



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

i2X Workshop | GridTech Connect CA

June 24th, 2024

An initiative spearheaded by the Solar Energy Technologies Office and the Wind Energy Technologies Office

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Welcome & Opening Remarks

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Interactive Exercise: Visioning
Generator Interconnection in 2035

Solar Energy Technologies Office (SETO) Overview

MISSION

We accelerate the **advancement** and **deployment of solar technology** in support of an **equitable** transition to a **decarbonized economy no later than 2050**, starting with a decarbonized power sector by 2035.

WHAT WE DO

Drive innovation in technology and soft cost reduction to make solar **affordable** and **accessible** for all Americans

Enable solar to support the **reliability, resilience**, and **security** of the grid

Support **job growth**, **manufacturing**, and the **circular economy** in a wide range of applications



Why interconnection and why now?

*From 90 MW/day of new PV 165 MW/day within 11 years**
needs faster **Interconnection procedures**

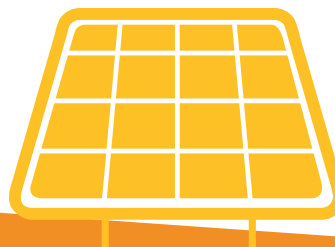
Zero-Carbon Future

Irreversible path to zero-carbon electricity system by 2035 is contingent on paradigm-shifts in interconnection practices to deploy clean energy technologies at exponential scales



Complexity

The modern grid is transforming rapidly, and grid Interconnection processes are growing ever more complex as penetrations levels increase and technologies advance



Equity

Inclusive and just transition. Broad group of stakeholders required to fully understand the regulatory, technical, and process challenges in interconnection



4x

The current annual deployment levels for wind and solar decarbonize by 2035

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 working groups



Data & Analytics

Collect and analyze interconnection data to inform solutions development



Strategic Roadmap

Create roadmap to inform interconnection process improvements



Technical Assistance

Leverage DOE laboratory expertise to support stakeholder roadmap implementation



i2X is a collaboration among DOE offices and labs

SETO



Michele Boyd

WETO



Jian Fu

SETO



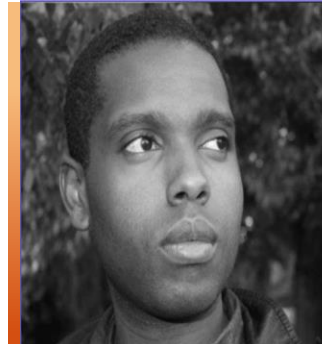
Ammar Qusaibaty

WETO



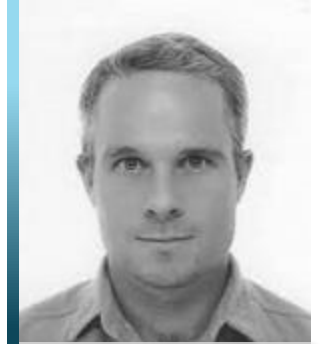
Cindy Bothwell

SETO



Dexter Hendricks

WETO



Bret Barker



i2X Activity Highlights

Stakeholder Engagement

- 900+ people at 530+ organizations partnered with i2X
- 25+ public events and engagements (e.g., RE+ 2023)
- 22 Solution e-Xchange meetings covering six topics
- EEJ Technical Advisory Committee
- 85+ Office-Hour Calls with stakeholders

Data & Analytics

- BPS interconnection cost reports for MISO, PJM, NYISO, SPP, and ISO-NE, plus a summary published (LBNL)
- Queued Up report on BPS interconnection timelines (LBNL)
 - 2022, 2023, 2024 Editions
 - <https://emp.lbl.gov/queues>

Technical Assistance

- 12 technical assistance projects covering flexible interconnection, utility data management, streamlining interconnection modeling, and alternatives to costly grid network upgrades
- Workforce upskilling with i2X/NERC bootcamps for BPS grid engineers on using Electromagnetic Transient (EMT) modeling methods and techniques

Strategic Roadmap

- Final Transmission Interconnection Roadmap released on April 17th, 2024.
- Distribution Interconnection Roadmap draft release via a request for information process (RFI) planned for Q3 FY 24.





California ISO

California ISO Interconnection Processes and Enhancements Initiative

Bob Emmert, Senior Manager, Interconnection Resources
Jason Foster, Manager, Queue Management

GridTech Connect, June 24, 2024

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Agenda

- FERC Order 2023
- ISO Interconnection Process Enhancement Initiative
 - Interconnection Application Request Intake and Scoring Process
- Contract and Queue Management overview and enhancements

Interconnection Application and Study Process Overview (ISO Interconnection Resources team)

- Interconnection request intake
 - Interconnection package eligibility for study process
 - Review for completeness, eligibility, scoring, and possible auction
 - Technical review/validation for successful projects and scoping meetings for projects moving to the study process
- Study results meetings and mid-study project modifications and validation of commercial readiness deposits
- Transmission plan deliverability request validation, scoring and processing of customer's option
- Processing of study costs
- Processing of withdrawals

CAISO FERC Order 2023 Overview

- Filed May 16, 2024
- Applies to C15 and future clusters only
- Generally adopts all prescribed revisions, including new timelines for studies:
 - 150 days for cluster study (formerly Phase I)
 - 150 days for reassessment
 - 120 days for interconnection facilities study (formerly Phase II)
- Maintains CAISO traits: cost caps for network upgrades, use of per unit cost guides, affected system notification, allocation of transmission capacity for resource adequacy (TPD), and cash reimbursement for customer funded network upgrades

Compliance with Order

Complete compliance

- Heatmap (early)
- Cluster Study
- Definitions
- Definitive POI
- Request/Engagement windows
- Scoping Meeting
- Metrics
- Evaluation Process
- 3-year COD Extension
- Cluster Study Provisions

Minor variations

- Restudy Triggers
- LGIA Tender, Negotiation, & Execution
- Cluster Subgroups
- Restudy
- Allocation of Study Costs
- Allocation of Upgrade Costs
- Shared Upgrades
- Increased Financial Commitments/Readiness and Withdrawal Penalties

