

Queued Up: Status and Drivers of Generator Interconnection Backlogs

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Solar and Storage Finance USA

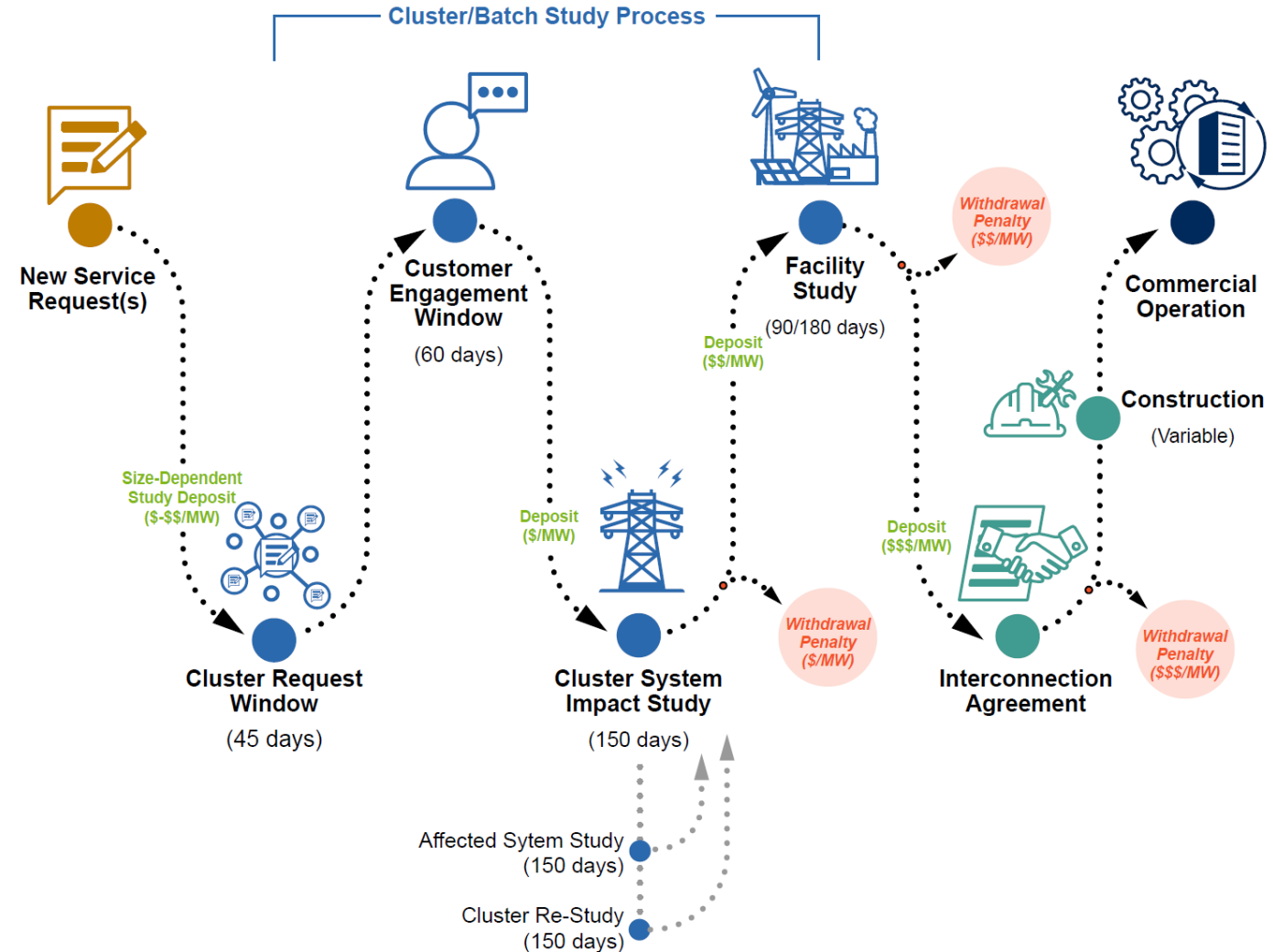
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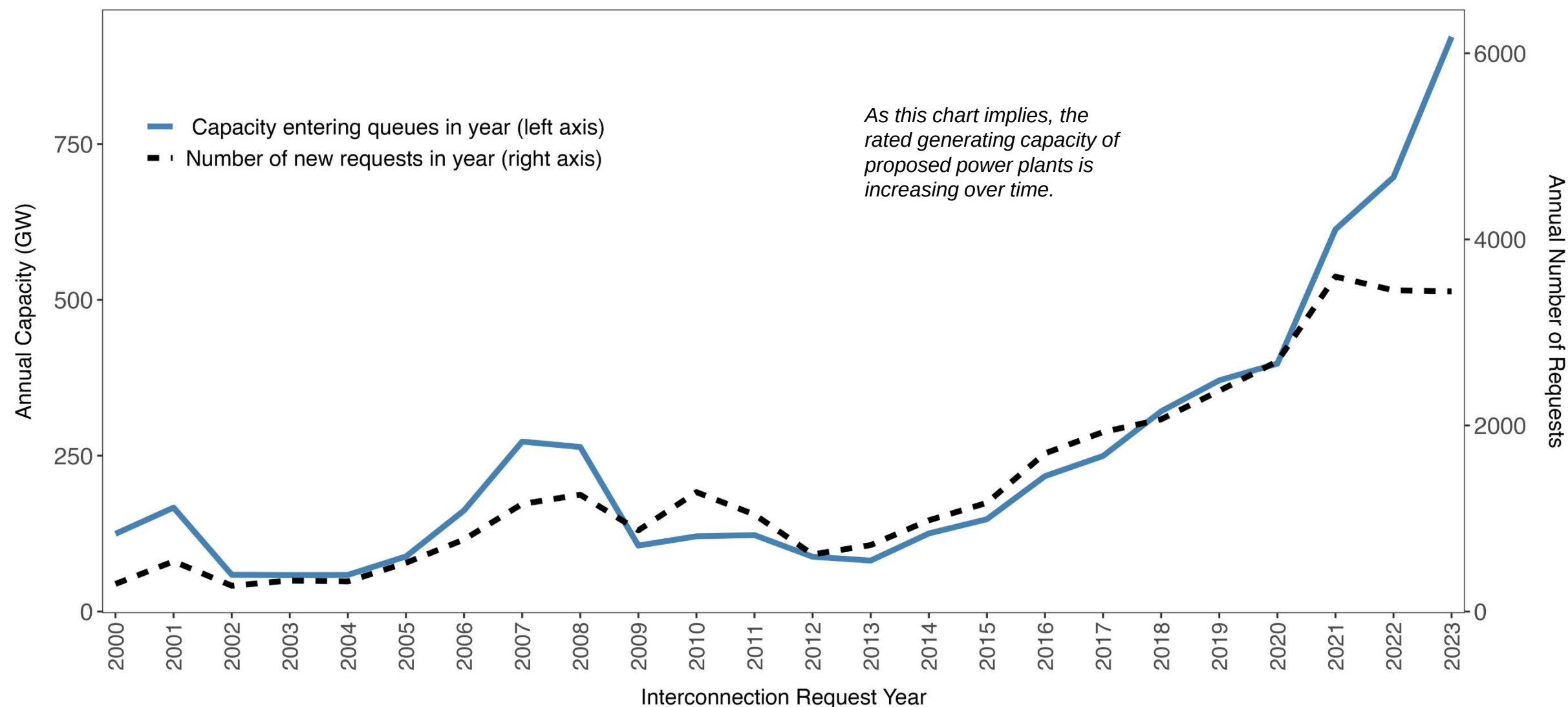
Current interconnection process was designed in 2003 for an electricity system with fewer, larger, centralized power plants (though RTOs have implemented some reforms)

