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Interconnection Innovation eXchange:
A DOE Roadmap for Unlocking Queue Backlogs

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INTERCONNECTION INNOVATION e-XCHANGE

U.S. DEPARTMENT OF ENERGY

Outline

- Status of U.S. Interconnection Queues (Fresh release!)
- Evidence of a Problem
  - 1. Delays and bottlenecks
  - 2. Increasing interconnection costs
- DOE i2X Program Roadmap: Opportunities for Reforms and Solutions

*I will focus on **transmission interconnection**, not distribution/DER interconnection*

Thanks to DOE, and especially the i2X program, for supporting this work


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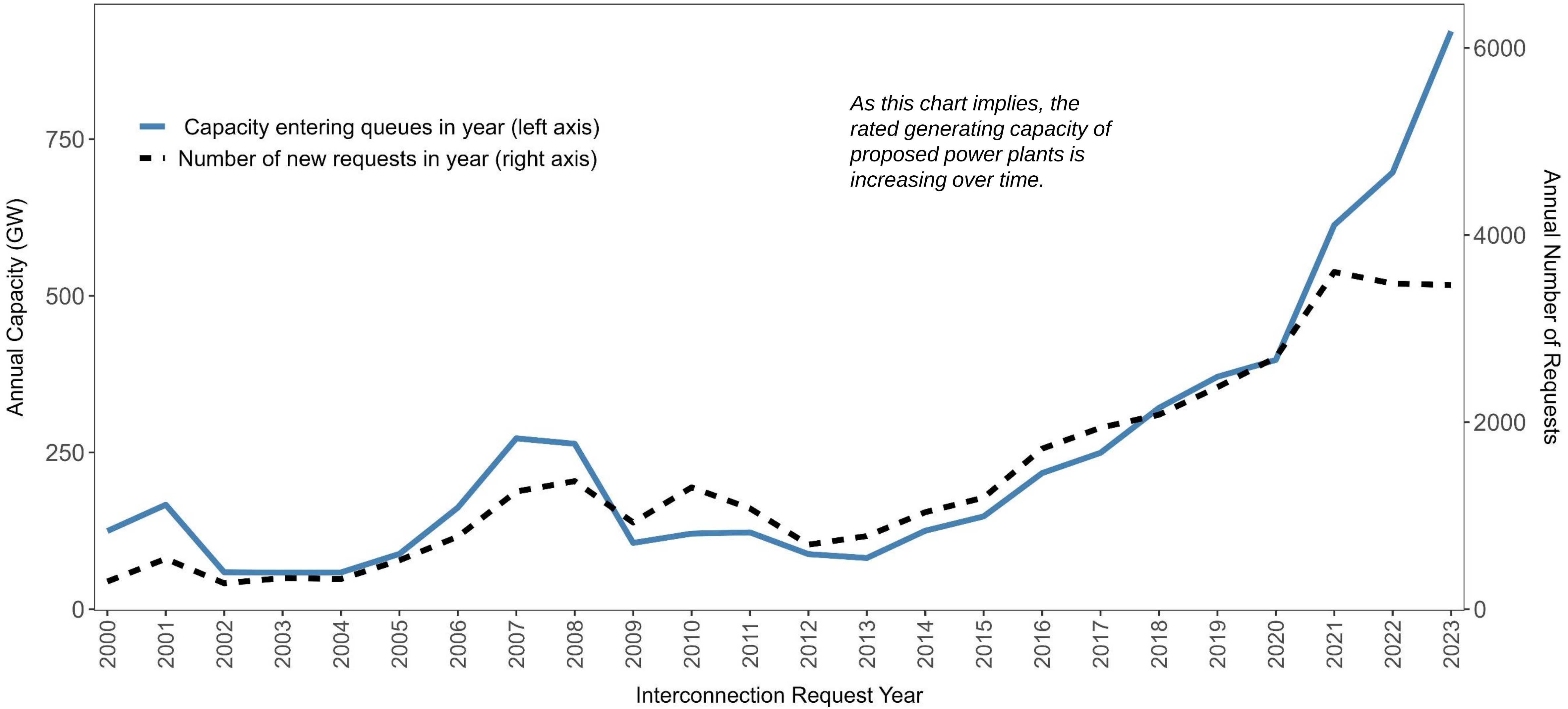
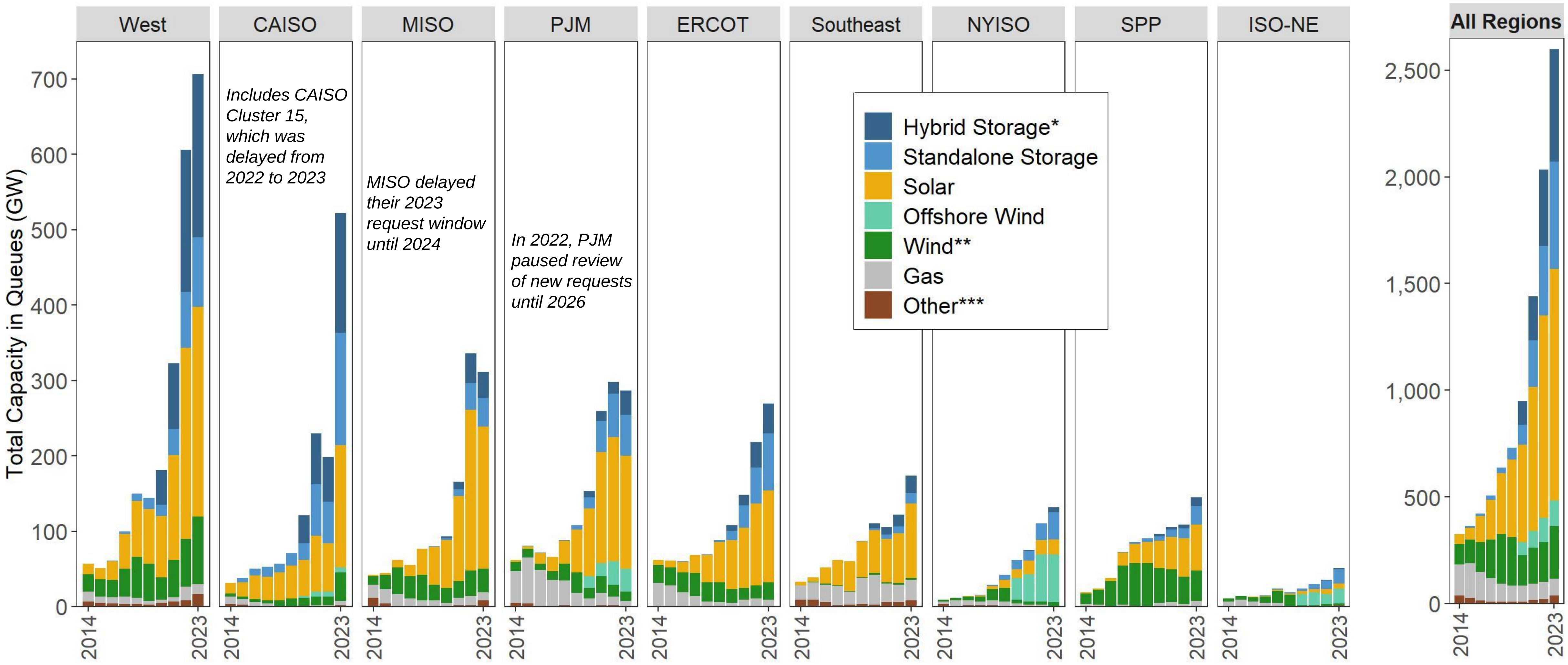
There has been a substantial increase in annual interconnection requests (both in terms of number and capacity) since 2013; over 900 GW added in 2023 alone



Notes: (1) This total annual volume includes projects with a queue status of "active", "suspended", "withdrawn", or "operational".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.

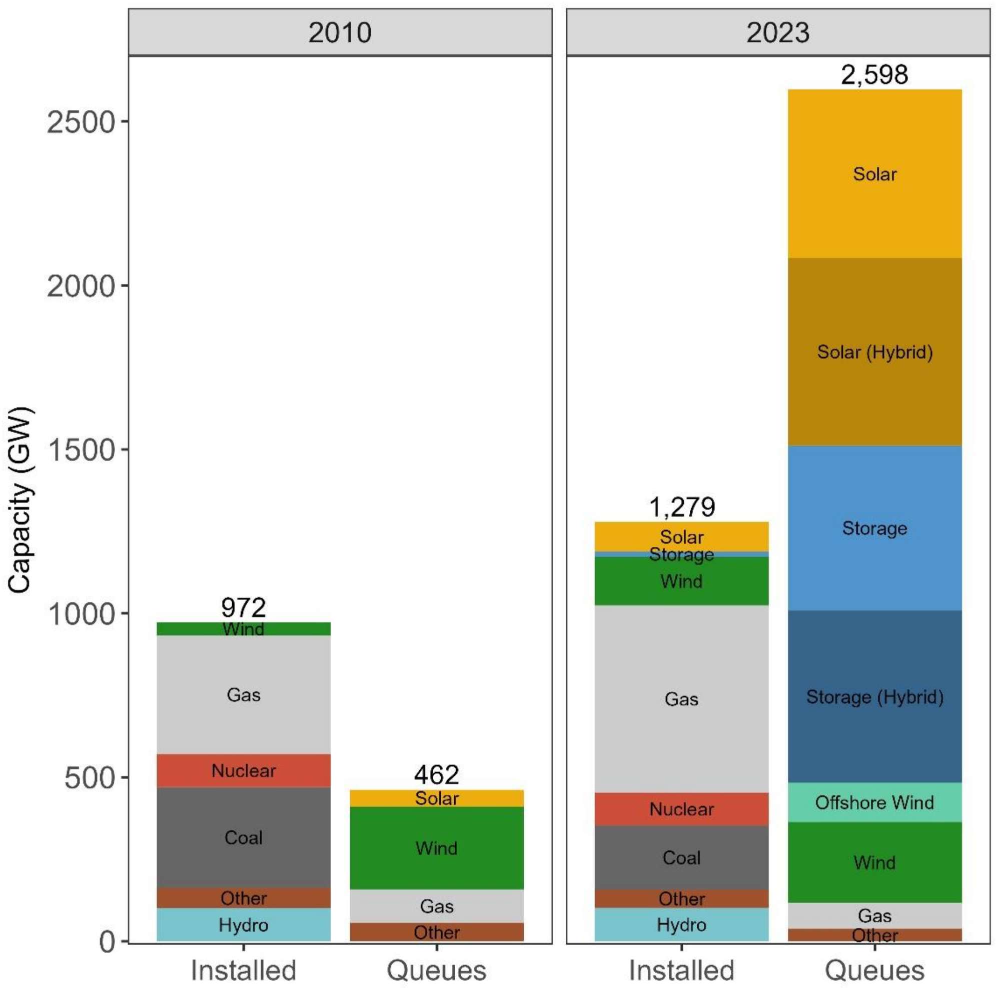
Active queue capacity is highest in the West (706 GW), followed by CAISO (523 GW). Several regions have delayed accepting or processing new requests due to backlogs



