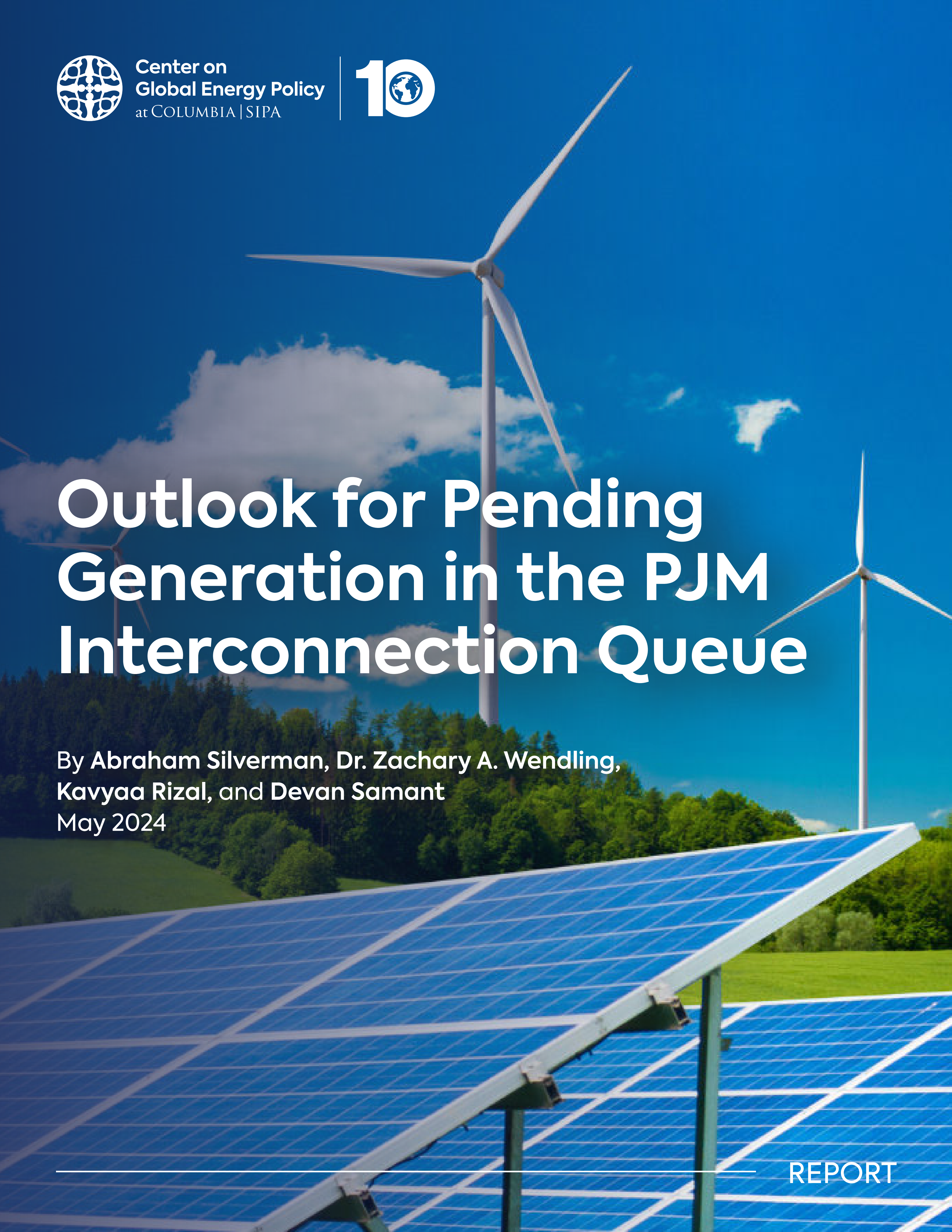

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Outlook for Pending Generation in the PJM Interconnection Queue

By **Abraham Silverman**, **Dr. Zachary A. Wendling**, **Kavyaa Rizal**, and **Devan Samant**

May 2024

REPORT

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Columbia University CGEP
1255 Amsterdam Ave.
New York, NY 10027
energypolicy.columbia.edu

@ColumbiaUEnergy

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Acknowledgements

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About the Authors

Abraham Silverman joined the Center as the Director of the Non-Technical Barriers to the Clean Energy Transition initiative. The Non-Technical Barriers initiative is designed to identify major legal and regulatory bottlenecks to the clean energy transition and then provide state and federal policy makers pragmatic solutions to address those challenges. Major focus areas include Legal and Regulatory Barriers at the state and federal level, Market Rules and Economic Incentives, and Social Acceptance & Just Deployment of Infrastructure.

Before joining the Center, Abe served at the New Jersey Board of Public Utilities as the General Counsel and Executive Policy Counsel. Abe's portfolio included developing offshore wind, solar, electric vehicle, energy storage, and interconnection reform programs, along with quantifying and managing ratepayer impacts of the clean energy transition. Abe also led the State's engagement with PJM Interconnection, the regional grid operator for New Jersey, on topics such as implementing New Jersey's first-in-the-nation offshore wind transmission solicitation, resource adequacy, clean energy market design, and transmission policy.

Previously, Abe spent more than a decade at NRG Energy, Inc., as the Deputy General Counsel & Vice President of Regulatory Affairs. Abe supported NRG's power markets team, power plant operations group, renewable development and state retail electricity market programs. Abe also led the company's advocacy at the Federal Energy Regulatory Commission, as well as anti-trust compliance work at the Department of Justice/Federal Trade Commission. Abe has also worked as an associate at Perkins Coie LLP and as a staff attorney at FERC. Abe has a Bachelor's Degree from the University of Maryland and a JD from the George Washington University Law School.

Abe has testified before the United States Senate's Energy & Commerce Committee, the Federal Energy Regulatory Commission, the New Jersey Senate, and is the author of numerous pleadings at the state and federal level, including before the U.S. Supreme Court and various U.S. Courts of Appeals.

Dr. Zachary A. Wendling is a Senior Research Associate at the Columbia University Center on Global Energy Policy (CGEP). His research experience includes the role of technology and innovation in energy transitions, energy systems modeling, and sustainable development. Before joining CGEP, Dr. Wendling was the project manager for the Global Commons Stewardship Index at the Sustainable Development Solutions Network and the principal investigator for the Environmental Performance Index at the Yale Center for Environmental Law & Policy, where he did his postdoctoral training. Dr. Wendling holds a Ph.D. in Public Affairs from the Paul H. O'Neill

School of Public & Environmental Affairs at Indiana University Bloomington, with major fields in policy analysis and environmental policy. He earned a joint Master of Public Affairs – Master of Science in Environmental Science and a B.S. in Biology, also from Indiana University.

Kavyaa Rizal is a Master of Science in Urban Planning candidate at Columbia University, concentrating on urban analytics, climate resilience and renewable energy. As a Graduate Research Assistant at CGEP, Kavyaa works on data collection and analysis of various renewable-energy and decarbonization policy focused research projects under the Non-Technical Barriers initiative.

Devan Samant is a data scientist and master's student in Columbia Engineering. His prior experiences in regulation and analytics in risk consulting are being applied to research in clean energy generation and climate modeling. Devan works on the Non-Technical Barriers initiative.

Executive Summary

The United States is witnessing rapidly growing interest in clean electricity generation, driven by soaring consumer demand for clean energy and the country's goal to reduce greenhouse gas emissions. In parallel, the time it takes for new, clean generation projects to move from design to execution in the US has lengthened, meaning that the rising interest has not been matched by supply. The country's largest grid operator, PJM Interconnection (PJM), has experienced the most severe delays and backlog in new generation—projects entering the queue today have little chance of coming online before 2030.

It is widely understood that an increasingly lengthy interconnection process, which involves a series of studies and upgrades grid operators must take to ensure projects can connect to the grid safely and reliably, is responsible for this state of affairs. It is not clear how this longer process interacts with other known project development challenges—such as siting and permitting issues, supply chain constraints, and inflationary pressures—and to what extent such interactions may lengthen the timeline for bringing projects online. Understanding these dynamics can help answer critical questions about grid reliability going forward, including whether it will be necessary to delay or cancel the planned retirement of aging fossil fuel-fired generation resources that the new generation is intended to replace.

This report attempts to fill this knowledge gap. It presents results of an author-developed survey of those best positioned to understand the impacts of interconnection process delays: project developers in the PJM market. The key finding from the survey is that PJM's increasingly lengthy interconnection process is exacerbating siting and permitting challenges and leading to knock-on delays in equipment procurement and financing decisions, suggesting the timeline for new generation in this market will likely remain long for the foreseeable future. Given the importance of new entry to keeping prices competitive and maintaining reliability amid the retirement of older fossil resources, PJM will need to find ways to reduce interconnection delays or reconsider when those fossil resources should be retired.

Other notable findings include the following:

- Most developers expect to delay construction milestones or suspend some or all of their development efforts.
- Only 10 percent of developers report that any of their projects will come online within 12 months of receiving an interconnection service agreement, and most report their projects

will require at least 24 months from the time they receive such an agreement to reach commercial operation.

- Developers report very few duplicative interconnection requests, potentially calling into question the conventional wisdom that such projects are a major cause of interconnection delays.
- Over half of the developers who reported withdrawing, suspending, or pausing projects identified interconnection upgrade costs as a significant concern.
- Solar developers report that an outlook of lower value for renewable energy attributes (such as renewable energy credits) was a key factor in their decision to cancel or delay projects, while forward energy prices were less important.
- Offshore wind developers noted that the federal permitting process may require them to consider alternative points of interconnection or alternative turbine sizes, which can create late-stage changes to a project that may not qualify for PJM's traditional process for amending interconnection requests.

Introduction

The Inflation Reduction Act of 2022 and consumer demand for clean energy is driving record interest in new clean generation in the United States. But the time it takes for new clean generation resources to move from design to execution has increased markedly over the past five years, with the median project *completed* in 2023 taking five years from interconnection request to commercial operation.[1] These timelines are only increasing as the interconnection process—that is, the process grid operators go through to ensure that a new generator can connect to the grid safely and reliably—has itself grown from approximately two years in length to five.[2]

The backlog of new generation is particularly severe in the 13-state, plus the District of Columbia, region overseen by PJM Interconnection LLC (PJM), the largest grid operator in the United States, where an influx of new projects, increasing numbers of late-stage project withdrawals, and spiraling numbers of restudies[3] have overwhelmed the queue process, leading to multi-year delays and a freeze in processing new interconnection studies.[4] In consequence, absent significant reforms or market innovations, most projects entering PJM's queue today are unlikely to come online before 2030—and certainly not in the quantities necessary to satisfy demand for clean energy across the region that PJM serves, leading PJM to question whether it can maintain grid reliability.[5]

While experts broadly agree that interconnection delays are hampering the clean energy transition,[6] there is a relatively poor understanding of how these delays are interacting with other recognized development challenges, such as siting and permitting issues, supply chain constraints, and inflationary pressures, and how those interactions affect the timeline for developers to bring projects online.[7] As policymakers debate whether to delay or cancel the planned retirement of aging fossil fuel-fired generation resources due to concerns that new generation will not be ready to take their place,[8] having a grasp of these relationships and the commercial outlook for how long it takes to bring new resources to market could prove critical.

In an attempt to address this knowledge gap, the authors conducted a survey of developers with projects in the PJM interconnection queue. Responses were received from 30 independent developers representing 69 total projects across a range of generator technology types that entered the queue between 2017 and 2023 and reached an advanced stage of the interconnection process by June 2023. The authors also conducted limited follow-up interviews with developers.

The report begins by contextualizing the PJM backlog and explaining its implications for grid reliability. It then introduces the survey of developers and presents the survey results. The report concludes by analyzing the policy implications of the findings and offering a set of recommendations to policymakers and other stakeholders should they wish to resolve the delays caused by the interconnection process in the regions PJM serves and beyond.