- A project developer initiates a new **interconnection request (IR)** and thereby enters the **queue**
- A series of **interconnection studies** establish what new transmission equipment or upgrades may be needed and assigns the costs of that equipment
- The studies culminate in an **interconnection agreement (IA)**: a contract between the ISO or utility and the generation owner that stipulates operational terms and cost responsibilities
- Most proposed projects are **withdrawn**, which may occur at any point in the process
- After executing an IA, many projects are built and reach **commercial operation**



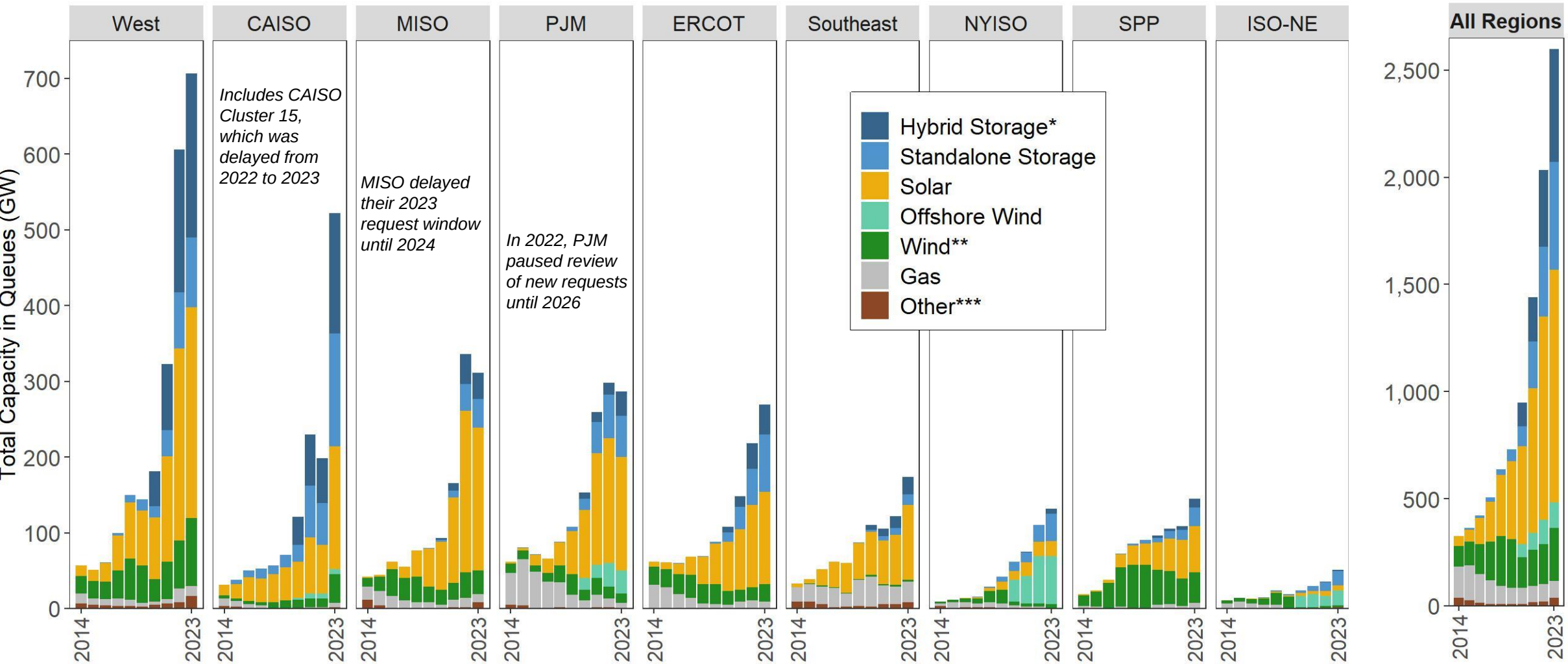
Note: These steps are in accordance with Federal Energy Regulatory Commission (FERC) pro-forma interconnection procedures as outlined in FERC Order 2023. Some ISOs already use a cluster-study approach. The data presented in this report pre-date Order No. 2023 implementation.

Annual interconnection requests surged from 2013-2023, but decreased by nearly 50% in 2024



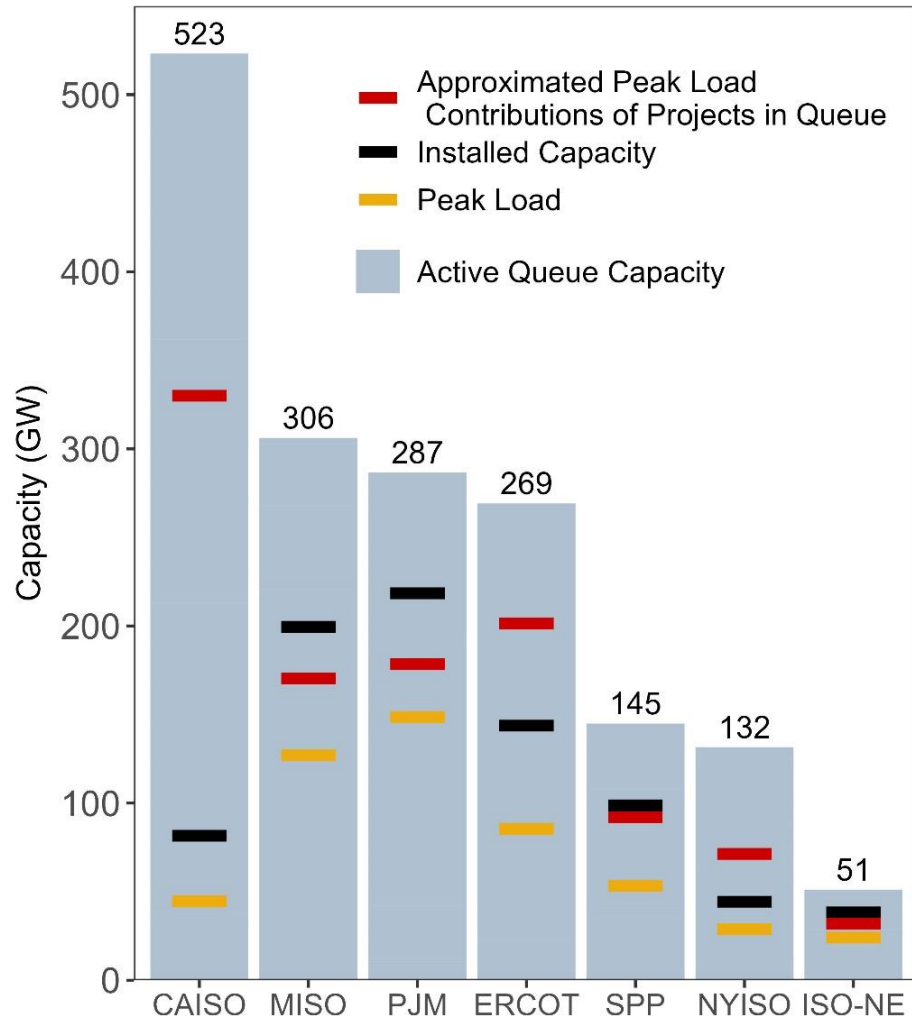
Notes: (1) This total annual volume includes projects with a queue status of "active", "suspended", "withdrawn", or "operational". (2) All values – especially for earlier years – should be considered approximate.

