U.S. DEPARTMENT OF ENERGY | Office of Policy

Queued Up… But in Need of Transmission

Unleashing the Benefits of Clean Power with Grid Infrastructure

The nation needs transmission infrastructure to unlock the enormous benefits and opportunities that the clean energy transition presents from spurring economic growth, to revitalizing domestic manufacturing, to creating millions of good jobs for American workers. Moreover, studies often find that the benefits of transmission exceed the costs, by enabling access to low-cost generation, helping to maintain reliability and avoid power outages, and supporting clean energy supply.

Yet, a large amount of potential clean power capacity is struggling with the wait times and costs of connecting to the transmission grid, and the construction of new high-voltage transmission lines has declined over the last decade. To alleviate the growing gridlock, transmission planning and interconnection processes need reform. Permitting and allocating costs for transmission also pose barriers, both for generator interconnection and regional and inter-regional grid infrastructure.

The Bipartisan Infrastructure Law contains important economic programs and authorities to help kick-start transmission investments. The proposed climate and clean energy incentives package in Congress would go much further in supporting large-scale transmission investment, including through a 30% investment tax credit.

Beyond these two Acts—one a law and one a proposed law—the U.S. Department of Energy is working to support transmission investment through the 'Building a Better Grid' Initiative. Actions by the Federal Energy Regulatory Commission (FERC), regional planning organizations, grid operators, states, utilities, and others will also play critical roles in facilitating and maximizing the benefits of new transmission. An all-of-government and all-of-society approach is crucial to fully realize the benefits of a modernized grid and move the nation forward to a more secure and equitable clean energy future for all Americans.

Queued-Up

The total amount of new electric generation capacity needed to meet ambitious 2030 clean energy goals is already in the early development pipeline.

More than 930 gigawatts (GW) of solar, wind, hydropower, geothermal, and nuclear capacity are currently sitting in interconnection queues seeking transmission access, along with over 420 GW of energy storage (Figure 1).[1] This is roughly the same amount of clean capacity needed to hit an 80% clean electricity share in 2030. It is also a large step towards the capacity needed to reach 100% clean electricity in 2035 under accelerated electrification, consistent with the nation's decarbonization commitments.[2]

[1] Rand et al. 2022. "Queued Up: Characteristics of Power Plants Seeking Transmission Interconnection As of the End of 2021." Berkeley Lab.

[2] An 80% clean electricity scenario for 2030 estimates the need for ~950 GW of new clean power capacity and ~225 GW of storage (Abhyankar et al. 2021. "2030 Report: Powering America's Clean Economy." UC Berkeley, Goldman School of Public Policy.). A separate study from the U.S. Department of Energy assesses a scenario that reaches ~70% clean by 2030, envisioning ~510 GW of additional clean power capacity and 60 GW of storage by 2030 (DOE. 2021. "Solar Futures Study." U.S. Department of Energy.). Finally, the Long-Term Strategy of the United States establishes a pathway to net-zero greenhouse gas emissions by 2050, inclusive of a 100% clean electricity share by 2035; it requires 1,680-1,800 GW of new clean power capacity by 2035 as well as 130-150 GW of battery storage (United States Executive Office of the President. 2021. "The Long-Term Strategy of the United States: Pathways to Net-Zero Greenhouse Gas Emissions by 2050." Washington, D.C.).

These prospective projects are spread widely across the nation. At a minimum, this demonstrates that developers are interested in building-out clean power projects in all regions of the country, with significant potential infrastructure investment and related benefits such as job creation and economic growth—but these benefits are only realized if developers can get their projects over the finish line.

