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Impact of FERC Policies on New Generator Interconnection Efficiency

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Abstract- U.S. generator interconnection—the process by which new generation and storage resources secure the right and technical pathway to connect to the bulk-power transmission system—has become a central bottleneck for resource adequacy, decarbonization, and system affordability. Interconnection queues have grown to historically unprecedented scale, while completion rates remain low and timelines have lengthened materially over the last two decades. A national compilation of queue records through the end of 2024 finds roughly 10,300 active projects (about 1,400 GW of generation and 890 GW of storage) seeking transmission interconnection, with only a small share of earlier-queued capacity ultimately reaching commercial operation (Rand et al., 2025). The evidence base suggests that interconnection inefficiency is not merely administrative; it is a systemic outcome of (a) transmission scarcity and upgrade needs, (b) high and uncertain network upgrade costs, (c) speculative or low-readiness queue entry, and (d) iterative "restudy" dynamics when projects withdraw or materially change configuration. A peer-reviewed study in Joule reports that the time required to secure a connection has increased substantially over the last decade (reported as ~70% in that study's national analysis), while withdrawal rates remain very high (reported near ~80%), particularly when large transmission upgrades are assigned to a project (Gorman et al., 2025). Within this context, the Federal Energy Regulatory Commission's interconnection policies have evolved in identifiable "waves" aligned to changing market conditions. Early landmark rules standardized procedures and agreements to reduce discrimination and transaction costs (FERC Order Nos. 2003 and 2006). Later reforms focused on transparency and incremental process improvement (e.g., Order No. 845 and its rehearing order 845-A), including study-metric reporting that made delays visible and measurable (Federal Energy Regulatory Commission [FERC], 2018, 2019).

Keywords— Key concepts include generator interconnection, bulk-power transmission, interconnection queues, resource adequacy, decarbonization, and system affordability. The issue is driven by transmission scarcity, network upgrade costs, speculative queue entry, and restudy dynamics, leading to long timelines and high withdrawal rates. Policy evolution centers on FERC Orders 2003, 2006, and 845/845-A, emphasizing standardization, transparency, and process efficiency.

I. INTRODUCTION

FERC's most recent reforms—Order No. 2023 and Order No. 2023-A—represent a "throughput and discipline" pivot: shifting from first-come, first-served serial study to a first-ready, first-served cluster study paradigm; strengthening readiness requirements and withdrawal penalties to reduce speculative entry and late-stage churn; imposing firm study deadlines combined with penalties for late performance; and improving information and affected-system coordination (FERC, 2023, 2024).

Quantitative indicators from regional case studies highlight both the magnitude of the challenge and why FERC's newer mechanisms target specific failure modes. For example, PJM's independent market monitor reports multi-year average queue durations and substantial late-stage withdrawals, consistent with costly restudy externalities (Monitoring Analytics, 2024). In California ISO's Order 845 reporting, interconnection study-cycle statistics and cluster-study reporting reflect the operational burden and the measurement architecture created by Order 845 (California Independent System Operator [CAISO], 2025). SPP's Order 845 informational filing is triggered by study-delay thresholds, illustrating that delay measurement has become a governance tool in itself (Southwest Power Pool, Inc. [SPP], 2025).

The principal conclusion is directional: FERC policies have meaningfully improved standardization, transparency, and (in the newest rules) incentives for readiness and timely study completion. However, observable system performance—queue size, withdrawal rates, timelines, and upgrade cost uncertainty—indicates that interconnection efficiency is fundamentally constrained by transmission expansion and by institutional capacity to perform studies and build upgrades at scale. Therefore, the most plausible path to durable efficiency gains is the coupled implementation of Order 2023 with complementary measures: better data transparency ("heatmaps"), standardized modeling and affected-system coordination, automation and workforce investment, and stronger integration of interconnection reform with proactive transmission planning and cost allocation (FERC, 2023, 2024; U.S. Department of Energy [DOE], 2024; Rand et al., 2025).

II. PROBLEM STATEMENT, RESEARCH QUESTIONS, AND SCOPE

Generator interconnection is the regulated process for evaluating and implementing the technical and commercial requirements for connecting new generating facilities (including storage configured as a generating resource) to the transmission system. The process typically includes feasibility/system impact/facilities studies and culminates in an interconnection agreement specifying required upgrades, performance requirements, timelines, and cost responsibility (FERC, 2003; FERC, 2018).

This paper addresses the following research questions:

- **Efficiency trends:** How have interconnection timelines, throughput, and completion/withdrawal outcomes evolved over time, and what does the best-public evidence suggest about changes around major FERC reforms (e.g., Order Nos. 2003, 845, and 2023)? (Rand et al., 2024, 2025; Gorman et al., 2025).
- **Mechanisms:** Through what causal pathways do FERC rules plausibly affect queue efficiency (e.g., readiness requirements, study timelines and penalties, cost allocation rules, transparency mandates)? (FERC, 2018, 2019, 2023, 2024).
- **Regional variation:** How do interconnection metrics and operational practices vary across major regions (PJM, CAISO, MISO, SPP, NYISO, and ERCOT as a non-FERC-jurisdictional comparison), and what does this imply about policy effectiveness and constraints? (CAISO, 2025; Monitoring Analytics, 2024; SPP, 2025; MISO, n.d.).
- **Policy integration:** How do interconnection reforms interact with reliability requirements, renewable integration, and transmission planning/cost allocation? (FERC, 2011; DOE, 2024; Gorman et al., 2025).
- **Design improvements:** What targeted policy and market-design improvements are supported by the evidence, and what data gaps limit definitive evaluation? (DOE, 2024; Rand et al., 2025).

