2018/12/29/23-big-ev-battery-stories-newsbonanza/

[7] "GM Calls For National Electric Vehicle Policy, Says EVs Should Be 25% Of All New Cars By 2030," Forbes https://www.forbes.com/sites/sebastianblanco/2018/10/26/gm-calls-for-national-electric-vehicle-policy-says-evs-should-be-25-of-all-new-cars-by-2030/#6c99969a1cf0

[8] "Reducing Maintenance Costs With Electric Vehicles," NYC DCAS. https://www1.nyc.gov/assets/dcas/downloads/pdf/fleet/NYC-Fleet-Newsletter-255-March-8-2019-Reducing-Maintenance-Costs-With-Electric-Vehicles.pdf

[9] "Daimler is working on electric truck charging rate 'up to 3MW,'" Electrek. https://electrek.co/2019/04/29/daimler-electric-truck-charging-3mw/

[10] "EV clustered charging can be problematic for electrical utilities," Fleetcarma. https://www.fleetcarma.com/ev-clustered-charging-can-problematic-electrical-utilities/

[11] "A Comprehensive Guide to Electric Vehicle Managed Charging," Smart Electric Power Alliance https://sepapower.org/resource/a-comprehensive-guide-to-electric-vehicle-managed-charging/

[12] "Annual Energy Outlook 2019," the U.S. Energy Information Administration. https://www.eia.gov/outlooks/aeo/

[13] "Electric Vehicles Are Driving Electric Rates Down," Synapse Energy. https://www.synapse-energy.com/sites/default/files/EVs-Driving-Rates-Down-8-122.pdf

[14] "Electric Vehicle (EV) Rate Plans," PG&E. https://www.pge.com/en_US/residential/rate-plans/rate-plan-options/electric-vehicle-base-plan/electric-vehicle-base-plan.page

[15] "Over 500,000 Electric Cars in California!" Clean Technica. https://cleantechnica.com/2018/12/18/over-500000-electric-cars-in-california/

[16] "CEC: California EV chargers will add 1 GW of peak demand by 2025," Utility Dive. https://www.utilitydive.com/news/cec-california-ev-chargers-will-add-1-gw-of-peak-demand-by-2025/519517/

[17] "Uncoordinated trouble? Electric vehicles can be a grid asset, but only with planning and investment," Utility Dive. https://www.utilitydive.com/news/uncoordinated-trouble-electric-vehicles-can-be-a-grid-asset-but-only-with/515787/

[18] "Impact of uncoordinated plug-in electric vehicle charging on residential power demand," Nature Energy. https://www.nature.com/articles/s41560-017-0074-z

[19] “Electric vehicles can be grid assets or liabilities. How utilities plan will decide,” Utility Dive. https://www.utilitydive.com/news/electric-vehicles-can-be-grid-assets-or-liabilities-how-utilities-plan-wil/442661/

[20] “Confronting the Duck Curve: How to Address Over-Generation of Solar Energy,” Office of Energy Efficiency & Renewable Energy. https://www.energy.gov/eere/articles/confronting-duck-curve-how-address-over-generation-solar-energy

[21] “Plug-In Electric Vehicle Resource Center: True or Not?” Drive Clean. https://www.driveclean.ca.gov/pev/Dispelling_Myths.php

[22] “Arizona Utility Studies How Electric Vehicles Impact Power Grid,” NGT News. https://ngtnews.com/arizona-utility-studies-electric-vehicles-impact-power-grid

[23] “Workplace Charging for Plug-In Electric Vehicles,” U.S. Department of Energy. https://afdc.energy.gov/fuels/electricity_charging_workplace.html

ABB Inc.
901 Main Campus Drive
Raleigh, NC 27606

abb.com/us

9AKK107046A9202