Can we Short Circuit the Interconnection Queue?

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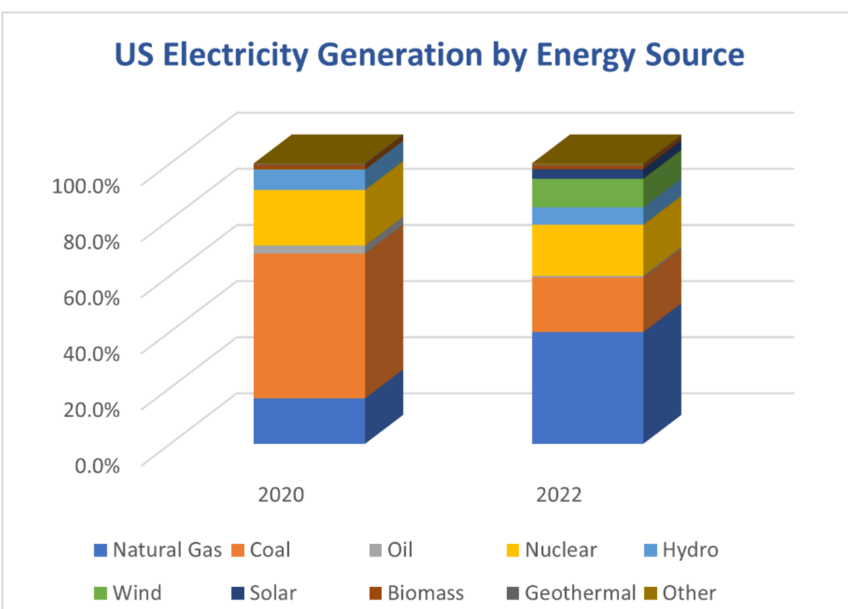
Heading Towards the Energy Transition

There is no question that the US has started the process of moving towards the energy transition. For example, with respect to national electricity generation, in 2000 only 9% was from renewable sources, with hydropower representing the vast majority of that (and solar virtually zero). By 2022 renewable energy represented more than 21% of all US electricity generation, with wind being responsible for 10% and solar responsible for more than 3%. During that period coal dropped from being responsible for more than 50% to under 20% and oil dropped from over 3% to almost 0%; but natural gas grew from 16% to 40%, and fossil fuels still represented 60% of electricity generation.



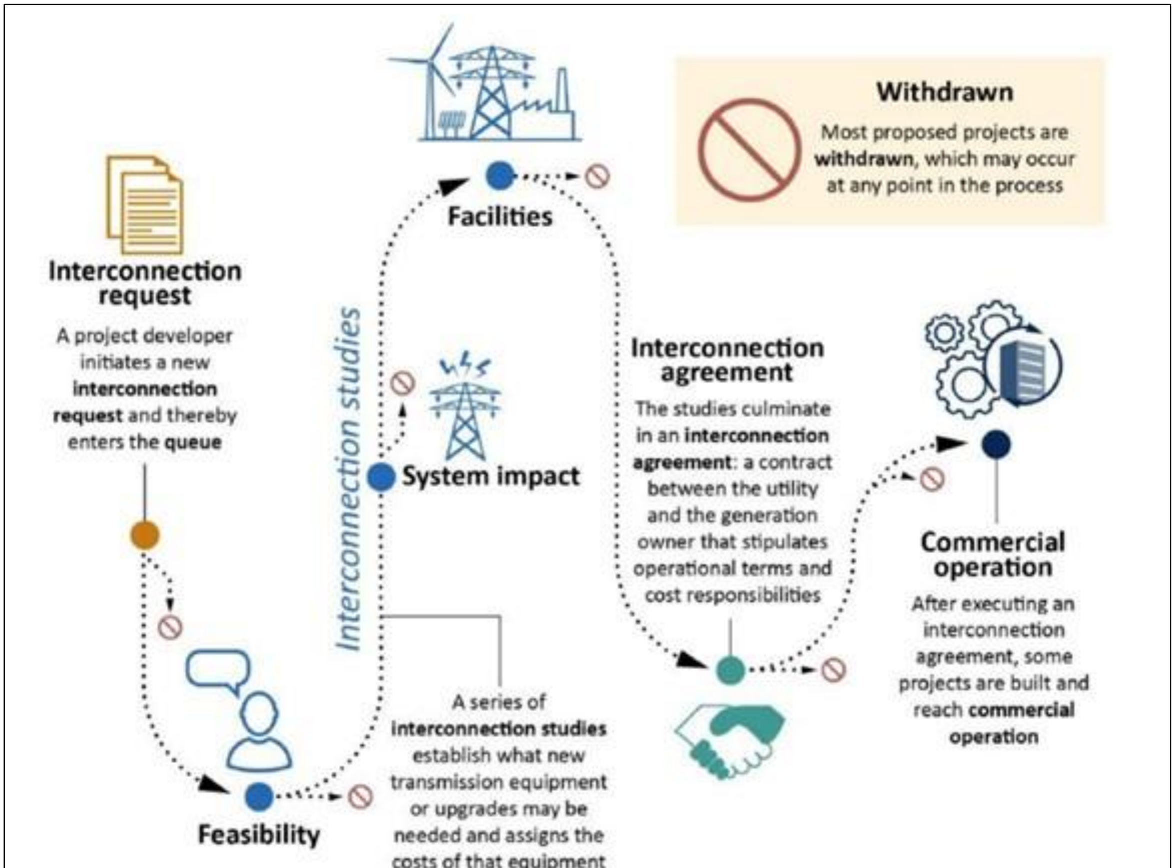
While progress has been slow, we are clearly moving in the right direction. And there are a large number of solar and wind generation projects waiting for approval, along with a large number of storage projects aimed at addressing the intermittent nature of solar and wind.