Alternative

Compliance with Order

Complete compliance

Minor variations

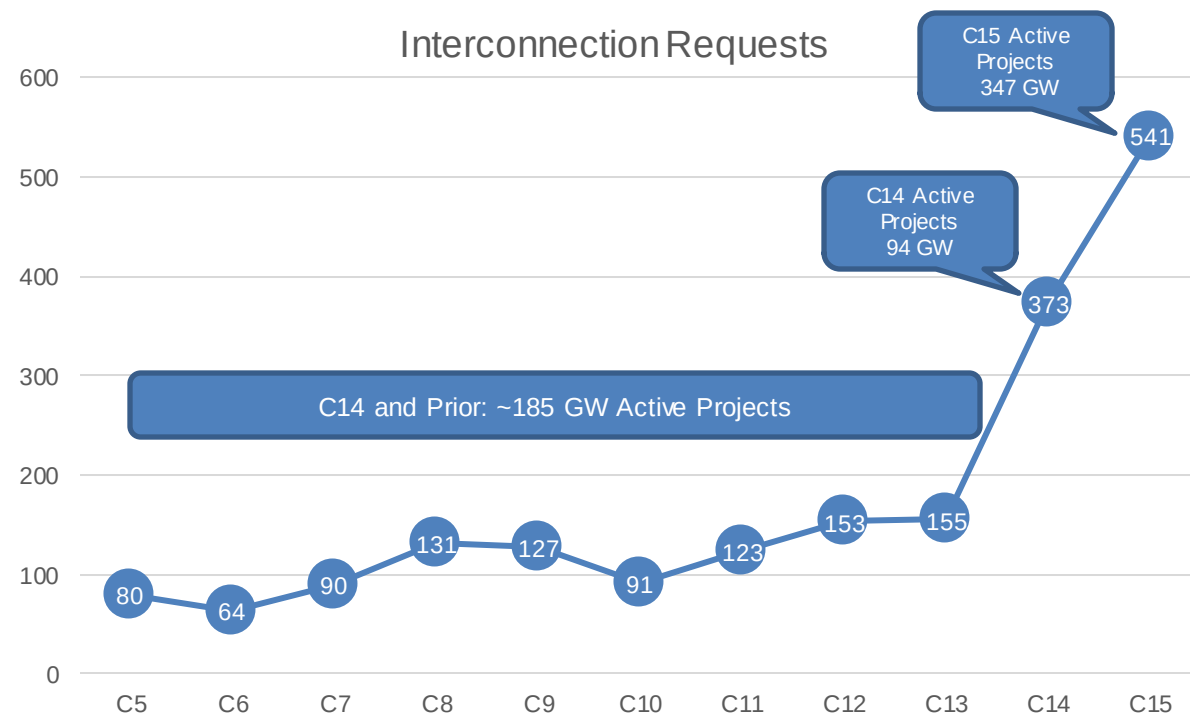
Alternative

- Site Control
 - Elimination of Reasonable Efforts Standard
 - Penalties for Late Studies
 - CAISO as Affected System
 - Notifying Affected Systems
 - Co-Located Facilities
 - GETs
 - Modeling Requirements
- Applicability of Ride-through Requirements
 - Ride-through Requirements

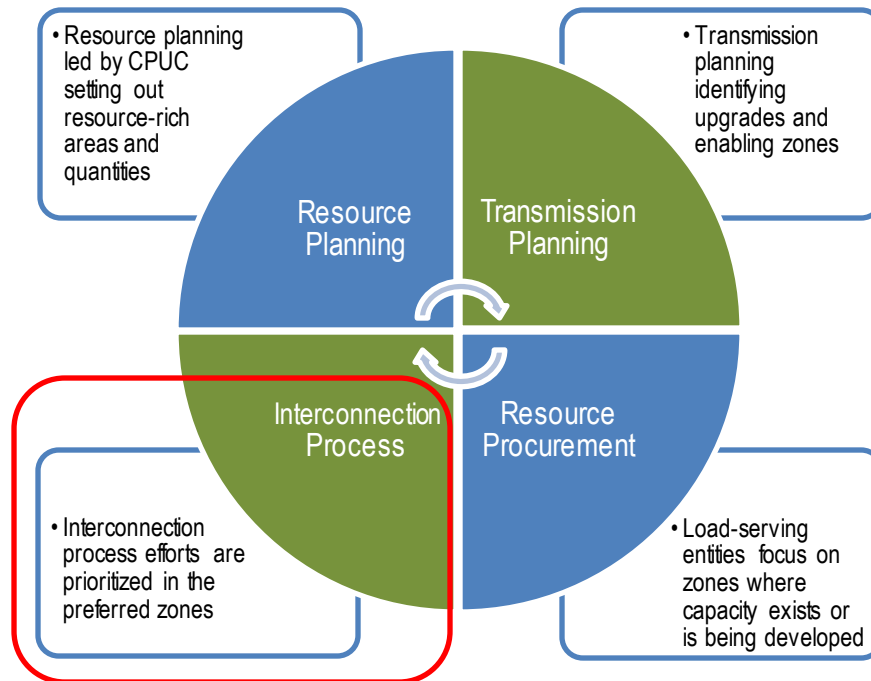
2023 CAISO Interconnection Process Enhancements (IPE) Initiative for Interconnection Application and Study Processes

Current circumstances have reinforced the need for transformative changes

- CPUC resource portfolios call for over 7,000 MW per year for the CAISO's 2023-2024 planning cycle
- Interconnection requests continue to skyrocket
 - Many in areas not part of state resource plans, and in high volumes even in those areas.
 - Cluster 15 in April 2023 vastly exceeded expectations.
 - The queue now has roughly three times the capacity of that which will be needed to achieve California's 2045 requirements.



Transformative change to the interconnection process is part of a larger coordinated strategy with state agencies



Expectations:

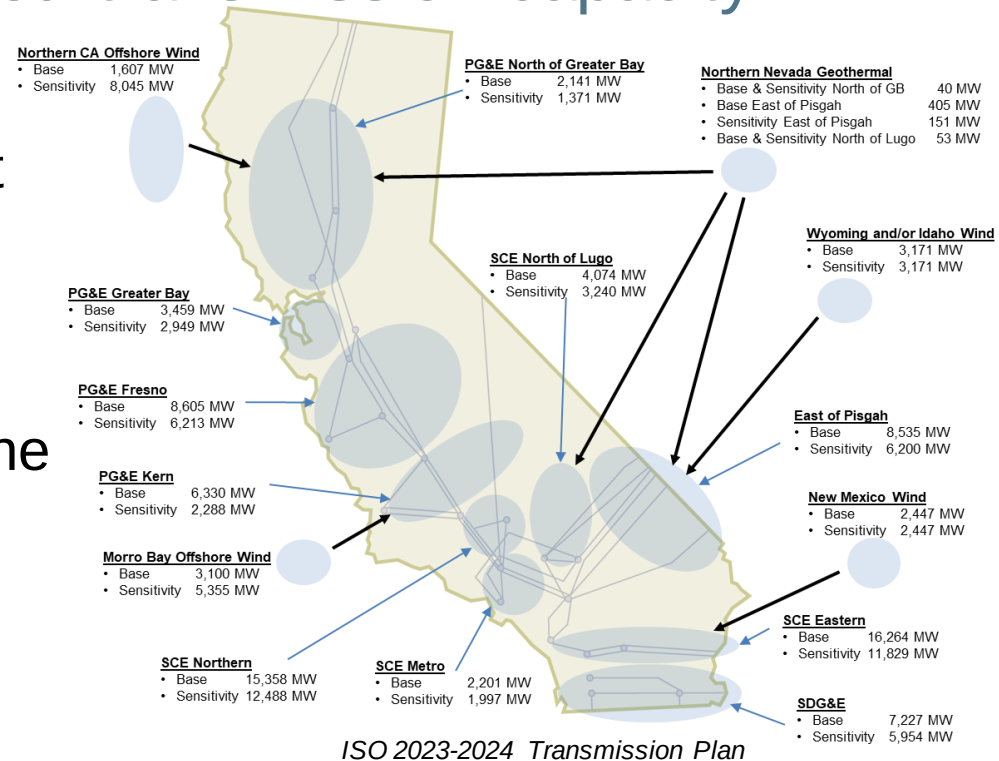
- The CPUC will provide direction to its jurisdictional load serving entities (LSEs) to pursue resources in the key zones.
- Procurement will focus on the expected quantities enabled by the planned transmission development, as set forth in the ISO's transmission planning process (TPP);
- State agencies, local regulatory authorities, and LSEs will continue to significantly inform the ISO's TPP.

Transmission Plan Deliverability (TPD)

- In the ISO, resources do not get firm transmission service, projects obtain a status – Full Capacity Delivery Status (FCDS), that allows the FCDS capacity to participate in California's Resource Adequacy program.
- The ISO transmission planning process determines the needed additional transmission capacity to support the CPUC's future resource needs determined in its integrated resource planning process. The needs of non-CPUC jurisdictional load serving entities are integrated as well.
- The ISO determines the available existing and planned capacity/TPD and allocates that capacity to projects that meet viability criteria, primarily having an executed purchase power agreement or shortlisted for procurement.

ISO zonal approach prioritizes interconnections in areas with available and planned transmission capacity

- Designate zones with available TPD or merchant zones using a constraint-based approach based on the project's point of interconnection to determine projects that move forward to scoring.
- Determine which projects advance to studies using project score, distribution factor, up to 150% cap of available capacity for each known area constraint.
- 150% enables cap of studied capacity and sufficient competition for offtaker procurement after the study process.