Active queue capacity is highest in the West (706 GW), followed by CAISO (523 GW). Several regions have delayed accepting or processing new requests due to backlogs



Active capacity in queues is greater than peak load and installed capacity in all ISOs

*RTO Installed Capacity & Peak Load vs. Active Queues
by end of 2023*



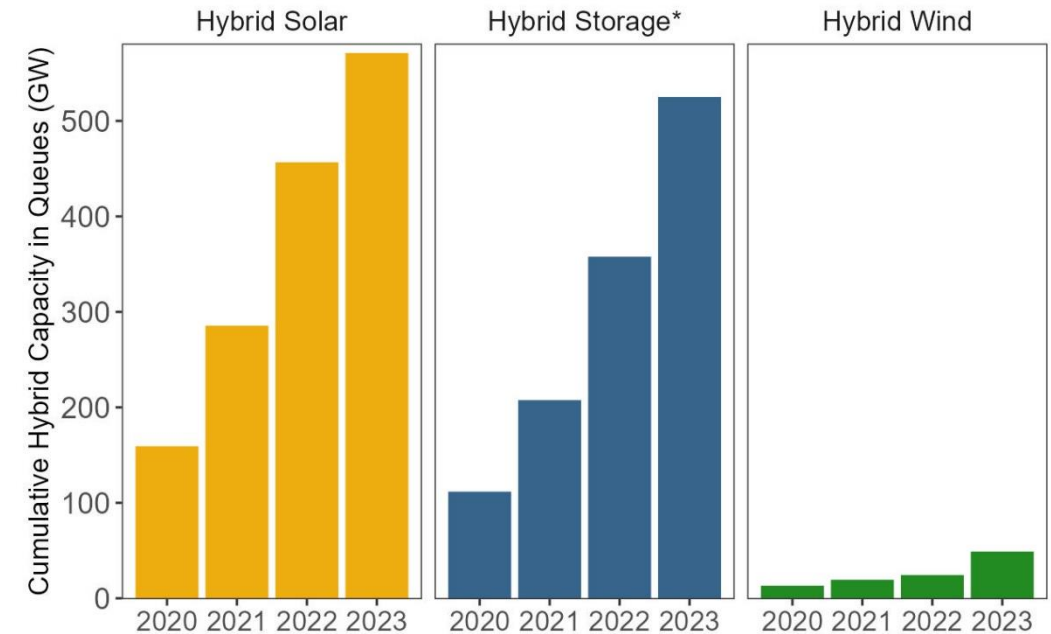
Comparisons of queue capacity to installed capacity or peak load should also consider generators' contributions to resource adequacy, for example their "effective load carrying capability" (ELCC).

As variable resources, solar and wind contribute a smaller percentage of their nameplate capacity to resource adequacy and peak load compared to dispatchable generation like natural gas. The red lines in the chart are a simplified estimate of the peak load contribution of projects in the queue.

Notes: (1) Hybrid storage in queues is estimated for some projects. (2) Total and RTO installed capacity from EIA-860, December 2023. (3) Peak load data from RTO websites. (4) Peak load contributions by region relies on [NERC 2023 reliability assessments](#) for standalone solar, onshore wind, and hydro. Storage, gas, coal, and nuclear are approximated with a peak load contribution of 100%, even though in practice their contributions will be smaller. Offshore wind contributions are based on recent reliability studies.

Capacity in hybrid plants is increasing: Hybrids comprise 53% of active solar capacity (571 GW), 51% of storage (525 GW), and 13% of wind (49 GW)

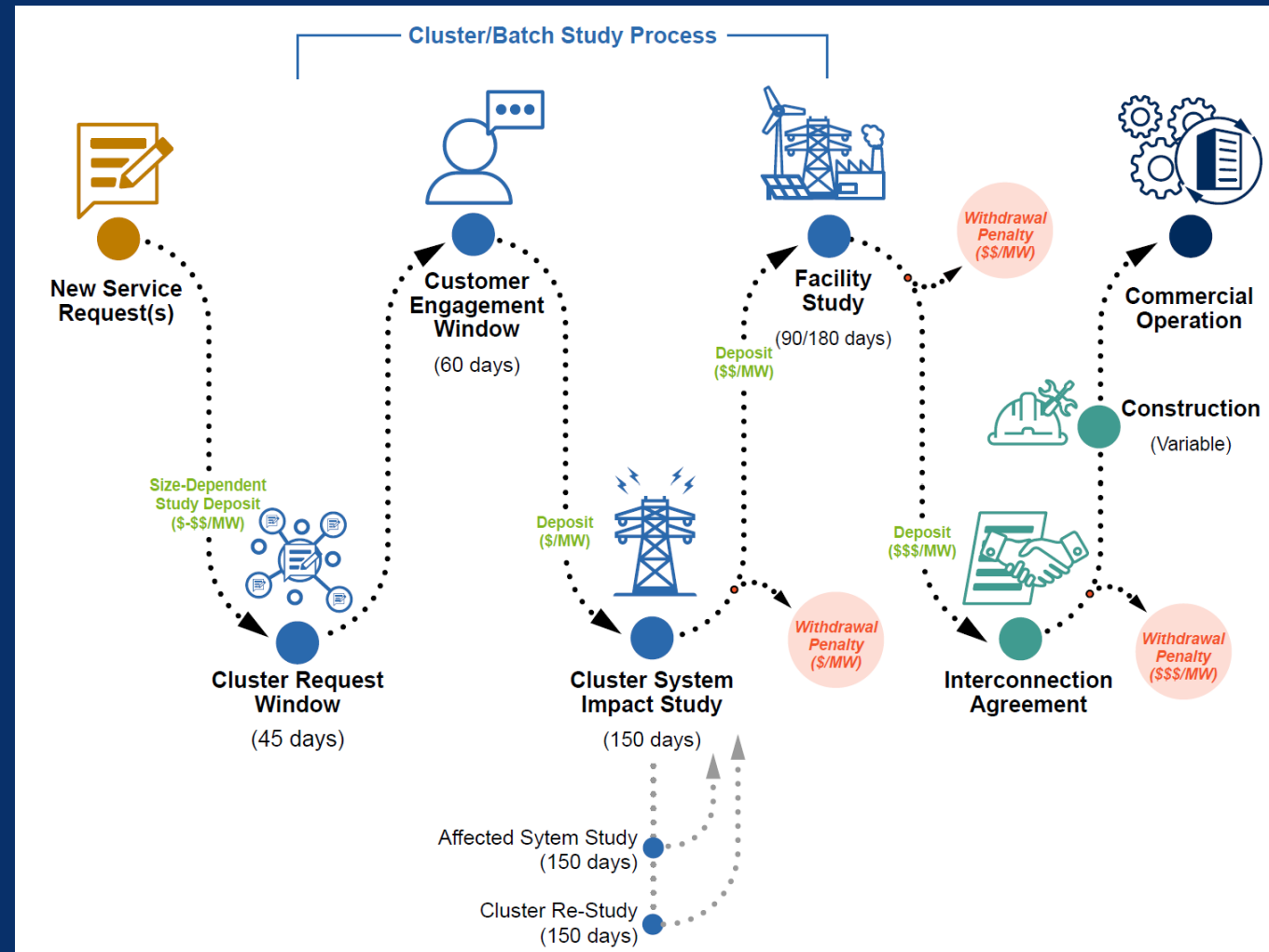
Region	% of Proposed Capacity Hybridizing in Each Region			
	Solar	Wind	Gas	Storage*
CAISO	98%	34%	88%	52%
ERCOT	49%	7%	4%	34%
ISO-NE	30%	0%	10%	8%
MISO	20%	6%	0%	48%
NYISO	24%	4%	16%	16%
PJM	24%	1%	0%	37%
SPP	22%	2%	3%	32%
Southeast (non-ISO)	34%	0%	0%	63%
West (non-ISO)	81%	30%	29%	72%
TOTAL	53%	13%	12%	51%



