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Queued Up: 2024 Edition

Characteristics of Power Plants Seeking Transmission Interconnection As of the End of 2023

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Lawrence Berkeley National Laboratory

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PLEASE NOTE:
- All participants will be muted during the webinar
- Please submit questions via the Q&A window
- The webinar is being recorded, and both that recording and the slides will be shared on our website and via email after today's presentation

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INTERCONNECTION INNOVATION e-XCHANGE
U.S. DEPARTMENT OF ENERGY

Berkeley Lab Team Introduction

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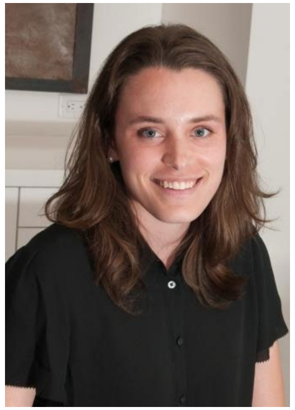

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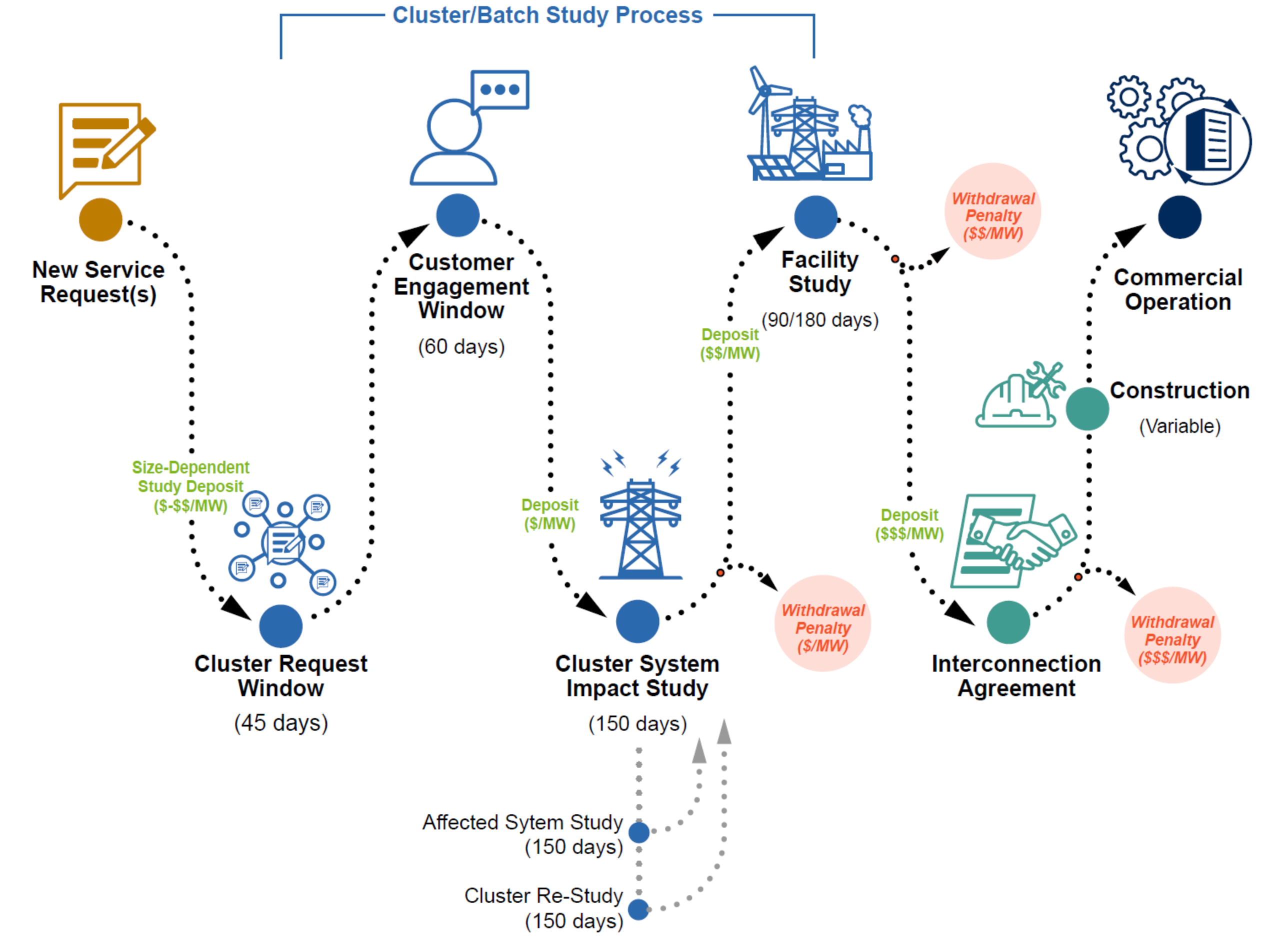
Background: Interconnection Queues and Typical Interconnection Process

What are interconnection queues?

Utilities and regional grid operators (a.k.a., ISOs or RTOs) require projects seeking to connect to the grid to undergo a series of studies before they can be built. This process establishes what new grid system upgrades may be needed before a project can connect to the system and then estimates and assigns the costs of that equipment. The lists of projects that have applied to connect to the grid and initiated this study process are known as “interconnection queues”

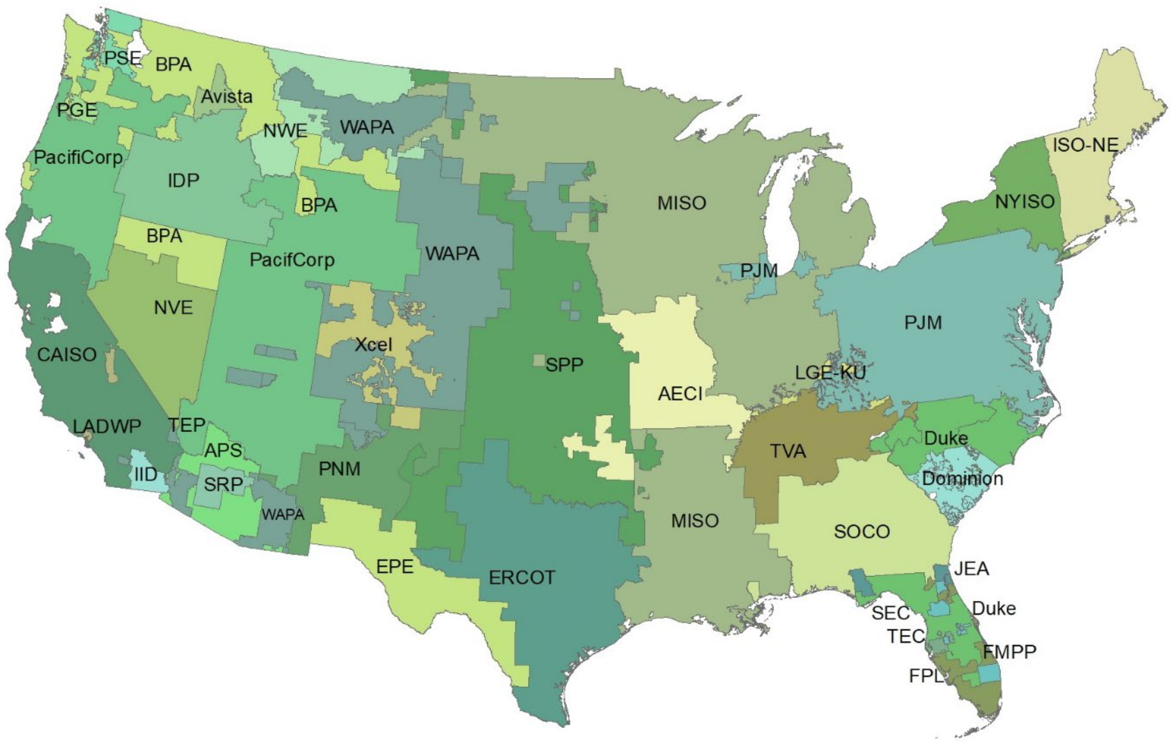


Visit https://emp.lbl.gov/queues to access related resources including the complete dataset used for this analysis and interactive data visualization tools

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.

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 bulk-power system, not distribution-connected or behind-the-meter[1]
  - 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)
    - 11,597 “active” projects (~2,598 GW)
    - 325 “suspended” projects (~54.9 GW)
    - 17,873 “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

1. There are different processes for transmission- and distribution-system interconnection. This report only covers transmission interconnection.

FERC Order 2023 overhauled the interconnection process, and many RTOs have pending and proposed 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)***

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*)
- Did not accept any new requests in 2023 due to pending reforms

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
- Require power purchase agreements to proceed to Phase II studies
- Proposed to delay Cluster 16 request application window from April 2024 (new date TBD) due to queue volume and pending reforms

PJM

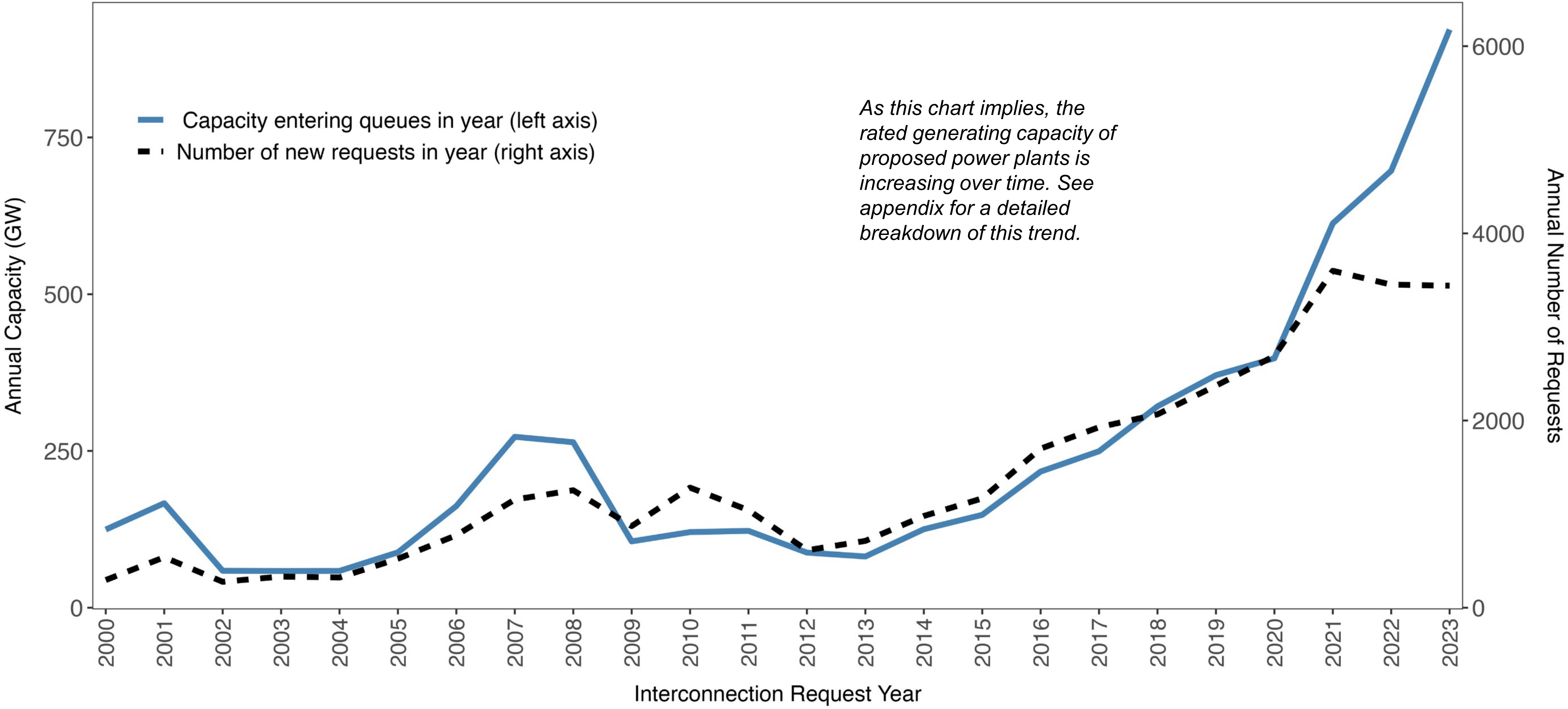
- Implemented transition from serial first-come, first-served queue process to a first-ready, first-served clustered cycle approach, grouping projects into three-phase cluster cycles for studying and allocating interconnection costs (*approved by FERC, November 2022*).
- Will not review new requests until early 2026 as it processes backlog

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

Annual interconnection requests have surged since 2013 (both in terms of number and capacity); 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.

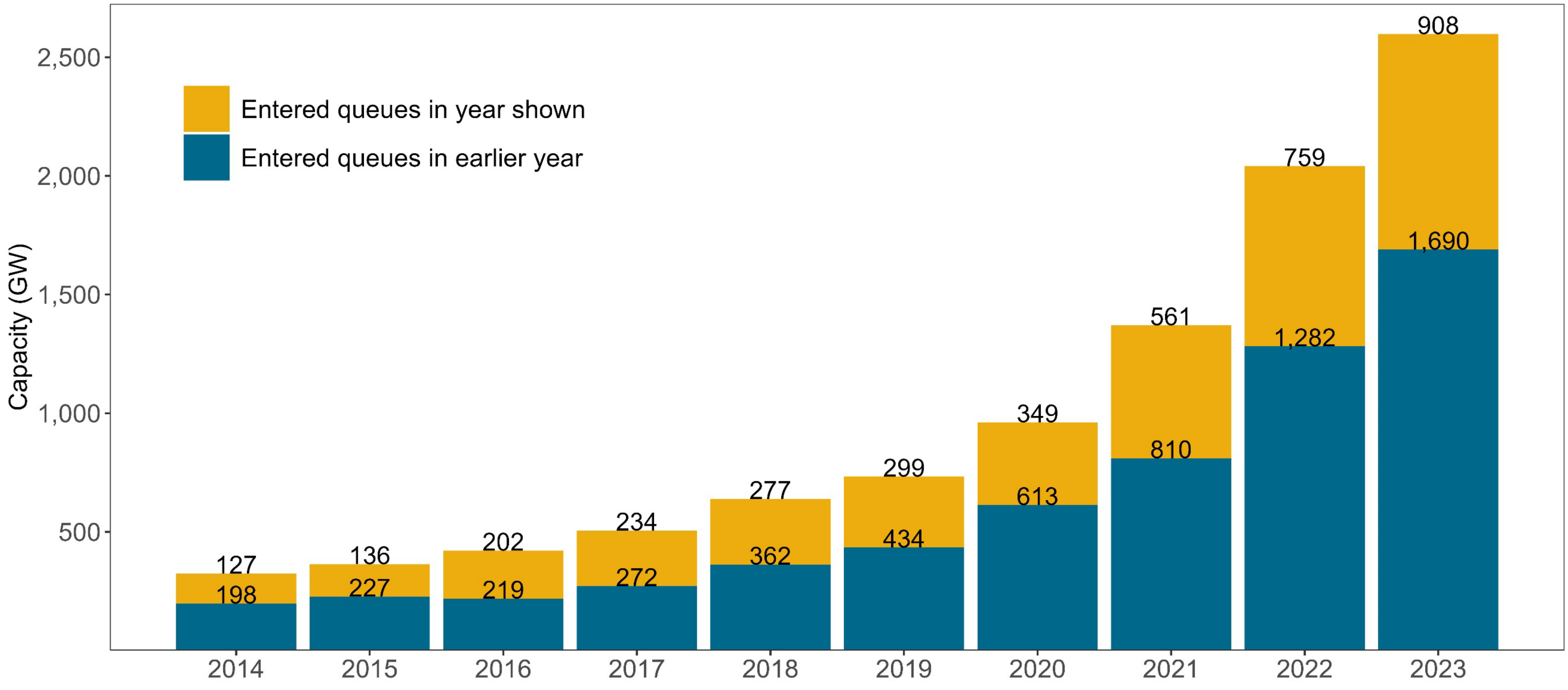
Active Projects in Interconnection Queues: Volume, Regional Trends, Study Phase, and Hybrids

Includes data from all 7 ISO/RTOs and 44 non-ISO balancing areas, totaling 11,597 proposed projects

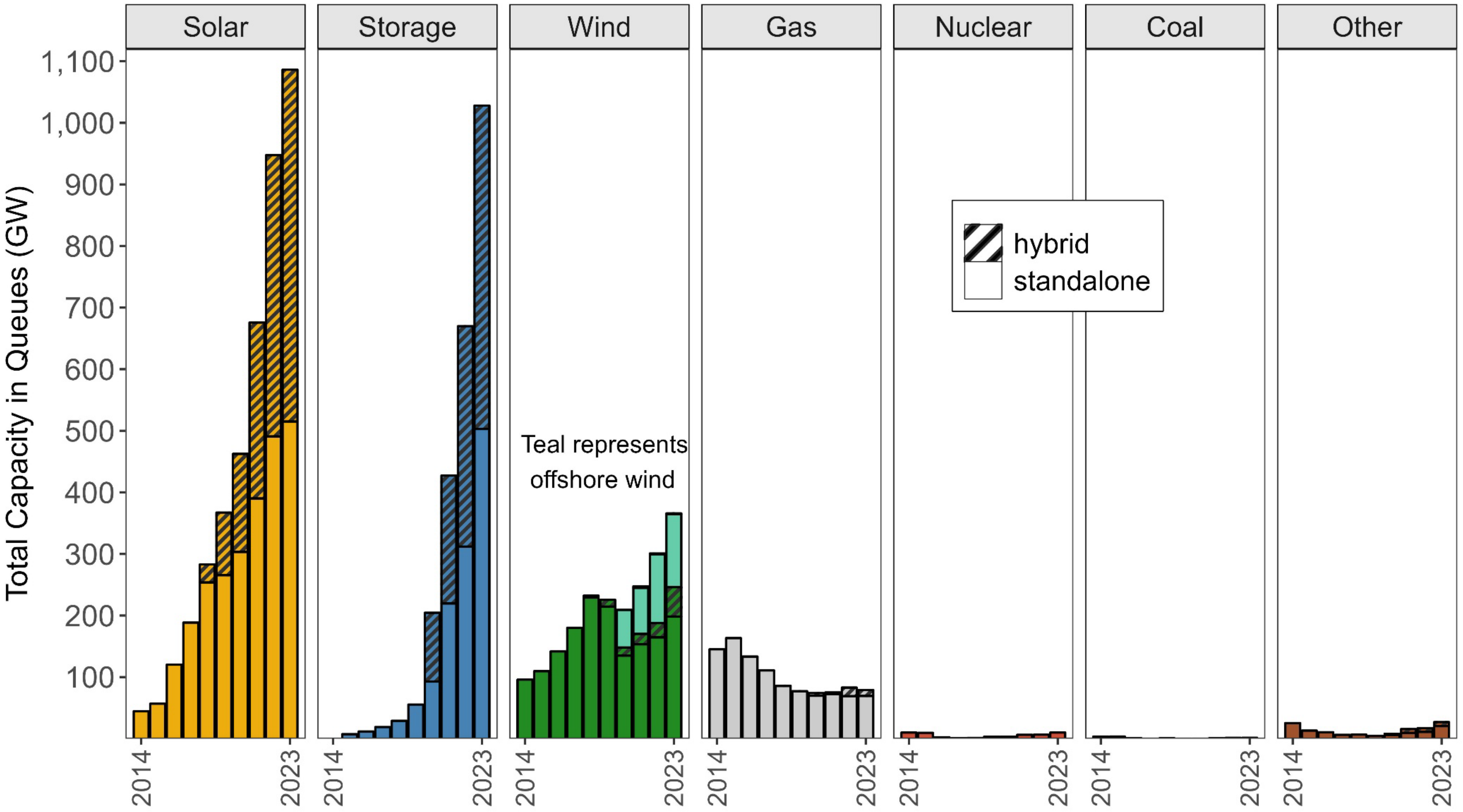
Region	*n* (active)	Capacity (GW)
CAISO	995	523.3
ERCOT	1,090	269.2
ISO-NE	405	51.2
MISO	1,669	311.5
NYISO	492	131.6
PJM	3,065	286.7
SPP	703	144.9
Southeast (non-ISO)	1,134	173.3
West (non-ISO)	2,044	706.5

Notes: (1) Active capacity (GW) shown includes some estimates for hybrid storage capacity in cases where it was missing. (2) Data were sought from 7 ISOs and 44 non-ISO BAs (full list available in appendix). (3) CAISO includes Cluster 15

Total (cumulative) active capacity in queues is now nearly 2,600 GW (2.6 TW); New (annual) capacity entering the queues has increased every year since 2014



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

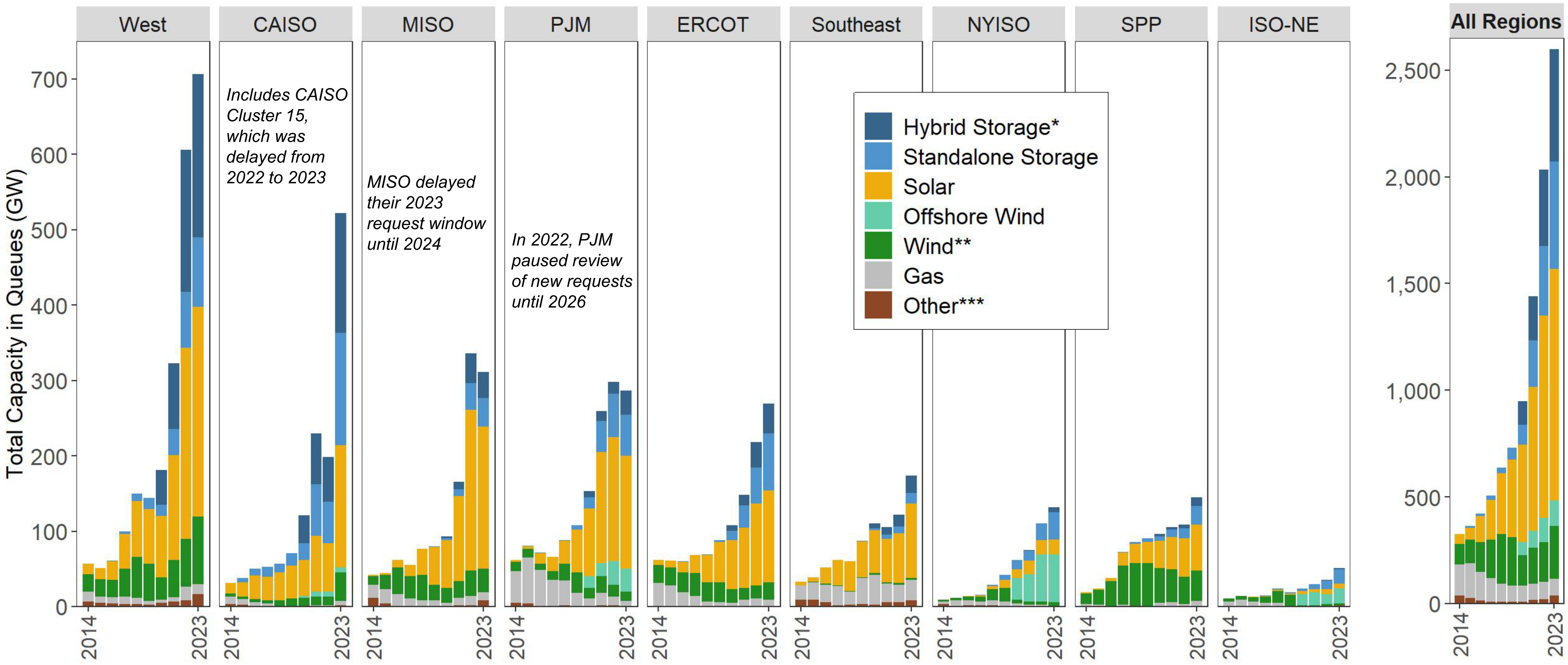


- "**Wind**" includes both onshore and offshore.
- "**Other**" includes
  - Hydropower
  - Geothermal
  - Biomass/biofuel
  - Landfill gas
  - Solar thermal
  - Oil/diesel
- "**Storage**" is primarily (99%) battery, but also includes pumped storage hydro, compressed air, gravity rail, and hydrogen.

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

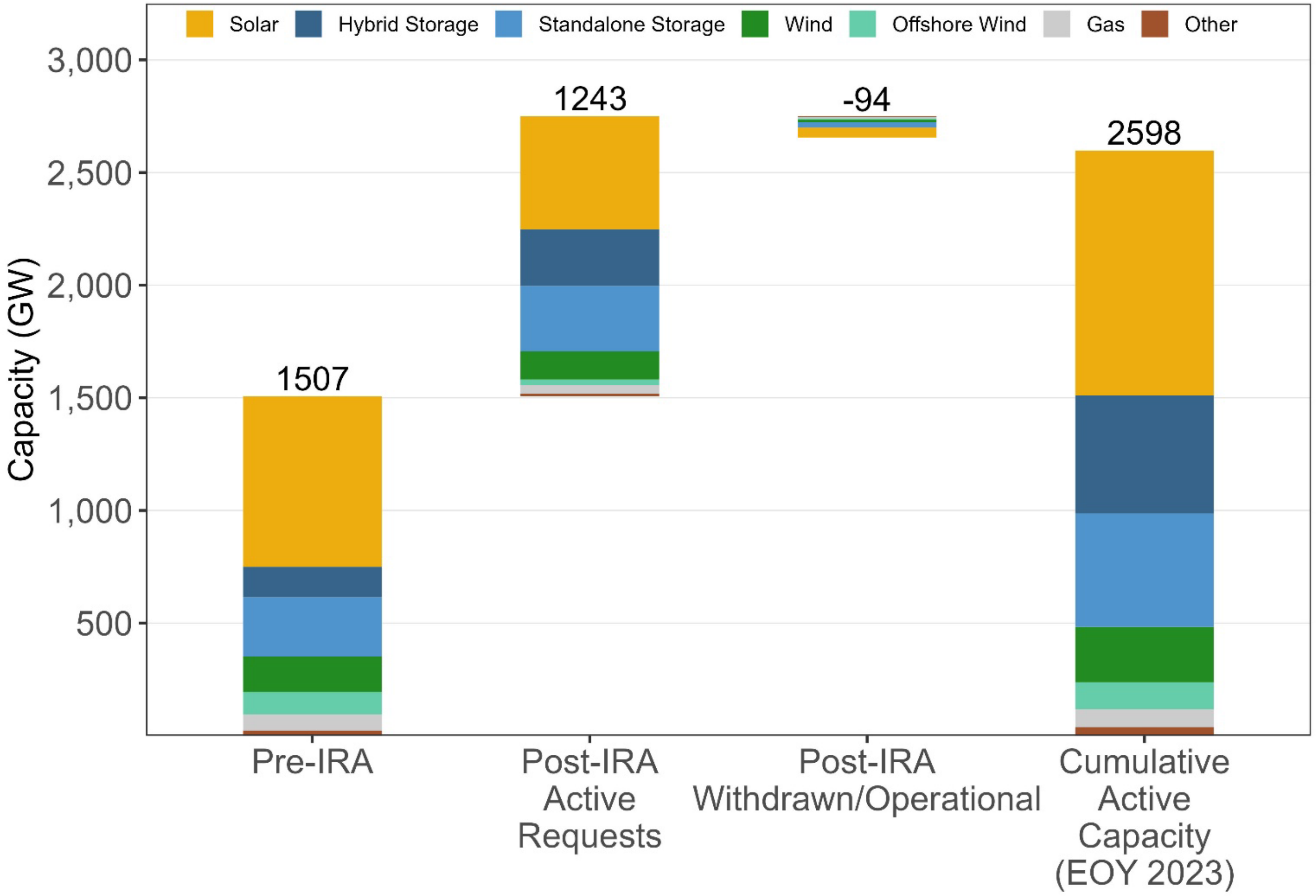
Notes: (1) Hybrid storage capacity is estimated for some projects using storage:generator ratios from projects that provide separate capacity data, and that value is only included starting in 2020. Storage duration is not provided in interconnection queue data. (2) Wind capacity includes onshore and 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.

