Powering Our Electric Vehicle Future

BY ALAN S. BROWN

Electrical vehicles (EVs) could surpass half of all new car sales by 2026. The grid has more than enough power to keep them charged — if it can solve its distribution problem.

There are many reasons not to buy an electric vehicle. EVs are often more expensive than internal combustion engine vehicle (ICEV) equivalents. They have short—often, much shorter—driving ranges and may take 12 or more hours to recharge fully. Some people may have to rewire their homes to charge them, while others who live in apartments and condominiums may have no access to chargers. No wonder global consultant Accenture found that two out of every five conventional car owners said they would never consider an electric vehicle.

Yet, the other 60 percent of buyers cannot seem to get enough of them. Despite the COVID-19 pandemic and an economic decline in 2020, EV sales rose 40 percent in 2020 to 3.24 million units, or 4.2 percent of the global light vehicle market. In Germany, EVs accounted for more than one of every five cars sold in the fourth quarter of 2020.

Right now, the market for battery-based EVs consists of two types of vehicles: plug-in hybrid electric vehicles (PHEVs), where a small internal combustion engine complements a limited-range battery (like the Toyota Prius); and battery electric vehicles (BEVs), which only use battery power (like the Tesla) and now dominate the market.

That is just the start. Boston Consulting Group (BCG) estimates that by 2030, the world's automakers will offer more than 400 EV models. By 2026, they will account for more than half the light vehicle sales. This is four years earlier than BCG had projected just twelve moths before.

"The shift to electric vehicles is happening quickly, though it has been 10 years in the making," said Dawn Neville, who manages electric vehicle programs for New Jersey and New York's Public Service Electric & Gas (PSE&G). "It's not nearly as fast as cellphone adaption, but it could follow similar trajectory."

It will certainly reshape the grid as we know it. On an annual basis, recharging an average EV consumes about as much power as the average American household. No wonder that a Department of Energy study found that EVs would play a key role in boosting demand for electricity by 38 percent by 2050. That may sound like a hefty increase, but utilities are used to planning for capacity increases decades into the future.

On the other hand, adding a new house worth of electrical demand with every new EV is likely to have a big impact on electrical distribution. EVs are unevenly distributed and concentrate in upscale communities. What will happen when those EV owners return from work and all plug in their EVs at the same time to recharge?

PLUGGING IN

Several factors drive the rapid growth of electric vehicles. Climate change is the most important. Most nations and virtually all climate scientists recognize that carbon dioxide emissions are leading to warmer and more extreme weather. Vehicles account for 17 percent of the world's energy-related greenhouse emissions, according to the Intergovernmental Panel on Climate Change.

EVs promise to make a big dent in those emissions. They produce fewer emissions and greenhouse gases even when charged with electricity from coal-burning power plants, according to an analysis by the Department of Energy's Alternative Fuels Center (AFC).

When AFC looked at well-to-wheel emissions (emissions from vehicles as well as fuel production, distribution, and use), it found that U.S. BEVs had one-third and PHEVs one-half the emissions of ICEVs.

Nations have taken note and acted. The European Union set a net-zero automotive emissions target for 2050 as part of the European Green Deal. Paris will ban ICEVs by 2024 and Rome & Milan by 2030. More than 15 nations and California plan to phase out ICEVs by 2035. President Biden recently announced plans to slash emissions levels and target 50 percent EV sales by 2030.

In almost every case, incentives are underwriting the cost of buying EVs. The United States, for example, gives EV buyers a $7,500 tax credit. Many states also provide incentives. New Jersey, for example, up to $5,000 for consumers and up to $9,000 for fleet owners.

The incentives are important because batteries, the most expensive part of an EV, drive costs higher than ICEVs. This, however, is changing rapidly. The Electric Power Research Institute (EPRI) and BCG find that EV batteries have fallen from $700/kWh in 2009 to $540/kWh in 2014 to under $150/kWh today. Thanks to continued improvement in cell chemistry and assembly procedures and greater production scale, EPRI predicts prices to drop to $80-105/kWh by 2025 and $70-90/kWh by 2030.

The electric motors used in EVs are mechanically simpler and less expensive to make and assemble than internal combustion engines. Add to that greater efficiency—EVs have only 20 percent engine losses compared with 70 percent for ICEVs, according to EPA—and EVs could prove a bargain.

In fact, EPRI expects the five-year total cost of ownership for BEVs to drop below those of ICEVs by 2028, according to EPRI. BCG believes it could happen globally as soon as 2022 or 2023, depending on the region and vehicle size.