And therein lies the problem.

The Interconnection Queue

Electric transmission system operators (ISOs, RTOs, and utilities) require projects seeking to connect to the grid to undergo a series of impact studies before they can be built. This process establishes what new transmission equipment or upgrades may be needed before a project can connect and assigns the costs of that to the project applicants. During what is known as the system impact study phase such studies include short circuit analyses, stability analyses, and power flow analyses. In the facilities study phase, grid operators build upon the findings of the system impact phase by identifying the physical infrastructure and associated procurement that would be required to integrate the proposed project. The grid operators may also appraise the suitability of a proposed project based on its existing resource mix, reliability factors, and other parameters that reflect how a new or modified interconnection point would impact overall grid operations.

The list of projects in this process is known as the ***Interconnection Queue***.



Source: Derived from image courtesy of Lawrence Berkeley National Laboratory and used with permission. | GAO-23-105583

The number of projects in the Interconnection Queue has grown dramatically over the last 20 years, resulting in major delays in getting projects approved. More than 10,000 energy projects — the vast majority of them wind, solar, and storage — were waiting for permission to connect to electric grids at the end of 2022, up from 8,100 the year before and 5,600 in 2020. As a result, interconnection wait times until approval have grown significantly. They averaged five years in 2022, up a year from the average of four years for projects built between 2018 and 2021 and more than double the time it took about a decade ago.

Interconnection Queue lengths are now widely recognized among developers and other stakeholders as the No. 1 barrier to deploying renewable energy.

And when companies finally get their projects reviewed, they often face another hurdle: the local grid is near or at capacity, and they are required to spend much more than they planned for new transmission lines and other upgrades – if the lines can be built at all. A study from Princeton University and the National Renewable Energy Laboratory estimates that the transmission system will need to expand by 60 percent by 2030 to accommodate the demand for renewables. More on this theme later.

And building sufficient transmission infrastructure to support the projects in the queue is not just a technical challenge but also a political one - since the coordination and planning that's required may involve multiple utilities and grid operators, as well as multiple states, cities, and counties.

Many applicants give up before their proposals are approved. According to the Lawrence Berkeley National Laboratory, fewer than a quarter of solar and wind proposals actually make it through the Interconnection Queue. Moreover, about 72% of projects requested between 2000 and 2016 were ultimately withdrawn entirely. And that creates a new problem: when a proposed energy project drops out of the queue the grid operator often has to redo studies for other pending projects - and shift costs to other developers, which can trigger more cancellations and delays.

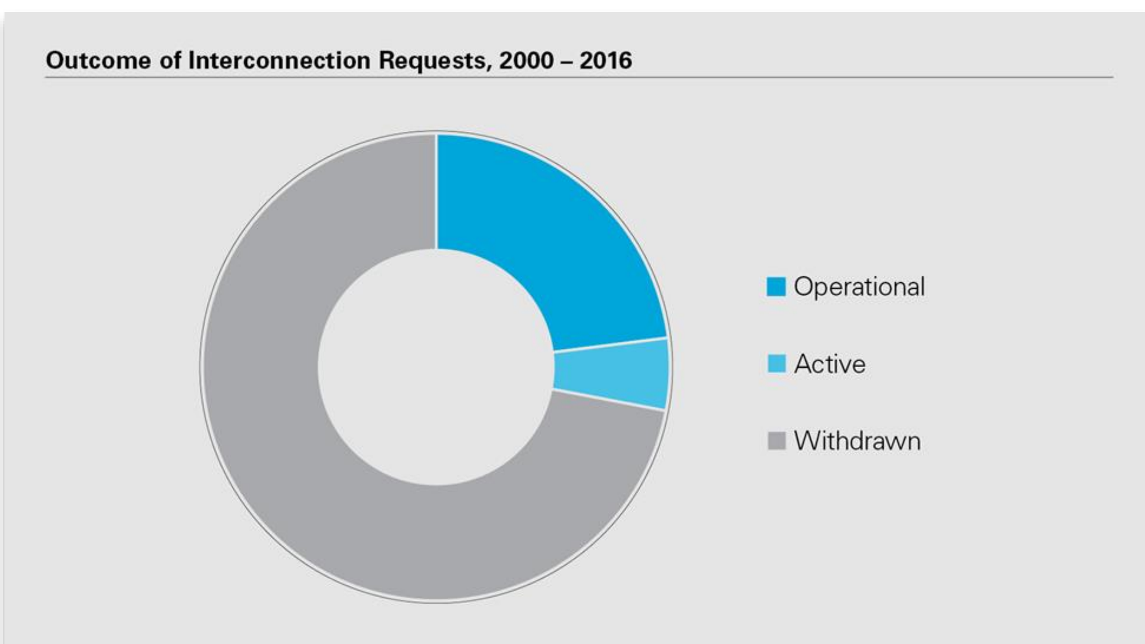
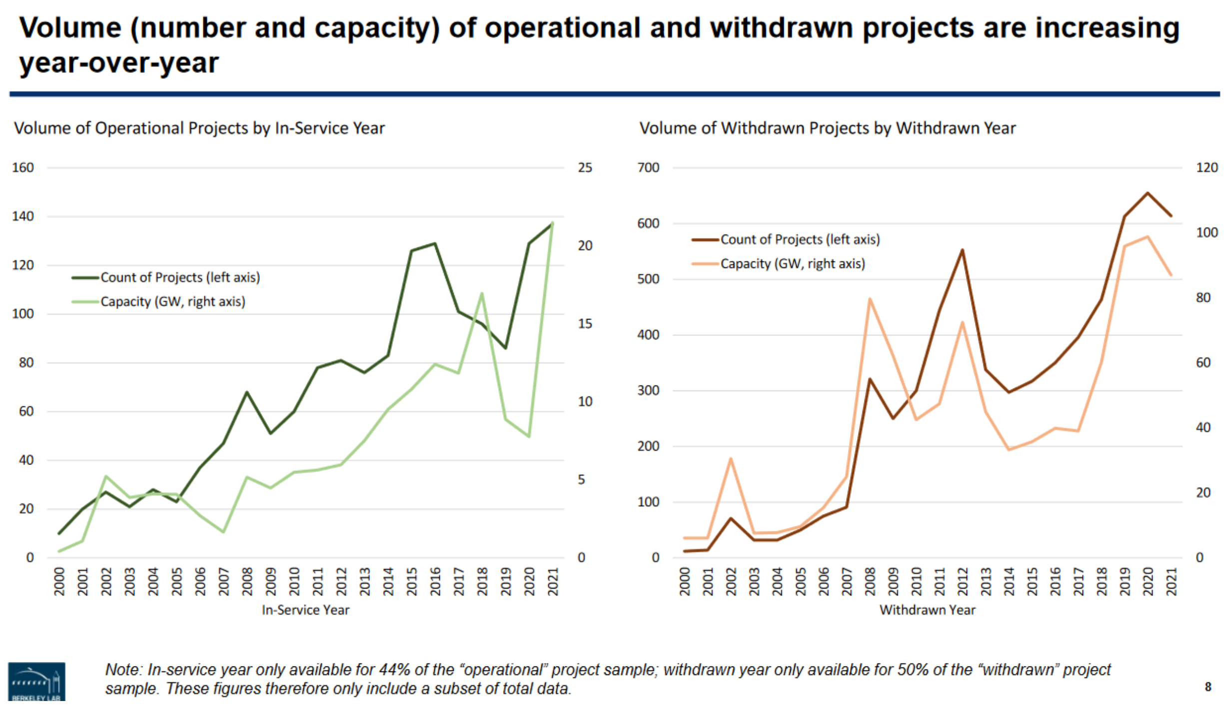


