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The Fix for the Electric Grid's Mid-life Crisis Might be in the Garage

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Inside…

Key Points:

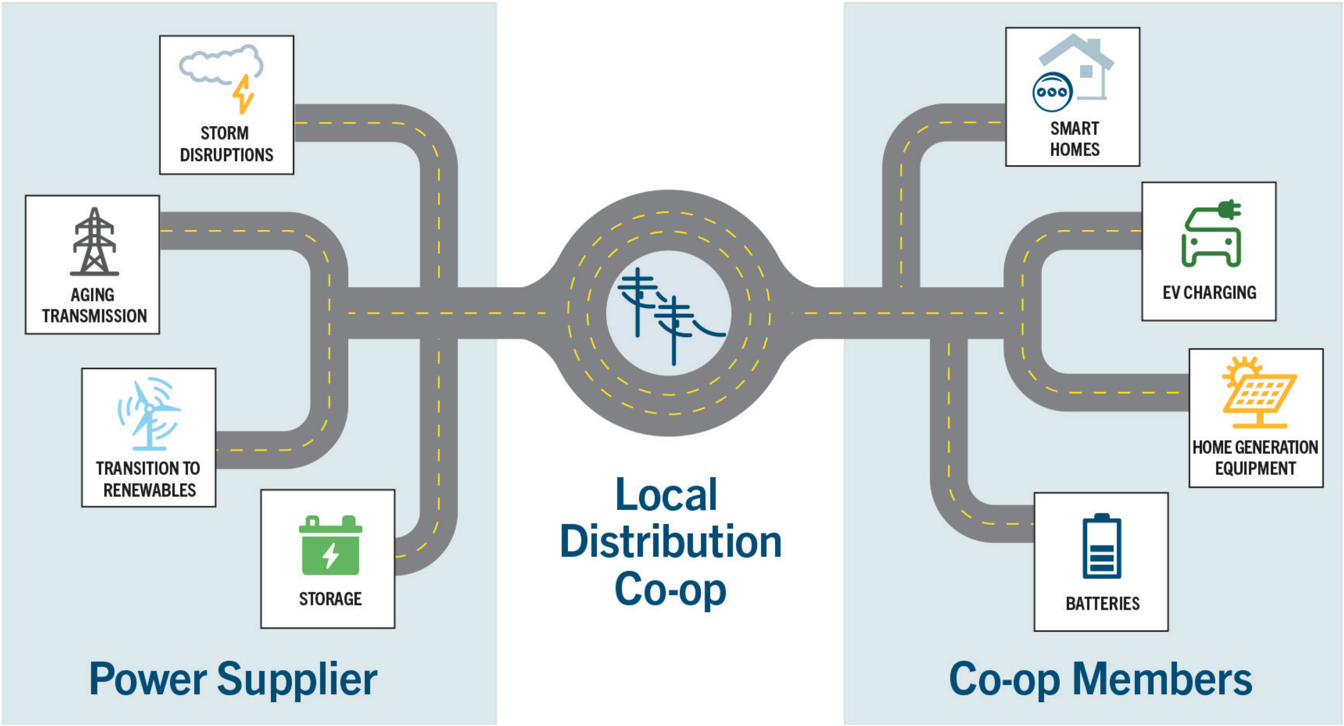
- The U.S. electric grid is now experiencing something of a mid-life crisis. It was designed and built with the presumption of a stable climate and a centralized, unidirectional flow of electricity. But that premise is quickly changing.
- During periods of system stress, upstream grid operators are increasingly turning to large customers to voluntarily curb their power use. Next-generation distribution management systems in the future may unlock even greater demand flexibility.
- New programs are already being introduced to shift demand, adding greater flexibility to an increasingly inflexible system, thereby avoiding strains on the grid. And, utilities are looking to electric vehicles as an important source of future flexibility.
- Indeed, electric vehicle adoption could prove to be either the greatest grid disruptor or possibly the most effective grid-balancing tool. Where EV technology impacts ultimately land will likely boil down to the effectiveness of advance planning efforts and agile member communications.