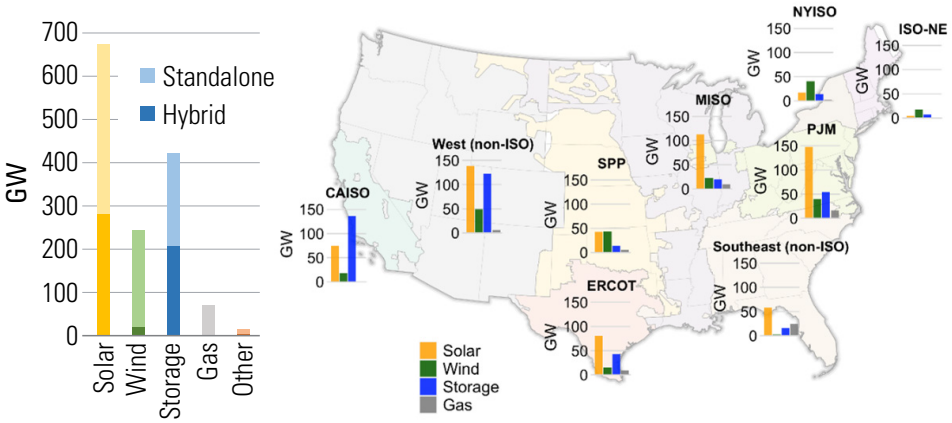
What Are Interconnection Queues?

Grid operators require projects seeking to connect to the grid to undergo a series of impact studies, to insure the grid will remain safe, stable, and reliable when new generators plug in. This process establishes what new transmission upgrades are needed before a project can connect to the system, and then estimates and assigns the costs of those upgrades to the project and/or transmission owner. Projects in this process are known to be in the interconnection queue.

Gridlocked

Many of these prospective clean power projects are struggling to connect with the transmission grid. Failure rates and wait times in the queues suggest growing interconnection and transmission challenges. These challenges present an opportunity to improve institutional processes.

Figure 1. Power Plants Seeking Transmission Connection by Type (left) and Mapped to Region (right)



Notes: (1) Hybrid plants are those paired with one or more other type of generation or storage. (2) Data for Alaska and Hawaii were not collected. Represents queues as of the end of 2021.

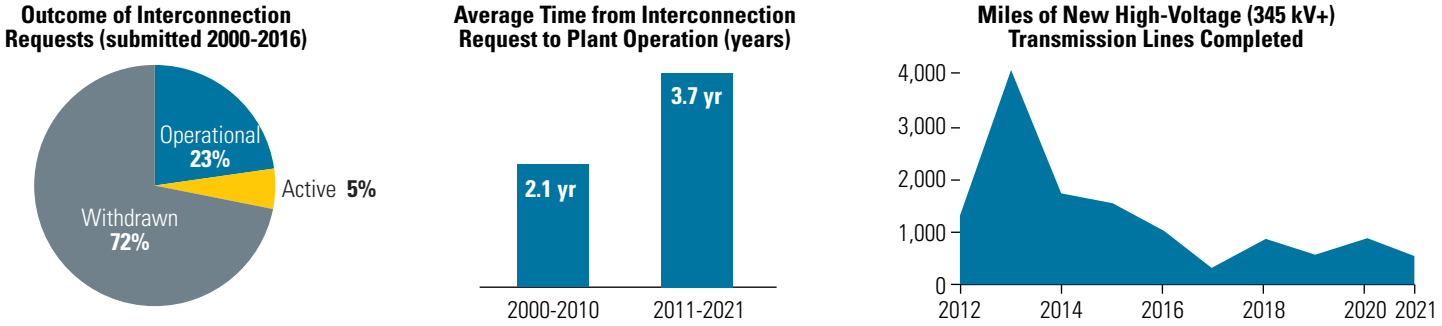
Among a subset of queues for which data are available, less than one-quarter of the projects that sought connection from 2000 to 2016 have been built (see Figure 2). Importantly, completion percentages appear to be declining in recent years (since 2013) and are lower for wind (20%) and solar (16%) than for natural gas (33%). Wait times are also on the rise: in four independent system operators (ISO), the typical duration from interconnection request to commercial operation for all project types increased from ~2.1 years for projects built in 2000-2010 to ~3.7 years for those built in 2011-2021.[3]

These trends partly reflect strong growth in interconnection requests and other factors, but they are also driven by transmission upgrade costs that, in many cases, the interconnecting generator must bear. Specifically, developers often incur costs *not only* to connect to the existing transmission system, but also costs needed to upgrade the broader, high-voltage transmission grid.[4] These latter upgrade costs can be significant,[5] are hard to predict in advance, and can provide system-wide benefits that extend beyond the interconnecting generator.[6] Larger transmission upgrades and investments of this nature may benefit from a more planned and coordinated process than can be achieved when processing individual generator interconnection requests one-by-one, and build-out of the higher-voltage grid can ease the interconnection process.[7]

