HOW ELECTRIC VEHICLES CAN SUPPORT THE GRID

By Constance Douris | *September 2018*

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EXECUTIVE SUMMARY

Many people recognize that electric vehicles benefit the environment, but fewer realize the electric grid can operate more efficiently with these cars. They are cheaper to maintain and operate than traditional cars and can flexibly respond to grid demand by charging during off-peak times. With their storage capability, electric cars can also incorporate more renewable energy sources, provide backup power during outages and export electricity to the grid.

Worldwide automakers are spending billions to create new electric vehicle models. Even oil companies such as Shell, BP and Total are investing in charging stations to benefit from this new market. However, automakers are ahead of the customer when it comes to electric vehicles because their advantages need to be better communicated to increase adoption.

States such as California and New York are adopting more distributed energy resources, including solar photovoltaic, energy storage and wind turbines, and the electric grid is becoming more decentralized as a result. These assets enable new models of energy generation and retail, including peer-to-peer electricity trading to buy and sell electricity to neighbors and friends. Thus, the grid is becoming a mix of centralized and decentralized power generation.

Utilities' business models are being challenged by distributed resources along with the declining cost of electricity, energy efficiency programs and changes to the economy. However, electric vehicles represent a new energy demand that could

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help some utilities partially make up for selling less power and keep customer rates low. Furthermore, utilities could invest in charging infrastructure to accelerate electric vehicle adoption. More of these cars on the grid would stabilize rates for all customers as the power system modernizes with smart technologies.

Assessing the impact of electric vehicles on the grid is complex and highly dependent on many variables, including where a car is located on the grid and the time of day it is charged. If too many electric vehicle owners charged simultaneously, large spikes in electricity demand could cause stress and strain on the grid, potentially affecting its stability, efficiency and operating costs. There is no need for concern because utilities have plenty of time to plan and prepare for these cars since they only represent a small portion of the market today.

For electric vehicles to be widely adopted, there must be equitable access to charging stations because not everyone has a private garage or stable access to electricity. Fast chargers that are publicly accessible could allow drivers to add about 50 to 60 miles of charge in about 30 minutes and workplace and wireless charging may be more convenient for drivers.

Worldwide efforts are being made to increase electric vehicle adoption. China currently has the highest number of electric cars on the road, surpassing the United States. However, it is critical for drivers to have backup power available to charge their electric vehicles in the event of an outage. The aftermath of Hurricane Maria in Puerto Rico demonstrates the devastating consequences that may result when electricity is unavailable for an extended period of time.

INTRODUCTION

Last year, about 200,000 electric vehicles (EVs) were sold in the U.S. out of 17 million new cars. [1] This may partially be because the cost of electric cars is decreasing and several states are offering incentives to purchase these types of vehicles. However, much work has yet to be done to increase awareness of EV advantages.

The average EV transaction price decreased by 11 percent in 2017 compared to the prior year. [2] Some affordable models coming soon or available today include the $35,000 Tesla Model 3 (220-mile range) and the $37,495 Chevrolet Bolt (238-mile range). While the up-front price tag for an EV may still appear expensive, they are cheaper to maintain and operate which saves owners money over the long term.

Bloomberg New Energy Finance noted that EVs could account for half of all new cars sold by 2040[3] and the Edison Electric Institute predicts seven million EVs will be on American roads by 2025.[4] Several major automakers, including General Motors (GM), Ford, Volkswagen and Daimler, have publicly committed to investing in additional models. Even oil companies, such as Shell, BP and Total are investing in charging infrastructure to benefit from this new market.[5]

While many people are aware of the environmental benefits of EVs, few realize these cars have the capability to make the electric grid operate more efficiently. EVs can respond to grid demand by flexibly charging during off-peak times. They can also provide backup power during outages and export electricity to the grid. This is why many states in the United States and countries around the world are incentivizing their adoption.

PROMOTING ELECTRIC VEHICLES

In coming years, automakers will unveil dozens of new EV models. Ford alone announced in January that it is investing $11 billion in EVs. Furthermore, a glance at automakers' EV investments worldwide is revealing: $19 billion in the United States, $21 billion in China and $52 billion in Germany. Clearly, these seasoned companies do not doubt the future EV market.