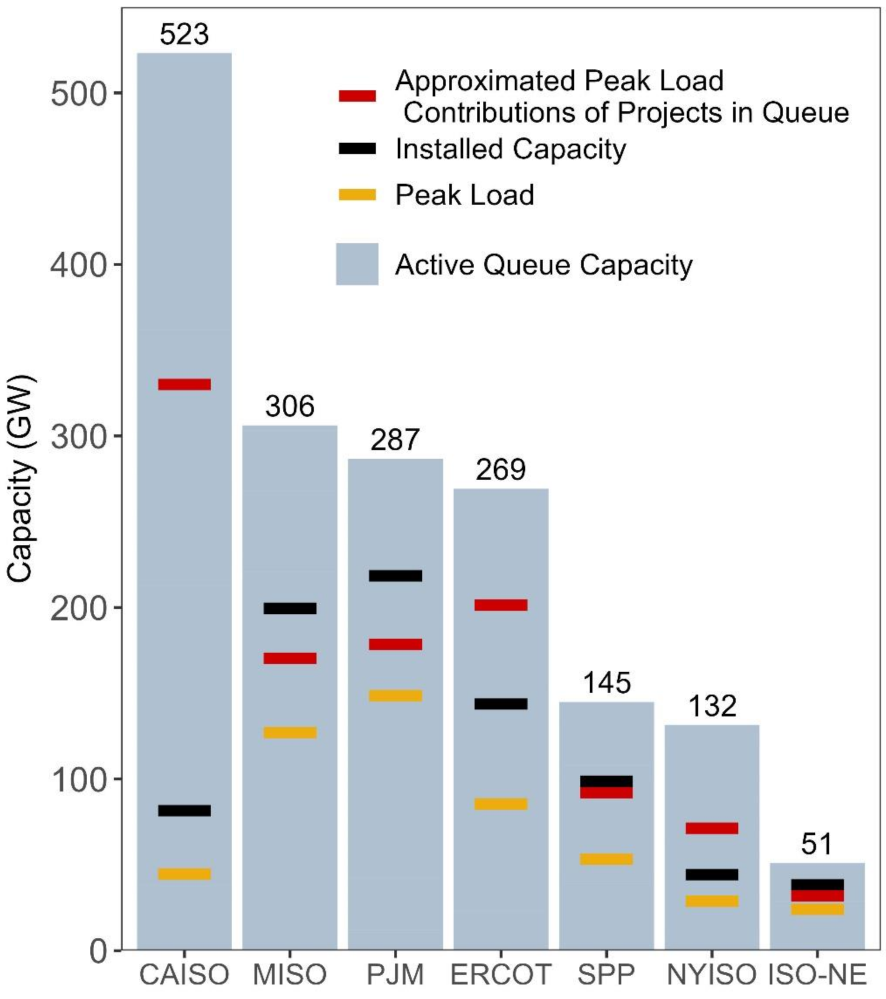
*Notes: (1) *Hybrid storage capacity is estimated for some projects using storage:generator ratios from projects that provide separate capacity data, and that value is only included starting in 2020. Storage duration is not provided in interconnection queue data. (2) **Wind capacity includes onshore and offshore for all years, but offshore is only broken out starting in 2020. (3) ***Other in this chart includes Coal, Nuclear, Hydro, Geothermal, and Other / Unknown. (4) Not all of this capacity will be built.*

Active capacity in queues (~2,600 GW) exceeds installed capacity of entire U.S. power plant fleet (~1,280 GW), as well as peak load and installed capacity in all ISO/RTOs

Entire U.S. Installed Capacity vs. Active Queues



RTO Installed Capacity & Peak Load vs. Active Queues

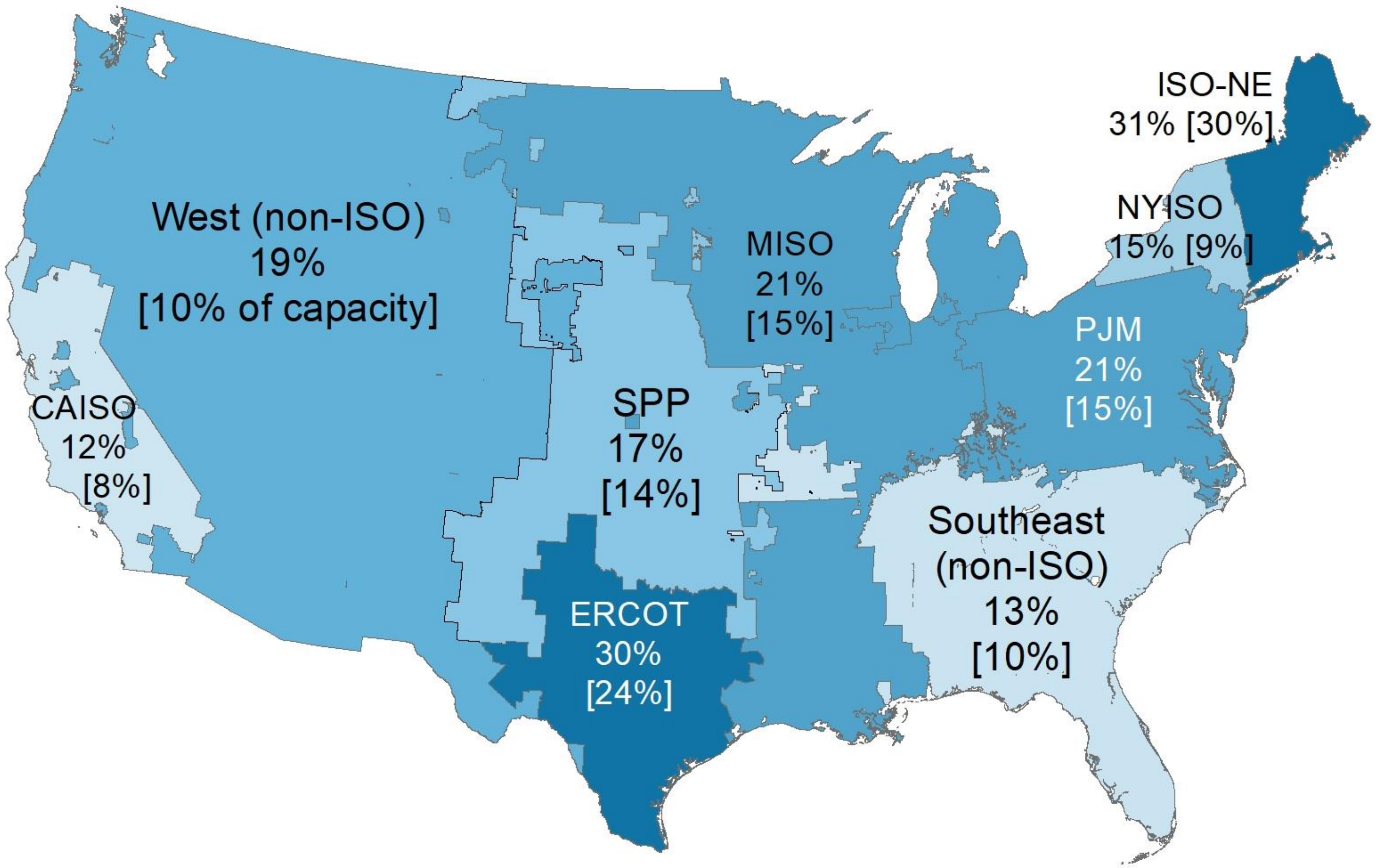


Comparisons of queue capacity to installed capacity or peak load should also consider generators' contributions to resource adequacy, for example their "effective load carrying capability" (ELCC). As variable resources, solar and wind contribute a smaller percentage of their nameplate capacity to resource adequacy compared to dispatchable generation like natural gas.

Decarbonizing the electric sector therefore requires higher levels of *installed* solar and wind capacity to achieve the same resource adequacy contributions. High levels of storage can offset this need to some degree. Electrification of buildings and transport will also result in load growth.

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.

Only 19% of projects that applied for interconnection prior to 2019 have been built – 72% have been withdrawn (8% are still actively trying!)



One consequence of high withdrawal rates is the need to restudy the projects that remain in the queue, increasing uncertainty in cost outcomes and further elongating the process

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.