- **Solar** hybridization relative to total amount of solar in each queue is highest in CAISO (98%) and non-ISO West (81%), and is above 20% in all regions
- **Wind** hybridization relative to total amount of wind in each queue is highest in CAISO (34%), the non-ISO West (30%), and is less than 10% in all other regions

Notes: (1) Some hybrids shown may represent storage capacity added to existing generation; only the net increase in capacity is shown; (2) Capacity for hybrid plants (e.g., Wind+Solar+Storage) is captured in each generator category (i.e., the solar component shows up in hybrid solar, storage in hybrid storage), presuming the capacity is known for each type.

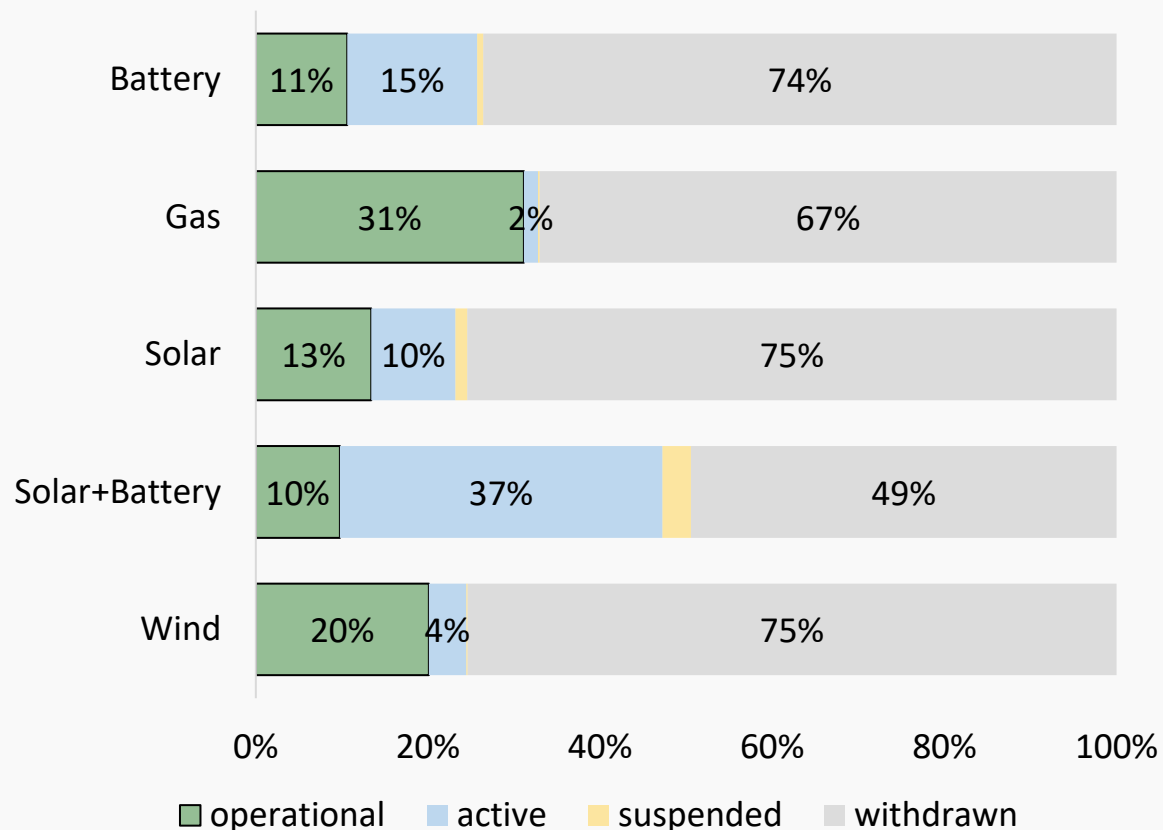
Evidence of a Problem #1: Low completion rates and long timelines



There is considerable variation in completion rates across generator types; Solar (13%) and Battery (11%) have lower historical average than Gas (31%) or Wind (20%)