It has been challenging to educate drivers about the benefits of owning EVs and automakers are currently ahead of the customer.

However, it has been challenging to educate drivers about the benefits of owning EVs and automakers are currently ahead of the customer. Joe Eberhardt, President and Chief Executive Officer of Jaguar Land Rover North America, stated that automakers must "find a way to convince customers that there is a real benefit and advantage to having an electric vehicle." [6]

To motivate consumers to buy EVs, the United States provides up to a $7,500 tax credit,

ChargePoint's informative dashboard delivers real-time data to help customers get the most out of EV charging solutions. (With permission from ChargePoint)

depending on battery size. Automakers are thus incentivized to manufacture EVs as consumers pursue this credit. However, the credit is reduced after an automaker sells 200,000 EVs, including some plug-in hybrids. GM is one company that expects to reach this cap before the end of this year.[7]

Many states in the U.S. recognize the benefits of EVs and provide purchasing incentives for drivers. In California, EVs are eligible for Clean Air Vehicle decals which allow single occupants to access high occupancy lanes. Furthermore, Pacific Gas and Electric Company, Southern California Edison and San Diego Gas & Electric offer discount rates for vehicle charging during off-peak hours.

California Governor Jerry Brown signed an executive order to decrease carbon pollution from cars and trucks and boost the number of zero-emission vehicles in California. Governor Brown's new target is five million zero-emission vehicles in California by 2030.[8]

Texas has the AirCheckTexas Drive A Clean Machine program that provides up to a $3,500 rebate to replace a traditional vehicle with an EV, as long as some county, income, and vehicle condition requirements are met. Austin Energy is a utility that offers reduced rates for off-peak charging with a one-time enrollment fee.

The Drive Clean Rebate for Plug-in Electric Vehicles in New York offers up to $2,000 for EVs. There is also a charger rebate program that provides up to $5,000 for installation. Drivers with EVs can also access high occupancy lanes with a decal. Consolidated Edison offers a time-of-use rate plan for EV charging and Cleanview Energy offers a $75 rebate for a new ChargePoint residential charger.

In Florida, Jacksonville Electric Authority offers up to $1,000 after purchasing or leasing an EV. Drivers of EVs can access high occupancy vehicle lanes with a decal and the car does not have to be tested for emissions. The Orlando Utilities Commission offers up to $200 per charging station to businesses that install them.

The Trump Administration has expressed interest in softening the 2022-2025 federal fuel efficiency standards which may create some risk for the EV industry. However, California

and nearly a dozen other states could still enforce existing emissions rules even if the administration is successful. According to California Assembly member Phil Ting, who introduced a bill this year to ban gas powered cars by 2040:

> *With cars, California's influence extends far beyond state lines. The largest car-buying market in the United States, California, has historically set air quality standards that surpass the Environmental Protection Agency's. The state's regulations also have a magnifying power, since more than a dozen states have adopted California's rules as their own. Those rules are poised to remain in place regardless of any policy changes in Washington.*[9]

UTILITIES CAN HELP ELECTRIC VEHICLE ADOPTION

As the grid transforms to include decentralized resources, customers will be able to produce their own electricity and even buy and sell it to neighbors and friends. Utilities could help accelerate EV adoption by managing the planning, integration and operation of charging infrastructure.[10]

More EVs on the grid would decrease and stabilize rates as other factors contribute to increased costs, such as investing in a smarter grid. In addition, if EVs are enabled with controlled "smart" charging they can deliver additional benefits for utilities by providing other services such backup power and demand response.

California initially banned utilities from owning and operating EV charging infrastructure, fearing it would stifle private competition and make electric customers subsidize infrastructure used by a minority of the population.[11] However, the ban was lifted in 2015 after California realized that EV chargers are necessary to meet its electric transportation and environmental goals. The state also understood that electric companies could help accelerate the necessary infrastructure.