Modernizing the once-mighty U.S. electric grid hinges on consumers

Considered one of the greatest engineering feats of the 20th century, the U.S. electric grid is now experiencing something of a mid-life crisis in the early innings of the 21st century. It's not just that the nation's power system is aging; it was designed and built with the presumption of a stable climate[1] and a centralized, unidirectional flow of electricity. It was a one-way street, originating from a flexible thermal power station to a mostly predictable but inflexible electricity consumer, requiring on-demand service. The U.S. electric grid has mostly operated smoothly as one big synchronous machine since its inception – switch the lights on and voilà, the electricity is there.[2]

However, as aging centralized thermal resources are being replaced with more variable renewables[3] and long-distance delivery systems are showing their age, this synchronization (or technically speaking, system inertia) appears to be decreasing – by extension, U.S. power outages have increased, up 64% this decade compared to the previous decade.[4] Age, weather and the generating resource mix is undermining

EXHIBIT 1: The Electricity Sector No Longer Lives on a One-Way Street



Source: CoBank

the U.S. power systems faster than the infrastructure can be replaced, reinforced, and possibly re-envisioned.

To bridge the gap, upstream grid operators are increasingly turning to large customers to voluntarily curb their power use during periods of high demand in order to keep the lights on.[5,6] As grid management technologies evolve, this manual upstream coordination might give way to an increase in downstream controls, with a greater amount of electricity "traffic flow" in the future coordinated at the distribution level[7] *(Exhibit 1)*. After all, it is here that true re-balancing can take effect – where automated consumer load shedding, distributed generation aggregation or the netting of these activities can occur to offset an increasingly inflexible centralized generating resource. Put another way, these localized, distributed resources could potentially backfill, supplement or even replace more expensive long-distance grid fixes and/or offset the variations in centralized renewable resources.

With upstream supply transitioning at the same time consumer technologies are fast evolving[8], it's time to re-frame industry roles and responsibilities. As the National Academies of Sciences, Engineering and Medicine wrote, "understanding how electricity consumers behave, and how devices and energy services can be aggregated for supply, and how such trends affect system loads is emerging as one of most profound technological, regulatory and planning challenges and opportunities facing the future of the grid."[9]

Consumers' future electricity requirements could gradually decrease, particularly with more behind-the-meter on-site energy generation (like solar), or substantially increase with electric vehicle adoption and greater electrification – which makes planning all the more difficult. It's clear that consumers will play an increasingly important role in grid management and therefore, need to be at the center of this discussion.

EXHIBIT 2: Bigger EVs Require Bigger Charges

Vehicle Type	Class 1 Passenger Cars & Small SUVs	Class 1&2 Pickup Trucks and Large SUVs	Class 2/3 Light Duty Vehicles	Class 3-5 Buses/Utility Vehicles	Class 6-8 Bucket Trucks	Class 6-8 Trucks/Tractor Trailers
Charge Rate (kW) Level 2	7-11	11-19.2	19.2	13-19.2	19.2	19.2
	Typical peak residential demand 5-7 kW			Typical Depot: ~20-100kVa (Lighting/HVAC loads)		
Charge Rate (kW) DCFC	50-350	150-350	50-150	50-150	150	150
Battery Size (kWh)	40-100	100-200	67-140	110-230	250-350	250-350
Range (mi)	150-350	100-300	120-150	105-205	~90 (with aux power)	~90 (with aux power)
Efficiency (kWh/mi)	0.25-0.35	0.4-0.6	0.5-1	1-1.5	2-4	2-4

Source: 1898 & Co., a division of Burns & McDonnell Engineering Co.