Chart courtesy of Berkeley National Laboratory

Some developers will submit multiple proposals for wind and solar farms at different locations without intending to build them all. Instead, they hope that one of their approvals will come after that of another developer who will then have to pay for the network upgrades. Or they shop the same project around to multiple regional grid operators in order to find the best deal. The rise of this sort of speculative bidding (or "speculative queuing") has further jammed the queue.

Furthermore, in many cases successful applicants have not proceeded to construct and operate a renewable generating facility if agreements have not been reached with customers to purchase the energy.

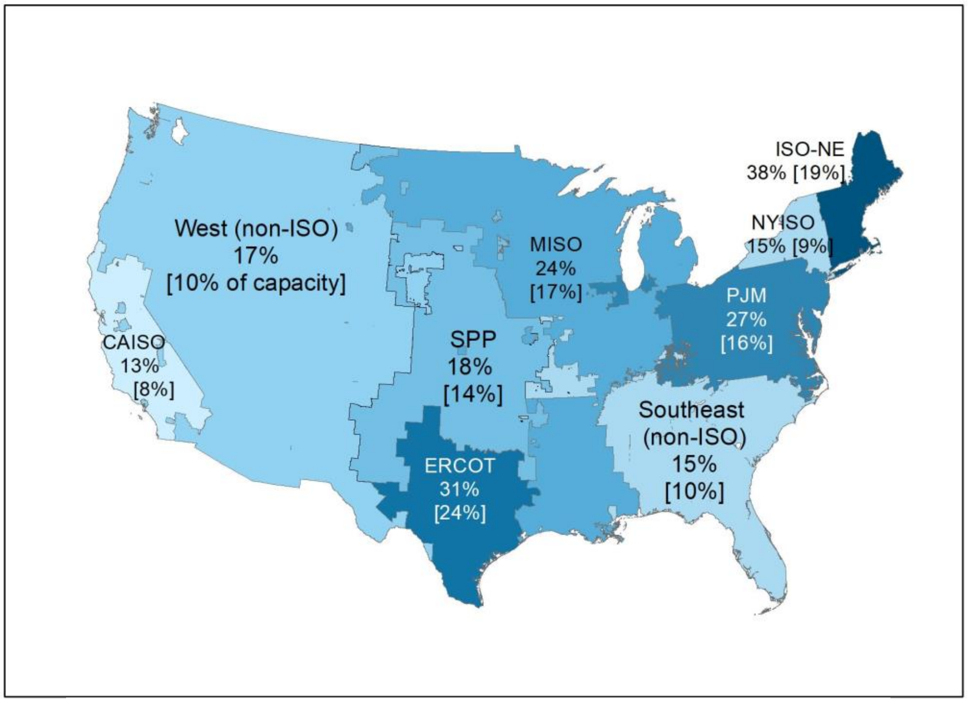
Both the number of project applications and project withdrawals have been rising considerably on a year-to-year basis, as evidenced in the following graph from Berkeley National Laboratory.



The rates of interconnection applications that actually reach commercial completion vary significantly by region. The highest is 38% in the New England region (where the grid operator is ISO New England). The Texas grid operator, Electric Reliability Council of Texas (ERCOT) comes in next with a completion rate of 31%. Texas doesn't require the same level of network upgrades to get power generation connected to the grid so getting a project online in Texas is generally faster and lower cost than in the rest of the country[1]. (Texas also has a unique risk in that ERCOT can decide to limit the amount of power that a generator can sell to the market if a particular electric corridor gets overly congested).