California's three large investor-owned utilities, Southern California Edison, Pacific Gas and Electric Company, and San Diego Gas & Electric, have proposed making significant investments to advance EV infrastructure.[12] In May of this year alone, the California Public Utilities Commission authorized four programs with a collective budget of $738 million.[13]

More EVs on the grid would decrease and stabilize rates for all customers.

Southern California Edison plans to raise $570 million for EV charging stations and other electric transportation services. The company will develop charging stations for electric buses and trucks and implement rate incentives to encourage EV owners to charge during off-peak hours. The utility also has an approved program to deploy 1,500 chargers at workplaces and multifamily houses.

Pacific Gas and Electric Company is implementing a $130 million hybrid ownership program and will deploy 7,500 EV charging stations over three years.[14] The utility will install charging stations at customer sites in underserved markets, such as apartment complexes and workplaces, and at locations in disadvantaged communities. The company will pay for and build the electrical infrastructure from the power line to the charging station and offset a portion of the charging costs for all participating customers, depending on site locations.

San Diego Gas & Electric is implementing a $45 million utility-owned charger pilot program to install 3,500 charging stations at 350 businesses, apartment complexes and condominium communities in its territory. More EV charging stations in convenient locations will help balance demand on the grid and increase convenience for drivers.

WHO SHOULD OWN CHARGING INFRASTRUCTURE?

There is debate as to whether utilities should own and operate EV charging infrastructure. Some states are reluctant to permit utilities to pay for EV charging infrastructure with ratepayer dollars because electricity customers would have to fund a service not used by everyone.[15] However, EVs should be considered a public good because they provide many benefits to the grid.

Massachusetts allows utilities to build the underground infrastructure for charging stations but leaves the above-ground installation to private companies, which is an arrangement called a "make ready." National Grid, which provides electricity in New York, Rhode Island and Massachusetts, is proposing to spend $24 million on 140 sites. This approach may relieve private companies of the fear that utilities will squeeze them out of the market.[16]

Since EVs can provide many benefits to the grid and stabilize rates, they should be considered a public good that benefit all.

In Texas, only utilities are allowed to own and operate EV charging stations that are purchased from private companies.[17] Since electricity is being sold via these chargers, only utilities are allowed to own and operate them because they are also required to demonstrate that they have "the financial and technical resources to provide continuous and reliable service to customers." Utilities have been actively installing charging stations in the state, including in urban areas.

Ameren, a power company based in Missouri, submitted a request to earn a return on a charging network which was rejected by the Missouri Public Service Commission.[18] Because the board found that installing and operating EV charging stations is different

from operating an electric utility, utilities cannot charge customers for the costs of charging infrastructure and must operate in the marketplace.

Kansas City Power & Light submitted a similar request for more than a thousand charging stations. The Kansas Corporation Commission denied the request, preferring to let "the private sector invest in the [EV] market, rather than have ratepayers finance the speculative venture."

Kentucky is an example of a state that has implemented a solution to allow utilities to invest in charging infrastructure and only charge customers that use the service. Louisville Gas & Electric and Kentucky Utilities Company charge drivers an hourly rate under $3 per hour to use ChargePoint stations, but exact fees and taxes vary on location. Ratepayers who do not utilize charging stations will not pay.

AVAILABLE CHARGING FOR ALL

To ensure equitable access to EV charging for residents of all housing types, it is important to accommodate "Garage Orphans." These are residents without off-street parking and people that do not have reliable access to electricity.

Workplace charging would be convenient for EV owners without a garage or stable access to electricity. While drivers will be able to charge their EVs at work, other challenges may arise, such as ensuring the availability of redundant charging access points and managing the complexity of charging multiple cars in a single day.

EV infrastructure must continue to expand so that drivers travelling long distances can conveniently charge their vehicle. As charging stations become more plentiful, drivers will feel more comfortable travelling far knowing they can charge their EV along the way.

Fast charging could save drivers time because it can add 50 or 60 miles of charge to an EV in under 30 minutes. However, to make this type of charging competitive, it must cost less than gasoline. A rate design that supports effective fast charging business models is needed to avoid high fees that may affect infrastructure expansion and utilization.