While lack of access to transmission is a major barrier, there are many potential reasons that proposed power plants do not always move to the construction phase. Some projects in the queues are

[3] Rand et al. 2022. "Queued Up: Characteristics of Power Plants Seeking Transmission Interconnection As of the End of 2021." Berkeley Lab.
[4] Caspary et al. 2021. "Disconnected: The Need for a New Generator Interconnection Policy." Americans for a Clean Energy Grid.
[5] Gorman et al. 2019. "Improving estimates of transmission capital costs for utility-scale wind and solar projects to inform renewable energy policy." Energy Policy 135: 110994.
[6] ICF. 2021. "Just & Reasonable? Transmission Upgrades Charged to Interconnecting Generators Are Delivering System-Wide Benefits." Prepared for the American Council of Renewable Energy.
[7] Caspary et al. 2021. "Disconnected: The Need for a New Generator Interconnection Policy." Americans for a Clean Energy Grid.

Figure 2. Indicators of the Challenges Facing Transmission Interconnection, Planning, and Construction



more exploratory in nature, in part driven by uncertainty in the scope and cost of necessary transmission upgrades and the extended timelines associated with the current interconnection process. Other challenges include securing land, permits, community support, power purchasers and financing, as well as unanticipated changes to project economics and available policy incentives. Regardless, there is growing recognition that the interconnection process needs to be reformed, and that current backlogs in the queues are an indicator of the need for improved transmission planning and enhanced transmission investment.

Transmission Needed

There is a need to refresh the nation's approach to larger-scale, regional and inter-regional transmission infrastructure, tackling challenges related to permitting, planning, and cost allocation. Many of the best wind and solar resources are not located near existing transmission infrastructure; new transmission lines would be needed to access these areas. Despite this reality, and despite significant expenditure on transmission upgrades in recent years, the number of miles of newly built high-voltage transmission has declined over the last decade from an annual average of 2,000 miles from 2012-2016 to an average of just 700 miles from 2017-2021 (Figure 2).[8]

Studies often find that the benefits of transmission infrastructure exceed the costs—by enabling access to low-cost generation and sharing resources over broader geographic regions and in helping to maintain reliability and avoid power outages.[9] What's more, transmission investment can enable clean energy growth and its associated benefits, helping the nation meet its climate goals, growing the economy, creating jobs for American workers, and making the air we breathe cleaner and our communities healthier.[10] By its very nature, the interconnection process as currently designed is an inefficient means of building out this transmission infrastructure; indeed, current queue backlogs are to a degree a symptom of the need for a more planned and coordinated process for large-scale transmission investment.

Studies differ in their estimates of the optimal amount of new transmission, in part due to different input assumptions and modeling approaches. Many topologies deserve consideration, and growth in storage may reduce the need for new transmission to some degree—at least relative to cases without storage.[11] Variations in estimated transmission build and investment across studies is also partly definitional: some only report large-scale inter-regional transmission, whereas others report all transmission including high-voltage lines, transmission upgrades, and the lines needed to connect generators

[8] FERC. 2022. "Energy Infrastructure Update." Federal Energy Regulatory Commission (and earlier editions).

[9] For example: (1) FERC. 2020. "Report on Barriers and Opportunities for High Voltage Transmission." Prepared by staff of the Federal Energy Regulatory Commission. (2) SPP. 2016. "The Value of Transmission." (3) PJM. 2019. "The Benefits of the PJM Transmission System." (4) MISO. 2017. "MTEP17 MVP Triennial Review." (5) Brinkman et al. 2020. "Interconnections Seam Study." National Renewable Energy Laboratory. (5) MISO. 2022. "LRTP Tranche 1 Portfolio Detailed Business Case."

