Navigating the PJM interconnection process for wind and solar projects

By Himali Parmar, Shankar Chandramowli, Siddharth Kalia, ICF

Introduction

Over the last two years, the number of renewable projects in the PJM interconnection queue has sky-rocketed, bringing with it a whole new set of challenges for developers. With several PJM states adopting aggressive clean energy goals (see Exhibit 2), we anticipate an even greater surge of renewable projects in the PJM queue in the coming years. Solar and offshore wind projects will dominate this surge. Given the size of the PJM market, with peak demand exceeding 148 GW, it is reasonable to expect the power grid to accommodate new renewables in most PJM zones. However, we should expect to see local limitations on the transmission system and expensive network upgrades. Due to many projects dropping out of the queue, the result will be increased queue processing times and greater uncertainty on expected network upgrade exposure.

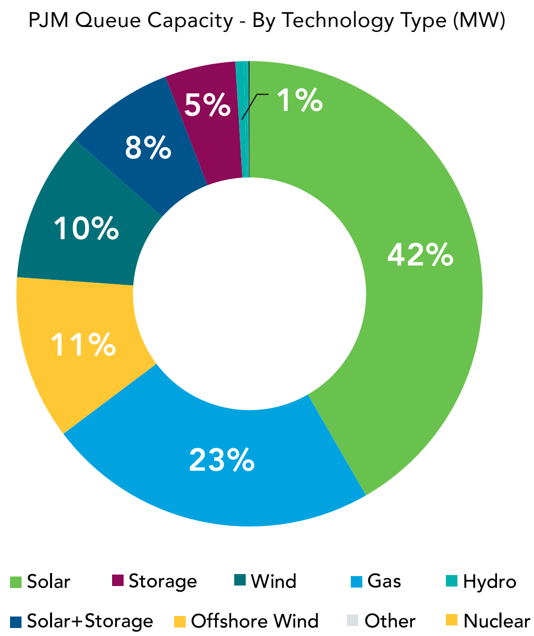
In the context of increasing renewable penetration in PJM, developers should pay particular attention to interconnection-related diligence at a detailed sub-regional level. This diligence is especially critical for greenfield development or early-stage project acquisition to avoid setbacks as the project moves through the interconnection queue process.

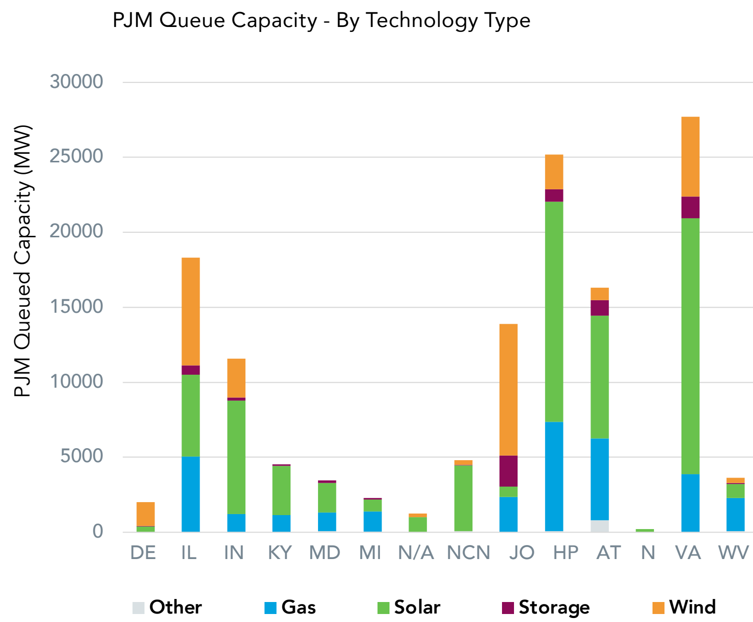
This ICF report presents an overview of the queue process, related industry trends, and some emerging issues related to network upgrades and cost exposure for renewable projects. We have highlighted two case studies, involving the PENELEC and Dominion sub-regions, that illustrate the emerging issues related to network upgrades, queue drop-offs, and project delays.

Solar, wind, and storage projects have increasingly dominated interconnection requests across major ISO/RTOs in the United States. New gas builds designed to fill the void left by coal-fired unit retirements dominated PJM queue requests until recently. In recent months, however, solar projects have come to dominate the mix.

