Research

The Cost of Upgrading Electric Distribution

EWELINA CZAPLA | AUGUST 10, 2021

Executive Summary

- The Biden Administration committed the United States to generating carbon pollution-free electricity by 2035 in its submission under the Paris Climate Agreement—a commitment that will require modifying electrical distribution systems.
- Distribution systems deliver electricity to consumers, and these systems will face added strain in response to upstream expansion of the transmission system and consumer adoption of photovoltaic solar panels and electric vehicles.
- The cost imposed on the distribution system by electric vehicle and photovoltaic solar panel adoption alone is nearly $1 trillion.

Introduction

The Biden Administration has committed the United States to generating carbon pollution-free electricity by 2035 under the United Nations Paris Climate Agreement.[1] Achieving this goal will require an unprecedented amount of investment in generation infrastructure—approximately $2 trillion of investment in capital and operations and maintenance costs[2]—as well as the transmission system—an estimated $314 to $504 billion in capital costs.[3] In addition, meeting this goal will require modifying the distribution system (meaning the system that brings electricity to the end user). Not only will upstream expansion and modification require changes to the distribution system, but consumers' growing use of distributed energy resources (DERs) must be addressed through distribution upgrades to ensure reliability.

Utility bills are comprised of costs associated with generation, transmission, and distribution. This analysis builds upon the prior American Action Forum research, which estimated the generation and transmission costs to meet the 2035 goal. Like the prior research, it relies on the provisions of congressional Democrats' proposed Climate Leadership and Environmental Action for our Nation's (CLEAN) Future Act to illustrate potential policy pathways to achieve the Biden Administration's goal, as this bill shares the same goal while containing more policy specifics.

This analysis finds that, as with new generation and transmission, distribution investment would need to increase dramatically as distribution costs would increase by as much $1 trillion to support the adoption of electric vehicles (EV) and photovoltaic (PV) solar panels.

Distribution Development

Distribution systems operated by local utilities were designed to deliver electricity to consumers. These systems could be described as unidirectional, delivering a centralized source of electricity to a passive consumer. Consumers are installing increasing numbers of DERs, however, changing the nature of the distribution system.

DERs include solar photovoltaics (PV), battery storage, demand response systems, and energy efficiency systems. With these technologies, consumers can generate electricity, curb their demand, and send electricity to the grid. These changes have resulted in an increasingly multidirectional, decentralized system where consumers are participants.[4]

Of the total generating capacity in the United States in 2020, about 27 gigawatts (GW) was small-scale solar PV installed in residential, commercial, and industrial settings. The EIA's 2021 Annual Energy Outlook reference case estimates that in 2035 residential distributed generating capacity will be 57 GW (84 billion kilowatt hours [kWh])[5] while commercial distributed generating capacity will be 40 GW (63 billion kWh).[6] That said, "[m]anaging a grid with increasing amounts of customer-sited variable generation increases wear and tear on the distribution equipment required to maintain voltage and frequency within acceptable limits and to manage excessive heating of transformers during reverse power flow."[7] As a result, reliability can be undermined and additional flexibility is required in distribution systems.

The CLEAN Future Act aims to increase the adoption of DERs, such as PV solar panels and EVs. The bill reforms the Public Utility Regulatory Policies Act (PURPA) to establish a standard under which electric utilities offer a community solar program to all ratepayers. It also calls for the establishment of a program to provide loans and grants for the construction or installation of community solar facilities or solar generating facilities to serve multi-family affordable housing.

The CLEAN Future Act also amends PURPA to require states to consider implementing policies that encourage deployment of battery storage systems, microgrids, electric vehicle charging stations, and other DERs. The amendments would also allow utilities' rate recovery to include DERs in the same way it includes transmission and distribution costs; historically, decided by states . The bill suggests that the Department of Energy (DOE) take on a role traditionally reserved for the private sector, and utilities in particular, by determining where it thinks demand for EV charging may occur in the future. It would create grants to determine where charging stations may be needed to meet demand and to make that data publicly available. It would also seek to increase the deployment and accessibility of electric vehicle charging infrastructure in underserved or disadvantaged communities.