Falling costs and government regulations are certainly spurring EV growth. Yet, EVs are popular for another reason—they are cool. In the beginning, EVs were seen as underpowered eco-conscious vehicles that no one would enjoy driving. Elon Musk changed that with the Tesla, a car that could blow by all but the most exotic supercars on a highway and that was filled with high-tech gadgets. Tesla widened the appeal of EVs to a much broader audience, even as competition begins to erode EV prices.

BUILDING OUT

EVs are certainly on the way, but it will take a new type of infrastructure to fuel them. Today, nearly everyone fuels up at a gas station. Not EVs. The Department of Energy estimates that 80 to 90 percent of all charging will take place at home.

Today, many EVs come with Level 1 chargers. They work well for PHEVs with limited battery range, adding just 3-5 miles of driving range per hour of charge. That works for a Toyota Rav4 Prime with 42 miles of battery range. For BEV like the Volkswagen ID.4 with 230 miles of range, the home alternative is a Level 2 charger. It generates from 15 to 30-plus miles of driving range per hour, but may cost $1,000 to more than $2,000 with installation.

A Level 1 charger plugs into a standard 120V outlet. Not the Level 2. "Typically, most people want a Level 2 charger, but

Left: EVs top off at a public charging station. Below: A home charger takes hours to charge an EV, fast chargers can deliver up to 5-6 miles of range per minute.

it requires a 240V outlet," PSE&G's Neville said. "We estimate that about 10 percent of our customers will need to upgrade their service before they can install one."

Public chargers operate differently. While home chargers range from 7 kW to 12 kW, service station chargers run 50 kW to 375 kW. The most powerful of them deliver 5 to 6 miles of range per minute. That would give a typical battery an 80 percent charge in 15 to 30 minutes, Neville said.

Today, entrepreneurs have built a network of 50,000 fast Level 3 and Level 4 chargers. President Biden wants to build 500,000 new public chargers by 2030. It sounds like a lot, but pales in comparison to the nation's 135,000 service stations and 1.4 million pumps. Still, with most charging taking place at home, it might be enough.

PricewaterhouseCooper (PwC), a large consulting firm, looked at the economics of fast-charging stations. It found Level 4 chargers cost twice as much as Level 3 units. To achieve the same profitability as a Level 3 station, a Level 4 outlet must charge a 10 c/kWh premium. That works out to $5 premium for 50 kWh charge equal to 100 miles of range that saves 15 to 20 minutes. PwC estimates some consumers would pay up to four times more for Level 4 roadway charging than they would at home.

Either way, charging will leave motorists with time to kill. This might alter where companies site chargers. Volta Charging, for example, partners with retailers, shopping malls, and grocery stores, where motorists have something to do while their vehicles recharge. Volta offers the first 30 minutes of charging free, but offsets its costs from local advertising shown on the charger.

McKinsey & Co. expects fleets to embrace EVs enthusiastically. While EVs may cost more up front, their high efficiency will quickly recoup any additional expenses. McKinsey estimates that the total cost of ownership for fleet EVs will be 15 to 25 percent less than ICE vehicles by 2030. Fleet owners could save further money by installing solar or wind power to power their rechargers.

RIDING THE CURVE

Despite the growth of EVs, most analysts are not worried about capacity. Today, PHEVs and BEVs account for about 1 million of the United States' 250 million vehicles. Even if more than half of light vehicle sales are EVs by 2026, there would only be 40 to 50 million EVs on the road by 2030.

It sounds like a lot, but not compared with America's electricity output. A 2019 Department of Energy-funded study estimated that if the number of EVs on the road in 2030 rose to 40 million, they would require 27 terawatt-hours of additional output. That is not even one percent of the 4,178 TWh of electricity the United States consumed in 2018.

This does not mean utilities have nothing to worry about. The issue facing them is distribution.

"The problem is not so much the amount of electricity consumed but the instantaneous demand for electricity when everyone charges their car when they get home from work," Anshuman Sahoo, a principle at BCG, said. "It's less about kilowatt-hours than making sure the grid is equipped to transmit that power when you need it."

Sahoo likens buying an EV to building a new home. If half the families in a 50-home development buy an EV for local commutes, it will add the equivalent of 25 new homes to the electrical distribution circuit that serves them.