The current PJM interconnection queue has 135 GW of active capacity, with solar projects being the single largest technology type at 56 GW. Solar projects are followed by gas projects (32 GW) and wind projects (29 GW), both onshore and offshore. Offshore wind requests, currently around 15 GW, are expected to surge after 2025 to meet state mandates.

Exhibit 1 - Summary of PJM interconnection Queue Data





Source: PJM Interconnection Queue (May-2020)

Exhibit 2. State Renewable Mandates /Targets in PJM

State	Tier I Target	Solar Carve-out	Offshore Wind Buildout
New Jersey	50% by 2030	5.1% by 2021, TBD by 2030	3,500 MW by 2030, 7,500 MW by 2035
Pennsylvania	8% by 2021	0.5% by 2021	N/A
Maryland	50% by 2030	14.5% by 2028	1,568 MW by 2030
Delaware	25% by 2026	3.5% by 2025	N/A
Ohio	8.5% by 2026	N/A	N/A
Washington, D.C.	100% by 2032	10% by 2041	N/A
Illinois	25% by 2025	1.5% by 2025	N/A
Virginia	100% by 2050	16.7 GW by 2036 (both solar and onshore wind)	5,200 MW by 2035

Source: Compiled by ICF

PJM's Transmission Planning Process

The backbone of PJM's transmission planning process is the Regional Transmission Expansion Plan (RTEP) framework.[1] The RTEP assessment, carried out on an annual basis, identifies transmission system upgrades and enhancements required to maintain grid reliability and economical operation of the PJM wholesale power market. PJM's RTEP process looks at a 15-year planning horizon to determine the transmission needs driven by load growth, capacity resource adequacy, generation resource integration, market efficiency, public policy, and operational performance requirements. The RTEP process culminates in a single recommended portfolio of transmission projects for the entire PJM footprint.

The recommended portfolio of projects is then reviewed by the PJM Board of Managers. Once the projects are approved by the Board, the recommended facilities and upgrades will formally become part of PJM's transmission planning database.

As part of RTEP, PJM implements four types of studies. They include reliability planning, economic planning, interconnection planning, and local planning. PJM conducts reliability and economic planning for all related upgrades for all facilities above 100 KV. For facilities below 100 KV and not under PJM operational control, local transmission owners (TOs) conduct the study. Generator and merchant transmission requests for interconnections as well as requests for long-term firm transmission service would be considered in interconnection planning.

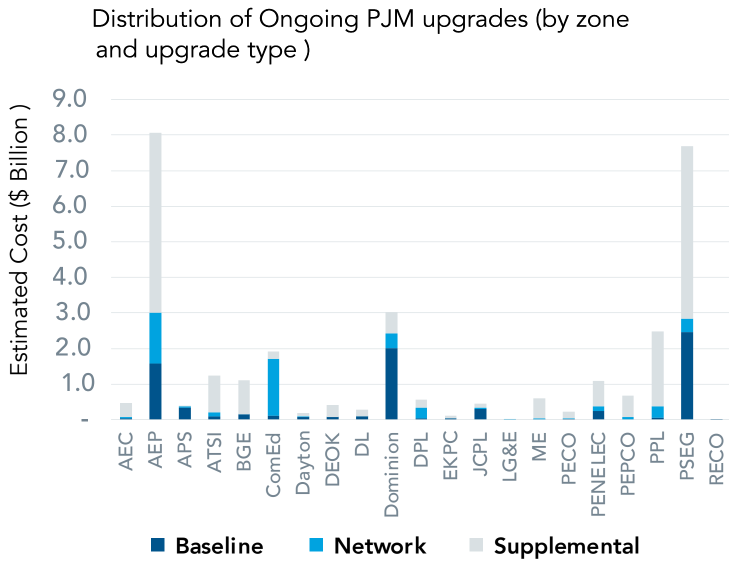
The RTEP process identifies three types of upgrades: baseline upgrades (from RTEP), customer-funded network upgrades, and additional upgrades. Baseline upgrades include projects planned from the RTEP process for reliability, operational, economic planning, or public policy purposes, with the cost allocated among affected TOs. Customer-funded network upgrades stem from generator and transmission interconnection requests. Equipment material conditions drive supplemental projects (e.g., the need for replacing aging infrastructure), infrastructure resilience, operational flexibility (e.g., improving customer service), and other state policy objectives[2].