[1] Texas has a history of getting projects done. in the early 2000s Texas officials saw that existing power lines wouldn't be able to handle the growing number of wind turbines being built in west Texas. Texas issued new legislation in 2005 that resulted in planning for billions of dollars in upgrades and Texas now leads the nation by a wide margin in the amount of electricity generated by wind power.

On the low end, the California Independent System Operator region only has a 13% completion rate, and the New York Independent System Operator region is at 15%. Completion rates by region are shown below.



Share of projects that requested interconnection from 2000 to 2017 that have reached commercial operation by region.
Chart courtesy of Lawrence Berkeley National Laboratory

The amount of work involved in reviewing all of the projects in the queue is causing some grid operators to take a step back. For example, PJM, which operates the nation's largest regional grid covering 13 states and the District of Columbia, has been so inundated by connection requests that last year it announced a freeze on new applications until 2026 so that it can work through a backlog of thousands of proposals, mostly for renewable energy. At PJM there were 2,700 energy projects —including more than 2,000 renewable projects representing 202 GW of renewable energy - stuck in the interconnection queue as of September 2022. For context, there were 200 GW of clean energy resources operating in the entire United States in 2021. Note that a single natural gas plant could deliver 1,200 megawatts and be covered in a single application. To get that same amount of capacity with renewables could require 6-10 different projects and applications to the queue. PJM has claimed there are about 38,000 MW of renewable projects that are not being built because of siting, supply chain, or other issues not related to PJM's interconnection process.

Rising Costs to Connect to the Grid

As noted earlier, the low percentage of interconnection requests that actually get built is also partly the result of increasing costs to connect to the grid.

In the MISO region, for instance, interconnection costs were generally less than $100 per kilowatt-hour from 2008 to 2016 but have risen to a few hundred dollars per kWh for wind and solar, with spikes as high as $1,000 per kWh in some parts of the region. As a specific example, in 2018, EDP North America, a renewable energy developer, proposed a 100-megawatt wind farm in southwestern Minnesota, estimating it would have to spend $10 million connecting to the grid. But after MISO completed its analysis, EDP learned the upgrades would cost $80 million. It canceled the project.

As another example: the Oceti Sakowin Power Authority, a nonprofit governmental entity owned by seven indigenous Sioux tribes, has been working to build 570 megawatts of wind power generation (over 2 locations) to sell to customers in South Dakota. In late 2017, the Authority paid a $2.5 million deposit to secure a place in line for its application to be reviewed by the Southwest Power Pool. Five years later, in 2022, the Southwest Power Pool came back and told the group that the fee to connect to the grid would actually be $48 million because connecting the new power to the grid would require major updates to the transmission infrastructure.

The Oceti Sakowin Power Authority was given 15 business days to come up with the extra $45.5 million. Not surprisingly they couldn't do it and had to drop out. Now they are reevaluating the size and composition of the project and hope to reenter the Interconnection Queue by the end of the year.

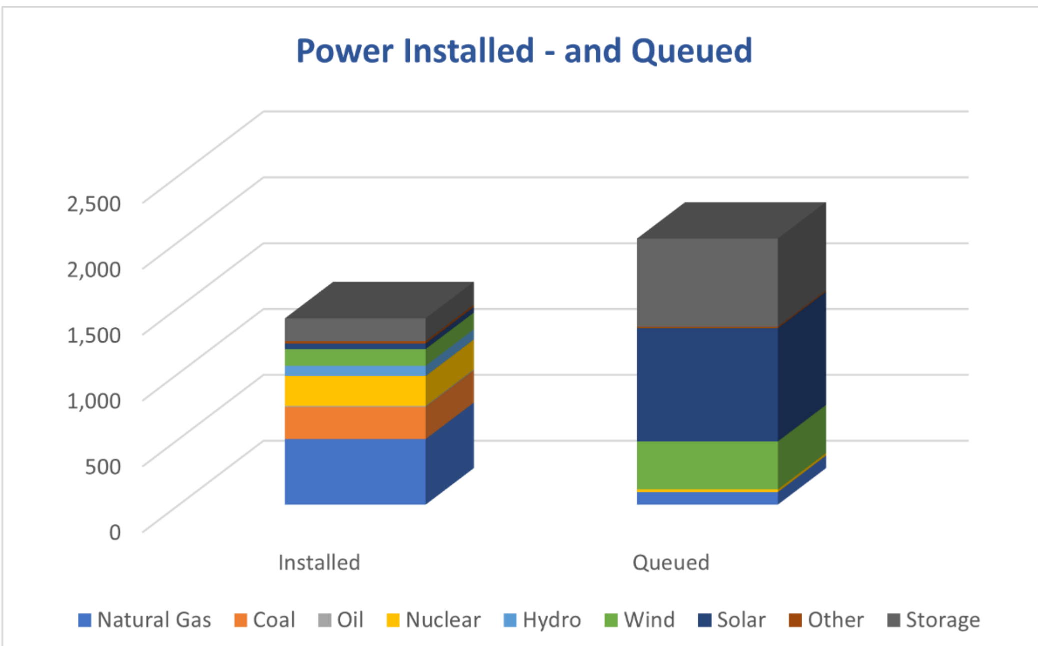
The transmission line to support the larger of the 2 Oceti wind projects will need to cross this rangeland and the Missouri River to interconnect with a Basin Electric transmission line on the east side of the river.
Photo courtesy Oceti Sakowin Power Authority

One can only expect that the cost of connecting to the grid will only increase as transmission lines get even more congested as new generation facilities are added. This will only exacerbate the challenges associated with accomplishing the energy transition.