EVs must be equipped with a vehicle compatible inlet for fast charging. SAE International, an American organization that develops standards, is creating the Combined Charging Standard to support fast charging. Automakers support this guideline and announced the launch of a 400-station fast charging network that adheres to this standard across multiple European countries by 2020. It is supported by the BMW Group, Daimler, Ford, the Volkswagen Group and Shell.

Wireless charging operates by having an EV parked over a base pad where it must remain stationary to charge.[19] Plugless Power, a family of EV supply equipment manufactured by Evatran, offers a wireless solution for many EVs on the road today. The Department of Energy's Vehicle Technologies Office is supporting a project with the Oak Ridge National

The T3 Brightfield® grid-connected Solar Driven® charging station has 18.2 kilowatts of solar-generating capacity. (With permission from Brightfield)

Laboratory and industry to develop a wireless EV charging system to fully charge a car in an hour or two.[20] Nissan envisions roads that wirelessly charge vehicles in motion as part of the future smart city.[21]

In California and Hawaii, residents of multi-family dwellings have the right to install EV charging stations. However, residents must pay for them, take out insurance policies for property damage and compensate landlords or homeowner associations for harm or loss. California law also requires housing construction with four or more off-street parking spaces to have at least one EV charging station installed for every four parking spots.

One current hot topic is how blockchain, a decentralized distributed ledger that records online transactions, can support EV charging. This technology would allow EV drivers to share available charging stations and make money through a peer-to-peer network. Details to efficiently utilize blockchain for charging EVs are still being defined. Blockchain may even permit customers to select which fuel sources, such as natural gas, nuclear, or solar, charge their EVs.

ELECTRIC GRID IMPACTS

An EV could consume as much electricity in a single charge as an average refrigerator does in a month and a half; in some cases, adding an electric car on the grid is equivalent to adding three houses.[22] While it is important to be aware of how this new electricity demand will impact the electric system, EVs represent a small portion of the market today and utilities have plenty of time to prepare for this new load.

The effects of charging an EV are dependent on where it is located on the grid and the time of day it is charged. If many EV owners charged simultaneously, large spikes in electricity demand could cause stress and strain on the grid and affect stability, efficiency and operating costs because the local distribution grid was not built to handle large spikes in power demand.

For instance, if drivers charge multiple EVs with the same transformer, known as clustering, power quality could be degraded because utility equipment could prematurely fail. The grid could potentially be overloaded as a result and cause damage or a power outage. The Sacramento Municipality Utility District found that transformers' loss-of-life factor is increased by up to 10,000 times with a higher EV penetration rate.

To date, only a small fraction of EVs have resulted in distribution system upgrades. Utilities spend about $5 billion annually to maintain the distribution system. Of that amount, only about $610,000 was for upgrades to accommodate EVs.[23] This means EVs have yet to create costly cascading problems to the grid. However, as more EVs are adopted by consumers, more upgrades to the grid will likely be needed and utilities have plenty of time to prepare.

In addition, various utilities aim to use distributed resources, such as renewable energy, storage and demand response, to partially control charging impacts of EVs.[24] Utilities can send Wi-Fi communication signals to these assets, including EVs and chargers, to influence when drivers charge their cars based on grid usage or cost.

At this time, many utilities have no way of knowing when a transformer is overloaded.[25] Some utilities in California and Texas are working on receiving notifications when a customer purchases an EV in their service territory so they can plan ahead and avoid long-term degradation of electricity reliability. Other states should also create systems to receive notifications to plan for the appropriate infrastructure and support EV adoption.

Out of the $5 billion utilities annually spend to maintain the distribution system, about $610,000 was for upgrades to accommodate EVs

Rate structures are another mechanism for utilities to manage the EV load. Hawaiian Electric recently transitioned its public EV chargers to time-of-use rates. This method accounts for *when* and *how much* electricity is used and provides customers with pricing options based on low or high demand.[26]

Minnesota is the first state to require investor-owned utilities to offer separately metered time-of-use rates for residential customers that drive EVs. Xcel Energy's off-peak rate is seven cents per kilowatt hour compared to 21 cents during the on-peak period, with both rates including fuel costs.[27] Customers have the choice of paying this rate for all of their home electricity needs or installing a second meter solely for EV charging. Xcel Energy is exploring ways to reduce the metering cost for customers that select to meter EV charging separately from their home.