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.*

Over 1,200 GW (including >500 GW of solar, >540 GW storage, and 125 GW wind) has requested interconnection since the passage of the IRA



The IRA included a range of tax credits and other provisions anticipated to supercharge clean energy development. These include, for example:

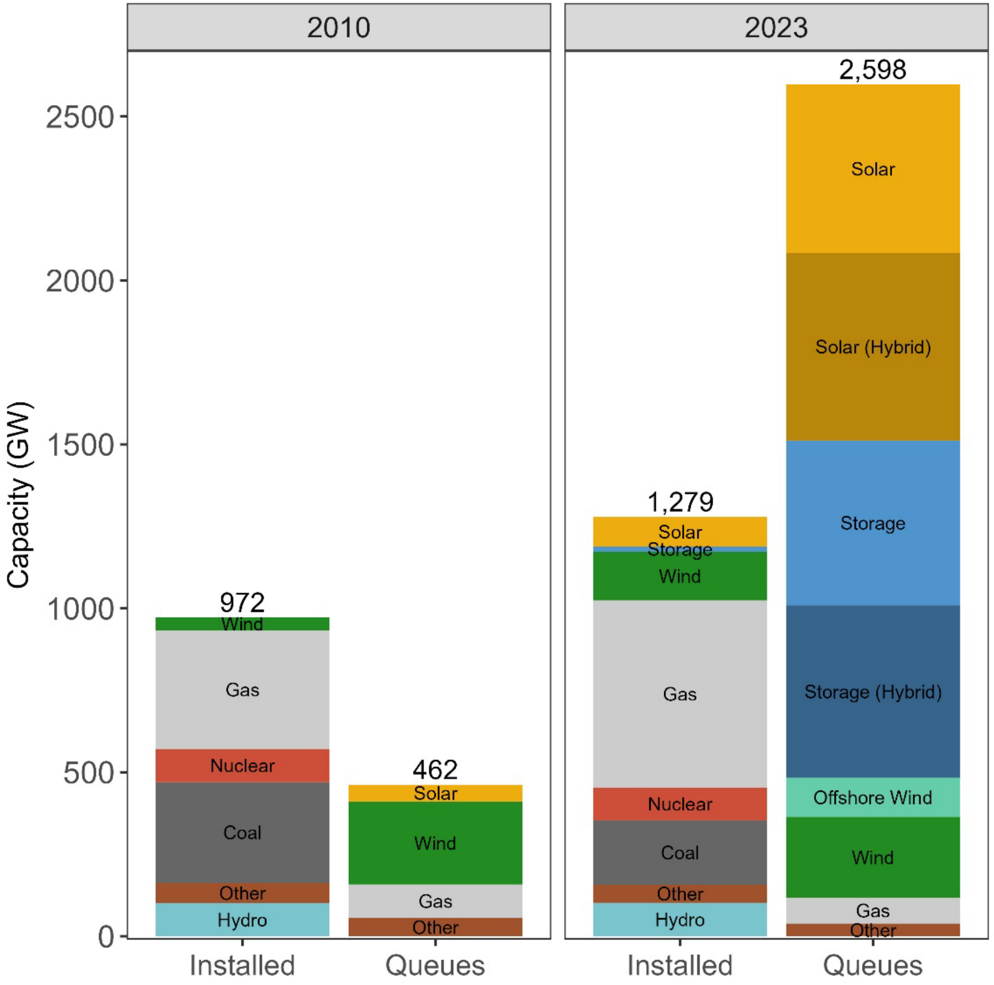
- Extension of existing credits, including technology-neutral Production Tax Credits (PTCs) and Investment Tax Credits (ITCs)
- Emissions-based phase-out, no earlier than 2032
- Standalone storage eligible for ITC; new nuclear as of 2025
- Choice between PTC and ITC: whichever is most valuable
- Bonuses for energy community and domestic content
- USDA grants for rural coops to transition to clean electricity

Although not all of the post-IRA interconnection requests can be attributable to the IRA, these provisions increased developer interest in clean energy and the queues are one indicator of this.

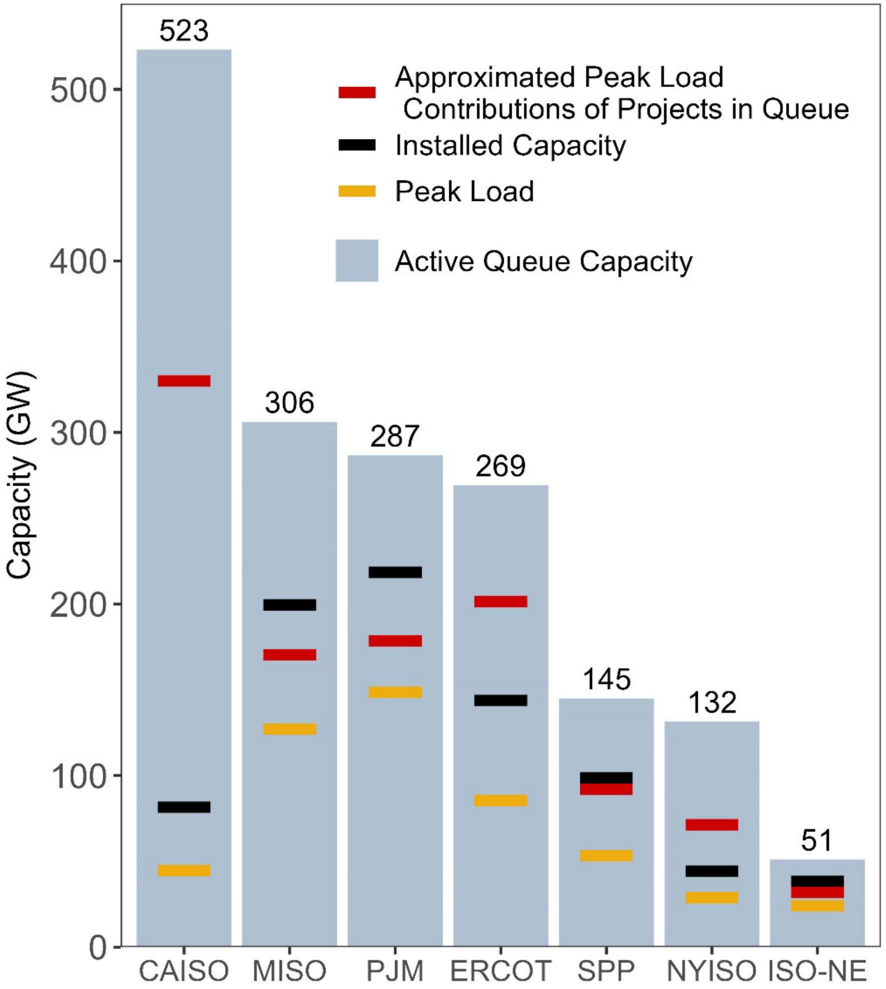
Notes: (1) Pre-IRA includes the cumulative active capacity in the queues as of July 2022. (2) Post-IRA requests include all requests submitted since August 2022. (3) Withdrawn / Operational includes any projects that withdrew or came online since August 2022.

Active capacity in queues (~2,600 GW) is twice the installed capacity of U.S. power plant fleet (~1,280 GW); greater than peak load and installed capacity in all ISOs

Entire U.S. Installed Capacity vs. Active Queues



RTO Installed Capacity & Peak Load vs. Active Queues

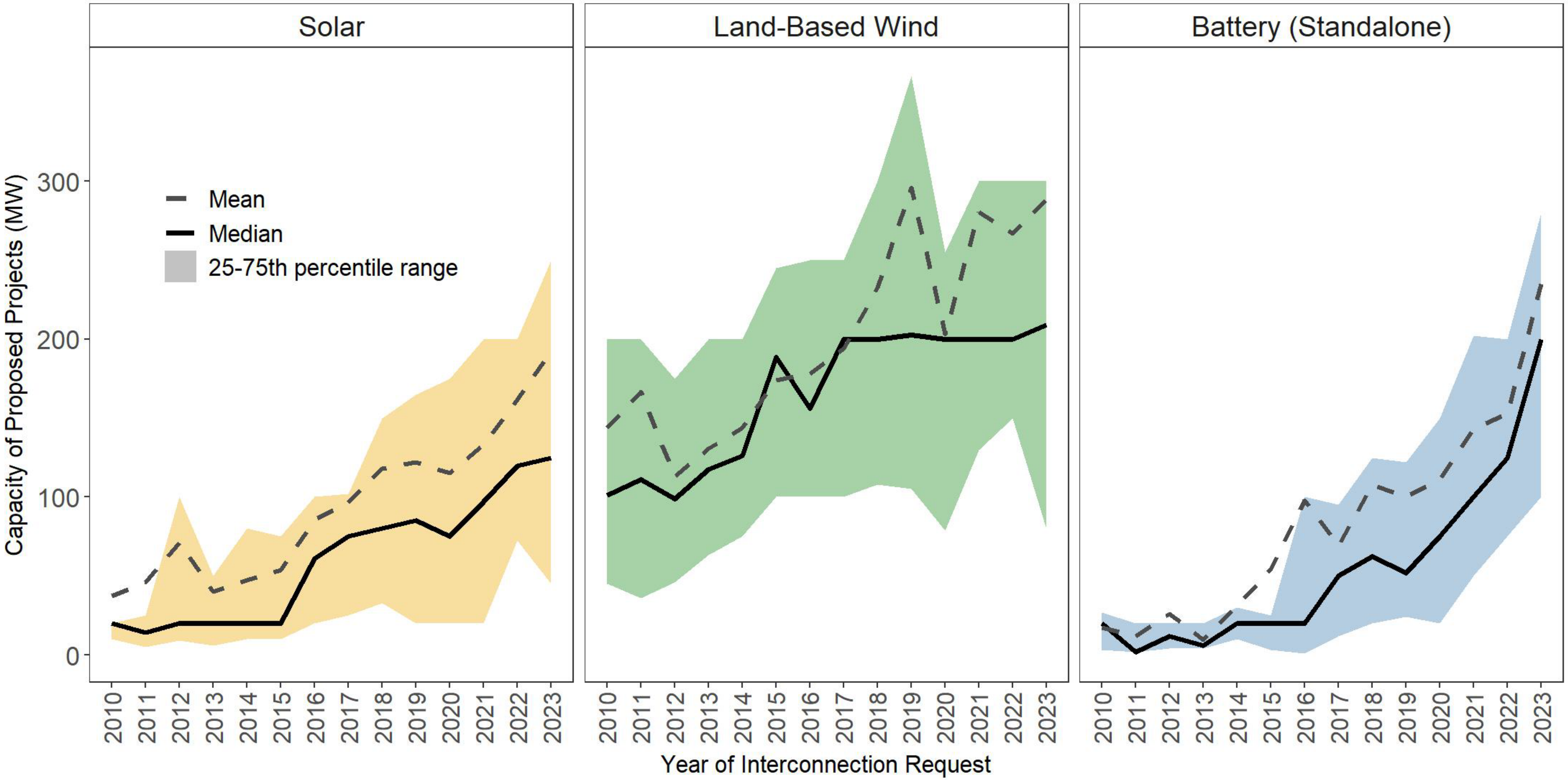


Comparisons of queue capacity to installed capacity or peak load should also consider generators' contributions to resource adequacy, for example their "effective load carrying capability" (ELCC). As variable resources, solar and wind contribute a smaller percentage of their nameplate capacity to resource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

Decarbonizing the electric sector 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.

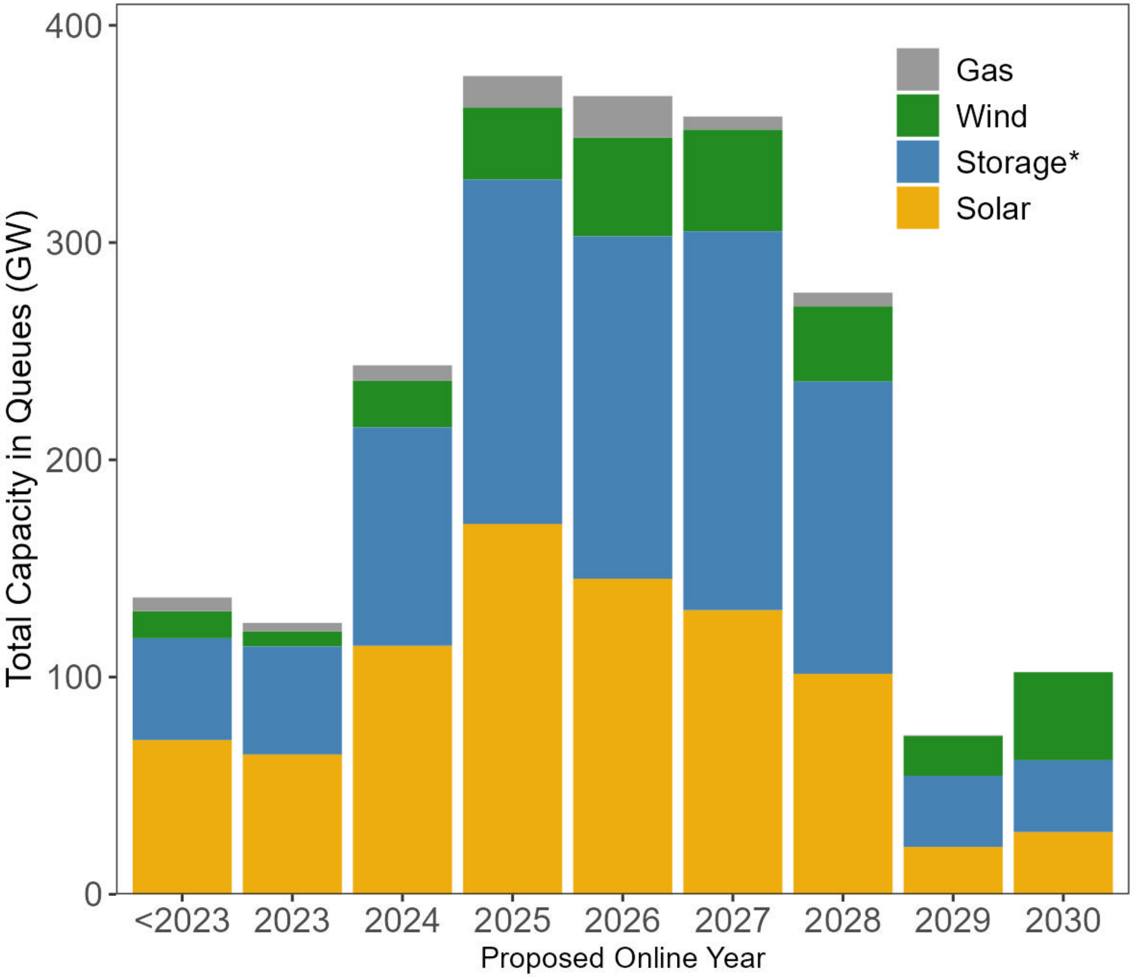
Notes: (1) Hybrid storage in queues is estimated for some projects. (2) Total and RTO installed capacity from EIA-860, December 2023. (3) Peak load data from RTO websites. (4) Peak load contributions by region relies on NERC 2023 reliability assessments for standalone solar, onshore wind, and hydro. 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.

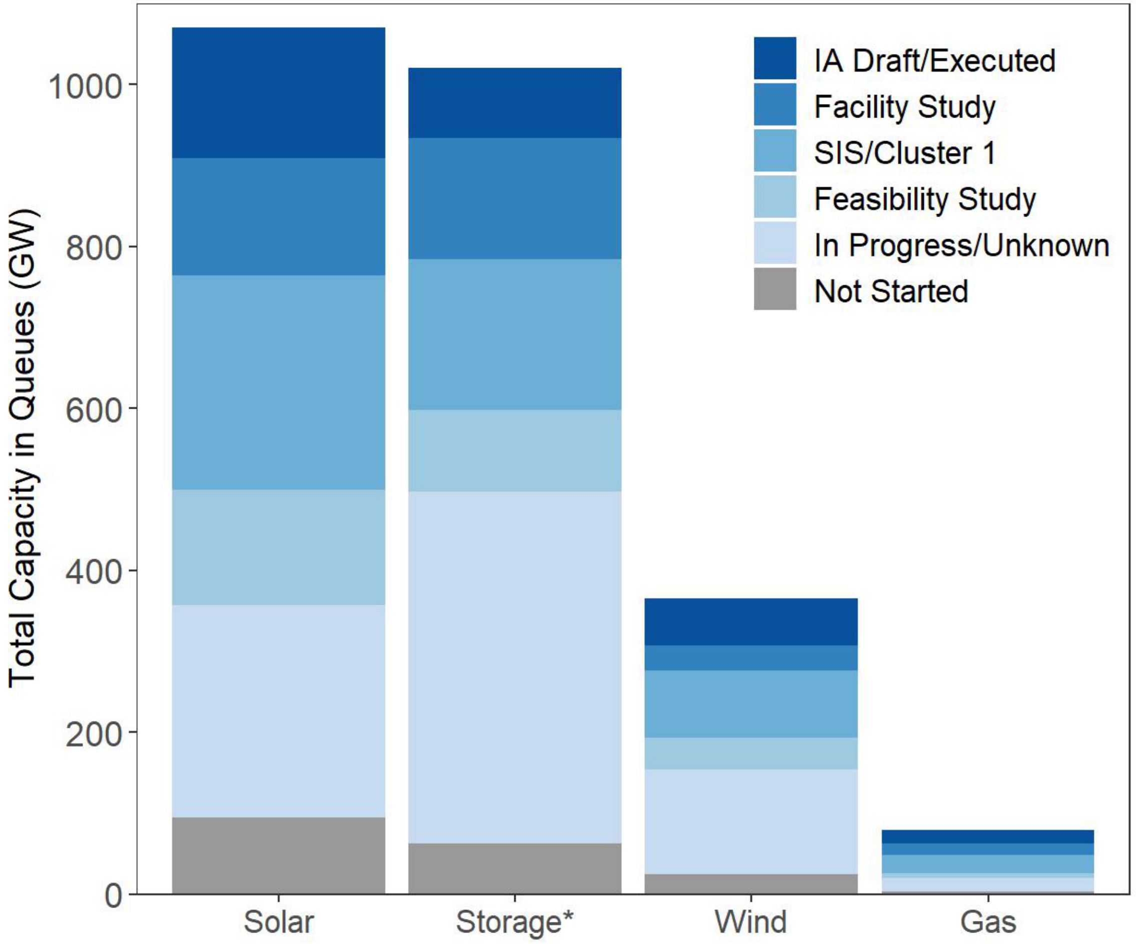
The mean Solar plant requesting grid connection in 2023 was 193 MW, >250% larger than in 2015; proposed Wind (+66%) and Battery (+330%) plants have also grown since 2015



49% (1,271 GW) of active capacity in queues has proposed online date by end of 2026; 12% (311 GW) already has an executed interconnection agreement (IA)

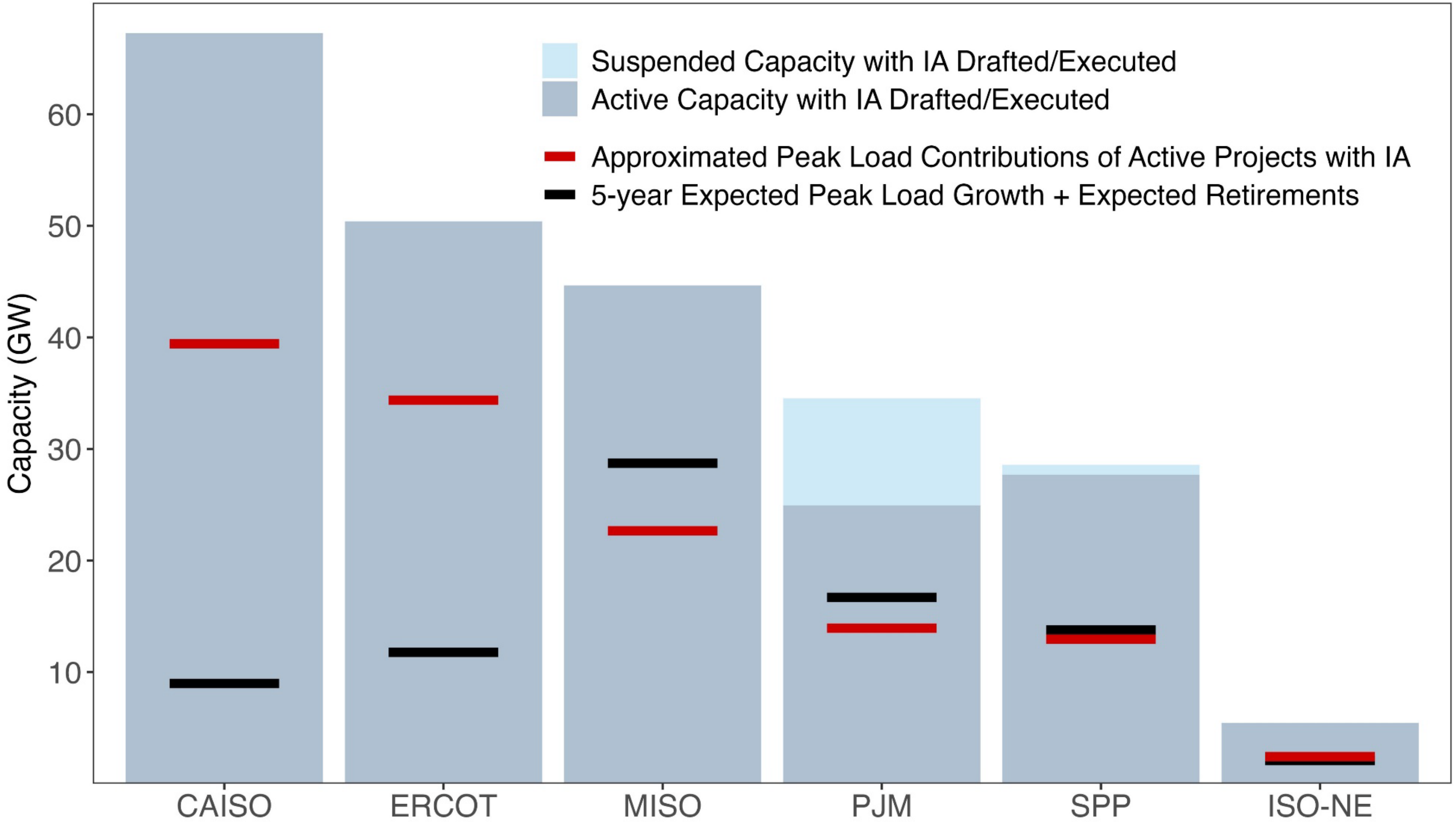
52% of solar (566 GW) is proposed to come online by the end of 2026, compared to 50% of storage (514 GW) and only 33% of wind (120 GW). 14% of solar capacity has an IA, compared to 15% of wind and just 10% of storage.





*Notes: (1) *Hybrid storage capacity is estimated for some projects. (2) Proposed online dates are included in the developer's original interconnection request, and may differ from actual online date. (3) Not all of this capacity will be built. (4) Study status categories are simplified and correspond to the process pre-FERC Order No. 2023 reforms.*

CAISO currently has the most capacity with draft or executed IAs (67 GW). IA capacity exceeds forecasted load growth + retirements in all regions

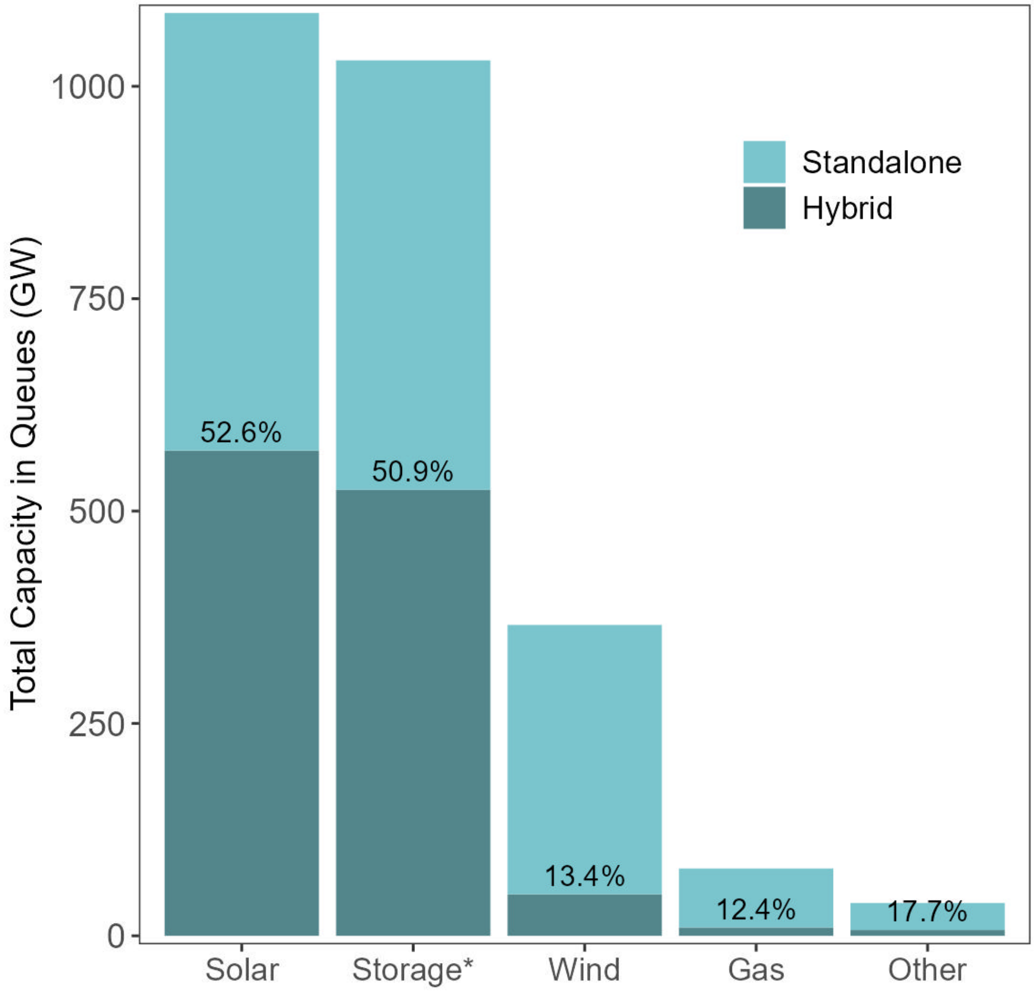


While total capacity of generators and storage active in interconnection queues provides an indication of longer-term developer interest in grid expansion, it provides less insight into shorter-term resource adequacy concerns related to power plant retirements and/or load growth that is being driven by transport electrification, manufacturing growth, and data centers. Signed interconnection agreements provide a better understanding of the nearer-term pipeline of project development (see graph).

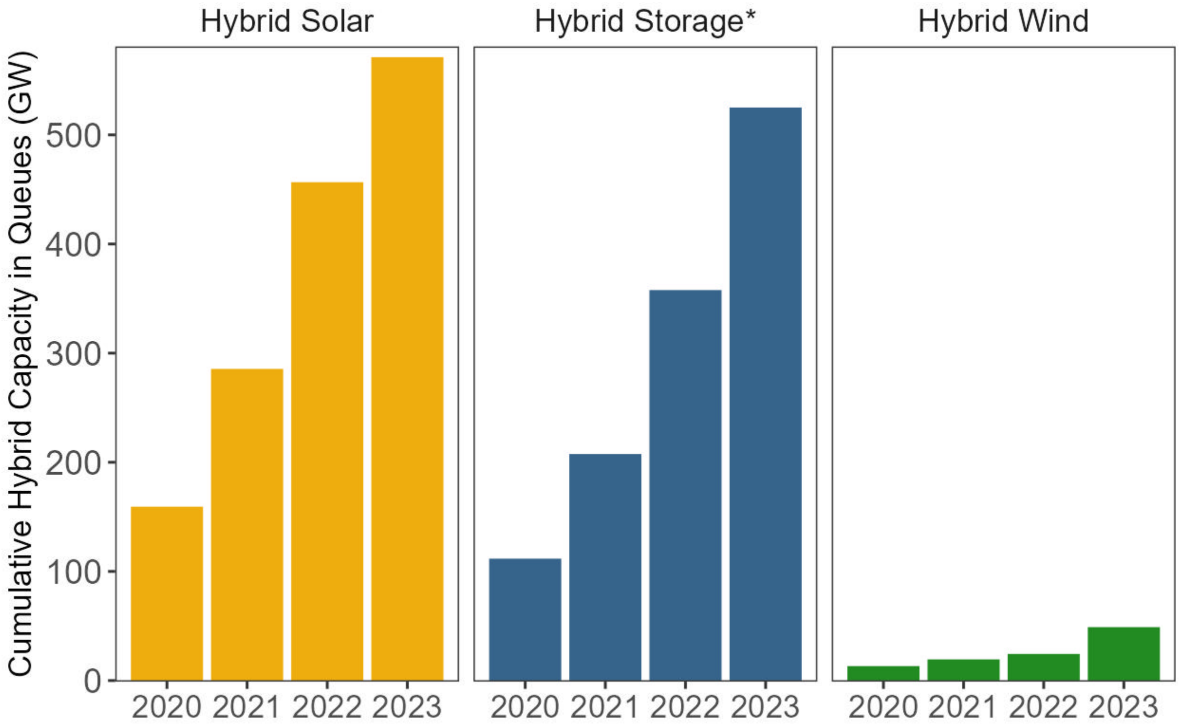
Predicting future power plant retirements and load growth is difficult. The graph indicates varying levels of difference between expected load growth and retirements when compared to the quantity of interconnection requests with a signed interconnection agreement.

Notes: (1) IA capacity bars include capacity in the queues that has either a draft or fully executed interconnection agreement. The darker blue portion of the bar includes only active capacity; light blue portion includes suspended queue requests with an executed/drafted IA. The implication of "Suspended" queue status differs by ISO. e.g., in PJM it is voluntary and elected by the developer; in MISO it requires a force majeure event to suspend a project. (2) 5-year peak load growth and expected retirements from NERC's 2023 electricity supply and demand database. (3) 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)



Hybrid storage capacity is estimated using storage:generator ratios from projects that provide separate capacity data



- **Solar Hybrids** include: Solar+Storage (548 GW), Solar+Wind (0.2 GW), Solar+Wind+Storage (12 GW)
- **Wind Hybrids** include: Wind+Storage (35 GW), Wind+Solar (0.2 GW), Wind+Solar+Storage (13 GW)
- **Storage Hybrids** may be paired with any generator type; most are paired with solar
- **Gas Hybrids** include: Gas+Solar+Storage (10 GW) [not shown above]

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.

Operational & Withdrawn Projects: Volume and Completion Rates

Operational project data were available from all 7 ISO/RTOs and 31 non-ISO balancing areas, totaling 4,155 projects.