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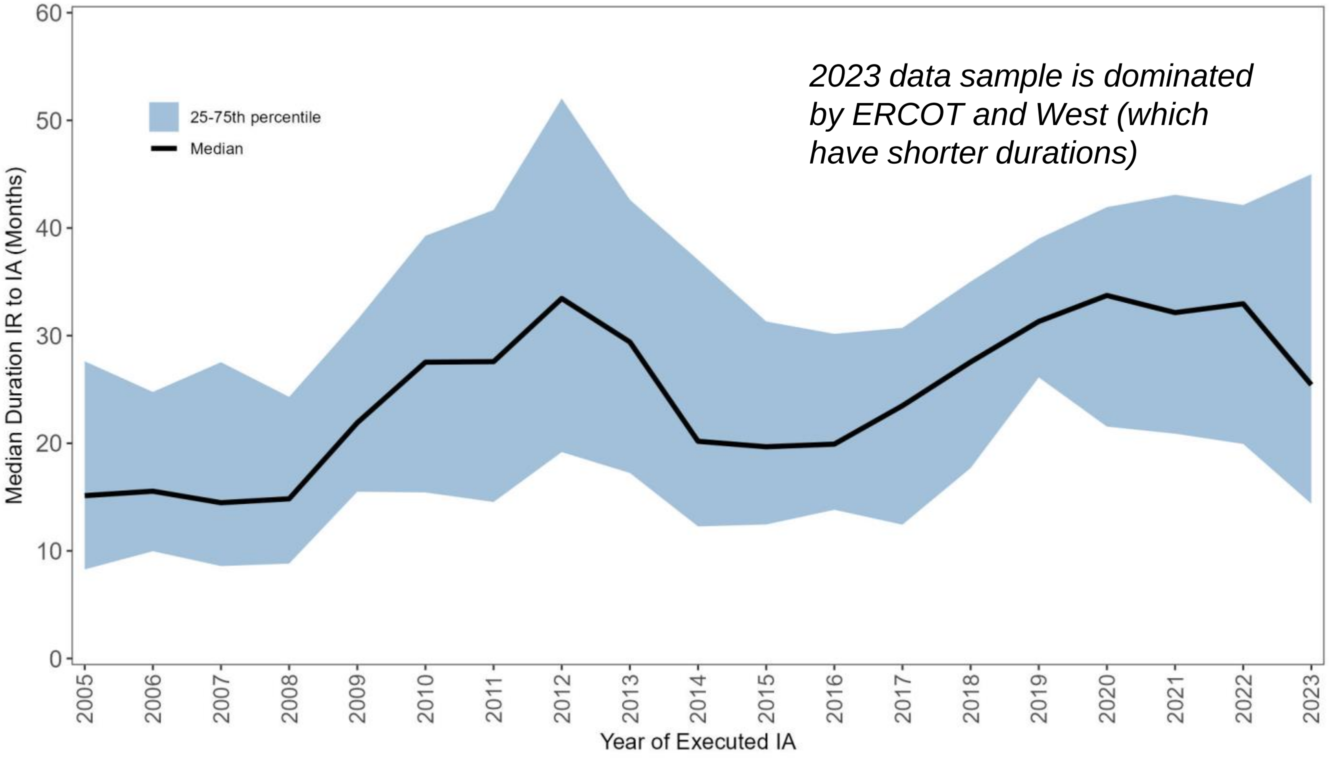
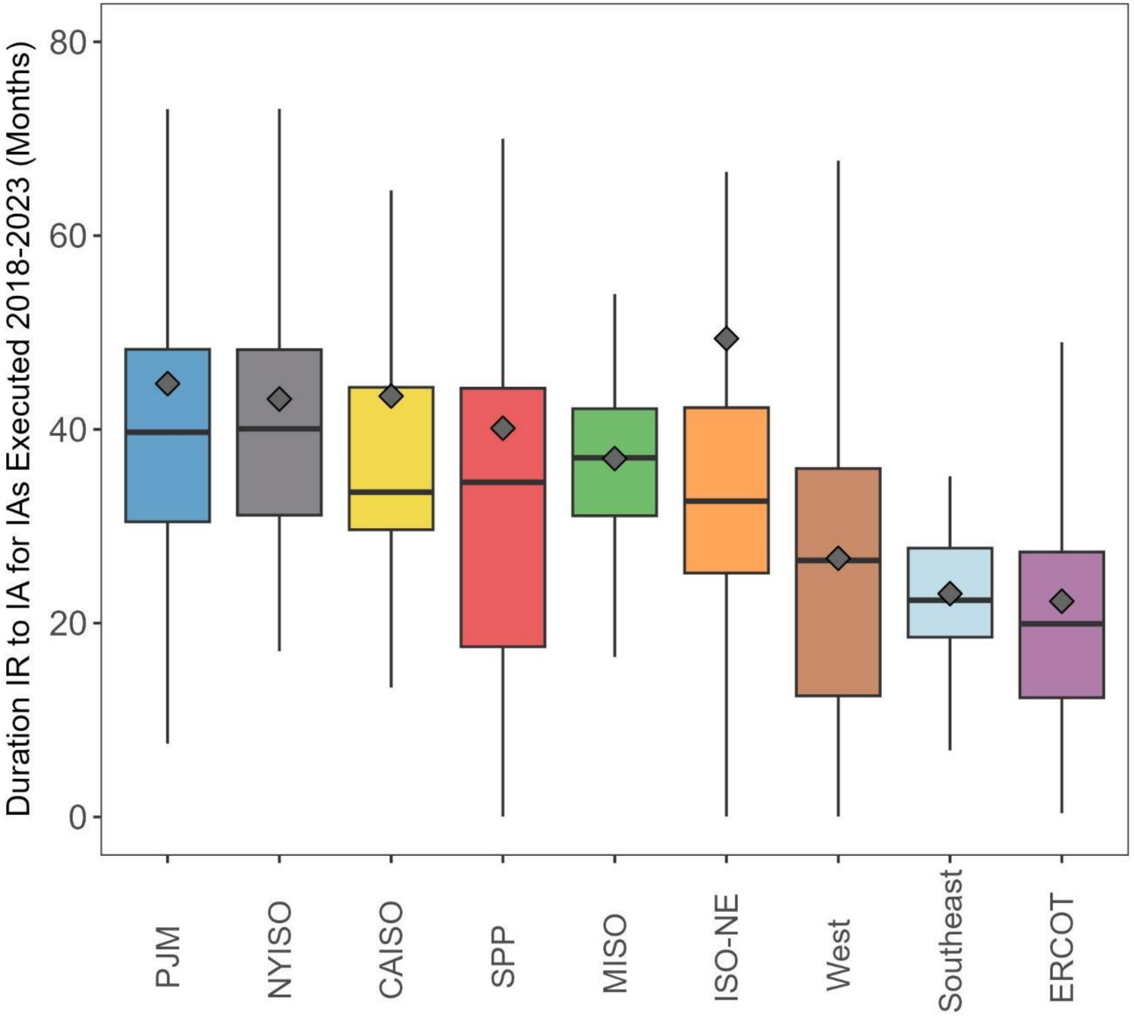
Evidence of a Problem #1: Increasing Interconnection Processing Timelines

Study duration is increasing in many regions, exceeding 3 years in PJM, SPP, NYISO, and MISO for IAs executed from 2018-2023; ERCOT and Southeast are notably faster

Duration Analyzed: | *Interconnection Request (IR)* → *Interconnection Agreement (IA)* → *Commercial Operations (COD)*



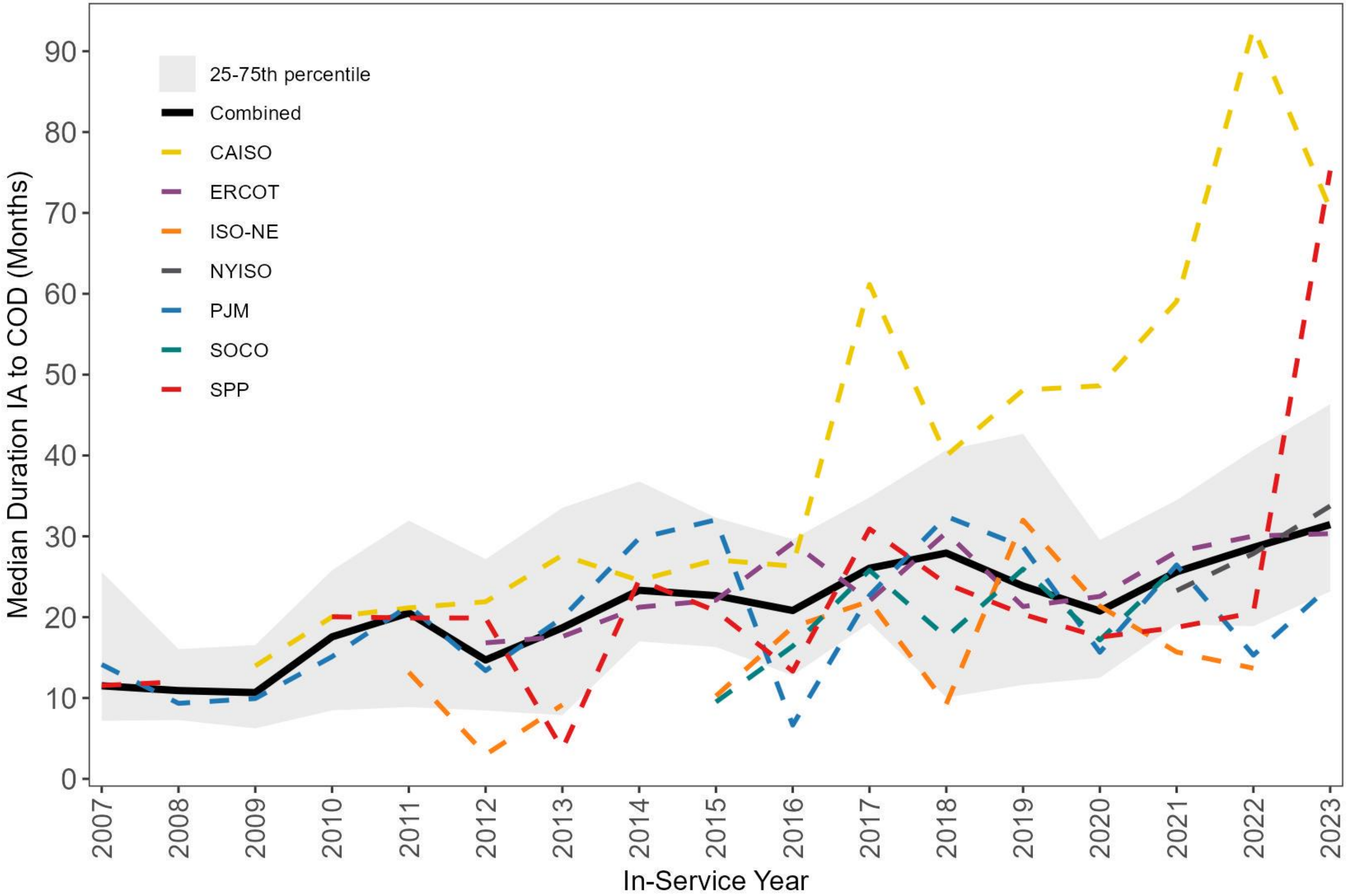
2023 data sample is dominated by ERCOT and West (which have shorter durations)



Notes: (1) Data are only shown where sample size is >2 for each region and year. (2) Not all data used in this analysis are publicly available. (3) "West" includes PacifiCorp, Public Service Co. of New Mexico, Idaho Power; "Southeast" includes Southern Company, Seminole Electric Cooperative.