Pacific Gas and Electric Company, San Diego Gas & Electric and Southern California Edison are offering time-of-use rates to customers.[28] Other states planning to do the same include Arizona, Rhode Island and Minnesota.

The Salt River Project, a utility in Arizona, has about 4,400 EV drivers in its territory that account for one megawatt of demand during peak usage — equal to the amount of energy needed to power around 1,000 homes.[29] The company recently examined 100 EV drivers' charging habits by using FleetCarma data that included time, duration and location and found that time-of-use rates motivated drivers to charge EVs during off-peak times.[30]

Demand charges can be a challenge for companies that own and operate direct current fast chargers. These charges are based on customers' highest amount of electricity use at a given point in time, usually per month. A single EV charger that delivers a small

amount of electricity to a customer for thirty minutes once in a month could cause a company to pay a high demand charge based on its highest point of usage. It is possible for one charger to get hit with a high charge even if it is only used once with no regard to whether the grid was experiencing a high demand at that time.

In addition, the California Public Utility Commission's Energy Division has warned that demand charges should be used sparingly since they do not account for different electricity load types. This pricing structure was originally created so utilities could charge commercial companies for large amounts of electricity that may require the activation of expensive "peaker" plants and pay for larger infrastructure.

Dynamic pricing, which provides real-time electricity pricing, is another way to refine charging signals on the grid. The Citizens Utility Board and Environmental Defense Fund recently found that almost all customers in Commonwealth Edison's Illinois territory would have saved money with this rate design without changing their behavior.[31] However, Advanced Meter Infrastructure would be needed to measure demand in small time increments and bill customers. Dynamic pricing will likely not be widely adopted due to its complexity and additional cost.[32]

MANAGED CHARGING

Managed charging, also known as smart charging, allows a utility or third party to charge an EV when it is best for the grid, much like traditional demand response programs. Several pilot programs are underway to experiment with this strategy.

BMW and Pacific Gas and Electric Company are financially incentivizing customers to delay EV charging in response to demand on the grid with a phone application. This prevents over-exertion of the grid and ensures cars are ready for their next scheduled trip.[33]

San Diego Gas & Electric is incentivizing EV drivers to charge when the prices and demand are low with special rates. Drivers are informed of prices for electricity a day before via a phone application. These differing rates offer an opportunity to minimize peak demand charging while maximizing the use of renewable energy and other infrastructure.[34]

Southern California Edison and Pepco offer three pricing options for workplace managed charging. The highest rate provides drivers with uninterrupted charging. The middle rate charges the car at a slower speed and switches to a slower mode during peak demand. The third and lowest choice completely restricts charging vehicles during high demand.

SUPPORTING THE ELECTRIC GRID

EV batteries can regulate fluctuations caused by disparities in electricity generation and demand. These batteries have the potential to balance power flows by providing electricity when demand exceeds supply or absorb excess power when it surpasses demand. Less electricity is wasted and wear and tear on existing infrastructure is diminished. Thus, these vehicles are a public good because the community benefits from the support they provide the power system.

Since utilities must guarantee continuity of the electricity supply, they spend a lot of money on infrastructure and maintenance. Improvements to the electric system, including transformers or modernizing distribution lines with heavier wire, are expensive. One transformer alone can cost millions of dollars, depending on the size and manufacturer.[35] Thus, EV batteries could reduce utilities' infrastructure upgrade investments.

Maintaining voltage level on the grid is one of the most critical challenges for operators. Many major outages are usually partially attributed to problems with transmitting volatile power to load centers.

Transmission lines carry high voltage electricity so less is lost in transit by dissipating as heat. Because power generators produce low voltage electricity, transformers are needed to transfer low voltages to high voltages on transmission line and vice versa to deliver electricity to customers. Since EV batteries are already located within load centers where electricity is needed, they can provide power without the need to alter voltages because it is not travelling far.

