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# Electric Vehicle-to-Grid Integration: From Concept to Reality


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**Inside…**



## *Key Points:*

- While vehicle-to-grid (V2G) integration remains more concept than reality in the U.S., it will likely afford economic value to cost-conscious utilities and their ratepayers in the long term.
- Although relatively few in number today, electric vehicles (EVs) are becoming less expensive, more convenient to drive, more abundant, and therefore meaningful as potential utility resources.
- Though it is small now, the U.S. market share of EVs is projected to grow rapidly beginning in the mid- to late-2020s.
- Automobile manufacturers, various electric utilities, and research institutions are working to address multiple technical and non-technical hurdles to EVs' widespread integration with the grid.
- Once these hurdles are overcome, electric utilities across the U.S. will be able to build V2G systems incrementally, commensurate with their consumer demand, budgets, and system characteristics.

## *Harnessing V2G Integration*

V2G integration is characterized by many EV owners connecting their vehicles to the power grid at their home and/or workplace, at which point the system operator can charge or discharge the EVs' batteries within agreed-upon parameters. To date, there have been approximately 20 V2G pilot programs across the U.S., along with dozens more internationally.

Projected technological developments could enable electric utilities to use the lithium-ion (li-ion) batteries of grid-connected EVs to maintain both local power quality and resource adequacy in the next 5-10 years.[1]

Although the batteries of most existing passenger EVs have individual capacities between 20 and 100 kWh – just 2 to 12 percent of the average U.S. household's monthly electricity consumption[2] – the combined energy storage resource of many grid-connected EVs could prove economically valuable to the utilities who harness it.

However, EVs have yet to gain significant market share in the U.S. This will remain the primary hurdle to widespread V2G integration into the late 2020s. *(Exhibit 1)* illustrates the scope and extent of this hurdle. Notably, California had the highest density of plug-in EVs in 2017 with fewer than 10 per 1,000 people.[3]



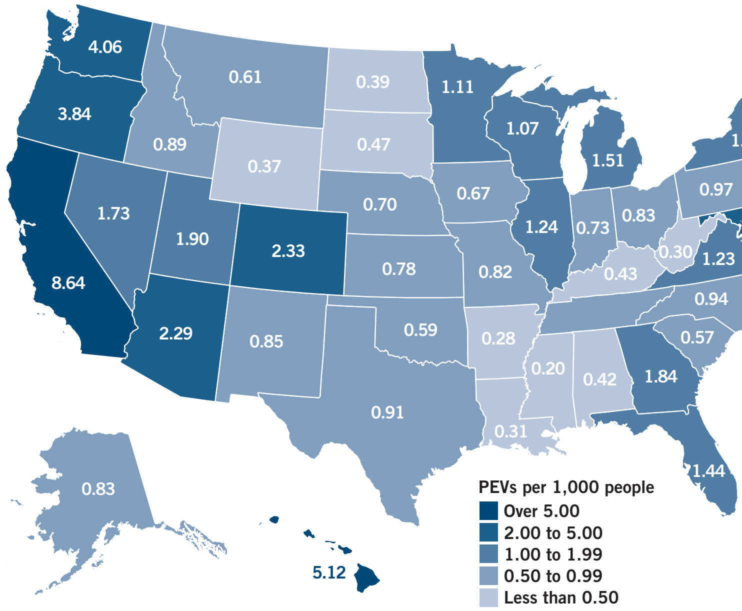
Just 5 million plug-in EVs have been sold globally. The U.S. accounted for over 1 million of those. EV sales appear to be accelerating, however.

In 2018, 2 million new EVs were sold globally – a 72 percent year-over-year (YoY) increase. U.S. consumers purchased over 360,000 of those EVs for a YoY increase of 81 percent nationally.

EVs' share of new U.S. vehicle sales is projected to rise by over 20 percent through 2030[4] due to their rapidly decreasing unsubsidized cost, increasing driving range, and the continued buildout of charging stations. Moreover, multiple automobile manufacturers plan to follow Nissan by offering EVs with bi-directional capability (the ability to both charge and discharge the battery).