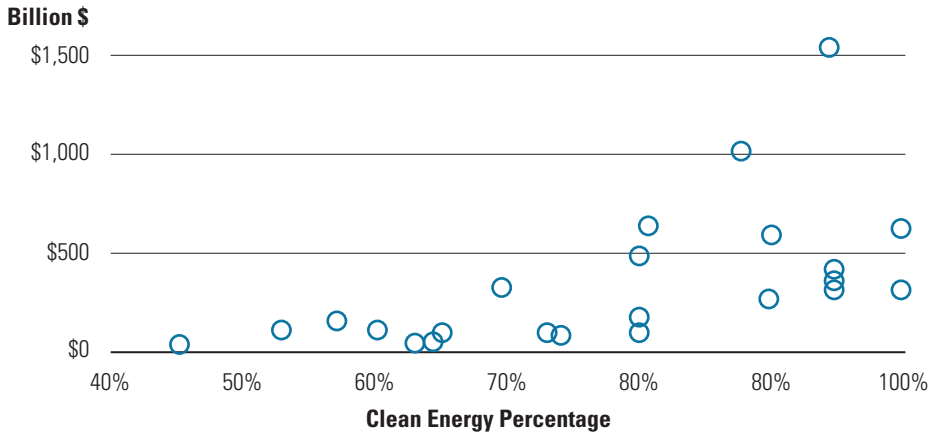
[10] ESIG. 2021. "Transmission Planning for 100% Clean Electricity." Energy Systems Integration Group.

[11] See: (1) Jayadev et al. 2020. "U.S. electricity infrastructure of the future: Generation and transmission pathways through 2050." *Applied Energy* 260: 114267. (2) Abhyankar et al. 2021. "2030 Report: Powering America's Clean Economy." UC Berkeley, Goldman School of Public Policy.

to the nearest substation or load center. Regardless, numerous studies demonstrate that significant grid investment is needed to reach high clean energy shares (see Figure 3[12]).

Many studies also show that investing in the power grid provides benefits in excess of costs. Focusing on national-scale studies, one assessment finds that investing in large-scale transmission could save the nation $1 trillion under a 95% clean energy future, relative to the same scenario but without those grid investments.[13] Another study concluded that inter-state coordination and transmission expansion would reduce the system cost of a 100% clean power system by 46% compared with a hypothetical state-by-state approach.[14] A study from the National Renewable Energy Laboratory estimated benefit-to-cost ratios of around 2-to-1 for large-scale inter-regional transmission expansion under high clean power futures.[15] Other studies have found that inter-regional transmission infrastructure may be somewhat less crucial in achieving high levels of clean power supply when low-cost storage and solar are available (relative to wind heavy systems), though even in this case significant transmission would still be necessary.[16]

Figure 3. Transmission Investment with Growing Clean Energy Shares



Expanding the Transmission Grid

The nation needs transmission infrastructure to achieve high shares of clean energy, and that infrastructure provides numerous benefits beyond its contribution to power-sector decarbonization. Backlogs in the generator interconnection process and recent studies focused on national transmission needs both point to a common conclusion—policy will play a vital role in facilitating and maximizing the benefits of new transmission. Permitting, planning, and paying for transmission all pose barriers, both for generator interconnection and for higher-voltage regional and inter-regional grid infrastructure.[17]

The Bipartisan Infrastructure Law—enacted in November 2021—contains financing programs and authorities to help kick-start transmission investments, a subset of which are listed in Table 1. Notably, these include a $2.5 billion transmission facilitation program and revised authorities for the designation of national electric transmission corridors.

[12] The figure summarizes cumulative (undiscounted) transmission investment costs at varying clean energy percentages—also with varying time-periods. Sources: (1) Larson et al. 2021. "Net-Zero America." Princeton University. [E+ scenario]. (2) Brinkman et al. 2020. "Interconnections Seam Study." National Renewable Energy Laboratory. (3) Brown and Botterud. 2021. "The Value of Inter-Regional Coordination and Transmission in Decarbonizing the US Electricity System." *Joule* 5(1): 115-134. (4) Clack. 2021. "The role of transmission in deep decarbonization." Energy Systems Integration Group Webinar. (5) Abhyankar et al. 2021. "2030 Report: Powering America's Clean Economy." UC Berkeley, Goldman School of Public Policy. (6) Cole et al. 2021. "Quantifying the Challenge of Reaching a 100% Renewable Energy Power System for the United States." *Joule*, doi.org/10.1016/j.joule.2021.05.011. (7) Cole and Craig. 2021. "2021 Standard Scenarios Report: A U.S. Electricity Sector Outlook." National Renewable Energy Laboratory. Only a subset of published scenarios are included in the figure. Note also that the y-axis scale in the figure is curtailed; Larson et al.'s transmission investment estimates extend above this scale at clean energy shares above 95% under an economy-wide zero-carbon pathway, reaching $2,210 billion with a 98% clean energy share in 2050.