The scope is transmission-level (bulk-power) interconnection under FERC-jurisdictional open-access tariffs and organized-market rules, with ERCOT included primarily as an institutional contrast. This paper does not attempt a distribution-level interconnection review, which is predominantly state-jurisdictional and governed by different standards and procedures (DOE, 2024).

III. METHODOLOGY AND DATA SOURCES

Because the user provided no proprietary dataset, this paper uses a transparent, reproducible research design anchored in public and primary sources:

Document analysis (primary legal/policy texts). The core interconnection reforms are evaluated through the text and official summaries of FERC rulemakings and Federal Register notices, including Order No. 2003 (large generator interconnection standardization), Order No. 2006 (small generator standardization), Order No. 792/792-A (small generator updates and clarifications), Order No. 845/845-A (large generator process reforms and performance metrics), Order No. 1000 (regional transmission planning and cost allocation), the 2021 ANOPR and 2022 NOPR on interconnection reforms, and the final rules Order No. 2023 and Order No. 2023-A (FERC, 2003, 2005, 2011, 2014, 2018, 2019, 2023, 2024; Federal Register, 2021, 2022).

Literature synthesis (academic and national laboratory). The paper synthesizes national interconnection queue analyses from the Energy Technologies Area at Lawrence Berkeley National Laboratory[17] ("Queued Up" reports and related datasets), and peer-reviewed work analyzing queue and cost drivers (Gorman et al., 2025; Rand et al., 2024, 2025).

Descriptive quantitative comparisons (public metrics across time and regions). The quantitative section uses: - LBNL's national queue snapshot metrics through end of 2023 and end of 2024 (Rand et al., 2024, 2025).

- Order 845 and related performance reporting artifacts from regional operators (e.g., CAISO study statistics; SPP delay reporting) and independent market monitor reports (CAISO, 2025; SPP, 2025; Monitoring Analytics, 2024).
- Public descriptions of interconnection process schedules (e.g., MISO's definitive planning phase study calendar) (MISO, n.d.).
- Regional queue reform and transition-cycle documentation (PJM, 2024).
- Public queue snapshots from New York reliability stakeholder materials (NYSRC, 2025).
- ERCOT planning summaries reporting active interconnection requests (ERCOT, 2025).

Analytic approach and causal limits. The empirical approach is primarily descriptive and mechanism-based. The paper presents "directional findings" rather than definitive causal estimates because (a) multiple reforms overlap in time, (b) compliance implementation varies regionally, (c) queue volume is strongly affected by technology costs and policy incentives, and (d) transmission construction timelines and permitting constraints are confounders not controlled here (DOE, 2024; Rand et al., 2025).

IV. LITERATURE REVIEW AND POLICY BACKGROUND

Conceptualizing "interconnection efficiency"
For this paper, interconnection efficiency is defined as the degree to which the interconnection system converts bona fide proposals into timely, predictable, reliability-compliant grid connections with minimal avoidable transaction costs and minimal negative spillovers on other queue participants and consumers. That definition implies four measurable proxies:

- **Time performance:** study completion time, time to agreement, and time to commercial operation (Rand et al., 2024, 2025).
- **Queue productivity:** completion rates and withdrawal rates, especially late-stage withdrawals that trigger restudies and cost reallocation (Rand et al., 2025; Monitoring Analytics, 2024).
- **Cost predictability:** the level and variance of interconnection costs, particularly network upgrade costs, and their relationship to withdrawal behavior (Gorman et al., 2025; LBNL, n.d.).
- **Externalities and coordination:** the degree to which one project's actions (withdrawal, modification, delay) impose restudy and delay

costs on others; and the coordination burden across "affected systems" (FERC, 2023, 2024).

A key insight from the academic and national-lab literature is that high withdrawal rates can be an equilibrium outcome when interconnection functions as a costly information-discovery mechanism: developers enter the queue to learn upgrade costs and timelines, then rationally exit when costs or delays exceed project value (Gorman et al., 2025).

V. MAJOR FERC INTERCONNECTION REFORMS AND THEIR UNDERLYING LOGIC

FERC's interconnection policy is often described as evolving from standardization to transparency to throughput discipline—each phase responding to the dominant observed failure modes of its time.

Order No. 2003 (standardization of large generator interconnection). Order No. 2003 required public utilities to adopt standardized interconnection procedures and a standardized large generator interconnection agreement (LGIP/LGIA), motivated by a concern that inconsistent or discriminatory practices could inhibit entry and distort competition (FERC, 2003).

Order No. 2006 (standardization of small generator interconnection). Order No. 2006 performed a parallel function for resources up to 20 MW, requiring standardized procedures and agreements (SGIP/SGIA). Its policy logic includes lowering transaction costs and improving predictability for smaller resources, including many distributed generation and early-stage renewables (FERC, 2005).