The PJM Backlog and Its Implications for Reliability

Explaining the PJM Interconnection Queue

At the end of 2023, 2,600 gigawatts (GW) of generation and energy storage were waiting to connect to the grid nationwide—more gigawatts of generation than currently operate in the entire United States.[9] Zero-carbon resources, including wind, solar, and energy storage, comprised more than 90% of this capacity.[10] Increasing delays in the timeline for interconnection of new resources are well documented, with the average project now taking approximately five years to get through the study process, complete any necessary grid upgrades, and reach commercial operation.[11] These delays strongly impede the deployment of clean energy resources, harming economic competition, market efficiency, and reliability. They also blunt the impact of the Inflation Reduction Act of 2022, which provides incentives for new projects to reach commercial operation within a decade. The availability of these incentives is expected to drive significant reductions in greenhouse gas emissions through the remainder of the decade, but will only do so if generation is actually able to come online.[12]

Efforts to accelerate the interconnection study process are well underway at the Federal Energy Regulatory Commission (FERC). FERC's landmark Order No. 2023,[13] for instance, required all FERC-jurisdictional utilities to adopt new interconnection queuing rules into their tariffs. Regional electricity market operators, including PJM, are provided additional flexibility to propose rules tailored to their specific needs. PJM's compliance filing, along with that of the nation's other independent system operators (ISOs) and regional transmission organizations (RTOs), are due in late spring 2024.

The interconnection queue in PJM mirrors the national trend, where over 2,600 gigawatts of new generation is stuck in a queue. The number of new projects entering the PJM queue tripled between 2018 and 2021, and the total capacity of pending projects is now over 200 GW.[14] The surge in projects led PJM to freeze its interconnection queue in May 2022.[15] According to PJM's Independent Market Monitor, the FERC-recognized independent auditor for the PJM market, "as of December 31, 2023, 268,472.8 [megawatts] were in generation request queues in the status of active, under construction or suspended."[16] This represents "a decrease of 19,019.9 MW (6.6 percent) from the 287,492.7 MW at the end of 2022."[17] Approximately 75% of the generation awaiting study is zero-carbon,[18] compared to the current approximately 160 GW capacity of the entire existing PJM system. Just over 4,400 MW of new generation entered service in 2023. Of that generation, 70% was combined cycle or combustion turbine gas-fired resources, 20% was solar, 6.5% was wind, and the remainder was battery and solar as well as storage units.[19] Although PJM is implementing emergency reforms to its interconnection program, it expects that alleviating the backlog will take several years.

In late 2023, PJM stated that it "expected to clear 300 new generation projects totaling [26 GW] in 2024" and that "another [46 GW] of nameplate generation capacity in projects...should clear PJM's study process and be ready for construction by mid-2025, for a total of [72 GW] of projects."[20] Thus, even completing tens of gigawatts of interconnection studies annually still leaves PJM significantly behind the voracious consumer demand for clean energy.

Implications for Reliability

The speed at which projects move through the PJM interconnection queue and the rate at which those projects come online have major implications for the reliability of the electric grid. It is an electrical industry axiom that a reliable electric grid requires the availability of sufficient generation resources to meet electricity demand on peak days, plus an appropriate reserve margin. In practical terms, this "balance sheet" approach to reliability means that as existing generation resources retire, they must be replaced with resources of comparable capacity.

In 2023, PJM officials expressed concern that new resources may not reach commercial operation in sufficient quantities to replace retirements in the existing fleet.[21] As PJM put it, "the amount of generation retirements appears to be more certain than the timely arrival of replacement generation resources, given that the quantity of retirements is codified in various policy objectives, while the impacts to the pace of new entry of the Inflation Reduction Act, post-pandemic supply chain issues, and other externalities are still not fully understood."[22] PJM's Independent Market Monitor likewise stated that "the markets face a challenge from potentially high levels of expected thermal generator retirements, with no clear source of replacement capacity or the fuel required for that capacity."[23]

One of the complicating factors identified in PJM's Energy Transition Report is that the reliability value of a new generator is a function of both the size (or nameplate) of the generator and how it is likely to operate during periods of stress on the grid. PJM notes that it would take just over 107 GW (nameplate) of new renewable and battery resources to provide 30 GW of reliability value.[24] The reliability value (or "capacity accreditation" in PJM lingo) of a resource is set by PJM based on complicated probabilistic models conducted by PJM,[25] often referred to as Expected Load Carrying Capability (ELCC).[26] The ELCC value is intended to reflect the likelihood that any given generation resource will be available when needed and accounts for factors such as correlated outages of natural gas resources during cold weather[27] or correlated output of solar resources. The result is that PJM's balance sheet reliability analysis is likely to evolve over time as system conditions change, which makes long-term estimates of grid reliability challenging.

Currently, PJM relies on a mix of largely fossil fuel-fired and nuclear generators to meet its reliability needs. However, PJM forecasts that 40 GW, or 21% of its total installed capacity, will retire by 2030.[28] This estimate includes 12 GW of previously announced retirements, 25 GW of retirements driven by federal and state environmental policies, and 3 GW of projected economic retirements.[29] PJM's Independent Market Monitor puts the potential retirement figure even higher, noting that "although the exact numbers may vary, an estimated total of between 24,000 MW and 58,000 MW of thermal resources are at risk of retirement."[30]

Among the policies driving these retirements, several are notable:

- Illinois's Climate and Equitable Jobs Act mandates the retirement of 5.8 GW[31] of coal-fired and high-emitting gas resources.[32]
- A trio of rules from the US Environmental Protection Agency (EPA), namely, the Coal Combustion Residuals, Effluent Limitations, and Good Neighbor Rules, will result in the retirement of approximately 10 GW of generation retirements.
- New Jersey's Carbon Dioxide Rules will result in approximately 3 GW of generation retirements.[33]

While PJM has weathered similar scale retirements in the past (particularly during the mid-2010s, in response to Obama-era EPA rules), the expected replacement schedule is one of the more substantial transitions away from fossil generation in its history.[34]

PJM has highlighted the two dominant drivers of uncertainty about future reliability: the speed at which new generators are proposed and the rate of success for generators currently in the interconnection queue. PJM selected several different measures of the volume of new generation currently in the queue that is likely to reach commercial operation, and made additional assumptions about how much new generation is likely to enter the queue between 2023 and 2030. PJM's "High New Entry" scenario projects sufficient new entry to offset resources anticipated to retire.[35] However, PJM's "Low New Entry" scenario reaches the opposite conclusion, namely, that insufficient new generation will come online to keep up with anticipated retirements. The result would be either higher prices for consumers or a reliability crisis. Only PJM's "High New Entry" scenario adds enough new generation to almost entirely offset the anticipated retirements of fossil resources, even after applying PJM's new ELCC methodology.[36] In its December 21, 2023, update, PJM stated that "at the end of 2023, about [40 GW] of projects that had completed the

PJM study process had yet to move through construction, due to issues including siting, supply chain and financing."[37]

While numerous parties have identified concerns with PJM's analysis—in some cases, calling into question its key conclusion[38]—the specter of a reliability crisis continues to drive sharp energy policy debates. Surveying developers with projects currently in the interconnection queue sheds new light on the dynamics behind this uncertainty.

Study Design

Generation developers have a unique perspective on the challenges of bringing new resources to market, including elongated interconnection study processes, siting and permitting, inflationary pressures, market outlook, and delayed supply chains. The authors identified a range of possible project challenges based on their experiences and conversations with developers and PJM, and then prepared a survey of 27 questions to assess which, if any, developers saw as most salient in the development process.

When respondents designated challenges as highly significant to their projects, the survey prompted them with more specific questions about those challenges. The survey also included questions about how the hurdles presented by atypical events, such as the COVID-19 pandemic and related supply chain and inflationary issues, compared with the more typical aforementioned challenges. Several questions allowed respondents to identify other challenges not identified in the survey. Finally, survey participants were invited to participate in informal follow-up interviews.

Sample

Because the authors were interested in projects that could potentially come online in the next several years, the survey focused on projects that entered PJM's interconnection queue between January 1, 2017, and May 16, 2023. The sample was then further narrowed down to projects at an "advanced stage" of the interconnection process as of June 1, 2023, meaning those that had just started the Facilities Study process, completed a Facilities Study, or tendered or executed an Interconnection Service Agreement (ISA) or the equivalent.[39] Throughout the analysis, the term "project" is used to refer to a single proposed generation project or generator uprate that was assigned a queue position by PJM.[40] The term "developer" or "project sponsor" refers to the ultimate upstream corporate parent. Each developer's parent was identified by cross-matching the name of the specific development project with the upstream parent in FERC filings, interconnection agreements, and/or general web searches. In cases where two upstream owners are partners for a project, both were invited to participate in the survey.

Data on projects was obtained from PJM's New Services Queue. The latter includes project technology, location, and progress through the interconnection queue,[41] as well as links to ISAs and the interconnection studies performed by PJM, which provide additional information not available in the database itself. While these study documents are a mix of machine-readable and non-machine-readable data, web scraping techniques, optical character recognition, and independent research were used to identify developer names and contact information. The survey team also worked with PJM and a variety of business- and policy-oriented trade associations to alert developers to the existence of the survey and solicit participation.

Table 1 contains a description of the projects in PJM's interconnection queue and those in the sample. In total, 496 projects listed in the New Services Queue met the survey qualifications. Of those, project-level data could be extracted for 412 projects and email addresses obtained for 332 projects across 89 developers. The 412 projects had an estimated nameplate capacity of 30 GW. In total, 30 developers representing separate corporate parents substantially completed the survey, divided evenly between two outreach methods. One method involved sending the survey via email to 224 distinct email addresses that had been compiled. One hundred of the emails were opened, and 15 surveys were substantially completed. The second method involved sharing a generic link to the survey to other developers that met the survey qualifications through webinars and informal communications. Fifteen respondents substantially completed the survey using the generic link.

Table 1: Description of sample size and participation

Criteria	Description	Projects	Developers	Nameplate capacity (GW)
Eligible	Entered queue January 1, 2017–May 16, 2023 *and* As of June 1, 2023, either (1) started or completed Facilities Study, *or* (2) tendered or executed Interconnection Service Agreement	496	–	–
Described	Project-level information available from PJM's New Services Queue databases and online sources	412	–	30
Contacted	Discernable email contact information available	332	89	26.4
Responses	Completed survey	69	30	7.1

Respondents to the generic survey were included in the data set if they stated that they had a project that met the survey qualifications. In total, 30 responses in which at least one substantive portion of the survey was completed were received, including from both developers who responded via email and those who used the generic version. Respondents spanned 69 projects that could be tied to specific queue positions, totaling 7.1 GW of generation or storage, or approximately 24%

of the nameplate capacity and 17% of the projects meeting the qualifications for participation in the survey.[42] The 69 project tally likely undercounts total project participation given that some developers represent projects that were not captured by the authors' automated electronic scraping.[43] When asked to self-report the number of eligible projects they represent, developers reported additional projects. The lower, more conservative figure was used to calculate the total survey participation rate. Some questions directly asked the respondent how many projects they were developing. In such cases, the number of projects identified by the developer was used.

Survey

The online survey[44] asked questions about the following topics:

- Siting or permitting considerations at the federal, state, and local levels.
- Length of the interconnection process, both including and excluding new transmission construction.
- Expectations for commercial operation dates.
- Supply chains.
- Tariffs.
- Labor issues.
- Commercial outlook, including for energy, capacity, and environmental attributes.
- Implications of inflation on market conditions related to cost of capital, financing, tax equity, or other financing metrics.
- Regulatory changes related to Effective Load Carrying Capability rules.

The survey asked developers to identify challenges associated with projects that were "actively in development" as well as projects that were "withdrawn from the PJM queue, put into suspension, or for which your firm paused or ceased development." Unstructured follow-up interviews were also conducted with personnel from selected firms to better understand the challenges they are facing and obtain additional context.