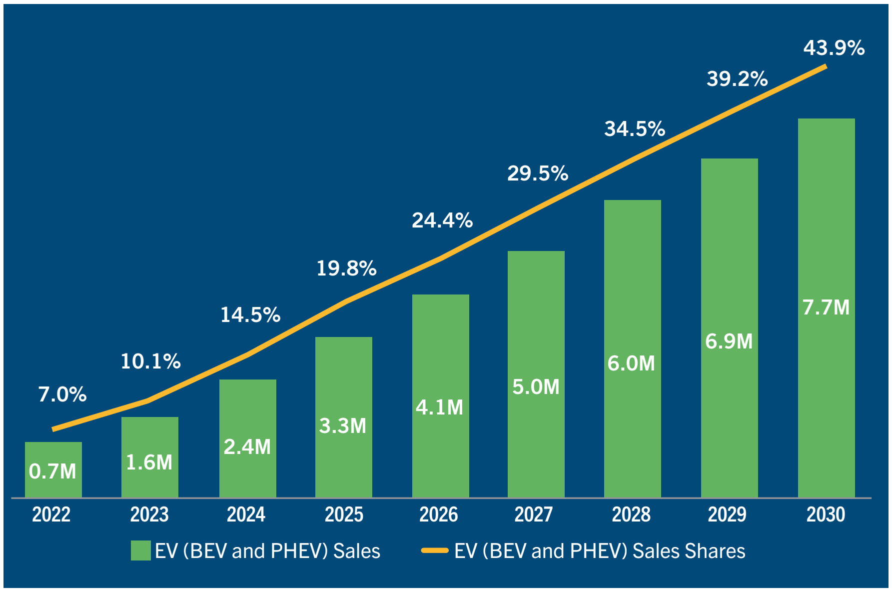
EVs and chargers: Grid disruptors or grid balancing tools?

Among consumer technologies or devices that will impact our future grid, electric vehicles stand out as the most disruptive. The transportation sector currently consumes roughly 27 quadrillion BTUs of energy annually, primarily from petroleum. In comparison, the electricity sector uses 37 quads total annually to supply electricity to end users in the U.S. – and that includes 24 quads of electrical system energy losses.[10] As the energy required for transportation shifts from fossil fuels to renewables and greater distributed energy resources are put to use, the impact could be enormous.

A Sandia National Laboratories study showed that uncontrolled EV charging at home increased system load by a significant degree in the evening when the residential, commercial, and mixed use feeders were already at peak load without EVs. In their case study, peak load (which often occurred around 8 p.m.) increased by 11.7% and 9.8% on average for residential and mixed feeders, respectively.[11] On a disaggregated basis, the disruption is just as unsettling, as home vehicle chargers are likely to be the largest electrical draw in an individual household.

A few years ago, the Department of Energy compared power draws of EV chargers to various household appliances. Charging at home on a 240-volt level 2 charger will draw about 7,200 watts or less; a typical electric furnace draws about 10,000 watts and a water heater uses 4,500. Since then, a greater array of bigger EVs has come on the market; the charging requirements of light-duty trucks and heavier vehicles would increase a household's electricity demand by 11,500 watts to possibly 19,200 watts *(Exhibit 2)*. Consequently, rampant uncontrolled charging could pose a major threat to local distribution networks.

EXHIBIT 3: U.S. EV Sales Shares to Reach 44% in 2030



Source: EVAdoption, LLC, April 2022

Yet, if the U.S. addresses integration issues, the associated grid benefits could be enormous. Co-ops that effectively coordinate with their membership could conceivably level out daily electricity demand on the network – and possibly even store excess renewable energy in these mobile batteries during extended vehicle idle periods to meet system peaks.[12]

Member education and outreach is priority #1

While co-ops agree that uncontrolled EV charging would disrupt the system, perspectives vary when it comes to the pace and timing of EV adoption in their own communities. That said, EV adoption in the U.S. is happening faster than originally anticipated.

Two years ago, we projected 10% of new cars by 2025 would be electric. In 2022, EVs already accounted for roughly 7% of new car sales. EV adoption is being boosted by incentives in the Inflation Reduction Act of 2022, perhaps the most significant legislation to accelerate transportation electrification in U.S. history.[13] The overall savings of owning an EV (thanks in no small part to the new federal funding) combined with the reality that the technology in new vehicles running on gasoline will become increasingly stale[14] could mean that 20% to 30% of all new vehicle sales will be electric within just five years[15] *(Exhibit 3).*

Putting vehicle acquisition costs aside, the real tipping point for community adoption appears to be tied to EV charging.[16] A recent *Consumer Reports* survey confirmed that charging issues are the top barriers to adoption – namely, concerns about running out of a charge while on the road and the lack of public charger availability.[17] Solving this problem by increasing charging options can be an important member-engagement opportunity for co-ops.

