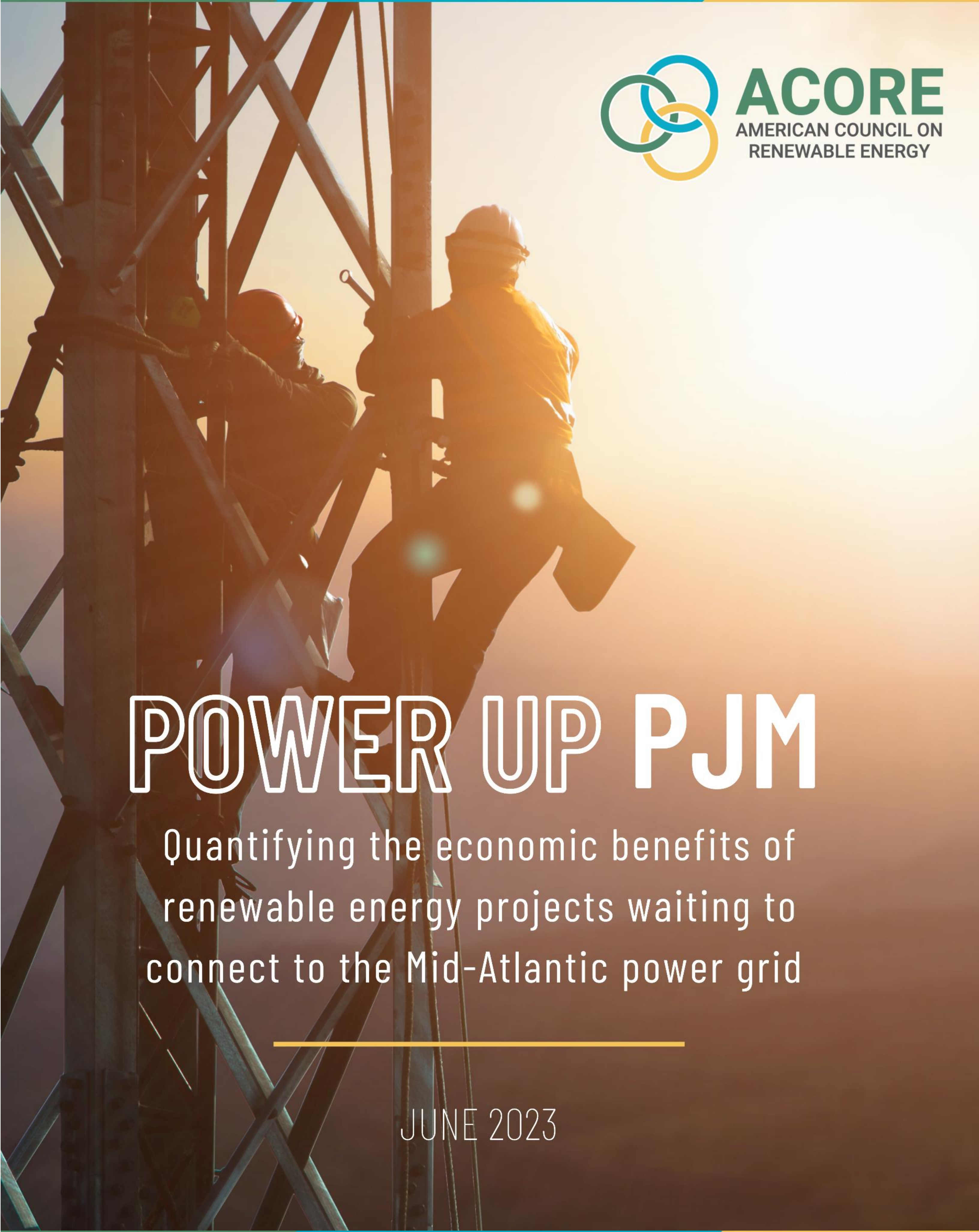


ACORE
AMERICAN COUNCIL ON RENEWABLE ENERGY

POWER UP PJM

Quantifying the economic benefits of renewable energy projects waiting to connect to the Mid-Atlantic power grid

JUNE 2023

Author

Noah Strand
Policy Associate
ACORE

Contributors

Kevin O'Rourke
Vice President, Strategic Partnerships and Public Affairs ACORE

Elise Caplan
Vice President, Regulatory Affairs
ACORE

Lesley Hunter
Senior Vice President, Programs and Sustainable Finance ACORE

Jose Zayas
Executive Vice President, Policy & Programs
ACORE

Daniel Wolf
Legislative Director
ACORE

Brendan Casey
Deputy Director, Economic Analysis
ACP

ABOUT ACORE

The American Council on Renewable Energy (ACORE) is a 501(c)(3) national nonprofit organization that unites finance, policy, and technology to accelerate the transition to a renewable energy economy.

Disclaimer

This report was prepared by the American Council on Renewable Energy (ACORE) and does not necessarily reflect the views of ACORE members or sponsors. There are no third-party beneficiaries or conflicts of interest associated with this publication, which is intended for free and public distribution. ACORE is not liable to any third-party with respect to the contents of this report, including any decisions or actions that its conclusions might encourage.

Contents

EXECUTIVE SUMMARY

The low-cost, clean power that American businesses and homeowners are demanding is ready for deployment, but thousands of projects seeking to connect to the nation's electricity grids are facing long delays and rising costs. Almost two terawatts of wind, solar, and battery storage projects are now waiting in interconnection queues across the country.[1] Although a lack of transmission capacity due to insufficient transmission planning is a root cause of the unprecedented backlog, several grid operators have also lagged in implementing interconnection queue process reforms.

PJM Interconnection LLC (PJM), a regional transmission organization (RTO) that manages the movement of wholesale electricity in the U.S. Mid-Atlantic region, is in the process of implementing queue reforms, but faces ongoing challenges. Over the past several years, thousands of new projects totaling 259 gigawatts (GW) of energy capacity have submitted interconnection requests in the region. Nearly all of those projects are wind, solar, and battery storage.[2]

Consistent with other grid regions, PJM's current queue challenges are primarily due to a lack of sufficient transmission development, but the region's outdated interconnection process has also served as a major contributing factor. Until recently, PJM's queue process had entailed studying and assigning the costs of transmission system upgrades to new generation on a project-by-project basis. Each new interconnection request would trigger numerous study phases and cost calculations, with many projects waiting years before ultimately withdrawing. This process – combined with a steady increase in new service requests – increased the wait time for projects and created significant uncertainty regarding their cost assignment. These factors contributed to the withdrawal of three-quarters of onshore wind, solar, and battery storage ("renewable energy") project applications in the region submitted between 2011 and 2016, a pattern also seen across the country.[3]

To begin addressing these issues, PJM proposed, and the Federal Energy Regulatory Commission (FERC) approved last November, a set of procedural reforms to expedite the approval of pending interconnection applications by Q1 2026.[4] The reforms have placed an embargo on all new service requests until this approximately four-year transition period has concluded. After reopening the queue, PJM will begin evaluating projects in groups and allocate the costs of the necessary network improvements accordingly. This

[1] Lawrence Berkley National Laboratory, "Queued Up: Characteristics of Power Plants Seeking Transmission Interconnection" (April 2023), *available at* https://emp.lbl.gov/queues.
[2] PJM New Services Queue data, *available at*: https://www.pjm.com/planning/services-requests/interconnection-queues.aspx.
[3] 735 applications withdrawn out of 995 total wind, solar, and battery storage applications entering the queue between 2011 and 2016. PJM New Services Queue, Rand, J. et al. Queued Up: Characteristics of Power Plants Seeking Transmission Interconnection as of the End of 2021. (April 2022) at 3.
[4] PJM Interconnection, L.L.C., 181 FERC ¶ 61,162 (2022).

approach, known as a cluster study approach, is a significant improvement from the prior framework and one used by other RTOs. To filter out more speculative projects, PJM's reforms will also require applicants to meet certain readiness requirements upon submitting a new service request and at various stages during the interconnection study process.

The changes provide an important opportunity to connect more renewable energy projects to the grid and deliver significant economic benefits to Mid-Atlantic states, including new jobs, capital investment, electricity cost savings, and improved air quality.

If PJM's reforms enable the renewable energy projects in the transition cycle to achieve commercial operation at a rate consistent with averages from less than a decade ago, Mid-Atlantic states could see the creation of approximately 199,000 job-years[5] and $33 billion in capital investment.

Our analysis also estimates that if PJM had proactively developed sufficient transmission capacity prior to enacting these reforms, the region could have enabled an additional 100,000 job-years and $17 billion in additional capital investment over the next four years.

Maximizing the economic benefits of PJM's current reforms will require the grid operator to work effectively and ahead of schedule.

PJM should take proactive steps to review and approve interconnection applications more efficiently, including at a minimum, hiring additional staff and implementing best practices such as process automation.[6] More fundamentally, transmission planning and development process improvements are needed to integrate more resources onto the grid.[7]

By improving the interconnection process and transmission planning overall, PJM can simultaneously tackle rising demand, bolster reliability, reduce costs, stimulate the economy, and secure a clean energy future for consumers in the region.

Further, FERC must finalize or initiate new rulemakings to incorporate rising interconnection needs into regional transmission planning, standardize the interconnection study process, require greater consideration of technologies to improve the efficiency of the grid and distribute the costs of transmission upgrades required for interconnection equitably.