Interviews

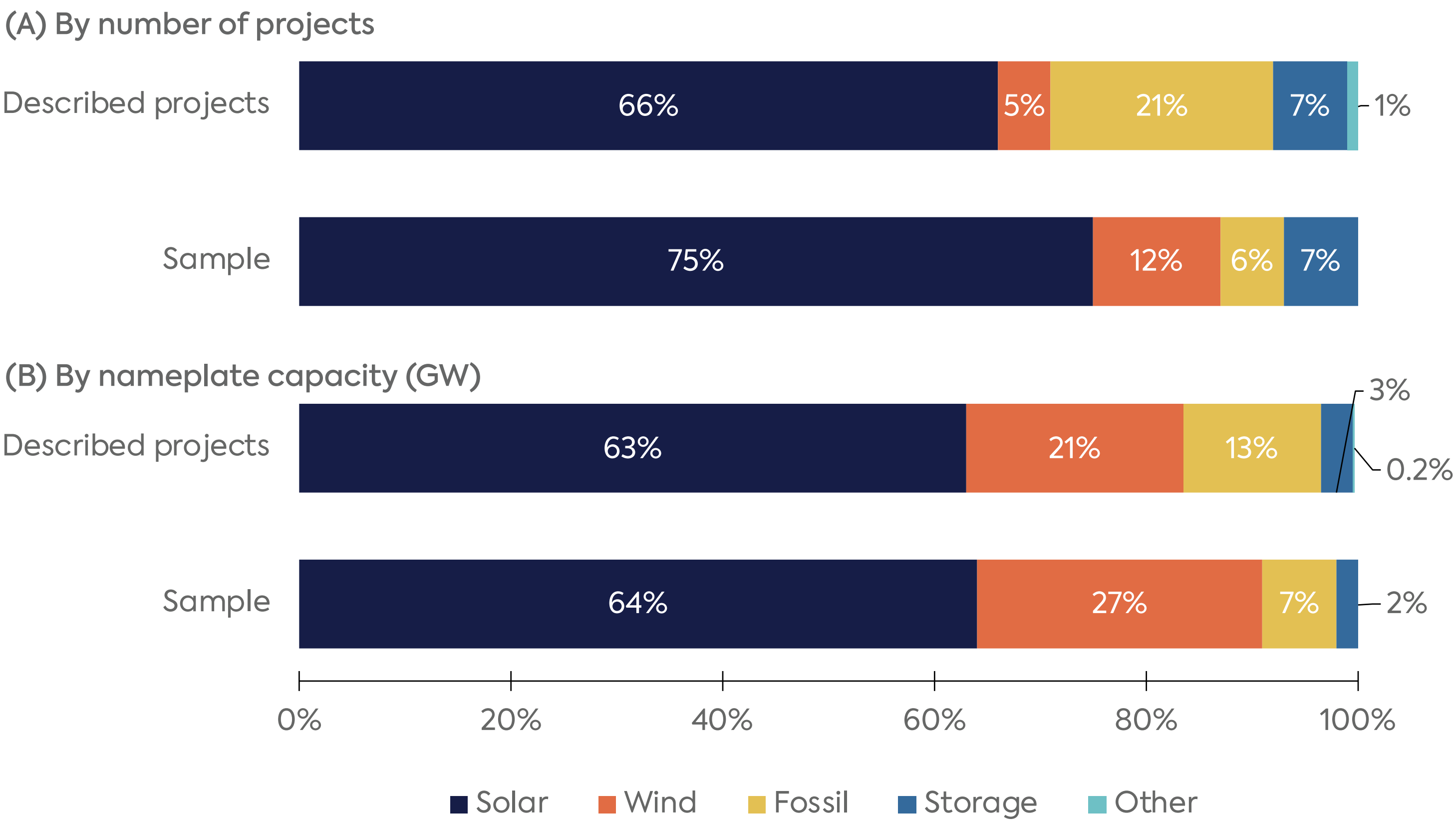
Developers with eligible projects were also invited to participate in unstructured interviews. Six total interviews were conducted. Most interview participants also participated in the survey process, although one firm with eligible projects participated only in the interview process. The interviewees provided additional context for as well as explanations of their experience with the interconnection process.

Results

Descriptive Statistics

Figure 1 shows that the population of described projects (see Table 1) is largely solar or hybrid solar with storage (66%), compared with 75% in the sample, which underrepresents fossil fuel projects and overrepresents wind projects. Likewise, by nameplate capacity, 63% of described projects in the interconnection queue are solar or solar with storage, compared with 64% of the capacity in the sample. The sample contains more wind (27% vs. 20%) and less fossil fuel (7% vs. 13%) than the population's capacity.

Figure 1: Comparison of percentage composition of the sample (n = 69, 7.1 GW) to all described projects (N = 412, 30 GW) by number of projects and nameplate capacity



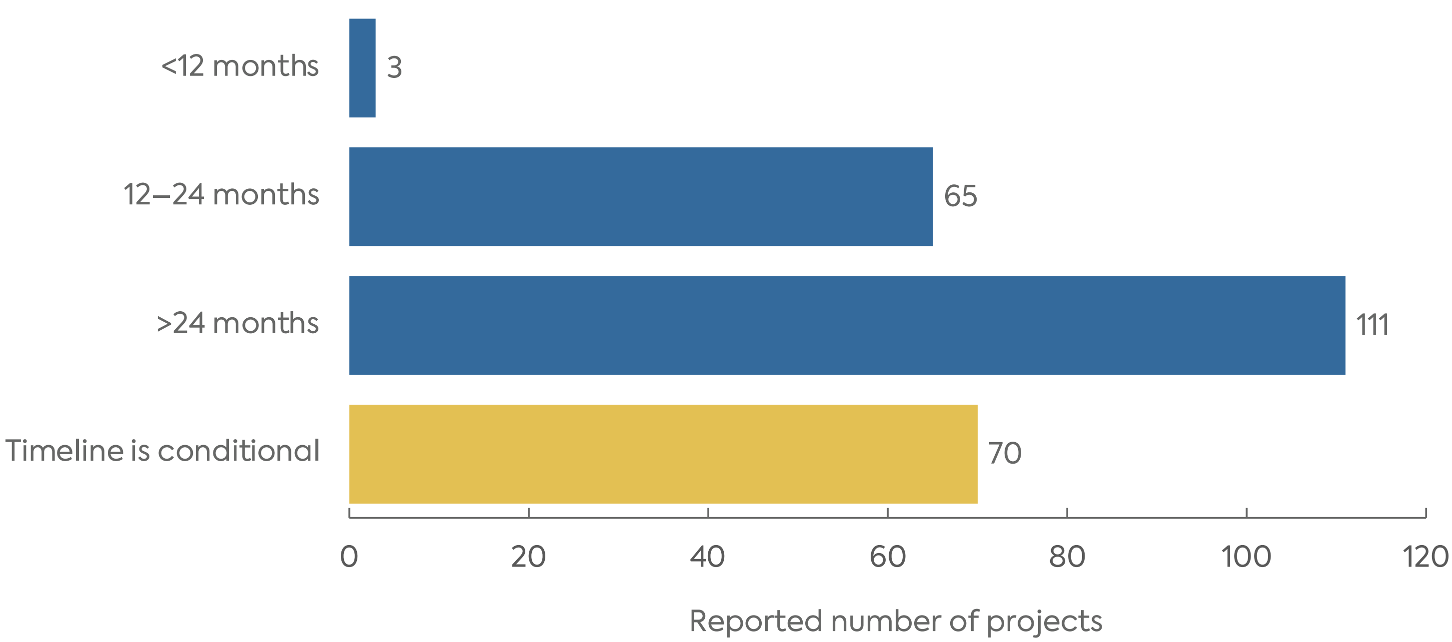
Note: Solar and wind projects include those with and without storage.
Source: Authors' analysis.

Timeline for Bringing Projects Online

The rate at which new interconnection projects make it through the queue and eventually reach commercial operation represents the difference between a reliability crisis with sub-10% reserve margins and a healthy grid.[45] To better understand the developers' outlook on timing, the survey asked how long it would take for each of their projects to reach commercial operation from the time they received an ISA. Eighteen developers responded to this portion of the survey (Figure 2).

Figure 2: Expected timeline for projects if developers received an Interconnection Services Agreement today, based on 18 respondents

"If all your projects received an Interconnection Services Agreement today, how many would reach commercial operation in the following time frames?"



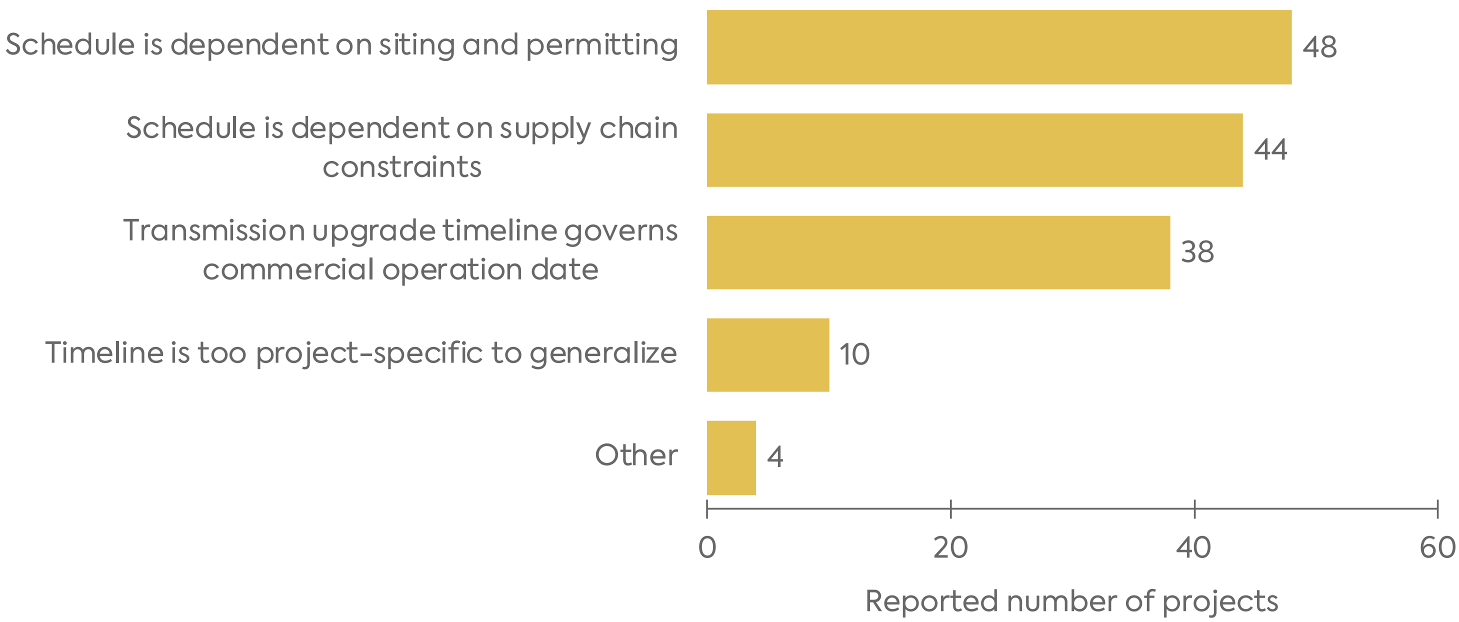
Source: Authors' analysis.

Note that the number of projects was self-identified by the developers, which resulted in a higher number of projects. The three projects with the fastest timelines were an uprate to a natural gas facility, a wind farm, and a solar farm. Medium-term projects included wind, solar, and natural gas resources. Projects expected to take longer than 24 months spanned multiple technologies.

Numerous respondents also said that timeline estimates were "conditional" on project-specific factors. To explore this aspect, the survey asked them to indicate how many of their projects depended on five different factors that were purposefully selected to explore the relative role of siting and permitting, supply chain, and network upgrade timelines (Figure 3).

Figure 3: Factors affecting projects with conditional completion timelines, based on 8 responses

"Thinking about your projects that have uncertain timelines, upon which of the following factors does the schedule depend?"



Source: Authors' analysis.