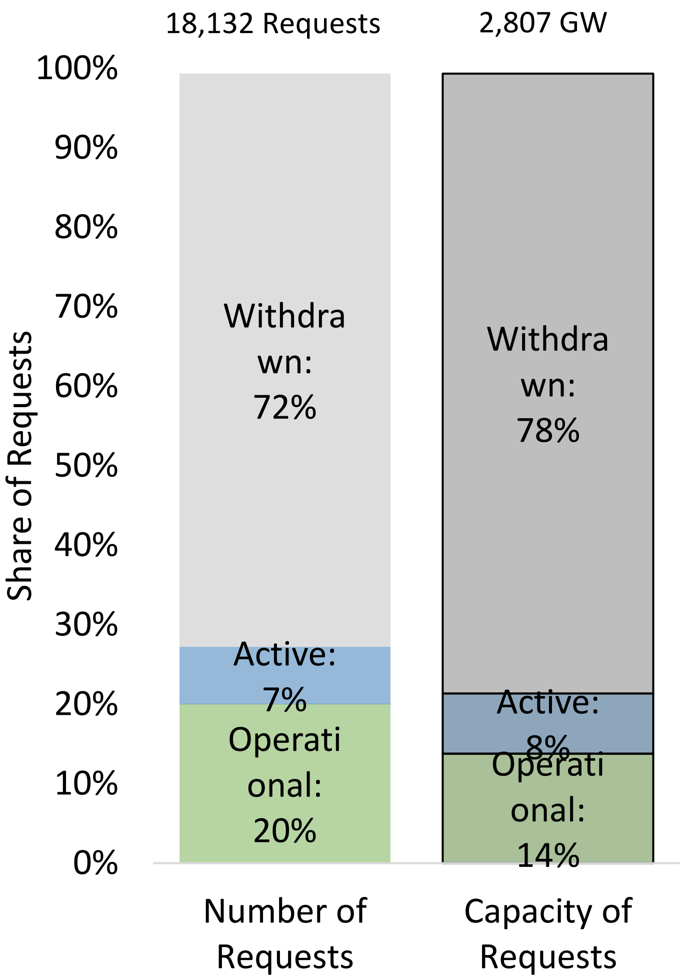
Region	*n* (Operational)	Capacity (GW)
CAISO	198	26.6
ERCOT	358	65.6
ISO-NE	255	34.7
MISO	459	66.7
NYISO	100	11.2
PJM	1,163	91.0
SPP	271	40.8
Southeast (non-ISO)	361	76.7
West (non-ISO)	990	57.2

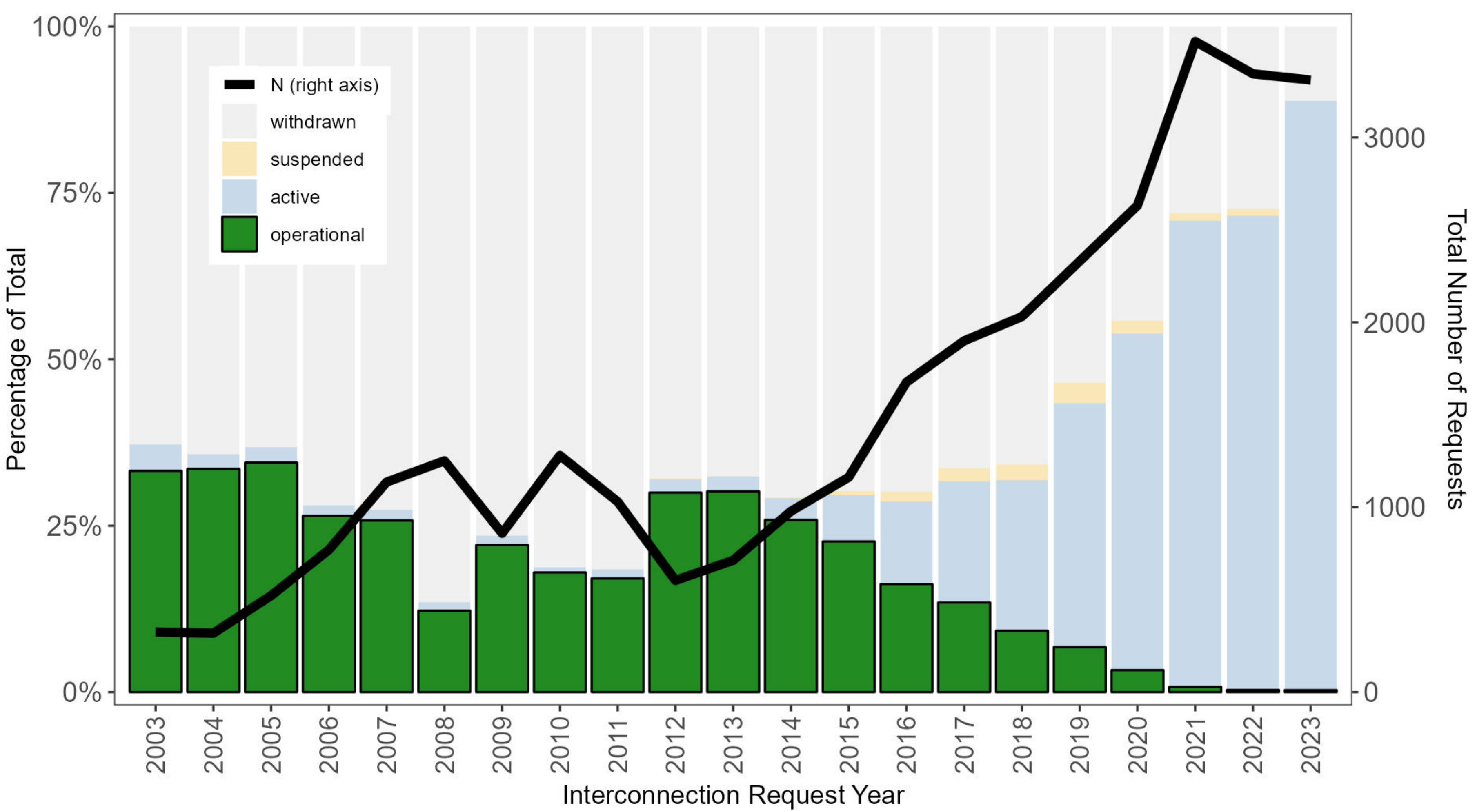
Withdrawn project data were available from all 7 ISO/RTOs and 37 non-ISO utilities, totaling 18,372 requests.

Region	*n* (Withdrawn)	Capacity (GW)
CAISO	1,630	401.0
ERCOT	803	195.6
ISO-NE	605	90.8
MISO	2,113	408.6
NYISO	843	135.7
PJM	4,089	476.4
SPP	1,419	280.8
Southeast (non-ISO)	2,001	450.1
West (non-ISO)	4,370	657.9

*Notes: (1) The number of operational and withdrawn projects with available data may be fewer than the total number of operational or withdrawn projects for each entity. (2) Data were sought from 7 ISOs and 44 non-ISO BAs; operational and withdrawn project data may be delayed or unavailable. (3) Capacity (GW) shown in these tables does **not** include estimates for missing hybrid storage capacity.*

The majority (>70%) of interconnection requests are withdrawn. Just 20% of requests (14% of capacity) submitted from 2000-2018 had been built as of the end of 2023

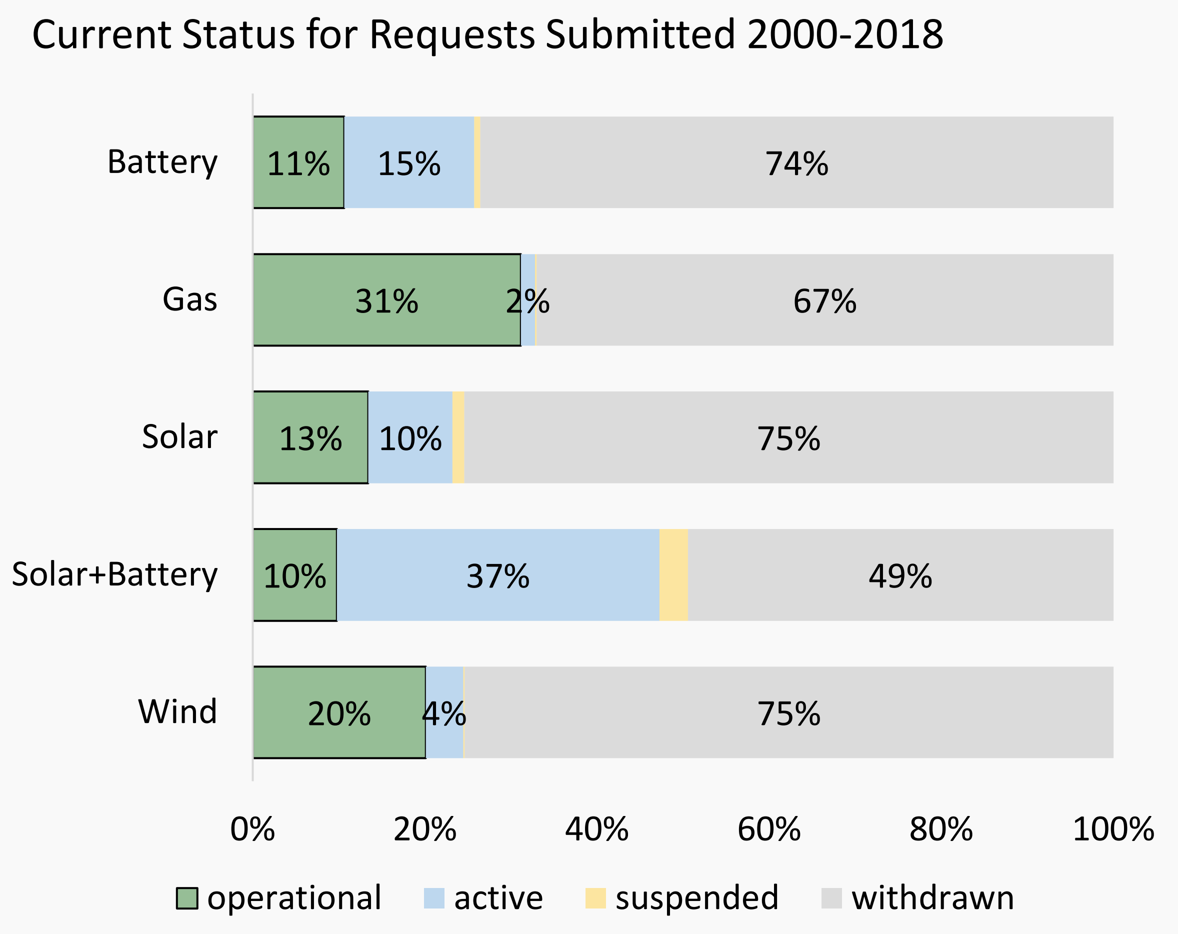




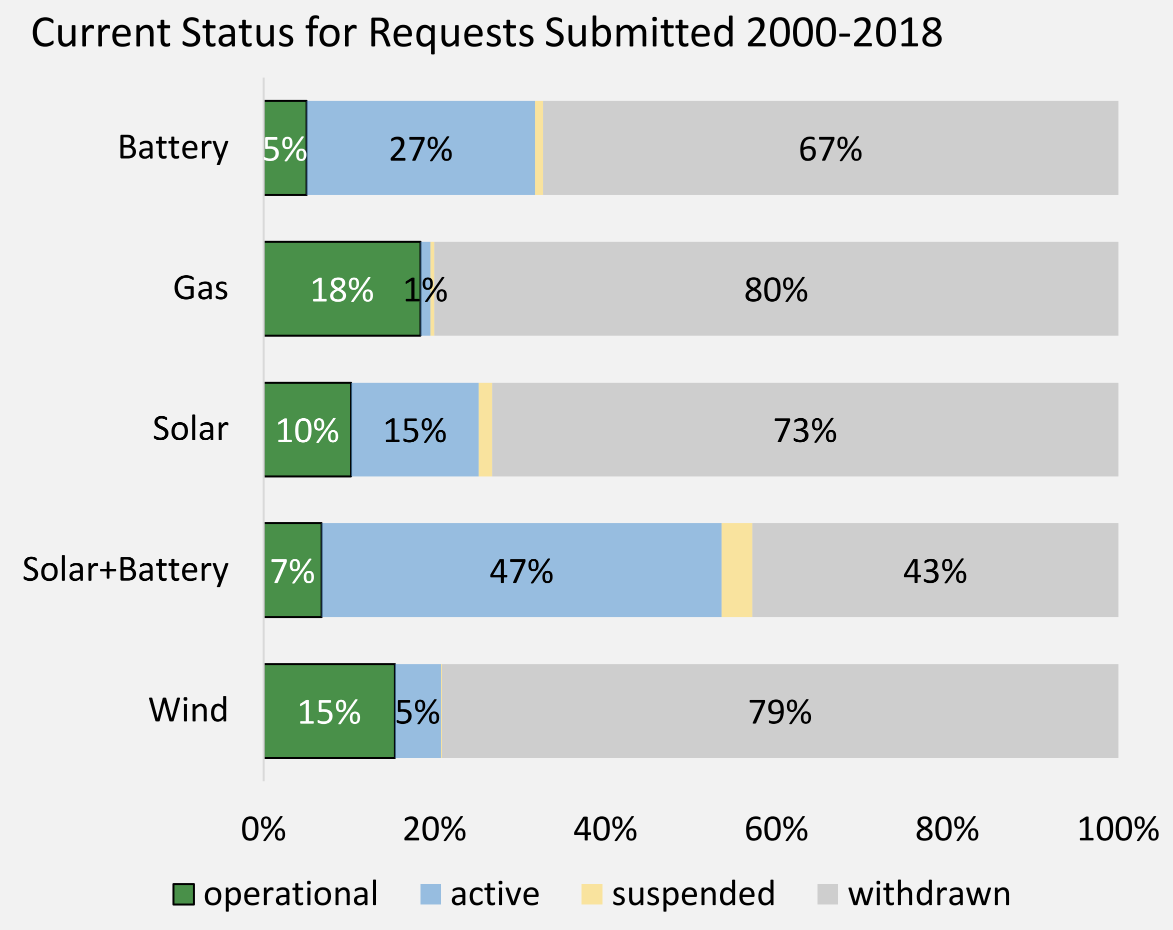
Notes: (1) Final outcome for projects entering the queues in recent years may not yet be determined; some take 5 or more years from request to COD. (2) Status shown represents a snapshot of all available data as of the end of 2023. (3) Completion rate shown in chart on right is calculated by number of projects, not capacity. (4) Limited to data from 7 ISO/RTOs and 30 non-ISO balancing areas which provide comprehensive status information.

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

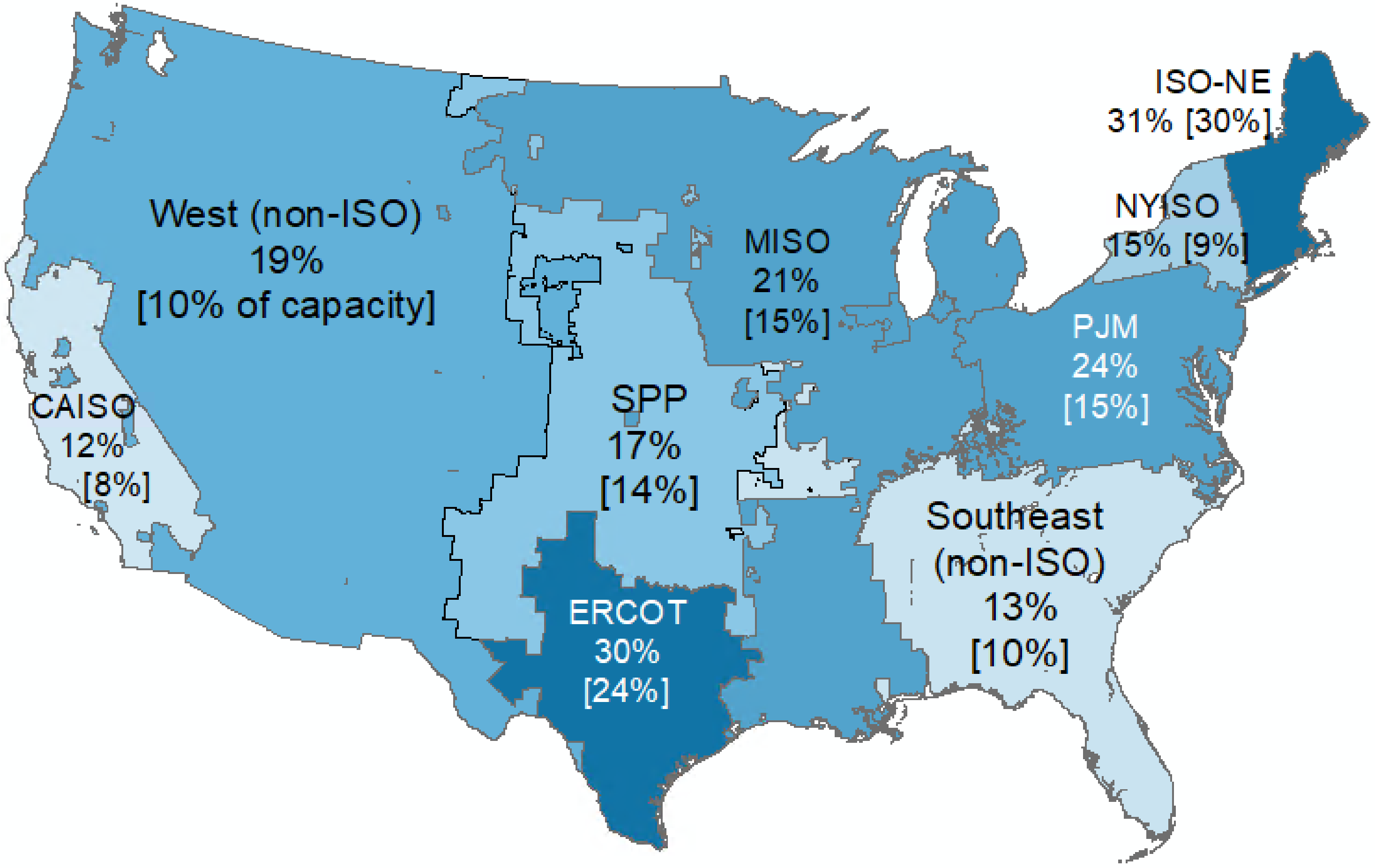


By Capacity of Requests



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

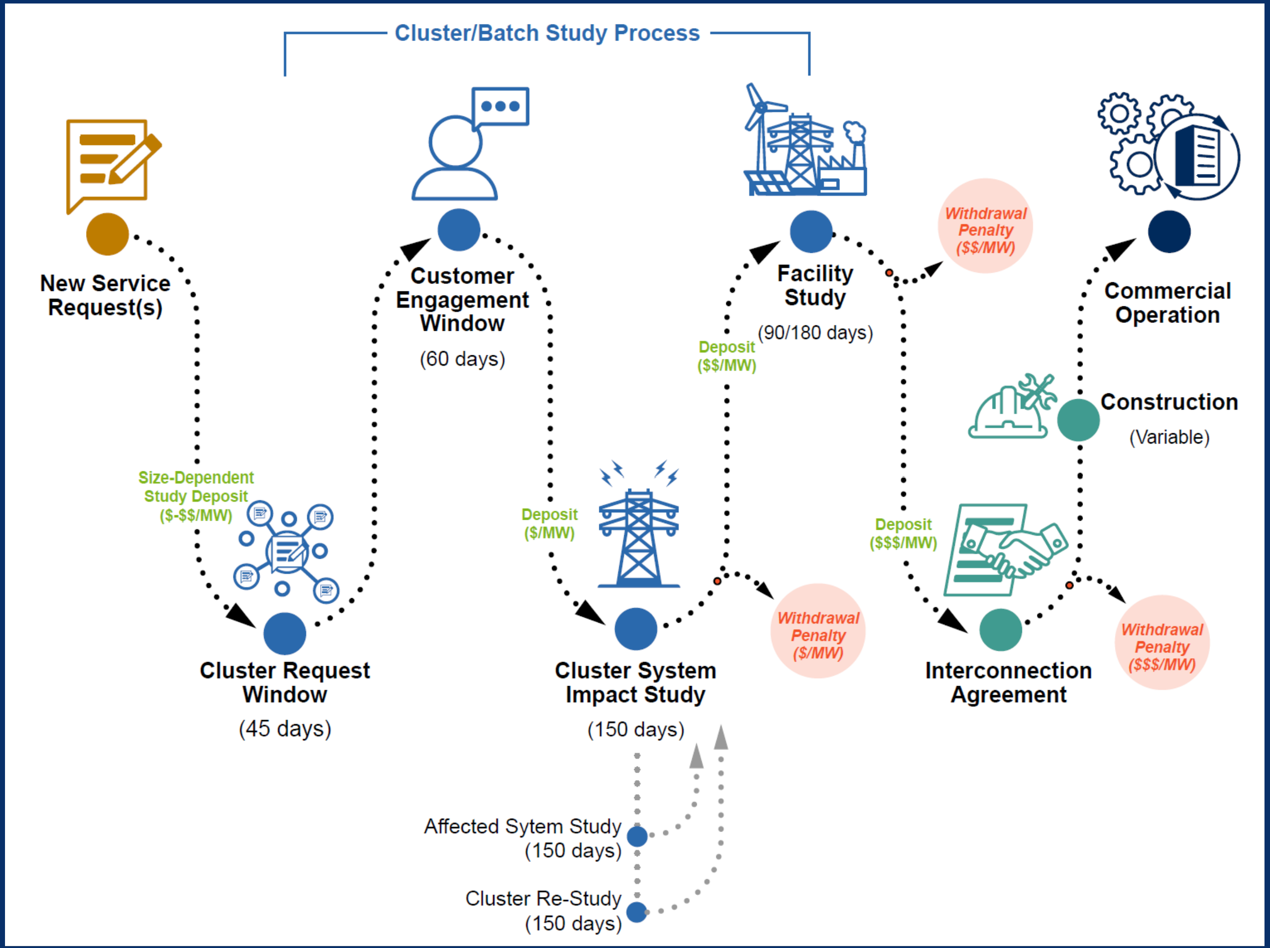
Notes: (1) Capacity-weighted completion rates are shown in brackets [ ]. (2) Percentages only include projects requesting interconnection from 2000-2018. (3) Includes data from 7 ISOs and 30 non-ISO balancing areas which provide comprehensive status information. (4) See appendix for time-series data.

Duration Trends: How Long Do Projects Spend In the Queues?

Withdrawn Projects:
- Duration from Interconnection Request (IR) to Withdrawn Date

All Projects:
- Duration from IR to Interconnection Agreement (IA)

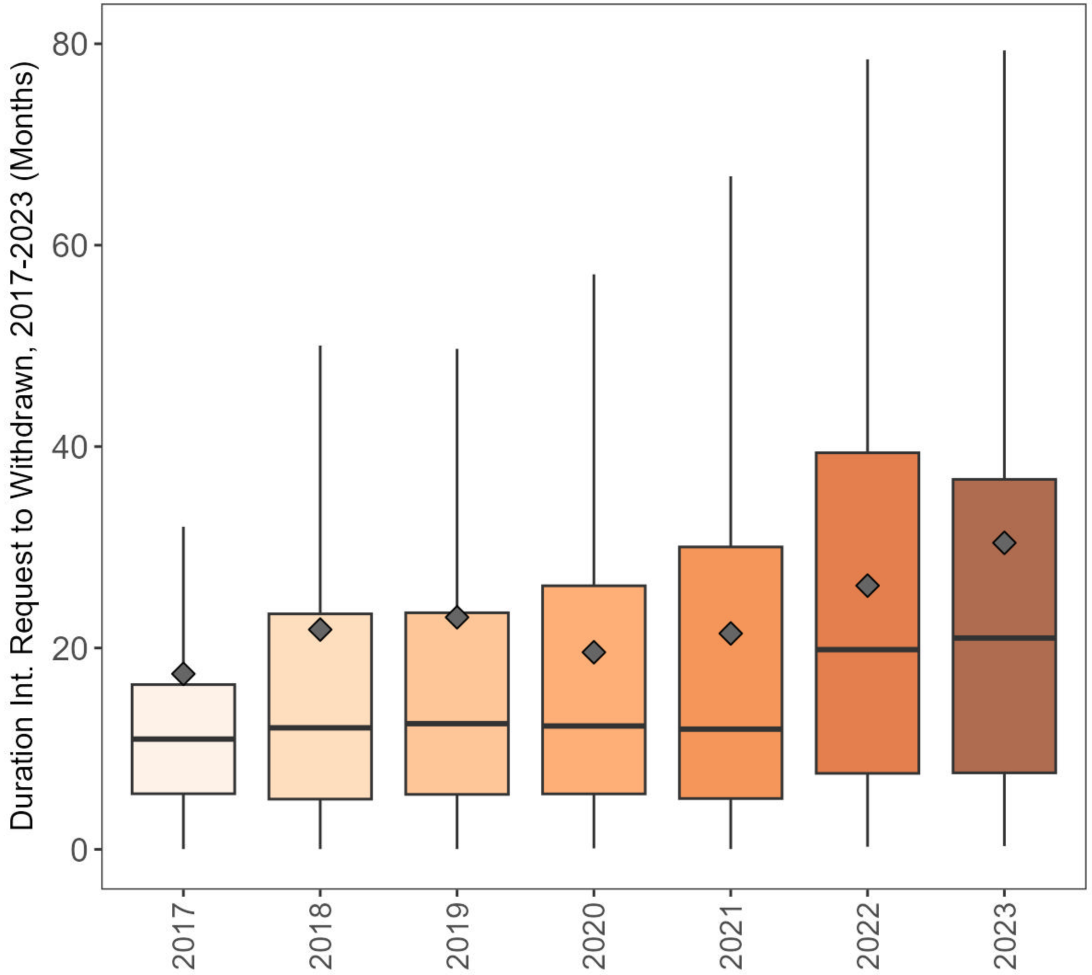
Operational Projects:
- Duration from IA to COD
- Duration from IR to Commercial Operations Date (COD)



Note: The interconnection process diagram (right) reflects the pro-forma process under FERC Order No. 2023. While some ISOs already follow this cluster-study approach, the data presented in this report pre-date Order No. 2023 implementation.