---

[5] Job-years are defined as the full-time equivalent of one job for one year. See Methodology section.
[6] See, e.g. Pearl Street Technologies, Intro to Interconnection, *available at* https://pearlstreet.substack.com/p/intro-to-interconnection (Noting that, "Today, there is considerable need to expedite conventionally manual elements of studies through process automation. Examples include reliably and quickly creating study models, performing input data quality checks, and identifying mitigation suggestions, particularly for non-convergent power flow simulations. Further, automation can provide entities beyond utilities and operators (e.g., developers) the ability to easily replicate study results and to better evaluate risk associated with projects' interconnection prior to submission to a queue.")
[7] Comments of ACORE. RM22-14-000 at 5 (October 2022), *available at* https://acore.org/acore-submits-comments-to-ferc-on-proposed-interconnection-reforms/.

INTRODUCTION

Wind, solar, and battery storage ("renewable energy") technologies have comprised the majority of new U.S. power plant additions in recent years. This trend is poised to accelerate due to a number of drivers: (1) the passage of the Inflation Reduction Act (IRA) of 2022, which provides long-term federal tax incentives for these technologies; (2) increased demand to meet existing state renewable portfolio standards; and (3) ever-increasing clean energy goals set by state and local governments and large corporate entities.[8] Yet navigating the process for connecting renewable projects to the power grid, known as interconnection, continues to prove challenging for renewable project developers and Regional Transmission Organizations (RTOs). Thousands of renewable energy projects across the nation are currently active in interconnection "queues," which are processes that facilities must enter before connecting to the grid and producing the electricity that powers American homes and businesses.[9]

As the largest RTO – serving approximately 65 million people in parts of 13 Mid-Atlantic states and the District of Columbia – PJM has perhaps the greatest challenge to solve. As of March 2023, the region reported 2,649 active projects in its generation interconnection queue, totaling roughly 259 gigawatts (GW) of generation capacity.[10] Of these projects, 84.6% are onshore wind, solar, and battery storage.[11] For comparison, PJM's total installed electric generation capacity is approximately 192 GW.[12]

Background

As with many other regions, PJM's interconnection queue backlog is largely the result of an outdated process originally designed to facilitate the interconnection of large-scale, predominantly fossil-fired power plants, as well as a failure to plan sufficient transmission capacity.[13]

---

[8] ACORE. Inflation Reduction Act of 2022: ACORE's Summary of Clean Energy & Transmission Provisions (August 12, 2022), *available at* https://acore.org/inflation-reduction-act-of-2022-acores-summary-of-clean-energy-transmission-provisions/; PJM. Energy Transition in PJM. Frameworks for Analysis. (December 2021). https://www.pjm.com/-/media/library/reports-notices/special-reports/2021/20211215-energy-transition-in-pjm-frameworks-for-analysis.ashx.

[9] PJM. Generation Interconnection Process. (January 2012). https://www.pjm.com/-/media/committees-groups/task-forces/nemstf/20120119/20120119-generation-interconnection-process-education-session-1.ashx.

[10] PJM New Services Queue data.

[11] *Id.* 219 GW total includes hybrid projects (e.g., storage paired with wind, solar, or both).

[12] PJM, Energy Transition in PJM: Resource Retirements, Replacements & Risks (February 2023), *available at* https://www.pjm.com/-/media/library/reports-notices/special-reports/2023/energy-transition-in-pjm-resource-retirements-replacements-and-risks.ashx. Note: total installed capacity does not reflect different capacity factors for renewable and conventional fuel technologies.

[13] PJM. Docket No. ER22-2110-000 Tariff Revisions for Interconnection Process Reform, Request for Commission Action by October 3, 2022, and Request for 30-Day Comment Period ("PJM Interconnection Reform Proposal"). *See also* Gramlich, R. et al. Disconnected. The Need for a New Generator Interconnection Policy. (January 2021).

When PJM established its *pro forma* interconnection process in January 2003, the region largely depended on fossil fuel generation. These resources typically have larger nameplate capacity and are sited in closer proximity to the load, resulting in fewer interconnection requests and less need for transmission expansion.[14] These characteristics enabled PJM to effectively examine projects on an individual basis, commonly referred to as "first-come, first-serve" process. This approach required three studies: (1) a Feasibility Study; (2) a System Impact Study; and, if applicable, (3) a Facilities Study. Because projects were studied relative to their position in the interconnection queue, withdrawal of a project at any stage would trigger new studies for all lower-queued projects without the higher-queued project in the model.[15]

While this requirement was feasible for a limited number of requests for large coal and natural gas facilities, the relatively recent cost declines of renewable projects in PJM has led to record volumes of interconnection applications.[16] At the same time, a lack of proactive transmission planning has resulted in the PJM grid becoming increasingly congested. These factors, combined with PJM's use of "First to Cause" network upgrade responsibility, led to rising costs and diminishing success for renewable generators seeking interconnection.

At the core of PJM's interconnection troubles is a lack of sufficient transmission capacity to allow new generators to connect. Under its former interconnection process, the RTO would use a System Impact Study to evaluate whether transmission improvements were needed to accommodate the new generation resources and, if upgrades were identified, assign costs. According to research by Lawrence Berkeley National Laboratory, average interconnection costs for active projects rose from $29/kilowatt (kW) to $240/kW between 2017 and 2022, an eightfold increase.[17]

These soaring costs have disproportionately impacted renewable projects, regardless of their status in the queue: the average interconnection cost for renewable energy projects studied in PJM between 2017 and 2022 ranged between $136/kW and $335/kW, compared to $24/kW for natural gas projects over the same period.[18] The bulk of the costs were often attributed to broader network upgrades, suggesting that new renewable generation was getting assigned the cost of upgrades that benefitted others on the system.[19] The cost of the upgrades also frequently exceeded the total cost of the new generation and were often revealed

[14] Disconnected at 7-8. *See also* PJM Interconnection Reform Proposal, Docket ER22-2110, Transmittal Letter at 6 (June 2022).
[15] Affidavit of Jason P. Connell on Behalf of PJM Interconnection, L.L.C. ¶ 7, PJM Interconnection Reform Proposal.
[16] PJM Interconnection Reform Proposal at 5.
[17] See I.J. et al. Interconnection Cost Analysis in the PJM Territory at 5 (January 2023), *available at* https://eta-publications.lbl.gov/sites/default/files/berkeley_lab_2023.1.12-_pjm_interconnection_costs.pdf.
[18] *Id* at 7. $335/kW for storage, $267/kW for hybrid solar, $253/kW for solar, and $136/kW for onshore wind. Figures represented in $2022/kW; note that this study does not evaluate offshore wind projects, for reasons discussed in greater detail in the Methodology.
[19] *Id* at 6-7; *see also* Disconnected at 13-14.

late in the interconnection process, “turning a viable project into a non-viable project.”[20]

Further compounding the problem, due to the size and serial nature of PJM’s former queue process, project withdrawals would trigger a far greater number of restudies than in prior years, resulting in significant delays and a torrent of further withdrawals. As a result, renewable energy projects submitting applications between 2000 and 2020 experienced nearly seven-year average waits between application submission and a final interconnection agreement - the longest of any U.S. grid region, according to BloombergNEF.[21] These long waits and increased costs help explain why nearly three-quarters of renewable project applications withdrew from the PJM queue between 2011 and 2016.[22]

As a result, the percentage of renewable projects reaching commercial operation in the region has fallen dramatically over the last several years. Only 2.7% of renewable energy megawatts (MW) entering the queue from January 1, 2017 to March 31, 2018 have reached commercial operation, representing a significant decrease from the 20.3% of renewable projects entering the queue between early 2011 and late 2016 that reached commercial operation.[23] After a series of incremental improvements failed to yield positive returns, PJM recognized the need for more significant changes to its long-standing interconnection approach.[24]

PJM’s Recent Interconnection Process Reforms

In early 2023, PJM began implementing a new interconnection process, developed through an 18-month stakeholder effort.[25] The reformed process, approved by FERC in November 2022, will discontinue the problematic “first-come, first-served” interconnection methodology, instead enabling projects with the highest development potential to progress toward interconnection, an approach referred to as “first-ready, first-served.”[26] The new rules initiate a three-phase interconnection study process where queue applicants are grouped in “clusters” according to queue cycle window. PJM plans to subdivide each queue cycle into groups of projects with similar locational attributes and share the costs based on generator contribution to overloaded network facilities.