Siting and permitting was the largest source of uncertainty, followed closely by supply chain constraints and transmission upgrades. Developers who selected "other" or added commentary to their responses identified state renewable energy incentives and the ability to comply with Ohio's Domiciled Worker Rule as major sources of uncertainty, while another identified state policy changes.[46]

Expected In-Service Dates

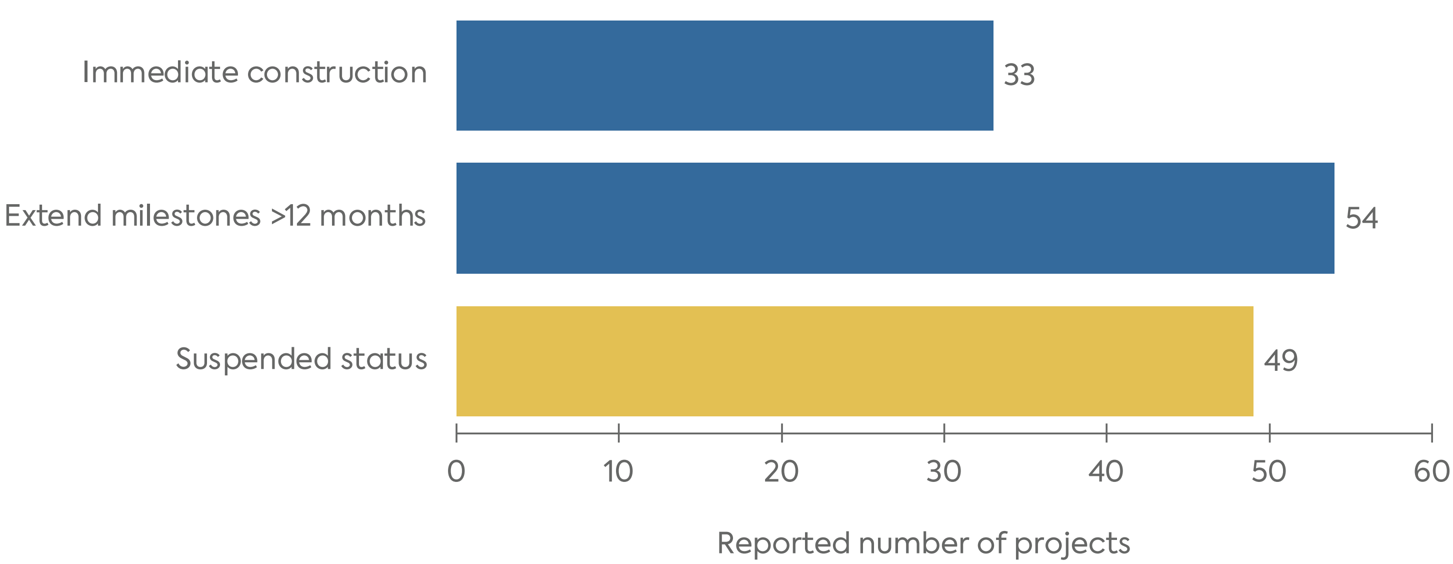
Expected in-service date is an important metric of the health of projects in the PJM queue. In-service dates are a function of two different but highly interrelated processes: the developer's construction of the facility itself; and the construction of network upgrades, or the grid enhancements necessary for the interconnecting utility to receive the power onto its transmission system. Generally, these upgrades must be completed before unrestricted commercial operations can commence. Each ISA issued by PJM includes a set of "construction milestones," applicable to both the developer and the interconnecting utility, that describe when each entity expects to complete its work.[47] If a developer misses its milestones, PJM can remove the project from its interconnection queue.

Because utility and developer construction activities often overlap or are dependent on each other, the PJM process allows developers to extend the milestones, which simply postpones their obligation to meet them, or to request that PJM put their project into "suspension," which allows the developer to pause construction activities until the project is restarted or canceled. In each case, the utility's milestones are revised accordingly. Milestones can also be extended by the transmission-owning utility to reflect delays in procurement of equipment, such as high-voltage transformers, or construction of network upgrades.

To explore how quickly developers expect to be able to begin construction on their projects, the survey asked whether they would commence construction of new facilities or take another action that would delay construction (Figure 4).

Figure 4: Next steps for projects receiving an Interconnection Services Agreement today, based on 27 respondents

"If you were to receive an Interconnection Services Agreement today, which of the following next steps would you be most likely to take?"



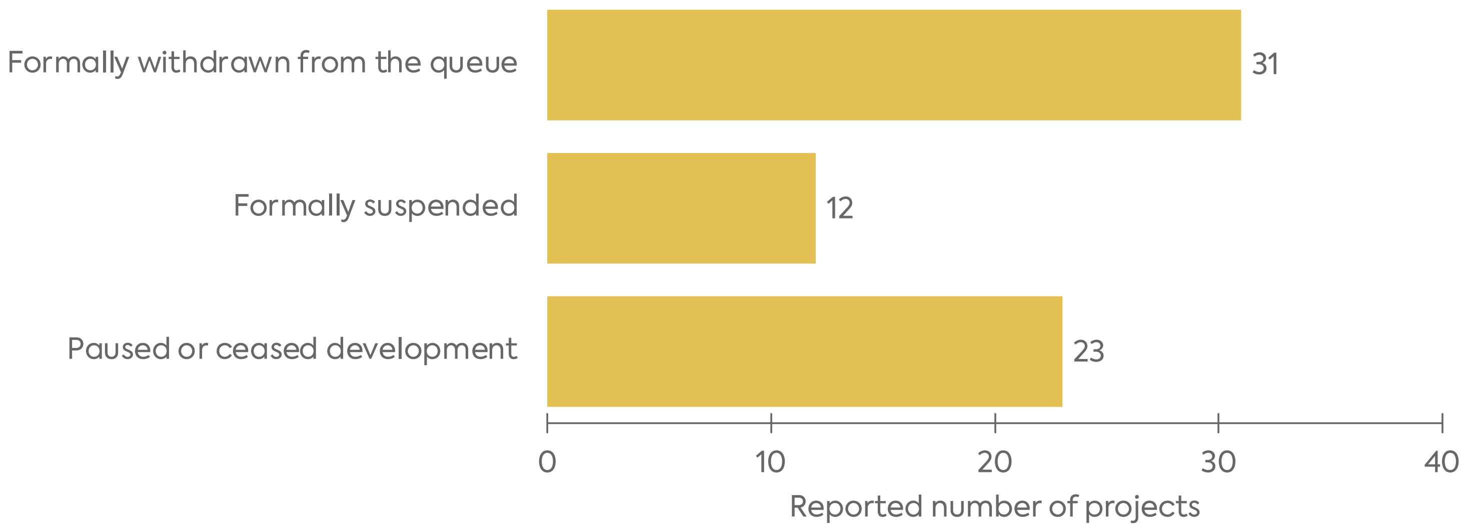
Source: Authors' analysis.

Eleven developers identified a total of 33 projects on which they anticipate commencing construction immediately after receiving an ISA, including uprates to existing natural gas facilities and solar resources. Eight developers representing 54 projects stated that their next step would be to extend milestones by more than 12 months. Another eight developers representing 49 projects across only wind and solar technology types indicated that they would put projects into suspended status. Several developers indicated that they would extend milestones and then likely put the project into suspension. During interviews, some developers indicated that projects would immediately proceed to final engineering. One developer explained, for instance, that once an ISA is received, the project would go to either a senior executive or the board of directors for a Final Investment Decision. The developer cautioned that taking a project to Final Investment Decision can be a lengthy process, as it typically requires identifying equipment and third-party financing arrangements before any determination can be made.

Another significant issue is the fate of projects that received construction milestone extensions or were suspended. Historically, such projects have remained in the interconnection queue despite not being under active development. Because studying a project consumes PJM resources regardless of its commercial prospects, PJM recently reformed its interconnection rules to remove these stalled projects from its queue by inserting two new requirements: increased maturity and financial security postings.[48] The survey asked developers how many of their projects were currently formally suspended, informally paused, or withdrawn from the queue. Developers report that approximately half were formally withdrawn from the queue (31/66) and 12 were formally suspended, in accordance with the new PJM rules. Twenty-three projects were informally paused by the developer (Figure 5).

Figure 5: Status of projects that received milestone extensions or were suspended, based on responses from 18 developers

"How many of your projects were withdrawn from the interconnection queue, put into suspension, or for which your firm paused or ceased development?"



Source: Authors' analysis.

The survey also provides insight into the question of how often developers submit multiple, marginally different interconnection queue requests for the same project. The extent to which these duplicative requests slow down PJM's efforts to complete interconnection studies has been hotly debated,[49] and several of PJM's recent queue reforms were designed to eliminate them. In the sample, only one developer identified an interconnection queue request that had been suspended or paused because it was extremely similar to another project with a separate queue position. Given this issue has been a major theme in PJM discourse, it was surprising to find only a single instance of it among the all the projects in the survey,[50] though it is possible that developers are unwilling to self-report filing a duplicative or speculative interconnection request.

Evaluating Major Challenges

Projects may face a variety of major challenges to successful completion. The authors identified challenges to be included in the survey based on their experience with interconnection challenges, review of ongoing interconnection reforms, and informal discussions with developers. Challenges were divided into two categories: non-financial barriers and financial and business barriers (Table

2). The survey also allowed developers to highlight specific aspects of these challenges and identify other challenges that were not included in the survey.

Table 2: Major challenges to projects in the interconnection queue

Non-financial barriers	Financial and business barriers
• Siting or permitting considerations at the federal, state, or local level. • Length of the interconnection study process (not including construction of network upgrades or interconnection facilities). • Length of the construction timeline for network upgrades or interconnection facilities or uncertainty around that timeline. • Supply chain concerns unrelated to solar tariffs or import restrictions. • Supply chain concerns related to solar tariffs or import restrictions. • Ability to establish site control. • Workforce or labor shortages. • Other (please describe).	• Ability to win a competitive solicitation or comparable process. • Lack of an offtake agreement. • Inflationary pressures related to equipment procurement costs. • Change in anticipated revenues from the capacity and/or energy market. • Change in financial market conditions related to cost of capital, financing, tax equity, or other financing metrics (separate from equipment procurement costs). • Change to state regulatory policy that affected value of environmental attribute or incentive programs. • Change in corporate strategy or risk appetite unrelated to a specific project. • Other (please describe).

Developers were asked to rate these major challenges on a five-point scale:

1 = The factor has no impact on the development of project(s)
2 = The factor has a small impact on the development of project(s)
3 = The factor has a moderate impact on the development of project(s)
4 = The factor has a major impact on the development of project(s)
5 = The factor has a decisive impact on the development of project(s)

Developers repeated this rating separately for two kinds of projects: (1) those in active development, which were defined as "your company's project or projects that reached the Facilities Study phase or that were tendered an Interconnection Service Agreement or the equivalent"; and (2) projects that have "been withdrawn from the PJM queue, put into suspension, or for which your firm paused or ceased development."

Non-Financial Barriers to Project Development

To assess non-financial barriers, the survey asked respondents to think generally about projects that were actively in development as well as those that are inactive (i.e., withdrawn from the queue or put into suspension by PJM, or paused or ceased development by a firm). In general, respondents rated non-financial barriers as more significant for projects in active development than for those that are inactive, potentially because projects that did not pencil out financially never reached the stage where non-financial barriers were relevant. The greatest difference between these project types related to length of construction timeline, which developers of active projects rated 3.7 out of 5 and developers of inactive projects rated 2.6, the lowest of any factor. For active projects, length of interconnection study process led with an average rating of 4.5 out of 5, indicating a significant burden on the rate of deployment for new energy resources. Respondents rated workforce issues (2.7) and establishment of site control (2.6) as the lowest barriers for active projects (Figure 6).

Figure 6: Average ratings on a five-point scale (5 = decisive impact, 1 = no impact) of non-financial barriers to projects in active development or inactive projects, based 23 respondents for active projects and 15 respondents for inactive projects

"Thinking about your projects that are {inactive / actively in development}, please rate the following factors associated with the interconnection process, siting, permitting, or supply chains on {your decision(s) / how much of a challenge they are to the project(s)}."