Some delays are also evident *outside of the interconnection process*: procurement / offtake, local permitting, construction, supply chain, etc.

Duration Analyzed: | *Interconnection Request (IR)* → *Interconnection Agreement (IA)* → *Commercial Operations (COD)*



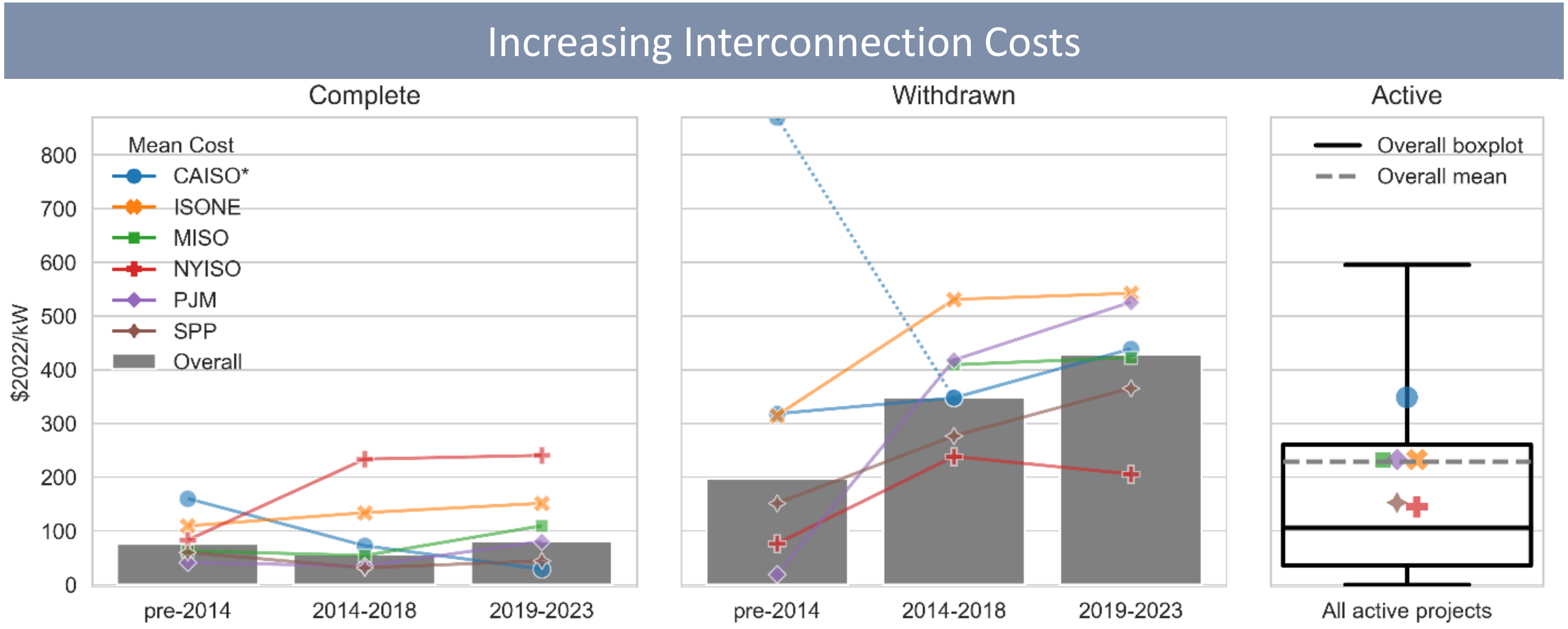
- Considering 836 projects across 6 entities, the typical IA to COD duration has increased modestly since 2007
- Permitting, supply chain, and procurement / offtake issues are an active area discussed around the industry
- Suggests that improvements in areas traditionally outside of the interconnection process are also needed

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.

Evidence of a Problem #2:
Increasing Cost to Connect

Interconnection costs have grown over time in all studied regions, suggesting increasing constraints on the U.S.'s transmission system

- Average interconnection costs have grown across regions and request types:
  - Often doubling for projects that have ***completed*** all studies
  - Projects that ***withdraw*** have the highest interconnection costs



Notes: reported costs reflect all transmission-owner-identified required upgrades, including upgrades at the point of interconnection and in the broader network, with the exception of CAISO values that do not include costs associated with the point of interconnection. The two CAISO withdrawn values in the pre-2014 period correspond to the exclusion (lower value) and inclusion (higher value) of projects that withdrew after phase 1 of cluster 5. CAISO's interconnection rules changed after the application window for cluster 5 closed, and the high cost and large number of withdrawals suggest that the set of proposed projects may have been different if the rules governing their interconnection studies were known in advance.

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A "wicked" problem: multifaceted drivers of interconnection backlogs

General sentiment: we are asking the queue process designed in 2003 to do too much. Reforms are needed, but also perhaps a fundamental re-thinking is required given clean energy transformation demanded.

Transmission expansion has been ***limited over the last decade, focused primarily on local reliability upgrades*** → Bulk grid not developing rapidly, leading to ***inadequate transmission*** and to high ***network upgrade costs assigned*** to generators in queue

Developers use queue requests for data collection given low information ***transparency, low entry cost, high network upgrade costs,*** and ***uncertain costs*** given serial nature and re-studies → Enormous ***increase in number and capacity*** of projects in queues, creating ***workflow and workforce challenges*** when relying on existing tools and administrative processes

Lack of ***standardization, inaccurate study data*** & assumptions, low consideration of ***grid-enhancing technologies***, generator technology changes, ***network cost assignment***, and late ***withdrawals*** → Multi-year ***queue delays*** leading to re-studies, ***reliability concerns, high generator-pays upgrade costs***, and frustrated stakeholders (developers and transmission operators alike)

A vicious cycle: the increasing number of requests increase delays and uncertainty, which further incentivizes developers to submit more requests

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The DOE's i2X Program Roadmap:
Opportunities for Reforms and Solutions

Many reform efforts are underway: FERC Order 2023 overhauled the interconnection process, and many RTOs have pending and proposed reforms.

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)***

Major ISO/RTO Reforms & Updates

MISO

- Increased milestone payments, adopted an automatic withdrawal penalty, and expanded site control requirements for interconnection facilities (*approved by FERC, January 2024*)
- Proposed a cap on total queue size (*rejected by FERC, January 2024*)

CAISO

- Interconnection Process Enhancements initiative proposed March 6, 2023
- Prioritize requests where transmission system has available existing or planned capacity and limit requests in a study area based on planed transmission capacity

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, November 2022*).

ERCOT

- Texas HB 1500 proposed an interconnection cost cap, will be an important PUC rulemaking to follow in the future

FERC Order 2023 - RM22-14-000. https://www.ferc.gov/media/e-1-order-2023-rm22-14-000

DOE’s Interconnection Innovation e-Xchange (i2X)

Mission: To enable a **simpler**, **faster**, and **fairer** interconnection of clean energy resources while enhancing the **reliability**, **resiliency**, and **security** of our **distribution** and **bulk-power electric grids**

Stakeholder Engagement

- Nation-wide engagement platform and collaborative exchanges
- Generate innovative solutions from discussion with utilities, grid operators, state/local governments, clean energy industry, non-profits

Data & Analytics

- Collect and analyze interconnection data to inform solutions development
- Increase transparency of interconnection process

Strategic Roadmap

- Create roadmap to inform interconnection process improvements
- Identify both near- and long-term opportunities and solutions

Technical Assistance

- Leverage DOE laboratory expertise to directly support stakeholders
- Focus on requests targeting key problems identified in roadmap

Focus today

Context and Frame of the Roadmap

Context and Scope of Roadmap

The Need for Reform

Rapid rise of interconnection requests and expectation that these levels will remain in future due to load growth, plant retirements, and government policy.

Connection to Ongoing FERC Initiatives

Solutions in the roadmap are intended to complement and support Order 2023. Want to provide comprehensive platform for industry-wide collaboration and longer-term process evolution.

Interrelationship of Solutions

Some of the solutions are complementary: to be effective, they would need to be implemented in tandem with other solutions.

Other solutions are exclusive: adopting one solution might obviate the need for or even preclude another.

Roadmap does not assess the cost of implementing the solutions.

Key Roadmap Components

Measurable success targets

Solutions and implementation time frames:

- *Short-term:* within 1-3 years (by 2027)
- *Medium-term:* 3-5 years (by 2029)
- *Long-term:* beyond 5 years (2030 and after)

Solution actors:

- Transmission providers (Utilities, ISOs, BAs)
- Regulators (FERC/NERC, State PUCs)
- Interconnection customers
- Consumer Groups
- Research community (including DOE)
- OEM and software vendors
- State, local, tribal governments
- Equity and public benefit organizations

DOE plays multiple roles: convening stakeholders, facilitating solution adoption, providing technical assistance, supporting the research community, and can also become a solution provider.