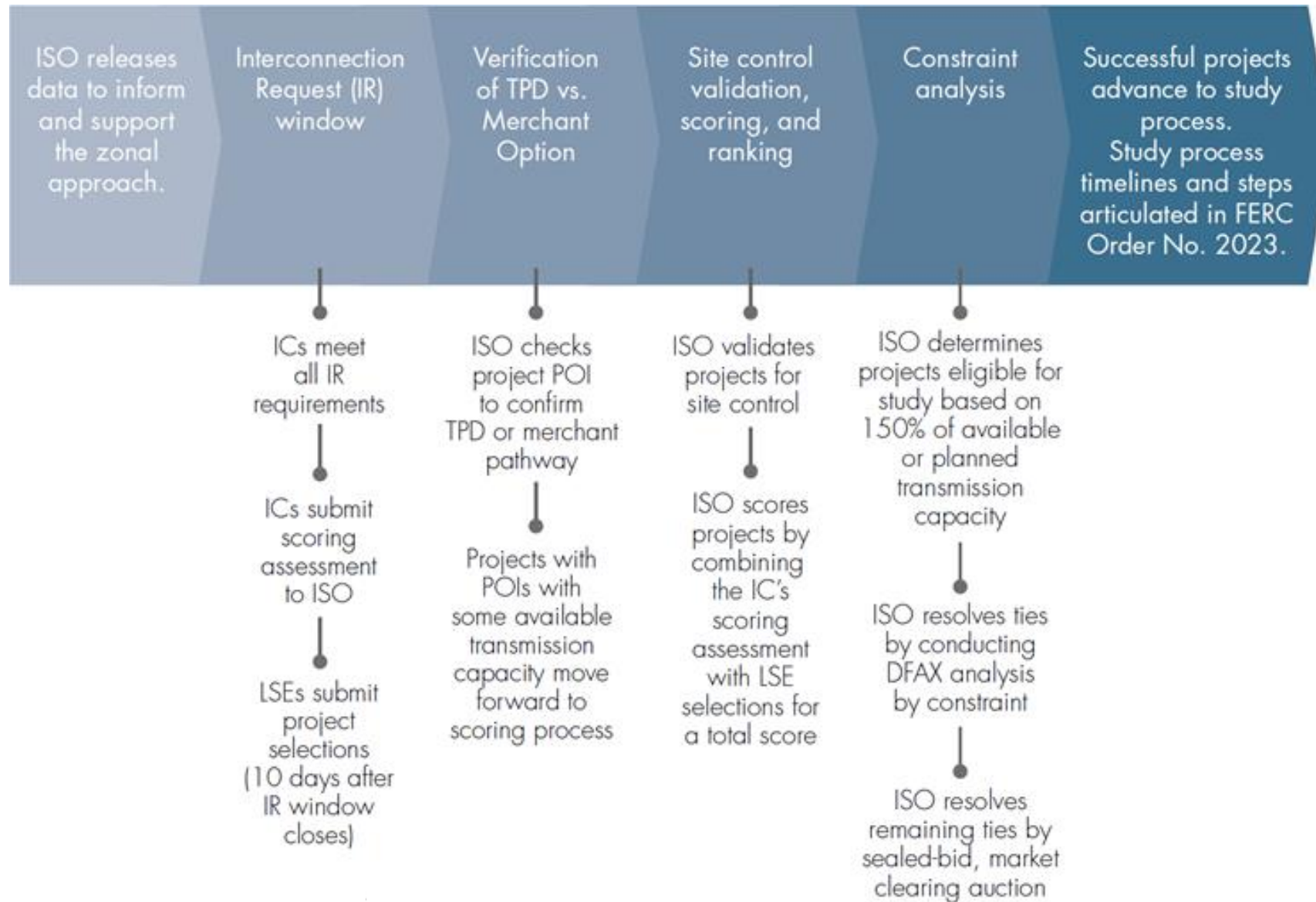
Expanded data availability is key to implementing the zonal approach

- The ISO will post information prior to the interconnection request window that includes critical information
 - Workbook with transmission capability estimates
 - Workbook with capacity at studied POIs behind known constraints
- The ISO will publically post individual interconnection reports, with confidential information redacted
- The ISO will provide a heat map with specific information after each cluster study and restudy (as required by Order No. 2023)
- And an enhanced TPD allocation report provides additional information on locations of available capacity

The interconnection request intake process will focus on project readiness and competition.

- A zonal approach that integrates planning, procurement, and interconnection studies
 - Provide accessible data prior to the cluster window.
 - Study project capacity up to a 150% cap of the available transmission capacity in each zone.
- Scoring criteria to prioritize and advance the most “ready” projects, with distribution factors resolving most ties.
- Auction as a tie breaker / backstop mechanism if needed to select the last incremental projects to hit the 150% capacity cap.

Interconnection Request intake process



The ISO scores projects based on interconnection customers' self-assessment and load serving entity (LSE) selections

- Commercial interest (30%): Incorporate LSE and offtaker interest early to ensure the most commercially ready projects advance to the study process
 - LSE allocation process (0 to 100 points, based on percentage of capacity of the project selected by LSEs)
 - Non-LSE interest (0 or 25 points)
- Project Viability (35%)
 - Completeness of an engineering design plan
 - Expansions of facilities under construction or in operation
- System need (35%)
 - Projects that can provide local resource adequacy
 - Long lead time resources

The ISO will use tie-breakers for equal scores behind a constraint

- Assess the distribution factor (DFAX) of the tying project's POIs to break the tie
 - DFAX is a measure of the impact of injections of energy from a generator at a particular location, which could result in required network changes on the grid
 - Projects will be selected in order of the lowest DFAX with the selection process ending with the project that caused the 150% threshold to be exceeded, regardless of the size of the last project
- If project ties still exist after the use of projects' DFAX, tied projects will move to an auction

The auction process is the final step for inclusion in the study process, if needed

- Only projects that remain tied following the DFAX tie breaker step will participate in the auction
- Market-clearing, sealed-bid auction for the right to be studied in a specific zone
 - Request auction bids (dollar per MW basis) after the project scoring process has been completed
 - Rank and select projects for study based on bid price, starting with the highest bid and progressing downward and ending with the project that exceeds the 150% MW transmission capacity limit
 - Bidders will only submit the clearing price at-risk auction financial security if they win the auction and proceed to be studied
 - Post the clearing price, but not the individual project bids, on the ISO website

Auction revenues will support network upgrades

- Auction funds posted by an interconnection customer will be in favor of the Participating Transmission Owner
 - Financial security instruments are the same as currently allowed for interconnection financial security
- For successful auction participants, the ISO will refund auction-posted security within 90 days of notifying the ISO of commercial operations
- If a project withdraws, or is withdrawn prior to reaching commercial operation, some or all of the auction-posted security will be forfeited and used to offset the cost of still-needed network upgrades

The ISO will treat Energy Only projects based on identification of need in the resource portfolios

- EO projects will have two options to interconnect:
 - Reimbursement option allows EO projects in zones where the CPUC portfolio identifies the need for EO resources
 - Eligible for reimbursement of the cost of reliability network upgrades
 - Capacity studied capped at 150% of EO portfolio amount for zone
 - Non-reimbursement option for all other EO resources that seek to interconnect in zones where the CPUC's portfolio has not identified the need for EO resources
 - Not eligible for reimbursement of cost of reliability network upgrades
 - No cap on the number of projects studied
- Zero Energy Only projects submitted interconnection requests in Clusters 10-15

The ISO “merchant option” for projects seeking to interconnect is zones with no available TPD capacity

- Cannot compete for TPD allocations
- Same cost recovery of posted financial security towards the cost of a Local Delivery Network Upgrade as TPD option projects
- Additional commercial readiness deposit toward the cost of the area Delivery Network Upgrade to ensure developer confidence in the project’s viability under the merchant option
- Project can be released from the merchant project’s funding obligation, if need is identified in future resource planning portfolios