To allow staff time to adjust to the new process, PJM will oversee a four-year transition period or “pause,” during which no new service requests are accepted until it has fully processed the projects in a two-part “transition cycle” covering

---

[20] Affidavit of Jason P. Connell on Behalf of PJM Interconnection, L.L.C. ¶ 12.
[21] Aristizabal Rico, J. US Grid Access Holding Up Renewables More than Five Years. BNEF. (September 2022). https://www.bnef.com/shorts/14755.
[22] PJM New Services Queue, Rand, J. et al. Queued Up: Characteristics of Power Plants Seeking Transmission Interconnection as of the End of 2021. (April 2022) at 3.
[23] Reflecting the solar, onshore wind, and battery storage projects that PJM reported as having reached commercial operations or underwent construction between April 1, 2011 and September 30, 2016. PJM New Services Queue data.
[24] PJM Interconnection Reform Proposal, Transmittal Letter at 7.
[25] Id at 2.
[26] Id at 8.

interconnection requests submitted between April 1, 2018 and September 30, 2021.[27] A subset of these projects, for which network upgrades are limited to $5 million or less, will be studied serially under an expedited process running parallel to the first transition cycle. PJM estimates that roughly 450 projects, about 17% of the total projects currently in the queue, will qualify for this “fast lane.”[28] Once the transition cycle is complete – which PJM expects to occur by Q1 2026 – the RTO will begin the application review for projects that entered the interconnection queue between October 1, 2021 and March 1, 2022.[29]

[27] Projects for which PJM has not tendered an Interconnection Service Agreement (ISA) or wholesale market participant agreement (WMPA) as of the ”Transition Date,” defined as the later of January 1, 2023 or the date by which all AD2 and prior queue windows ISAs or WMPAs have been executed or filed unexecuted. See PJM, Interconnection Process Reform (n.d.) *available at* https://www.pjm.com/planning/services-requests/interconnection-process reform#:~:text=Pursuant%20to%20the%20Commission's%20order,interconnection%20reform%20established%20Transition%20Date.
[28] PJM Interconnection Reform Proposal, Transmittal Letter at 3.
[29] *Id* at 8.

POTENTIAL BENEFITS
OF RENEWABLE ENERGY PROJECTS IN PJM'S QUEUE

The renewable energy projects trapped in PJM's interconnection queue would create thousands of new jobs, drive billions of dollars in capital investment, and deliver lower-cost power to the states in the region. These projects, if developed, will also help various PJM states, municipalities, and companies meet their decarbonization targets. As the federal government, state legislatures, and governors' offices work to incentivize and encourage the development of new low-cost renewable energy projects, PJM has a responsibility to ensure that ratepayers benefit from those initiatives. Taking steps to accelerate the deployment of hundreds of renewable energy projects in PJM's interconnection queue is a commonsense way to spur economic growth while also delivering environmental benefits.

There are 2,003 onshore wind, solar, and battery storage projects in the transition cycle, totaling roughly 167 GW of new generation capacity.[30] While not all proposed power generation projects will be developed,[31] if developers and PJM work together to bring these projects online at a pace consistent with the 20.3% completion rate observed in the region between April 1, 2011 and September 30, 2016, this effort would yield nearly 34 GW of new renewable energy projects in the next four years.[32]

Enabling Well-Paid Jobs

Some of the fastest growing U.S. occupations are in the renewable energy sector.[33] Workers in these industries make 30% more than the national median wage, ensuring that they have access to well-paid jobs that support them and their families.[34] *Figure 1* below provides state-by-state estimates of the potential jobs created by the completion of renewable energy projects eligible for consideration during PJM's planned four-year transition, if projects are completed at the pace seen in the region from 2011 and September 30, 2016. Job creation reflects roles in

---

[30] This study does not evaluate the potential benefits of offshore wind projects in the PJM queue due to a lack of historical completion data, the agreement between New Jersey and PJM to separately evaluate the state's offshore wind (OSW) resources, the likelihood that Maryland will adopt a similar approach, and Virginia's OSW requirement. For more details, see the Methodology section.

[31] PJM recently issued an analysis that utilizes historical project completion data to project future entry of renewable resources, noting "extremely low entry from onshore wind, offshore wind, solar, solar-hybrid and storage resources," although PJM does add some capacity to these historical rates for their projections, see PJM, Energy Transition in PJM: Resource Retirements, Replacements & Risks (February 2023), *available at* https://www.pjm.com/-/media/library/reports-notices/special-reports/2023/energy-transition-in-pjm-resource-retirements-replacements-and-risks.ashx. *See also*, PV Magazine, "PJM projects 48 to 94 GW of renewables will be built in the grid region by 2030," *available at* https://pv-magazine-usa.com/2023/03/09/pjm-projects-48-to-94-gw-of-renewables-will-be-built-in-the-grid-region-by-2030. This paper projects that the queue reforms have the potential to achieve greater success than PJM's projections, while further reforms are still needed.

[32] Applies the 20.3% historical MW completion rate observed between April 1, 2011 and September 30, 2016 to the 166.6 GW of new renewable generation capacity eligible for the PJM transition cycle (application submitted between April 1, 2018 and September 30, 2021). See Methodology.

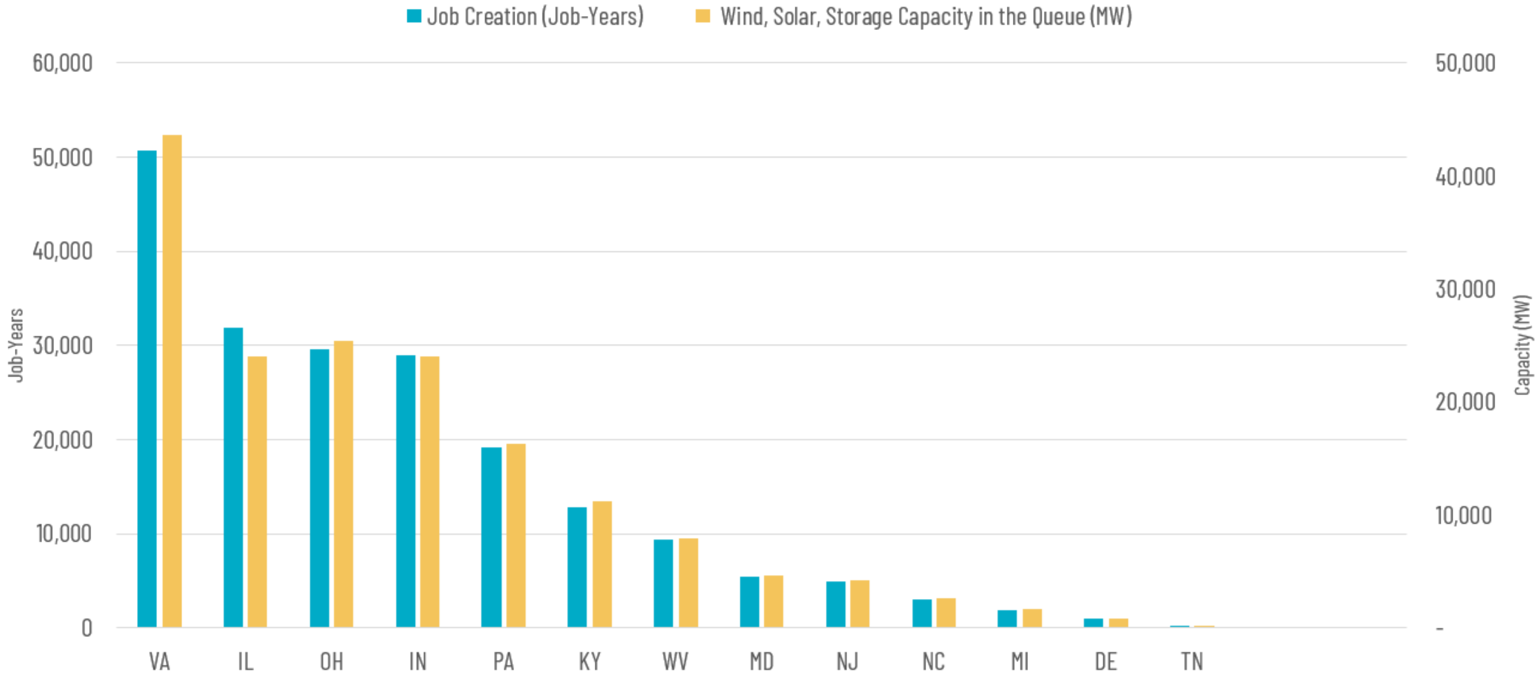
[33] American Clean Power Association and BW Research. Clean Energy Labor Supply (2021), *available at* https://cleanpower.org/resources/cleanenergylaborsupply/.

[34] Id.

construction and operations and maintenance (O&M) and is measured using job-years. In this report, job creation refers to direct and indirect construction and O&M employment only and does not cover induced jobs.[35]

[35] All job creation assumptions and definitions are taken from the IMPLAN modeling tool. For more details, see Methodology.