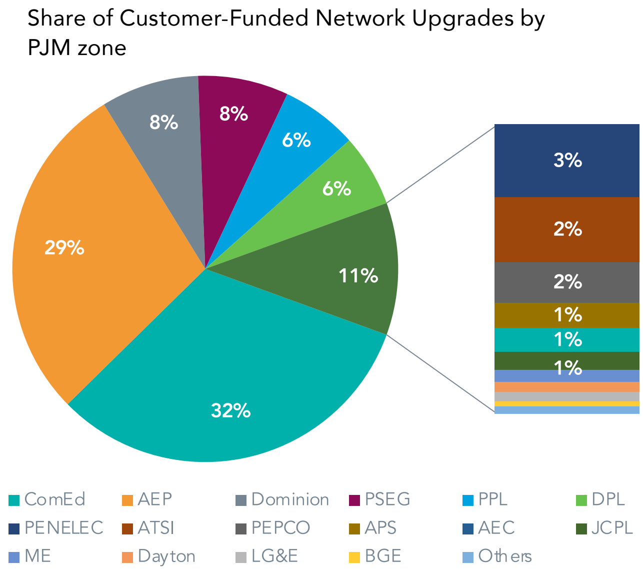
To date, the RTEP process has operationalized nearly $39.7 billion worth of upgrades. There is an additional estimated $31.5 billion worth of upgrades active in PJM's transmission planning process (including those under construction). Approximately 84% of the active upgrades are supplemental projects ($18. 3 billion) and baseline projects ($8.1 billion). Customer-funded network upgrades, at $5 billion, currently comprise 16% of active projects. Exhibit 3 illustrates the mix of ongoing network upgrades and customer-funded network upgrades across different transmission zones.

[1] The RETP process in this section is sourced from PJM RTEP documents unless stated otherwise https://www.pjm.com/library/reports-notices/rtep-documents.aspx

[2] See PJM Supplemental Projects: https://www.pjm.com/-/media/committees-groups/committees/pc/20190412-special-m3/20190412-item-04-m-3-lessons-learned.ashx

Exhibit 3. Breakdown of PJM's approved transmission upgrades





Source: PJM Transmission Construction Status (April-2020)

Understanding the PJM Interconnection Process

PJM's interconnection process involves a sequential cluster-based assessment represented by five major milestones: interconnection request, feasibility study, system impact study, facilities study, and interconnection/construction service agreements.[3] PJM allows two windows for projects to enter the queue (ending on March 31 and September 30, respectively). A requesting entity must provide descriptions of project location, size, equipment configuration, anticipated in-service date, and proof of site control for the proposed project to join the queue. In general, the in-service date must not be more than seven years from the requested date. In addition, unless a project demonstrates site control, it is not assigned an interconnection queue position.

The feasibility study is the first of the three assessments. It includes a limited power flow analysis[4] to identify any impacted transmission facilities that may occur from the injection of projects in the cluster. Additionally, PJM also provides high-level cost estimates to mitigate identified issues. At this stage, PJM does not offer cost allocation for each project.

The next step is a system impact study (SIS). This study involves detailed power flow assessments, including deliverability studies in the PJM region home to the generator.

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[3] The interconnection process described in this section is sourced from PJM's Manual 14A (New Services Request Process) unless stated otherwise.

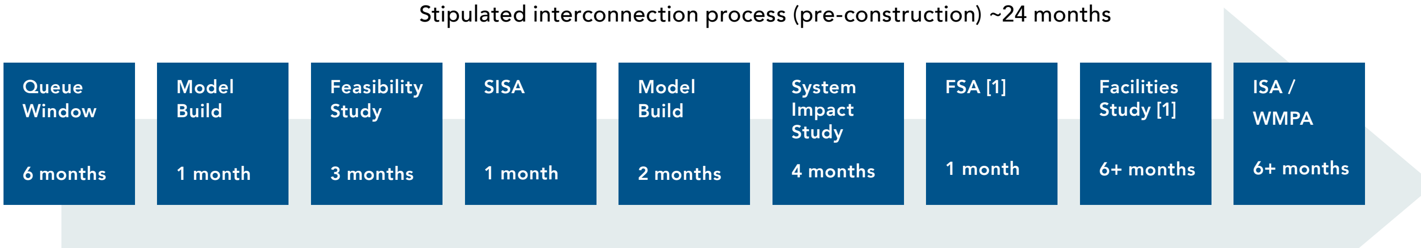
[4] The analysis is limited to short-circuit studies and load-flow analysis. This feasibility study does not include stability analysis.