Contract and Queue Management processes

- Interconnection Agreement tendering, negotiations, and execution
- Interconnection Agreement milestone management
- Modifications
 - Material Modification (Pre-COD) or Post-COD Mod
 - Permissible Technological Advancement
 - Construction Sequencing
 - Suspensions
 - Deliverability Transfers
- Affected System Outreach (between Phase 1&2/Cluster & Facility Study)
- Deliverability Retention Documentation
- Commercial Viability Criteria demonstrations to retain deliverability
- Limited Operational Studies
 - To determine the extent to which a project may achieve COD ahead of a reliability upgrade in-service.
- Repower Study Requests

Commercial Viability Criteria to retain deliverability

- Projects requesting to extend their Commercial Operation Date (COD) beyond 7 years or modifications to projects that have already exceeded the 7 years are subject to Commercial Viability Criteria
 - Criteria includes permitting, power purchase agreement, site exclusivity, and executed GIA in good standing
- Failure to meet criteria results in conversion to Energy Only deliverability status
- Limited exemption for no power purchase agreement
 - One year delay for conversion to Energy Only
- Energy Only conversion will result in a reduction to cost responsibility only if assigned upgrades are eliminated

IPE Contract and Queue Management processes:

- More stringent commercial viability criteria for projects to remain in the queue
- Limitations on TPD transferability to prevent circumvention of deliverability retention requirements
- Increase modification study from 45 to 60 days
- Increase modification deposit from \$10,000 to \$30,000
- New \$100,000 implementation deposit for queue management and implementation, and \$10,000 for distribution projects using the new resource implementation process
- Require all projects with a shared upgrade to post security once the first project provides an NTP

Commercial Viability Criteria to remain in the queue (2023 IPE)

- All projects in the queue must execute their Interconnection Agreement by a defined date
- Then, all projects in the queue must demonstrate commercial viability criteria by a defined date
 - Provide proof of having an executed PPA – for RA/TPD or as Energy Only
 - Provide Financial Security Posting or Order 2023 Deposit
 - Demonstrate 100% Site Control
 - Have executed ISO GIA, and be in good standing
 - Provide detailed status and demonstration of the following as a baseline for annual progress to commercial operation:
 - Progress of GIA Milestones, list of all expected permits and their current status, Status of engineering, design, and construction activities of generating facility and upgrades, and status of major equipment procurement.

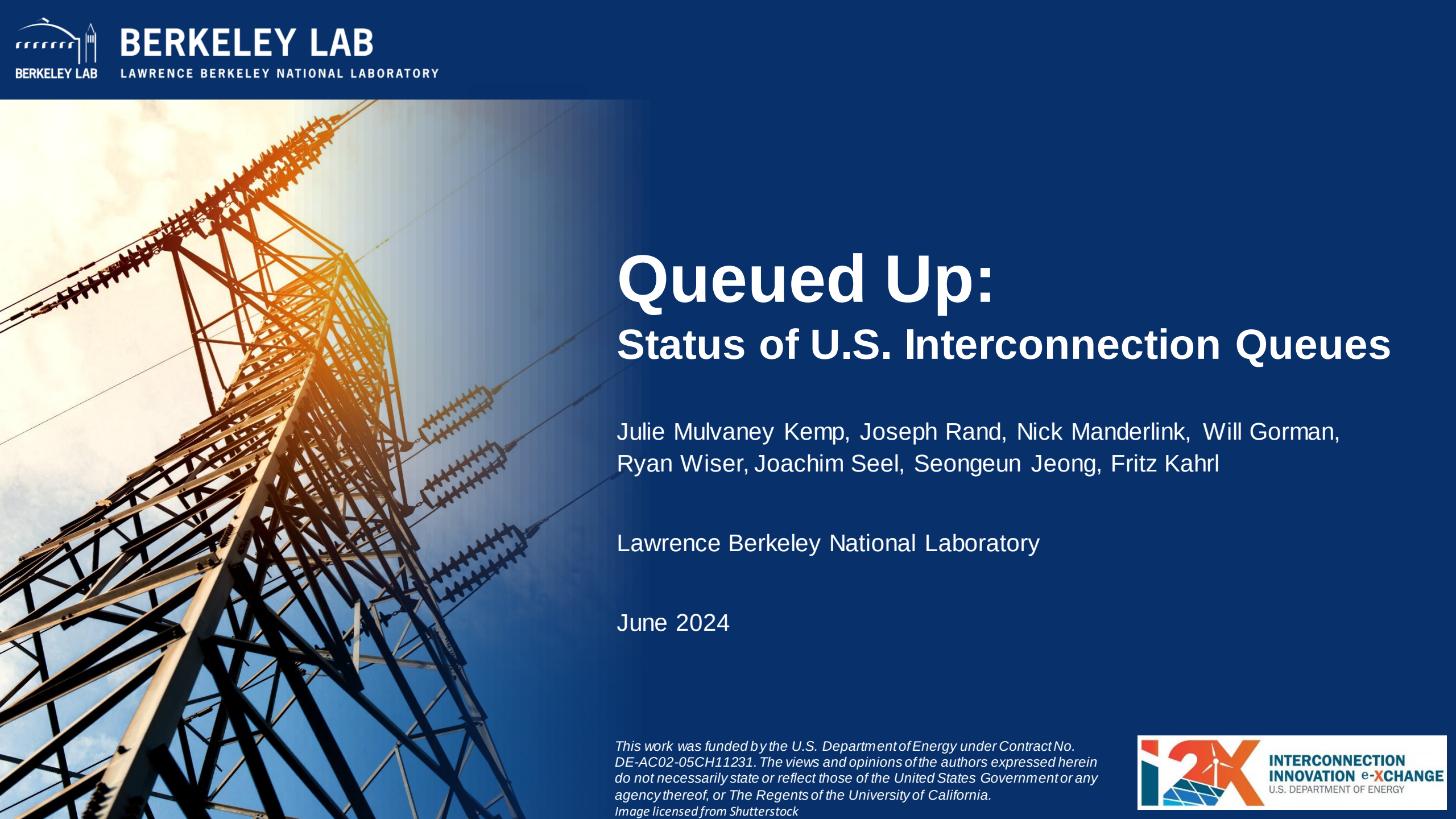


Join . Engage . Collaborate

15-minute Break

Website: energy.gov/i2x
Email: i2x@ee.doe.gov





BERKELEY LAB

LAWRENCE BERKELEY NATIONAL LABORATORY

Queued Up:

Status of U.S. Interconnection Queues

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Lawrence Berkeley National Laboratory

June 2024

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Berkeley Lab Team Introduction