Note: "Inactive" includes projects that PJM has withdrawn from its queue or put into suspension, or that the firm has paused or ceased development on. Respondents with inactive projects were not asked about workforce issues.
Source: Authors' analysis.

Length of Interconnection Process

During the interview process, and in response to the open-ended survey questions, several developers explained that uncertainty over the length of the study process was leading to longer siting and permitting timelines. Specifically, developers noted that local siting approvals and permits often lapse after a year or two and that many permits require that the developer start construction within a specified amount of time and then "make continuous progress" for that permit to be maintained. They further noted that when the length of the interconnection study process is knowable, they typically synchronize it with the permitting/siting process, but the uncertainty associated with the current interconnection process has led them to wait to submit new permitting or siting applications until they receive an Interconnection Services Agreement from PJM. As one developer stated during the interview process, "The permitting aspect is an issue. Some people start on both permitting and interconnection at the same time. But we've taken the approach that we're going to wait and see and start permitting at the end."

In the interviews, other respondents identified difficulties in maintaining "site control during extended and uncertain interconnection processes," explaining that options, which give the developer the exclusive right to purchase the property in the future, or other long-term property arrangements were expensive to maintain. One developer also expressed concerns about PJM's approach to deadline enforcement, asserting that "tariff compliance is one-sided; projects sit in limbo for 18 months, and then PJM finally gets in touch on a Friday afternoon and gives you three business days [to make major commercial decisions]."

Concerns about interconnection timelines applied to all technology types, with solar developers slightly more concerned (average score of 4.8) than fossil fuel developers (average score of 4.0). Concerns about the length of the interconnection process were likewise cited as a "major" or "decisive" factor by almost half of developers with paused, suspended, or withdrawn projects.

Siting and Permitting

Seven of the 10 developers who identified siting and permitting as a major non-financial barrier (covering a total of 47 projects) deemed siting concerns as a "decisive" or "major" factor in the cancellation of one or more projects, with many citing county-level siting and permitting challenges as the primary factor in either commentary or during the interview process. Other developers specifically identified siting and permitting concerns with "local communities," "mostly county and township jurisdictions," or "multiple townships and counties." State and local siting and permitting challenges were identified in virtually every state where projects are located, including Virginia, Ohio, Pennsylvania, Maryland, Kentucky, New Jersey, Delaware, West Virginia, and Indiana.

Developers also pointed to regulatory requirements at the state level as major challenges. Several identified the Certificate of Public Convenience and Necessity process in West Virginia as very challenging, particularly given that the state has relatively few areas that are topologically suitable for solar. One developer called out New Jersey's limits on the use of agricultural land for solar arrays.

During the interview process, one developer highlighted what they referred to as "a bit of a chicken and an egg problem—ideally you would time these things so [permitting and construction] would come together, but until you have some kind of certainty that you are going to get an interconnection, we've been unwilling to make massive spending on permitting." Several developers reported that, as a result, they must wait until they receive the ISA before they start the permitting process. This effectively delays the siting and permitting process until the end of the interconnection process instead of conducting these processes in parallel.

Developers also noted that the numerous restudies were leading them to delay both siting and permitting and investment decisions. For example, one developer noted that "PJM likes to think that the interconnection is the last thing that people need, but honestly, when the timelines were better known and adhered to, you could get through the [system impact study], and then you can start making investments, so long as you don't get a surprise in the facilities study phase. But now, you get repeated facilities study delays."

One of the major points that came up across the survey responses is that siting and permitting can be a time-consuming, expensive, and potentially risky investment of funds. As one developer wrote, "state[s] and their associated agencies have competing goals that are not aligned. Local jurisdictional approval[s] are highly subjective and again don't align with intentions and goals." Another noted that a single local siting entity "can tie up project approval through a never-ending appeals process." A different developer identified "litigation of permits" as a key challenge. In each case, developers are having to delay initiating siting and permitting activities.

Relatively few survey respondents for terrestrial projects identified the National Environmental Policy Act or other federal siting or permitting statutes as significant challenges, which likely relates to the fact that federal lands play a smaller role in energy siting decisions in the eastern portion of the United States. During the interview process, several developers did, however, identify concerns about the impact of projects on the habitat of a bat species that had recently been added to the endangered species list.

One offshore wind developer noted that the federal permitting process can propel them to consider alternative points of interconnection or alternative turbine sizes, both of which can trigger a material modification process at PJM, which requires PJM to formally determine whether the change is significant enough to require the generator to restart the interconnection process.

As they put it, the "interconnection process wants a definite design/certainty, while [federal regulators] want flexibility." These developers suggested that better coordination between PJM, FERC, and federal permitting agencies may be warranted. In Europe, by contrast, the Transmission System Operation (the PJM equivalent) identifies points of interconnection at the beginning of the process and starts the permitting process even before the contract is awarded.

Length of Construction Timeline

In general, solar projects appear to be more impacted than fossil projects by long network upgrade construction timelines, potentially because many of the fossil projects involve uprates to existing projects where the interconnection infrastructure largely exists already. While length of construction was cited as a major concern for projects in active development, it was cited far less prominently as a reason for project failure, with only one developer stating that it was a "decisive" reason for a project withdrawal/suspension or pause.

Supply Chain Concerns Unrelated to Solar Tariffs or Import Restrictions

Several developers noted that the length of the interconnection study process was complicating their efforts to address equipment procurement and supply chain issues. Equipment procurement decisions are typically made as late in the construction process as possible to ensure that the project incorporates the most state-of-the-art technology available and to minimize expenses associated with storing equipment. Several developers reported delaying their equipment procurement until after receiving an ISA to avoid the risk of locking in obsolete technology or ordering equipment that they would not be able to immediately deploy. Developers also report that the lack of certainty in interconnection timelines exacerbated their ability to deal with unexpected problems in the equipment pipeline, including as a result of solar tariffs and other pandemic-related supply chain challenges.

Supply Chain Issues Related to Solar Tariffs and Import Restrictions

Respondents were asked to rank the impact of supply chain considerations in general and those related to solar tariffs and import restrictions in particular.[51] When asked to rate the relative impact of all the challenges they previously rated as "major" or "decisive," developers tended to rank tariff/import considerations lower than other challenges, suggesting they were less of a concern than siting and permitting as well as the overall length of the interconnection process. Even firms that ranked tariffs/import considerations as "decisive" said that they were only the third or fourth most significant challenge they faced. Trade issues, however, have the potential to evolve very quickly, and remain a focus for clean energy developers. This shows the complexity of project development and how multiple issues can be decisive to a project's long-term success.

Establishing Site Control

Over the past several years, numerous ISOs and RTOs, including PJM, have ratcheted up site control requirements significantly in an effort to drive down the number of projects in the interconnection queue that have little chance of reaching commercial operation (often colorfully referred to as "zombie projects").

Several developers, whether in their written comments or during the interview process, noted that maintaining site control throughout a lengthy interconnection study process was a challenge. Developers noted that site control is often demonstrated through options agreements, which typically involve an option payment to the property owner, who then agrees not to sell the property to another buyer for a fixed period. Generally, option agreements need to be renewed annually, with larger premiums charged for longer-term tie-ups. Renewing these options can involve expensive and time-consuming negotiations. Solar and wind developers cited site control as a significant challenge, whereas fossil fuel developers did not. As noted above, many of the developers of natural gas-fired projects involve uprates to existing facilities. Because the developer already owns the land on which the existing power plant was sited, they would not experience any issues with site control.

Workforce Issues

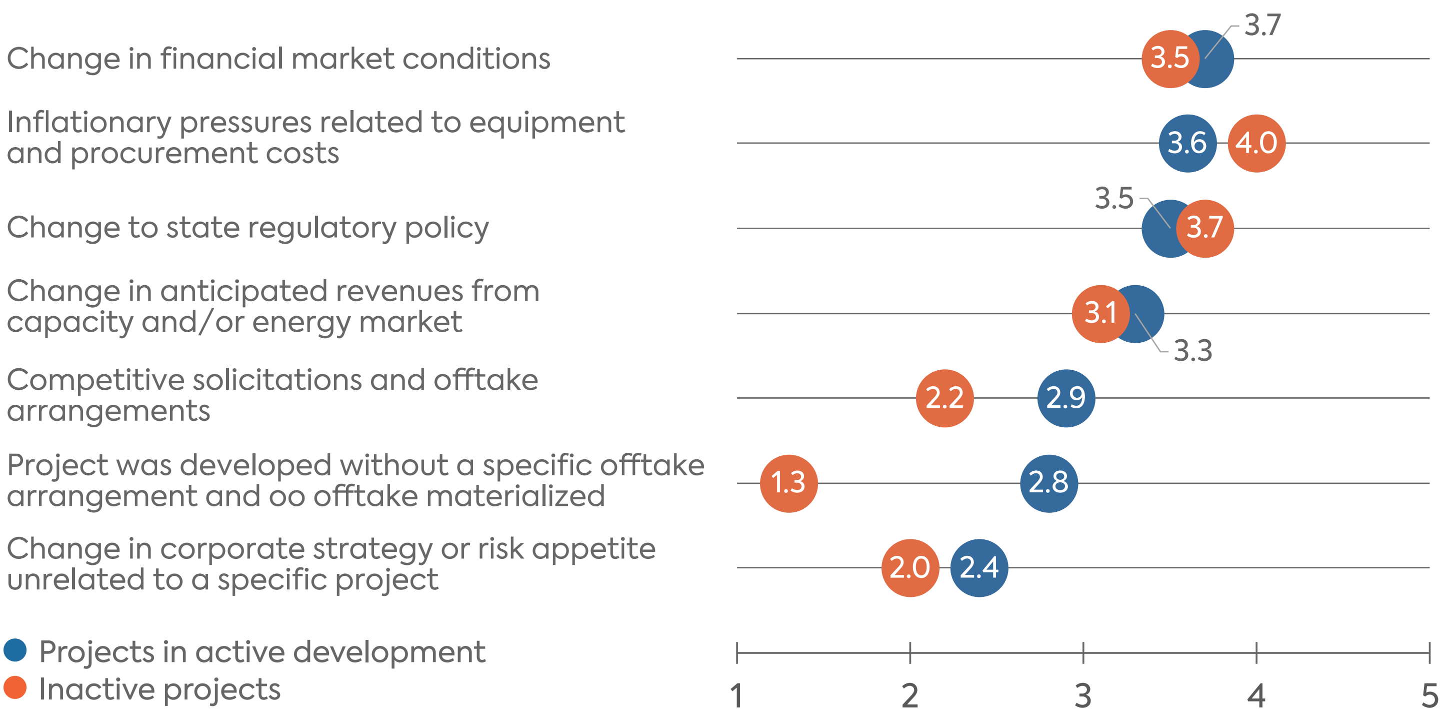
While concerns about workforce Issues were generally not highly ranked, during the interview process several developers referenced Ohio's restrictions on domiciled workers as a key challenge.

Financial and Business Barriers to Project Development

Among the five financial and business barriers included in the survey, respondents identified three as most significant to active and inactive projects alike: changes to financial market conditions, inflation-driven increases in equipment procurement costs, and changed outlook on state incentives. They deemed the two remaining challenges—absence of an offtake agreement and changes in corporate strategy or risk appetite—as less impactful, though more important for projects in active development than for inactive projects (Figure 7).