The average duration from interconnection request to withdrawal date has edged upward in recent years

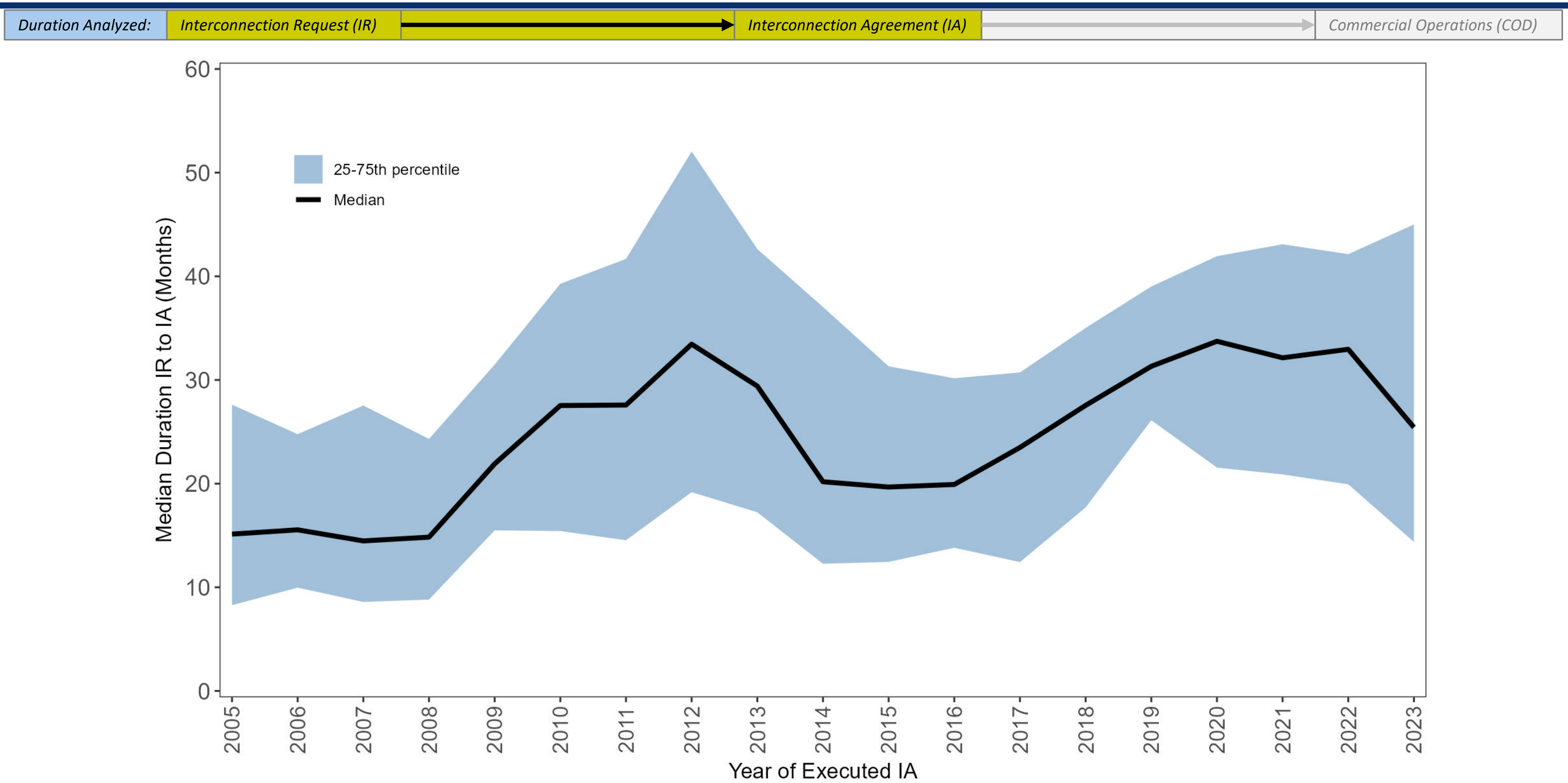
Duration Analyzed:	Interconnection Request (IR)	→	Withdrawn Date	→	Commercial Operations (COD)



- This trend implies that some recently-withdrawn projects have waited longer in the queues before making the determination to withdraw
- Later stage withdrawals can be costly for developers and can disrupt assumptions built into other projects' interconnection studies, necessitating re-studies in some cases and lengthening study durations

Note on Boxplots*: Many of the following slides utilize box and whisker plots. The boxes represent the interquartile range (IQR), with the central horizontal line being the median. Gray diamonds are the mean. Whiskers (vertical lines) are 1.5 times the IQR. Outliers are not shown.*

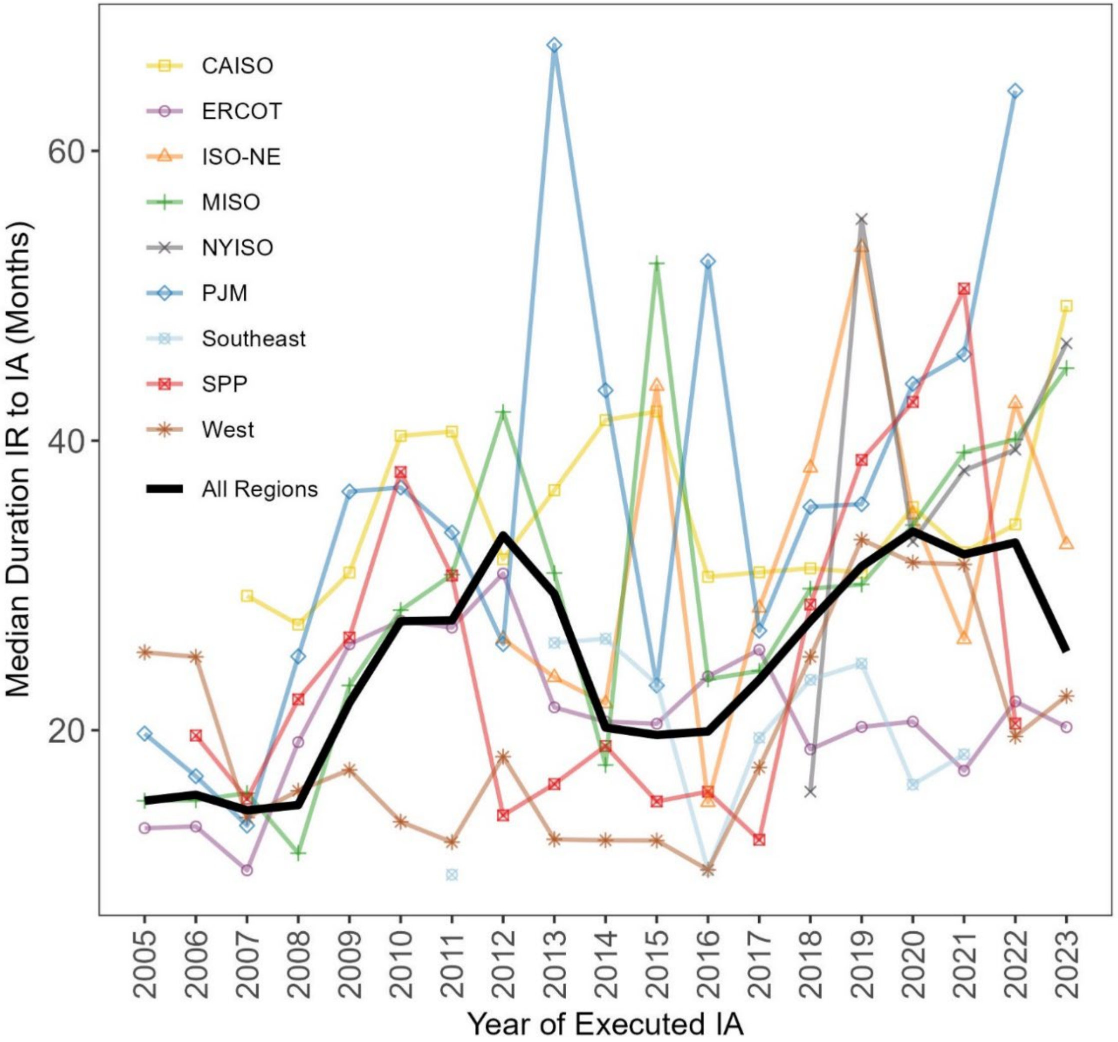
Duration from interconnection request to interconnection agreement had increased recently, but moderated slightly in 2023 (note: 2023 data sample is dominated by ERCOT and West[1])

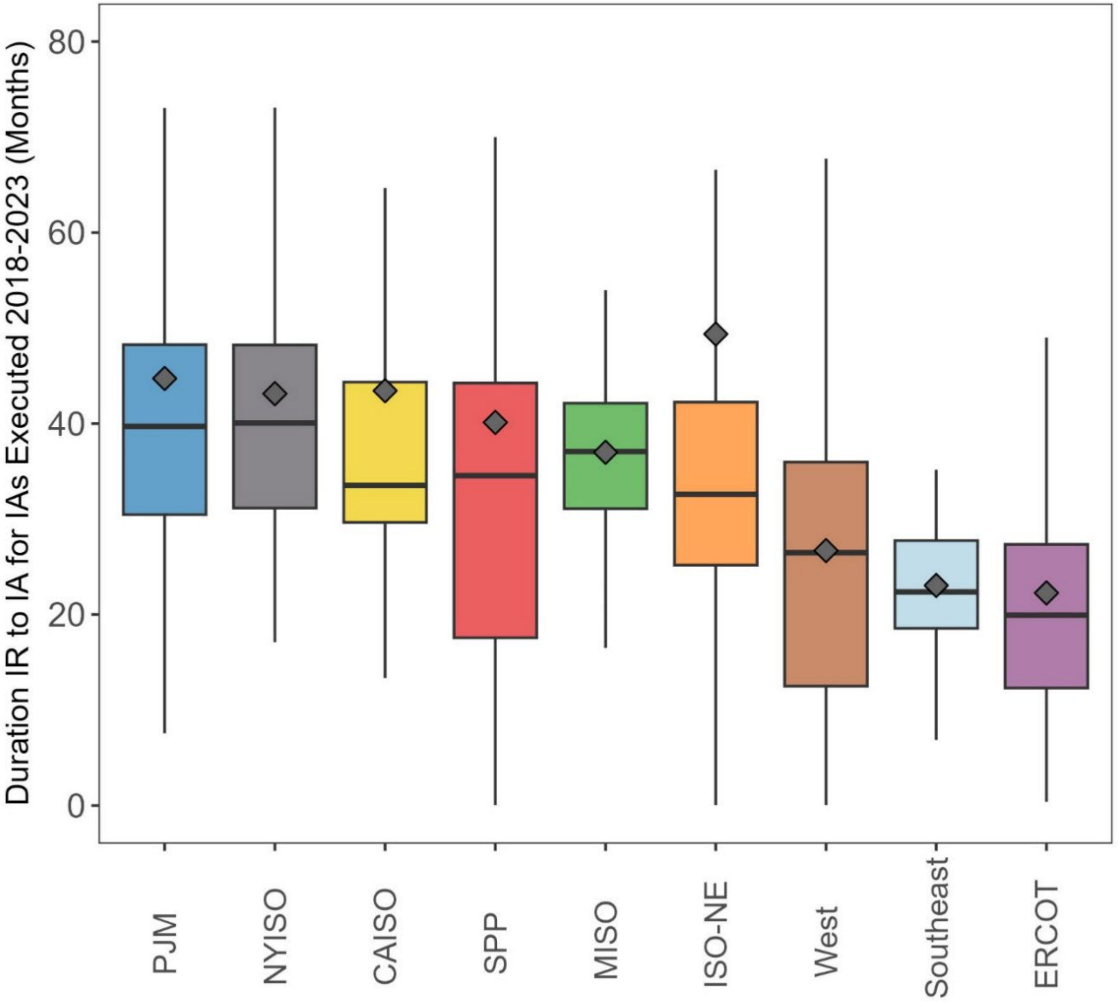


Notes: (1) The majority of the 2023 data sample for this analysis came from ERCOT (39%) and the West (23%), which typically have relatively shorter durations (see next slide). (2) Sample includes 3,864 projects from 7 ISO/RTOs and 5 non-ISO balancing areas with executed interconnection agreements since 2005. (3) Not all data used in this analysis are publicly available.

IR to IA duration is typically longest FERC-jurisdictional ISOs. ERCOT and the non-ISO regions (Southeast and West) have fastest processing times

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

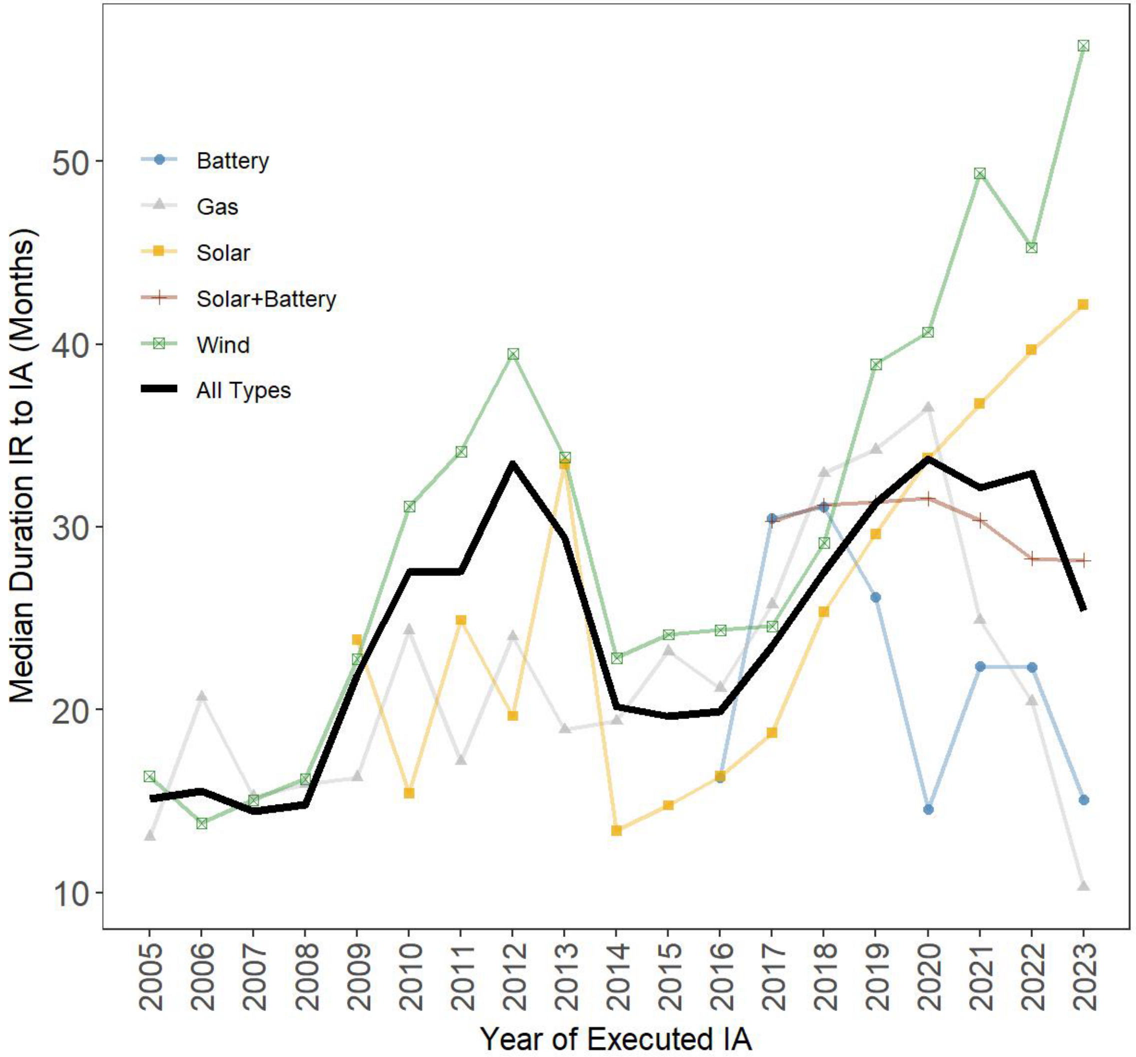


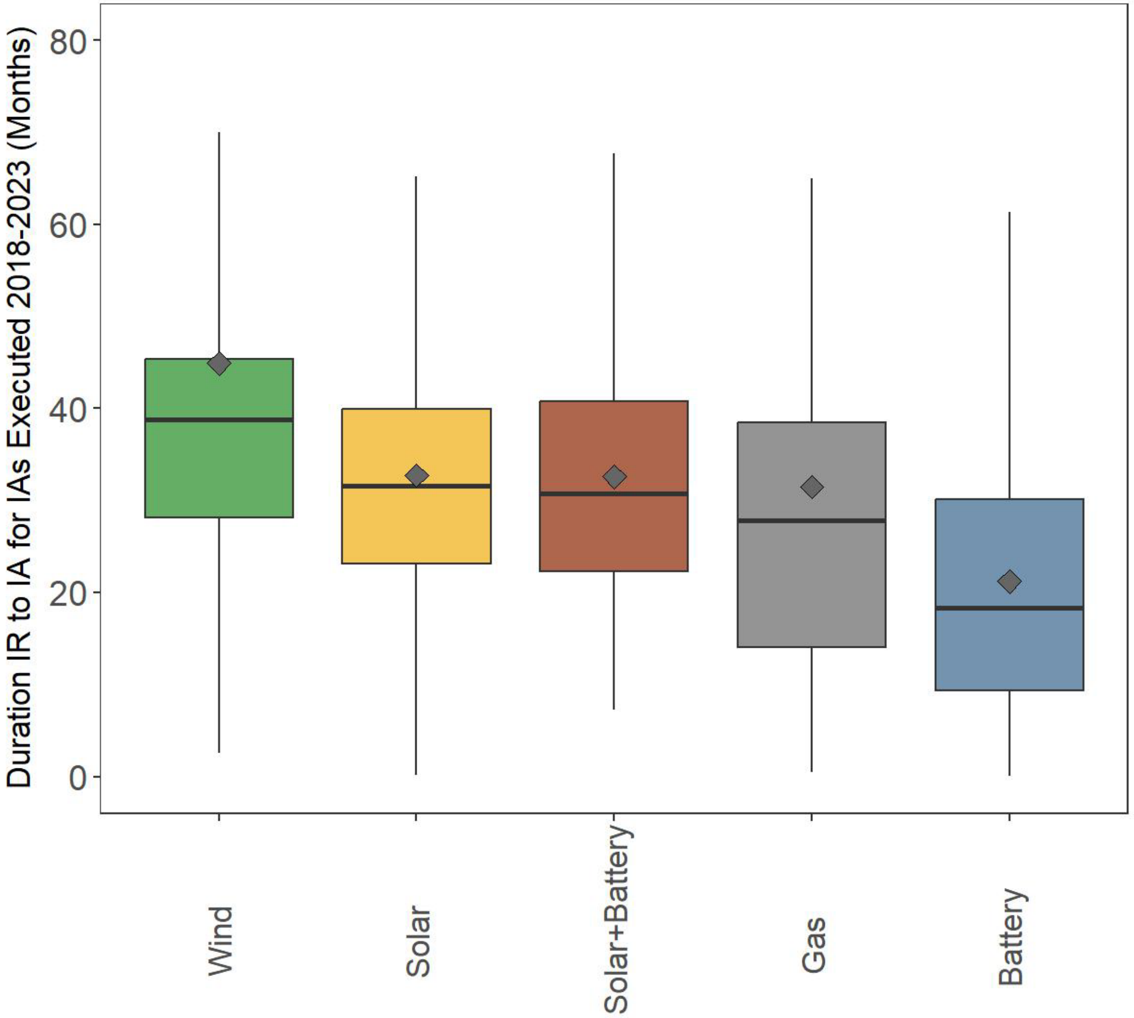


Notes: (1) Sample includes 3,864 projects from 7 ISO/RTOs and 5 non-ISO balancing areas with executed interconnection agreements since 2005. (2) Not all data used in this analysis are publicly available. (3) Date of IA execution for projects with IA agreement completed in 2023 was not accessible in database format from SPP and PJM (though 160 IAs were executed in PJM in 2023).

Wind projects typically face longer interconnection study timelines; recent battery and gas projects have been processed much more quickly

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





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

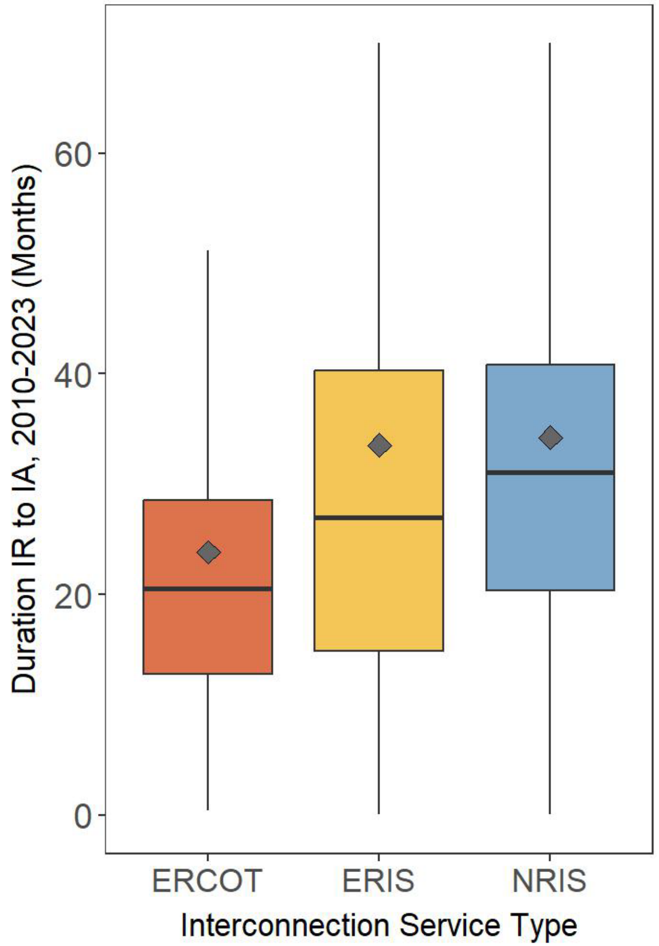
Duration Analyzed:	Interconnection Request (IR)	→	Interconnection Agreement (IA)	→	Commercial Operations (COD)

Network Resource Interconnection Service (NRIS) allows the Interconnection Customer to connect its Generating Facility to the Transmission Provider's Transmission System and be deliverable during congested grid conditions, such that the generator can be designated as a capacity resource and contribute to resource adequacy requirements.

Energy Resource Interconnection Service (ERIS) allows the Interconnection Customer to connect its Generating Facility to the Transmission Provider's Transmission System to be eligible to deliver the Generating Facility's electric output using the existing firm or non-firm capacity of the Transmission Provider's Transmission System on an "as available" basis.

	% of Active Capacity	
region	**ERIS**	**NRIS**
CAISO	12%	88%
MISO	4%	96%
PJM	0%*	100%*
SPP	26%	74%
ISO-NE	16%	84%
West	18%	82%
Southeast	23%	77%

**Some projects in PJM are requesting ERIS, but their capacity is so small they round to 0% of total capacity*



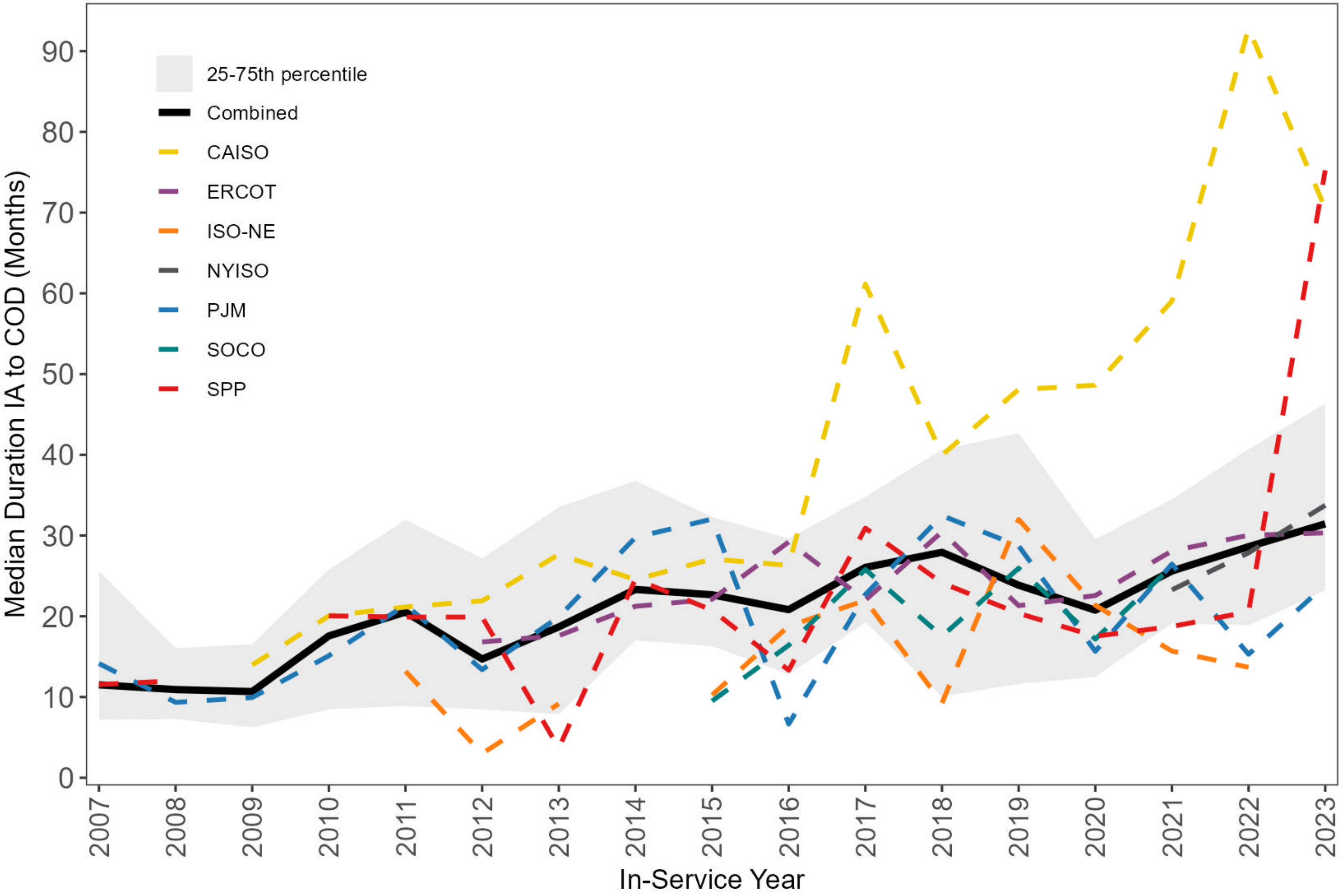
The mean IR-IA duration for ERIS requests submitted since 2010 (33.5 months) is not significantly shorter than that for NRIS requests (~34.2 months) (p = 0.27).

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.

Typical duration from IA to commercial operations date (COD) has increased modestly; in some regions (e.g., CAISO and SPP), recent projects are facing substantial delays after securing an IA

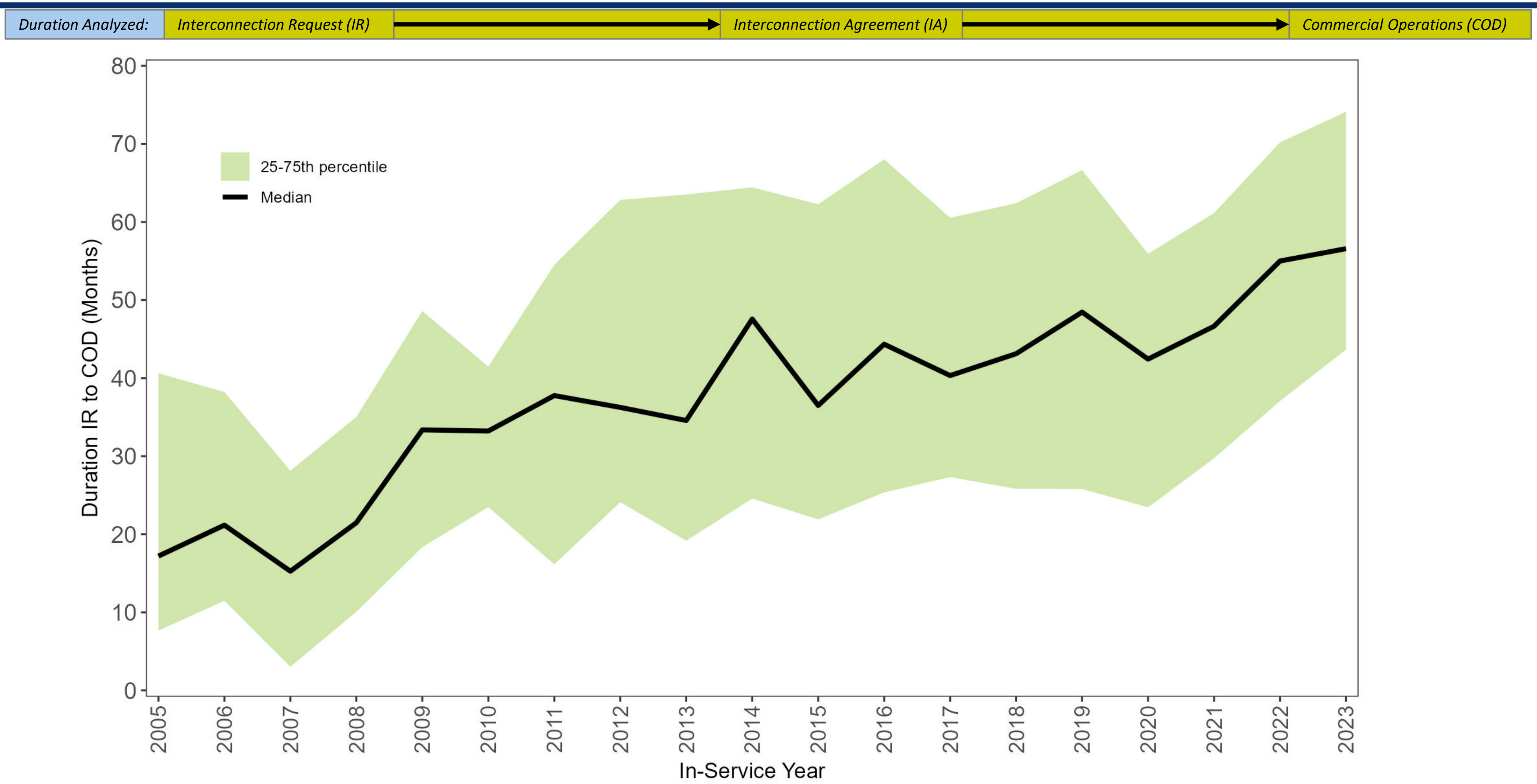
Duration Analyzed: *Interconnection Request (IR)* → *Interconnection Agreement (IA)* → *Commercial Operations (COD)*



- Limited data were available to analyze typical durations from interconnection agreement to commercial operations
- Considering 861 projects across 6 entities, the typical IA to COD duration has increased modestly since 2007.
  - From ~17 months for projects built from 2007-2015 to ~25 months for projects built from 2016-2023.
- But, that duration has increased dramatically for CAISO projects in the last 5 years.
  - The typical solar project built in CAISO since 2018 took over 4 years to reach commercial operations *after securing an interconnection agreement*; those built in 2022 averaged over 6 years.

Notes: (1) Data were only available for 861 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.