Assumptions

The following analysis is focused on the impact of consumer adoption of PV solar panel installations and EVs. The analysis does not include the cost incurred by the consumer to purchase the equipment. Instead, the analysis reflects the capital costs incurred to modify the distribution system to accommodate the adoption of PV and EVs.

Costs to the distribution system associated with the adoption of PV solar panels and EVs by consumers will ultimately vary from one utility to another. In particular, the costs will be driven by each utility's ability to successfully forecast the adoption of this technology in their service area.

PV Solar Panels

In a study of utilities in the Western Interconnection, the western half of the domestic grid, the National Renewable Energy Laboratory found that during a 15-year period (2016–2030), "systematically misforecasting DPV adoption over multiple successive planning cycles increases the present value of utility system costs by up to $7 million per terawatt-hour ([2017$/]TWh) of electricity sales, relative to utility system costs under a perfect forecast."[8] Since this value represents the highest possible cost, this analysis assumes a cost of $3.5 million per TWh.

The analysis assumes that the installation of small-scale solar photovoltaic systems (capacity less than 1 megawatt) will continue to grow from 23.2 GW in 2019 by about 5 GW per year.[9] The capacity is assumed to generate electricity in 2035 at the same rate as in 2020, about 4 hours each day.[10]

EV Adoption

A study conducted by Boston Consulting Group (BCG) found that "depending on charging patterns, [utilities] will need to invest between $1,630 and $5,380 in grid upgrades per electric vehicle (EV) through 2030." The variation in cost is associated with the number of electric vehicles attempting to charge as well as the time of day in which the charging takes place. It considers the fluctuations in electricity demand throughout the day and the cost of optimized and unoptimized EV charging. The costs are based on an estimated 10 to 20 percent market penetration by EVs. The study also found that with increasing EV market penetration, utility rates for consumers continue to grow.[11] The study was completed in 2019 and only estimates cost through 2030, an approximately 10-year period. For the purposes of this analysis, an additional 5 years of cost will be added to the total cost.

The number of new vehicles sales is estimated to grow until 2035 when it reaches about 19 million new car sales per year, according to a Deloitte study. Similarly, the number of new EV sales per years is expected to grow. In 2035, 45 percent of new cars sold in the United States are projected to be EVs, in Deloitte's "disruptive" scenario.[12] This estimate is also in keeping with President Biden's executive order calling for 50 percent of car sales in the United States produce zero-emissions by 2030.[13] This analysis will rely on the disruptive estimates. The total number of EVs on the road will be determined by assuming linear growth in sales between 2020, when 2 percent of the 14.6 million cars sold were EVs, and 2035.[14]

Analysis

To determine the cost to the distribution system due to the installation of PV solar panels, the total generating capacity was calculated by adding 5 GW per year from 2020 to 2035 resulting in a total of approximately 102 GW of generating capacity in 2035. The generating capacity installed since 2020 was multiplied by the hours of generation time to produce 154,656,606,550.28 MWh. When the assumed $3.5 million per TWh cost is applied to the total electricity generated in 2035, the result is a cost of $395 billion.

To determine the costs associated with electric vehicles, the assumed linear trend in the growth of car sales and percentage of EV sales were calculated. The compounded annual growth rate for EV sales was applied to the annual car sales to determine the total quantity of cars sold between 2020 and 2030. The total quantity of vehicles sold was then multiplied by $1,630 and $5,380 per EV and an additional 50 percent was added to capture the additional 5 years of cost. The total cost ranges from $161 billion to $533 billion.