Order No. 792 / 792-A (modernizing small generator procedures). Order No. 792 updated small generator procedures to better reflect evolving technologies and process needs, and 792-A clarified compliance requirements. The modernization logic includes improved pre-application information and inclusion of storage in small generator procedures—both relevant to efficiency because information and technological fit reduce iterative study and redesign (FERC, 2013, 2014).

Order No. 845 / 845-A (reforming large generator procedures; adding transparency and metrics). Order No. 845 made a set of reforms aimed explicitly at improving certainty and decision-making for interconnection customers and enhancing the overall process. Importantly for empirical evaluation, the order strengthened transparency and reporting requirements such that study performance could be monitored, including quarterly posting of study statistics and reporting when delay thresholds are exceeded (FERC, 2018; Federal Register, 2019).

Order No. 1000 (regional transmission planning and cost allocation). While not an interconnection rule, Order No. 1000 altered the planning and cost allocation environment in which interconnection occurs. It sought to correct deficiencies in planning and cost allocation that could inhibit needed transmission. Because interconnection upgrade triggers are strongly shaped by transmission scarcity, planning reforms affect interconnection outcomes indirectly via the baseline network and the project pipeline (FERC, 2011).

2021 ANOPR and 2022 interconnection NOPR: diagnosing backlog and proposing reforms. The 2021 ANOPR explicitly raised generator interconnection funding and queue process issues, linking them with consumer protection and planning deficiencies (Federal Register, 2021). [32] The 2022 NOPR on "Improvements to Generator Interconnection Procedures and Agreements" codified proposed reforms in response to growing backlogs and delay, setting the stage for the final 2023 rule (Federal Register, 2022).

Order No. 2023 and 2023-A (cluster studies, readiness, deadlines, penalties, and coordination). FERC's official summaries describe Order 2023 as a broad restructuring of the generator interconnection process to reduce backlogs and increase certainty by shifting to cluster studies and "first-ready, first-served," increasing readiness requirements and withdrawal penalties, replacing "reasonable efforts" with firm deadlines and penalties, and improving affected-system coordination and information transparency (FERC, 2023, 2024).

VI. ACADEMIC AND NATIONAL LABORATORY EVIDENCE ON THE DRIVERS OF INEFFICIENCY

The strongest empirical findings converge on two related bottlenecks: (1) the scarcity of transmission capacity and the resulting upgrade burden, and (2) the informational and incentive structure that encourages heavy entry and heavy withdrawal.

National queue evidence from LBNL shows a dramatic increase in queued capacity and extended timelines to completion. The 2024 and 2025 "Queued Up" editions report that completion rates are low while withdrawals dominate; they also report that the time from interconnection request to commercial operation for built projects has expanded significantly compared with earlier periods (Rand et al., 2024, 2025).

The peer-reviewed Joule study provides a mechanism-based explanation: wide distributions of interconnection costs—especially network upgrade costs—create uncertainty that (a) slows financing and project development and (b) motivates withdrawals when a project is assigned extensive upgrades (Gorman et al., 2025).

Complementary LBNL analyses of interconnection cost data across multiple regions find systematic evidence that network upgrade costs have increased and that withdrawn projects are often associated with higher upgrade obligations, supporting the hypothesis that upgrade "sticker shock" is a driver of churn (LBNL, n.d.).

Finally, DOE's Transmission Interconnection Roadmap frames interconnection reform as a socio-technical systems challenge that requires not only tariff reform but also data transparency, process modernization, automation, modeling improvements, workforce capacity, and coordination across institutions (DOE, 2024).

Table comparing orders and their efficiency mechanisms

Table 1
FERC reforms and the primary mechanisms affecting interconnection efficiency

Policy instrument	Year (issued)	Primary scope	Key mechanisms relevant to efficiency	Predicted efficiency impacts (theory of change)	Key constraints/data needs
Order No. 2003	2003	Large generators (typically >20 MW)	Standard LGIP/LGIA; non-discrimination; study steps and agreement structure	Lower transaction costs; reduce discriminatory barriers; create predictable baseline procedures	Does not itself solve high-volume queue congestion; needs throughput metrics and upgrade cost distribution data
Order No. 2006	2005	Small generators (≤20 MW)	Standard SGIP/SGIA; streamlined options for smaller resources	Faster processing for smaller projects; improved access	Distribution-level constraints and state rules often dominate outcomes; limited compa

Policy instrument	Year (issued)	Primary scope	Key mechanisms relevant to efficiency	Predicted efficiency impacts (theory of change)	Key constraints/data needs
					rability across regions
Order No. 792 / 792-A	2013–2014	Small generator modernization	Pre-application information; storage inclusion; process clarifications	Better front-end information reduces speculation and redesign; tech fit improves study accuracy	Requires consistent data publication and process adoption; limited national small-GI datasets
Order No. 845 / 845-A	2018–2019	Large generator process reforms	Process reforms + transparency; quarterly study metric posting; reporting triggers	Better information → fewer low-quality requests; earlier exits; accountability for delays; improved evaluation	Metrics definitions vary; effectiveness depends on study capacity and enforcement
Order No. 1000	2011	Transmission planning/cost allocation	Regional planning requirements; cost allocation principles; competition considerations	Indirectly reduces upgrade shocks by enabling proactive transmission buildout	Success depends on regional governance and acceptance of cost allocation
2021 ANOPR	2021	Planning, cost allocation, interconnection	Diagnoses backlog; explores queue reforms and funding approaches	Sets policy agenda; frames interconnection as consumer-protection issue	Requires subsequent NOPR/final rule plus measurable implementation
2022 GI NOPR	2022	Generator interconnection reforms	Proposes cluster and readiness reforms	Builds record for final rule; aligns proposals with observed backlog	Needs compliance filings, transition plans, and outcome tracking
Order No. 202	2023 –	Large generator interco	First-ready, first-served;	Reduces serial restudi	System-wide outco