The Roadmap is Organized Around Four Interconnection Goals

Goal #1: Increase Data Access and Transparency

- Highlight improvements that ***go beyond*** FERC Order 845 and 2023 to improve decision making
- Facilitate screening, optimal siting, and ***automation***
- Enhance equitable outcomes by ***enabling benchmarking, tracking, and auditing*** of processes and reform performance

Goal #2: Improve Process and Timeline

- Backlogs and delays result of ***rapid growth in requests*** and ineffective management
- Balance tradeoff between ***quantity of projects and maintaining competition***
- Provide ***interconnection opportunities*** for all

Key focus areas
- Queue Management
- Affected System Studies
- Inclusive and fair process
- Workforce Development

Goal #3: Promote Economic Efficiency

- Acknowledge that ***interconnection and transmission planning*** are closely related
- Focus on both ***allocative efficiency*** ('who pays') and ***productive efficiency*** ('minimizing costs')

Key focus areas
- Cost Allocation
- Planning Coordination
- Interconnection Studies

Goal #4: Maintain a Reliable, Resilient, and Secure Grid

- In recent years, there has been ***a series of disturbance events*** leading to IBR disconnection
- Foundation to manage ***high penetration rates of IBRs*** and minimize disturbances

Key focus areas
- Interconnection Models and Tools
- Interconnection Standards

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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In Total, There are 35 Solutions Identified in the Roadmap

(Select) Solutions for Goal #2

Queue Management

2.5 Create new and expand ***fast-track options*** for interconnection (e.g. surplus, generator replacement, energy-only)

2.6 Consider ***market-based approaches*** to rationing interconnection access

Affected System Studies

2.7 Increase ***voluntary collaboration on affected system studies***

Inclusive and Fair Process

2.10 Incorporate ***equity goals in transmission planning*** and valuation

Workforce Development

2.11 Assess scale of ***interconnection workforce growth requirements***

(Select) Solutions for Goal #3

Cost Allocation

3.2 Ensure that generators have option to be ***re-dispatched rather than paying for network*** upgrades (energy-only)

Planning Coordination

3.4 More closely ***align interconnection and transmission planning*** processes

Interconnection Studies

3.6 Continue to develop ***new best practice study methods***, and harmonize methods to adapt to a changing generation mix

3.7 Explore options for generator self-funding of their ***own interconnection studies***

(Select) Solutions for Goal #4

Models and Tools

4.1 Require submission ***of verified EMT models*** for all IBRs, and develop ***screening criteria*** to determine when EMT studies are necessary within a region

4.4 Advance ***computational speed*** of interconnection reliability assessments

Interconnection Standards

4.5 Adopt comprehensive set of generation interconnection requirements consistent with ***IEEE Standard 2800-2022***

4.8 Evaluate **cybersecurity concerns** during the interconnection process

Contact:

Will Gorman (wgorman@lbl.gov)

More Information:

- Visit https://www.energy.gov/eere/i2x to learn about and participate in the DOE's i2X program
- Visit https://emp.lbl.gov/queues interconnection queue analysis and data
- Visit https://emp.lbl.gov/interconnection_costs for research on generator interconnection costs

Acknowledgements:

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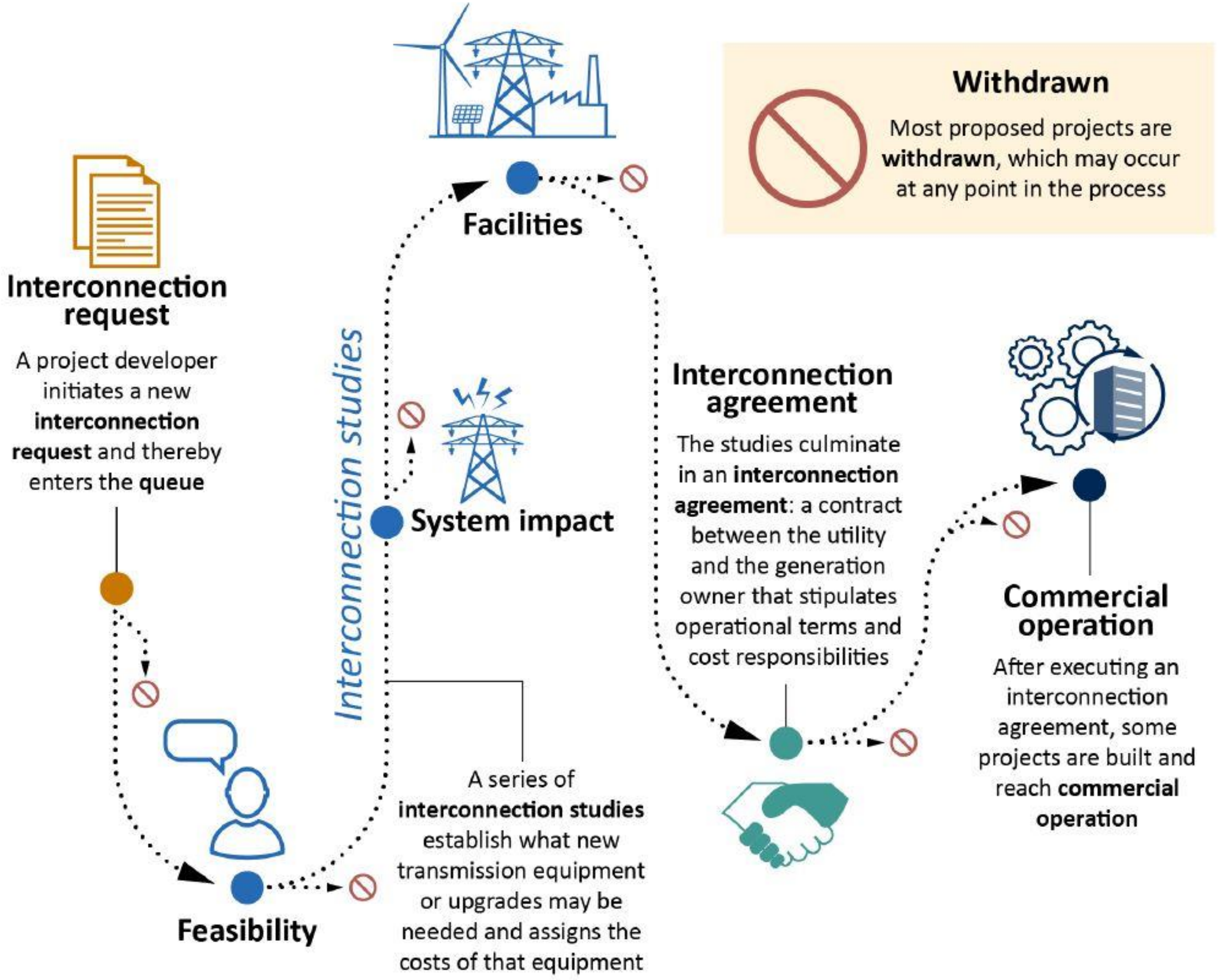
Appendix Slides

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

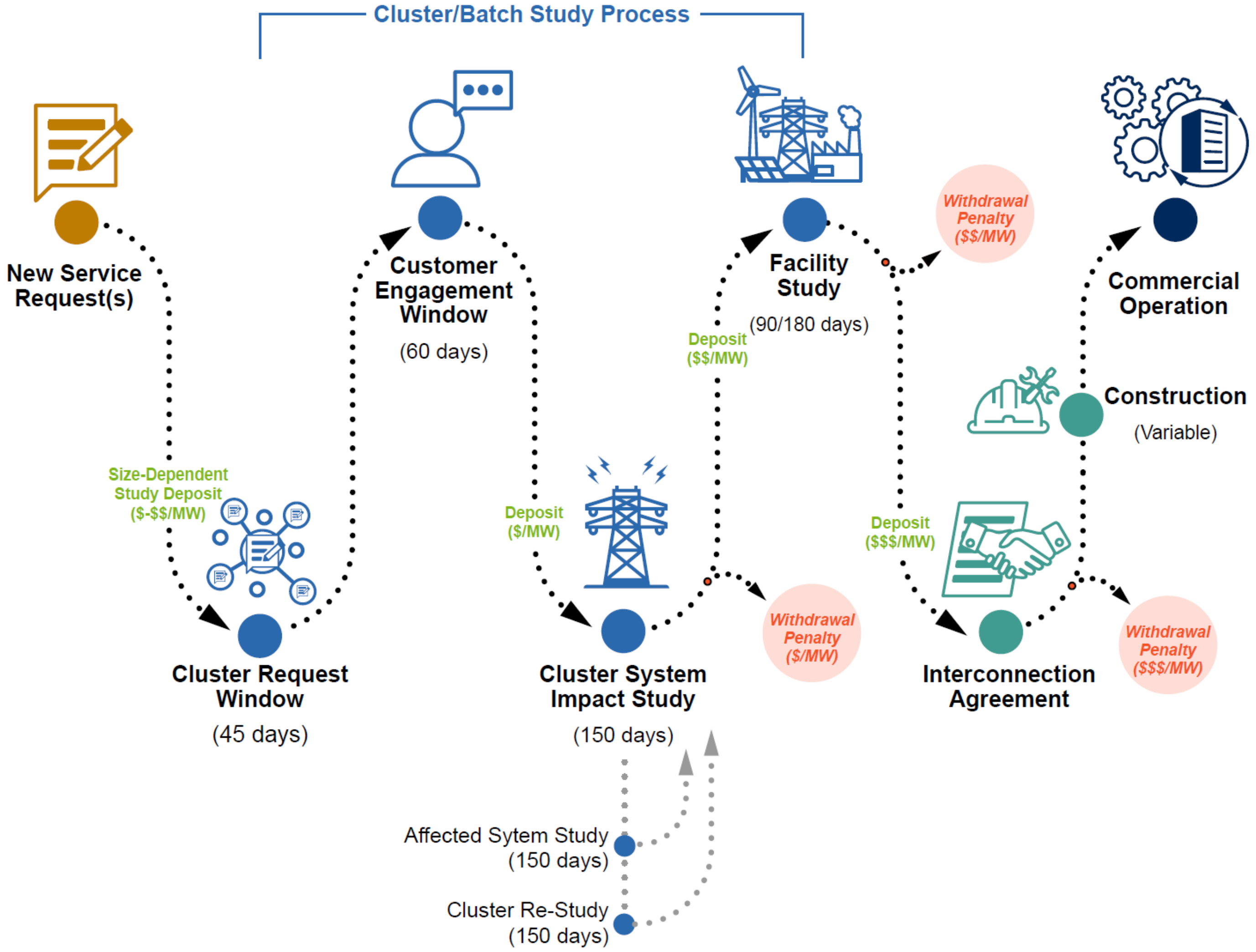


Source: Derived from image courtesy of Lawrence Berkeley National Laboratory and used with permission. | GAO-23-105583