Figure 1: Potential Job Creation from Renewable Projects in PJM's Interconnection Queue Reform Transition Cycle



Rank	State	Job Creation (Job-Years)	Wind, Solar, Storage Capacity in the Queue (MW)
1	Virginia	50,690	43,661
2	Illinois	31,878	24,074
3	Ohio	29,548	25,356
4	Indiana	28,951	24,072
5	Pennsylvania	19,101	16,311
6	Kentucky	12,820	11,159
7	West Virginia	9,351	7,876
8	Maryland	5,402	4,638
9	New Jersey	4,943	4,179
10	North Carolina	2,974	2,587
11	Michigan	1,893	1,647
12	Delaware	986	847
13	Tennessee	179	156

CUMULATIVE

198,716
Job-Years

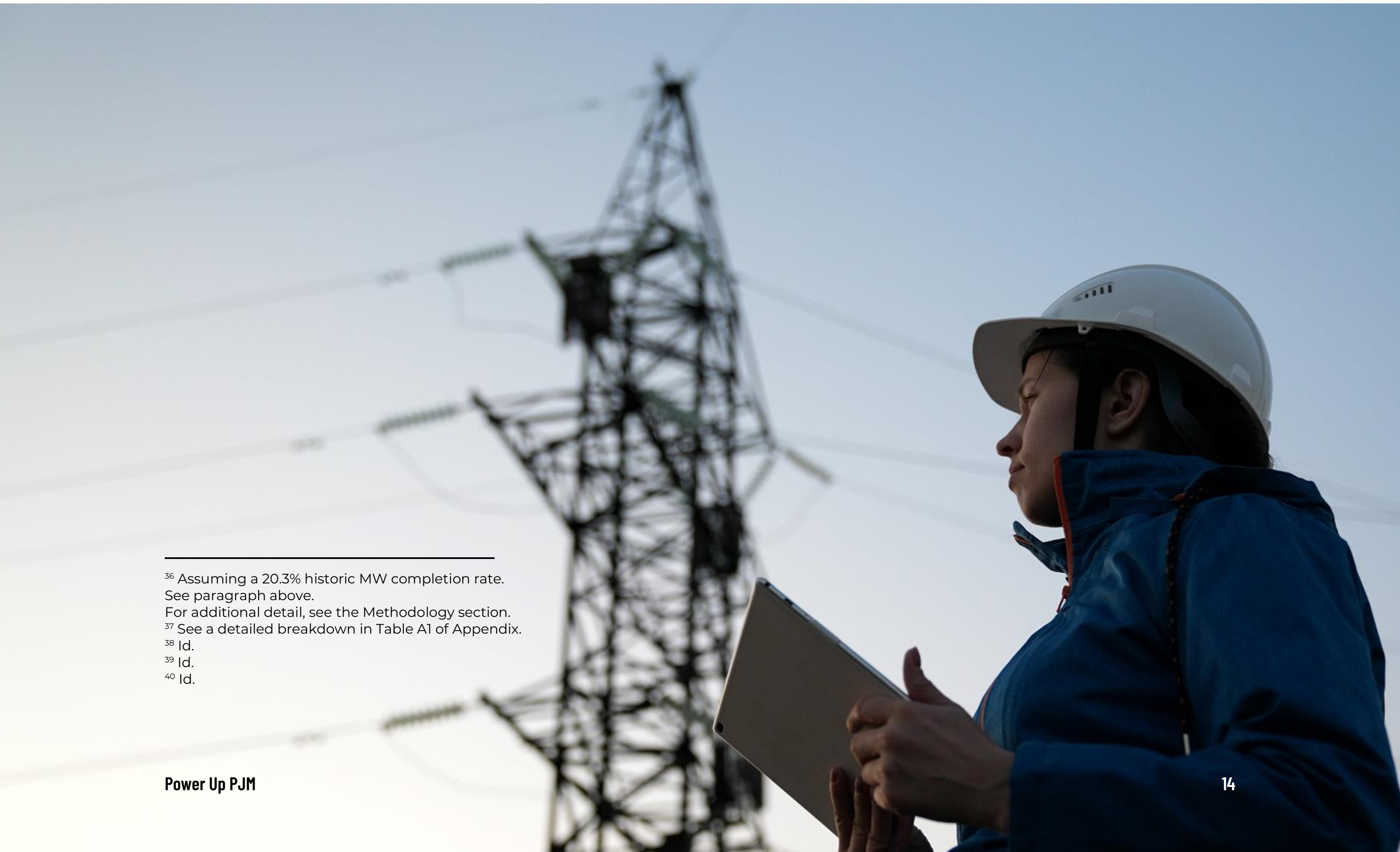
166,563
MW

As noted in *Figure 1*, the renewable energy projects that PJM will review during the transition can stimulate meaningful job growth in each of its 13 states. In total, these projects are expected to deliver nearly 199,000 job-years.[36] Advancing these renewable energy projects would have far-reaching benefits for states in the region.

Virginia is projected to benefit from more jobs in the solar and battery storage sectors than any other state in the region.[37] Illinois is poised to benefit from the most wind energy jobs.[38] Ohio ranks third in overall job creation potential, trailing only Virginia in both solar and battery storage jobs.[39] High volumes of active solar capacity in Indiana and Pennsylvania place these states at fourth and fifth, respectively, in overall job creation potential.[40]

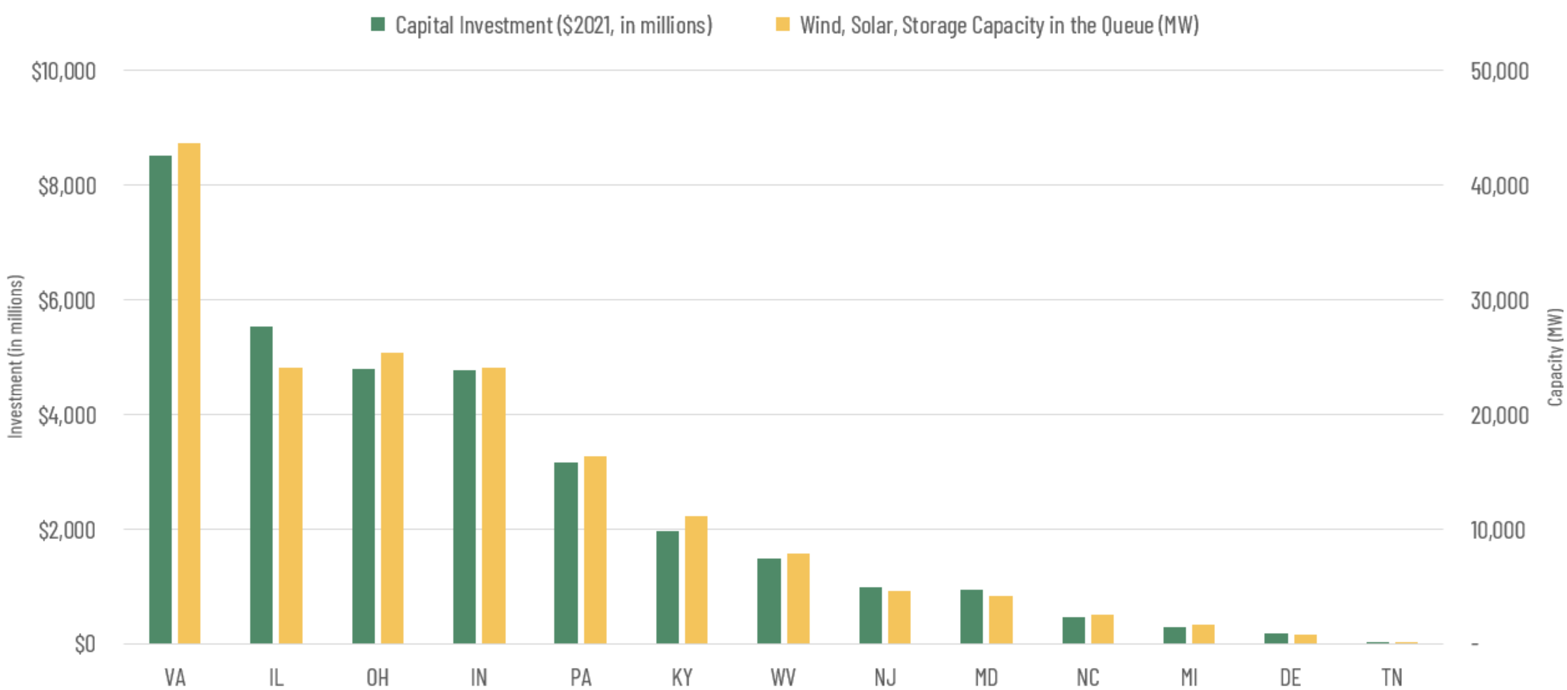
Capital Investment

Renewable energy projects represent significant capital investments, which can help stimulate long-term economic growth for communities across PJM. Construction workers are likely to spend a portion of their paychecks on locally sold goods and temporary lodging, and construction materials are often locally sourced as well. *Figure 2* below estimates the capital investments in PJM states if active renewable energy projects eligible for consideration during the region's planned four-year transition reach commercial operations at a pace seen in the queue from April 1, 2011 to September 30, 2016.



[36] Assuming a 20.3% historic MW completion rate.
See paragraph above.
For additional detail, see the Methodology section.
[37] See a detailed breakdown in Table A1 of Appendix.
[38] Id.
[39] Id.
[40] Id.

Figure 2: Potential Capital Investment from Renewable Projects in PJM's Interconnection Queue Reform Transition Cycle



Rank	State	Capital Investment ($2021, in millions)	Wind, Solar, Storage Capacity in the Queue (MW)
1	Virginia	$8,524	43,661
2	Illinois	$5,528	24,074
3	Ohio	$4,802	25,356
4	Indiana	$4,765	24,072
5	Pennsylvania	$3,154	16,311
6	Kentucky	$1,955	11,159
7	West Virginia	$1,497	7,876
8	New Jersey	$980	4,638
9	Maryland	$940	4,179
10	North Carolina	$457	2,587
11	Michigan	$290	1,647
12	Delaware	$171	847
13	Tennessee	$27	156

CUMULATIVE

$33.09
Billion

166,563
MW

If that pace of deployment is achieved, renewable project developers would invest approximately $33 billion in PJM states.[41] Virginia would attract the most capital investment of any state in the region, largely due to potential investments in solar and battery projects.[42] Illinois is poised to attract more onshore wind investment than any state in the region and the second-most overall investment, followed again by Ohio, Indiana, and Pennsylvania. Of states outside the top five spots, Kentucky derives its sixth-highest overall capital investment potential almost exclusively from active solar projects, while New Jersey and Maryland – ranked at 8th and 9th overall, respectively – lead the way in battery storage capital investment potential.[43]

Electricity Costs

In addition to job creation and capital investment, newly interconnected renewable resources can deliver wholesale electricity cost savings for PJM consumers. Electricity prices rose considerably in the last year, in PJM and across the U.S., partly due to volatility in the natural gas market.[44] Between 2021 and 2022, PJM's average summer wholesale prices more than doubled.[45] The renewable energy active in the interconnection queue presents a timely solution.