Joe Rand



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Seongeun Jeong

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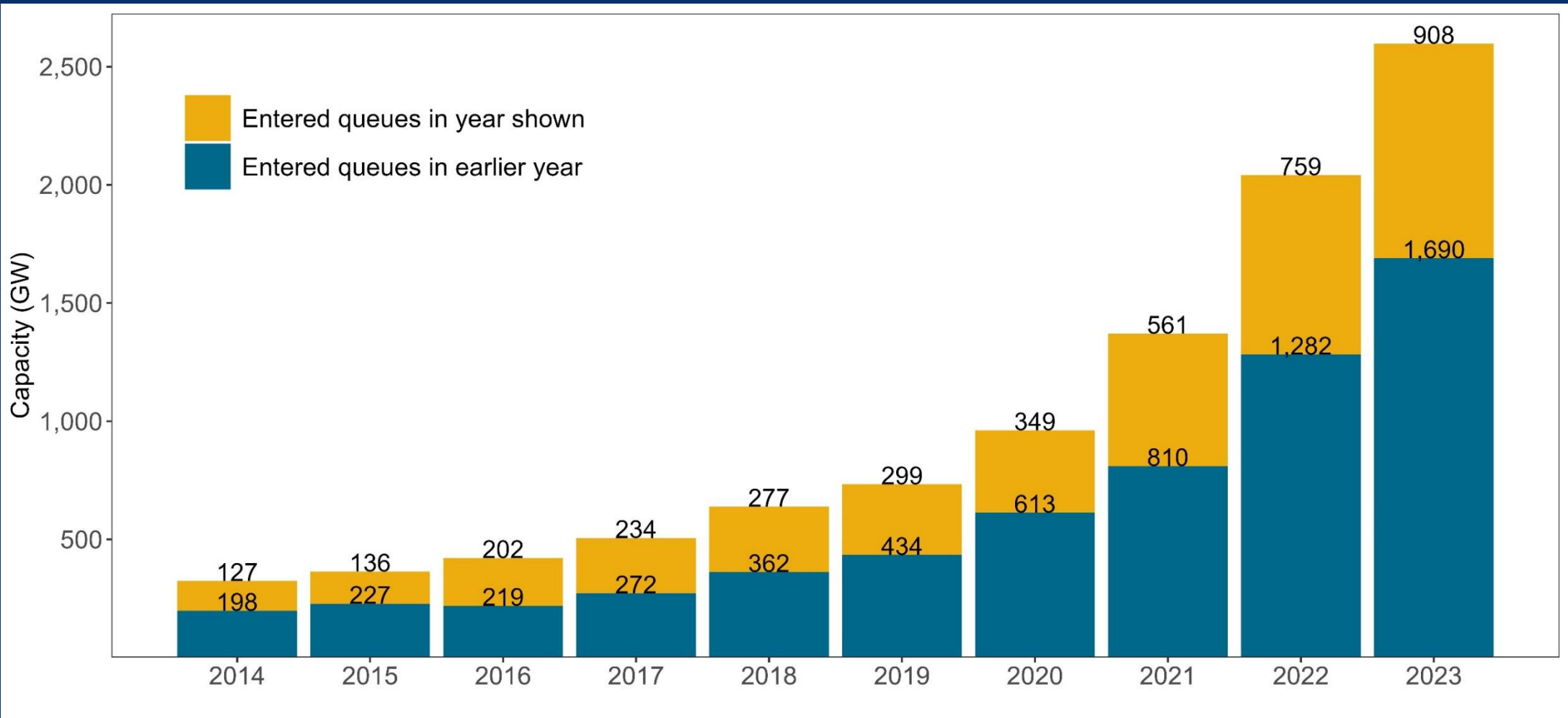
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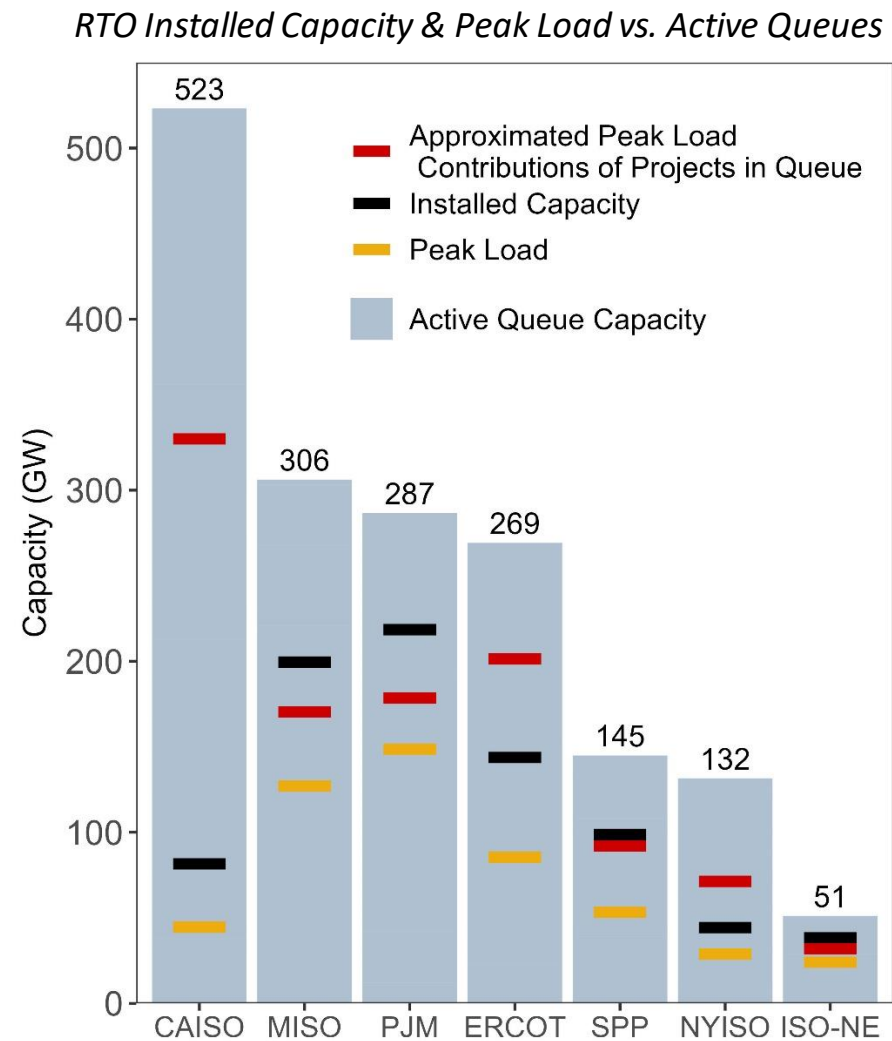
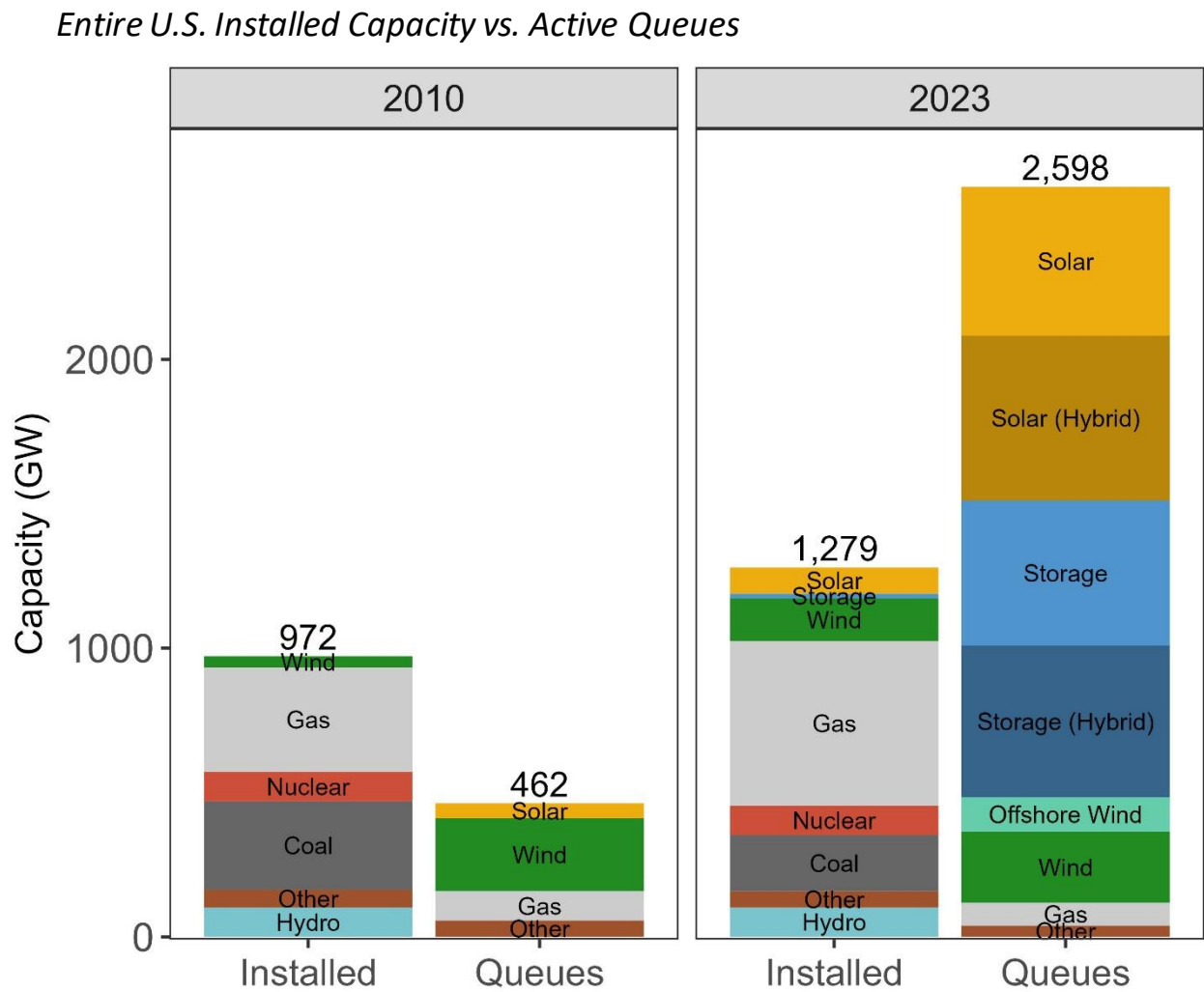
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Active Interconnection Requests: ~2.6 TW !