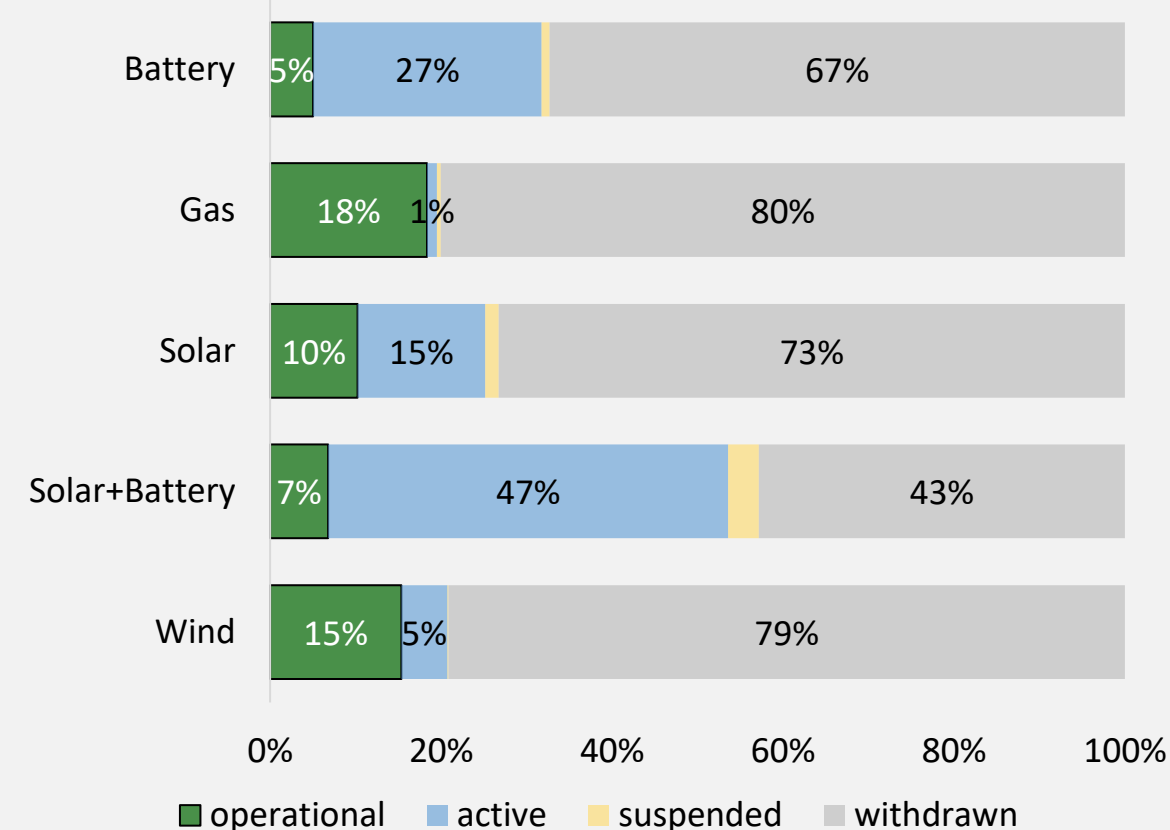
By Number of Requests

Current Status for Requests Submitted 2000-2018



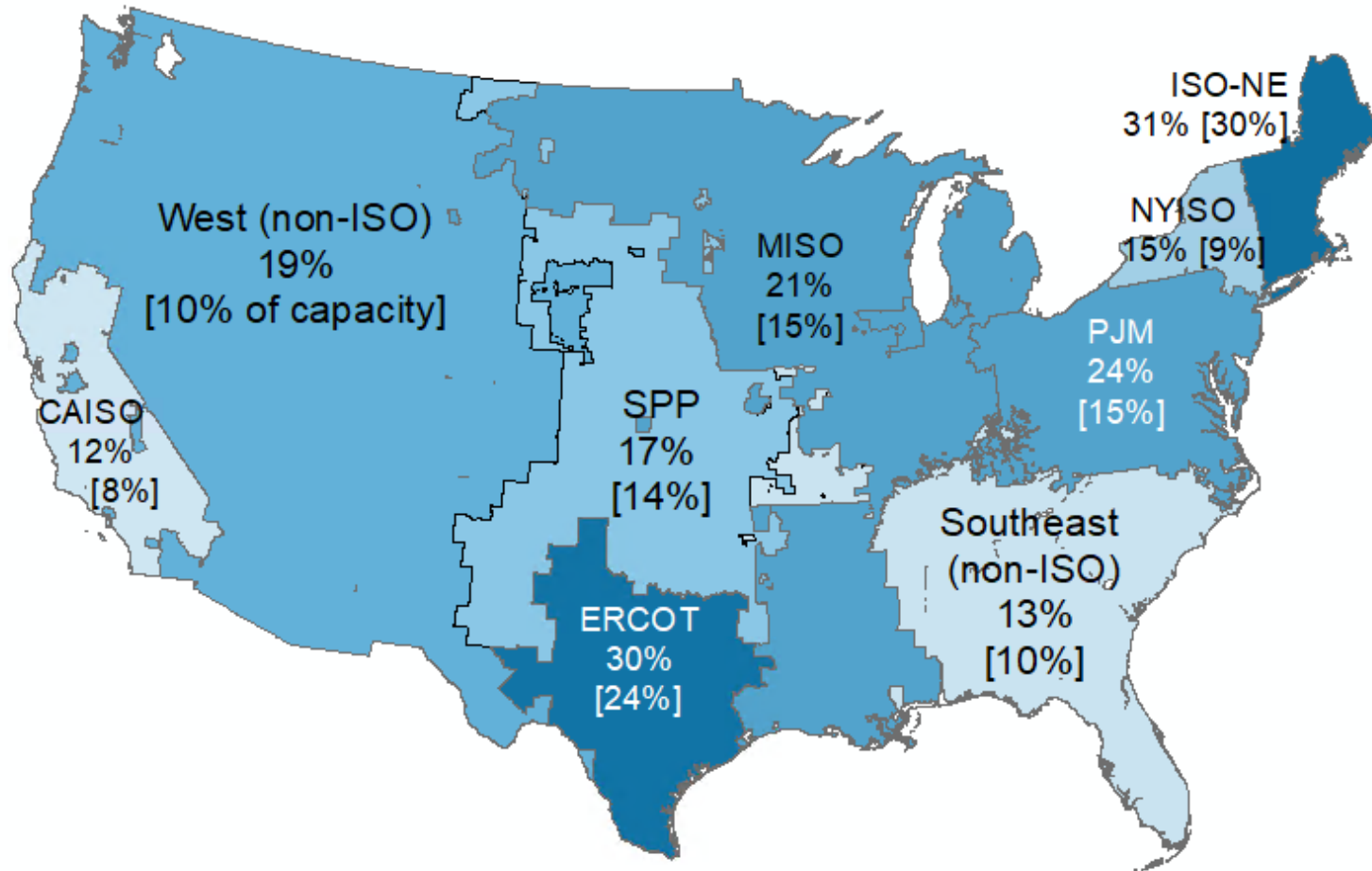
By Capacity of Requests

Current Status for Requests Submitted 2000-2018



Note: (1) Calculated as number of projects operational as of EOY 2023 divided by the total number of requests per year. (2) Includes data from 7 ISOs and 30 non-ISO BAs which provide comprehensive status information. (3) See appendix for time-series data

The share of projects requesting interconnection from 2000-2018 that have reached COD is relatively low across regions: Only ISO-NE and ERCOT exceed 30% completion