Figure 7: Average ratings on a five-point scale (5 = decisive impact, 1 = no impact) of financial and business barriers to both projects in active development and inactive projects, based on 19 respondents for active projects and 13 for inactive projects

"Thinking about your projects that are {inactive / actively in development}, please rate the following factors associated with project finance or economics on {your decision(s) / how much of a challenge they are to the project(s)}"



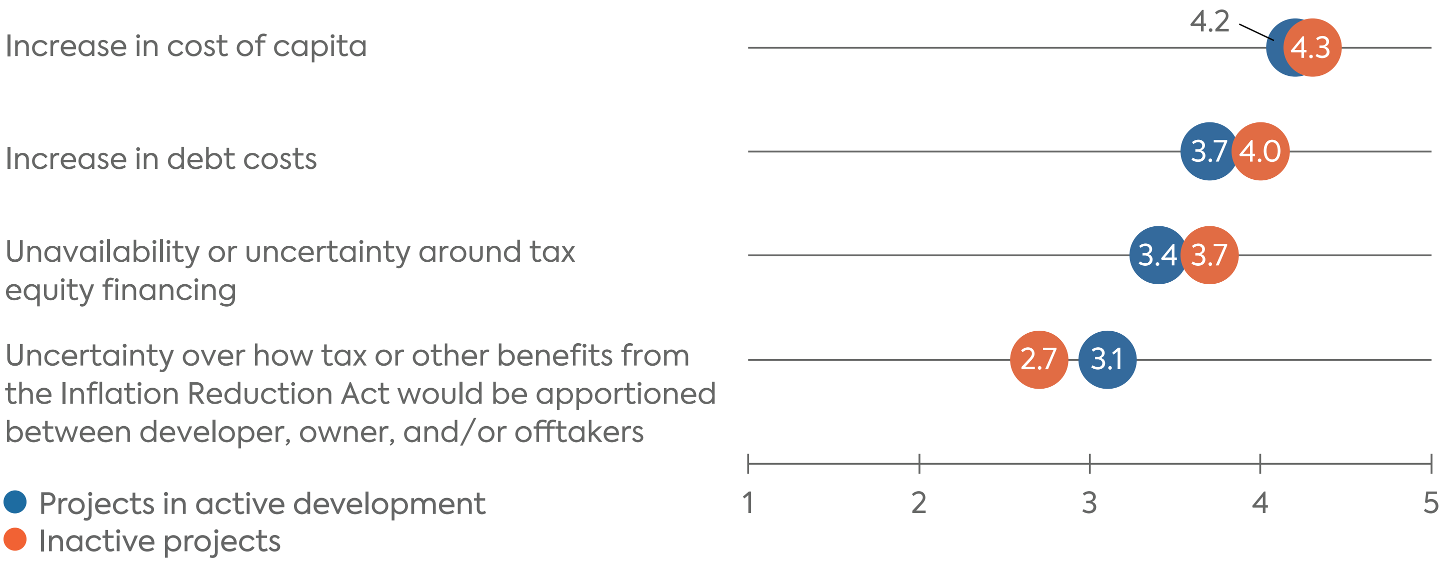
Note: The "Inactive" category includes projects that PJM has withdrawn from its queue or put into suspension, or that a firm has paused or ceased development on.
Source: Authors' analysis.

Change in Financial Market Conditions Related to Cost of Capital, Financing, Tax Equity, or Other Financing Metrics (Separate from Equipment Procurement Costs)

Developers identified changes in financial market conditions related to cost of capital, tax equity, and other financing metrics as a top concern for both active and canceled or paused projects, suggesting that macroeconomic factors related to cost of capital are top of mind for developers. One developer also identified access to tax equity as a significant challenge.

Respondents were also asked to rate four financial market conditions on the same five-point scale for both active and canceled or suspended (Figure 8).

Figure 8: Average ratings on a five-point scale (5 = decisive impact, 1 = no impact) for impact of financial market conditions on active and inactive projects, based on 11 respondents for active projects and 4 respondents for inactive projects



Source: Authors' analysis.

Notably, developers of natural gas-fired projects ranked changing financial conditions fourth, behind state incentives policies, changes in anticipated energy and capacity revenues, and inflationary pressure on equipment, likely reflecting the longer development timeframes associated with fossil units.

Inflationary Pressures Related to Equipment Procurement Costs

Inflationary pressures on equipment procurement were identified as a significant challenge to projects in active development and as a predominant cause of the suspension, pausing, or withdrawal of inactive projects, with approximately three-fourths of respondents citing inflation as the most severe challenge their projects faced. Solar developers rated this issue as slightly less significant than did developers of natural gas-fired and wind generation resources. This discrepancy may reflect the fact that steel and other commodities greatly affected by inflation over the past several years are a larger component of wind turbine and natural gas projects than they are of solar projects.

Change to State Regulatory Policy that Affected the Value of Environmental Attribute or Incentive Programs

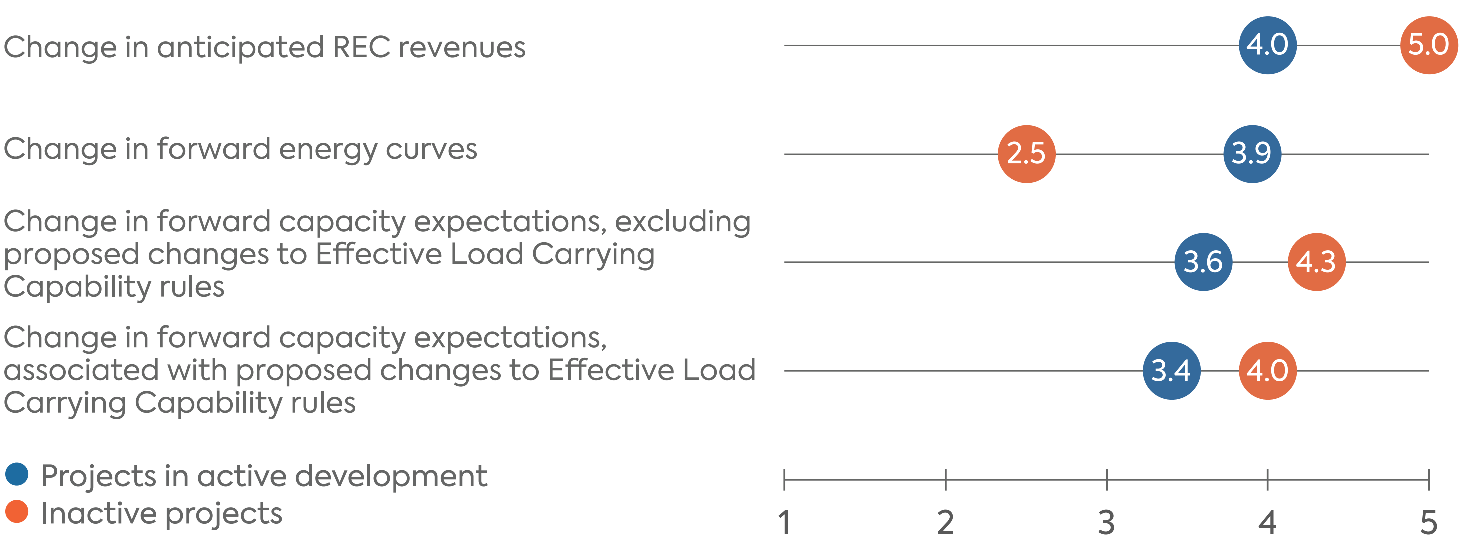
Fossil fuel developers identified state policies as "decisive," likely because of the impact of those policies on new renewable generation, which could have a depressive effect on energy and capacity market revenues. Solar developers appeared to be less concerned with changes to state incentive policies, giving it an average score of 2.8 out of 5, suggesting that they are either comfortable with the regulatory risk associated with solar incentives or are successfully hedging that risk through their sales of environmental attributes of power purchase agreement structures.

Change to Anticipated Revenues from the Capacity and/or Energy Market

Solar and wind developers appeared less concerned about changes to wholesale market revenues, giving it an average score of 3.1 out of 5, perhaps because they are utilizing power purchase agreements or other contractual structures to minimize exposure to fluctuations in wholesale revenues. If so, these results suggest that relatively few solar projects are built on a merchant basis, and that capacity makes up a smaller slice of total project revenues than it does for natural gas facilities.

Firms identifying wholesale revenues as "major" or "decisive" impacts were asked to rate on the same five-point scale a series of factors related to future revenue expectations (Figure 9).

Figure 9: Average ratings on a five-point scale (5 = decisive impact, 1 = no impact) of the importance of changes in anticipated revenues from the capacity and energy markets to projects, based on responses from 8 developers with active projects and 3 with inactive projects



Source: Authors' analysis.

Solar developers (who comprised a significant portion of the pool) were nearly evenly divided between the four options. Developers of natural gas-fired generation resources identified forward energy curves as the most significant factor, which comports with the general expectation that natural gas resources earn most of their revenue from the energy market. The second most significant factor for these fossil developers was capacity market expectations (excluding changes in ELCC rules), followed by changes in anticipated REC revenues and ELCC-driven capacity market changes.

Competitive Solicitations and Offtake Arrangements

Respondents were asked to address their experiences with offtake arrangements in two separate questions, one focused on competitive solicitation processes and the other on whether they developed projects without a specific offtake arrangement in place.

In general, the ability to win a competitive solicitation or comparable process received an average score of 2.9 out of 5, with the small number of wind developers rating this challenge significantly higher (4.3 out of 5) than solar (2.3 out of 5) or natural gas developers (2.0 out of 5). Rankings for the question about offtake arrangements were similar, with an average score of 2.8 out of 5, and a similar trend between technology types.

Two developers indicated that the lack of a specific offtake arrangement was a "decisive" factor in their project development plans. An additional developer indicated that lack of offtake was a "major" factor, while the remaining developers ranked this issue lower. One developer identified the inability to win a competitive solicitation as a "major" reason for the suspension, withdrawal, or pausing of a project. However, the relatively small number of developers who identified lack of offtake or inability to win a competitive solicitation tended to regard that challenge as a significant barrier (either the biggest or the second biggest).

The binary ratings on this topic are likely the result of differing business risk appetites. Developers who highlighted challenges associated with arranging an offtake agreement or winning a competitive solicitation also tended to rate changes in forward energy curves as significant issues. This suggests that, similar to fossil developers, developers with more merchant exposure were more concerned about long-term energy price forecasts. Natural gas developers also fall into this category, since they typically develop on a merchant basis and do not rely on offtake agreements

Change in Corporate Strategy or Risk Appetite Unrelated to a Specific Project

One developer stated that changes in corporate strategy or risk appetite represented a "major" issue for their development efforts, while a separate developer cited this factor as a "major" reason for the cancellation of one or more projects. However, this view was not widely shared, as most developers across technology classes rated this challenge as having "no," a "small," or a "moderate" impact on their development efforts.

Interconnection Upgrade Costs

While the survey did not focus on interconnection upgrade costs, eight of the 15 developers that reported withdrawing, suspending, or pausing one or more projects cited interconnection upgrade costs as a key issue.

Outlook on Future Development Efforts

Unlike other questions that focused on existing projects under development, this section of the survey asked about the developer's general outlook on development. Provided a list of potential issues that included solar tariffs and supply chain constraints, developers were asked, "Thinking about 12 months into the future, which of these factors do you anticipate will continue to negatively affect your development efforts?" The summary of the responses is in Table 3.