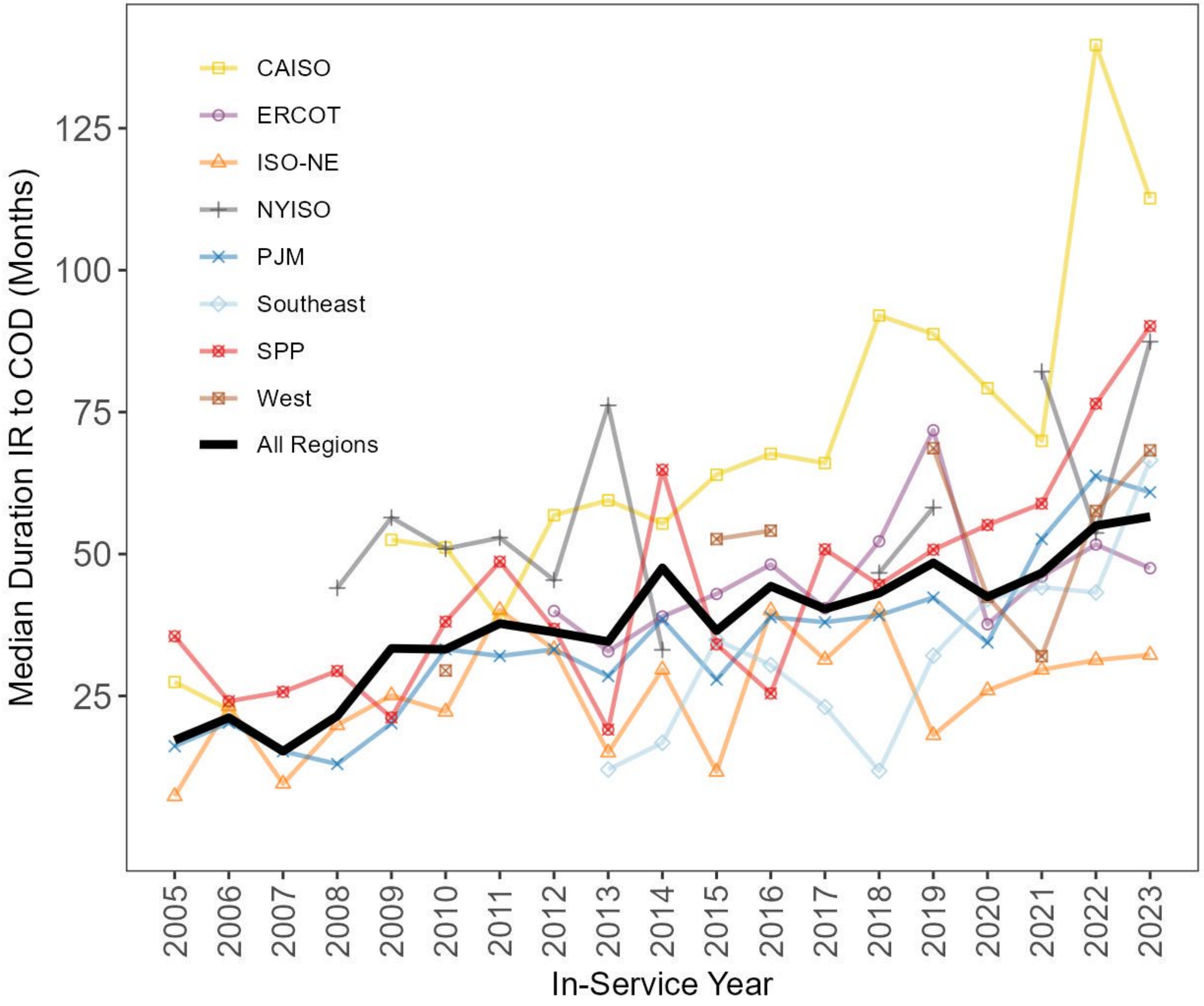
The median duration from interconnection request (IR) to commercial operations date (COD) continues to rise, approaching 5 years for projects completed in 2022-2023

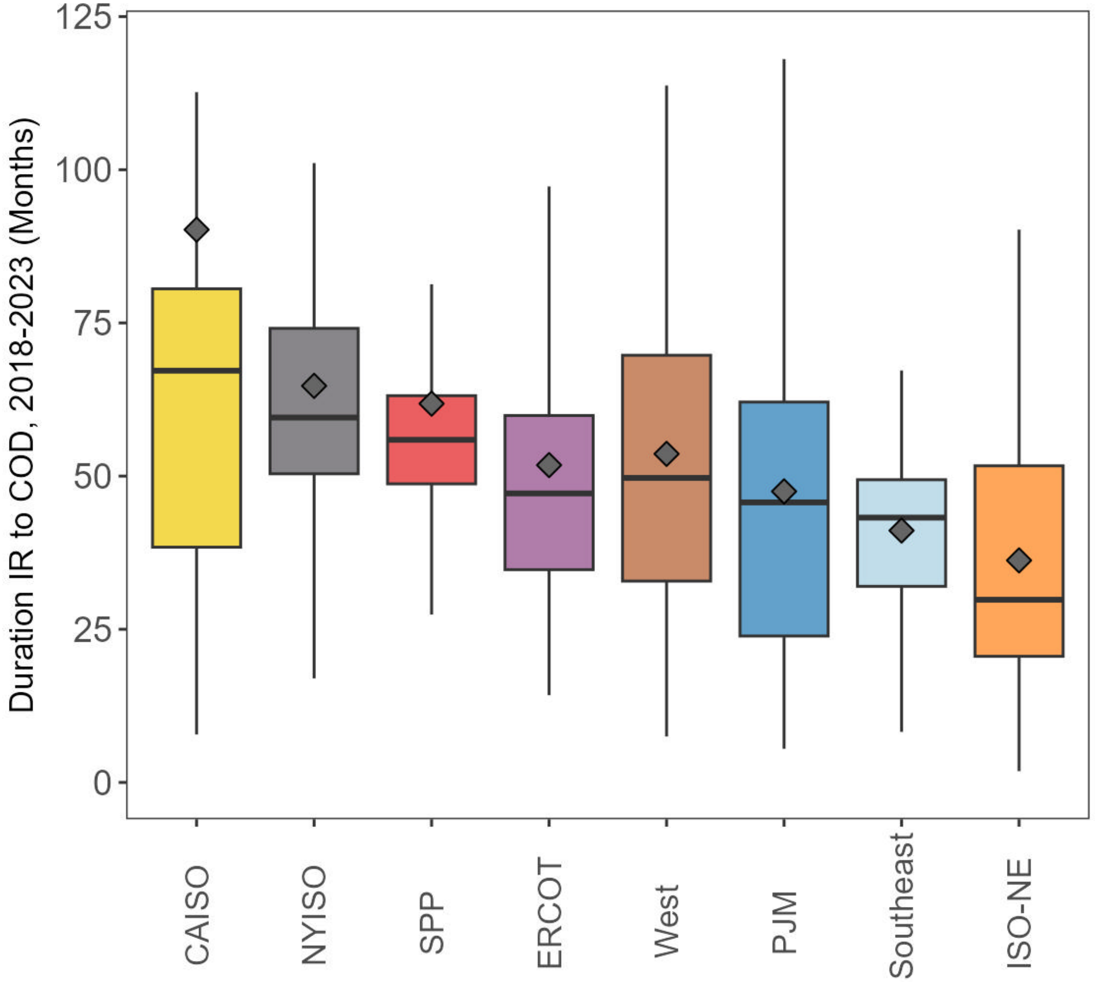


Notes: (1) In-service date was only available for 6 ISOs (CAISO, ERCOT, ISO-NE, NYISO, PJM, SPP) and 8 non-ISO BAs (Duke, FPL, LADWP, PSCo, SOCO, SEC, SRP, TSGT) representing 61% of all operational projects. (2) Duration is calculated as the number of months from the queue entry date to the commercial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

The request to operational timeline has been increasing in all regions; duration tends to be longest in CAISO, NYISO, and SPP and shortest in ISO-NE

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



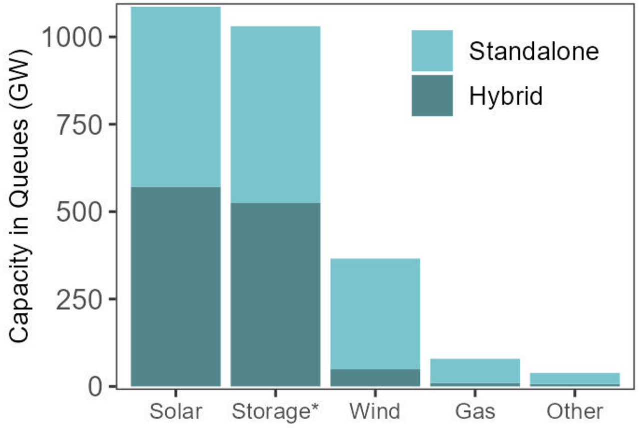


Notes: (1) In-service date was only available for 6 ISOs and 8 non-ISO BAs representing 61% of all operational projects; .(2) Duration is calculated as the number of months from the queue entry date to the commercial operations date.

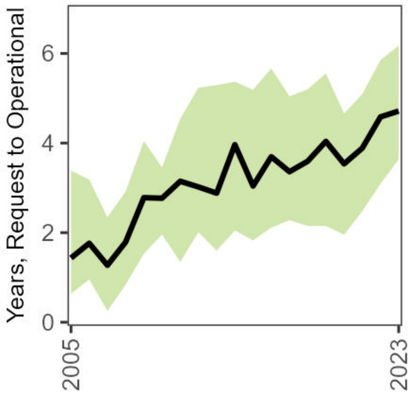
As of the end of 2023, there were nearly 11,600 projects actively seeking grid interconnection across the U.S., representing 1,570 GW of generation and approximately 1,030 GW of storage.

Developer interest in solar, storage, and wind is strong

- Solar, storage, and wind make up 95% of active queue capacity
- Over 1,200 GW of generation and storage projects submitted interconnection requests after the passage of the IRA.



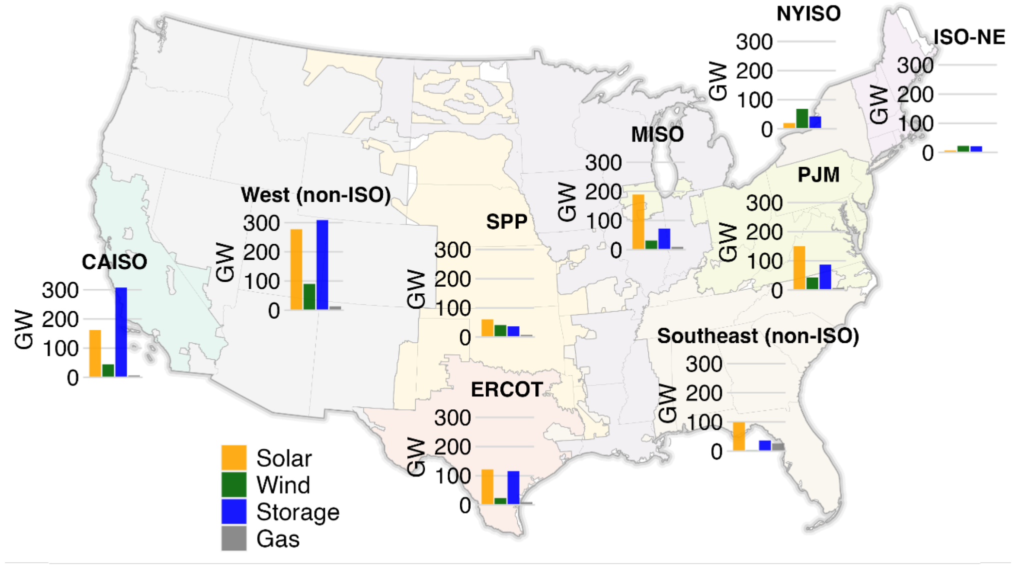
Completion rates are generally low; wait times are increasing



- Only ~20% of projects (14% of capacity) requesting interconnection from 2000-2018 reached COD by the end of 2023
- Interconnection delays are increasing: The typical project built in 2023 took nearly 5 years from the interconnection request to commercial operations[1], compared to 3 years in 2015 and <2 years in 2008.

Proposed capacity is widely distributed across the U.S.

- Substantial proposed solar capacity exists in most regions of the U.S.; >1 terawatt (TW) of solar active in queues
- >1 TW of storage is also active in the queues, primarily in the West and CAISO, but also in ERCOT, MISO, and PJM
- >360 GW of wind capacity in the queues, most in the non-ISO West, NYISO (offshore), PJM, and SPP.



FERC Order 2023 is an important step toward addressing interconnection backlogs and bottlenecks.
Additional operational and technical solutions like those outlined in the Interconnection Innovation eXchange (i2X) Interconnection Roadmap can further improve efficiency, reliability, and help meet decarbonization goals

DOE's Transmission Interconnection Roadmap identifies 35 solutions to mitigate queue backlogs, focus on 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

Final Roadmap is available now. 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.

Contact:

Joseph Rand (jrand@lbl.gov)

More Information:

- Visit https://emp.lbl.gov/queues to download the data used for this analysis and access an interactive data visualization tool
- Visit https://emp.lbl.gov/interconnection_costs for related research on interconnection costs

Acknowledgements:
This work was funded by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, in particular the Solar Energy Technologies Office and the Wind Energy Technologies, in part via the Interconnection Innovation eXchange (i2X). We thank Michele Boyd, Ammar Qusaibaty, Dexter Hendricks, Cynthia Bothwell, Jian Fu, Patrick Gilman, Gage Reber, and Paul Spitsen for supporting this project.

Appendix

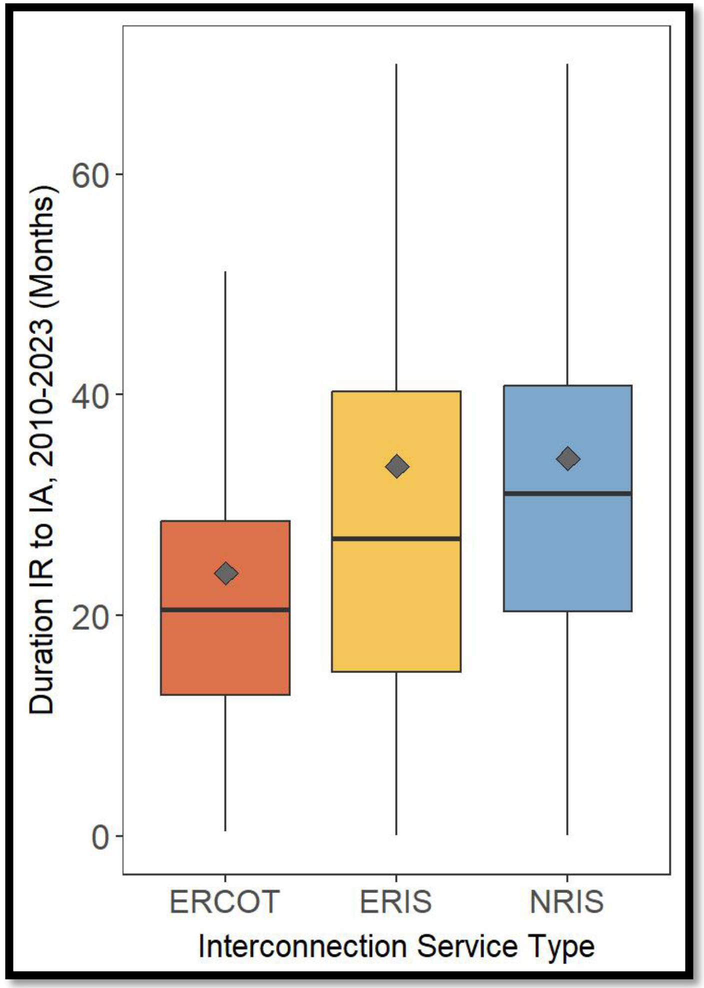
Balancing Areas Included In Data:

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	

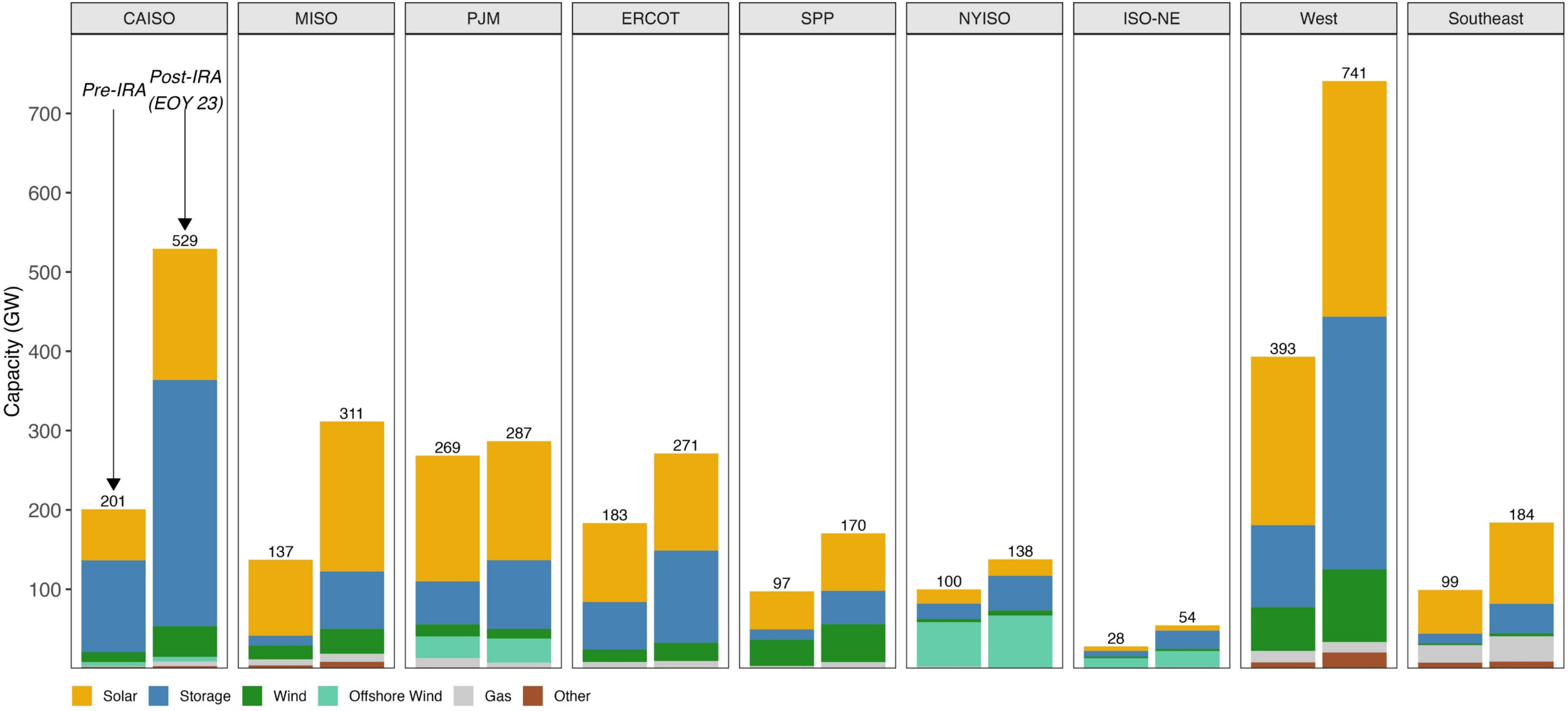
Important Analytical Additions in the 2024 Edition of "Queued Up"

- **Regulatory activities**
  - Summary of key activities at the federal and balancing area level (slide 7)
  - Analysis of post-IRA interconnection request volume (slide 13 + appendix)
- **ERIS and NRIS applications**
  - Capacity of ERIS and NRIS projects within the queue (slide 20)
  - Timeline from interconnection request to signed IA by service type (slide 38)
- **Completion rates**
  - Capacity of executed IAs by region and relative to retirements / load growth (slide 22)
  - Detailed analysis of the study phase at which queue withdrawals occur (slide 30)
  - Comparison of operational projects from queue data with EIA-860 (slide 26)
- **More detailed breakdown of 'other' project categories**
  - Detail on Nuclear, Hydro, and Geothermal projects in the queue (see Slide 18)
  - Breakout of non-battery storage within the Queues (slide 19)
- **Miscellaneous items**
  - Implied peak load contribution of projects in Queue (slide 14)
  - DOE Transmission Interconnection Roadmap for possible solutions (slide 46)



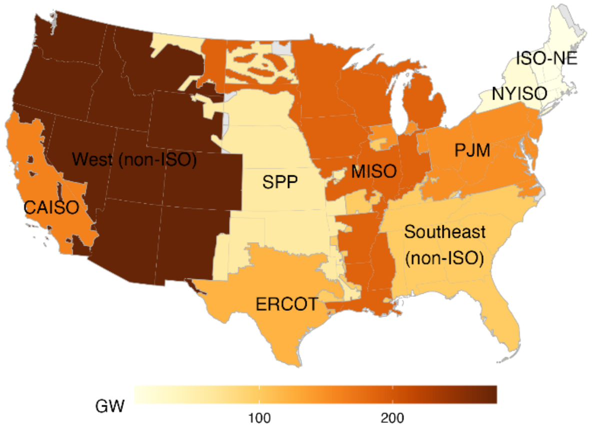
Notes: (1) See slide 38 for full explanation of chart. (2) y-axis measures time from submitting an interconnection request to receiving an interconnection agreement. (2) ERIS is energy-resource interconnection service, NRIS is network-resource interconnection service

Clean energy has ballooned in many regions' queues after the passage of the Inflation Reduction Act (IRA), which likely spurred additional development interest

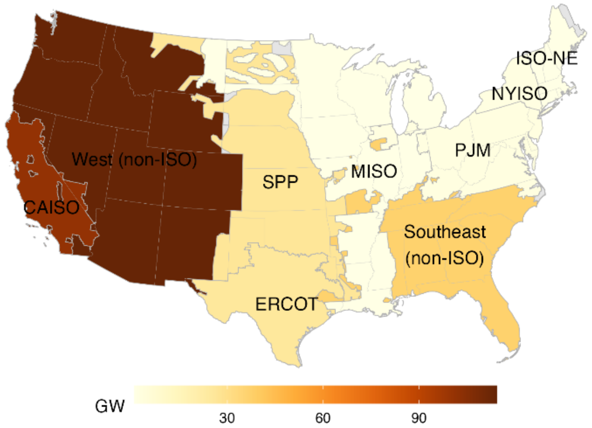


Proposed solar is widespread, with less in SPP and Northeast; Most wind in the West, SPP, and offshore; Proposed storage in all regions but highest in the West and CAISO; Gas is primarily in the Southeast

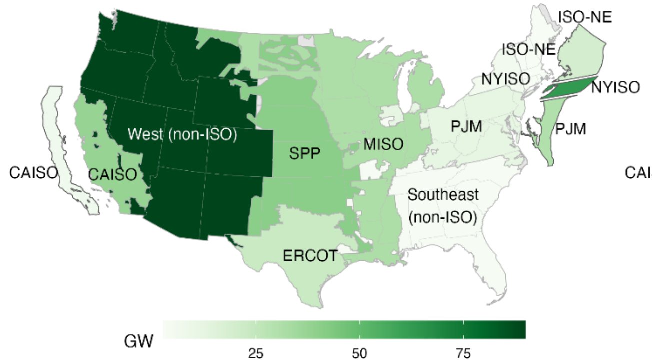
Total Solar Capacity in Interconnection Queues at the end of 2023



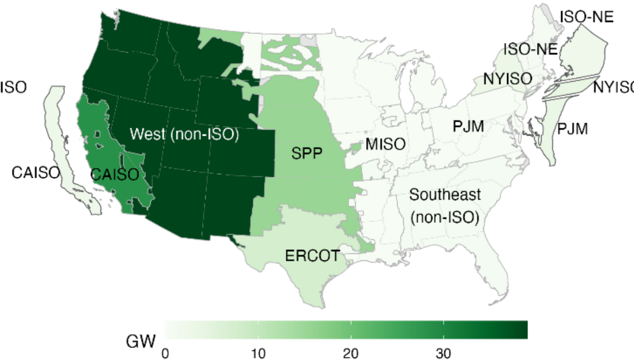
New Solar Capacity Added to Interconnection Queues in 2023



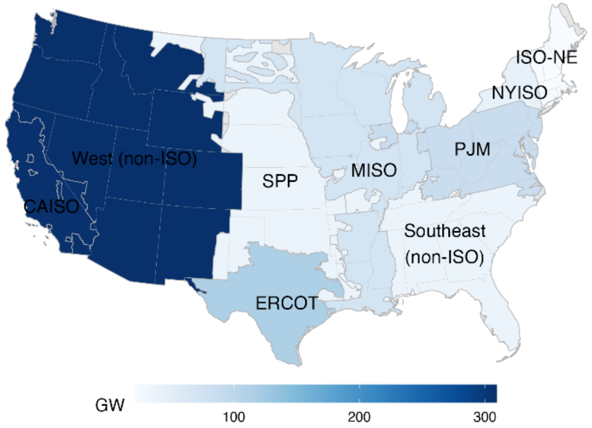
Total Wind Capacity in Interconnection Queues at the end of 2023



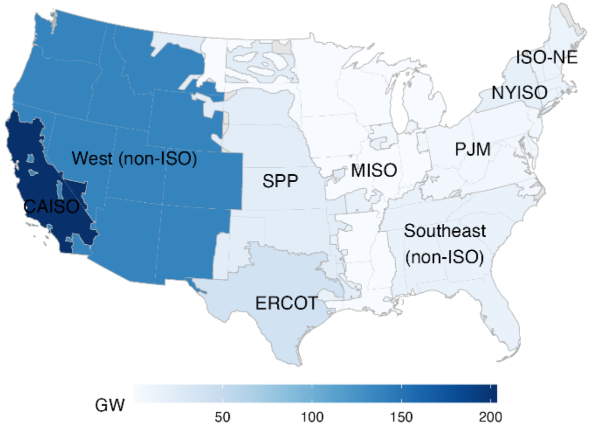
New Wind Capacity Added to Interconnection Queues in 2023



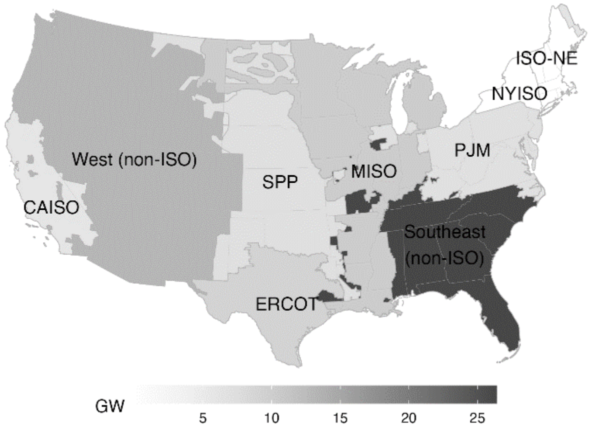
Total Storage Capacity in Interconnection Queues at the end of 2023



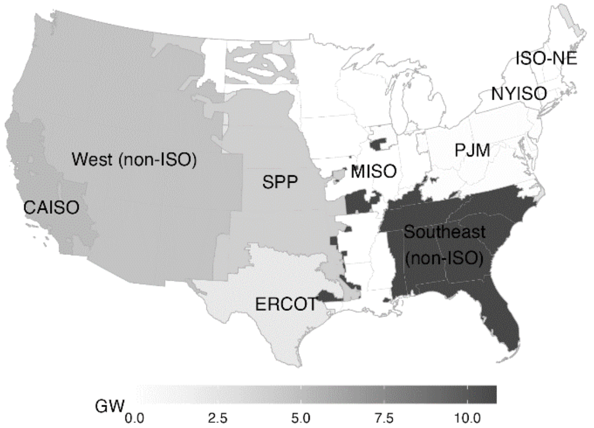
New Storage Capacity Added to Interconnection Queues in 2023