- Transmission grid operators require new projects looking to connect to the grid to undergo a series of impact studies
- These studies determine the grid upgrades necessary to allow projects to connect safely and reliably, and allocate the cost of those upgrades
- Withdrawals can result in multiple re-studies: a vicious cycle of delays, backlogs, & higher costs

New Interconnection Study Process and Timeline Post FERC order 2023

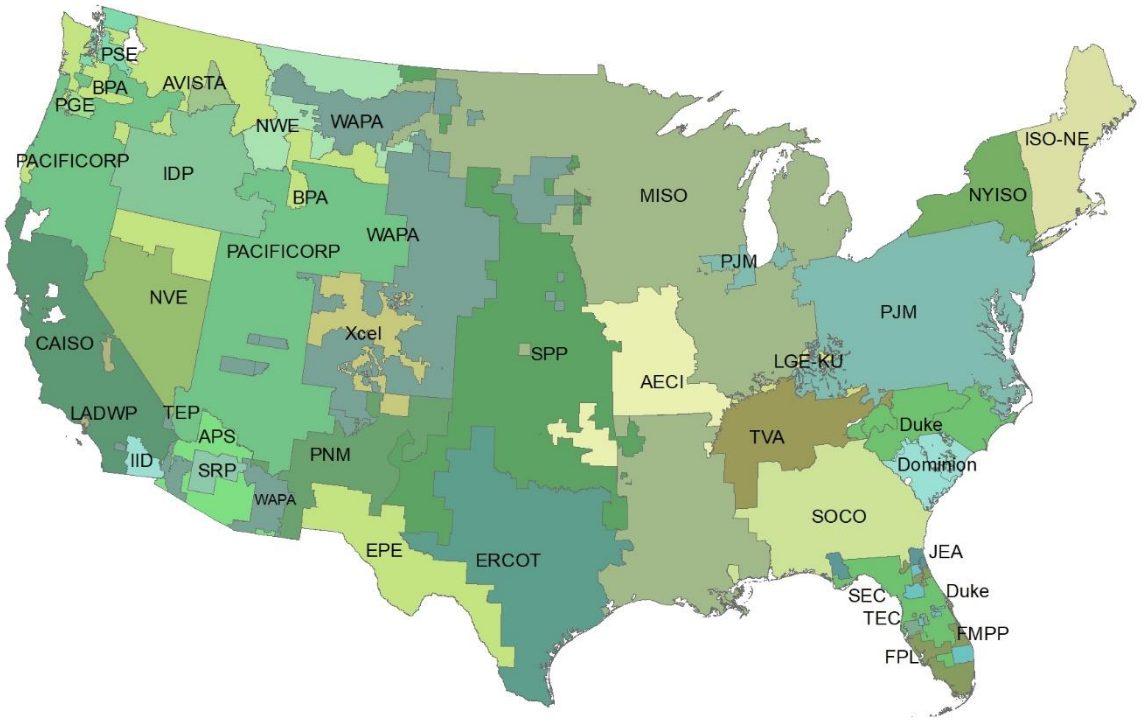
- A project developer initiates a new ***interconnection request (IR)*** and thereby enters the ***queue***
- A series of ***interconnection studies*** establish what new transmission equipment or upgrades may be needed and assigns the costs of that equipment
- The studies culminate in an ***interconnection 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) approved open-access transmission tariffs and generator interconnection procedures as outlined in FERC Order 2023.

Data Sources

- Data collected from interconnection queues for 7 ISOs / RTOs and 44 non-ISO balancing areas (including utilities and Power Marketing Administrations), which collectively represent >95% of currently installed U.S. electric generating capacity
  - Includes projects that connect to the transmission system, not distribution-connected or behind-the-meter
  - Includes projects in queues through the end of 2023
  - Substantial data cleaning, standardization, and QA/QC conducted by Berkeley Lab analyst team
  - The full sample includes:
    - 4,155 “operational” projects (~470.4 GW)
    - 11,841 “active” projects (~2,598 GW)
    - 325 “suspended” projects (~54.9 GW)
    - 18,372 “withdrawn” projects (~3,097 GW)



Coverage area of entities for which data was collected
Data source: Homeland Infrastructure Foundation-Level Data (HIFLD)
Note that service areas can overlap
No data collected for Hawaii or Alaska

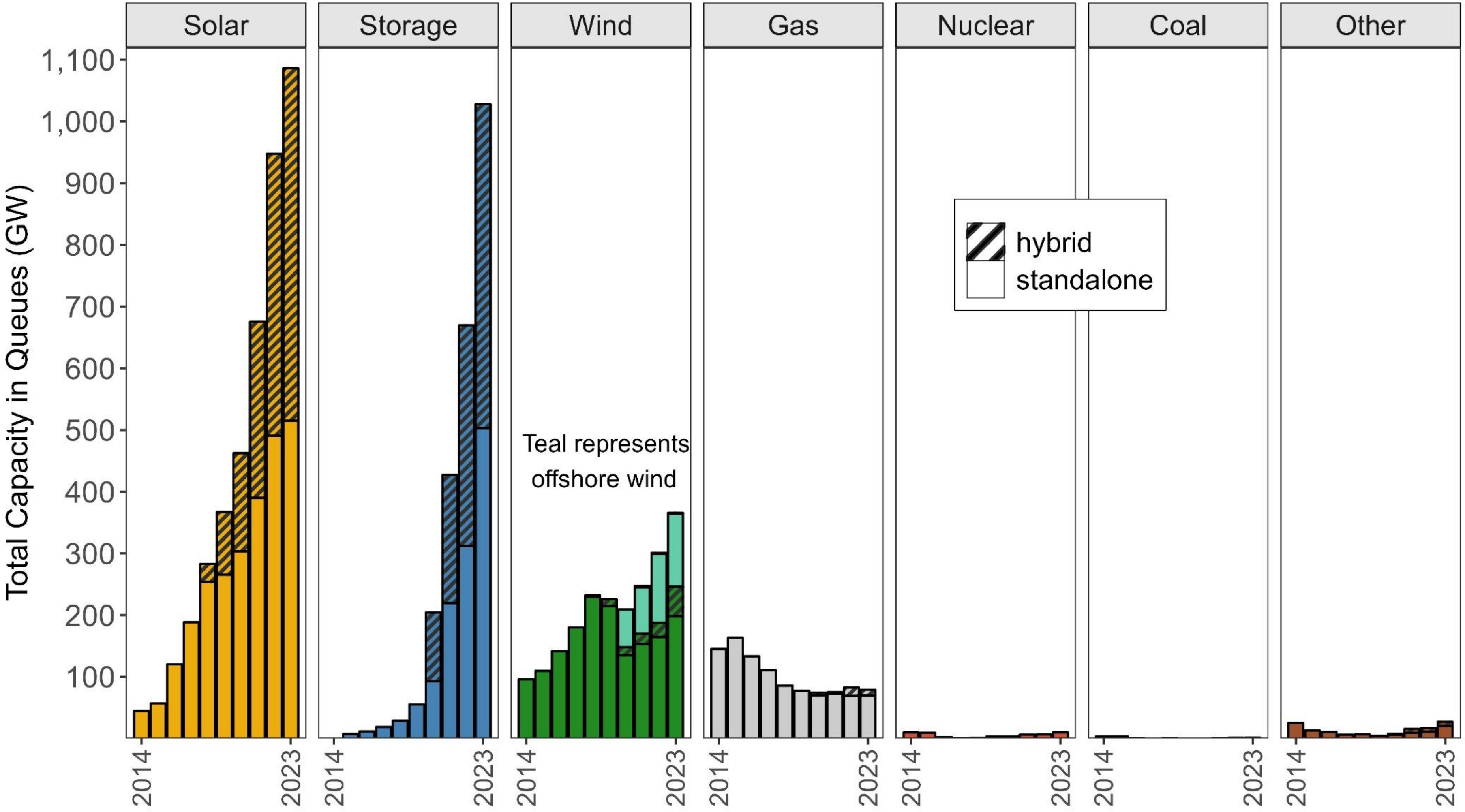
A full list of included balancing areas can be found in the Appendix

Balancing Areas Included In Data:

ISO/RTOs	Southeast (non-ISO)	
CAISO	Associated Electric Coop.	Georgia Transmission Corp.
ERCOT	Dominion	Jacksonville Electric Authority
ISO-NE	Duke Carolinas	LG&E & KU Energy
MISO	Duke Florida	Santee Cooper
NYISO	Duke Progress	Seminole Electric Coop.
PJM	Duke/Progress	Southern Company
SPP	Florida Municipal Power Pool	Tampa Electric Co.
	Florida Power & Light	Tennessee Valley Authority

West (non-ISO)		
Arizona Public Service	Imperial Irrigation District	Public Service Co. of CO
Avista	L.A. Dept. Water & Power	Public Service Co. of NM
Black Hills Colorado	Navajo-Crystal	Puget Sound Energy
Bonneville Power Admin.	NorthWestern	Salt River Projects (4 entities)
Cheyenne Light Fuel & Power	NV Energy	Tri-State G&T
El Paso Electric	PacifiCorp	Tucson Electric Power
Grant PUD	Platte River Power Authority	WAPA (4 regions)
Idaho Power	Portland General Electric	

Solar (1,086 GW) , Storage (1,028 GW), and Wind (366 GW) make up 95% of active capacity in queues, with 3% (79 GW) from Gas. Most solar and storage capacity is in hybrid plants