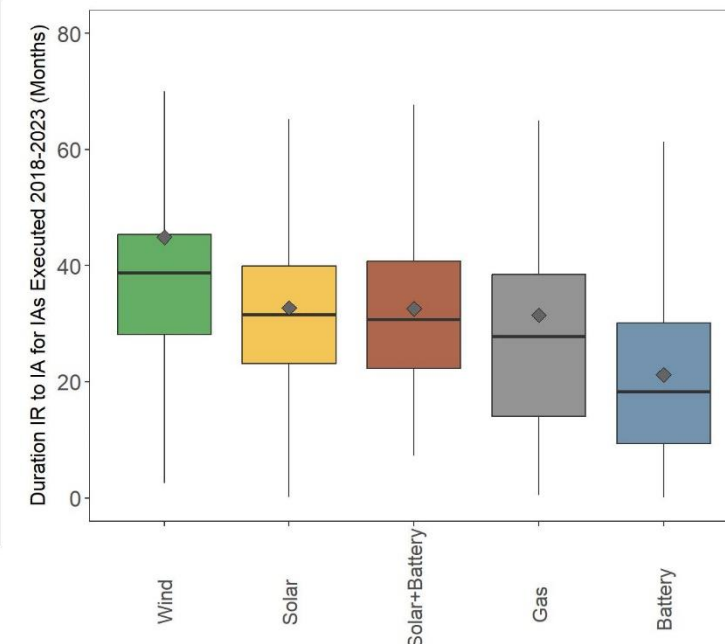
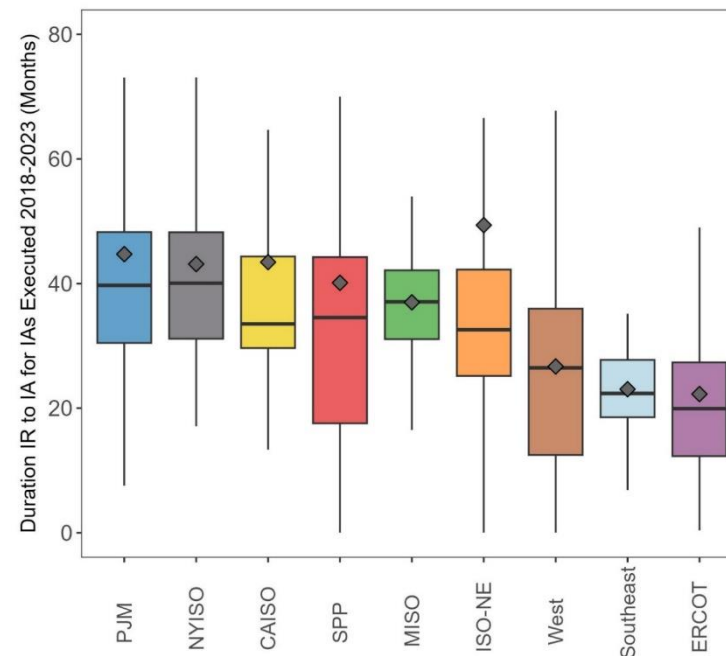
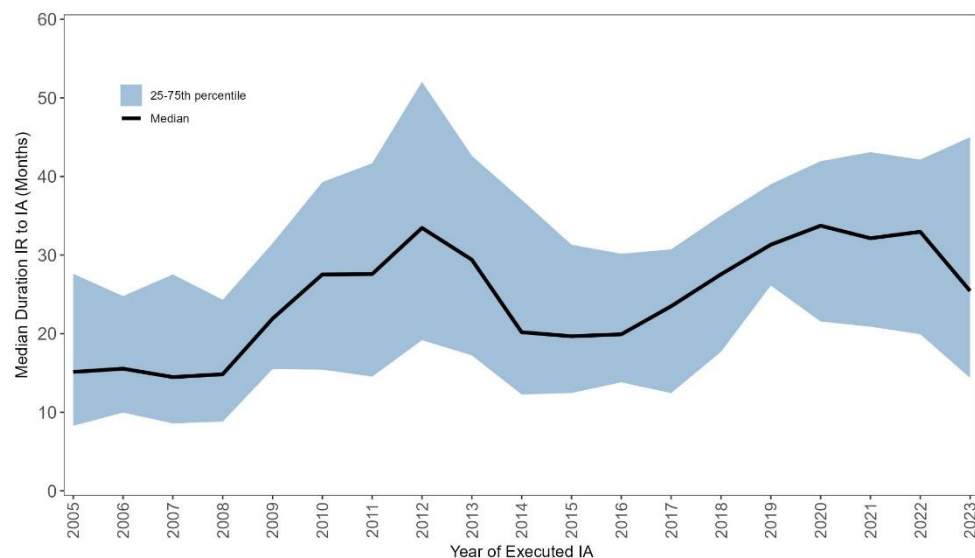
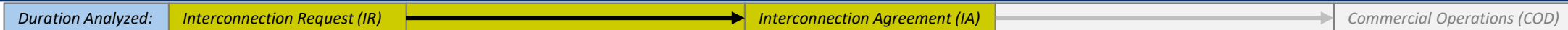


- Capacity-weighted completion rates are even lower; shown in brackets [%]
 - ISO-NE and ERCOT are the only regions with >20% of capacity reaching commercial operation date (COD)
- For interconnection requests from 2000-2018, ISO-NE (31%) and ERCOT (30%) had the highest project completion percentages, with CAISO (12%) and the Southeast (13%) lower on average
- These rates are variable by year, and trends may be shifting as queue volumes and reforms evolve
- The difference between regions, temporal trends, and the implications of these low rates on electric-sector decarbonization, are important areas for future research

Notes: (1) Capacity-weighted completion rates are shown in brackets []. (2) Percentages only include projects requesting interconnection from 2000-2018. (3) Includes data from 7 ISOs and 30 non-ISO balancing areas which provide comprehensive status information. (4) See appendix for time-series data.

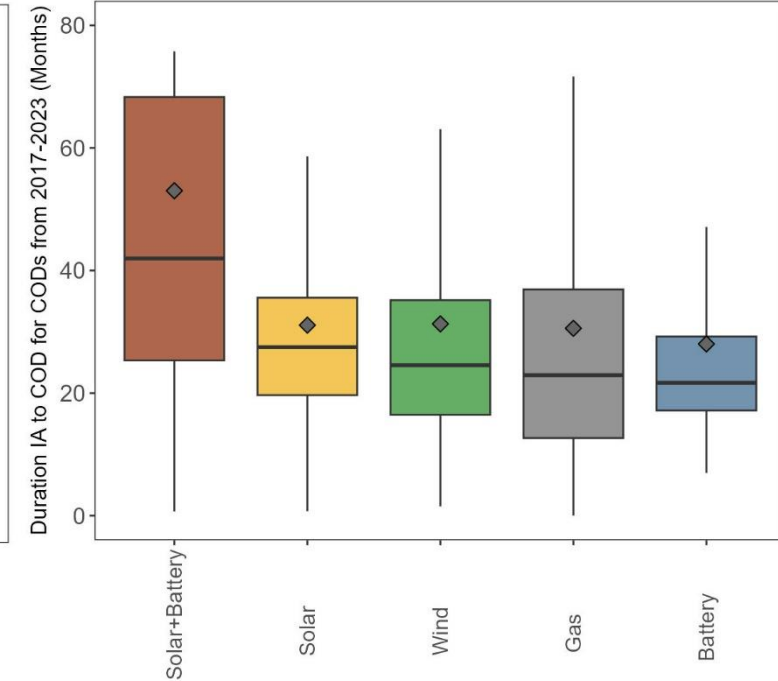
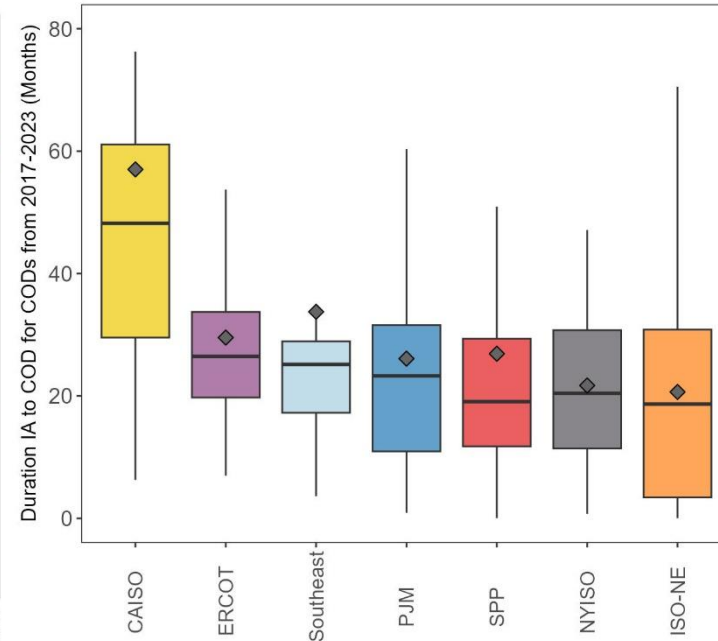
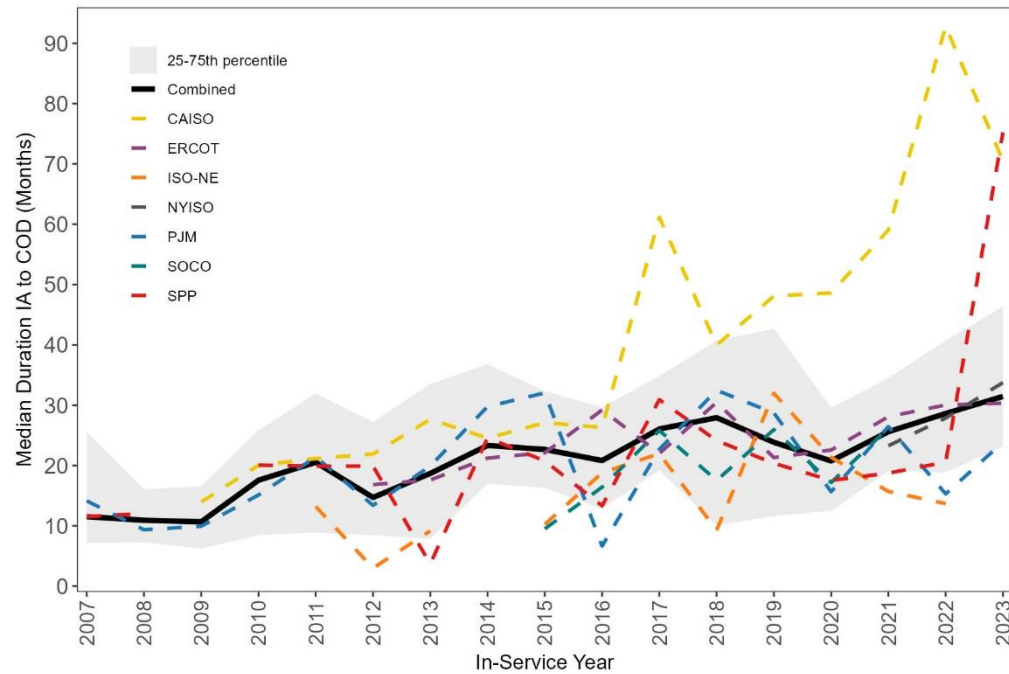