Total Gas Capacity in Interconnection Queues at the end of 2023

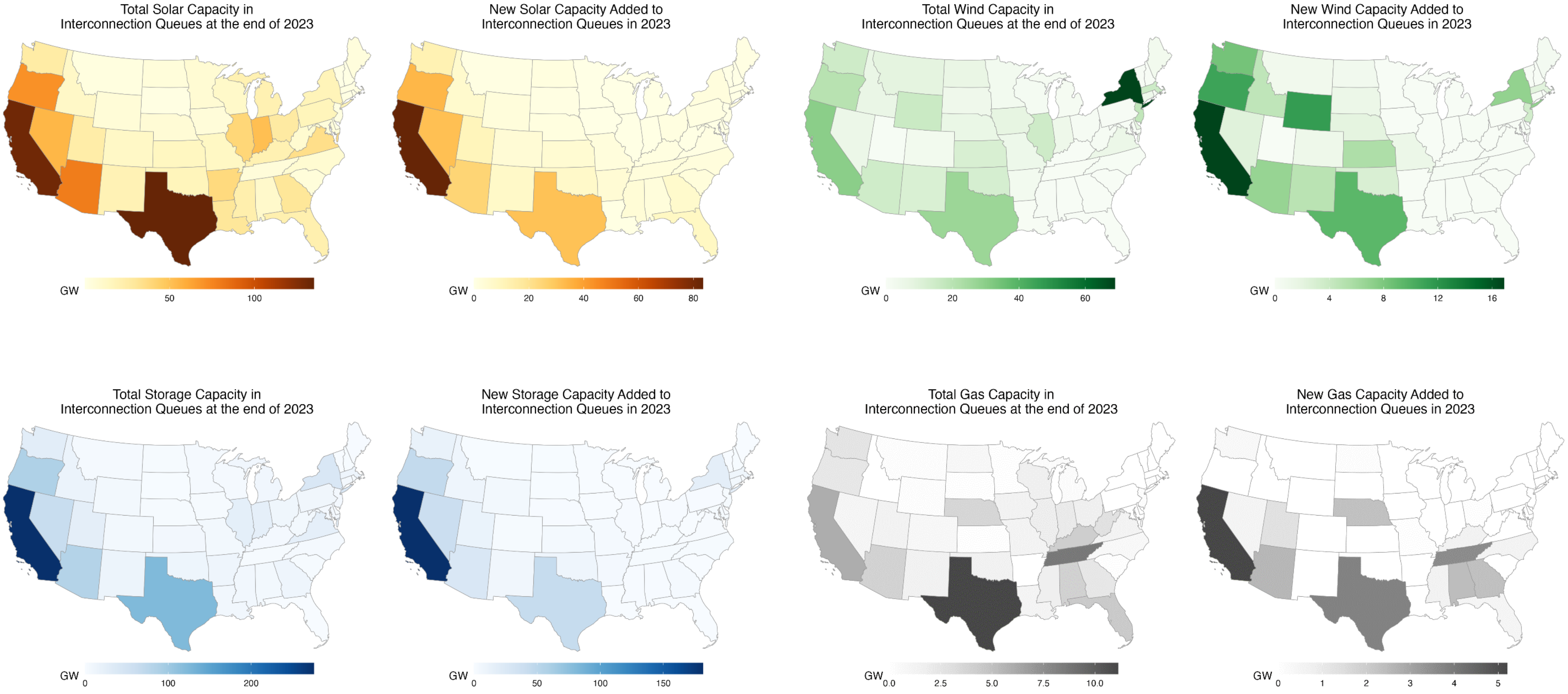


New Gas Capacity Added to Interconnection Queues in 2023

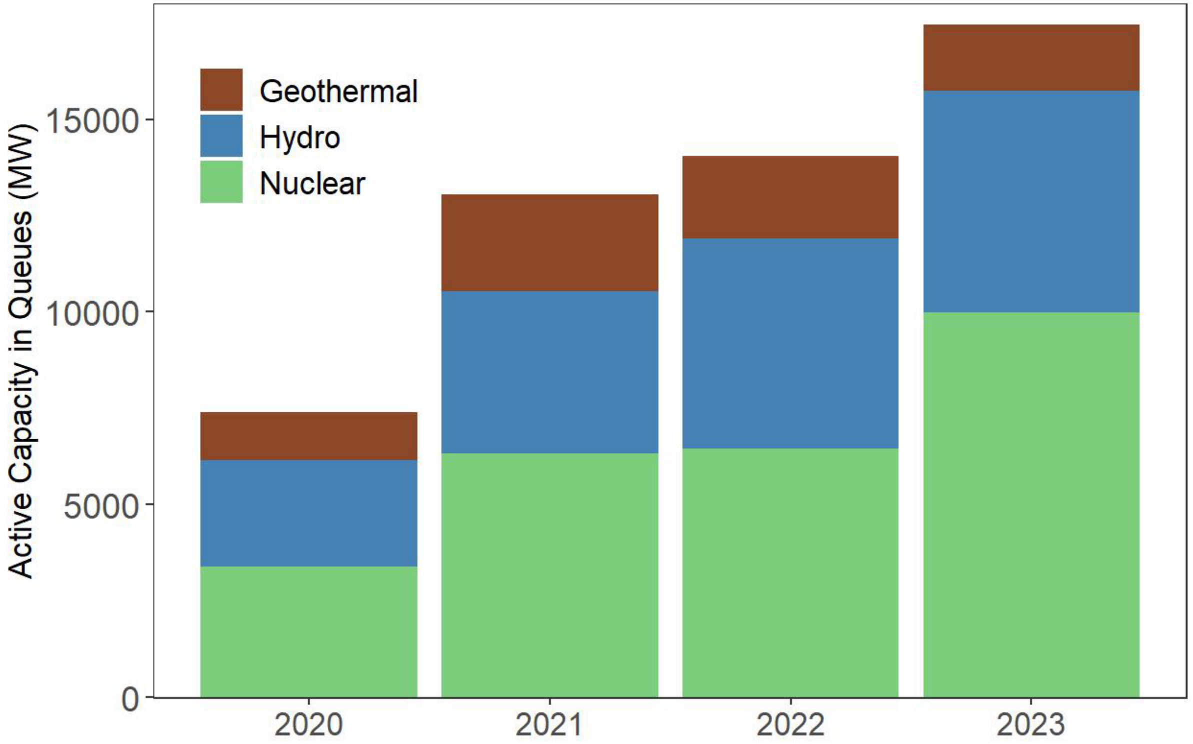


Note: Proposed and ongoing reforms in MISO and PJM resulted in few (or no) new requests in those regions in 2023 (see slide 7)

CA and TX dominate solar requests; Wind is in the West, Plains, and East Coast (offshore); Storage is highest in CA, TX, OR, AZ; Most gas in TX and Southeast, with new requests in CA



Although Nuclear, Hydro, and Geothermal make up less than <1% of the active capacity in queues, this still represents >15 GW of capacity, indicating important development interest

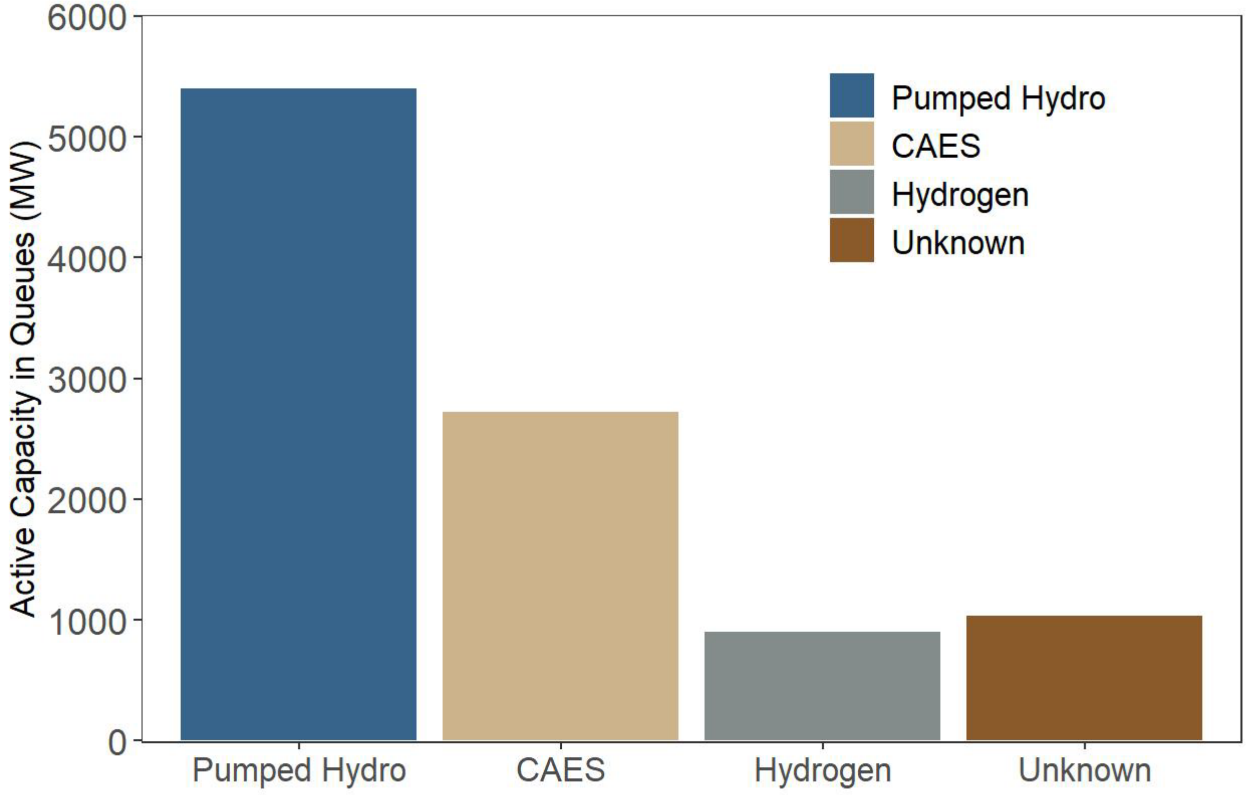


	Active Capacity in Queues (MW)		
Region	Hydro	Nuclear	Geothermal
CAISO	74		
ISO-NE	35		
MISO	201		
PJM	363		
Southeast (non-ISO)	693	5,441	
West (non-ISO)	4,380	4,552	1,711

Active Nuclear capacity seeking grid connection increased to 10 GW in 2023 (up from ~6.5 GW in 2022), while Hydropower capacity held steady at ~5.7 GW. Geothermal capacity contracted slightly to 1.7 GW (from 2.1 in 2022).

Hydropower plants are proposed in several regions, but the majority of capacity is in the non-ISO West. Proposed Nuclear is only in the non-ISO Southeast and West, and Geothermal is only found in the West.

Batteries make up ~99% of storage capacity in the queues, but there are 10 GW of active requests for Pumped Hydro, Hydrogen, and Compressed Air Energy Storage (CAES)



	Active Capacity in Queues (MW)			
Region	Pumped Storage	CAES	Unknown	Hydrogen
CAISO	2,402		1,036	
West (non-ISO)	3,000	2,720		902

All active requests for non-battery storage projects are in CAISO and the non-ISO West.

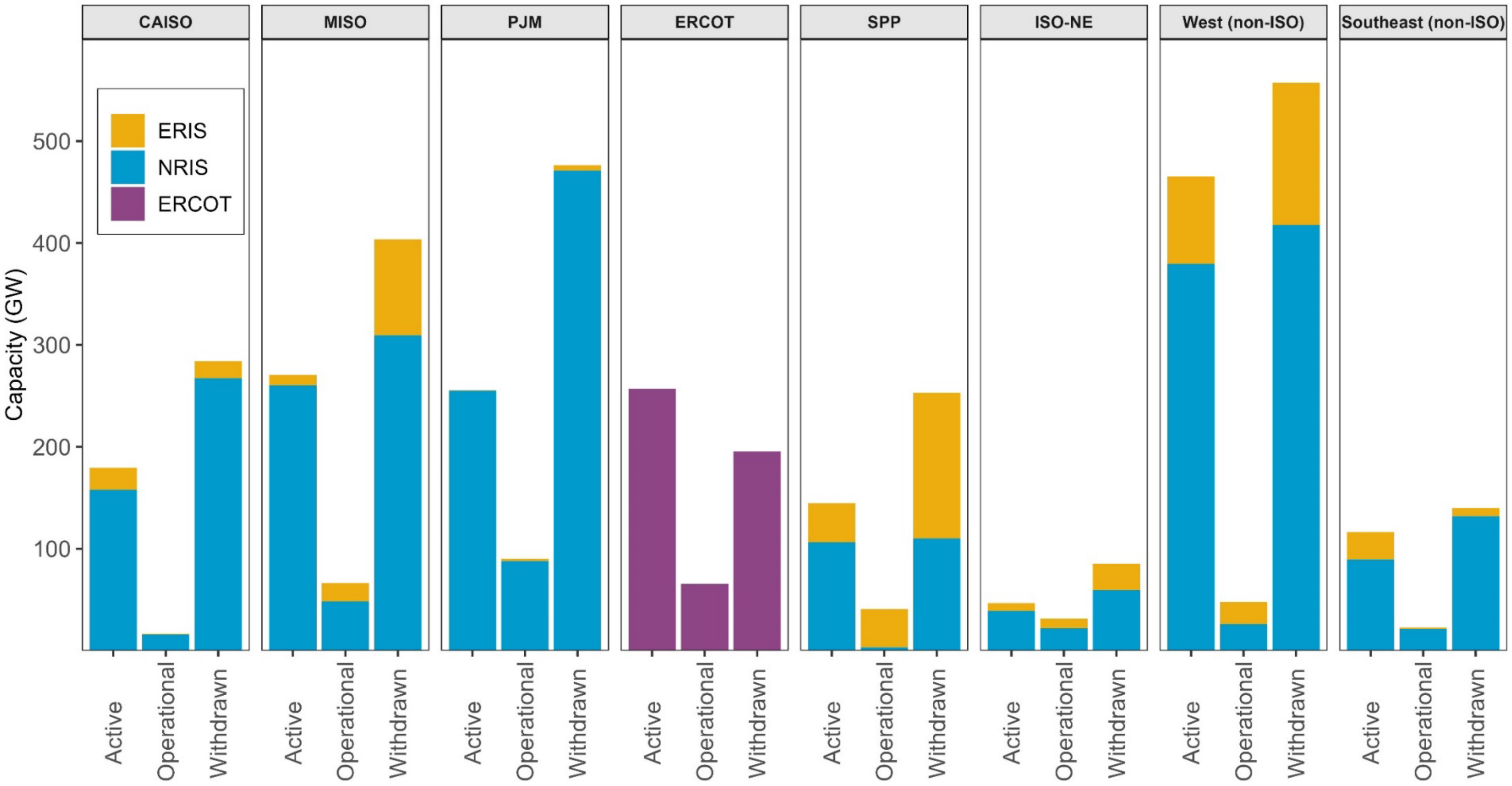
Hybrids comprise a sizable fraction of all proposed solar plants in multiple regions; wind hybrids are less common overall but still a large proportion in CAISO + West

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

74%* of all active capacity requested Network Resource Interconnection Service (NRIS). Energy Resource Interconnection Service (ERIS) is less common. ERCOT's approach is more similar to ERIS

*Outside of ERCOT, **87%** of active capacity requested to be studied for NRIS.



Network Resource Interconnection Service (NRIS) allows the Interconnection Customer to connect its Generating Facility to the Transmission Provider's Transmission System and be deliverable during congested grid conditions, such that the generator can be designated as a capacity resource and contribute to resource adequacy requirements.

Energy Resource Interconnection Service (ERIS) allows the Interconnection Customer to connect its Generating Facility to the Transmission Provider's Transmission System to be eligible to deliver the Generating Facility's electric output using the existing firm or non-firm capacity of the Transmission Provider's Transmission System on an "as available" basis.

	% of Active Capacity	
region	**ERIS**	**NRIS**
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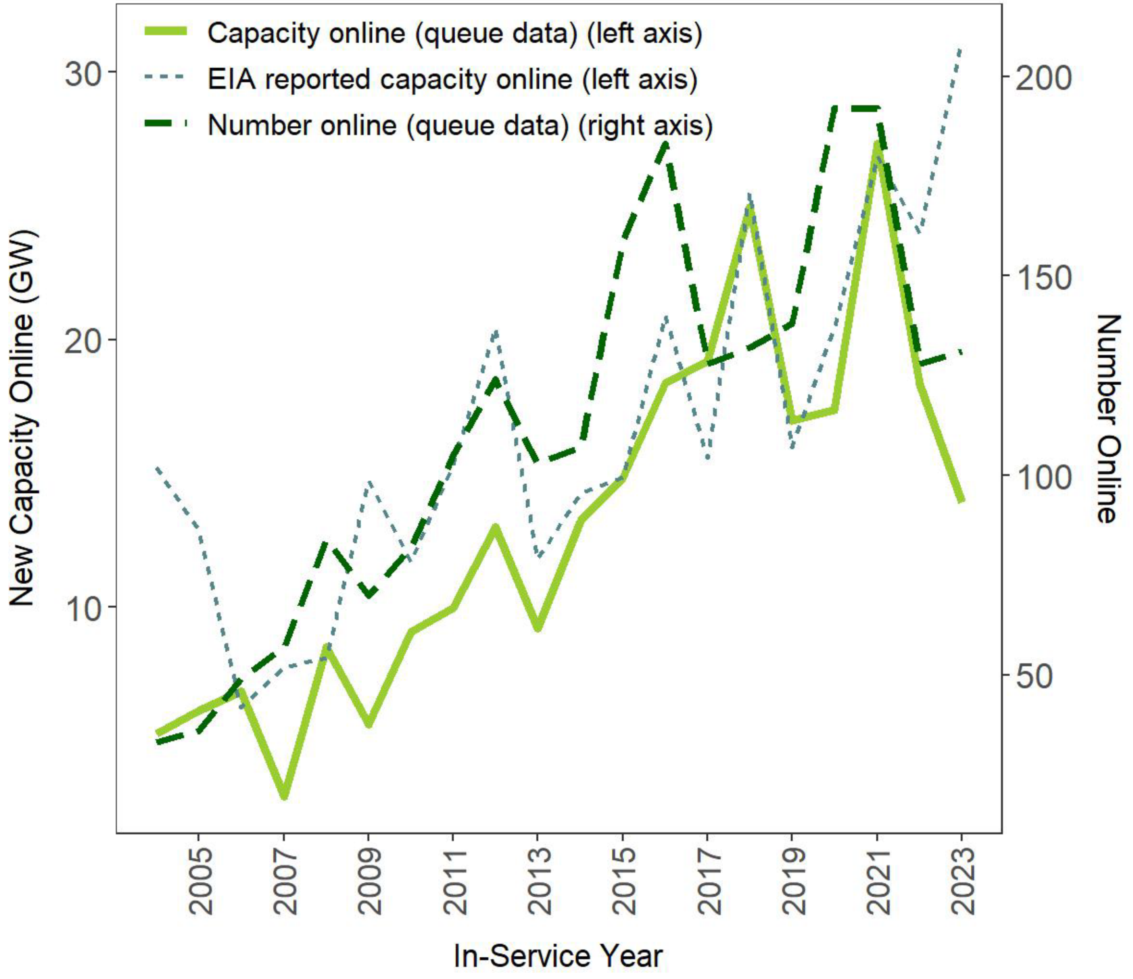
MISO	4%	96%
PJM	0%*	100%*
SPP	26%	74%
ISO-NE	16%	84%
West	18%	82%
Southeast	23%	77%

**Some projects in PJM are requesting ERIS, but their capacity is so small they round to 0% of total capacity*

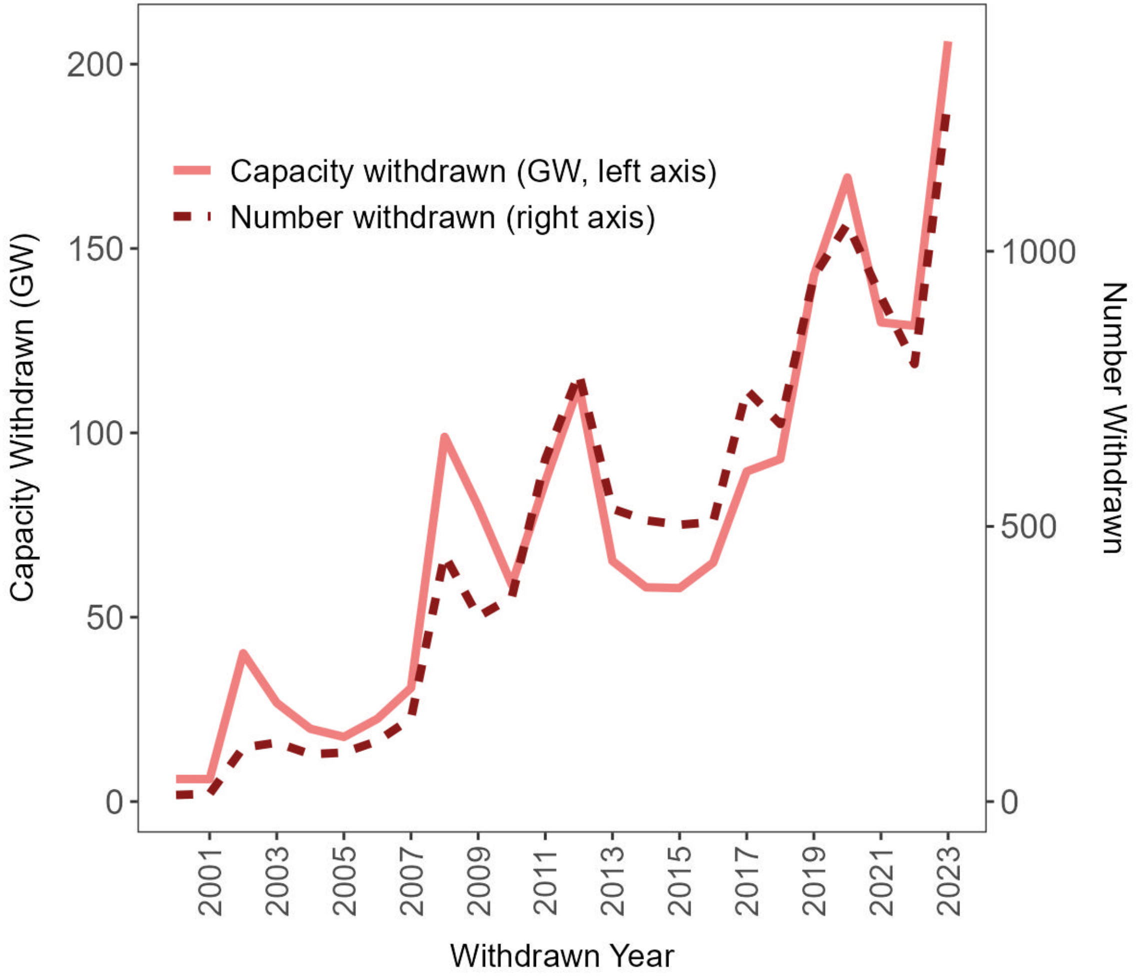
Notes: (1) NRIS and ERIS were developed under FERC Order 2003, and apply to FERC-jurisdictional transmission providers. (2) ERCOT is not FERC jurisdictional, but uses a "connect and manage" interconnection service that is more similar to ERIS. (3) Data available for 27,693 requests from 6 ISOs and 2 non-ISO balancing areas.

Volume (number and capacity) of operational and withdrawn projects is trending upward; more than 1,250 requests (>200 GW) were withdrawn in 2023

Operational Projects



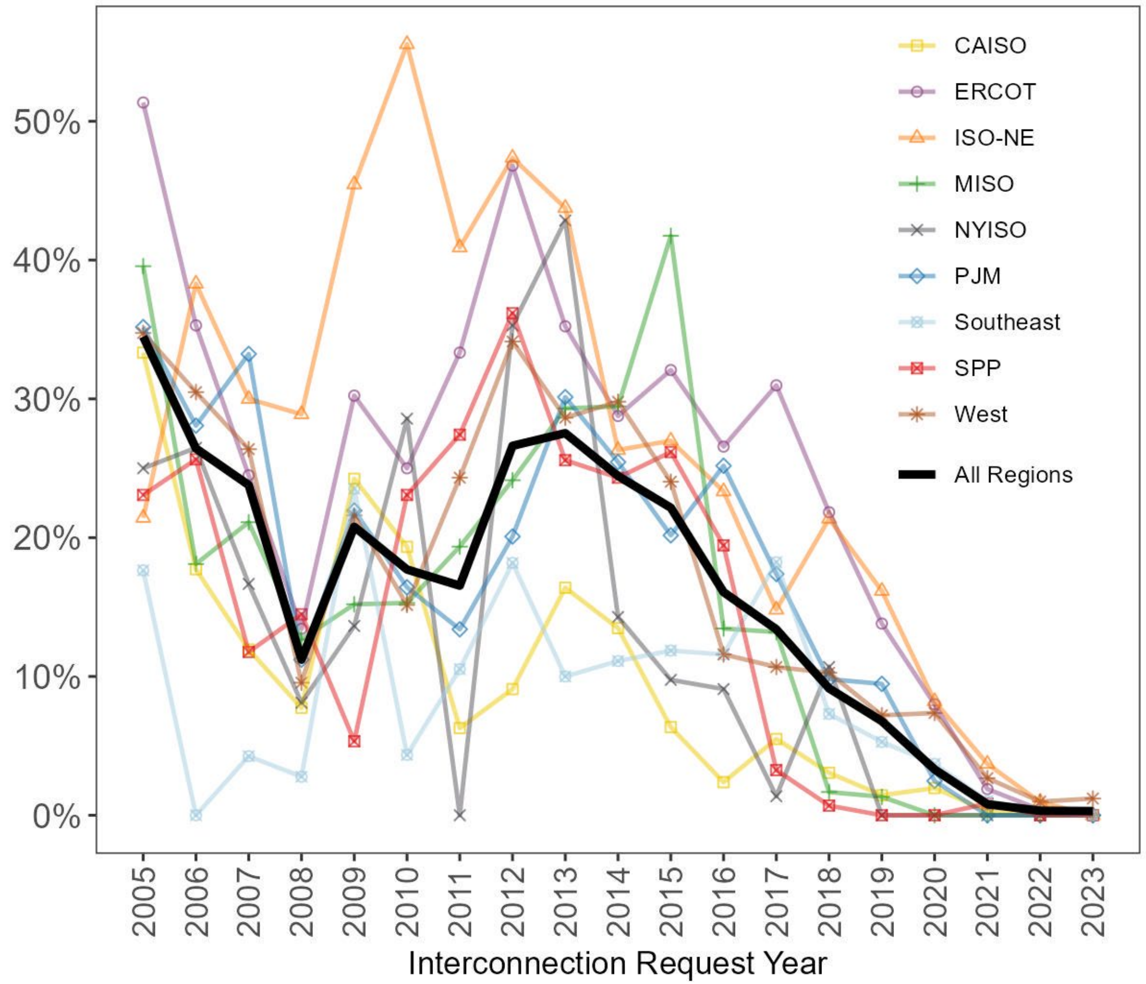
Withdrawn Projects



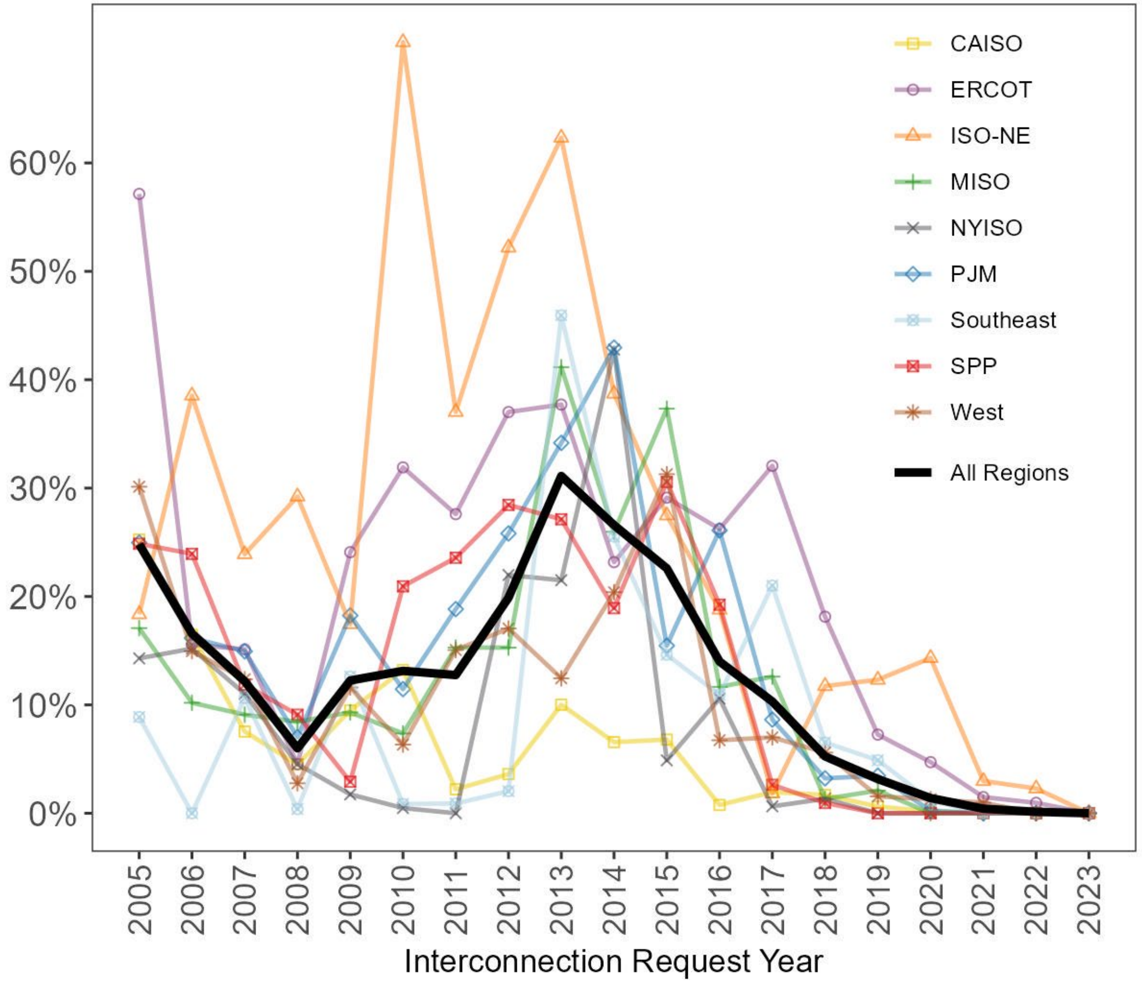
Note: (1) In-service year only available for 61% of the "operational" project sample; withdrawn year only available for 64% of the "withdrawn" project sample. These figures therefore only include a subset of total data. (2) The discrepancy between queue capacity and EIA capacity in recent years (2022-2023) is attributable to lags in online/operational status reporting in the queue data.