Status of Renewable Energy

One of the manifestations of the Interconnection Queue problem is that, after years of breakneck growth, large-scale solar, wind and battery installations in the United States actually fell 16 percent in 2022, according to the American Clean Power Association. In addition to the Interconnection Queue, they also blamed supply chain problems for this.

That being said, the amount of renewable energy projects in the queue far exceeds the amount of solar and wind power already deployed; in fact, the total amount of power generation and storage (primarily battery storage) in the queue – 2020 gigawatts – exceeds the total amount of generation and storage installed by almost 700 gigawatts. Solar represents more than 800 GW of the queue, while wind represents about 365 GW. Storage projects represent about 670 GW. In contrast, natural gas represents under 100 GW.



Electric storage projects have fared particularly poorly while languishing in Interconnection Queues, largely as a result of the complex nature of co-located components (e.g., solar-plus-storage generating facilities).

And queue lengths are expected to grow even more as the Inflation Reduction Act spurs even greater interest in renewable energy among developers.

But the fact remains that renewable energy continues to be added to the grid, and there are already more than enough projects in the queue to accomplish the transition of the electric grid – if they are all implemented (which cannot reasonably be expected). The question is what can be done to shorten the queue, lower the costs, and speed up installation of these new generation and storage facilities.

Steps Being Taken to Shorten the Interconnection Queue

Clearly something needs to be done to try to address the Interconnection Queue bottleneck, and that does appear to be beginning to happen.

The Federal Energy Regulatory Commission (FERC) has just (July 2023) issued some rules aimed at achieving this objective. The ruling requires all public utilities/transmission providers to adopt revised generator interconnection procedures and agreements to try to ensure that approved generation and storage projects can connect in a reliable, efficient, transparent, timely, and non-discriminatory manner. The new rules require grid managers to study projects in batches and prioritize those that are closest to construction, a reform that several regional grids were already pursuing. Other changes include penalties for grid operators that fail to complete studies on time; stricter financial requirements for applicants to weed out speculative proposals; and changes that could make it easier to integrate batteries into the grid. Elements of the new ruling include the following:

Implement a first-ready, first-served cluster study process

- Transmission providers will now need to conduct larger interconnection studies encompassing numerous proposed generating facilities rather than separate studies for each individual facility. This is intended to increase the efficiency of the process, help minimize delays, and improve cost allocation by analyzing the transmission system impacts of multiple projects at once.

- To ensure that projects can proceed through the queue in a timely manner, queue applicants will be subject to specific requirements, including financial deposits and site control conditions, to enter and remain in the interconnection queue.
    - The deposits are set at a rate of $10,000 per MW, subject to a floor of $500,000 and ceiling of $2,000,000.

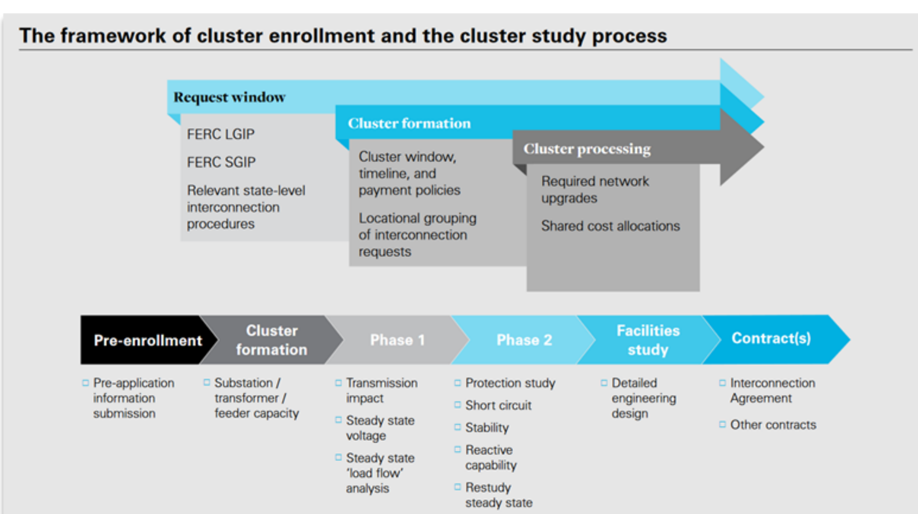


Image courtesy of FERC

Speed up interconnection queue processing

- The rule establishes firm deadlines and includes penalties if transmission providers fail to complete interconnection studies on time. (Transmission providers can appeal their penalties to FERC).

- The rule establishes a detailed systems study process, including uniform modeling standards and pro forma system agreements.

- The rule also introduces application withdrawal penalties. The amount would be based on a number of factors, including the phase of the cluster study and the commercial readiness of the proposed project. The total penalty would range from one to five times the actual allocated cost of all studies performed to that point and — contingent on the circumstances and timing of the withdrawal — capped at between $1 million and $5 million.

Incorporate technological advancements into the interconnection process

- The rule requires transmission providers to allow more than one generating facility to co-locate on a shared site behind a single point of interconnection and share a single interconnection request. This reform creates a more efficient standardized procedure for these types of generating facility configurations.

- Generation applicants can now add a generating facility to an existing interconnection request under certain circumstances without such a request being automatically deemed a material modification.

Modify the basis for allocating grid upgrade and other costs

- Transmission providers are now required to allocate any upgrade grid costs on a proportional method basis – including to applicants in earlier cluster studies as well as those in subsequent cluster studies that benefit from the same network upgrade. FERC expects this reform to reduce the frequency of an individual applicant being allocated a large network upgrade that benefits subsequent interconnection applicants, reduce the incentive to submit multiple speculative requests, and reduce the level of cascading withdrawals and re-studies. FERC has noted that a number of grid operators and utilities — including CAISO, MISO, SPP, NYISO, Public Service Commission of Colorado, Dominion Energy, Duke Energy, and Tri-State Generation & Transmission — have previously adopted the proportional impact method.