Duration from interconnection request to interconnection agreement had increased recently, but moderated slightly in 2023 (note: 2023 data sample is dominated by ERCOT and West¹)



Notes: (1) The majority of the 2023 data sample for this analysis came from ERCOT (39%) and the West (23%), which typically have relatively shorter durations; date of IA execution for projects with IA agreement completed in 2023 was not accessible in database format from SPP and PJM (though 160 IAs were executed in PJM in 2023). (2) Sample includes 3,864 projects from 7 ISO/RTOs and 5 non-ISO balancing areas with executed interconnection agreements since 2005. (3) Not all data used in this analysis are publicly available.

Moving from an executed IA to COD tends to take substantially longer in CAISO compared to other regions; standalone battery projects are quickest to complete this phase



Notes: (1) Data were only available for 836 projects across 5 ISO/RTOs and one utility (Southern Company), out of 4,155 total "operational" projects in the full dataset. (2) Not all data used in this analysis are publicly available.

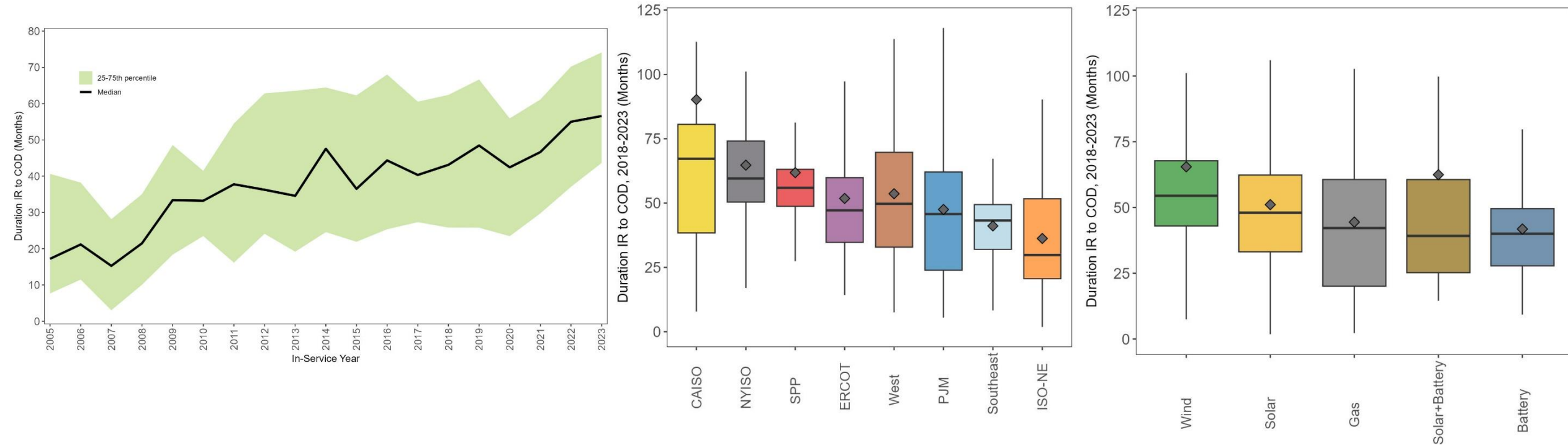
The median duration from interconnection request (IR) to commercial operations date (COD) continues to rise, approaching 5 years for projects completed in 2022-2023

Duration Analyzed:

Interconnection Request (IR)

Interconnection Agreement (IA)

Commercial Operations (COD)