Recent research from Princeton University forecasts that the average total wholesale cost of electricity for utilities and other load-serving entities who sell power to retail customers would fall from $61.3 per megawatt-hour (MWh) in 2021 to roughly $45/MWh in 2035 as a result of increased renewable deployment, driven primarily by new federal tax credits in the Inflation Reduction Act.[46]

These findings are consistent with a 2021 framework developed by PJM that examined the integration of renewable power across three scenarios: a status quo "Base" scenario, a "Policy" scenario in which 22% of electricity is generated with renewable sources, and an "Accelerated" scenario where 50% of overall generation comes from renewables.[47] In its analysis, PJM estimated that the average locational marginal price, which is the price of energy in PJM's wholesale market, would be lowest under the Accelerated scenario, ranging from $29 to $47/MWh compared to $34 to $50/MWh and $35 to $55/MWh under the Policy and Base scenarios, respectively.[48] The report also predicted that total annual system production costs under the Accelerated scenario would equal roughly $12.7 billion, representing a 40% decrease.[49]

---

[41] See a detailed breakdown in Table A3 of the Methodology.
[42] See a detailed breakdown by technology type in Table A3 of Appendix.
[43] Id.
[44] EIA. EIA expects significant increases in wholesale electricity prices this summer (June 2022), *available at* https://www.eia.gov/todayinenergy/detail.php?id=52798.
[45] Id.
[46] Jenkins D., J. et al. Cleaner, Faster, Cheaper. Impacts of the Inflation Reduction Act and a Blueprint for Rapid Decarbonization in the PJM Interconnection at 36. (December 2022). https://zenodo.org/record/7429042.
[47] PJM. Energy Transition in PJM: Frameworks for Analysis. (December 2021). https://www.pjm.com/-/media/library/reports-notices/special-reports/2021/20211215-energy-transition-in-pjm-frameworks-for-analysis.ashx.
[48] Id at 10.
[49] Id.

Public Health Benefits

Recent analyses also suggest that completion of renewable energy projects in the PJM interconnection queue will result in public health benefits from reduced air pollution, furthering the critical importance of the PJM transition period. A 2019 study estimated that the greatest total health benefits per MWh from renewable deployment in the country would occur in the PJM region largely due to the displacement of coal generation.[50]

A 2022 analysis similarly identified PJM states as the leading beneficiaries of health benefits from potential renewable deployment.[51] The research estimated that 1 MWh of additional wind power in PJM would reduce sulfur dioxide and nitrogen oxide emissions by 2.2 kilograms and 0.85 kilograms, respectively, leading to a total health benefit of roughly $44/MWh.[52] Analyses of fossil fuel plants in PJM show that replacing such resources with cleaner renewable and storage projects would provide significant health benefits for environmental justice communities, who have disproportionately borne the emissions impacts of fossil fuel plants.[53]

[50] Buonocore, Jonathan J., et al. Climate and health benefits of increasing renewable energy deployment in the United States (October 2019), *available at* https://iopscience.iop.org/article/10.1088/1748-9326/ab49bc.
[51] Qiu, M., Zigler, C., & Selin, N. Impacts of wind power on air quality, premature mortality, and exposure disparities in the United States (December 2022), *available at* https://www.science.org/doi/10.1126/sciadv.abn8762.
[52] Id.
[53] For example, a 2021 analysis by the Applied Economics clinic found that 58% of PJM's fossil fuel plants are located within 1 mile of an EJ community, and 81% within 5 miles. EJ communities are defined for this study as where 20% or more of households are low-income and/or where 30% or more of residents are Black, Indigenous, and People of Color (BIPOC). See PJM's Capacity Market: Clearing Prices, Power Plants and Environmental Justice (Updated November 2021), available at https://static1.squarespace.com/static/5936d98f6a4963bcd1ed94d3/t/61a661d46da1cf0463cae9f3/1638293976900/PJM%27s+Capacity+Market_Clearing+Prices%2C+Power+Plants%2C+and+Environmental+Justice_AEC_30Nov2021.pdf.

PJM'S MISSED OPPORTUNITY

PROACTIVE TRANSMISSION PLANNING AND UPGRADES COULD HAVE YIELDED GREATER BENEFITS

As previously noted, if PJM had proactively planned more transmission capacity, it's likely the recent interconnection reforms in the region could yield even greater benefits. For example, the Midcontinent Independent System Operator (MISO) began to implement the same cluster study approach in 2008, which PJM has accepted, and approved a $5 billion portfolio of 17 regional transmission projects in December 2011.[54] As a result, MISO saw 29.8% of the renewable energy MW in its interconnection queue reach commercial operation or undergo construction between April 1, 2011 and September 30, 2016, while only 20.3% of the MWs in PJM's queue reached operation during that time.[55]

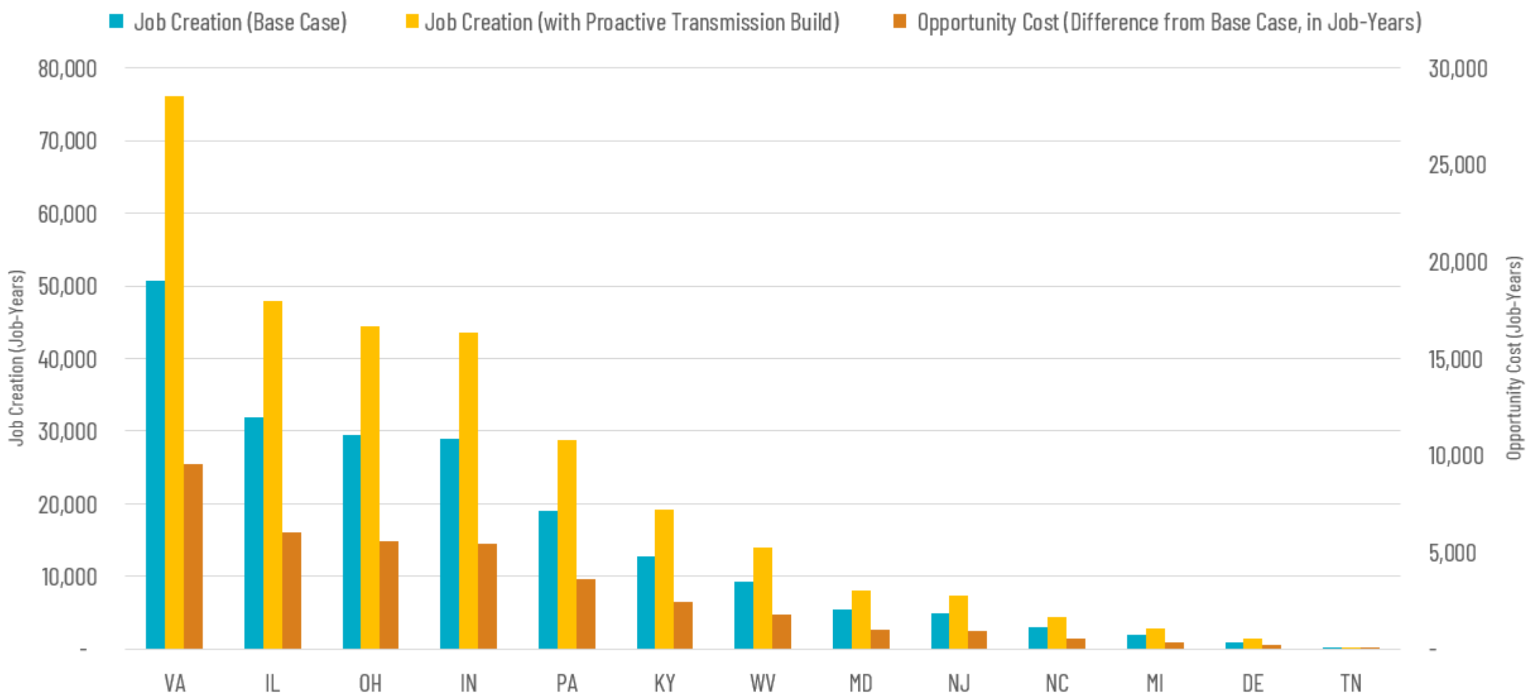
Therefore, this section assumes that if PJM had recently completed similar transmission upgrades, an additional 50% increase in MW completion rate over its historical average would have been possible during the transition cycle. The charts below detail that possibility, assuming that 30.5% of the projects in the cycle reach commercial operation.