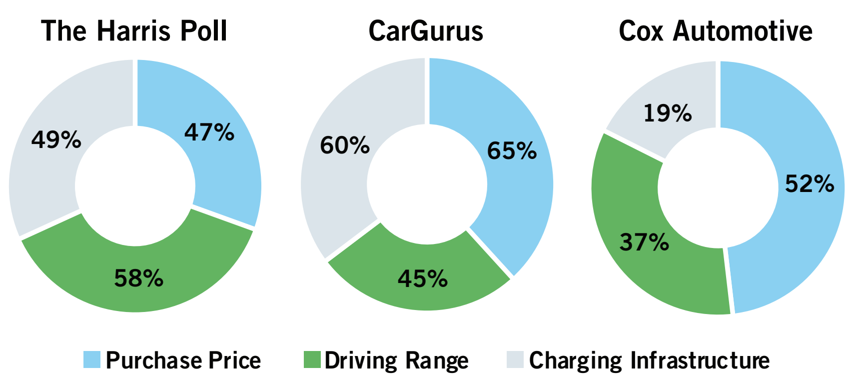
With this gradual transition in mind, electric utilities across the U.S. should begin considering how to use these energy resources and how best to design and manage the nuanced billing arrangements with customers who participate in V2G integration.

**EXHIBIT 1: Plug-in Electric Vehicles per 1,000 People, 2017**




Source: U.S. Department of Energy

**EXHIBIT 2: U.S. Consumer Concerns Regarding EV Ownership**




Sources: Volvo/The Harris Poll, CarGurus, Kelly Blue Book/Cox Automotive

## *Overcoming Consumer Concerns*

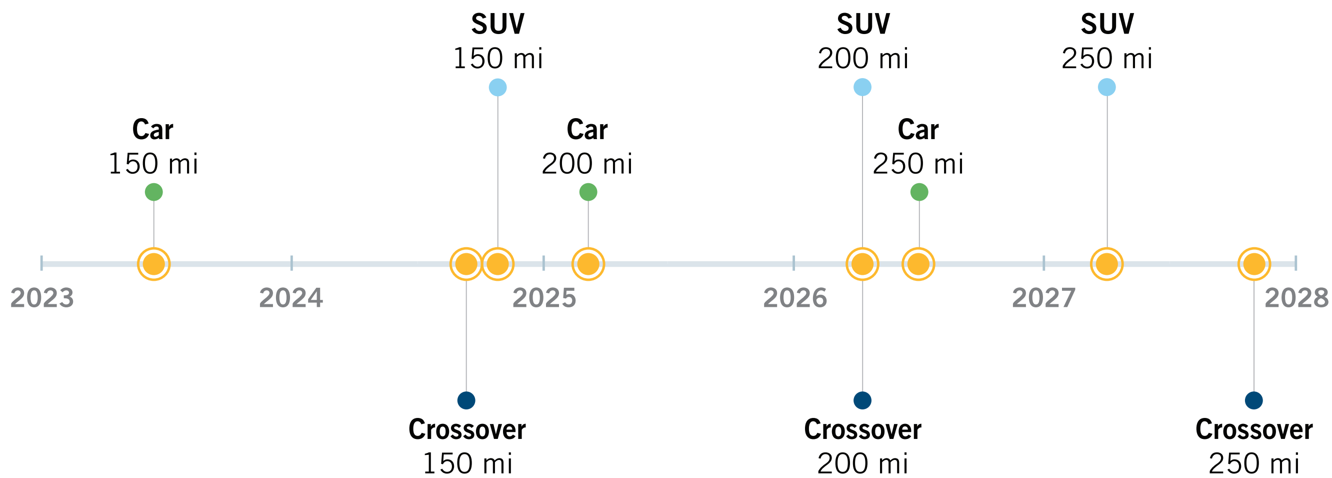
While today's U.S. consumers routinely express interest in the fuel savings and environmental benefits afforded by EVs, considerations of initial (first-owner) cost and convenience usually win out. In recent surveys, U.S. consumers have most often identified EVs' relatively high, unsubsidized initial cost as a barrier to ownership.