The study identifies the system constraints relating to the project and the necessary upgrades[5]. At this stage comes assignments for project contribution to overloads and high-level cost allocation for upgrades—to later be refined in the facilities study stage.

During a facilities study, the SIS results are "retooled" or updated to reflect the latest queue/transmission topology changes. After successfully completing a facility study, the applicant and interconnected transmission owners (ITOs) must execute an interconnection service agreement (ISA)[6].

Exhibit 4: PJM interconnection process timeline

Stipulated interconnection process (pre-construction) ~24 months



[1] May be waived depending on complexity of interconnection or required network upgrades.

Technology type	Average interconnection process time (months)
Coal	28
Diesel/oil	22
Nature gas	32
Solar	35
Wind	55
Average time (all-technologies)	**34**

Average interconnection study cost for a 100 MW solar project in PJM (in $000)	
Feasibility	$20–$26
SIS	$50
Facilities study	$100
Note: These costs do not account for any network upgrades cost assigned to the project.	

Source: Compiled by ICF using PJM Manual 14A and generator interconnection queue as of May-2020—
See https://www.pjm.com/planning/services-requests/interconnection-queues.aspx

[5] PJM classifies interconnection upgrades under three types: direct local/network upgrades, non-direct local/network upgrades, and attachment facilities. Local upgrades are on the network's distribution side, and whole network upgrades are on the transmission-side of the network. "Direct" denotes the upgrades as greenfield upgrades (e.g., a new tapping substation), while "non-direct" denotes rebuilds, replacements, or upgrades to existing system facilities. Once energized, we expect network upgrades to carry network flows while attachment facilities carry flows from the specified generator only.

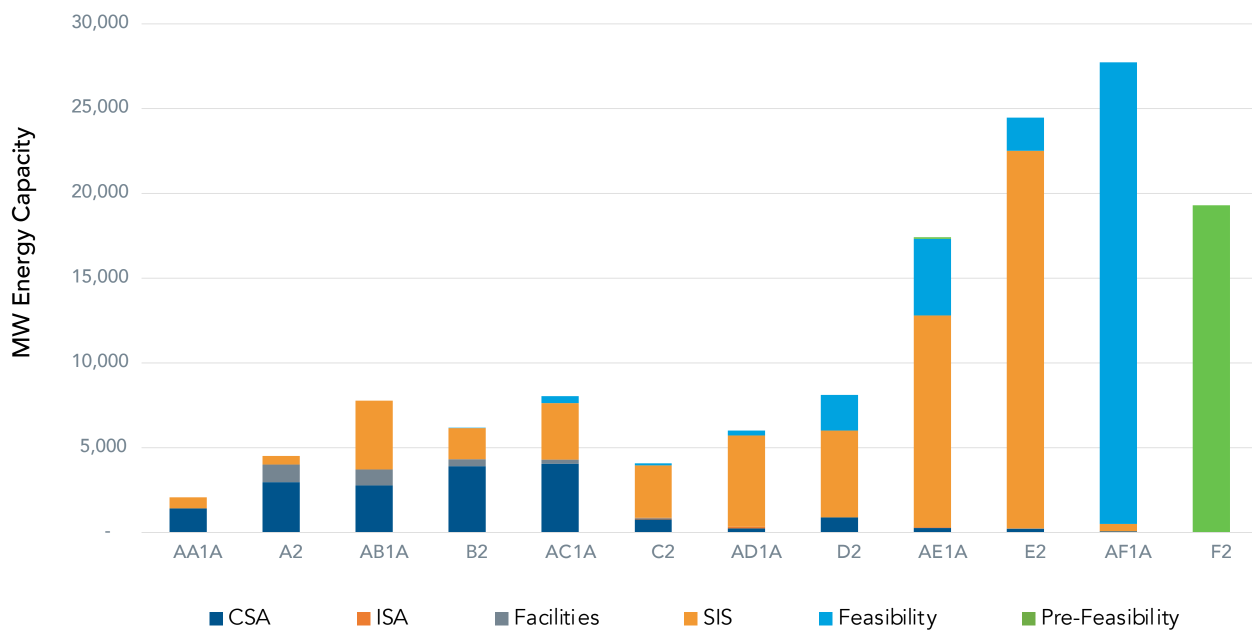
[6] The ISA defines the obligation of the generation or transmission developer regarding cost responsibility for any required system upgrades. In addition to the ISA, the project developer also executes an interconnection construction service agreement (CSA) with the ITO and the system operator, PJM, to outline the scope and cost responsibilities for constructing interconnection facilities/network upgrades.