Table 3: Percentage of respondents who identified factors anticipated to negatively affect future development efforts, based on 16 total responses

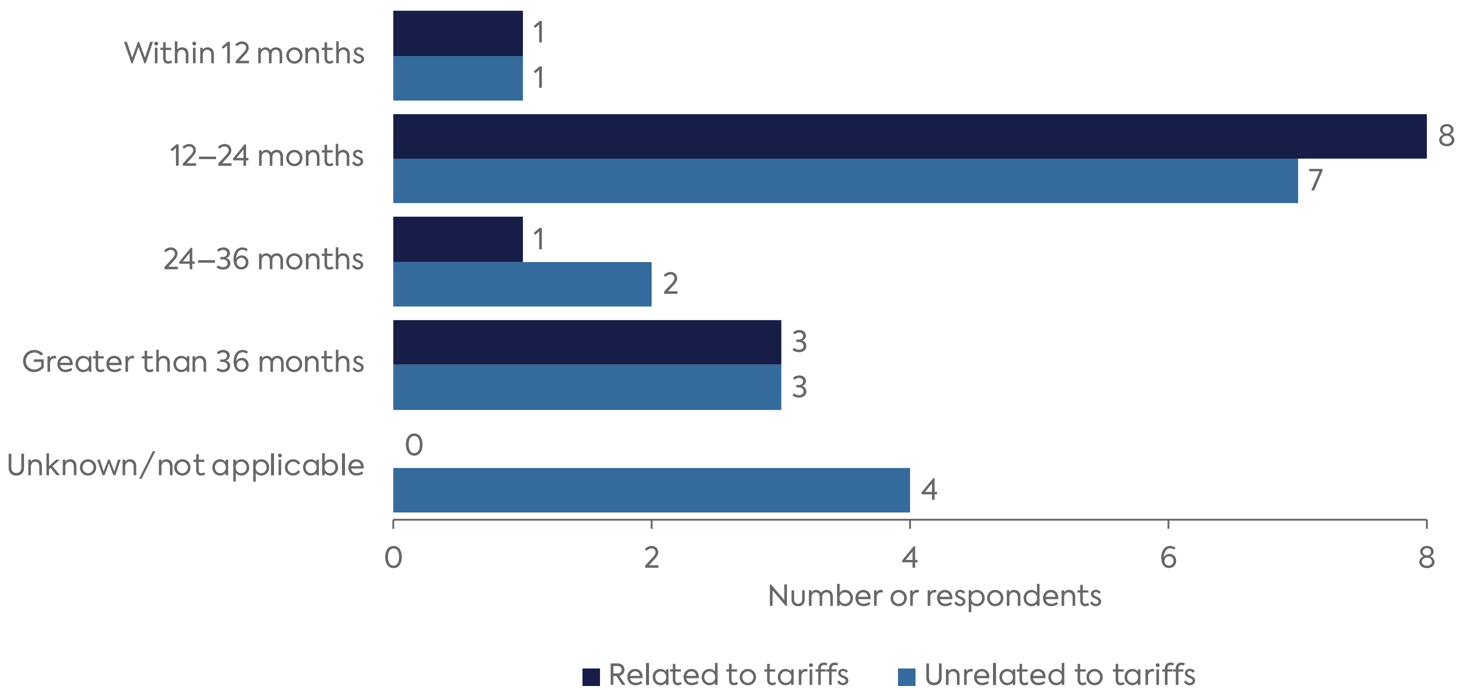
Factor	%
Length of the construction timeline for network upgrades or interconnection facilities or uncertainty around that timeline.	90%
Supply chain concerns unrelated to solar tariffs or import restrictions	81%
Siting or permitting considerations at the federal, state, or local level	57%
Inflationary pressures related to equipment procurement costs	57%
Change in financial market conditions related to cost of capital, financing, tax equity, or other financing metrics (separate from equipment procurement costs)	57%
Length of construction timeline for network upgrades or interconnection facilities or uncertainty around that timeline	57%
Supply chain concerns related to solar tariffs or import restrictions	43%
Change to state regulatory policy that affected value of environmental attribute or incentive programs	38%
Change in anticipated revenues from the capacity, energy, and/or REC market	29%
Ability to establish site control	24%
Other, please describe	19%
Ability to win a competitive solicitation or comparable process	14%
Potential inability to line up an off-take arrangement	14%
Reallocation of resources to another project	14%
Change in corporate strategy or risk appetite unrelated to a specific project	14%

In their outlook for the year ahead, developers expressed many of the same concerns they expressed for past periods, with interconnection timelines continuing to be at the top of the list, followed by macroeconomic factors such as supply chain and cost of capital as well as network upgrade construction timelines and siting and permitting. Several developers called out interconnection costs, pressure from PJM around milestone dates, availability of labor for equipment procurement and construction, and the prospect that high demand for skilled labor could result in higher costs.

In response to the question "When do you estimate that supply chain issues for solar panels {*related*

/ not related} to solar tariffs are likely to be resolved?," most respondents estimated 12–24 months, though nearly a quarter stated "unknown" or "not applicable" when considering issues unrelated to tariffs (Figure 10).

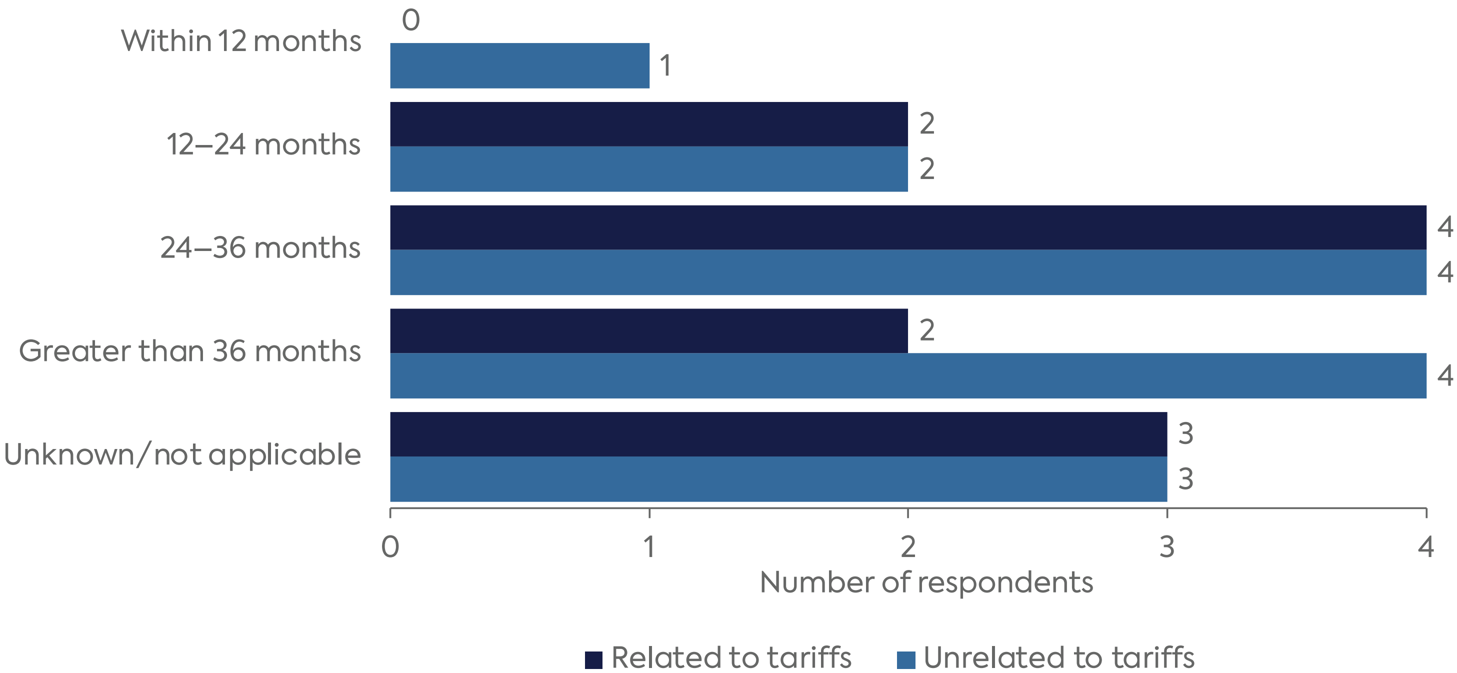
Figure 10: Estimated timeframe for solar panel supply chain issues to be resolved, based on 17 responses.



Source: Authors' analysis.

Developers have also struggled with supply chain issues limiting the availability of transformers. In response to the question "What is your outlook on when supply chain issues for transformers or other issues {*related / not related*} to solar tariffs are likely to be resolved?," developers expressed that, unlike supply chain issues related to solar panels, they expect it will take a long time, with approximately 30% saying either 24–36 or more than 36 months and only one saying within 12 months (Figure 11).

Figure 11: Estimated timeframe for supply chain issues related to transformers to be resolved, based on 14 responses.



Source: Authors' analysis.

During the interview process, several developers noted that it is typically the utility's responsibility to procure high-voltage breakers and transformers. One developer noted that it was currently taking transmission owners over two years to procure high-voltage circuit breakers, and they had recently been told that procuring a 345 kilovolt circuit breaker would take four years in another market region. The data reflect this pessimism, with developers reporting extended delays in transformer supply.

Conclusion

The idea that the interconnection process is fundamentally broken is not new. Nor is the idea that additional reforms will be necessary to fix the process.[52] Interconnection delays are fundamentally caused by a transmission grid that is not sized to meet the amount of new clean generation that is being brought to market and an overly lengthy process for identifying how to grow the grid.

The survey highlights that stakeholders, including PJM, may need to adjust their expectations of how quickly new generation resources can come online. Developers report that most of their projects will take two or more years to reach commercial operation, even after they complete the interconnection process. Survey respondents repeatedly highlighted the pernicious interplay between interconnection delays and siting and permitting challenges—in particular, the fact that site-specific permits and siting approvals expire after a period of inactivity that is typically shorter than the interconnection queue process. Further, the wide range of potential interconnection study times is leading developers to delay high-risk siting and permitting activities,[53] which can be the most contentious and risky part of the development process, until the end of the study process, potentially adding years to commercial operation timelines. This is a troubling sign, suggesting that delays and project cancellations will continue to occur at high levels for the foreseeable future.

This lengthy timeline also underlines the role that interconnection plays in PJM's competitive markets. New generation has the power to displace more expensive resources and discipline the exercise of supply-side market power. But Interconnection queue delays blunt the ability of PJM to ensure effective competition in its markets since even relatively inefficient generators (or those exercising market power) are more difficult to displace with new, lower-cost resources.

Solving the interconnection crisis will likely require two changes: creating effective planning processes that identify where new transmission headroom is likely to be needed; and expanding the transmission system to meet that need. The path to a transmission grid that is "fit for purpose" is long, however, involving difficult questions around cost causation and allocation. PJM is currently considering reforms to its long-range transmission planning process, which lags behind that of other regions in the US.[54] The new reforms are designed to identify proactively the transmission needed to meet future queue needs and address the reliability needs of the grid.[55] FERC is also expected to issue a regional transmission rule in the near future focused on transmission planning reforms on the national level.[56]

Beyond these measures, a significant overhaul of interconnection processing policies will likely be needed. FERC's recent interconnection reforms in Order No. 2023 are an important step forward but are unlikely to fully resolve the problem.[57] FERC may want to consider a range of fixes, from technical reforms that can increase access to the grid in the short term[58] to wholesale revisions to the existing interconnection study framework.[59] Given the immediate needs of the grid, interconnection solutions will likely need to be pursued in parallel with longer-term grid reform efforts. Some that policymakers may wish to consider include:

- Allowing retiring generators to be replaced with new resources at the same location.[60]
- Increasing the use of advanced technologies, such as Grid Enhancing Technologies, that allow more power to flow over existing transmission lines.[61]
- Transitioning from today's study-intensive "invest and connect" model to a study-light "connect and manage" model.[62]

State regulators and other policymakers will also be wise to manage the phaseout of existing resources carefully. One way of doing so is to build "reliability safety valves" into environmentally driven retirement schedules. This safety valve could dynamically adjust retirement dates based on PJM's expected reserve margin or success in bringing on replacement generation. While the PJM market structure sends higher price signals during times of supply scarcity to attract new resources, there may be a lag in new entry, particularly given the lengthy interconnection process.

Notes

1. Joseph Rand et al., "Queued Up: 2024 Edition – Characteristics of Power Plants Seeking Transmission Interconnection As of the End of 2023," Lawrence Berkeley National Laboratory, April 2024, https://emp.lbl.gov/publications/queued-2024-edition-characteristics; and Joseph Rand et al., "Queued Up: Characteristics of Power Plants Seeking Transmission Interconnection As of the End of 2022," Lawrence Berkeley National Laboratory, April 2023, https://doi.org/10.2172/1969977.

2. Federal Energy Regulatory Commission, "Order No. 2023: Improvements to Generator Interconnection Procedures and Agreements," 184 FERC ¶ 61,054 (2023) at P 39–40, https://www.ferc.gov/media/order-no-2023 (finding that "[f]or generating facilities built in 2022, wait times in the interconnection queue saw a marked increase to now roughly five years").

3. See FERC, Order No. 2023 at P 49 (noting that "a withdrawal can trigger costly restudies and create uncertainty in the interconnection process for interconnection customers and transmission providers alike").