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



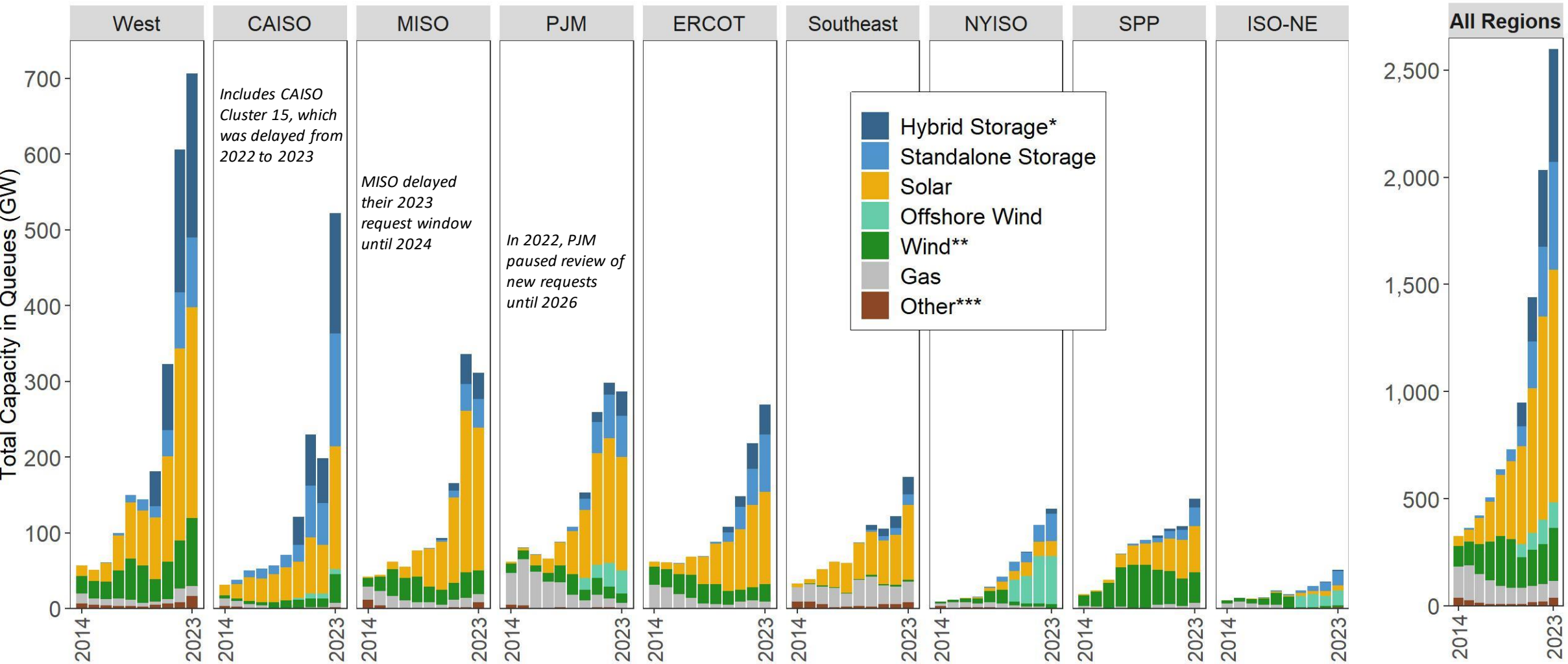
Active capacity in queues (~2,600 GW) is twice the installed capacity of U.S. power plant fleet (~1,280 GW); greater than peak load and installed capacity in all ISOs



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.



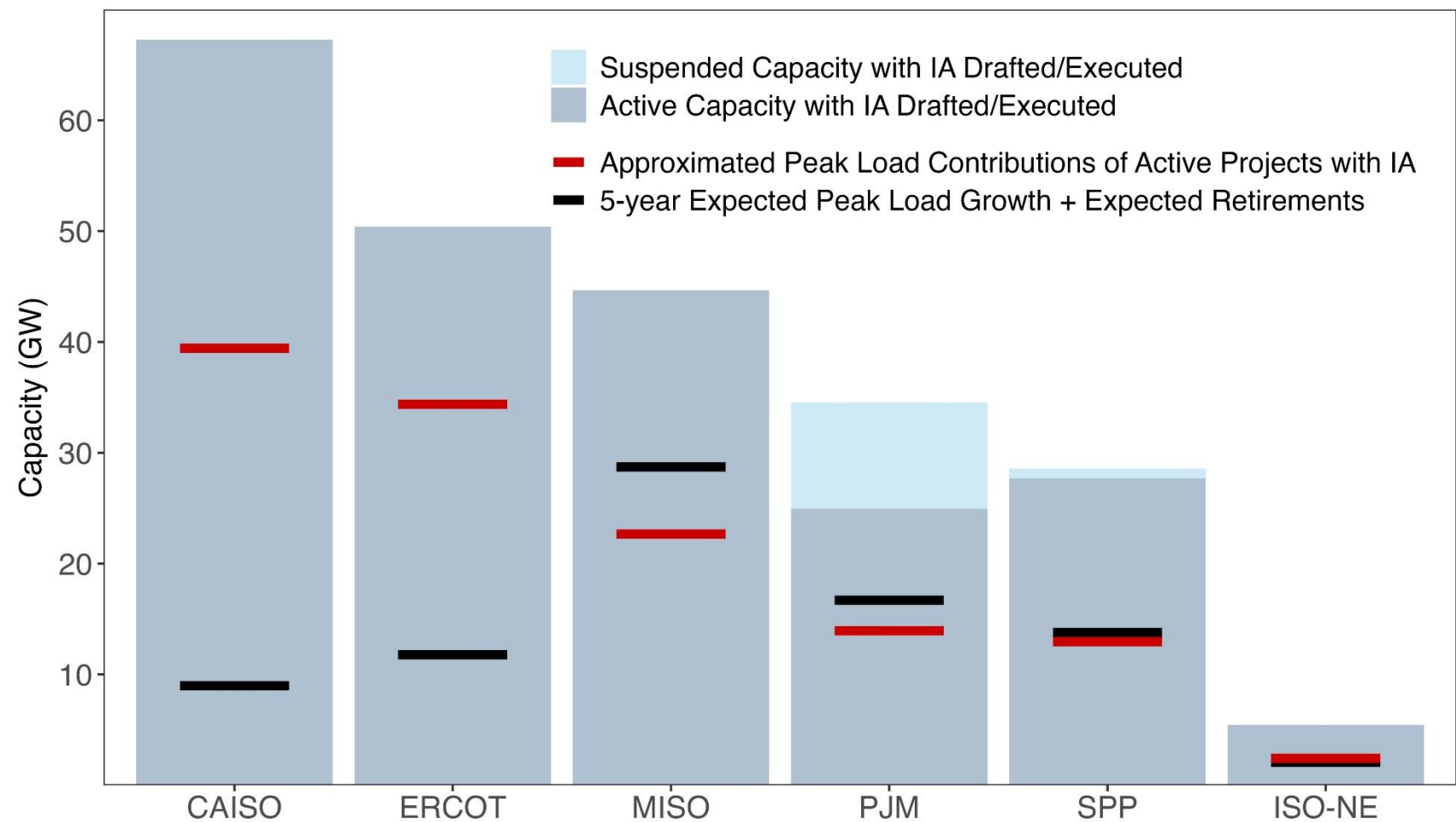
Active queue capacity is highest in the West (706 GW), followed by CAISO (523 GW). Several regions have delayed accepting or processing new requests due to backlogs