[13] Clack. 2021. "The role of transmission in deep decarbonization." Energy Systems Integration Group Webinar.

[14] Brown and Botterud. 2021. "The Value of Inter-Regional Coordination and Transmission in Decarbonizing the US Electricity System." *Joule* 5(1): 115-134.

[15] Brinkman et al. 2020. "Interconnections Seam Study." National Renewable Energy Laboratory.

[16] See: (1) Abhyankar et al. 2021. "2030 Report: Powering America's Clean Economy." UC Berkeley, Goldman School of Public Policy. (2) Jayadev et al. 2020. "U.S. electricity infrastructure of the future: Generation and transmission pathways through 2050." *Applied Energy* 260: 114267.

[17] See, e.g.: (1) Joskow. 2021. "Facilitating Transmission Expansion to Support Efficient Decarbonization of the Electricity Sector." MIT Center for Energy and Environmental Policy Research. (2) Pfeifenberger et al. 2021. "Transmission Planning for the 21st Century: Proven Practices that Increase Value and Reduce Costs." Brattle and Grid Strategies.

Table 1. Bipartisan Infrastructure Law: Subset of Transmission-Related Provisions Now Being Implemented*

Transmission facilitation program	$2.5 billion revolving fund for DOE to facilitate the construction of large-scale transmission via capacity reservation contracts, loans, and public-private partnerships
Designation of National Interest Electric Transmission Corridors	Enables FERC to issue a federal permit in a DOE-designated corridor when a state rejects the project; establishes that DOE is to look at future capacity constraints when designating corridors
Preventing outages and enhancing the resilience of the electric grid	$5 billion for DOE grants to states, tribes, and utilities to reduce the likelihood and consequences of disruptive events on the power grid, including hardening transmission
Energy infrastructure federal financial assistance program	$5 billion for DOE grants to demonstrate innovative approaches to transmission, storage, and distribution infrastructure, and new approaches to enhance regional grid resilience
Deployment of technologies to enhance grid flexibility	$3 billion for DOE grants to enhance grid flexibility, including advanced transmission technologies such as dynamic line rating, flow control devices, advanced conductors, and network topology optimization

* Additional transmission related programs are briefly described in DOE's 'Building a Better Grid' Notice of Intent[18]

The proposed climate and clean energy incentives package legislation would go much further—as an engine of clean power growth and in supporting grid investment, including through a 30% investment tax credit and a variety of grant and loan programs focused on transmission infrastructure.

In addition to implementing provisions in the *Bipartisan Infrastructure Law*, the Department of Energy is also acting within pre-existing authorities to catalyze nationwide development of new and upgraded high-capacity transmission lines through its 'Building a Better Grid' initiative. Under this initiative, DOE will identify critical national transmission needs and support the buildout of transmission facilities that meet those needs through collaborative transmission planning, innovative financing mechanisms, coordinated permitting, and continued research and development. The Department's Notice of Intent[19] describes these coordinated activities in further detail.

Beyond these steps, FERC has a leading role to play in establishing and reviewing the rules implemented by grid operators and utilities for interconnection, transmission planning, and cost allocation. FERC's ongoing rulemaking 'Building for the Future through Electric Regional Transmission Planning and Cost Allocation and Generator Interconnection' is tackling these critical issues.[20] Active engagement by regional planning organizations, grid operators, utilities, states, non-governmental organizations, and the private sector will also be important, as these stakeholders are each engaged in varying ways in planning, regulating, and implementing interconnection procedures and transmission expansion. Finally, government bodies at all levels will dictate the structure and pace of the transmission permitting process, as will impacted communities.

The benefits of a modernized grid will be fully realized only with an all-of-government and all-of-society approach.

[18] https://www.energy.gov/articles/doe-launches-new-initiative-president-bidens-bipartisan-infrastructure-law-modernize
[19] https://www.energy.gov/articles/doe-launches-new-initiative-president-bidens-bipartisan-infrastructure-law-modernize
[20] https://www.ferc.gov/news-events/news/advance-notice-proposed-rulemaking-building-future-through-electric-regional