Study costs and turnaround times

Project developers are required to pay for interconnection studies. The interconnection process places increasing financial obligations on the developer as they advance through the subsequent stages. The waiting time for a PJM interconnection study is typically around 24 months; however, turnaround times have increased as the queue has skewed towards renewables. This increase is attributed to project drop-offs and the resulting need for re-studies.

The two-year timeline does not account for the actual construction phase of the project and associated network upgrades. Historically, generator projects in PJM have an average interconnection queue time of slightly less than three years from entry into the queue to ISA execution. Recent clusters have shown longer interconnection queue times. In addition, the backlog of projects in the SIS and facilities study stages have grown. The cluster size has also increased in recent years. For example, AF1 and AF2 clusters average around 25 GW each.

Exhibit 5 Active PJM Queued Projects (by completed study status)



Note: Project status as per PJM Interconnection Queue (as of May 2020)—
See https://www.pjm.com/planning/services-requests/interconnection-queues.aspx

Cost Allocation

While feasibility studies guide overload and high-level network upgrade costs, the system impact study allocates upgrade costs to individual projects. While projects terminated between the feasibility and impact studies may eliminate the need for some upgrades identified in the feasibility stage, the system impact study calculates and reports the costs associated with overloads that continue to persist.

Typically, the first project in the cluster causing an overload (i.e., loading on the line exceeding 100%) triggers the need for a network upgrade and is assigned the network upgrade cost. These costs are typically reported as "new system reinforcements" in the project SIS report. Network upgrades are shared across preceding clusters until they are fully cost-allocated across projects with signed interconnection agreements. Network upgrades identified in preceding clusters are reported as "contributions to previously identified upgrades" in the project SIS reports.

Following the first queued project triggering the need for an upgrade, subsequent queued projects within the same cluster and following clusters (for significant upgrades) share some cost responsibility towards mitigating the overload under certain conditions. The cost allocation is contingent on contributing MW impact to the overload (or MW contribution to the applicable line rating) or project distribution factor (DFAX) on the overload beyond a set threshold. The allocation also depends on the total cost and voltage level of proposed network upgrades. In addition, drop-offs can result in the mitigation of some of the identified overloads or need for network upgrades. Network upgrades are typically assessed in the SIS studies of individual projects and finalized in facilities studies.

Exhibit 6. PJM's network upgrade cost allocation criteria

<table>
<tr><th></th><th>Cost of Upgrades
(Less than $ 5 million)</th><th>Cost of Upgrade
(more than $5 million)</th></tr>
<tr><td rowspan="3">Eligibility Criteria</td><td colspan="2">Queued projects are subject to cost allocation after the need for the upgrade is identified. They are subject to certain conditions outlined below (i.e., eligibility/allocation based on the order of the PJM queue position).</td></tr>
<tr><td colspan="2">MW contribution is 5 MW or more and 1% of overloaded line rating.</td></tr>
<tr><td>Or DFAX impact is greater than 5% and MW contribution is more than 3% of line rating.</td><td></td></tr>
<tr><td>Transmission facilities (rated less than 500kV)</td><td colspan="2">DFAX impact is greater than 5% or MW impact is greater than 5% of the line rating.</td></tr>
<tr><td>Transmission facilities (rated at or higher than 500kV)</td><td colspan="2">DFAX impact is greater than 10% or MW impact is greater than 5% of the line rating.</td></tr>
<tr><td>Other Criteria</td><td>Allocation will not occur outside of the cluster triggering the need</td><td>Allocation can span subsequent clusters</td></tr>
</table>

Source: Compiled by ICF from PJM BPM Manual 14A (Attachment B) See https://www.pjm.com/-/media/documents/manuals/m14a.ashx

Case Studies

In the context of increasing renewable penetration, greenfield development, or early-stage acquisition requires careful interconnection-related diligence at a detailed sub-regional level. Every project has its unique impacts on the power grid; thus, generalizing interconnection issues could lead to significant exposure in some cases and the loss of a competitive edge in others. While the network upgrade cost exposure is interconnection- and cluster-specific, it is also important to juxtapose this with the queue process's dynamics and project drop-off trends.