Since EVs store energy in their batteries, they can incorporate more renewable energy on the grid. Energy absorbed by EV batteries can be used to operate the vehicle or sold back to the grid to help meet supply and demand. Vehicle-to-grid (V2G) technology provides EVs with the capability to discharge electricity onto the grid.

Because electric vehicles can store energy in their batteries, they can incorporate more renewable energy on the grid.

NUVVEgives is an aggregation platform that enables an EV battery to store and sell unused energy back to the grid. It is a cloud-based application that ensures a vehicle has sufficient charge for its next trip before determining how much excess capacity is available to sell. Nuvve's charging station receives instructions from the aggregation platform via communication software which then allows NUVVEgives to access a battery and determine whether to charge or discharge electricity.

V2G can improve the power system's resiliency and reliability and make customers money. At Los Angeles Air Force Base, a two-year V2G study was recently completed

with Southern California Edison and the California Independent System Operator (CAISO) wholesale electricity market. The demonstration comprised 32 electric and hybrid cars, trucks and vans that provided frequency regulation, which is the constant adjustment of power to maintain grid frequency and ensure stability, to the CAISO market. This service allowed the military base to earn money and pay for energy and new vehicle costs while enhancing grid reliability.

REDUCING THE COST OF BUSINESS

According to the Department of Energy, charging an electric car costs about half as much as fueling a gasoline-powered car. The U.S. average per gallon of gasoline is $2.50 while it would cost $1.10 per eGallon to charge an electric car.[36] As a result, electric cars, buses and trucks save money on fuel and maintenance.

Currently, the United Parcel Service (UPS) operates more than 770 electric or hybrid vehicles and more than 8,500 alternative fuel and advanced technology trucks worldwide. By 2020, UPS aims that one in four of its vehicles to be electric, hybrid or alternative-fuel. By 2022, 1,500 UPS trucks will operate on electricity, which is 66 percent of the fleet.[37]

In addition, a recent public-private partnership between UPS and the New York State Energy Research and Development Authority to convert vehicles from diesel to

By 2022, 1,500 UPS trucks will operate on electricity, which is 66 percent of the fleet. (With permission from the United Parcel Service)

electric was announced. This development supports New York Governor Andrew Cuomo's goal to reduce emissions by 40 percent in 20 years.[38]

Twelve large cities, including Los Angeles, Mexico City and Seattle, recently pledged to incorporate all-electric buses in public transportation fleets beginning in 2025.[39] BAE Systems is an international company that provides six different types of over 8,000 hybrid and electric buses in North America and Europe. Each model produces zero or near-zero emissions, including the nearly 2,000 Series-E hybrid-electric buses operating today.[40]

Other companies that are incorporating EVs include Frito-Lay, FedEx and Coca-Cola. Frito-Lay operates more than 250 EVs worldwide. FedEx introduced Nissan e-NV200 vehicles for pickup and deliveries in the United Kingdom earlier this year.[41] Coca-Cola introduced hybrid electric delivery trucks in New Orleans in 2009.[42]

Tesla plans to begin production of its new electric heavy-duty truck in 2019.[43] J.B. Hunt Transport Services and Meijer Inc. are two customers interested in buying them. In addition, Volkswagen committed $1.7 billion to develop the required technology for electrification of trucks and buses by 2022.[44] The company is focused on shrinking the size and increasing the efficiency of batteries to make electric trucks and buses more appealing.

Electric cars, buses and trucks save money on fuel and maintenance.

Cost-effective fleet management options will become even more critical as the automotive industry transitions to a ride-sharing future.[45] Variables that will play a significant role in implementation include the amount of time to charge a vehicle and the cost of electricity when it is charging. Uber is helping drivers purchase or lease EVs and is incentivizing drivers to educate riders about these new cars to increase awareness and bring more of them on the road.[46]

Lyft will provide at least one billion rides per year using autonomous vehicles (AVs) by 2025, all powered by 100 percent renewable energy.[47] AVs are likely to be electric because they are cheaper and easier to maintain than traditional automobiles and EVs are also simpler for computers to drive. Trips would become even more affordable since drivers would not be needed.