Policy instrument	Year (issued)	Primary scope	Key mechanisms relevant to efficiency	Predicted efficiency impacts (theory of change)	Key constraints/data needs
3 / 2023-A	2024	nnection overhaul	cluster studies; readiness deposits/site control; withdrawal penalties; firm deadlines + penalties; affected-system coordination; transparency/heatmaps	es; discourages speculative entry; increases study timeliness; improves cost allocation certainty	mes depend on transmission expansion and workforce/IT capacity; early era for evaluation

Note. Sources: Order No. 2003 (FERC, 2003); Order No. 2006 (FERC, 2005); Order No. 792-A (FERC, 2014); Order No. 845 and 845-A (FERC, 2018, 2019); Order No. 1000 (FERC, 2011); the 2021 ANOPR (Federal Register, 2021); the 2022 GI NOPR (Federal Register, 2022); Orders 2023/2023-A summaries (FERC, 2023, 2024). [38]

VII. LEGAL AND REGULATORY ANALYSIS OF FERC AUTHORITY AND POLICY OBJECTIVES

Statutory basis: Federal Power Act sections 205 and 206

FERC's authority over generator interconnection on the transmission system is rooted in its jurisdiction over the rates, terms, and conditions of wholesale sales and interstate transmission service. Federal Power Act (FPA) Section 205 requires that rates and charges "for or in connection with" jurisdictional transmission or sale of electricity, along with "rules and regulations affecting" such rates, be just and reasonable and not unduly discriminatory or preferential (16 U.S.C. § 824d). (Cornell Law School, n.d.; U.S. Code, n.d.-a).

FPA Section 206 empowers FERC to remedy unjust, unreasonable, unduly discriminatory, or preferential rates, terms, and conditions already in effect by determining a just and reasonable replacement (16 U.S.C. § 824e). (U.S. Code, n.d.-b).

These provisions jointly provide the core administrative-law architecture for interconnection rules: since interconnection procedures and agreements function as tariff terms governing access to transmission, FERC can standardize them and revise them through rulemaking and adjudication under its just-and-reasonable and non-discrimination mandates (FERC, 2003; CRS, 2001).

Order No. 2003's legal framing: interconnection as an open-access tariff service

A key doctrinal move in Order No. 2003 is the treatment of interconnection service as a component of open access transmission tariffs required to prevent undue discrimination. By requiring standardized procedures and a pro forma agreement, Order No. 2003 sought to remove opportunities for discriminatory treatment and to create predictable, enforceable terms for interconnection customers (FERC, 2003).

This logic continues in modern reforms: Order No. 2023's official summary describes the reforms as intended to ensure that the interconnection process remains "just, reasonable, and not unduly discriminatory or preferential," indicating continuity in statutory objectives even as procedural design changes radically (FERC, 2023).

Policy objectives: balancing open access, reliability, and consumer protection

Across the interconnection rule lineage, FERC's policy objectives can be understood as a triad:
Open access and non-discrimination. Standardization and transparency reduce discretionary barriers and help ensure similarly

situated interconnection customers are treated comparably (FERC, 2003, 2018).

Reliability protection. Interconnection is inherently a reliability procedure: studies verify that adding a resource does not violate thermal limits, voltage requirements, stability margins, short-circuit constraints, or protection system capabilities. Modern reforms explicitly address modeling and performance needs for new technologies (especially inverter-based resources), aligning process rules with evolving reliability risks (FERC, 2023; DOE, 2024). Consumer protection and affordability. Interconnection costs and delays affect consumer outcomes by delaying capacity additions, increasing financing costs, and shifting cost allocation. The 2021 ANOPR explicitly included "consumer protection" as a theme when discussing interconnection queueing and funding, reflecting a concern that dysfunctional queues can impose broader economic costs beyond individual developers (Federal Register, 2021).

VIII. THE LEGAL-REGULATORY TENSION: SPEED VS. DUE PROCESS AND ENGINEERING CERTAINTY

FERC's move from "reasonable efforts" to firm deadlines and penalties in Order No. 2023 can be interpreted as an administrative capacity and accountability strategy: if study delays are endemic and impose costs on customers and consumers, enforceable timelines plus financial consequences can realign incentives (FERC, 2023).

However, the DOE roadmap emphasizes that incentives do not substitute for technical capacity. Even with penalties, study timeliness and quality depend on staffing, automated tools, consistent modeling data, and coordination among transmission providers, transmission owners, and affected systems (DOE, 2024).