In separate surveys conducted recently by The Harris Poll, CarGurus.com, and Cox Automotive *(Exhibit 2)*, 47-65 percent of respondents deemed the initial purchase price to be an impediment. The driving range was cited by 37-58 percent. The existing charging infrastructure was listed by 19-60 percent. (The percentages for each survey sum to greater than 100 as respondents were asked to list, not rank, their concerns.)

Because the battery has long been an EV's most expensive component, the pace of V2G integration will depend greatly on their future cost.



**EXHIBIT 3: Projected Timeline of Initial Price Parity for Light-Duty EVs**




Source: The International Council on Clean Transportation

## *Betting on Batteries*

Given the historically high prices of these batteries, price parity between EVs and comparable vehicles with internal combustion engines (ICEs) has until recently seemed a distant prospect. However, li-ion battery pack prices have declined significantly in recent years. A -7 percent compound annual growth rate has been the norm.

The primary drivers of this cost reduction are incremental innovation and the increased battery manufacturing capacity realized by Panasonic, BYD, LG Chem, and Samsung SDI and others. These manufacturers have invested heavily in meeting the burgeoning global demand for EVs, stationary battery energy storage systems, and handheld electronic devices.

Bloomberg NEF's latest survey of industry stakeholders suggests approximate average li-ion battery pack prices will fall from $175/kWh in 2018 to $105/kWh in 2025 and nearly $60/kWh in 2030. These cost reductions, if realized, will drive price parity between many EV models and their ICE competition in the mid- to late-2020s.

That cost parity will arrive first for cars, crossovers, and SUVs, which comprise 41, 26, and 22 percent of the U.S. market for new light-duty vehicles, respectively.[5] (Pickup trucks, which represent 11 percent of the U.S. market for new light-duty vehicles, are not addressed herein given data limitations.)

Lower-cost, lower-range EV options such as cars with a driving range of 150 miles are projected to reach unsubsidized price parity in 2023. Cars capable of 200 miles and 250 miles should close the price gap by 2025 and 2026, respectively.

The growing crossover and SUV segments are projected to follow suit in the 2024-2027 timeframe with similar driving ranges.[6] See *Exhibit 3* for a timeline of these anticipated milestones.

## *Supplying Charging Demand*

EV owners typically recharge at home during off-peak hours. This generally occurs at a single-family home where the requisite EV charging infrastructure already exists. Notably, over 78 percent of adults in the nation's rural areas live in single-family homes versus 65 percent of adults in urban areas. This existing charging infrastructure is likely to supply most of the demand for electricity from EV owners through 2020. EV sales could be hindered thereafter by insufficient charging infrastructure.

However, efforts to develop incremental EV charging infrastructure are being led by many carbon-conscious states and local governments, as well as revenue-minded automobile manufacturers, vehicle fleet owners, and electric utilities. For instance, the state-led Regional Electric Vehicle Plan for the West (REV West) initiative is deploying a vast network of primarily DC fast chargers,



enabling EV owners to drive seamlessly across the interstates of Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming. Many other states, such as California, Missouri, and Kansas, have also taken leadership roles in this regard. Moreover, charger availability may become less concerning to potential EV buyers as battery ranges increase to 150, 200, and 250 miles (or more).

### *Other Technical Considerations*

When an EV is integrated into a grid, its battery's state of charge would be automatically optimized to meet the expected needs of both the driver and the grid manager. This coordination will require bi-directional EVs (e.g., the Nissan LEAF), chargers, and meter technology to enable both charging and discharging of the battery. It will also require compatible communication technologies and policies. While NREL and others have made progress in this regard by leading the complete revision of IEEE Standard 1547, the levels of V2G integration discussed in the following section will require further harmonization of components and business practices. Utilities and other stakeholders will also need to address issues related to the vehicle's warranty and condition that may arise from its use on the grid.

Additionally, to minimize energy consumption by EVs during peak periods, utilities and EV owners will need to agree on charging schedules. EV-specific time of use (EV TOU) rate designs can be instrumental in achieving such arrangements. For example, the results of two EV TOU pilot programs offered by San Diego Gas & Electric and Salt River Project, respectively, suggest that participating EV owners shifted their consumption to off-peak hours when appropriately incentivized.[7] Cooperatives across the U.S. are testing this concept with EV TOU rates of their own, using on- and off-peak rates specific to their individual systems.[8] Further information sharing concerning EV-specific rate designs, along with various other technical elements of V2G systems not discussed herein, will be critical to the realization of this promising concept.