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.

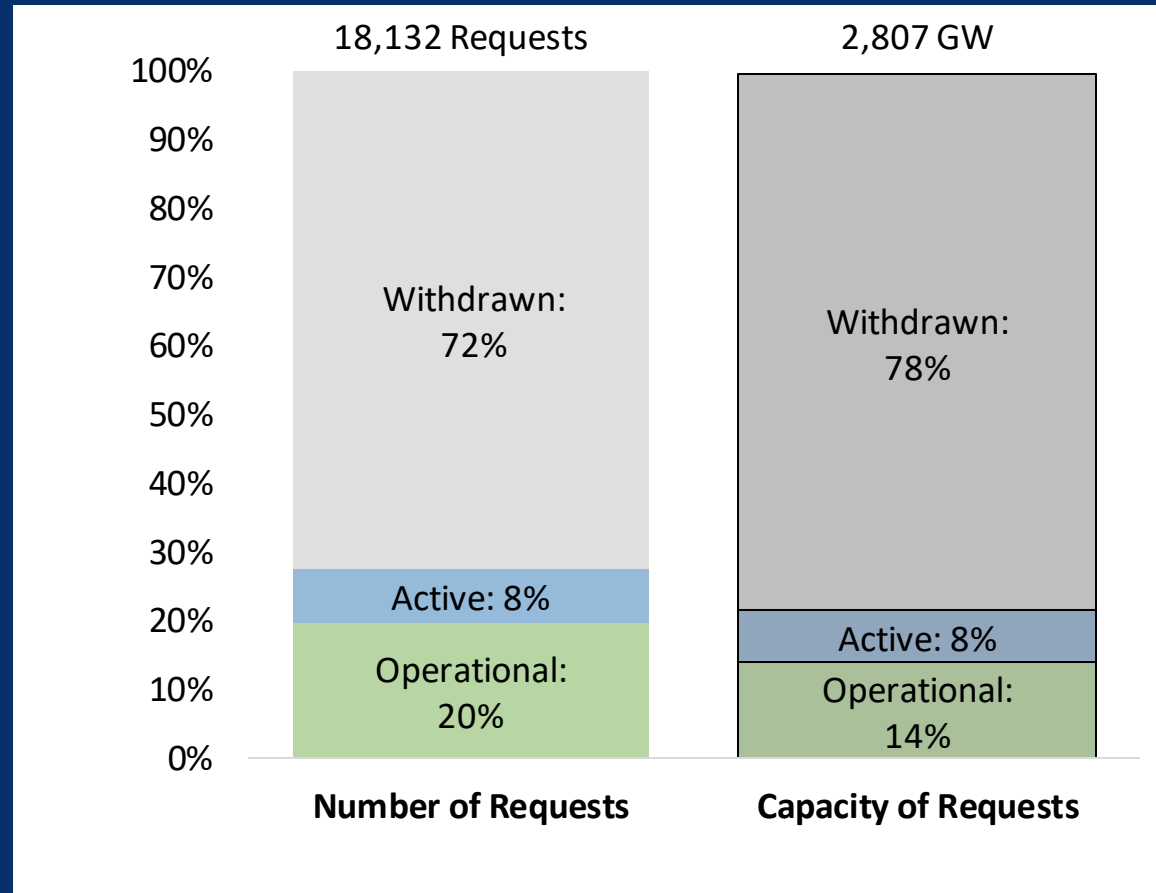
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CAISO currently has the most capacity with draft or executed IAs (67 GW). IA capacity exceeds forecasted load growth + retirements in all regions

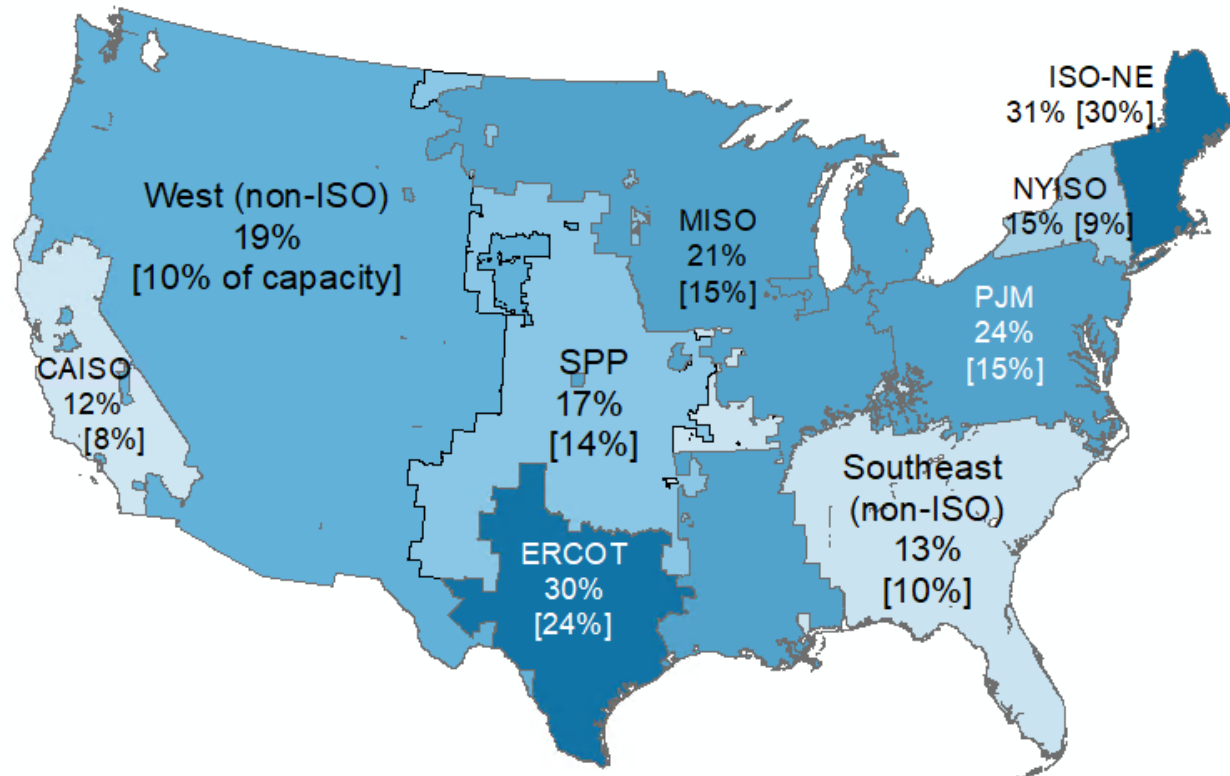


Notes: (1) IA capacity bars include capacity in the queues that has either a draft or fully executed interconnection agreement. The darker blue portion of the bar includes only active capacity; light blue portion includes suspended queue requests with an executed/drafted IA. The implication of “Suspended” 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.