4. Rand et al., "Queued Up: 2024 Edition" (noting that PJM completed zero interconnection service agreements in 2023).

5. See PJM, "Energy Transition in PJM: Resource Retirements, Replacements & Risks," February 24, 2023, 2, https://www.pjm.com/-/media/library/reports-notices/special-reports/2023/energy-transition-in-pjm-resource-retirements-replacements-and-risks.ashx.

6. See, e.g., Claire Wayner et al., "Going the Distance on Interconnection Queue Reform: FERC's Rulemaking Takes Us Only Part of the Way to Effective and Efficient Interconnection," RMI, August 2023, https://rmi.org/going-the-distance-on-interconnection-queue-reform/; Robi Nilson, Ben Hoen, and Joseph Rand, "Survey of Utility-Scale Wind and Solar Developers Report," Lawrence Berkeley National Laboratory, January 2024, https://emp.lbl.gov/publications/survey-utility-scale-wind-and-solar (finding that, on a national basis, interconnection delays were the second biggest cause of canceled projects and the biggest driver of delays.

7. See, e.g., Nilson et al., "Survey of Utility-Scale Wind and Solar Developers Report."

8. As FERC notes, "backlogs in the generator interconnection process, in turn, can create reliability issues as needed new generating facilities are unable to come online in an efficient and timely manner." FERC, Order No. 2023 at P 3. See also Monitoring Analytics, "2023 State of

the PJM Market Report," 2024, 1, https://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2023/2023-som-pjm-sec1.pdf. ("The markets face a challenge from potentially high levels of expected thermal generator retirements, with no clear source of replacement capacity or the fuel required for that capacity.")

9. See Rand et al., "Queued Up: 2024 Edition."

10. Ibid., 3.

11. FERC, Order No. 2023.

12. See, e.g., Jesse D. Jenkins et al., "Mission Net-Zero America: The Nation-Building Path to a Prosperous, Net-Zero Emissions Economy," *Joule 5*, no. 11 (2021), https://doi.org/10.1016/j.joule.2021.10.016.

13. FERC, Order No. 2023.

14. For detailed background about PJM's efforts to fix its queue, see PJM Interconnection LLC, 181 FERC ¶ 61,162 (2022), footnote 15, https://pjm.com/directory/etariff/FercOrders/6581/20221129-er22-2110-000%20and%20-001.pdf.

15. PJM Interconnection LLC, 181 FERC ¶ 61,162 (2022) at P 57.

16. Monitoring Analytics, "2023 State of the Market Report," 74.

17. Ibid., 74.

18. Ibid., 75.

19. Ibid., 75.

20. PJM, "New Interconnection Process Reaches Next Milestone," press release, December 21, 2023, https://insidelines.pjm.com/new-interconnection-process-reaches-next-milestone/.

21. See PJM, "Energy Transition in PJM."

22. Ibid., 17.

23. Monitoring Analytics, "2023 State of the Market Report," 1.

24. PJM, "Energy Transition in PJM," 13.

25. See PJM, "Update on Reliability Risk Modeling," May 30, 2023, https://www.pjm.com/-/media/committees-groups/cifp-ra/2023/20230530/20230530-item-03---reliability-risk-modeling.ashx.

26. Mark Specht's primer "ELCC Explained: The Critical Renewable Energy Concept You've Never Heard Of," is an excellent resource for understanding capacity accreditation. Union of Concerned Scientists, 2020, https://blog.ucsusa.org/mark-specht/elcc-explained-the-critical-renewable-energy-concept-youve-never-heard-of/.

27. See PJM's report detailing extensive outages of fossil resources during December 2022 Winter Storm Elliott weather event: https://pjm.com/-/media/library/reports-notices/special-reports/2023/20230717-winter-storm-elliott-event-analysis-and-recommendation-report.ashx.

28. See PJM, "Energy Transition in PJM," 8.

29. Ibid., 5.

30. Monitoring Analytics, "2023 State of the Market Report," 1.

31. See PJM, "Energy Transition in PJM," 7.

32. For a detailed description of the statute, including reference emissions rates, see https://epa.illinois.gov/topics/ceja/electric-generating-units.html.

33. See PJM, "Energy Transition in PJM," 8.

34. Ibid., 6, figure 2.

35. PJM's commercial probability model suggests that less than 10% of the projects starting the interconnection process are expected to actually reach commercial operation and suggests that "after adjusting the new renewable capacity by Effective Load Carrying Capability (ELCC) derations, this commercial probability analysis estimates net 13.2 GW-nameplate / 6.7 GW-capacity to the system by 2030." See PJM, "Energy Transition in PJM,"12.

36. The PJM Energy Transition Report's High New Entry Scenario included "107 GW-nameplate/30.6 GW-capacity after ELCC derations. Net natural gas entry was approximately 5 GW, and renewables was 48.5 GW-nameplate/10.4 GW-capacity."

37. PJM, "New Interconnection Process Reaches Next Milestone."

38. See Letter from Ohio Manufacturers Association, December 21, 2023, https://www.pjm.com/-/media/about-pjm/who-we-are/public-disclosures/20231221-oh-manufacturers-assoc-letter-re-competitive-electricity-markets-during-rapid-system-technological-transformation.ashx; and James F. Wilson, "Maintaining the PJM Region's Robust Reserve Margins," National Resources Defense Council and Sierra Club, May 2023, (https://www.sierraclub.org/sites/www.sierraclub.org/files/2023-05/Wilson%20R4%20Report%20Critique%20Revised.pdf.

39. A small subset of projects in the study window received Wholesale Market Participation Agreements in lieu of an Interconnection Services Agreement, but are effectively the same for the purposes of our study.

40. "Uprates" are when an already-existing facility requests that PJM formally increase the maximum sustained output for the facility. Uprates are usually occasioned by improvements in power plant efficiency, changes in fuel type, or operational experience that justifies a higher output level.

41. PJM," Services Request Status," https://www.pjm.com/planning/service-requests/services-request-status.

42. Several developers self-identified as having more projects that appear in the queue. Because these were likely data entry errors or a misunderstanding of the question, we manually adjusted several of the numbers to bring them into line with what appears in the queue.

43. See Sarah Johnston, Yifei Liu, and Chenyu Yang, "An Empirical Analysis of the Interconnection Queue," National Bureau of Economic Research working paper, December 2023, https://doi.org/10.3386/w31946 (finding that they were able to identify developers for 39% of overall entrants into the PJM interconnection queue increasing to 52% and 81% of projects that had advanced further through the interconnection process).

44. The full survey instrument is available for download on the Center on Global Energy Policy website.

45. While PJM's Energy Transition Report focused on the reliability implications of reserve margins below 10%, low reserve margins typically lead to steeply increasing consumer costs, which could have major implications for energy affordability, even if grid reliability isn't compromised. See PJM, "Energy Transition in PJM," 15.

46. Ohio law requires that developers of most energy projects qualify for advantageous tax treatment if they receive the support of local government and employ a certain percentage of workers domiciled in Ohio. Section 5727.75, "Exemption on Tangible Personal Property and Real Property of Certain Qualified Energy Projects." For a summary of the implications of Ohio's siting rules, see https://www.bricker.com/Documents/Resources/QEP%20_project_white_paper.pdf.

47. For example, the Solar Energy Industries Association suggests that a typical large (250 MW) project takes approximately two years to construct after completion of the interconnection study process, construction of network upgrades, siting, permitting, and other necessary

steps. SEIA, "Development Timeline for Utility-Scale Solar Power Plant," https://www.seia.org/research-resources/development-timeline-utility-scale-solar-power-plant.

48. FERC recently approved a variety of changes to PJM's interconnection rules, including requiring developers to include deposits with their interconnection requests and to demonstrate that the project met certain project maturity requirements, e.g., demonstrating site control. These deposits are designed to ensure that developers are willing to post financial security behind their development efforts and reduce the incidence of speculative or low-probability projects.

49. Emma Penrod, "Why the Energy Transition Broke the US Interconnection System," Utility Drive, August 22, 2022, https://www.utilitydive.com/news/energy-transition-interconnection-reform-ferc-qcells/628822/.

50. In an analysis of the PJM queue, Johnston et al. suggest that the low concentration of projects among developers counters assertions that speculative interconnection requests are burdening queue processing. They find that in "cases where a developer had more than one generator in an entry cohort, either all or none of the generators were completed 71% of the time," and that "these data are generally consistent with developers being willing to build all generators that are individually profitable." Johnston et al., "An Empirical Analysis of the Interconnection Queue."

51. For a summary of solar tariff and import issues, see Lilly Yejin Lee and Noah Kaufman, "Q&A: Solar Tariffs and the US Energy Transition," Energy Explained, Center on Global Energy Policy, November 13, 2023, https://www.energypolicy.columbia.edu/qa-solar-tariffs-and-the-us-energy-transition/.

52. See, e.g., Comments of FERC Commissioner Allison Clements at the Raab Associates' New England Electricity Restructuring Roundtable on Dec. 8, *available at*: https://www.rtoinsider.com/65517-clements-raab-roundtable/.

53. See, e.g., Nilson et al., "Survey of Utility-Scale Wind and Solar Developers Report."

54. See Lewis (Zhaoyu) Wu, Abraham Silverman, Harrison Fell, and James Glynn, "A Quantitative Analysis of the Impact of Key Variables on Power Transmission Infrastructure Project Development in the US," Center on Global Energy Policy, Columbia University, April 5, 2024, https://www.energypolicy.columbia.edu/publications/a-quantitative-analysis-of-variables-affecting-power-transmission-infrastructure-projects-in-the-us/ (showing that transmission expansion in PJM has lagged behind several other regions).

55. See PJM's Long-Term Regional Transmission Planning initiative, https://www.pjm.com/

committees-and-groups/workshops/ltrtp.

56. See Federal Energy Regulatory Commission, "Building for the Future Through Electric Regional Transmission Planning and Cost Allocation and Generator Interconnection," 179 FERC ¶ 61,028 (2022).

57. Silverman, et al., "FERC's Interconnection Reform: Why It Matters for the Clean Energy Transition," Energy Explained, Center on Global Energy Policy, August 7, 2023, https://www.energypolicy.columbia.edu/fercs-interconnection-reform-why-it-matters-for-the-clean-energy-transition/.

58. See, e.g., RMI, "Clean Repowering: How to Capitalize on Fossil Grid Connections to Unlock Clean Energy Growth," January 2024, https://rmi.org/insight/clean-repowering.

59. See, e.g., Tyler Norris, "Beyond FERC Order 2023: Considerations on Deep Interconnection Reform," Nicholas Institute for Energy, Environment & Stability, Duke University, August 2023, https://nicholasinstitute.duke.edu/publications/beyond-ferc-order-2023-considerations-deep-interconnection-reform.

60. See, e.g., RMI, "Clean Repowering."

61. See, e.g., WATT Coalition, "Grid Enhancing Technologies in Generator Interconnection," https://watt-transmission.org/grid-enhancing-technologies-in-generator-interconnection/; and Russell Mendell, Mathias Einberger, and Katie Siegner, "FERC Could Slash Inflation and Double Renewables with These Grid Upgrades," RMI, July 7, 2022, https://rmi.org/ferc-could-slash-inflation-and-double-renewables-grid-upgrades/.

62. "Under the "connect and manage" model, the grid operator narrows the scope of the interconnection study process to look at the grid enhancements necessary to allow the generator to physically interconnect to the grid. Questions around deliverability of the power are deferred to subsequent studies. This reduces the complexity of the interconnection process, resulting in faster studies and increased ability to process interconnection requests. In exchange, interconnecting generators accept higher congestion and curtailment risk until deliverability studies and necessary upgrades are completed." See Silverman et al., "What's Next in Interconnection Reform? Lessons from International Experience," Energy Explained, Center on Global Energy Policy, August 15, 2023, https://www.energypolicy.columbia.edu/whats-next-in-interconnection-reform-lessons-from-international-experience/; see also Tyler Norris, "Beyond FERC Order 2023."

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