By creating an 'informational connection study' process in the new rule, FERC hopes to enhance information sharing and enable project developers to more accurately forecast available capacity and potential upgrade costs prior to finalizing any binding agreements. FERC has demonstrated that transparency — and improved data accessibility — is a priority.

Furthermore, FERC believes that the number of projects requesting interconnection will decrease as the reforms take effect and developers no longer believe they must apply for multiple prospective projects to increase their odds of success.

As noted earlier, some regional grid operators had initiated reforms to their Interconnection Queue processes prior to the recent FERC ruling. As an example, in early 2023 (following widespread power plant outages during the winter storm Elliott in December 2022) PJM submitted a filing to FERC requesting approval of revisions that would implement the 'first-ready, first-served' cluster method that included:

- A 'fast-lane' process for approximately 450 existing projects to clear the existing backlog
- Adding requirements such as readiness deposits and improving site control procedures
- Analyzing cost responsibility of individual projects in the cluster
- Expediting the process to obtain interconnection agreements for projects that do not require network upgrades or further studies

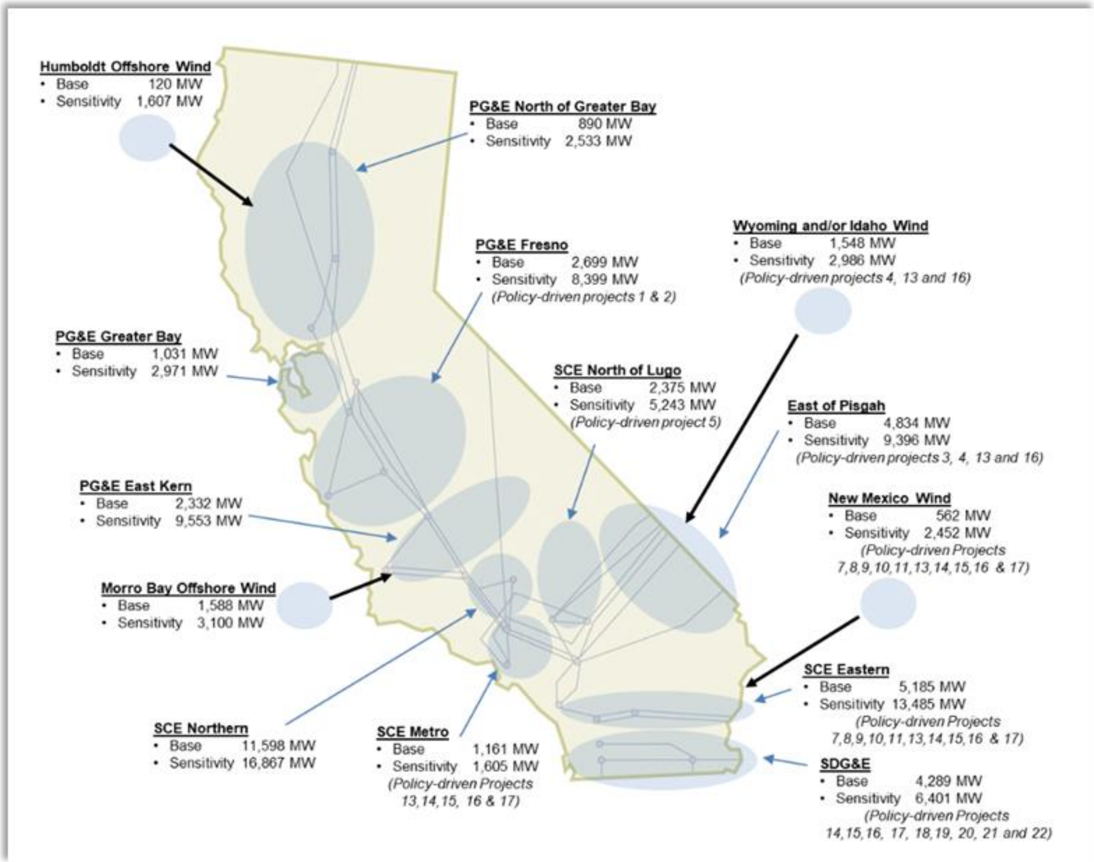
The PJM board directed the grid operator's Resource Adequacy Senior Task Force to consider ways to improve risk modeling, especially for the winter; enhance accreditation so a resource is paid in line with its reliability contribution; and ensure that capacity suppliers are fully paid for the risks they take.

As another example of trying to spread the costs among a wider set of energy providers rather than allocating it to individual developers on a project-by-project basis; in May 2023, California's grid operator, the California Independent System Operator (CAISO) approved a $7.3 billion plan to build thousands of miles of new high-voltage transmission lines.

While three of the largest of the 45 transmission projects in the plan will be open to competitive bidding from independent developers, most will be built by the state's three big investor-owned utilities, Southern California Edison, Pacific Gas & Electric and San Diego Gas & Electric.

For the first time, CAISO's new transmission plan brings clean energy developers and transmission-planning policies onto the same page. Under previous planning methods, the developers would in effect need to guess where there would be grid capacity and might file multiple interconnection requests for the same project in hope of finding at least one spot where the grid could support them. But that led to CAISO engineers being required to study the grid impacts of far more clean energy projects than were actually going to be built, while long-term transmission planning lacked data that could clarify where the actual development would most likely take place.

The new process, by contrast, uses a “zonal” focus for transmission planning and coordination of procurement and interconnection, starting with identifying the zones where the majority of new clean energy projects are being proposed.