We have presented two case studies—involving PENELEC and Dominion—to highlight this intersection.

PENELEC case study

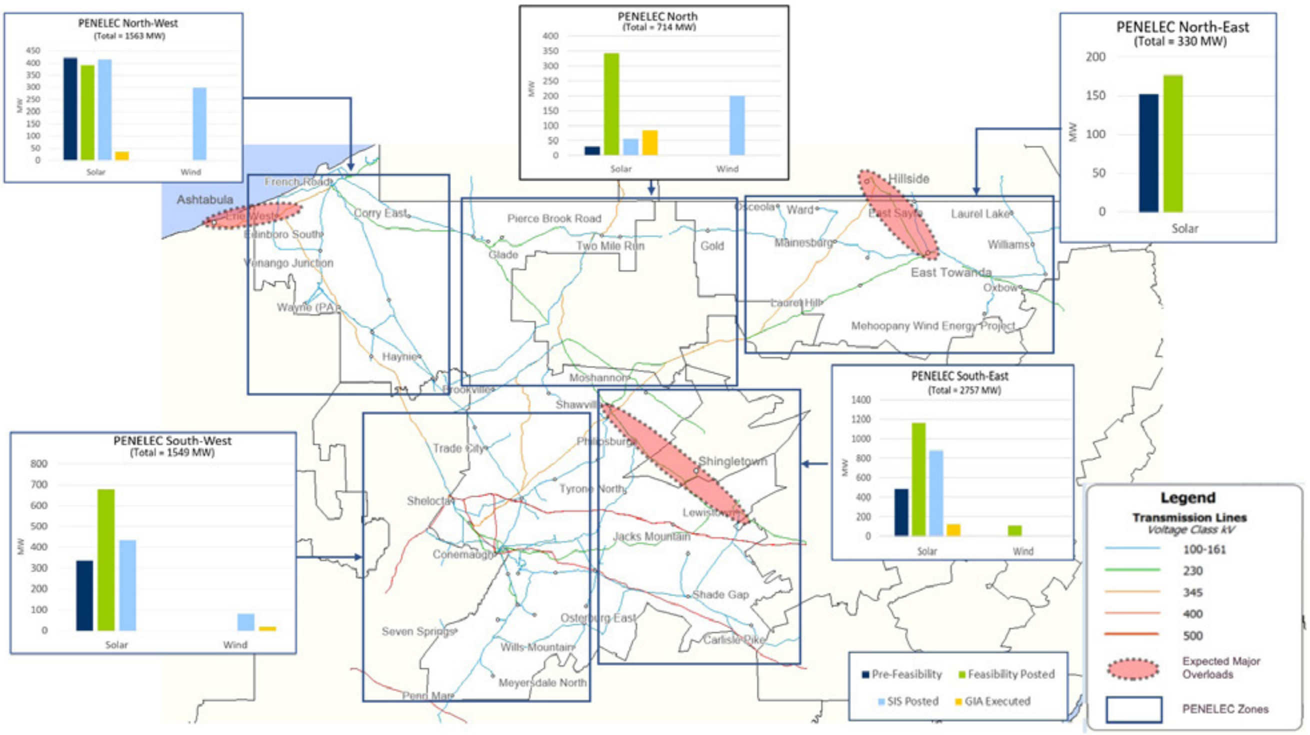
According to the recent PJM queue, roughly 3.3 GW of solar projects seek interconnection in PENELEC, and most projects are in southern PENELEC. Of all active solar projects in the PENELEC queue, more than 70% of solar projects are in the feasibility study or pre-feasibility stage.

ICF's review of feasibility and system impact studies for projects seeking interconnection in the PENELEC load zone have shown a very significant uptick in upgrade costs. For example, several projects in AF1 cluster (the most recent PJM cluster with feasibility studies) report $1 billion of network upgrade cost exposure in their feasibility assessments. ICF identified close to $1.3 billion in the feasibility study stage for projects in PENELEC, which would translate to a network upgrade cost of $275/kW of queued capacity.