Admittedly, the job of supplying system load is growing increasingly challenging for a confluence of reasons, ranging from service interruptions to the change in requirements that EVs and other consumer technologies pose. So, the time feels ripe to tune-up co-op member education and outreach programs, perhaps using EV charging as a part of those strategic membership discussions. We see a growing need to meet this "moment" in the same manner that the now-expansive energy efficiency programs became an industry rallying point out of the 1970's energy crisis.[18] And, we are not alone…

Plug In America, an EV advocacy group, recommends a very hands-on approach – offering test rides and drives, setting up retail "experience centers," and establishing critical collaborative partnerships with local dealerships, electricians and others.[19] At the end of the day, only electric co-ops have the power to influence EV drivers and fleet operators to charge at the proper time that will save members money and benefit the grid by more efficiently utilizing assets.

Managing EV charging depends on sending the right market signals

Because the average car spends about 95% of its life parked,[20] EV owners have few time constraints for charging – giving distribution co-ops ample opportunity to match charging load with optimal resource availability.[21] The trick is to develop and promote the right set of market signals to bring about the desired member behavioral shift.

The widely prevalent flat rate pricing structure that does not account for time or location incorrectly assumes that each kWh consumed imposes the same cost on a utility.[22] In the scenario used by Sandia researchers, the flat per-kWh rate would translate directly to underpayment for those members who use the grid more during peak demand hours, which increasingly includes EV households. Varying the price of the kWhs used – setting the member price higher during peak demand and lower at other times – allows more precise pricing for the cost of electricity used. Time-of-use (TOU) and other time-varying rate structures will not only prove to be more equitable, but might actually shift some of the load to a lower cost time of day.

Sufficiently prepared customers "understand and respond" to such rates, according to a Brattle Group survey of customer responses to over 300 time-varying rates in 62 pilots. In an interview with *Utility Dive*, report author and Brattle Group Principal Ahmad Faruqui emphasized that a "mountain of evidence" shows customers respond to TOU rates. The average impact of advanced metering infrastructure (AMI) and other enabling technologies is significant: Customers reduced their peak usage by 11.1% for every 10% increase in the price ratio.[23]

With their AMI meter use approaching 80% compared to 65% nationwide, rural electric cooperatives are actually ahead of the curve.[24] The problem is that technology alone will not solve the problem. In our Power Plays podcast interview last year, Faruqui acknowledges that while AMI use is on the rise, the voluntary adoption of time-of-use rates is not.[25] He emphasized that only about 1 out of 10 electricity customers have voluntarily opted into these rate structures.[26] In fact, absent a regulatory mandate, it is common for these rate designs to see very low levels of enrollment. Yet, as the timing of electricity consumption becomes increasingly important to maintain reliable grid operations, this may change.

Momentum appears to be building for greater regulatory change addressing this connection, prompting utilities to better align rate design with grid-friendly shifts in demand. One real life example is California. In 2015, the state mandated its utilities to default customers to TOU rates. Today, the lion's share of residential customers in the state are now or will soon transition. The massive West Coast influx of 20 million electricity customers onto a dynamic pricing plan could increase the national average from ~8% to ~16%.[27]

California EV owners have been offered the choice of TOU rates either under a whole-home program (under a single meter) or for stand-alone EV chargers (with installation of a second meter). Utilities found that the additional cost of installing a second meter (~$2,000) proved to be an obstacle for load-shifting the chargers.[28] To correct this problem and to pave the way to greater EV-to-grid integration, the state recently agreed to allow networked EV chargers to directly measure electricity consumption.[29,30]