Working under that assumption, our analysis estimates that if PJM had proactively developed sufficient transmission capacity prior to enacting these reforms, the region could have potentially enabled an additional 100,000 job-years and nearly $17 billion in additional capital investment over the next four years. Even if this level of benefit is not achievable in the near term, additional steps to improve long-term transmission planning can produce significant economic benefits in the future.

[54] Boyd, D. & Garvey, E. A Transmission Success Story: The MISO MVP Transmission Portfolio (November 2021), *available at* https://www.aeslconsulting.com/wp-content/uploads/2021/11/MISO-MVP-History.pdf. *See also*, Ghomsi, N.G. SPP and MISO Queue Management Process (November 2012), *available at* https://pubs.naruc.org/pub.cfm?id=53831B20-2354-D714-5158-7E0D6A8DCC92.
[55] MISO Interactive Queue data, *available at* https://www.misoenergy.org/planning/generator-interconnection/GI_Queue/gi-interactive-queue/; PJM New Services Queue data.

Additional Well-Paid Jobs

Figure 3: Potential Job Creation from Renewable Projects in PJM's Interconnection Queue Reform Transition Cycle with Proactive Transmission Planning and Upgrades



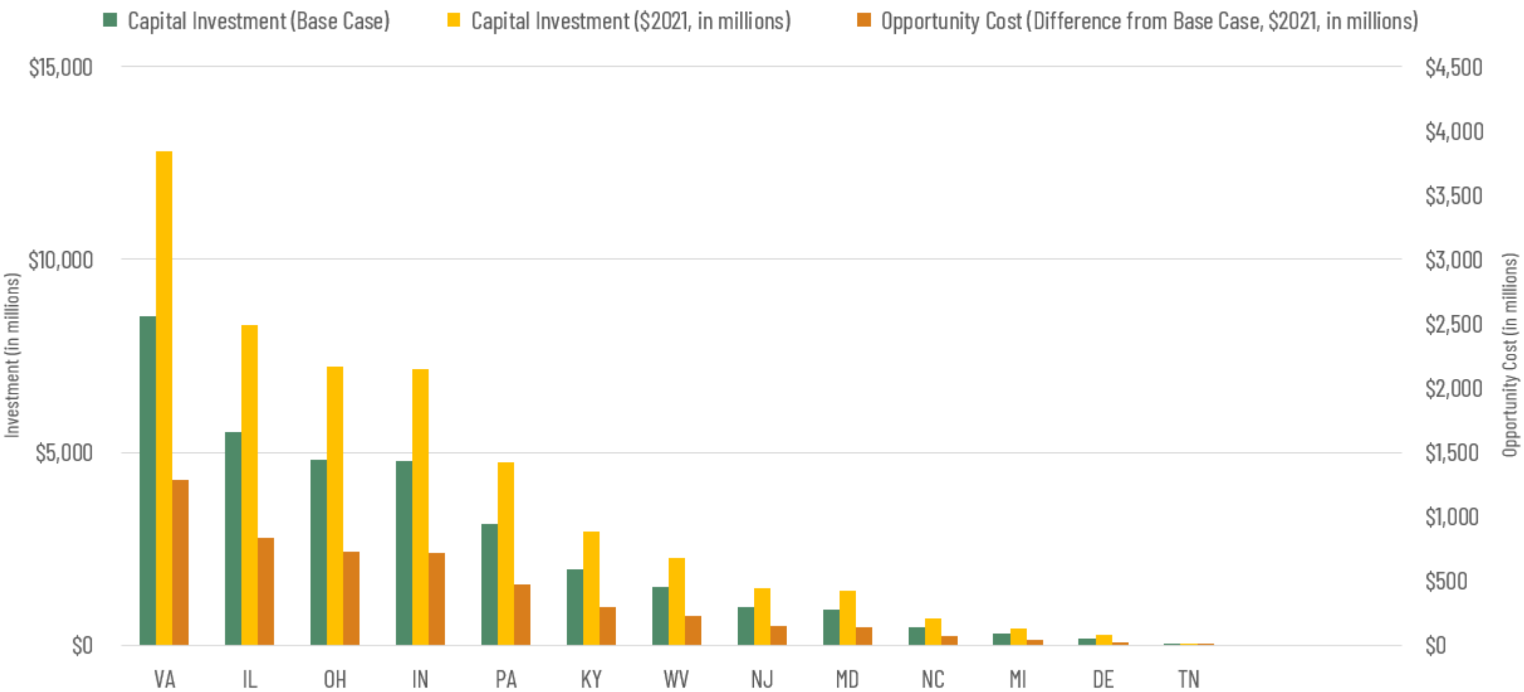
Rank	State	Job Creation (Base Case)	Job Creation (with Proactive Transmission Build)	Opportunity Cost (Difference from Base Case, in Job-Years)
1	Virginia	50,690	76,160	25,470
2	Illinois	31,878	47,896	16,018
3	Ohio	29,548	44,393	14,845
4	Indiana	28,951	43,499	14,548
5	Pennsylvania	19,101	28,699	9,598
6	Kentucky	12,820	19,261	6,441
7	West Virginia	9,351	14,050	4,699
8	Maryland	5,402	8,116	2,714
9	New Jersey	4,943	7,426	2,483
10	North Carolina	2,974	4,469	1,495
11	Michigan	1,893	2,845	952
12	Delaware	986	1,483	497
13	Tennessee	179	269	90

CUMULATIVE

99,850
Additional
Job-Years

Additional Capital Investment

Figure 4: Potential Capital Investment from Renewable Projects in PJM's Interconnection Queue Reform Transition Cycle with Proactive Transmission Planning and Upgrades



Rank	State	Capital Investment (Base Case)	Capital Investment ($2021, in Millions)	Opportunity Cost (Difference from Base Case, $2021, in Millions)
1	Virginia	$8,524	$12,807	$4,283
2	Illinois	$5,528	$8,305	$2,777
3	Ohio	$4,802	$7,216	$2,414
4	Indiana	$4,765	$7,161	$2,396
5	Pennsylvania	$3,154	$4,740	$1,586
6	Kentucky	$1,955	$2,937	$982
7	West Virginia	$1,497	$2,249	$752
8	New Jersey	$980	$1,471	$491
9	Maryland	$940	$1,413	$473
10	North Carolina	$457	$687	$230
11	Michigan	$290	$436	$146
12	Delaware	$171	$256	$85
13	Tennessee	$27	$40	$13

CUMULATIVE

$16,628
Billion in Additional Capital Investment

Recommendations for PJM

While PJM's newly adopted reforms represent an improvement over the status quo, many additional and more fundamental steps are needed. As described below, it is critical for states, renewable energy developers, and transmission owners to work with, and encourage, PJM to undertake a range of reforms to create a process for interconnection and transmission planning that supports a rapid, economically beneficial transition. While this report also recommends actions that FERC should take to improve the interconnection process across the country, PJM can further enhance its process without waiting for FERC to act. The following recommendations will help PJM to achieve timely completion of its transition cycle, and further improve the interconnection process going forward:

- *Further Process Streamlining:* There are a number of actions that PJM can consider implementing to accelerate the interconnection queue process, including streamlining the interconnection of new renewable resources replacing a retiring resource; reducing network upgrade costs by incorporating grid-enhancing technologies (GETs); and accelerating near-term transmission upgrades or expansions targeted to reduce the backlog of resources in the queues.[56] Other options include allowing the use of surplus interconnection and provisional interconnections before all studies are completed.
- *Comprehensive Transmission Planning:* While a final rule from FERC is essential, as discussed below, PJM can take steps without waiting for such a rule to implement a more holistic, long-term, multi-value planning process that incorporates the full scope of anticipated resources.
- *Additional Staffing:* Stakeholders identified staffing shortages as one of 12 key categories of improvement necessary to resolve the present backlog, describing "inadequate response times" by PJM points of contact and "insufficient resources available to process studies."[57] PJM should follow through on suggestions to hire new personnel, pay higher wages to retain

---

[56] See Earthjustice, Natural Resources Defense Council, Rocky Mountain Institute, Sierra Club, and Union of Concerned Scientists, *Letter to PJM CEO and Board of Directors* (March 28, 2023), https://pjm.com/-/media/about-pjm/who-we-are/public-disclosures/20230328-multiple-parties-letter-re-pjms-report-energy-transition-in-pjm-resource-retirements-replacements-risks.ashx.
[57] Connell, J. & McGill, S. Interconnection Workshop 3 PJM Response at 33. PJM. (January 2021). https://pjm.com/-/media/committees-groups/committees/pc/2021/20210129-workshop-3/20210129-item-03-pjm-presentation.ashx.

them, rely more heavily on contractors to perform studies, and relieve project managers of the responsibility to draft interconnection agreements.[58]

- *Automation:* The use of automation to process interconnection studies is another important strategy that PJM should consider to accelerate the interconnection process. Such automation can be used to complete a variety of tasks that, when undertaken manually, are time-consuming and require extensive engineering knowledge possessed by a small number of individuals.[59] Automation could also have a role in increasing the speed and accuracy of these studies. For example, Pearl Street Technologies, NextEra, Amazon Web Services, and SPP are demonstrating the use of automated data entry and validation, which allows engineers to focus on more critical planning matters.[60]