CAISO Transmission Planning Zones and Capacity

CAISO estimates that the 45 projects in the plan will allow the development of more than 17 gigawatts of solar resources within the state and in neighboring Arizona and Nevada, more than 1 gigawatt of geothermal power in California and Nevada, and wind power projects totaling more than 3.5 megawatts in CA and more than 4.5 megawatts in New Mexico and Wyoming.

In 2022 the Midcontinent Independent System Operator (MISO) approved a similar, $10.3 billion transmission plan that could support about 53 GW of wind, solar, hybrid and stand-alone battery projects.

Needless to say, these moves by FERC and several of the transmission organizations are a step in the right direction, but it will take several years to see how effective they will be at shortening the Interconnection Queue.

In fact, MISO has already run into issues. In May 2023, MISO announced it would delay opening its 2023 application window for proposed energy projects while working on reforms to reduce the number of projects entering the queue; in June MISO announced a freeze on accepting new requests to connect to its grid.

Clearway Energy Group, a large renewable energy developer based in New Jersey, [released a report](#) critical of MISO's approach in July 2023. They argued that, instead of rushing through queue reforms with little input from market participants, MISO should initiate a thorough stakeholder process to work through solutions. They further argued that capping the volume of projects that can enter a queue cycle does not solve the reality that many developers enter more projects into the queue than they intend to build, and thus MISO will still be spending time studying projects that will not advance. They stated that capping the size of queue cycles also creates a new problem - which is how to decide which projects are selected for a given cycle - and selecting a project application because it arrives shortly before the next one is arbitrary and does little to help advance the best projects.

Clearway proposed that MISO – and presumably by extension any grid operator - study projects for the “proper level of service.” They argue that MISO currently studies all projects entering the queue as if they’re seeking “full deliverability” (also known as Network Resource Interconnection Service or NRIS), which requires that a generator be able to transmit its power reliably to customers even during periods of peak electricity demand – increasing the time of the studies. Instead, they argue that MISO should look at some projects as “as-available” (energy-only/Energy Resource interconnection service or ERIS) which allows a generator to provide energy to the grid when there is transmission capacity available but does not guarantee the generator the ability to use the transmission system at all times. Instead, they could be forced to reduce output at times when the transmission system is constrained.

Since there are more projects entering the queue than needed to serve the peak load in the MISO region, Clearway argues that by focusing on “full deliverability” MISO is studying scenarios that will never happen - which is not the most efficient use of time and resources. Instead by focusing on an ‘as-available’ ERIS study framework first, they argue that MISO can achieve faster study results. Clearway goes on to say that, ultimately, this type of framework will result in a more efficient, lower cost grid for all customers.

Can Technology Play a Role?

Starting about 20 years ago there has been considerable interest in using *superconductors* for transmission lines rather than conventional copper or aluminum wires. Whenever electrical power runs through a transmission line, some is lost as waste heat. Currently, 8 percent to 15 percent of all energy produced for electrical grids is lost in this manner. The exciting potential of superconductors is that they can carry electricity over large distances with perfect efficiency, resulting in dramatic reduction of losses on these lines.

Superconducting transmission lines offer another potential benefit. In addition to greatly reduced losses, these lines have smaller diameters; can use smaller, less intrusive towers; and are possibly a solution to running high–power lines in dense urban areas, where there is insufficient space for the physically larger conventional cables.

Thus, if grid operators could begin deploying superconductor transmission lines there would be a huge increase in efficiency and the growth of renewable energy would require fewer new transmission lines, reducing the cost of the energy transition and helping to speed up the Interconnection Queue.

The problem is that superconductors have historically required extremely low temperatures to operate or need to be operated under extremely high pressure. This made it totally impractical for use in transmission systems.

The breakthrough for the potential implementation of superconductors for powerlines is the development of so–called high–temperature superconductors (HTS). Unlike previous superconductors, which required costly and complex helium–based cooling, the HTS only needs to be cooled to 77 K (-273°F), which can be done with liquid nitrogen.

Another promising candidate for superconducting power lines is magnesium diboride (MgB_2), which is based on raw materials that are abundant. However, it needs more expensive cooling systems than just liquid nitrogen.

The development of these newer designs has enabled multiple pilot systems to be installed in the US and elsewhere.