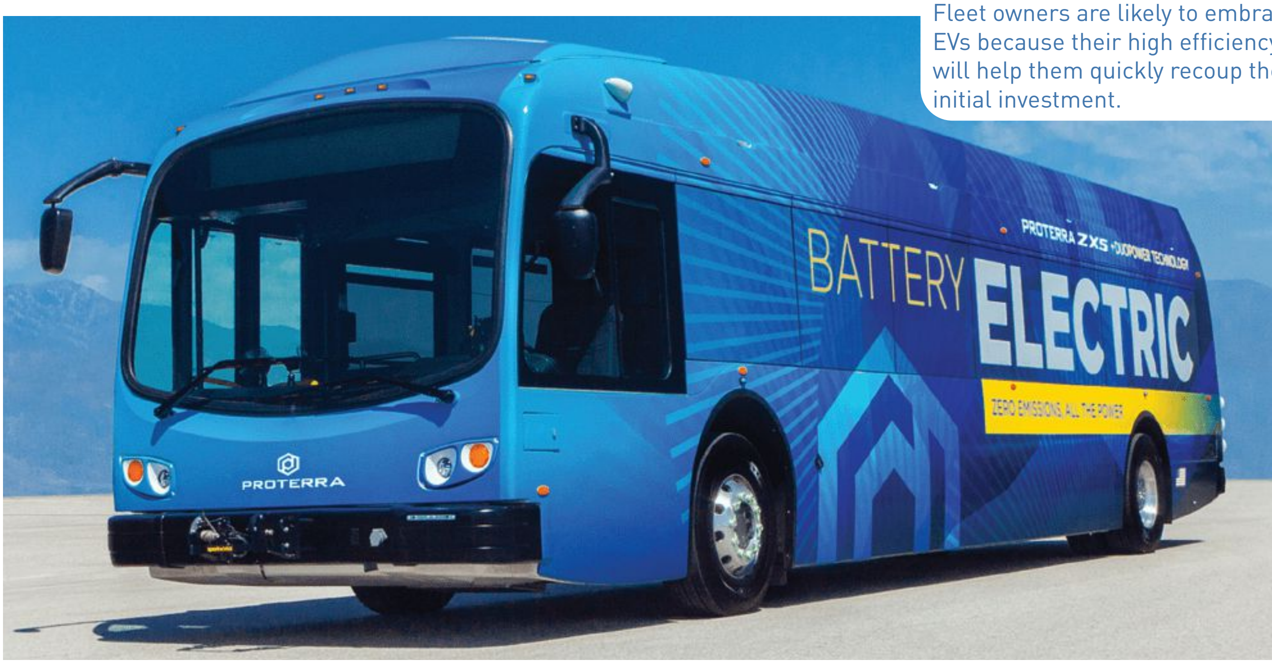
Neville agreed: "EV purchases tend to happen neighborhood by neighborhood. If you buy an EV, maybe your neighbors do it and then their neighbors do as well."

This is already happening in well-to-do neighborhoods and falling EV prices will spur the transition. This leaves utilities like PSE&G trying to manage the reliability of its distribution network. "If you and your neighbors all adopt EVs, we could have a voltage problem that continues back to the distribution center," Neville said.

Neighborhood by neighborhood growth is not only uneven, but tricky to estimate in the near term. "We need to understand what the adoption rate will be," Neville said. "We've done that based on state goals and some data from around the country, but those are all assumptions. The reality may be different, and we will have to adapt to it."

Longer term, Neville said, PSE&G and other utilities will have to build out those last-mile upgrades. It will have to decide where and when to build more substations and calculate where to place them to deliver instantaneous power when everyone plugs in at night.

Today's service stations are located on major roadways, but public chargers may be located near attractions that give motorists something to do while they wait.



Fleet owners are likely to embrace EVs because their high efficiency will help them quickly recoup their initial investment.

PEAKS

In the meantime, increased evening demand will strain the grid's distribution system—unless utilities find a way to manage it. Fortunately, they have several near-term and long-term options available, Sahoo said.

Rather than rushing to boost distribution capacity, most utilities would rather manage demand, Sahoo explains. One way to encourage EV charging during off-peak hours is to lower rates during those periods and use smart monitors to help motorists charge economically.

How would that work? Most owners plug in their EV when they return from work. It may remain plugged in for 12 hours or more. An app might show that charging between 6 - 9 p.m. is expensive, while between 9 p.m. and 8 a.m., when retail businesses close and cooling temperatures reduce demand for air conditioning, is less costly. Most people would choose to recharge after midnight to save money, while others might pay more to top off their battery if they wanted to go out that night.

Utilities could also manage recharging automatically, Sahoo said. They have already begun to do this for thermostats and air conditioners. They would monitor grid conditions and optimize recharging to balance the load more evenly among and within different distribution substations.

Of course, this works best if EV owners use Level 2 chargers rather than painfully slow Level 1 units. With a Level 2 charger, many motorists would need only a few hours of charging to top off their batteries. This will give utilities more room to match capacity and demand, and it explains why many utilities have begun to offer rebates on Level 2 chargers.

Utilities must also contend with the highly volatile and spiky load profiles of public fast-charging stations, according to a 2018 McKinsey report. When the consultants simulated a fast-charging station, they found it could quickly exceed the peak-load capacity of a typical feeder-circuit transformer.