Recommendations for FERC

PJM's interconnection queue backlog is, in part, due to a lack of sufficient transmission capacity. This is a result of a failure to adequately plan for future needs, consider the full range of benefits, and distribute the costs of upgrades fairly. These are problems affecting not just PJM but other RTOs and planning regions. Therefore, lasting solutions to the interconnection challenge will entail several fundamental reforms that lie within FERC's jurisdiction:

- *Strengthen and Finalize Transmission Rulemakings:* FERC must strengthen and finalize its proposed rulemakings on generator interconnection process reforms and transmission planning to accommodate an increasing volume of new service requests.[61] Regional and interregional transmission planning that neglects to consider rising interconnection demand will result in higher costs and congestion.[62] Moreover, using the network upgrade process to identify transmission improvements rather than the use of comprehensive transmission planning effectively "shift[s] the burden of identifying, planning for, and funding of these broadly beneficial upgrades onto the interconnection process, and the costs onto Interconnection Customers."[63] Proactive planning paired with the requisite construction of new transmission capacity will streamline the

---

[58] Id at 60. *See also* Commissioner Clements Concurrence Regarding PJM Interconnection, L.L.C. FERC (November 2022), *available at* https://www.ferc.gov/news-events/news/commissioner-clements-concurrence-regarding-pjm-interconnection-llc.
[59] Driscoll, W. Artificial intelligence could speed interconnection, says Amazon executive (October 2022), *available at* https://pv-magazine-usa.com/2022/10/17/artificial-intelligence-could-speed-interconnection-says-amazon-executive/.
[60] Caplan, E. & Strand, N. ACORE Grid Forum Gathered Energy Leaders to Discuss Opportunities and Obstacles to Achieving a Fundamental Transformation of America's Grid (October 2022), available at: https://acore.org/acore-grid-forum-2022/.
[61] Comments of ACORE. RM21-17-000 (August 2022), *available at* https://acore.org/wp-content/uploads/2022/08/ACORE-Comments-on-FERCs-Transmission-Planning-NOPR.pdf.
[62] Reply Comments of Americans for a Clean Energy Grid, Docket No. RM22-14-000 (December 2022) at 1-2, *available at* https://elibrary.ferc.gov/eLibrary/filelist?accession_num=20221214-5166.
[63] Joint Supplemental Comments of the American Clean Power Association, Advanced Energy Economy, the Solar Energy Industries Association, and the American Council on Renewable Energy on Generation Interconnection Queue Processing and Cost Allocation Reforms, Dockets RM21-17-000, AD21-15-000 (June 2022) at 2, *available at* https://acore.org/clean-energy-coalition-comments-on-generation-interconnection-queue-processing-and-cost-allocation-reforms, citing the Commission's transcript of the May 6, 2022 Federal State Joint Transmission Task Force, available in Docket No. AD21-15 at 17:3-6 (Thomas); 19:1-16 (Phillips) (May 2022).

interconnection process by reducing the need to study and pay for network upgrades.[64]

- *Common Methodologies:* A lack of uniformity in the current interconnection study process could limit the benefits of the newly approved cluster approach. Ad hoc study assumptions contribute to dissimilar treatment of projects in the interconnection queue and create uncertainties for interconnection customers.[65] The Commission did propose to provide greater certainty in the Affected Systems studies, which are a common source of interconnection delays, and should also do so for all interconnection studies. A standardized set of criteria would enhance the overall efficiency of the interconnection process by encouraging replicable study results, while improving the ability of PJM to adopt best practices, such as automation.[66]
- *Transmission Improvements:* Proactively planned transmission could reduce the burdens on the generation interconnection process but building large-scale new transmission lines takes years. As noted above, one means of expanding capacity of the transmission system is through the use of GETs, such as dynamic line ratings, which present an affordable alternative to otherwise costly network upgrades that frequently cause projects to withdraw from the queue.[67] Another option is reconductoring existing lines, using advanced conductors. FERC should therefore require the consideration of GETs and advanced conductors in the interconnection study process.[68]
- *Participant Funding:* Lastly, FERC should pursue participant funding reforms. Participant funding determines the amount new generators pay for system upgrades required during the interconnection process. The current PJM process requires generation facilities seeking interconnection to shoulder up to 100% of the costs of transmission upgrades despite their far-reaching benefits for the larger grid. FERC should establish a more just framework that allocates the costs proportionally among their anticipated beneficiaries, which would result in better project economics by reducing the uncertainty and inequity in the allocation of network upgrade costs.[71]

---

[64] The Brattle Group, Proactive Planning for Generation Interconnection (September 2022) at 9-10, *available at* https://www.esig.energy/proactive-planning-for-generation-interconnection-a-case-study-of-spp-and-miso/.
[65] Comments of ACORE. RM22-14-000 at 5 (October 2022), *available at* https://acore.org/acore-submits-comments-to-ferc-on-proposed-interconnection-reforms/.
[66] Id.
[67] Tschuchida, Bruce T., Ross, S., & Bigelow, A. Unlocking the Queue with Grid-Enhancing Technologies (February 2021), *available at* https://watt-transmission.org/wp-content/uploads/2021/02/Brattle__Unlocking-the-Queue-with-Grid-Enhancing-Technologies__Final-Report_Public-Version.pdf90.pdf.
[68] Joint Supplemental Comments of the American Clean Power Association, Advanced Energy Economy, the Solar Energy Industries Association, and the American Council on Renewable Energy on Generation Interconnection Queue Processing and Cost Allocation Reforms, Dockets RM21-17-000, AD21-15-000 (June 2022) at 15-16, *available at* https://acore.org/clean-energy-coalition-comments-on-generation-interconnection-queue-processing-and-cost-allocation-reforms/.

CONCLUSION

The interconnection challenge in PJM is a critical test for accelerating the pace of renewable energy deployment. Interconnection queue backlogs are extensive and growing in almost every RTO, delaying economic development for rural communities and potential cost savings for all consumers. If PJM's reforms succeed, the resulting installation of wind, solar, and battery storage projects will deliver meaningful benefits for local and state economies, catalyze new job creation, and deliver health benefits for states in the region and beyond.

However, roughly three-quarters of the projects in PJM's interconnection queue seek to come online by 2025, a year before PJM predicted it would finish evaluating applications in the transition cycles.[69] The financial viability of many currently active renewable projects may therefore depend on PJM clearing its backlogged queue and operating ahead of schedule, highlighting the urgency of the challenge.

Complementing these reforms with new FERC policies on generator interconnection and transmission planning is the only way to reduce future interconnection backlogs. Transmission planning and interconnection processes that are adapted to the changing resource mix will help secure a low-cost clean energy future that businesses and homeowners in PJM are demanding.

[69] Craig P., Daniel. Challenges Ahead for U.S Generator Interconnection Process (April 2022), *available at* https://frostbrowntodd.com/challenges-ahead-for-u-s-generator-interconnection-process/.

Appendix

Project Data

Capacity and location data for projects in the queue is from the PJM New Services Queue webpage, a publicly available resource encompassing the latest regional interconnection requests and updated daily by PJM staff.[70] The economic projections in this report are for all interconnection applications eligible for the PJM transition cycle, or submissions dated between April 1, 2018 and September 30, 2021, as officially listed in the queue on March 15, 2023. Data in this report excludes the District of Columbia, which had no active utility-scale renewable projects as of that date.

Economic Data

Table A1: Job-Years ("Potential Benefits" Scenario)

Estimated job-years by state, technology (summarized on page 13)

State	Solar	Onshore Wind	Battery Storage	Total
Virginia	35,985	107	14,598	50,690
Illinois	14,208	12,573	5,097	31,878
Ohio	23,191	763	5,594	29,548
Indiana	20,487	3,562	4,902	28,951
Pennsylvania	14,128	703	4,270	19,101
Kentucky	12,191	0	629	12,820
West Virginia	7,398	855	1,098	9,351
Maryland	3,356	0	2,046	5,402
New Jersey	1,245	0	3,698	4,943
North Carolina	2,773	0	201	2,974
Michigan	1,771	0	122	1,893
Delaware	633	0	353	986
Tennessee	179	0	0	179
	137,545	**18,563**	**42,608**	**198,716**

[70] Available at: https://www.pjm.com/planning/services-requests/interconnection-queues.