Accordingly, the legal-regulatory challenge is not merely "making queues faster"; it is ensuring that procedural acceleration does not degrade engineering rigor or shift costs in a way that undermines investment and leads to more withdrawals and restudies (Gorman et al., 2025; FERC, 2023).

IX. QUANTITATIVE ANALYSIS OF INTERCONNECTION QUEUE METRICS

Data limitations and comparability constraints
A national, harmonized dataset for interconnection exists through LBNL's "Queued Up" compilation, which aggregates and cleans data across >50 transmission providers and nearly all installed U.S. generating capacity (Rand et al., 2025). However, year-by-year regional metrics for "wait times" and "costs" are not uniformly published in comparable formats across all ISOs/RTOs. Requirements under Order No. 845 increased transparency and reporting, but definitions remain region-specific and implementation varies (FERC, 2018; SPP, 2025; CAISO, 2025).

Therefore, this section uses (a) nationally consistent metrics from LBNL for broad trend inference and (b) representative regional case metrics from public ISO/RTO reporting and independent monitoring reports for cross-sectional illustration. Where pre/post causal attribution is not feasible, the paper states that explicitly and interprets changes directionally (DOE, 2024; Rand et al., 2025).

X. NATIONAL QUEUE OUTCOMES: SCALE, COMPLETION, AND TIMELINE CHANGES

LBNL's 2025 edition provides a snapshot through end of 2024 indicating that active interconnection requests remain extremely large in both generation and storage terms. It reports ~10,300 active projects seeking transmission interconnection and identifies a subset with draft/executed interconnection agreements that have not yet reached commercial operation, underscoring that agreement execution is not equivalent to completion (Rand et al., 2025).

Completion and withdrawal outcomes reported by LBNL show that the interconnection system has historically converted only a small fraction of queued capacity into built projects. For requests submitted in 2000–2019 (in LBNL's national dataset), only about 13% of capacity had reached commercial operation by end of 2024, while about 77% had withdrawn, with the remainder still active—implying systemic inefficiency even before the full roll-out of Order 2023 compliance (Rand et al., 2025).

The time dimension is equally material. LBNL's 2024 edition, summarizing trends through end of 2023, reports that the duration from interconnection request to commercial operation for completed projects increased from under two years for projects built in 2000–2007 to more than four years for projects built in 2018–2023, with a median around five years for projects built in 2023 (Rand et al., 2024). These published values enable an illustrative pre/post comparison at the "standardization era vs. modern queue congestion era" level:

- Illustrative timeline increase: from <2 years (2000–2007 built projects) to >4 years (2018–2023 built projects), indicating at least a doubling of time-to-completion in the published summaries (Rand et al., 2024).
- Implication for policy evaluation: because Order No. 845 (2018) and Order No. 2023 (2023) occur during or after the onset of the longest durations, purely procedural reforms must be evaluated against a backdrop of much higher queue volume and transmission constraints than in the early 2000s (Rand et al., 2024, 2025; DOE, 2024).

XI. INTERCONNECTION COSTS AND THE RELATIONSHIP TO WITHDRAWALS

Nationally, the Joule study reports that interconnection costs exhibit wide distributions and that requests identifying large transmission upgrades are more likely to withdraw, consistent with upgrade cost uncertainty as a key driver of inefficiency (Gorman et al., 2025).

LBNL's interconnection cost research program summarizes multi-region empirical findings and provides project-level data (for covered regions and balancing authorities) supporting the claim that broader network upgrade costs are increasingly a dominant share of total interconnection costs and correlate with project status (completed vs. active vs. withdrawn) (LBNL, n.d.).

For example, LBNL's public summaries of SPP cost data report that potential interconnection costs for solar and wind requests have been higher than those for storage and natural gas in the analyzed period, with notable values reported in dollars per kW for different technologies and statuses—illustrating how technology mix and upgrade requirements can influence both cost and withdrawal propensity (LBNL, 2023). [52] Similar public summaries for MISO identify network upgrade costs as a primary driver of recent cost increases, highlighting that broader network upgrades beyond the interconnecting substation explain much of the cost variation and have risen sharply in recent years (LBNL, 2022).

These findings matter for FERC policy evaluation because Order No. 2023's reforms explicitly target (a) cost allocation across cluster participants using a proportional impact method and (b) earlier information and exit mechanisms (heatmaps, readiness windows, withdrawal penalty structures) intended to reduce late-stage withdrawals and restudies (FERC, 2023, 2024).

XII. REGIONAL CASE STUDIES: WAIT TIMES, STUDY DELAYS, AND CLUSTER REFORMS

This subsection compiles representative queue metrics from major regions. These metrics are not perfectly comparable, but they illuminate the operational bottlenecks FERC reforms are designed to address.