ISO-NE and ERCOT have consistently had higher completion rates than other regions; CAISO has been consistently lower

By Number of Requests

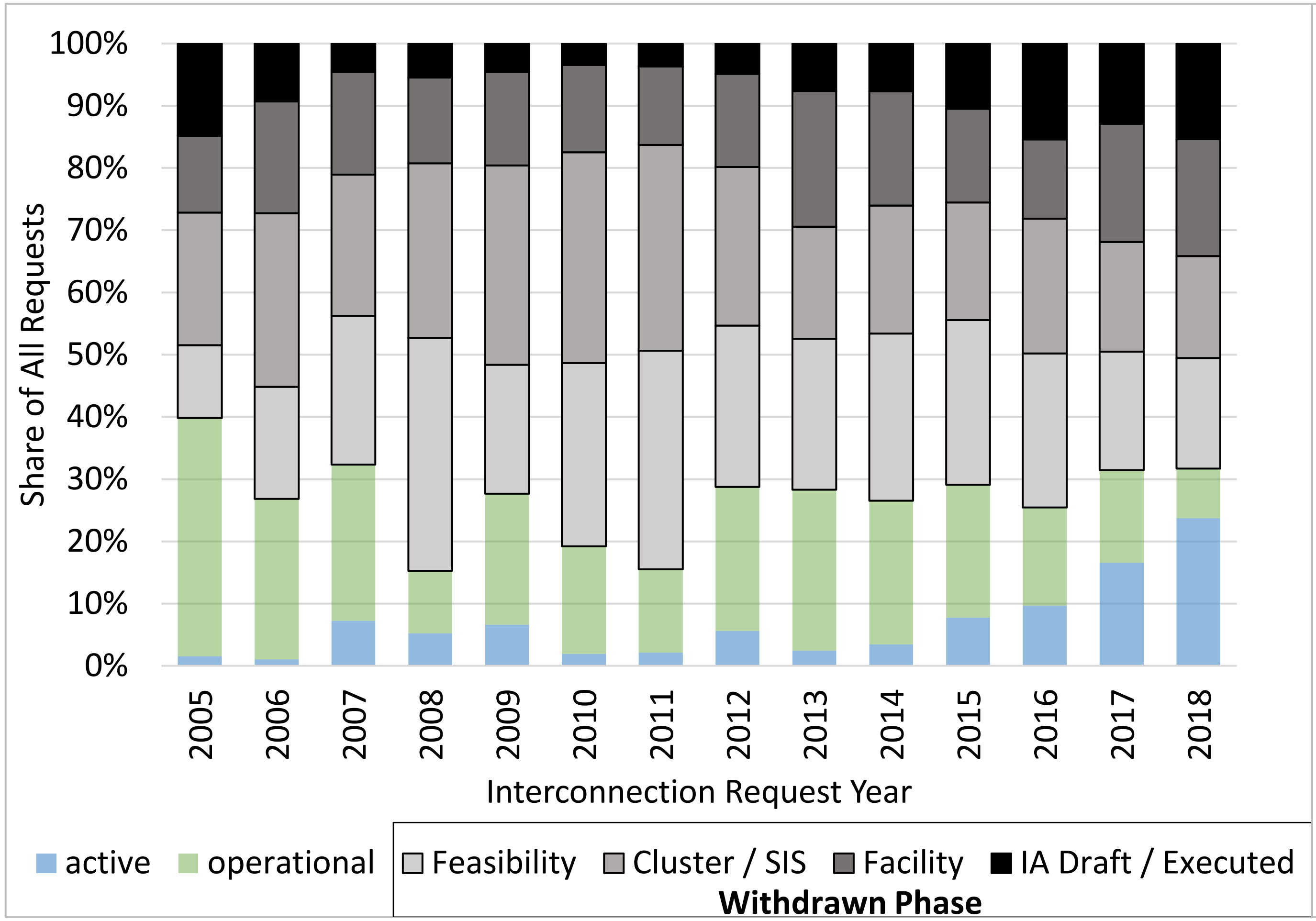


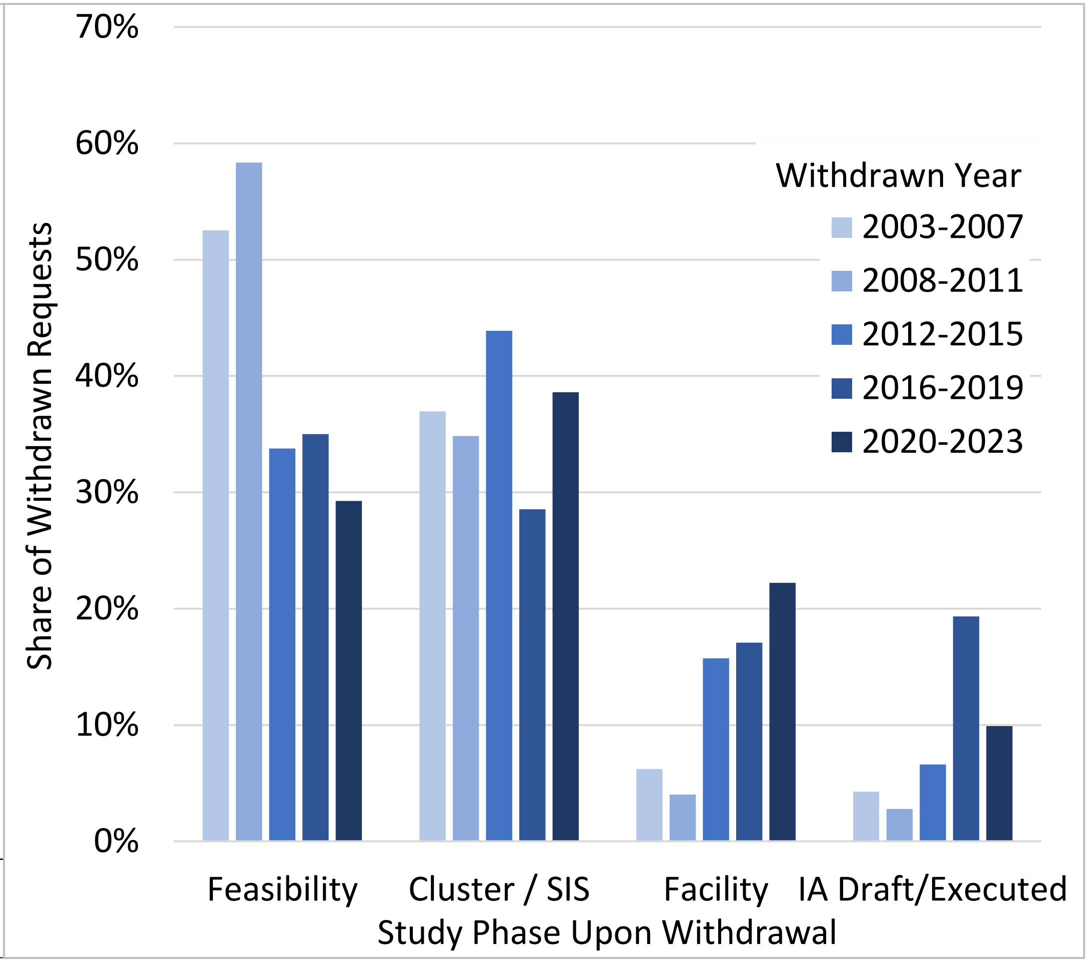
By Capacity of Requests



Note: (1) Completion rate shown here is calculated by <u>number</u> of projects online by end of 2023, not capacity-weighted. (2) Calculated as number of projects operational as of EOY 2023 divided by the total number of requests per year. (3) Includes data from 7 ISOs and 30 non-ISO BAs.

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



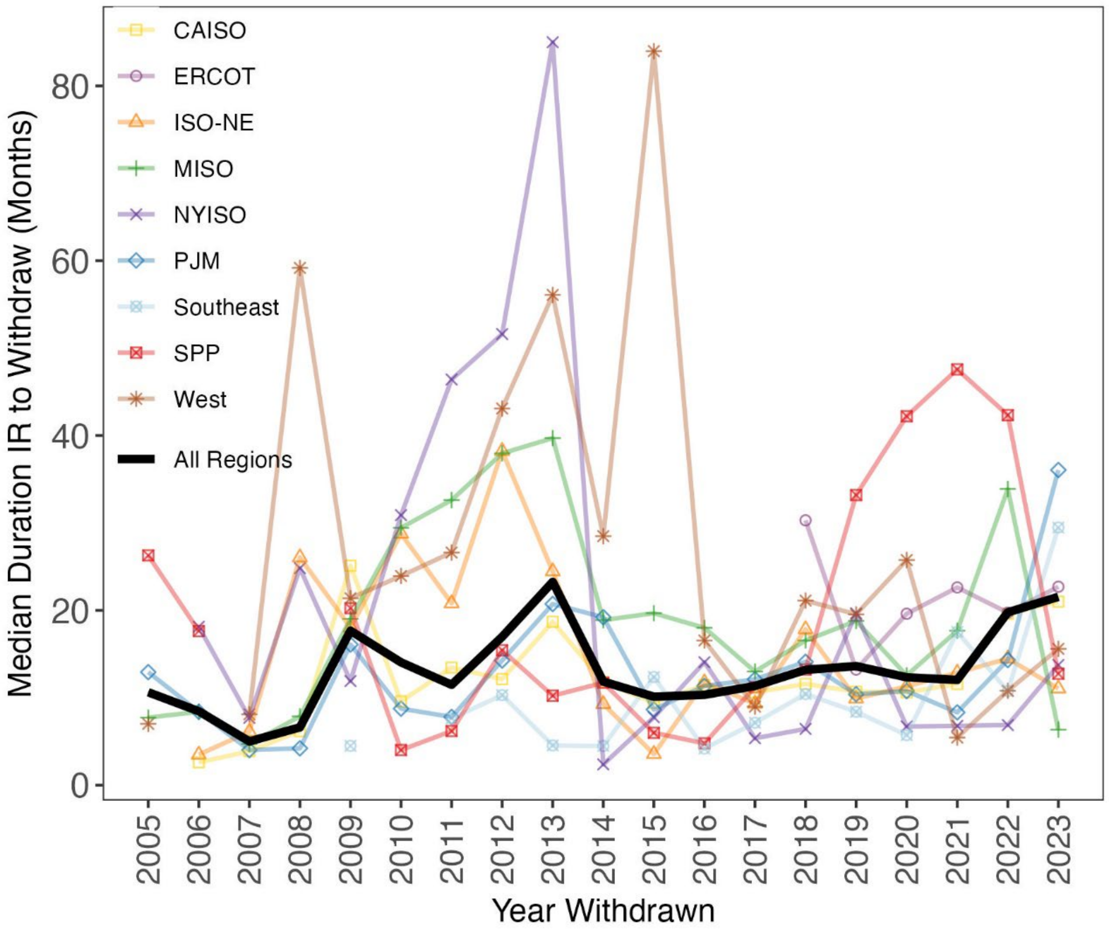


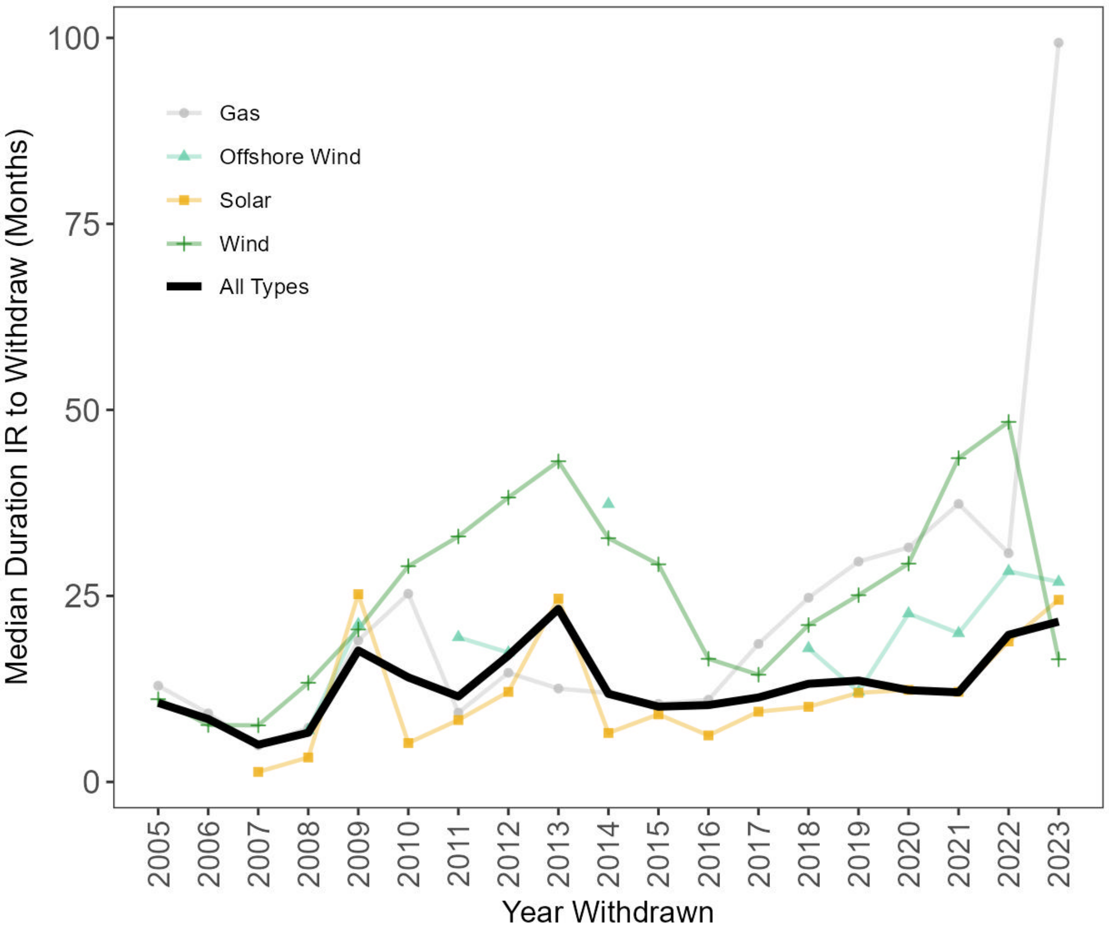
Late-stage withdrawals can be more costly for developers (sunk costs, deposits) and can trigger re-studies for other projects in the queue, increasing delays.

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).

Duration to withdrawal is trending up in several regions, and across technologies. A number of old Gas requests were withdrawn in Southern Co., NYISO, and PJM in 2023

Duration Analyzed: *Interconnection Request (IR)* → *Withdrawn Date* → *Commercial Operations (COD)*

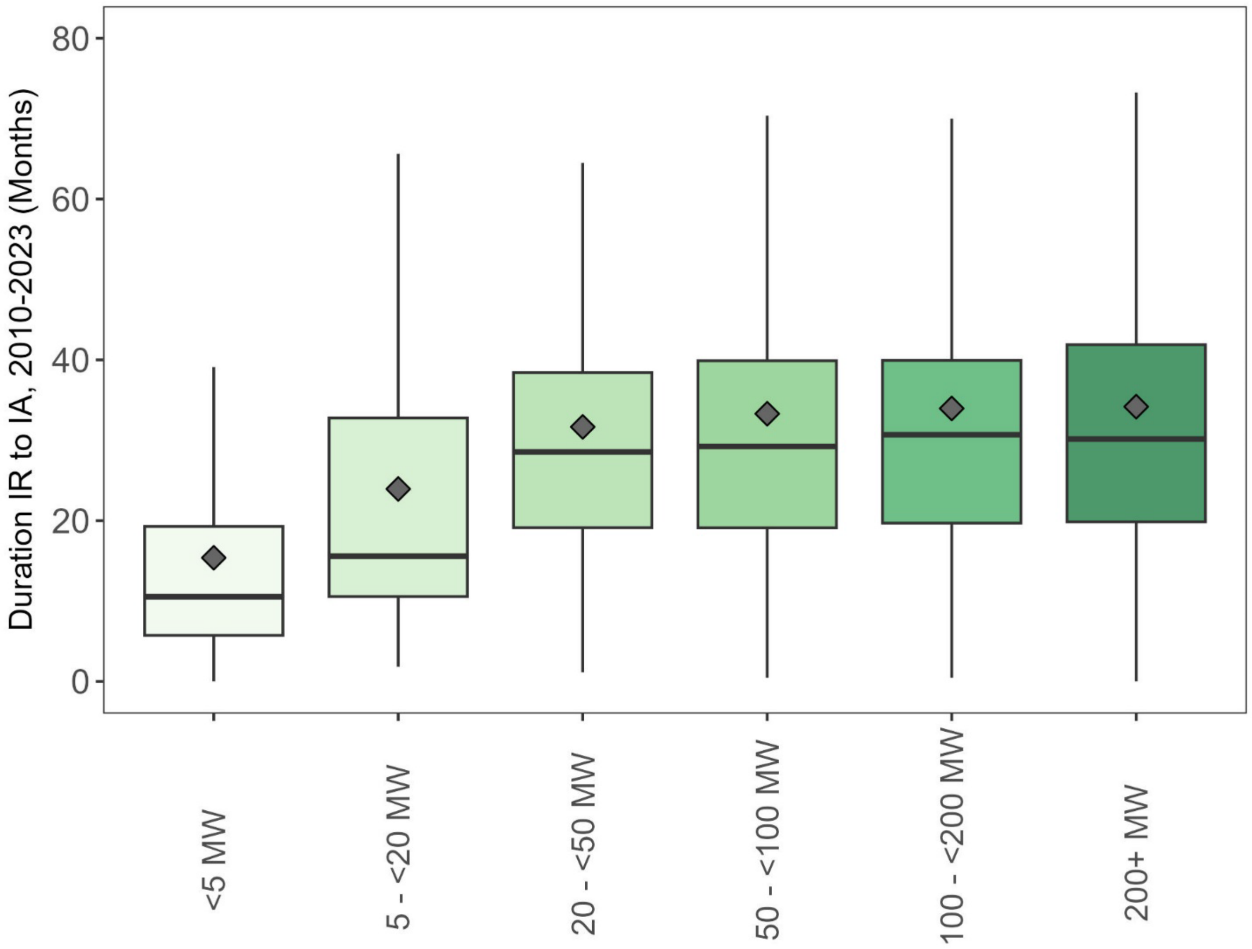




Notes: (1) Withdrawn date was available for 11,680 projects from 7 ISOs and 8 non-ISO balancing areas. (2) Duration is calculated as the number of months from the queue entry date to the date the project was withdrawn from queues.

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

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

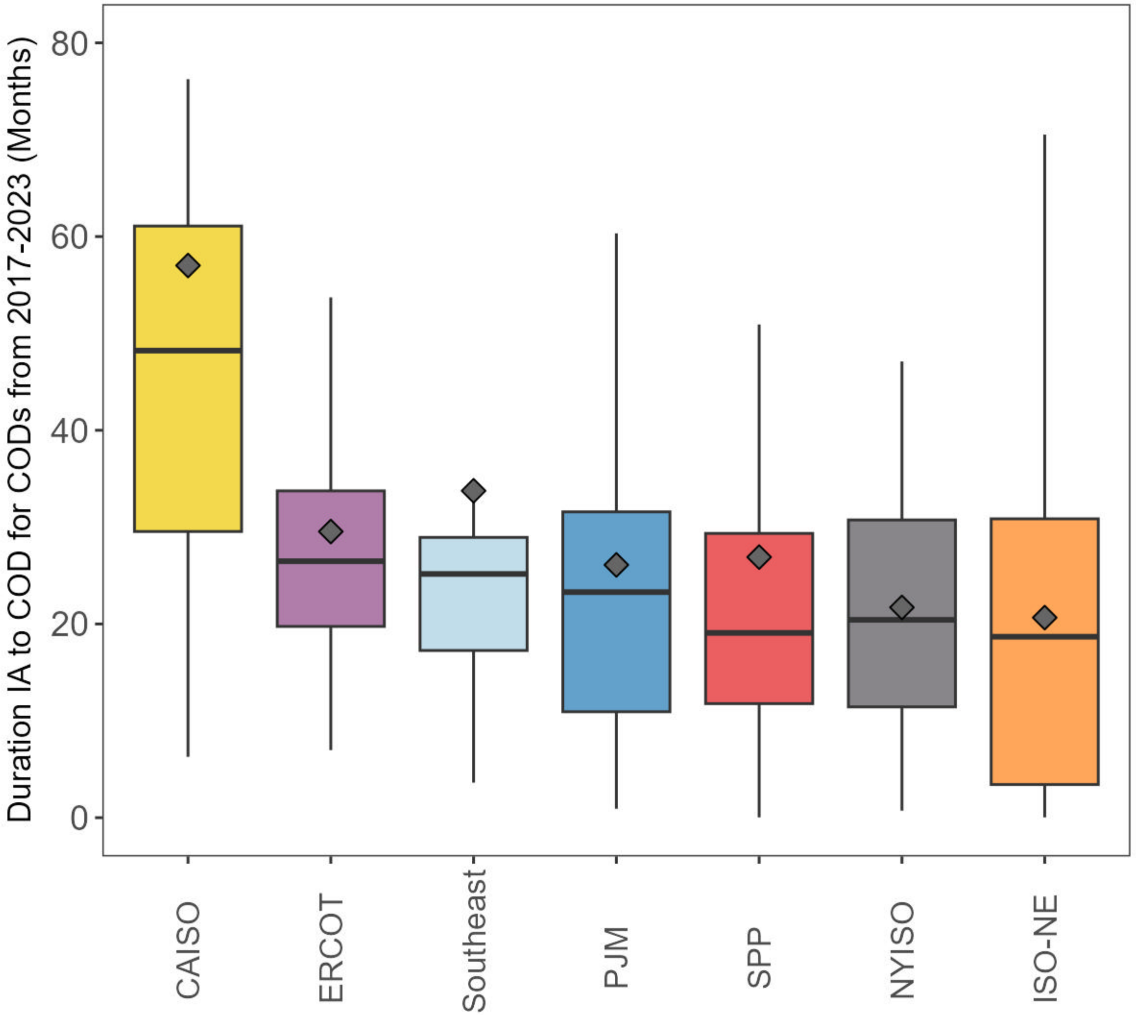


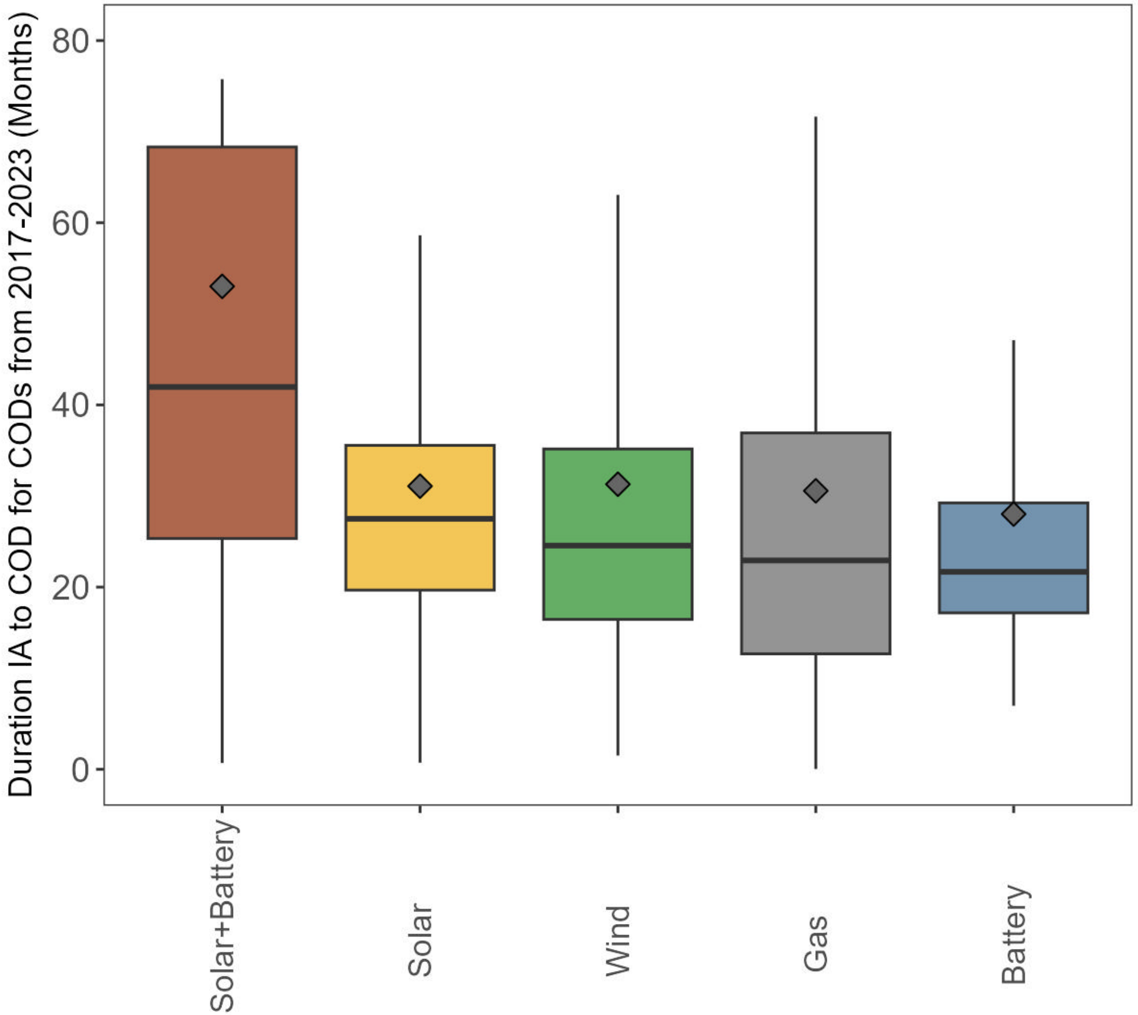
- On average, projects with rated capacity <20 MW complete studies and execute interconnection agreements much faster than larger projects
  - Median is 11 months for projects <5 MW
  - 18 months for projects 5 - <20 MW
- The median duration for projects 20 MW or larger hovers around 30 months across 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.

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

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

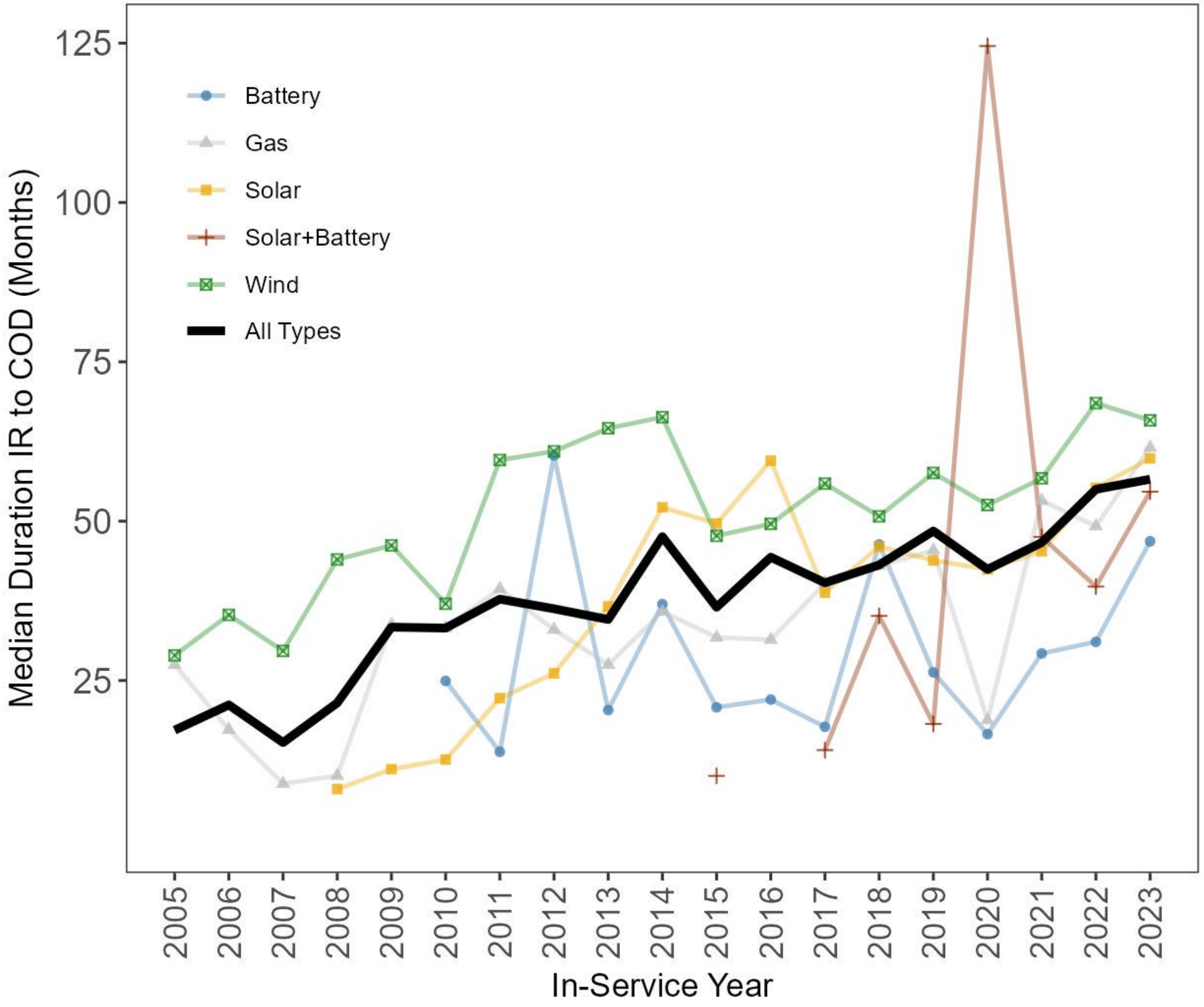


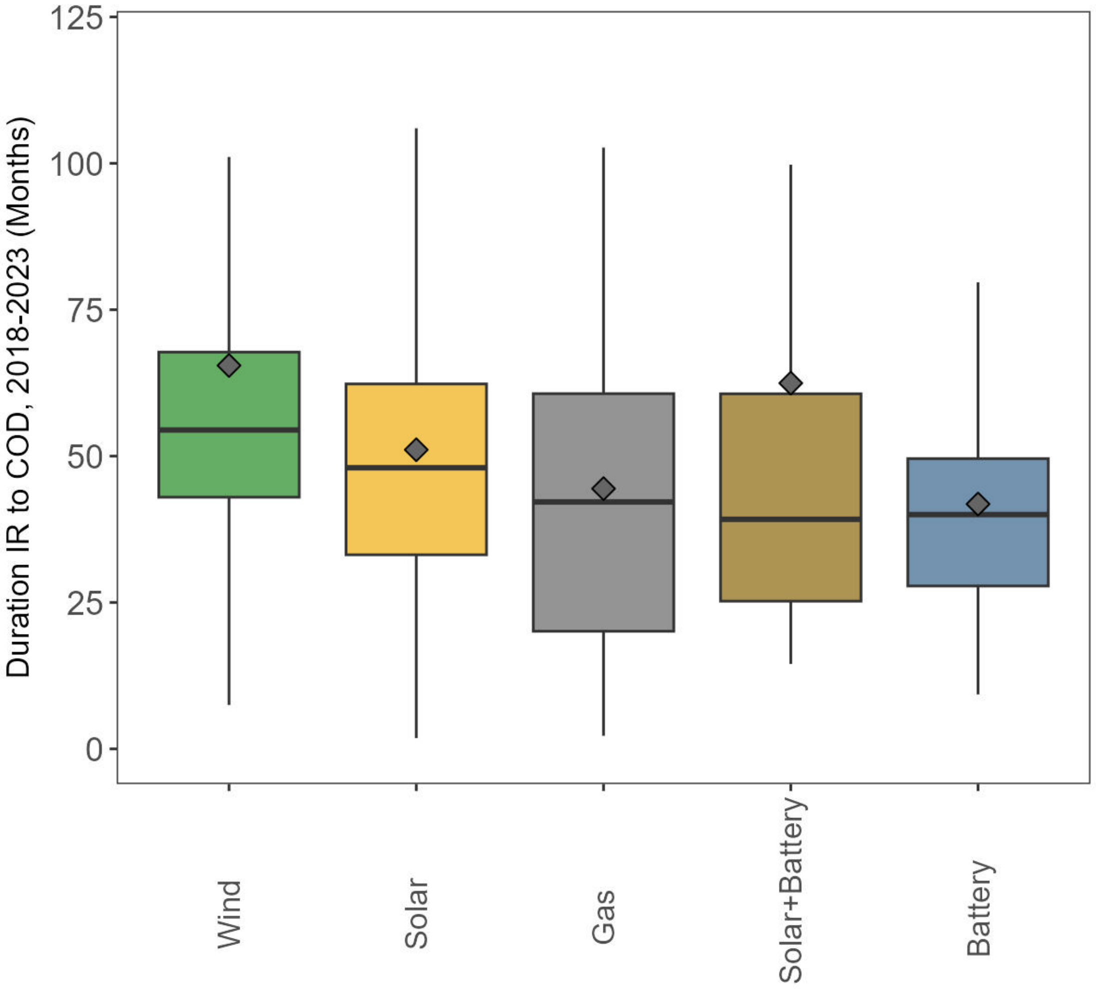


Notes: (1) Data were only available for 836 projects across 5 ISO/RTOs and one utility (Southern Company), out of 4,155 total "operational" projects in the full dataset. (2) Not all data used in this analysis are publicly available.