This new measure kills two birds with one stone: It not only encourages load shift for these households' most flexible appliance (the charger) but it also lays out communication protocols for EV chargers, which will ultimately enable vehicle-grid integration. This means that California's utilities will eventually be able to read the networked charger for electricity use and also send a signal to these devices to stop charging during periods of system strain.[31]

Conclusion

Shifting an even greater number of consumers to dynamic pricing reinforces the need for greater energy literacy, specifically "load shape awareness." And this is really the crux of the problem that needs to be addressed through member education programs. Limited studies on energy use awareness confirms that most consumers are largely unaware of their consumption habits.[32] Simply put, helping consumers adapt to an evolving energy system starts with a basic understanding of energy use and builds from there.

Influencing and managing the EV point of charge translates to packaging the right price signal with the needed information to make use of that signal. Consumers need to be: 1) informed of potential system impacts before plugging EVs into the local distribution system, 2) confident that abundant re-charge opportunities exist so that the vehicle's battery can be deployed beyond finite transport requirements and 3) presented with the right set of market signals for optimal charging.[33]

EV adoption could prove to be either the greatest grid disruptor or possibly the most effective grid-balancing tool in a local distribution company's toolbox. In many ways, electric distribution cooperatives were designed with this future in mind, given member alignment, but the pace of change might still surprise and amplifies the need for significant member coordination.

Sources used

[1] "The biggest problem facing the U.S. electric grid isn't demand. It's climate change", NPR, 24 November 2021.

[2] Historically, risks to the system primarily arose upstream, from large generator and network failures. To avert downstream issues, delivery systems have been reinforced to accommodate peak load. Consequently, outside of basic efficiency programs (originating back in the 1970s), there has been limited incentive for suppliers to influence consumer use with the notable exceptions of extreme weather events or disruptions in fuel create supply shortages. "Variable Renewable Energy: An Introduction", U.S. Congressional Research Service, June 2019.

[3] A growing number of which are actually located downstream behind-the-meter. "Home solar panel adoption continues to rise in the U.S.", Pew Research, 14 October 2022.

[4] "Surging Weather-related Power Outages", Climate Central, 13 September 2022.

[5] Significantly adding to the complexity of system reliability is the fact that upstream supply is becoming increasingly inflexible and downstream consumer demand is on the rise. As a result, regional cracks in the system are surfacing. Emergency cutback requests that occurred the previous summer in places like Indiana, New York, Texas and California and more recently from TVA and Duke Energy this winter will likely become more frequent and widespread.

[6] "ERCOT Creates Voluntary Curtailment Program for Large Flexible Customers During Peak Demand," ERCOT press release, 6 December 2022.

[7] The 'advanced' elements of an advanced distribution management system go beyond traditional distribution management systems by providing next-generation control capabilities. These capabilities include the management of high penetrations of distributed energy resources, closed-loop interactions with building management systems, and tighter integration with utility tools for meter data management systems, asset data, and billing. See NREL, "Advanced Distribution Management Systems".

[8] "Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States", NREL 2018.

[9] "The Future of Electric Power in the United States," The National Academies of Sciences, Engineering and Medicine, 2021.

[10] "U.S. energy consumption by source and sector, 2021," EIA, April 2022.

[11] "Uncontrolled Electric Vehicle Charging Impacts on Distribution Electric Power Systems with Primarily Residential, Commercial or Industrial Loads", Sandia National Laboratories, March 2021.

[12] Vehicle to grid applications are becoming more prevalent, especially electric school bus to grid projects. Utilities are exploring how electric school buses can function as giant rolling batteries to support the power grid, enabling greater renewable electricity generation and providing disaster relief, through the use of vehicle-to-grid (V2G) technologies. La Plata Energy Association (LPEA), a member-owned Colorado cooperative, was able to deliver the state's first V2G-capable electric bus.

[13] Starting in 2024, taxpayers will be able to elect to transfer credits to dealers, effectively allowing the credit to be a point of sale rebate. "Clean Vehicle Tax Credits in the Inflation Reduction Act of 2022", Congressional Research Service, 24 August 2022.