GM believes that all AVs must be electric and is linking its autonomous driving effort to EVs to compete with Tesla.[48] GM's goal is to offer an electric and autonomous ridesharing service, similar to the Tesla Network announced last year, and bring the cost of travel per mile to under a dollar.[49]

More than 8,000 BAE Systems hybrid-electric propulsion systems propel city buses around the globe. (With permission from BAE Systems)

BACKUP CHARGING OPTIONS

The aftermath of Hurricane Maria in Puerto Rico demonstrates the devastating potential consequences that may result from electricity unavailability for an extended period of time.[50] As EVs become more popular, how would a driver charge a vehicle when a power outage occurs? States and localities need to plan for backup charging infrastructure so that EVs are able to operate when power is unavailable.

When the main grid is not operating, microgrids could provide power and boost resiliency. A microgrid is a group of interconnected loads and distributed energy resources that connects and disconnects from the grid and has the ability to "island" or disconnect from the main power system. Smaller communities with distributed resources such as solar, wind and storage would reduce the strain on the power grid.[51]

Microgrids also boost reliability when charging EVs in a neighborhood or workplace. They can be placed near a specific location, such as a building, hospital, military base, university or commercial data center, to provide power during an outage using solar and other technologies.

During Hurricane Sandy in 2012, microgrids provided power to key sites. New York University's microgrid was able to disconnect from the main grid and provide electricity to the campus.[52] When power was unavailable at Princeton University, its microgrid powered its campus for three days. ChargePoint worked with Green Charge Networks in the past to pilot EV charging infrastructure applications with energy storage for backup.[53]

Last year, the city of Berkeley began designing a microgrid with solar and energy storage to power buildings and EV chargers with a $1.5 million grant from the California Energy Commission.[54] In addition, the University of California, San Diego is testing how EVs and microgrids work with 70 EV charging stations.[55] The university will use the car batteries to regulate grid frequency while compensating drivers for their use.

Schneider Electric unveiled a microgrid system with 16 spots for EV charging stations at its Boston ONE Campus.[56] The microgrid has a 400-kilowatt photovoltaic system built and operated by REC Solar. However, microgrids make some utilities concerned about safety issues related to keeping areas of the grid powered while other areas experience outage.[57]

Another way to provide backup infrastructure for charging EVs when power becomes unavailable is by deploying energy sources disconnected from the grid, such as Envision Solar International's EV ARC™ which utilizes solar energy and storage to charge EVs. New

Envision Solar's EV ARC™ operates on or off the grid with solar power and energy storage. (With permission from Envision Solar)

York City purchased $3.8 million EV ARCs that will deliver EV charging to the city's fleet.[58]

EV ARC™ units weigh about 10,000 pounds each and sit above ground, avoiding costly and timely digging, installation and permitting. One EV ARC™ takes about four minutes to set up and can easily be moved to different locations with the ARC MOBILITY™ trailer, making these units excellent temporary or permanent solutions. Because EV ARC™ units are decentralized, it is harder for a single weather event or terrorist attack to destroy them. Costs for electricity are also avoided since drivers are able to drive free on sunshine.

After the March 2011 earthquake and tsunami in Japan, Mitsubishi Motors sought to provide electricity from its i-MiEV electric cars to power homes. As a result, the MiEV Power Box was created.[59] This box can be placed in the car's trunk and ensure electricity is available at any time. It is about the size of two shoe boxes and weighs almost 25 pounds.

The Power Box can also operate with Nichicon's EV Power Station to provide electricity to an entire house. The station hooks up to a home's electrical system and is the size of a mini refrigerator. In addition, EV batteries could monitor power quality in the home and discharge electricity to prevent disturbances.

LEARNING FROM OTHER COUNTRIES

Many countries have realized the benefits of EVs and have made some noteworthy accomplishments. A better understanding of international efforts may encourage more U.S. states to pursue the adoption of EVs for a more efficient grid.

China currently has the highest number of EVs on the road, even though it taxes imported cars 10 times more than the U.S.[60] Chinese consumers have about 75 different EV models to choose from, which is more than any other country. Around 25 new EV car models were introduced in the country in 2016 alone.