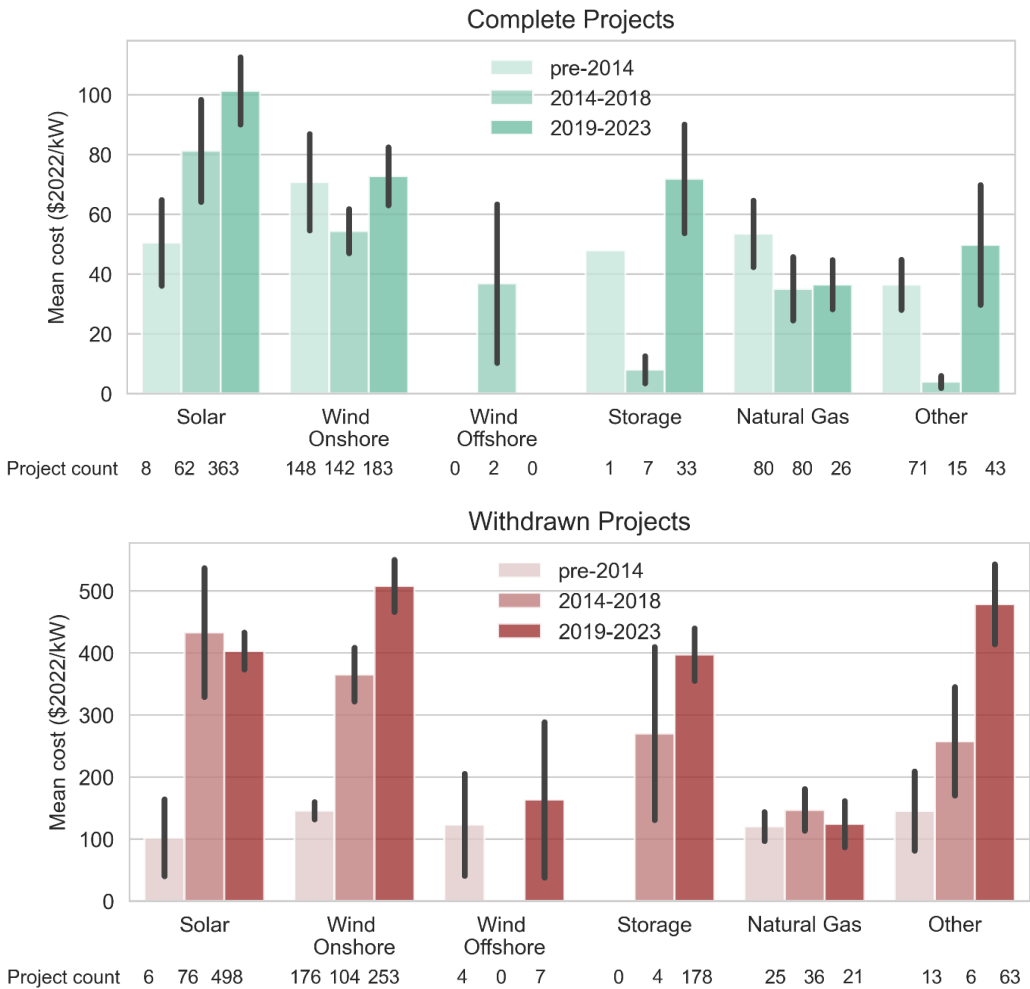


Notes: (1) In-service date was only available for 6 ISOs (CAISO, ERCOT, ISO-NE, NYISO, PJM, SPP) and 8 non-ISO BAs (Duke, FPL, LADWP, PSCo, SOCO, SEC, SRP, TSGT) representing 61% of all operational projects. (2) Duration is calculated as the number of months from the queue entry date to the commercial operations date.

Evidence of a Problem #2: Increasing cost to connect

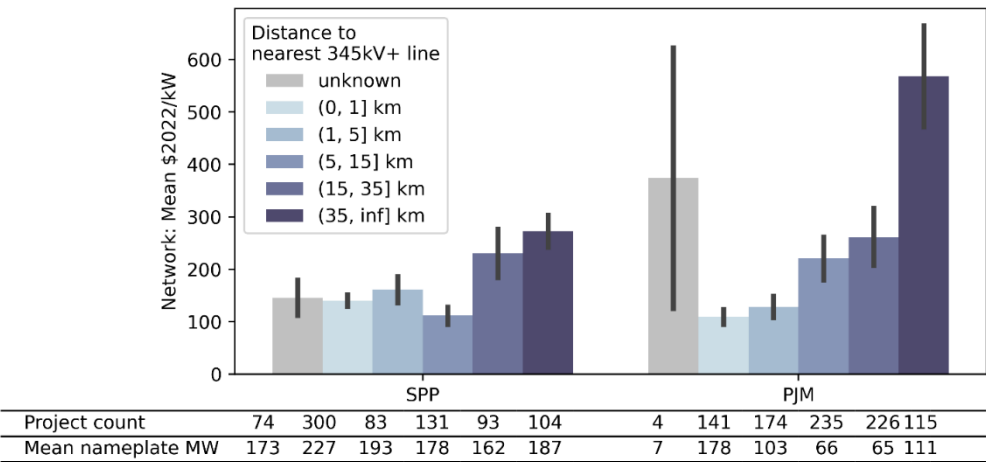
ISO-specific briefings and underlying project cost data available at
https://emp.lbl.gov/interconnection_costs

Renewables and storage often face higher interconnection costs than natural gas



- Solar costs are fairly consistent across regions:
 - Completed: 5-10% of total project Capex
 - Withdrawn: 20-40%

Hypothesis:
Renewables are often located in more rural areas where the existing transmission system is weaker, requiring costlier network upgrades.



Offshore Wind costs exclude transmission investments offshore

Looking Ahead: Reforms and Solutions

FERC Order 2023 overhauled the interconnection process, and many RTOs are proposing or implementing major interconnection process updates and reforms

Interconnection Reforms in FERC Order 2023

- **Cluster studies; first ready, first served**; higher **deposits & readiness** criteria for developers
- **Timeline, process, and reporting** requirements for transmission providers; **Financial penalties** for delays
- Visual representation (**heatmaps**) of **available transmission capacity**
- Improved and standardized process for **affected system studies**
- Improved procedures and **flexibility for storage and hybrid resources**
- Consideration of **alternative transmission technologies (GETs)**
- Compliance deadline: **May 2024**

Major ISO/RTO Reforms & Updates

CAISO

- Interconnection Process Enhancements (IPE) (*approved by FERC Oct. 2024*).
- Prioritizes requests where transmission system has available existing or planned capacity and limit requests in a study area based on planned transmission capacity.
- Delayed Cluster 16 request application window from April 2024 (new date TBD) due to queue volume and reforms (thus, no new requests in 2024).

PJM

- Implemented transition from serial first-come, first-served queue process to a first-ready, first-served clustered cycle approach, grouping projects into three-phase cluster cycles for studying and allocating interconnection costs (*approved by FERC Nov. 2022*).
- No new requests accepted in 2024 as they process backlog and begin transition clusters.
- New fast-track process for high resource adequacy projects (*approved by FERC Feb. 2025*)

MISO

- Increased milestone payments, adopted an automatic withdrawal penalty, and expanded site control requirements for interconnection facilities (*approved by FERC Jan. 2024*).
- Proposal to cap total queue size was approved by FERC (*January 2025*).

SPP

- Filed a waiver to delay closing of 2024 queue request window until March 2025, and defer opening the 2025 request window until April 2026 (*approved by FERC Oct. 2024*)



DOE’s Transmission Interconnection Roadmap identifies 35 solutions to mitigate queue backlogs, focus on four interconnection goals

Goal #1: Increase Data Access and Transparency	Goal #2: Improve Process and Timeline	Goal #3: Promote Economic Efficiency	Goal #4: Maintain a Reliable, Resilient, and Secure Grid
- Highlight improvements that <i>go beyond</i> FERC Order 845 and 2023 to improve decision making - Facilitate screening, optimal siting, and <i>automation</i> - Enhance equitable outcomes by <i>enabling benchmarking, tracking, and auditing</i> of processes and reform performance	- Backlogs and delays result of <i>rapid growth in requests</i> and ineffective management - Balance tradeoff between <i>quantity of projects and maintaining competition</i> - Provide <i>interconnection opportunities</i> for all <u>Key focus areas</u> - Queue Management - Affected System Studies - Inclusive and fair process - Workforce Development	- Acknowledge that <i>interconnection and transmission planning</i> are closely related - Focus on both <i>allocative efficiency</i> (‘who pays’) and <i>productive efficiency</i> (‘minimizing costs’) <u>Key focus areas</u> - Cost Allocation - Planning Coordination - Interconnection Studies	- In recent years, there has been <i>a series of disturbance events</i> leading to IBR disconnection - Foundation to manage <i>high penetration rates of IBRs</i> and minimize disturbances <u>Key focus areas</u> - Interconnection Models and Tools - Interconnection Standards

Roadmap available at <https://www.energy.gov/eere/i2x/doe-transmission-interconnection-roadmap-transforming-bulk-transmission-interconnection> . Full report provides detail of key solutions as well as identifying key target metrics that can be used to monitor the status of ongoing interconnection process reform. See <https://www.energy.gov/eere/i2x> for more information.



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More Information:

- Visit <https://www.energy.gov/eere/i2x> to learn about and participate in the DOE's i2X program
- Visit <https://www.energy.gov/eere/i2x/doe-transmission-interconnection-roadmap-transforming-bulk-transmission-interconnection> for the Transmission Interconnection Roadmap
- Visit <https://emp.lbl.gov/queues> for Berkeley Lab interconnection queue analysis and data
- Visit https://emp.lbl.gov/interconnection_costs for Berkeley Lab research on generator interconnection costs

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