Individual project contributions and queue drop-offs may affect the overall cost allocations determined by impending system impact studies; however, they indicate potential chokepoints, and we expect them to be more persistent as renewables increasingly dominate PJM new-builds. The identified chokepoints and most meaningful network upgrades are along three main corridors: the 345 kV transmission system along Lake Erie (Erie West–Ashtabula–Perry–Leroy Center 345kV); the 230 kV corridor connecting PPL–PENELEC–Upstate NY (Oxbow–Meshoppen–East Towanda–Hillside); and the 115 kV and 230 kV corridor from PENELEC to PPL to the east (Shawville–Shingletown–Lewiston–Juniata (see Exhibit 7). Queued projects located in North-Central Pennsylvania impact all three corridors and hence face the highest costs.

Note that the persistence of the identified overloads is subject to queue and market trends. For example, the proposed Lake Erie Connector Project (a 1,000 MW HVDC project injecting at the Erie West substation from Ontario, Canada) will likely impact the Erie West-Ashtabula 345 kV upgrade along Lake Erie. Contingent on this HVDC project proceeding, queued projects in the local PENELEC area will probably share the network upgrade cost for this proposed upgrade.

Exhibit 7. Map of PENELEC with queued projects and key constraints



Source: Compiled by ICF (based on PJM May 2020 queue snapshot)

Dominion case study

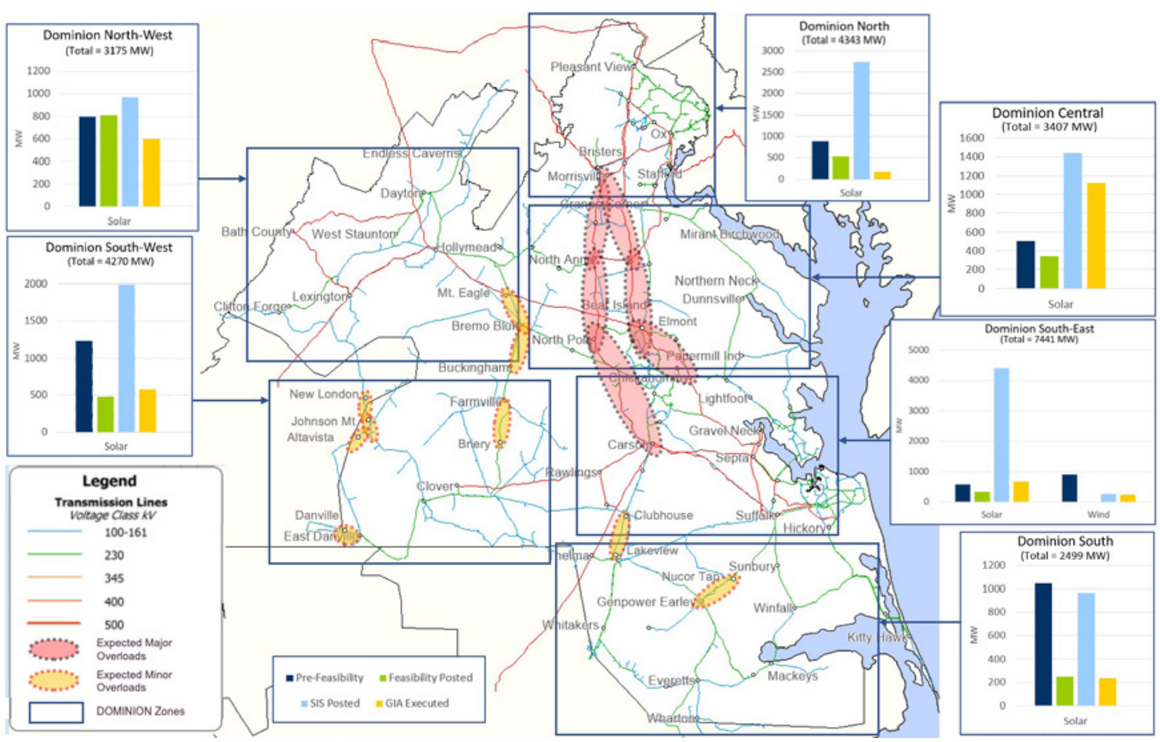
The Commonwealth of Virginia recently adopted the VA Clean Economy Act (VCEA) mandating 100% clean energy by 2050 (including from AEP Appalachian Power, which serves Virginia). Almost overnight, Virginia transitioned from a voluntary renewable target to a mandatory 30% RPS by 2030.