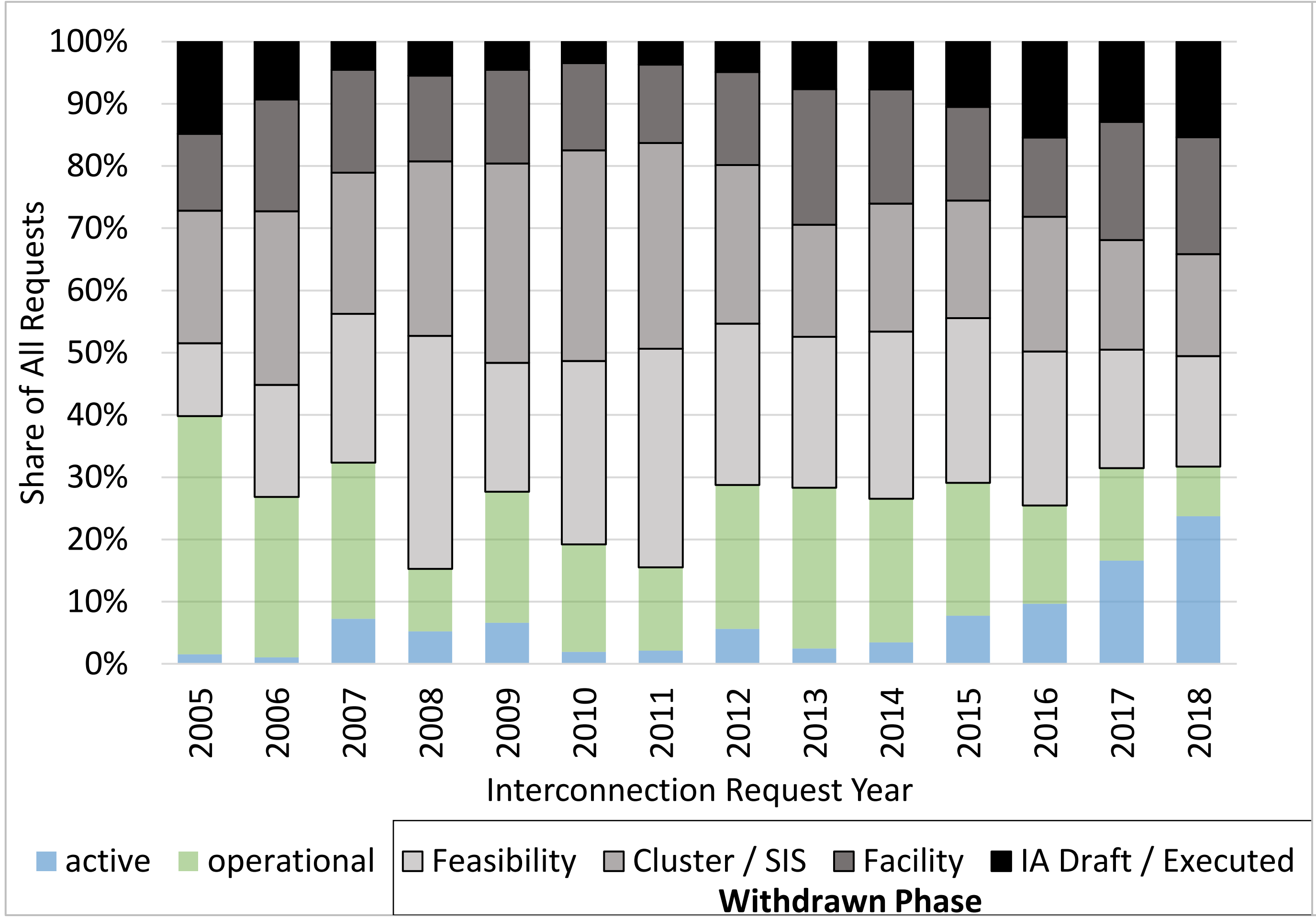


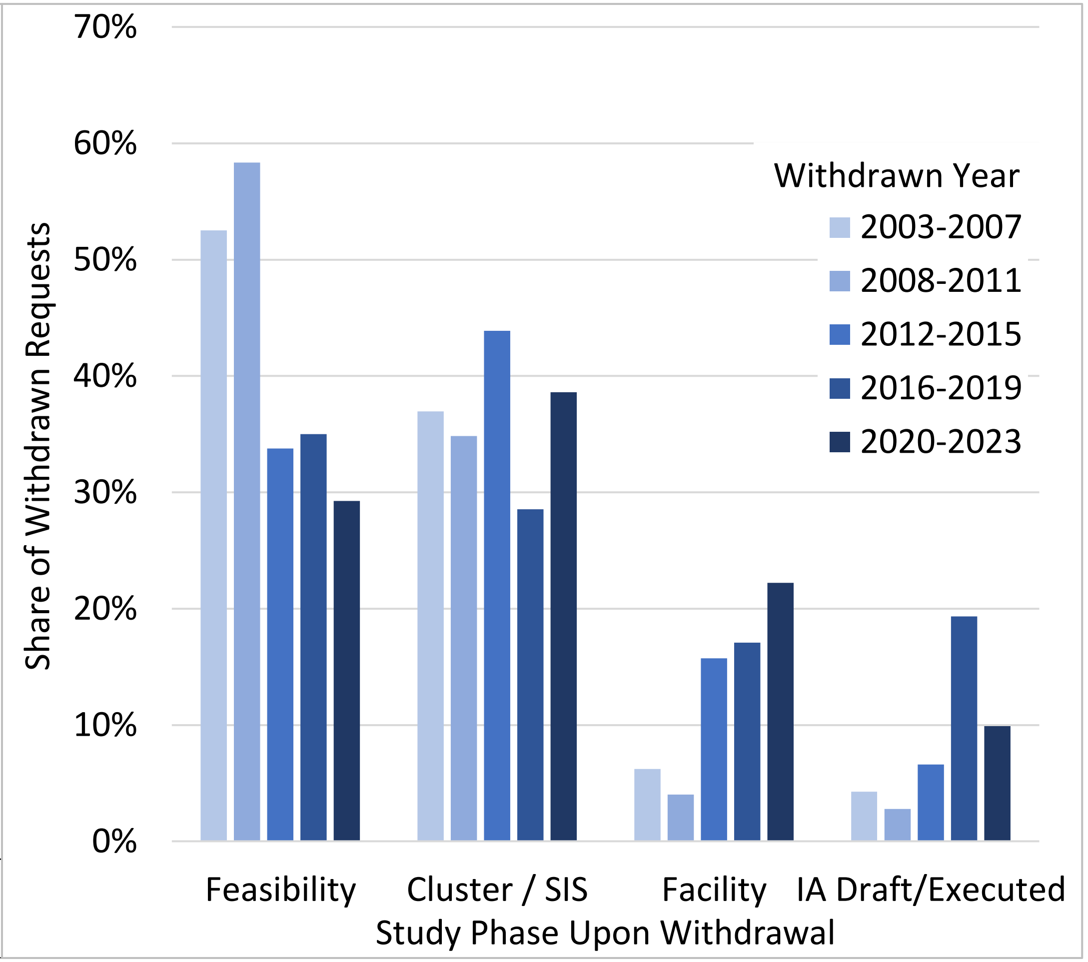
- “**Wind**” includes both onshore and offshore.
- “**Other**” includes
  - Hydropower
  - Geothermal
  - Biomass/biofuel
  - Landfill gas
  - Solar thermal
  - Oil/diesel
- “**Storage**” is primarily (99%) battery, but also includes pumped storage hydro, compressed air, gravity rail, and hydrogen.

See https://emp.lbl.gov/queues to access an interactive data visualization tool.

Notes: (1) Hybrid storage capacity is estimated for some projects using storage:generator ratios from projects that provide separate capacity data, and that value is only included starting in 2020. Storage duration is not provided in interconnection queue data. (2) Wind capacity includes onshore and offshore for all years, but offshore is only broken out starting in 2020. (3) Hybrid generation capacity is included in all applicable generator categories. (4) Not all of this capacity will be built.

Most withdrawals occur in earlier study phases (e.g., Feasibility or System Impact Study), but later-stage withdrawals (Facility or IA phase) may be increasing