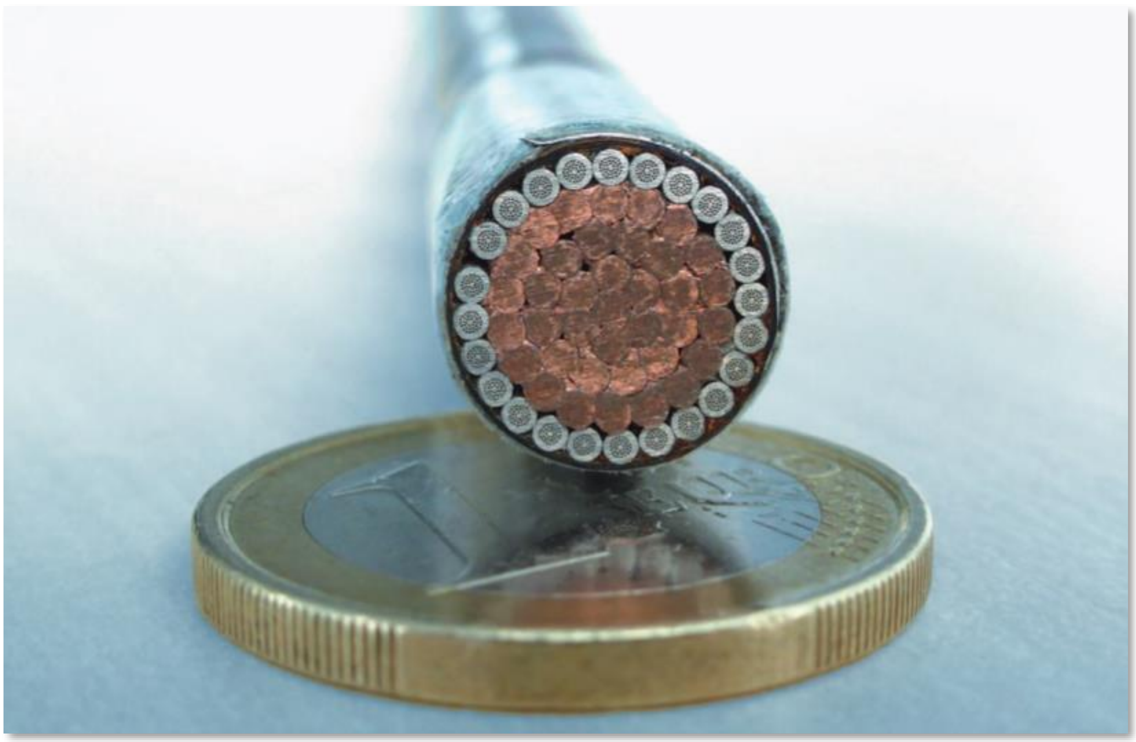


Photo of a superconducting cable composed of 24 MgB2 wires and a copper core with a diameter of 11 mm. Such cables can carry currents of 10 kA and potentially more.
Image courtesy of the Institute for Advanced Sustainability Studies (IASS), Potsdam

One of the oldest tests of superconductors for transmission lines in the US was carried out by the Long Island Power Authority in 2008. They installed a 600-meter-long underground superconducting cable with a capacity of 574 MW to connect a power substation to the overhead line network. Based on high-temperature superconductors, the LIPA cable was the world's longest in-grid cable for the next six years. The most significant superconducting project to-date, called the AmpaCity project, was begun in Essen, Germany in 2014 when a 1-kilometer-long underground AC superconducting cable was installed in the city center. It replaced a number of aging conventional high-voltage cables and became Europe's first such project. The cable is designed for a transmission power of 40 MW (five times more than a copper cable of the same size) and operates at medium voltage (10 kV instead of 110 kV), doing away with the need for voltage transformer stations. The AmpaCity cable is based on high-temperature ceramic superconducting materials and is cooled using liquid nitrogen. The German company that installed the system in Essen – Nexans - recently did an installation in the Chicago area, working with the US company

American Superconductor (AMSC).

Other superconducting cables of various lengths and capacities have been deployed or are under construction in various countries in Asia as well as Russia.

The technology is not quite ready for prime time and still on the expensive side, but research continues around the world towards the development of a "room temperature" superconductor[2] and hopefully we will see expanded use of superconductors in the transmission system in the coming years.

But some much less complex and readily available technologies could play a role as well.

The Working for Advanced Transmission Technologies (WATT) Coalition – which is composed of a group of companies offering a variety of grid-related technologies[3] - advocates for policy that supports wide deployment of grid-enhancing technologies (GETs) to accelerate the energy transition as well as lower energy costs. They posit that technology can:

- Reconfigure the grid so that more power can get transported across the network.
- Control the flow of power so that transmission assets are used safely and efficiently.
- Measure true capacity to make full use of existing infrastructure.

The specific technologies they offer and advocate on behalf of fall into these categories:

- **Dynamic line rating** (**DLR**), also known as **real-time thermal rating** (**RTTR**), is a method for estimating the true, real-time capacity of power lines with a goal of maximizing load, when environmental conditions allow it, without compromising safety.

- **Advanced Power Flow Control** devices installed on power lines can control the flow of power and allow operators to reroute power to lines with available capacity.

- **Topology Optimization** is designed to identify the best grid reconfigurations to reroute flow around bottlenecks.

For example, LineVision offers a sensor that is mounted on transmission poles and uses Lidar to monitor the transmission lines plus wind and temperature, which significantly affect transmission capacities, to help the transmission operator route power. This technology can also be used to reduce risks from wildfires.

The idea behind all of these technologies is to enable better use of transmission lines requiring fewer new lines to support new generation proposals. According to a study by The Brattle Group for the WATT Coalition, upgrading existing transmission lines with the latest technologies like these could effectively double the capacity of the grid in Kansas and Oklahoma by 2025.

[2] The NY Times recently published an article about a Korean discovery that had scientists very excited, but now has been declared not to be a superconductor.

[3] Members include: Ampacimon; Atecnum; LineVision; Lindsay Systems; Newgrid; SmartWires; Heimdall Power; Prisma Photonics; EDF Renewables; Hasi; Invenergy; and Pine Gate Renewables.

LineVision sensor. Image courtesy of LineVision

These types of technologies are not being adopted at a rapid rate. FERC's new rules encourage utilities and grid operators to adopt technologies like these but do not require it.

Where Does that Leave Us?

Transitioning the energy grid to renewables is probably taking longer to happen than expected, but it appears to be on its way. The combination of the time it takes to get through the Interconnection Queue and the need for costly new transmission lines has clearly affected the timetable. The good news is that there are new attempts to speed up the process. As noted, it will take a while before we see the results of FERCs new rules, but they should begin to have some effect within a couple of years. The grid operators appear to be on board with FERC's intentions, since some of them initiated similar processes before FERC released their rules.

There are now also a number of technologies that should help make more efficient use of transmission resources, reducing the time and cost of getting renewable resources on the grid. FERC and other groups should promote these types of technologies to the grid operators and utilities.

So, there is reason for some optimism – even as we recognize that it will still take a while to reach the energy transition of the US electricity grid.