The Dominion queue has close to 18 GW of active solar projects and 5 GW of (mostly offshore) wind projects. While most active solar projects in the queue are in southern Dominion, offshore wind projects are in eastern Dominion. With VCEA targets in place, ICF expects the queue size to increase in the coming years. In its 2020 Integrated Resource Plan (IRP), Dominion also anticipates up to 16 GW of solar additions within the next 15 years to meet VCEA mandates. To date, around 2 GW of solar projects in Dominion have come online with little network upgrade costs to cover local issues (on average, total interconnection costs for local solar projects have averaged less than 8% of estimated overnight capital costs).

But with significant growth anticipated in the coming years, expensive network upgrades for queued projects are imminent. For example, solar projects in recent clusters (AF1/AF2) have seen network upgrade costs primarily concentrated on different segments of the Carson–Morrisville 500kV corridor: the major 500kV north-south corridor within Dominion (see Exhibit 8). We expect the cumulative sum of upgrades on this 500kV intra-zonal backbone network to cost over $925 million. We expect queued projects in the southern part of the State to bear a significant share of this upgrade cost.

Dominion has acknowledged the need for system-wide upgrades due to expected changes in the resource mix. The share of local supplemental upgrades continues to be relatively low; hence, local issues may show up as network upgrades in the near-term. On average, Dominion expects solar interconnection/integration to increase to about $253/kW with a 15 GW addition within the next 15 years.[7] Network upgrades currently proposed for projects in Dominion corroborate this expected increase. In Dominion, the SIS study stage has proposed nearly $1.9 billion worth of upgrades for integrating approximately 23 GW of queued wind and solar projects, resulting in a network upgrade cost of $238/kW. Solar project developers will also have to endure longer queue processing times and uncertain network cost exposures due to increased queue size and project drop-offs.

Exhibit 8. Map of Dominion with queued projects and expected overloads



Source: ICF (based on PJM May-2020 Queue snapshot)

[7] See Dominion 2020 IRP (pp.68-69) - https://cdn-dominionenergy-prd-001.azureedge.net/-/media/pdfs/global/2020-va-integrated-resource-plan.pdf?la=en&rev=11cc4a7d1e8a4773a05633a75a25c8cd

Conclusion: Key takeaways

- With aggressive clean energy targets in PJM states, ICF expects an imminent surge in solar and wind capacity in the interconnection queue.
- Upcoming projects may face queue delays and significant network upgrade cost exposure because of local/regional transmission issues and queue drop-off trends.
- Case studies involving PENELEC and Dominion illustrate the complexity of assigning network upgrade costs with uncertain queue changes and supply-demand dynamics. Depending on project location, network upgrade costs may exceed $200/kW.
- In the context of increasing renewable penetration in PJM, greenfield development, or early-stage project acquisition requires careful interconnection-related diligence at a more detailed sub-regional level.

About the Authors

Himali Parmar leads ICF's transmission advisory practice. Himali has expertise in renewable integration, power system reliability assessments, interconnection strategy, production cost modeling, forecasting transmission congestion and losses and their effect on locational power prices, and asset valuation. Himali and her team have provided market and transmission due diligence support for over 30 GW of renewable projects, including storage.

Shankar Chandramowli, Ph.D. has over eight years of experience in energy policy research, transmission due diligence reviews, transmission and distribution planning in ISO/RTO markets, economic analysis of energy systems, production cost and optimization modeling, drafting policy memos, proposal writing, and public stakeholder engagement for policy research. He holds a Ph.D. in public policy from Rutgers University.

Siddharth Kalia is an electrical engineer and energy market research assistant for ICF's transmission team. He has provided research and analytical support in projects related to U.S. energy markets. Siddharth is proficient in energy market analysis and visualization tools, including ABB's Velocity Suite. He has spearheaded the development of various analytical templates for process automation.

Visit us at icf.com/work/energy

For more information, contact:

Himali Parmar
Himali.Parmar@icf.com +1.703.934.3497

Shankar Chandramowli
Shankar.Chandramowli@icf.com +1.703.251.0874

Siddharth Kalia
Siddharth.Kalia@icf.com

twitter.com/ICF
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