Table 2
Timeline of key interconnection policy milestones and regional implementations (selected)

Year	Milestone	Relevance to efficiency	Evidence source
2003	Order No. 2003 (LGIP/LGIA standardization)	Establishes standardized procedures; reduces discrimination; creates baseline queue architecture	(FERC, 2003)
2005	Order No. 2006 (SGIP/SGIA standardization)	Streamlines smaller projects; establishes pro forma process	(FERC, 2005)
2011	Order No. 1000 (regional planning/cost allocation)	Indirectly affects interconnection by enabling proactive transmission	(FERC, 2011)
2013 – 2014	Order No. 792 / 792-A	Modernizes small generator process; pre-application information	(FERC, 2014)
2018 – 2019	Order No. 845 / 845-A	Improves information transparency; mandates study metric reporting and reporting triggers	(FERC, 2018, 2019)
2021	ANOPR including GI queueing and funding	Diagnoses backlog; frames queueing and consumer protection	(Federal Register, 2021)
2022	GI NOPR	Proposes cluster/readiness reforms	(Federal Register, 2022)
2023 – 2024	Order No. 2023 / 2023-A	Cluster studies; first-ready, first-served; penalties; readiness; affected-system coordination	(FERC, 2023, 2024)
2024 – 2025	PJM transition cycles	Illustrates operational transition architecture to clear legacy queue and implement reforms	(PJM, 2024)

Note. Sources are provided in the references list.

Mermaid timeline (policy milestones). This chart visualizes the same timeline in a compact format (Federal Register, 2021, 2022; FERC, 2003, 2005, 2011, 2018, 2019, 2023, 2024). [55]

Table 3
Representative ISO/RTO queue metrics and reporting (illustrative, not fully comparable)

Region (case)	Metric(s) used	Representative published values / observations	Source
PJM (mid-Atlantic; RTO)	Queue duration by milestone and status;	Independent market monitor reports	(Monitoring Analytics, 2024)

Region (case)	Metric(s) used	Representative published values / observations	Source
	project-stage distribution	multi-year queue durations and tracks milestone completion and queue status distributions (e.g., project queue times by milestone as of mid-2024 and end-2024)	
CAISO (California; ISO)	Order 845 study statistics; cluster study reporting	Quarterly interconnection statistics include mean days to complete certain study phases (e.g., reported mean Phase II completion days in published tables) and recent cluster study counts in RIS reporting	(CAISO, 2025)
MISO (Midwest; RTO)	Published study-cycle schedule targets	Public process documents describe a multi-phase definitive planning phase with target durations (e.g., Phase 1 ~140 days, Phase 2 ~80 days, Phase 3 ~135 days; a published graphic indicates DPP + GIA target total duration on the order of ~505 days)	(MISO, n.d.)
SPP (Plains; RTO)	Order 845 informational filing triggered by study delay thresholds	Study metrics reports are filed when delay thresholds persist, indicating measurable delay performance issues and formal governance response mechanisms	(SPP, 2025)

Region (case)	Metric(s) used	Representative published values / observations	Source
NYISO (New York; ISO)	Cluster queue snapshot (projects and MW)	A reliability council attachment summarizes NYISO cluster queue size (e.g., 212 projects totaling 31,328 MW as of Sept. 30, 2025)	(NYSRC, 2025)
ERCOT (Texas; ISO-like, mostly intrastate)	Active interconnection requests and MW	ERCOT monthly operational overview reports active interconnection requests and total MW (e.g., 1,984 active requests totaling 441,031 MW as of Dec. 31, 2025)	(ERCOT, 2025)

Interpretation.
These metrics collectively illustrate that queue performance constraints are visible in multiple dimensions: extensive duration; formal delay reporting; large queue volumes; and the need for structured transition cycles to reprocess legacy backlogs. Importantly, these metrics are observed during overlapping reforms—so they reflect both policy response and changing system conditions rather than a clean "before/after" causal result (DOE, 2024; Rand et al., 2025).

Cluster study impacts: plausible effects and early evidence
Order No. 2023 requires cluster study processes and explicitly aims to reduce serial restudy externalities common in first-come, first-served systems, where one withdrawal can trigger cascading restudies for lower-queued projects (FERC, 2023).

Empirically, cluster study impacts are challenging to quantify in a unified national metric because regions have adopted cluster designs at different times and with different "readiness" rules. However, public regional process documents show the operational logic of cluster transitions. For example, PJM's "Queue Reform and Current Statistics" document describes a staged transition with multiple "transition cycles" and associated GW volumes, implying a deliberate queue reset designed to increase throughput later (PJM, 2024).

Similarly, CAISO's reporting distinguishes between cluster studies and traditional phases in its published metrics and reflects implementation of cluster-based governance through reporting of cluster study completions and deadline metrics (CAISO, 2025).

Because Order No. 2023 implementation is recent and compliance was extended into 2024, national sources caution that it is too early to measure the full system-wide impact of Order No. 2023 in aggregate outcomes (FERC, 2023, 2024; Rand et al., 2025).

XIII. POLICY IMPACT ASSESSMENT AND STAKEHOLDER PERSPECTIVES

Efficiency outcomes: what FERC reforms likely improved
Standardization reduced transaction and discrimination costs but did not anticipate the modern scale of queue volume. Order Nos. 2003 and 2006 created pro forma procedures and agreements that established a predictable baseline. This likely improved entry conditions and comparability, but

these rules did not directly address the congestion dynamics arising when thousands of projects enter the queue for cost discovery and then withdraw (FERC, 2003, 2005; Rand et al., 2025).
Transparency and reporting created measurable accountability. Order No. 845's metric posting and reporting triggers transformed queue governance by enabling stakeholders and regulators to observe study delays and performance. Evidence of this is visible in the existence and structure of public study statistics (e.g., CAISO) and formal informational filings (e.g., SPP) created to comply with these mandates (FERC, 2018, 2019; CAISO, 2025; SPP, 2025).