Table A2: Job Creation ("Missed Opportunity" scenario)

Estimated job-years by state, technology (summarized on page 15)

State	Solar	Onshore Wind	Battery Storage	Total
Virginia	54,066	161	21,933	76,160
Illinois	21,347	18,891	7,658	47,896
Ohio	34,843	1,146	8,404	44,393
Indiana	30,781	5,352	7,366	43,499
Pennsylvania	21,227	1,056	6,416	28,699
Kentucky	18,316	0	945	19,261
West Virginia	11,115	1,285	1,650	14,050
Maryland	5,043	0	3,073	8,116
New Jersey	1,870	0	5,556	7,426
North Carolina	4,167	0	302	4,469
Michigan	2,661	0	184	2,845
Delaware	952	0	531	1,483
Tennessee	269	0	0	269
	206,657	**27,891**	**64,018**	**298,566**

Table A3: Capital Investment by State ("Potential Benefits" scenario)

Estimated capital expenditures by state, technology in $2021, millions of dollars (summarized on page 19)

State	Solar	Onshore Wind	Battery Storage	Total
Virginia	$5,371	$20	$3,133	$8,524
Illinois	$2,121	$2,313	$1,094	$5,528
Ohio	$3,462	$140	$1,200	$4,802
Indiana	$3,058	$655	$1,052	$4,765
Pennsylvania	$2,109	$129	$916	$3,154
Kentucky	$1,820	0	$135	$1,955
West Virginia	$1,104	$157	$236	$1,497
New Jersey	$186	$0	$794	$980
Maryland	$501	$0	$439	$940
North Carolina	$414	$0	$43	$457
Michigan	$264	$0	$26	$290
Delaware	$95	$0	$76	$171
Tennessee	$27	$0	$0	$27
	$20,532	**$3,414**	**$9,144**	**$33,090**

Table A4: Capital Investment by State ("Missed Opportunity" section)

Estimated capital expenditures by state, technology in $2021, millions of dollars (summarized on page 20)

State	Solar	Onshore Wind	Battery Storage	Total
Virginia	$8,070	$30	$4,707	$12,807
Illinois	$3,186	$3,475	$1,644	$8,305
Ohio	$5,201	$211	$1,804	$7,216
Indiana	$4,595	$985	$1,581	$7,161
Pennsylvania	$3,169	$194	$1,377	$4,740
Kentucky	$2,734	$0	$203	$2,937
West Virginia	$1,659	$236	$354	$2,249
New Jersey	$279	$0	$1,192	$1,471
Maryland	$753	$0	$660	$1,413
North Carolina	$622	$0	$65	$687
Michigan	$397	0	$39	$436
Delaware	$142	0	$114	$256
Tennessee	$40	0	0	$40
	$30,847	**$5,131**	**$13,740**	**$49,718**

Table A5: Renewable Project Capacity

Active capacity eligible for PJM's transition cycle by state; technology in MW

State	Solar	Onshore Wind	Battery Storage	Total
Virginia	31,389	63	12,209	43,661
Ohio	20,228	450	4,678	25,356
Illinois	12,393	7,418	4,263	24,074
Indiana	17,870	2,102	4,100	24,072
Pennsylvania	12,324	415	3,572	16,311
Kentucky	10,633	0	526	11,159
West Virginia	6,453	505	918	7,876
Maryland	2,927	0	1,711	4,638
New Jersey	1,086	0	3,093	4,179
North Carolina	2,419	0	168	2,587
Michigan	1,545	0	102	1,647
Delaware	552	0	295	847
Tennessee	156	0	0	156
	119,975	**10,953**	**35,635**	**166,563**

Methodology

Exclusion of Offshore Wind From the Projections

Several states in PJM have significant offshore wind goals or mandates. However, given: (1) the lack of historic data on offshore wind (OSW) project completion rates; (2) New Jersey's (NJ) agreement with PJM to plan and pay for the necessary transmission upgrades outside of PJM's typical queue process; and (3) the likelihood that Maryland will adopt a similar approach to NJ, the report authors decided to not include the potential economic benefits of OSW in this analysis.

Job Creation

Jobs data was derived from assumptions generated via IMPLAN, an input-output modeling tool that estimates the economic impacts of certain investments using an extensive set of factors including industry-specific multipliers, local purchase percentages, and income-to-output ratios.[71] This data is reported in job-years, which is the full-time equivalent of one job for one year based on an annual, industry-specific average that accounts for seasonality.[72] To estimate job-years, IMPLAN combines quarterly Bureau of Labor Statistics data with comprehensive information across 500 categorizations from the North American Industry Classification System. While the IMPLAN model also forecasts induced employment impacts, this report accounts for direct and indirect job-years only. As defined by IMPLAN, direct employment is the number of job-years immediately supported by the development of renewable projects. Indirect employment is the number of job-years supported by the economic activity associated with those projects, such as business-to-business transactions. Induced employment, which this report does not consider, reflects the number of job-years that could be supported by greater household spending as a result of impacts calculated in the direct and indirect categories.

The job-year assumptions for this report are as follows:

- Solar job-years: 5.6475/MW
- Onshore wind job-years: 8.35/MW
- Battery storage job-years: 5.89/MW

Capital Investment

Capital investment data was generated using BNEF projections of capital expenditures (capex) adjusted by geography and technology. This report assumes the average of yearly capex figures for the period 2022-2026, which reflects the duration of PJM's announced transition cycle. The report assumes that capital

[71] See https://support.implan.com/hc/en-us/articles/115009510967-Employment-Data-Details.
[72] See https://support.implan.com/hc/en-us/articles/360044986593-Glossary.

investment does not occur until immediately after queued projects achieve an official interconnection agreement. Due to data availability, this report applies BNEF projections specific to the PJM service territory for solar and onshore wind, while national level BNEF projections are used for battery storage.

Solar and onshore wind capex are derived from the BNEF *U.S. Clean Energy Market Outlook*, which combines historical figures from industry surveys conducted by the National Renewable Energy Laboratory (NREL) and a BNEF least-cost model using mid-year projections and granular pricing estimates.[73] The BNEF model reflects a wide range of factors including equipment costs, engineering and procurement expenses, sales taxes, and supply chain constraints (e.g., solar import tariffs).

Due to data availability, this report uses national-level capex assumptions for battery storage derived from the latest edition of the BNEF *Levelized Cost of Electricity (LCOE)* report, which uses extensive developer surveys, regional reporting, and publicly available data to generate bottom-up, technology-specific projections.[74] The LCOE report also considers a similarly wide range of development, equipment, and performance cost factors, excluding subsidies and incentives (e.g., production/investment tax credits).

For battery storage capex, the LCOE report uses findings from *2022 Lithium-Ion Battery Price Survey: First Price Rise,* published in December 2022, which forecasts component prices based on recent trends in lithium-ion battery supply chains, learning curves, and market demand.[75] This report assumes that all active solar projects in the PJM queue are built with single-axis tracking technology, which represented 90% of the U.S. utility-scale solar capacity added in 2021.[76] Consistent with recent analyses, this report assumes a four-hour duration for all active battery storage projects.[77]

The results for capex by technology are as follows:

- Solar capex: **$843/kW**
- Onshore wind capex: **$1,536/kW**
- Battery storage capex: **$1,264/kW**

Project Completion Rates and Economic Scenarios

PJM's Historic Completion Rate ("Potential Benefits"): ***20.3%***

This report applies a representative historical MW rate of completion to all active wind, solar, and battery storage projects eligible for the transition cycle (applications submitted between April 1, 2018 and September 30, 2021). The historical MW rate of

[73] BNEF. 2H 2022 US Clean Energy Market Outlook: Supersized Buildup (October 2022), *available at* https://www.bnef.com/insights/29957.
[74] BNEF. 2H 2022 LCOE Update (December 2022), *available at* https://www.bnef.com/insights/30289.
[75] Stoikou, E. et al. 2022 Lithium-Ion Battery Price Survey: First Price Rise (December 2022), *available at* https://www.bnef.com/insights/30265.
[76] Bolinger, M., Seel., J., Warner, C., & Robson, D. Utility-Scale Solar, 2022 Edition: Empirical Trends in Deployment, Technology, Cost, Performance, PPA Pricing, and Value in the United States (September 2022), available at: https://emp.lbl.gov/publications/utility-scale-solar-2022-edition.
[77] NREL. Annual Technology Baseline. Utility-Scale Battery Storage (July 2022), *available at* https://atb.nrel.gov/electricity/2022/utility-scale_battery_storage.

completion reflects the wind, solar, and battery storage capacity reaching commercial operation or undergoing construction (4,689 MW) out of the total onshore wind, solar, and battery storage MW that entered the PJM queue between April, 1, 2011 and September 30, 2016 (23,094 MW). An April 1, 2011 lower limit was used to calculate the historical MW completion rate to capture the relatively higher: (1) volume of renewable projects seeking interconnection in PJM; and (2) economic competitiveness of renewable technologies compared to previous years. The September 30, 2016 upper limit is five years from the final date by which projects are eligible to be processed in the transition cycle (September 30, 2021), our assumption for the average length of time it takes for projects in the queue to reach commercial operation.

PJM's Historic Completion Rate + Transmission Upgrades ("Missed Opportunity"):
30.5%

This scenario assumes that proactive transmission planning and development on the part of PJM, paired with timely and effective implementation of a cluster study approach, would have enabled a 50% increase to the historical MW completion rate (20.3%) assumed above. The resulting scenario applies this boosted completion rate (30.5%) to all active wind, solar, and battery storage projects eligible to be processed in the transition cycle. A 30.5% MW completion rate is similar to the MW completion rate that MISO (29.8%) achieved for renewable projects entering its queue between April 1, 2011 and September 30, 2016 due in part to the successful use of a cluster study approach and proactive transmission investment. MISO started to gradually implement a first-ready, first-served cluster study approach in 2008 and approved 17 regional transmission projects in December 2011.[78]

[78] See, e.g. https://windsolaralliance.org/wp-content/uploads/2018/10/Corporates-Renewable-Procurement-and-Transmission-Report-FINAL.pdf. For MISO, *see also*, Ghomsi, N.G. SPP and MISO Queue Management Process (November 2012), *available at* https://pubs.naruc.org/pub.cfm?id=53831B20-2354-D714-5158-7E0D6A8DCC92.