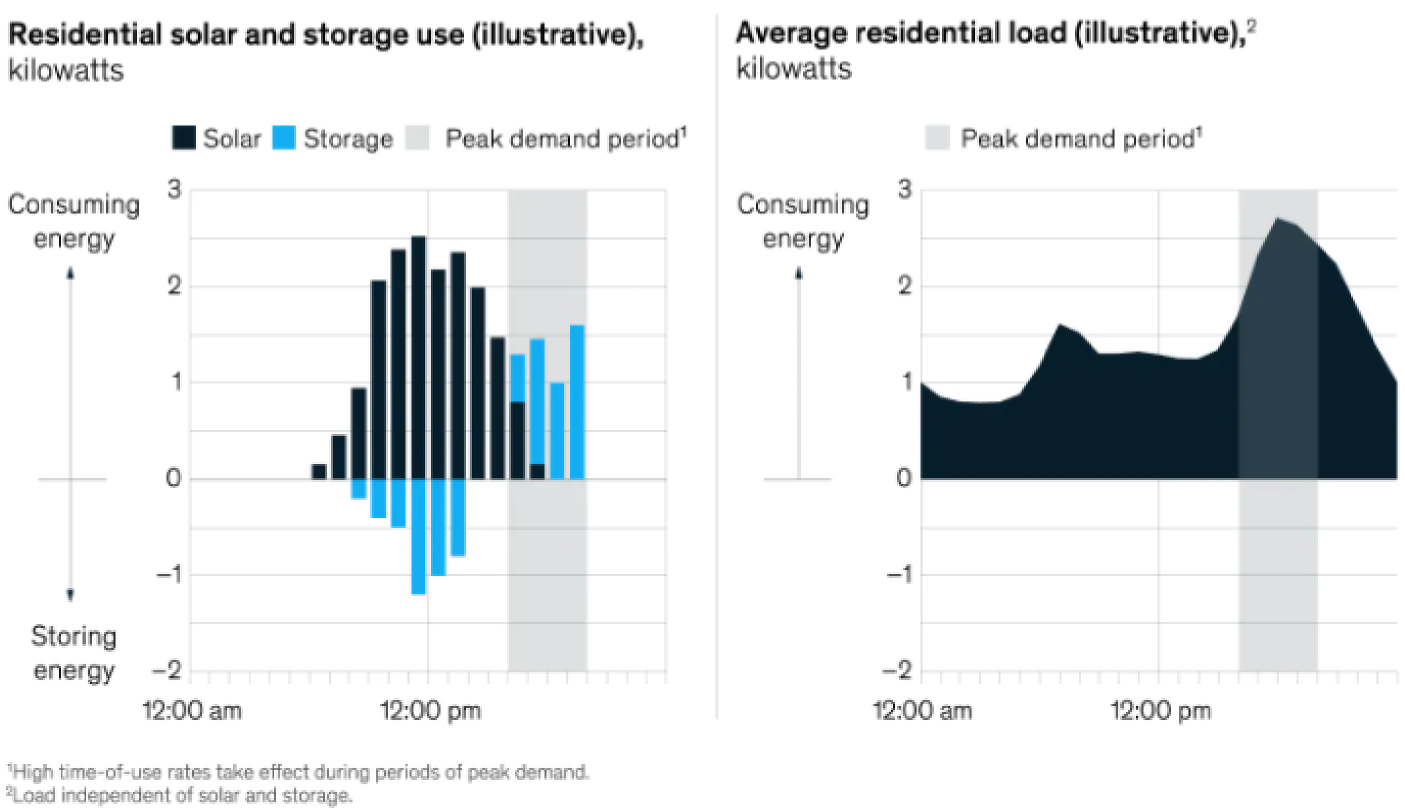
In total, the adoption of EVs and PV solar panels could create nearly $1 trillion of costs for the distribution system. These costs, however, only reflect a portion of the modifications necessary. They do not account for costs associated with battery storage that has been increasingly adopted in recent years. And, more broadly, costs will be created for the distribution system when the transmissions system is expanded and modified.

Over the course of 15 years, up to $61 billion would need to be invested annually to meet these costs. In 2019, when utility spending was at record highs, $31.4 billion was spent by utilities to replace, modernize, and expand existing distribution infrastructure. These costs were largely attributed to the construction and expansion of power lines.[15] The level of PV and EV adoption forecasted would therefore require distribution investment to double.

Discussion

Estimating the cost incurred by the distribution system is difficult because it is responsive to consumer trends. The extent to which consumers choose to adopt electric vehicles, PV solar panels, and other DER as well as the duration and timing of their usage impacts the rate at which utilities will modify distribution systems. Rebates and grants such as those that the CLEAN Future Act proposes may incentivize adoption.