> *"By 2025 the typical cooperative is likely to see its 23,000 customers acquire approximately 20 new light-duty EVs annually."*

### *Outlook on V2G Integration*

Under a base case scenario modeled by CoBank's Knowledge Exchange Division, the typical cooperative – defined generally by an average amount of customers and electricity sales – is likely to see noticeable EV uptake in the coming decade. If bi-directional EVs and chargers gradually become commonplace in the same timeframe, as expected, then the typical cooperative could see the following:

**Year 2025**

- 23,000 customers[9] acquire approximately 20 new light-duty EVs annually.
- Light-duty EVs with an average battery size of 100 kWh comprise 4 percent of new vehicle sales.
- Availability of 2.5 MWh or approximately 0.2 percent of the typical cooperative's average total daily electricity sales (including commercial and industrial load).

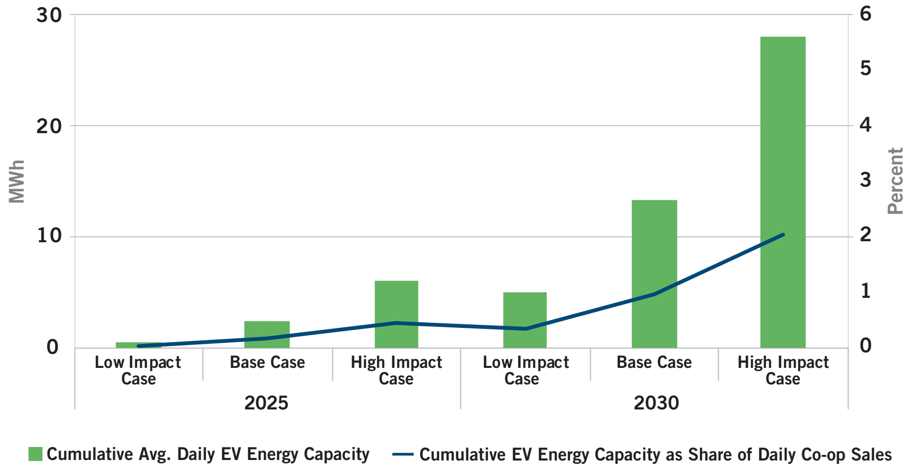
* Assumes 60 percent of each battery's capacity would be made available to the cooperative during peak hours – limited by owner preference, manufacturer-imposed discharge limitations, etc.

**Year 2030**

- 55 new light-duty EVs added to the system annually.
- Light-duty EVs with an average 200 kWh battery size comprise 11 percent of light-duty vehicle sales.[10]
- Availability of nearly 13.6 MWh in battery energy storage capacity cumulatively, amounting to approximately 1.0 percent of average total daily electricity sales.



**EXHIBIT 4: Projected EV Battery Energy Storage Capacity for a Typical Cooperative in 2025, 2030**




Source: CoBank Knowledge Exchange

Under a high-impact scenario (which assumes a slightly higher EV market share, battery capacities, and availability), the typical cooperative could reasonably expect 6.2 MWh and 28.3 MWh of cumulative battery energy storage capacity in 2025 and 2030, respectively. These values would equate to 0.5 percent and 2.1 percent of a typical cooperative's average daily electricity sales in those years, respectively. See *Exhibit 4*.

Over the long term, V2G integration represents an opportunity for electric distribution cooperatives to strengthen their relationships with customers while simultaneously gaining battery energy storage resources for use on their respective systems. However, V2G integration also represents multiple potential challenges with respect to technical and non-technical elements of the customer-utility relationship.

## *Sources Cited*


[1] Everoze & EVConsult

[2] U.S. Energy Information Administration

[3] U.S. Department of Energy

[4] Bloomberg New Energy Finance

[5] National Highway Traffic Safety Administration

[6] International Council on Clean Transportation

[7] The Brattle Group

[8] National Rural Electric Cooperative Association

[9] EIA Form 861

[10] McKinsey & Company