[14] "Carmakers Start to Starve Combustion Models Out of Existence", Bloomberg, 8 July 2022.

[15] Included in that landmark legislation is an extension of the existing federal light-duty EV tax credit, which provides up to $7,500 with the purchase of an EV through 2032. It also includes a new tax credit of up to $4,000 on used EVs, making certain that these vehicles continue to have a life beyond their first owner. Notably, these figures have doubled since our first gathering of the consensus estimates, see "Co-op EVolution – Bridging the Rural-Urban Divide on EV Adoption", CoBank, June 2021.

[16] "Electric Vehicle Myths", EPA web page, updated Dec. 22, 2022.

[17] At present, nearly three-quarters of Americans are now considering an EV purchase. "More Americans Would 'Definitely' Get Electric Vehicles, Consumer Reports Survey Shows", Consumer Reports, 7 July 2022.

[18] Today's 'crisis' might be defined as a globally tight fossil fuel market, given the absence of natural gas and petroleum products in response to the Russian invasion of Ukraine. Alternatively, the simple fact is that there is less iron in the ground to produce transport fuels, with climate concerns weighing against the odds of building more. U.S. refining capacity has contracted. In all, the 130 U.S. petroleum refineries had combined capacity to process nearly 18 million barrels a day earlier this spring, according to the Energy Information Administration, down from a peak of nearly 19 million in 2020. See Hassler, John; Krusell, Per; Olovsson, Conny, "Directed Technical Change as a Response to Natural Resource Scarcity", Journal of Political Economy, November 2021 for more.

[19] "The Missing Piece on Meeting Transportation Electrification Goals: Utility Education and Outreach Programs", Plug In America, December 2020.

[20] "The High Cost of Free Parking, Updated Edition", Donald Shoup, Feb 25, 2021.

[21] Boston Consulting Group envisions that 15%-20% of EV vehicle penetration will correspond to a 5%-10% increase in energy demand but a 22%–33% increase in grid capacity. See "Driving Change on the Grid—The Impact of EV Adoption", Power, 2 March 2020.

[22] "Today's rate designs are defective. How can utilities better recover their fixed costs, and from whom?", Utility Dive, an OpEd by Kenneth W. Costello, November 2022.

[23] "An emerging push for time-of-use rates sparks new debates about customer and grid impacts," Utility Dive, January 2019.

[24] According to EIA data, there were 103.1million advanced meters installed and operational out of 159.7million total meters in the United States in 2020, representing an advanced meter penetration rate of 64.6%. "Electric Co-op Facts & Figures," NRECA web page, published April 28, 2022.

[25] "Don't Be Afraid of Your Electricity Bill", CoBank Power Plays, 27 July 2022.

[26] EIA data for 2020, shows that roughly 12 million consumers out of the 158 million total have opted for dynamic pricing programs.

[27] "California utilities prep nation's biggest time-of-use rate rollout", Utility Dive, 6 December 2018.

[28] Without a separate EV meter, TOU rate would expose the home's entire electricity usage to high on-peak charges, not just the EV.

[29] "CPUC Decision Makes California First State in the Nation To Allow Submetering of Electric Vehicles", California Public Utilities Commission, 4 August 2022.

[30] While there are a number of stand-alone pilot programs elsewhere that support EV-charger sub-metering, California's state-wide default approach might encourage other states to follow suit. "New California rule will cut costs of home EV charging", Canary Media, 22 August 2022.

[31] "California becomes first state to roll out submetering technology to spur EV adoption", Utility Dive, 8 August 2022.

[32] Researchers at Stanford University and Oregon State University paired objective smart meter electricity consumption data with self-reported questionnaire data for about 200 California households and found that only about half the respondents correctly identified their dominant load shape. Moreover, the respondent's load shape awareness significantly dropped when participants had to judge their consumption patterns during the COVID-19 pandemic. Zanocco, C., Sun, T., Stelmach, G. et al. "Assessing Californians' awareness of their daily electricity use patterns." Nature Energy 7, 12 December 2022.

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