Fleets also pose a challenge. If a fleet of 200 electric public transit buses recharged slowly overnight on 80 kW chargers, they would require 16 MW of grid capacity, according to BCG. But if only 40 of those buses needed to recharge quickly during the day and spent 10 to 15 minutes on 450 kW to 500 kW chargers, they would need 18 MW of capacity. That is equivalent to 3,000 homes at their peak capacity.

The solution to some of these issues might come in the form of storage batteries, which are increasingly affordable. They would let public charging stations increase profit margins by using stored off-peak power to recharge EVs during more expensive peak power periods.

While high-speed chargers and electrical storage will likely prove expensive to implement, Sahoo believes entrepreneurs will find a way to overcome these barriers. He points to Volta's advertising driven chargers as an example. "A lot of solutions seem expensive now, but over the next few years, we'll see many innovative business models that make solutions to grid challenge feasible," he said.

BARRIERS

Despite industry optimism, high investment costs—and who will pay for them—is only one of several barriers that utilities will face as EVs roll into the market.

"Investment costs, and therefore the pressure on rates, will be magnified as EV adoption ramps up," Sahoo said. "That's because investment costs increase exponentially as EV penetration increases, given the need for more expensive equipment and a larger number of new assets."

In 2019, BCG estimated that the typical utility would have to invest between $1,700 and $5,800 in grid upgrades per EV through 2030, depending on how fast EVs move into the market and how well utilities convince EV owners to charge their vehicles during off-peak hours. This works out to rate increases of up to 1.4 cents/kWh on a national average utility rate of 11 cents/kWh, or 13 percent. Other studies by various firms see equivalent increases.

Utilities are regulated by the states. If state utility boards approve those investments, which utilities must make before demand for EVs begins to impact service, the bill will be passed through to utility customers. Many of them do not own electric vehicles.

This is why encouraging users to recharge when demand is low is so important. If utilities can shift recharging to non-peak hours, they can delay investment until the number of EVs has grown enough to make it profitable.

Some states have also put in place specific equity requirements for EV rollouts, Sahoo noted. These ensure that some of the money raised to build EV infrastructure will go to underserved communities, perhaps in the form of better infrastructure or perhaps improved EV bus service.

"There is a lot of research that shows electricity sales from EV use can put downward pressure on rates" by increasing market size and profitability, Neville added. "Besides, EVs do not just offer benefits to EV drivers. Cleaner air doesn't care who is driving the car. EVs will improve emissions for everyone."

To truly maximize environmental benefits, though, utilities will have to shutter carbon-emitting power plants and boost renewable energy. This is already happening in the U.S., where wind and solar account for nearly all planned new generating capacity.

Both wind and solar provide intermittent power and utilities are learning to manage this. The more critical issue involves timing. Engineers place wind turbines where winds are steadiest. The turbines produce more power at night when winds are strongest, which aligns with initiatives to get EV drivers to charge at night.

Solar power is another story. A growing source of electricity in California and other desert states, it stops producing power when people return home from work. Yet, California and other desert states where skies are sunny almost every day are investing heavily in new solar power.

In California, for example, solar power doubled in just five years to reach 15 percent of total electricity production. Utilities now have so much solar on the grid that their new rates have off-peak times in the middle of the day, observed Chris Nelder, an analyst who headed the Rocky Mountain Institute's carbon-free mobility practice for 15 years.

To put this resource to work, desert state utilities may need to encourage new types of infrastructure, such as chargers at offices, parking garages, retail locations, and grocery stores. Low-cost, long-term batteries may also help level the load by lowering the cost of charging at night and compensating for cloudy days.

This is all happening against the backdrop of a changing power grid, Sahoo noted. The grid is growing smarter and more distributed. At the same time, there is a push to electrify everything from buildings and boilers to home appliances to reduce carbon emissions.

One thing is certain however, EVs will play a big role in those changes. Take, for example, rooftop solar systems on private homes. One day, said Ben Kroposki, director of power systems engineering center at the National Renewable Energy Lab, homeowners might complement those systems with EVs and backup batteries to create a more decentralized energy grid where people can recharge their EV and power their appliances.

They could also sell solar power back to the grid with a bidirectional (vehicle-to-building, or V2B) energy system.

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David Slutzky, CEO and founder of Fermata Energy, a V2B startup, believes such systems could save fleet owners with fast chargers thousands of dollars per vehicle annually. Eventually, they might work for consumers as well.

Will that happen? There are still technical hurdles, but grid and its growing EV fleet are a work in progress. As EV driving ranges increase and costs fall, it will create a new type of grid and refueling infrastructure. Innovators will continue to find new ways to generate, store, buy, and sell electricity.

And eventually, even those two out of five car buyers who said they would not consider an EV are likely to get onboard.

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A more distributed power grid may take advantage of solar power to charge EVs at work during the day.