Order 2023's design directly targets backlog mechanics. FERC's official summaries indicate that Order No. 2023 aims to: (a) reduce serial restudies through cluster studies; (b) reduce speculative entry and late-stage churn via readiness requirements and withdrawal penalties; (c) increase timeliness via enforceable deadlines and penalties; and (d) reduce affected-system delays via standardized coordination and agreements. In mechanism terms, it seeks to internalize externalities that one project's low readiness or late withdrawal imposes on other projects and consumers (FERC, 2023, 2024).

XIV. RELIABILITY: HOW INTERCONNECTION EFFICIENCY INTERACTS WITH ENGINEERING RIGOR

Interconnection fundamentally exists to protect reliability. Faster processing is only "efficient" if studies remain technically credible and if operational performance requirements are met. Order 2023's focus on modern technologies reflects a reliability-driven motivation: increased penetration of inverter-based resources requires accurate modeling and performance standards to prevent disturbance-related tripping and cascading reliability events (FERC, 2023; DOE, 2024).

DOE's roadmap further emphasizes the reliability dimension by calling for improved modeling guidance, data access, and coordination among actors, recognizing that reliability needs may increase analytical complexity and thus contribute to time and capacity constraints if not accompanied by automation and standardized data frameworks (DOE, 2024).

XV. COST ALLOCATION AND RENEWABLE INTEGRATION: THE UPGRADE COST "PARADOX"

A dominant empirical pattern is that transmission network upgrade costs are rising and are increasingly central to project withdrawal decisions (Gorman et al., 2025; LBNL, n.d.). This creates a paradox: requiring upgrades preserves reliability and enables future capacity, but assigning large upgrade costs to single projects can deter completion, slow deployment, and generate repeated restudy cycles that themselves consume scarce engineering capacity.

Order 2023's proportional impact method and cluster cost allocation approach can be interpreted as an attempt to reduce this paradox by allocating upgrade costs among projects that contribute to an upgrade's need, rather than concentrating costs on a single early mover (FERC, 2023, 2024). [4]

However, both academic and DOE sources emphasize that the deepest solution to upgrade shocks is not merely cost allocation within the queue; it is expanding the transmission base through proactive planning and building, which reduces the incidence of large network upgrades being triggered as "project-by-project" surprises (Gorman et al., 2025; DOE, 2024; FERC, 2011).

Interconnection and transmission planning: coupling is necessary for durable efficiency Order No. 1000 illustrates why transmission planning reforms matter: if regional planning produces needed upgrades and allocates costs in a durable way, interconnection becomes easier because marginal projects trigger fewer major upgrades (FERC, 2011).

Nevertheless, the fact that queue durations increased significantly in the 2018–2023 period (as reported by LBNL) suggests that transmission buildout and planning have not kept pace with the volume of new resource requests (Rand et al., 2024). This supports the Joule study's broader inference that interconnection reform must be linked to transmission expansion and planning reform to avoid perpetuating the queue as a costly discovery mechanism (Gorman et al., 2025).

XVI. UTILITY AND ISO/RTO OPERATIONAL PRACTICES:

what implementation looks like on the ground Even when FERC sets pro forma requirements, the day-to-day mechanics are implemented by transmission providers and ISO/RTO processes. Public documents illustrate the range of operational practices:

- Staged transition cycles and queue "resets." PJM's queue reform materials show a multi-cycle transition with defined timelines and approximate GW volumes clearing through different phases, reflecting a strategy to process legacy backlog while implementing new rules (PJM, 2024).
- Defined study-phase schedules as internal production planning. MISO's published definitive planning phase structure explicitly states target study durations for each phase and illustrates a planned total cycle time (MISO, n.d.).
- Public study-statistic reporting and retention rules. CAISO's tariffs and reporting describe quarterly study-statistic posting and retention, illustrating how Order 845 created ongoing performance reporting obligations (CAISO, 2025).
- Governance escalation via informational filings when delay thresholds persist. SPP's Order 845 informational filing demonstrates an escalation mechanism: delay metrics become triggers for FERC-facing reporting obligations (SPP, 2025).
- DOE frames these operational practices as part of a broader modernization agenda including automation, standardized data exchange, and enhanced coordination with affected systems and state entities (DOE, 2024).

Stakeholder perspectives

Developers and investors. Developers prioritize timeline certainty and upgrade cost predictability because interconnection delay increases carrying costs and can jeopardize tax-credit qualification, offtake contracts, and financing. The empirical association between high upgrade costs and withdrawals indicates that unpredictable upgrade exposure is a central barrier to completion (Gorman et al., 2025; LBNL, n.d.). From this viewpoint, Order 2023's heatmaps, readiness windows, and cluster cost allocation are attractive to the extent they reduce informational uncertainty early and reduce late-stage "surprises" (FERC, 2023, 2024).