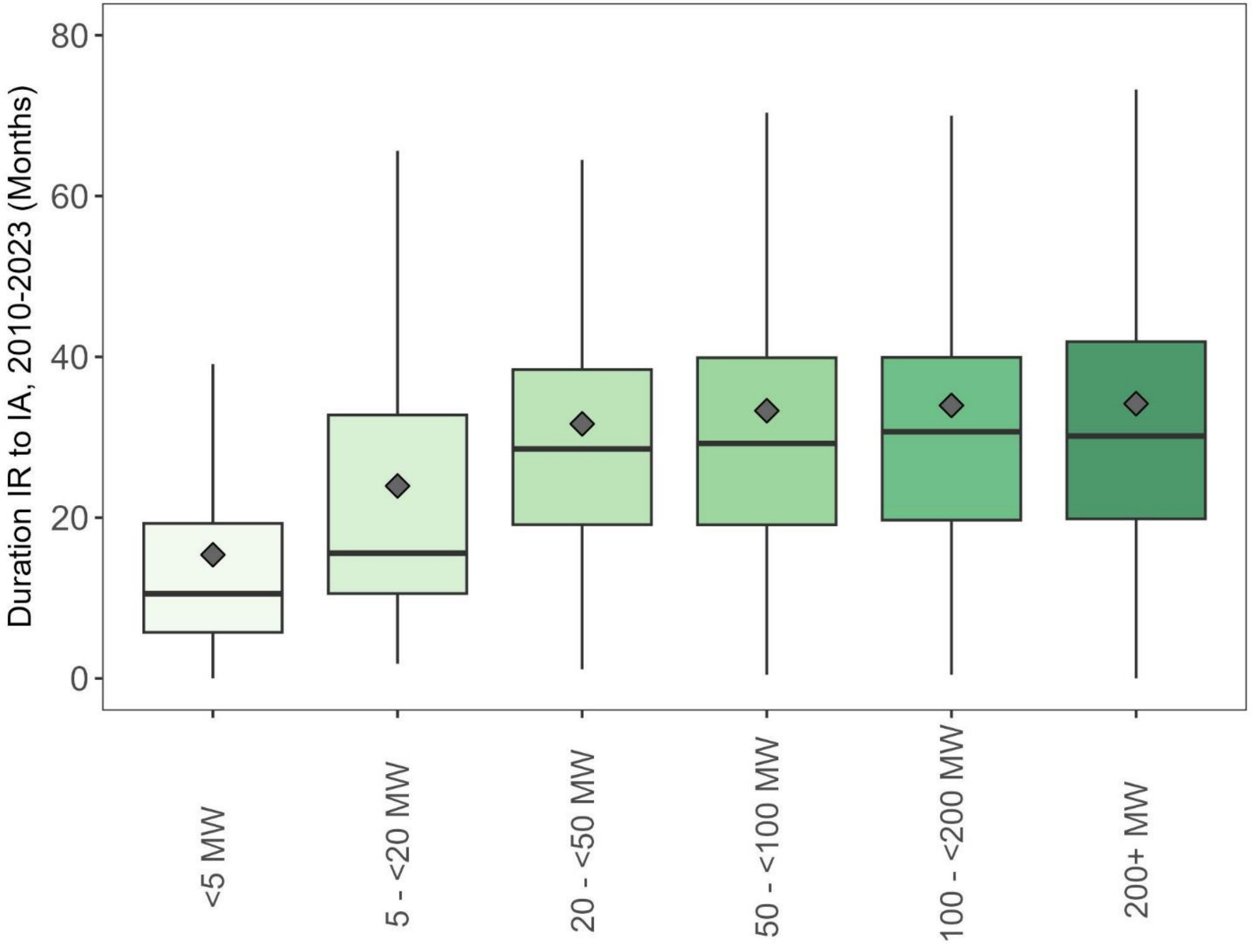




Late-stage withdrawals can be more costly for developers (sunk costs, deposits) and can trigger re-studies for other projects in the queue, increasing delays.

Note: Only includes data for entities that provide study phase for withdrawn projects and comprehensive status information (4 ISOs and 10 non-ISO balancing areas).

There is a clear step change in IR to IA duration between “small” (<20 MW) and “large” (>20 MW) generator interconnection procedures

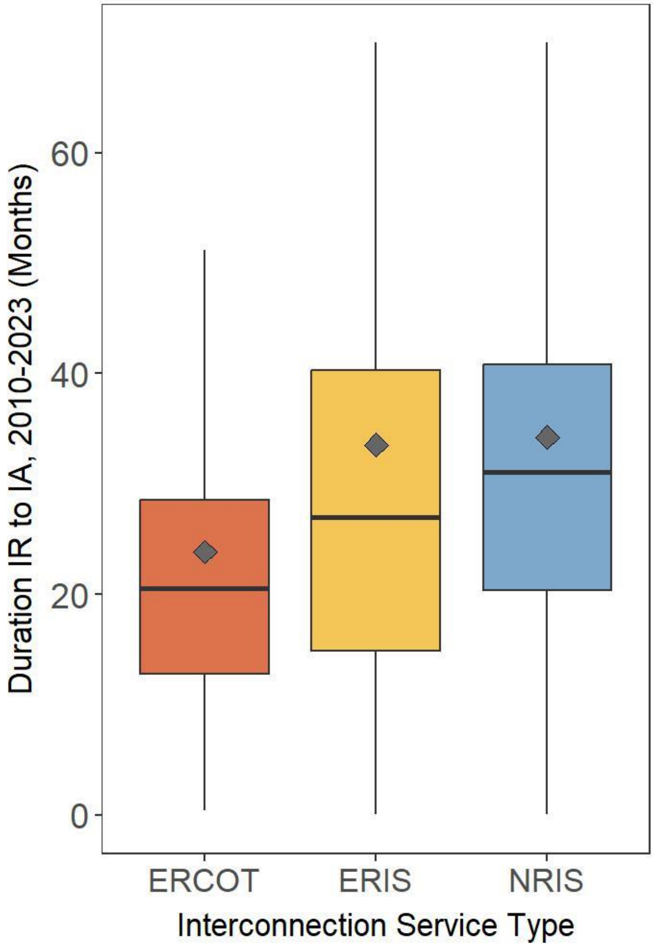


- On average, projects with rated capacity <20 MW complete studies and execute interconnection agreements much faster than larger projects
  - Median is 11 months for projects <5 MW
  - 18 months for projects 5 - <20 MW
- The median duration for projects 20 MW or larger hovers around 30 months across the four larger project groups analyzed
- 20 MW is the threshold between the FERC “large” and “small” generator interconnection procedures (LGIP / SGIP)
  - The median LGIP duration is twice the median SGIP duration for projects in our sample

Notes: (1) Sample includes 3,864 projects from 7 ISO/RTOs and 5 non-ISO balancing areas with executed interconnection agreements since 2005. (2) Not all data used in this analysis are publicly available.

Energy Resource Interconnection Service (ERIS) requests are not significantly faster to process than Network Resource Interconnection Service (NRIS) requests, though ERCOT requests are

Duration Analyzed: | *Interconnection Request (IR)* → *Interconnection Agreement (IA)* → *Commercial Operations (COD)*

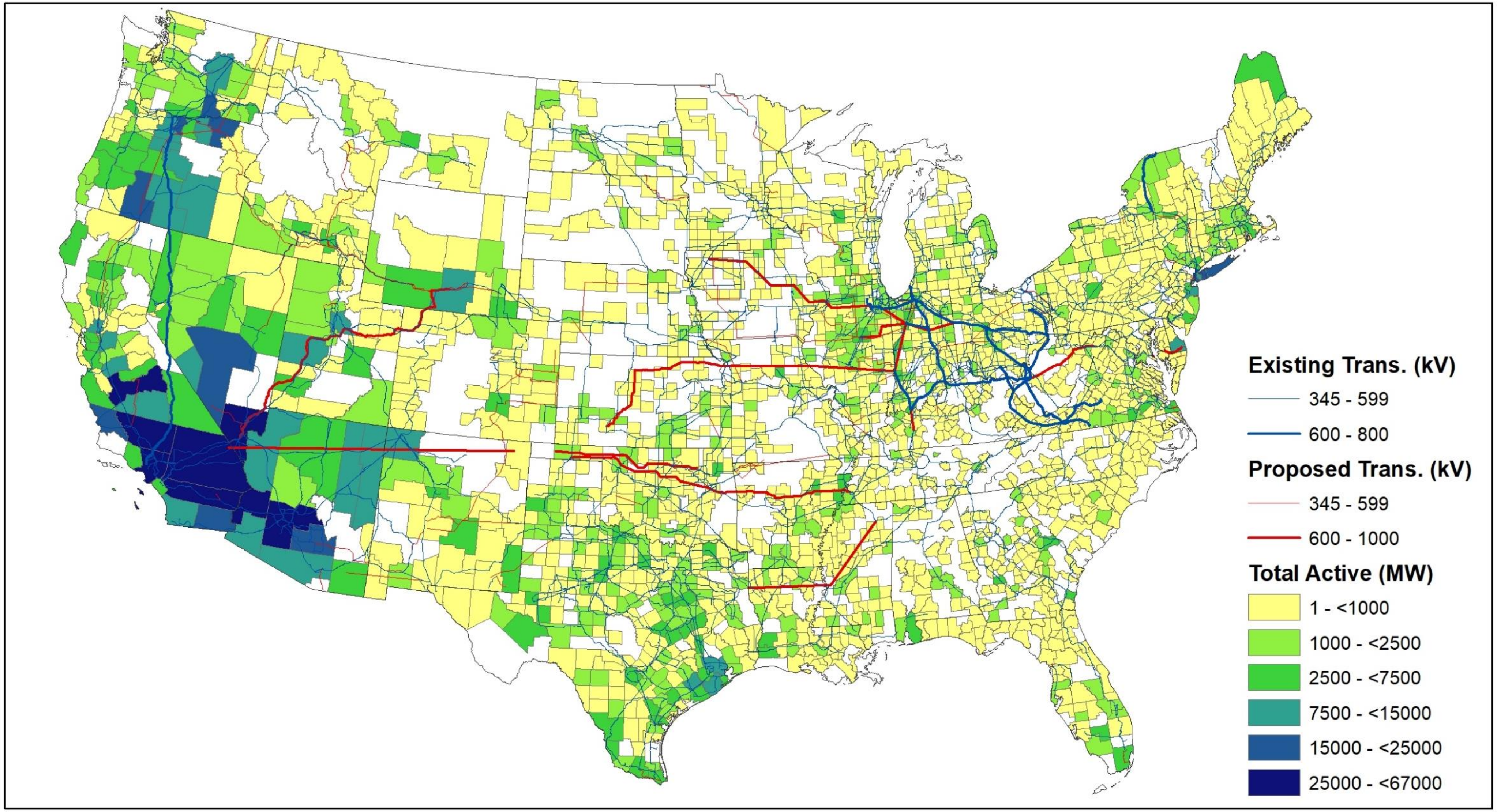


The mean IR-IA duration for ERIS requests submitted since 2010 (33.5 months) is not significantly shorter than that for NRIS requests (~34.2 months) ($p = 0.27$).

ERCOT – which is not FERC jurisdictional – utilizes a 'connect and manage' approach, which is similar to ERIS. But ERCOT requests are processed faster on average (~23.8 months) than ERIS requests in other regions since 2010 ($p < 0.001$).

Notes: (1) Sample includes 3,536 projects from 6 ISO/RTOs and 4 non-ISO balancing areas with executed interconnection agreements since 2005 that also provided service type information (2,894 since 2010). (2) Not all data used in this analysis are publicly available.

Total active capacity in queues: by county



Notes: (1) Includes "active" interconnection requests only. (2) County was missing or could not be determined for 6% of all active requests. (3) Transmission line data from Hitachi Velocity Suite. (4) See https://emp.lbl.gov/queues to access an interactive data visualization of these maps