Wind projects typically take longer than other types to go from request date to commercial operations, with standalone battery projects moving fastest

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

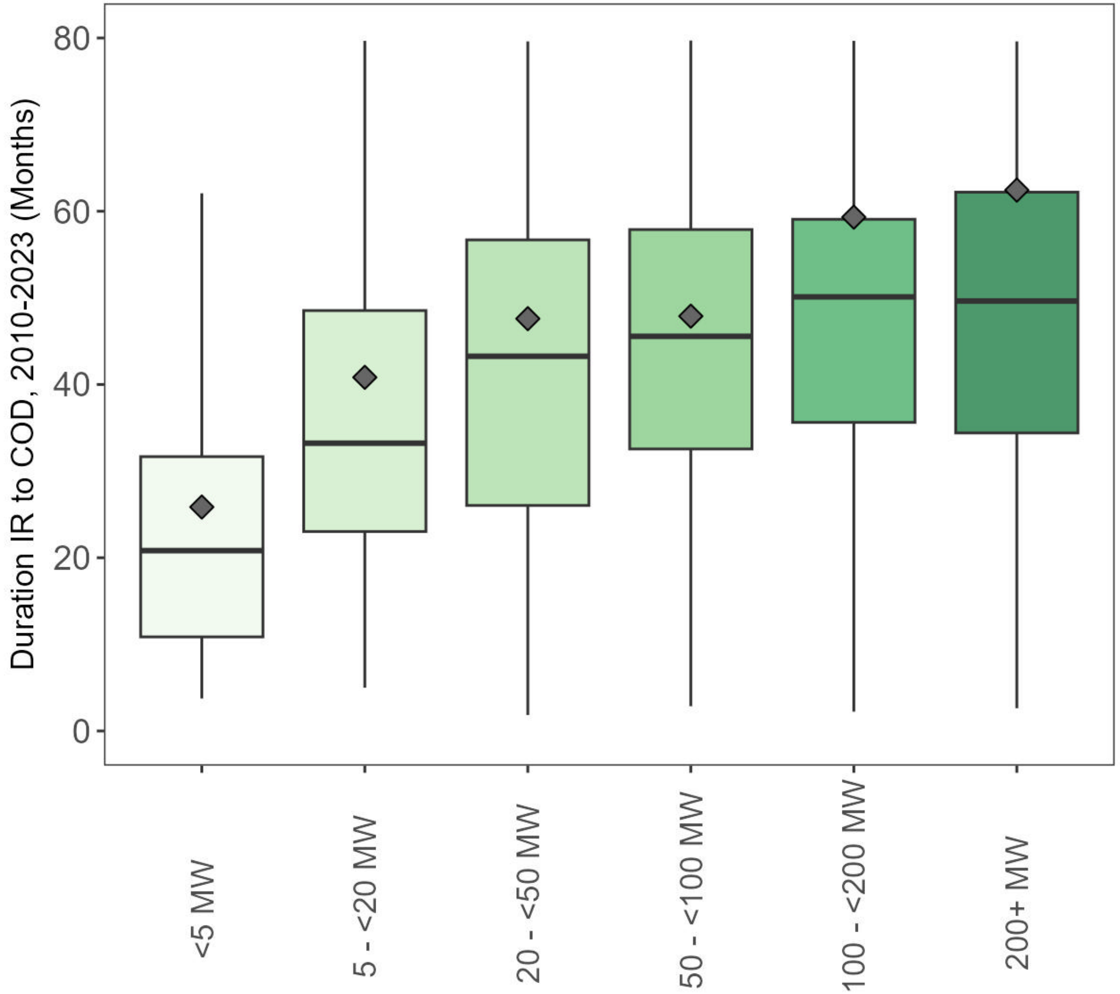




Notes: (1) In-service date was only available for 6 ISOs and 8 non-ISO BAs representing 61% of all operational projects; .(2) Duration is calculated as the number of months from the queue entry date to the commercial operations date.

Larger projects have longer development timelines: The average IR to COD duration increases monotonically by project size (MW)

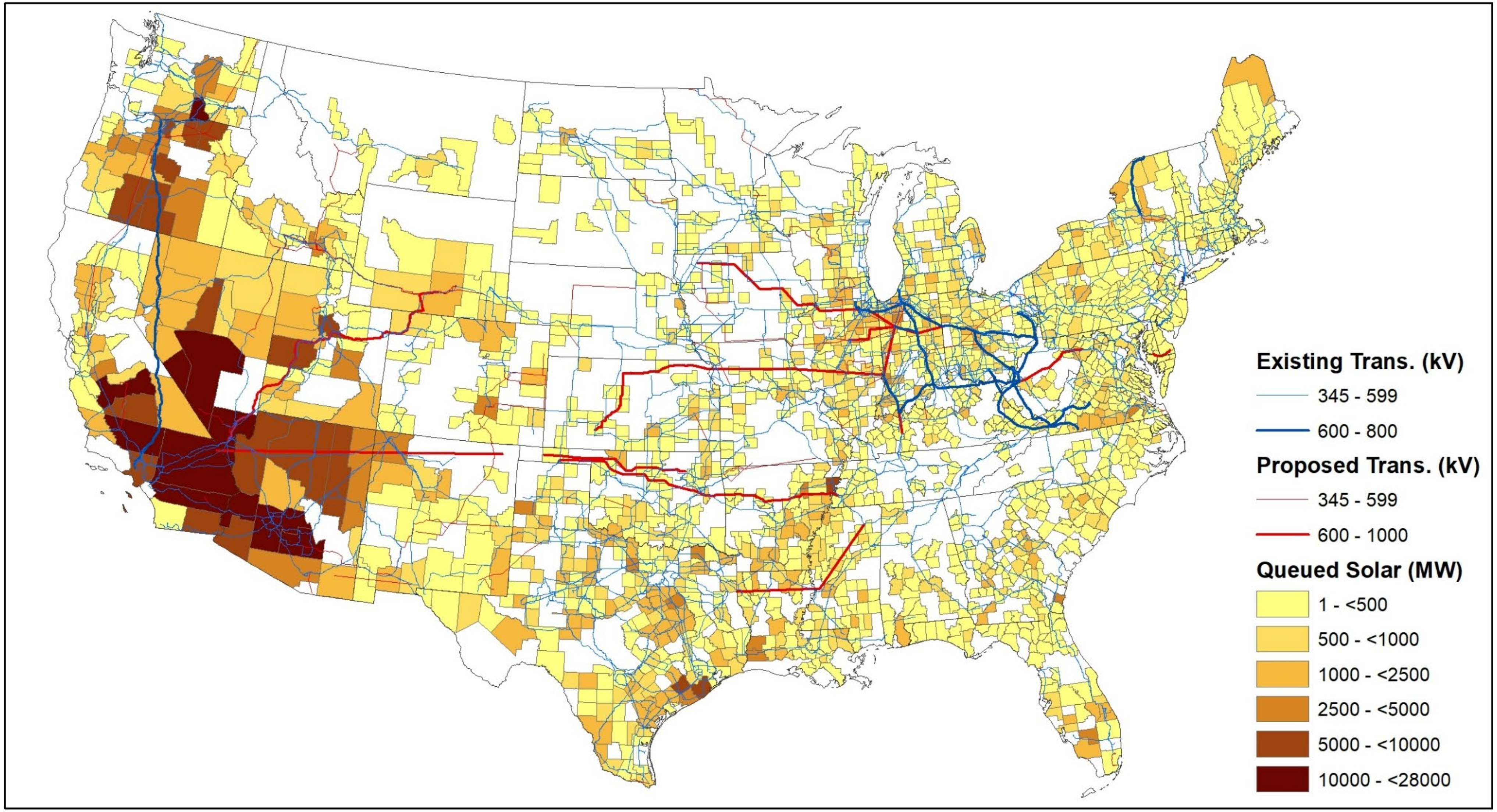
Duration Analyzed: *Interconnection Request (IR)* → *Interconnection Agreement (IA)* → *Commercial Operations (COD)*



- For the smallest projects in our sample (<5 MW), the median project came online less than 2 years (20 months) after the interconnection request
- The median 5-20 MW project, meanwhile, takes nearly 3 years (33 months) from IR to COD
- Larger projects spend even more time in the interconnection and development process, with the median 100-200 MW project taking >4 years and the median 200+ MW project taking over 4.5 years (55 months) from IR to COD

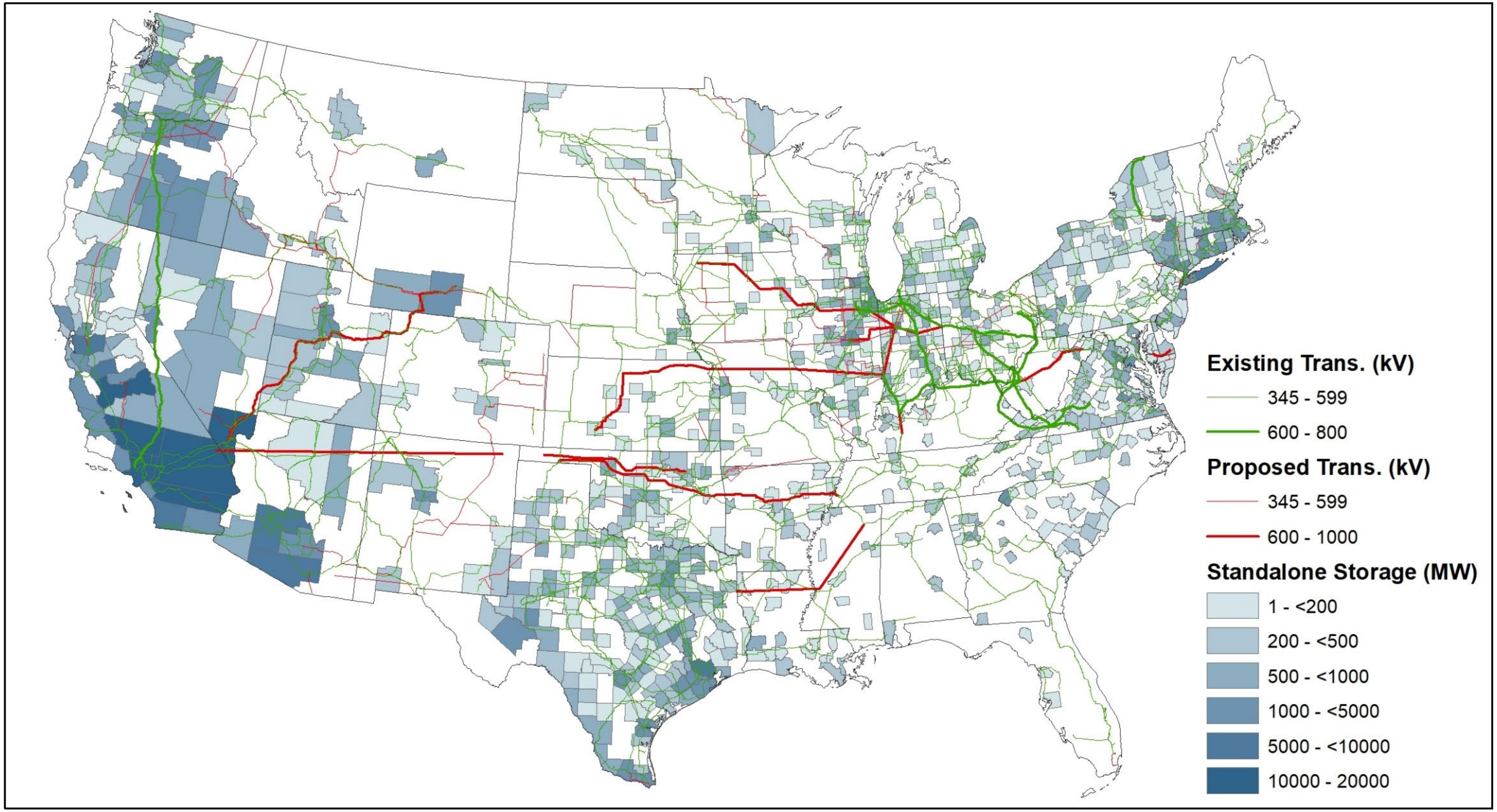
Notes: (1) Box-plot includes projects reaching commercial operations from 2010-2023. (2) Includes data from 6 ISOs and 8 non-ISO BAs representing 61% of all operational projects (3) Duration is calculated as the number of months from the queue entry date to the commercial operations date.

Active solar capacity in queues: by county



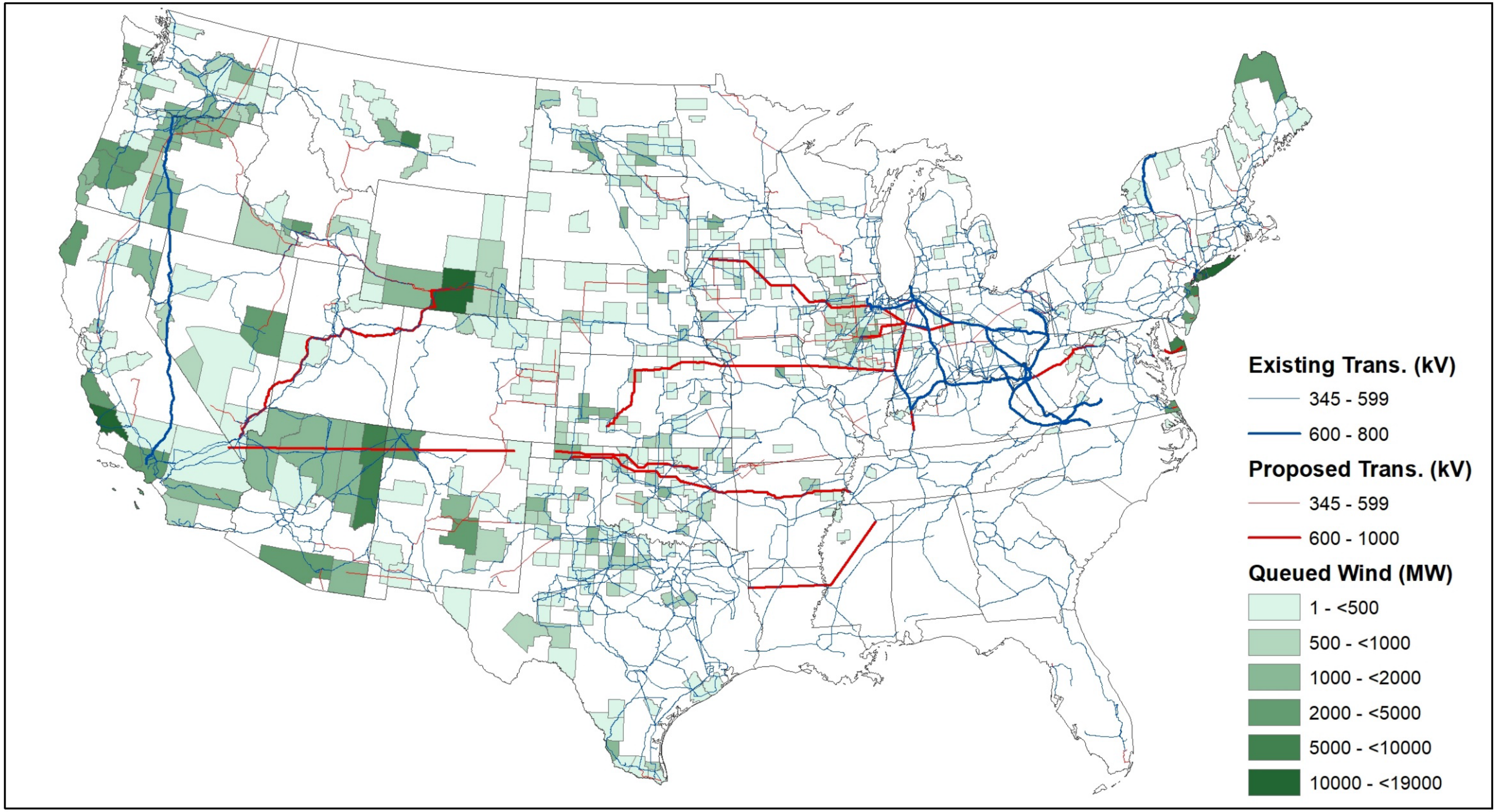
Notes: (1) Includes "active" interconnection requests only. (2) County was missing or could not be determined for 2.7% of active solar requests. (3) Transmission line data from Hitachi Velocity Suite. (4) See https://emp.lbl.gov/queues to access an interactive data visualization of these maps

Active standalone[1] storage capacity in queues: by county



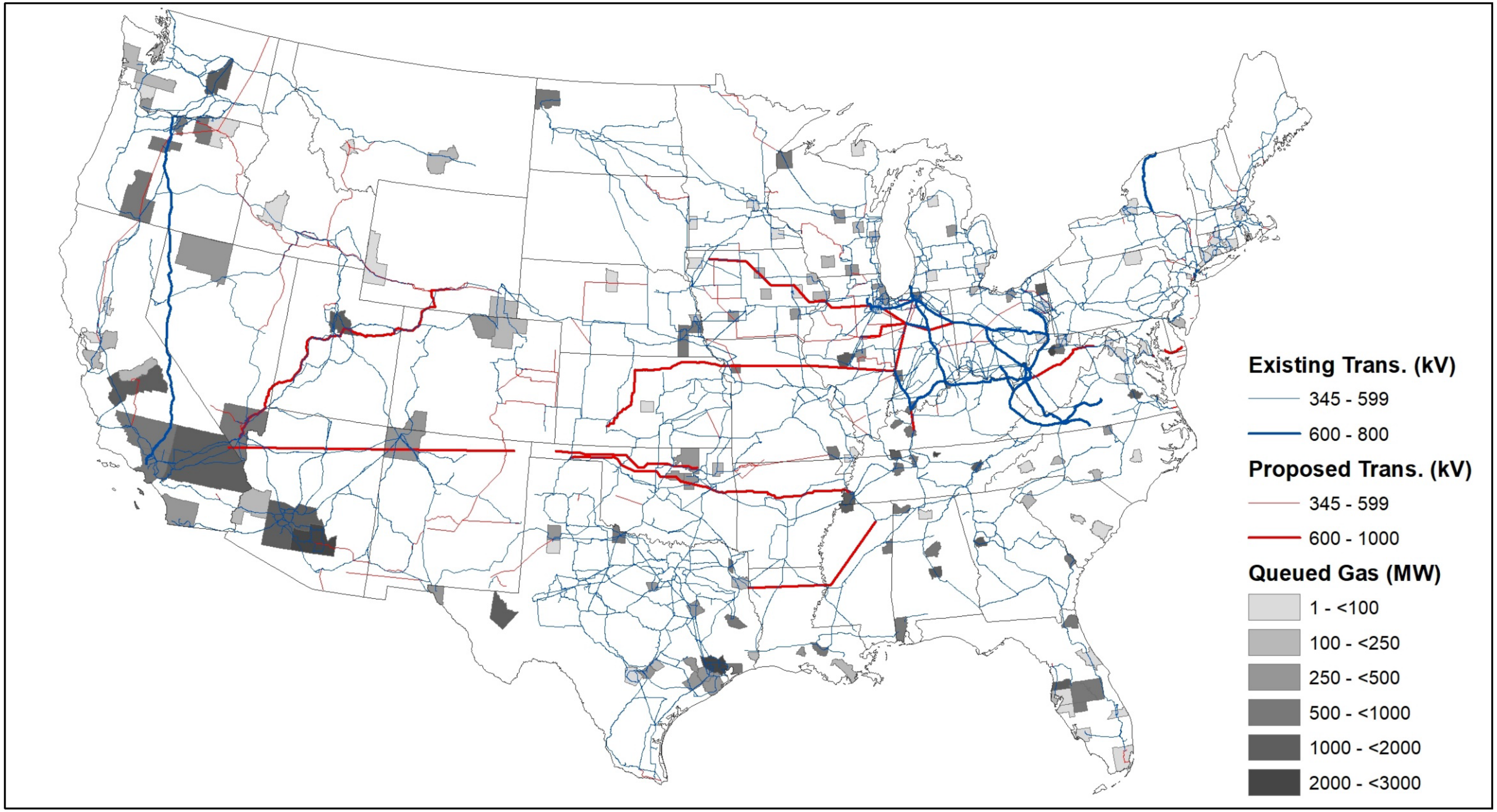
Notes: (1) Excludes hybrid storage capacity, which could not be estimated at the county-level. (2) Includes "active" interconnection requests only. (3) County was missing or could not be determined for 2% of active standalone storage requests. (4) Transmission line data from Hitachi Velocity Suite. (5) See https://emp.lbl.gov/queues to access an interactive data visualization of these maps

Active wind capacity in queues: by county



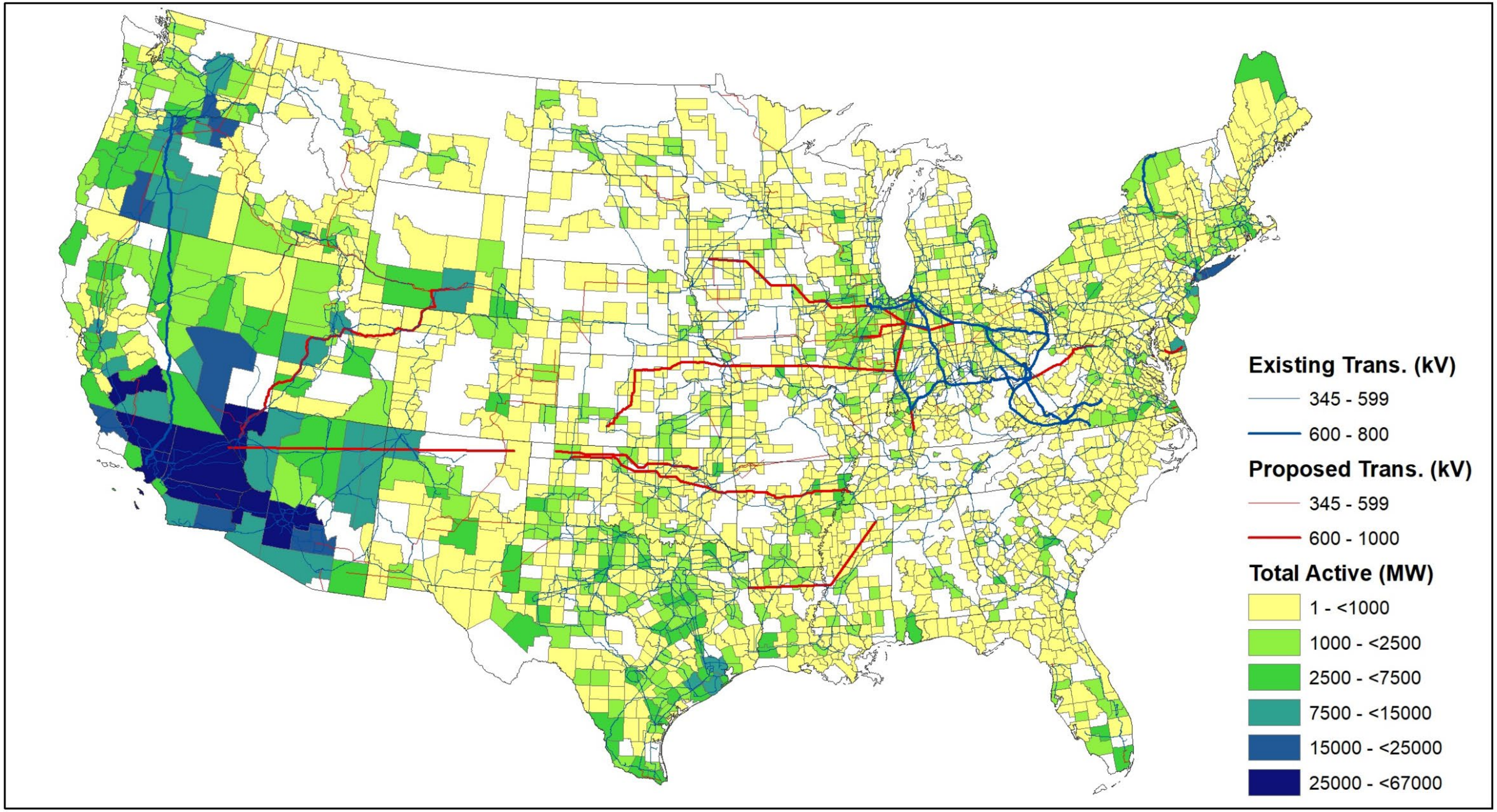
Notes: (1) Includes "active" interconnection requests only. (2) County was missing or could not be determined for 2.8% of land-based wind requests, and 16.1% of offshore wind requests. (3) Transmission line data from Hitachi Velocity Suite. (4) See https://emp.lbl.gov/queues to access an interactive data visualization of these maps

Active gas capacity in queues: by county



Notes: (1) Includes "active" interconnection requests only. (2) County was missing or could not be determined for 7.3% of active gas 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

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

As of the end of 2023, there were nearly 11,600 projects actively seeking grid interconnection across the U.S., representing 1,570 GW of generation and approximately 1,030 GW of storage.

- Solar (1,086 GW), storage (1,028 GW), and wind (366 GW) account for ~95% of all active capacity seeking transmission connection.
  - Over half of solar and storage capacity in the queues are from hybrid projects; Roughly 1/3 of wind capacity is for offshore projects
  - Over 1,200 GW of generation and storage projects submitted interconnection requests *after* the passage of the IRA.
- The combined capacity of just solar and wind now active in the queues (>1,400 GW) exceeds the total installed U.S. power plant fleet capacity, and is greater than the estimated 1,100 GW needed to approach a zero-carbon electricity target[2].
- Capacity in queues is widespread across U.S. but some states dominate: Texas has 13% of solar, 14% of gas, 12% of storage, and 7% of wind; New York has 19% of wind (mostly offshore); California has 27% of storage, 12% of solar, and 8% of wind.
- Hybrids now comprise a large – and increasing – share of proposed projects, particularly in CAISO and the West. 571 GW of solar hybrids (primarily solar+battery) and 49 GW of wind hybrids are in the queues.
- Roughly half (1,271 GW) of the active capacity in the queues is proposed to come online before 2026, and 12% (311 GW) already has an executed interconnection agreement (IA).
- The time projects spend in queues before reaching COD is increasing. For the regions with available data[3], the median duration from IR to COD has doubled from <2 years for projects built in 2000-2007 to over 4 years for those built in 2018-2023.
  - The full interconnection process timeline (from IR to IA) has also increased, though moderated somewhat in 2023
  - Larger projects have longer development timelines; interconnection study duration increases notably for projects >20 MW.
- Ultimately, much of this proposed capacity will not be built. Historically only ~20% of projects (and only 14% of capacity) requesting interconnection from 2000-2018 have reached commercial operations. As well, late-stage withdrawals may be on the rise.
- FERC Order 2023 is an important step toward addressing interconnection backlogs and bottlenecks. Additional operational and technical solutions like those outlined in i2X can further improve efficiency, reliability, and help meet decarbonization goals

Notes: (1) Hybrid storage capacity is estimated using storage:generator ratios from projects that provide separate capacity data. (2) See https://gridlab.org/2035-report/ (3) Data for this analysis were available for six ISO/RTOs and eight non-ISO balancing areas.