Beginning in 2019, China requires electric cars to make up at least 10 percent of each automaker's output.

Last year, China's government issued new rules that require automotive companies to sell more alternative-energy cars in the country. Beginning in 2019, China requires electric cars to account for at least 10 percent of each automaker's output. The minimum percentage increases to 12 percent in 2020. The new quota system allows the auto industry to take on more of the financial burden for electric cars and reduces the Chinese treasury's involvement which has paid for research grants and subsidies for EV developers and buyers.[61]

Worldwide automakers are speeding up their efforts to develop EVs and meet demand in China. French carmaker Renault plans to double sales outside of Europe, especially in

China, to boost its revenues to 70 billion euros by 2022.[62] Volvo announced plans to make electric cars in China for global sale starting in 2019 and even Tesla is considering opening a factory in China.[63]

Beijing has made it a priority to create favorable conditions for EV stakeholders. In several of its major cities, including Beijing and Shanghai, EVs are exempt from license-plate lotteries and high registration fees that apply to cars with internal combustion engines.

The number and locations of charging stations are critical for customers to feel comfortable driving EVs. Currently, China has about 150,000 public charging stations while the U.S. has about 16,000.[64] Beijing provides subsidies for private companies to build stations and plans to have a nationwide infrastructure network large enough to support five million EVs by 2020.

By 2035, the Netherlands plans to phase out all internal combustion engines. In addition, EVs are exempt from purchase and ownership taxes and company car tax for EVs is four percent compared to 22 percent for other vehicles. Almost half of Dutch drivers consistently charge while at work.

Today, Norway has about 2.5 million EVs, which is almost a quarter of total EVs worldwide. However, Norway began promoting EVs and the government began offering incentives to increase EV sales in 1989. In the mid-1990s, Norway cut the annual registration tax and exempted all drivers of electric cars from paying for toll roads.

EV owners in Norway are exempt from a 25% tax on the purchase of an EV and do not have to pay import taxes. Toll roads and ferry fees are waived, drivers pay a low annual road tax and there is free municipal parking. EVs in Norway also can access buses and high occupancy vehicle lanes, drivers get a 50% reduced company car tax and there is a 25% exemption tax on leasing.[65]

CONCLUSION

Electric vehicles improve air quality and have the potential to enhance grid resiliency and reliability. Their batteries can help balance supply and demand on the grid by reducing expensive infrastructure investments for utilities and regulating fluctuations caused by disparities in electricity generation. Thus, these vehicles are a public good because the community benefits from the support they provide the power system.

Because electric vehicles store energy in their batteries, they can incorporate more renewable energy on the grid. Energy absorbed by electric vehicles batteries can be used to operate the car or eventually sold back to the grid to help with supply and demand. Vehicle-to-grid technology provides electric cars with the capability to discharge electricity onto the grid.

Utilities could help accelerate EV adoption by managing the planning, integration and operation of charging infrastructure.[66] More EVs on the grid would decrease rates as other factors contribute to increased costs, such as investing in a smarter grid. In addition, if EVs are enabled with controlled "smart" charging they can deliver additional benefits for utilities by providing other services such backup power and demand response.

To ensure equitable access to EV charging for drivers of all housing types, it is important to accommodate residents without off-street parking and people that do not have reliable access to electricity. Workplace charging would also be convenient for EV owners without a garage or stable access to electricity. Electric vehicle infrastructure must continue to expand so that drivers travelling long distances can conveniently charge their vehicle. As charging stations become more plentiful, drivers will feel more comfortable travelling far knowing they can easily charge their car along the way.

Since electric vehicles are cheaper to operate and maintain and charging this type of car costs about half as much as fueling a gasoline-powered car, businesses such as the United Parcel Service, Frito-Lay, FedEx and Coca-Cola are adopting them. It is critical for automakers to communicate electric vehicle advantages to increase adoption and to motivate power companies to invest in charging infrastructure.

As electric vehicles become more prevalent in society, we must ensure backup power is available to charge these cars during an outage. Considering the devastating consequences that could result from the lack of electricity access for an extended time, backup power initiatives should be implemented to keep electric vehicles operational.

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