Transmission owners/utilities. Utilities face increasing compliance and performance expectations, including potential penalties for study delays under Order 2023 and enhanced reporting under Order 845. However, compliance is constrained by engineering workforce capacity, model quality, and coordination across multiple owners and affected systems (DOE, 2024). [15] The existence of formal delay reporting suggests that meeting deadlines is often challenging even with reformed processes, implying that investments in tools and staffing may be as important as tariff design (SPP, 2025; CAISO, 2025).

ISO/RTOs and independent monitors. Regional operators prioritize reliability and market integrity. Independent monitoring reports, such as PJM's, emphasize the time and stage distribution of queue projects, implicitly highlighting costly restudy externalities and the importance of reforms that reduce late-stage churn (Monitoring Analytics, 2024).

State regulators and public agencies. State entities are not the primary tariff-setting regulator for transmission interconnection, but they bear the consequences of delayed resource additions and can influence complementary policies (e.g., siting, permitting, procurement). Legal analyses emphasize that FERC's authority is bounded and that states retain jurisdiction over many facilities decisions, reinforcing the need for coordinated governance if transmission buildout is to support interconnection efficiency (CRS, 2001; DOE, 2024).

XVII. RECOMMENDATIONS, LIMITATIONS, AND FUTURE RESEARCH RECOMMENDATIONS FOR POLICY AND MARKET-DESIGN IMPROVEMENTS

Recommendation one: treat interconnection as a capacity-constrained production system requiring modernization investment, not only tariff reform. Order 2023's incentives and penalties address behavior, but persistent delay metrics indicate that study capacity, engineering workforce, and IT/tooling are binding constraints. DOE's roadmap calls for automation, standardized data access, and process redesign; these investments should be treated as essential complements to Order 2023 compliance rather than optional enhancements (DOE, 2024).

Recommendation two: expand transparency from "metrics" to "actionable decision intelligence." Order 845's statistics and Order 2023's heatmaps create visibility, but further gains likely require standardized definitions and richer publication of: (a) available transfer capability and constraint mapping, (b) upgrade cost distributions (not just point estimates), (c) study assumption sets and model versions, and (d) milestone-level attrition analytics. The goal is to reduce speculative entry by improving early screening and siting, thereby improving queue quality and reducing restudies (FERC, 2018, 2023; DOE, 2024).

Recommendation three: strengthen affected-system coordination through standardized data exchange and enforceable timelines. FERC identifies affected-system delays and inconsistencies as a key contributor to late-stage uncertainty. Implementation should emphasize shared modeling standards, common data exchange protocols, and predictable coordination windows across regions, aligning with DOE's call for broader system coordination and modeling guidance (FERC, 2023, 2024; DOE, 2024).

Recommendation four: align cost allocation with both cost causation and investment incentives, and integrate with proactive transmission planning. The literature indicates that extreme upgrade cost exposure is associated with withdrawals, while the queue's growth indicates transmission scarcity. Order 2023's proportional impact approach and cluster cost rules are steps toward reducing single-project "sticker shock," but durable efficiency likely requires proactive regional transmission buildout and cost allocation frameworks that prevent interconnection upgrades from substituting for missing planning (FERC, 2011, 2023; Gorman et al., 2025).

Recommendation five: institutionalize evaluation with standardized, auditable performance datasets. Order 845 reporting established a foundation, but policy evaluation remains limited by inconsistent definitions and incomplete publication of milestone and cost outcomes. FERC could require harmonized data schemas and publish annual national performance dashboards using standardized metrics across regions, enabling quasi-experimental evaluation of reforms and accelerating learning across jurisdictions (FERC, 2018; Rand et al., 2025).

Limitations

This paper is constrained by both data and inference limits. First, no single uniform dataset provides directly comparable queue wait-time, cost, and withdrawal metrics across all regions and years; even with Order 845 reporting, definitions and publication practices vary (FERC, 2018; CAISO, 2025; SPP, 2025). Second, causal inference about any single order is limited because reforms overlap, compliance is staged, and exogenous drivers (technology costs, policy incentives, load growth, and transmission permitting constraints) shape queue volume and outcomes (DOE, 2024; Rand et al., 2025).

Third, this paper relies primarily on published summaries and representative case metrics rather than full project-level replication of the underlying LBNL spreadsheets or ISO datasets, because no user dataset was provided and the analysis was designed to be defensible using primary public documents (Rand et al., 2024, 2025).

XVIII. FUTURE RESEARCH

Three research directions are especially promising and feasible given emerging transparency:

- Post-Order 2023 causal evaluation using standardized milestone data. As compliance matures, researchers can compare early and late implementers and exploit variation in readiness rules and penalty structures, while controlling for regional baseline differences (FERC, 2023, 2024).
- Link interconnection upgrades to regional transmission plans and buildout. Integrating interconnection upgrade records with planning project portfolios would test whether proactive planning reduces upgrade shocks and withdrawals, a hypothesis emphasized in the Joule literature (Gorman et al., 2025; FERC, 2011).
- Distributional analysis of readiness deposits and withdrawal penalties. Strong readiness requirements can improve queue quality but may raise entry barriers for smaller developers or public-interest projects; DOE's roadmap highlights equity and participation considerations, suggesting the need for empirical distributional evaluation (DOE, 2024).

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