In addition, utilities may implement policies that incentivize beneficial consumer behavior that reduces the need for constructing additional distribution facilities. Pricing schemes, such as time-of-use rates, may incentivize consumers to use DERs at a particular time of day that is most beneficial to the distribution system, reducing the modifications necessary to maintain reliability. The graphic below demonstrates the use of solar and accompanying battery storage to reduce reliance on the distribution system during peak demand periods. Alternatively, consumers may allow utilities to limit the power they consume by granting them access to control DERs.



SOURCE: MCKINSEY & COMPANY

Novel policies in electric regulation have proven difficult to implement due to increasingly competing interests posed by consumers who have or have not chosen to install DERs and utilities that are obligated to provide electricity at a reasonable rate while responding to state and federal policies. For example, net metering, the practice by which utilities pay consumers for the electricity they introduce to the grid, has become contentious. Consumers that introduce electricity to grid from their PV solar panels generate income that is reflected on their utility bill. The costs that are borne by the utility in modifying its system to accommodate PV solar panels, however, are passed on to all its ratepayers. As a result, those that do not install PV solar panels pay for these costs as well. Consumers who do not install PV solar panels may even carry a larger portion of the costs than those who do.[16]

Ultimately, the costs to distribution systems are reflected in the utility rates paid by consumers. In the case of EV adoption, for example, BCG found that a majority of its modeling resulted in rate increases between 1.4 and 12 percent.

Conclusion

The Biden Administration's commitment to attain carbon pollution-free electricity by 2035 will require expansion and modification of generation, transmission, and distribution infrastructure. These modifications are further complicated by the increasing adoption of DERs, such as PV solar panels and EVs. Distribution system modifications would require unprecedented amounts of investment, nearly $1 trillion, in ways similar to the generation and transmission systems. Together the three sectors could require over $3 trillion of investment over the next 15 years.

[1]
https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/United%20States%20of%20America%20First/United%2

[2] https://www.americanactionforum.org/research/the-cost-of-clean-generation/

[3] https://www.americanactionforum.org/research/the-cost-of-upgrading-electricity-transmission/

[4] https://www.nrel.gov/docs/fy20osti/74412.pdf

[5] https://www.eia.gov/outlooks/aeo/data/browser/#/?id=30-AEO2021&cases=ref2021&sourcekey=0

[6] https://www.eia.gov/outlooks/aeo/data/browser/#/?id=32-AEO2021&cases=ref2021&sourcekey=0

[7] https://www.eia.gov/todayinenergy/detail.php?id=36675

[8] https://www.nrel.gov/docs/fy18osti/71042.pdf

[9] https://www.eia.gov/outlooks/steo/report/electricity.php;
https://www.eia.gov/electricity/annual/html/epa_03_01_b.html

[10] https://www.eia.gov/outlooks/aeo/data/browser/#/?id=16-AEO2021&cases=ref2021&sourcekey=0

[11] https://www.bcg.com/publications/2019/costs-revving-up-the-grid-for-electric-vehicles

[12] https://www2.deloitte.com/global/en/pages/consumer-business/articles/future-of-car-sales-in-2035.html

[13] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/08/05/executive-order-on-

strengthening-american-leadership-in-clean-cars-and-trucks/ https://www.wsj.com/articles/u-s-to-set-electric-vehicle-sales-target-of-50-by-2030-11628154000?mod=politics_lead_pos1

[14] https://www.pewresearch.org/fact-tank/2021/06/07/todays-electric-vehicle-market-slow-growth-in-u-s-faster-in-china-europe/ ; https://ihsmarkit.com/research-analysis/global-electric-vehicle-sales-grew-41-in-2020-more-growth-comi.html

[15] https://www.eia.gov/todayinenergy/detail.php?id=48136 Additionally, $14.6 billion was spent on operations and maintenance, and $11.5 billion was spent on customer expenses, such as advertising, billing, and customer service.

[16] https://www.ncsl.org/research/energy/net-metering-policy-overview-and-state-legislative-updates.aspx