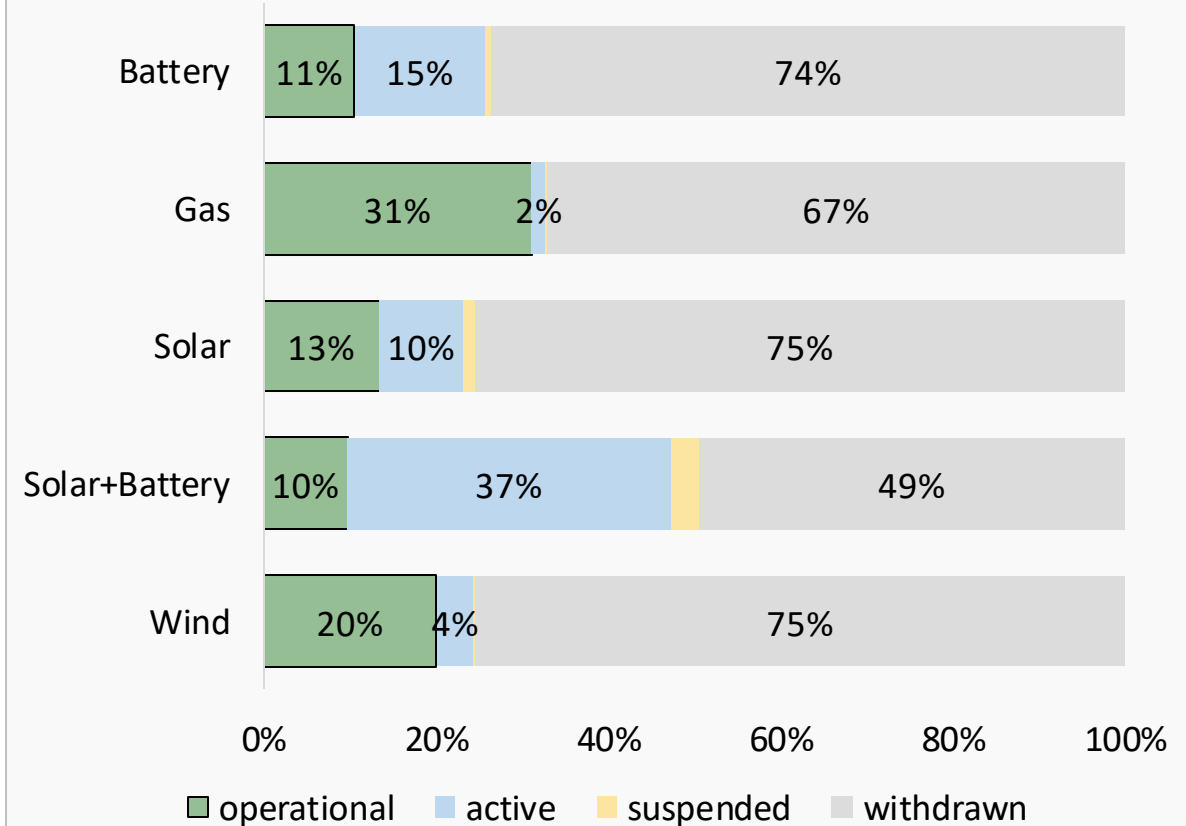
Evidence of a Problem #1: Low Completion / High Withdrawal



Variation in completion rates across regions and by generator type: ISO-NE and ERCOT have highest historical completion rate; Gas projects more often completed than others

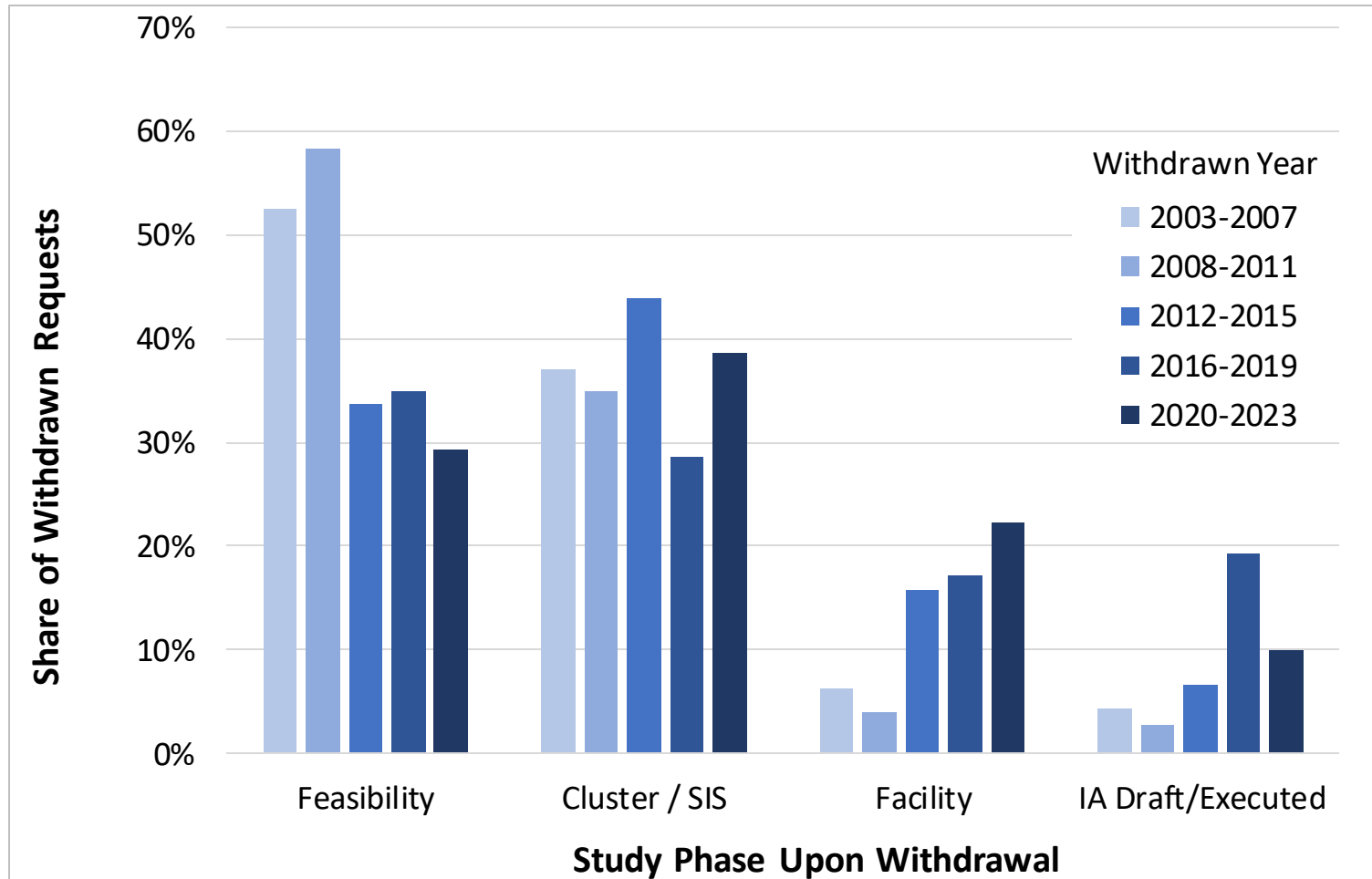


Current Status for Requests Submitted 2000-2018



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.

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

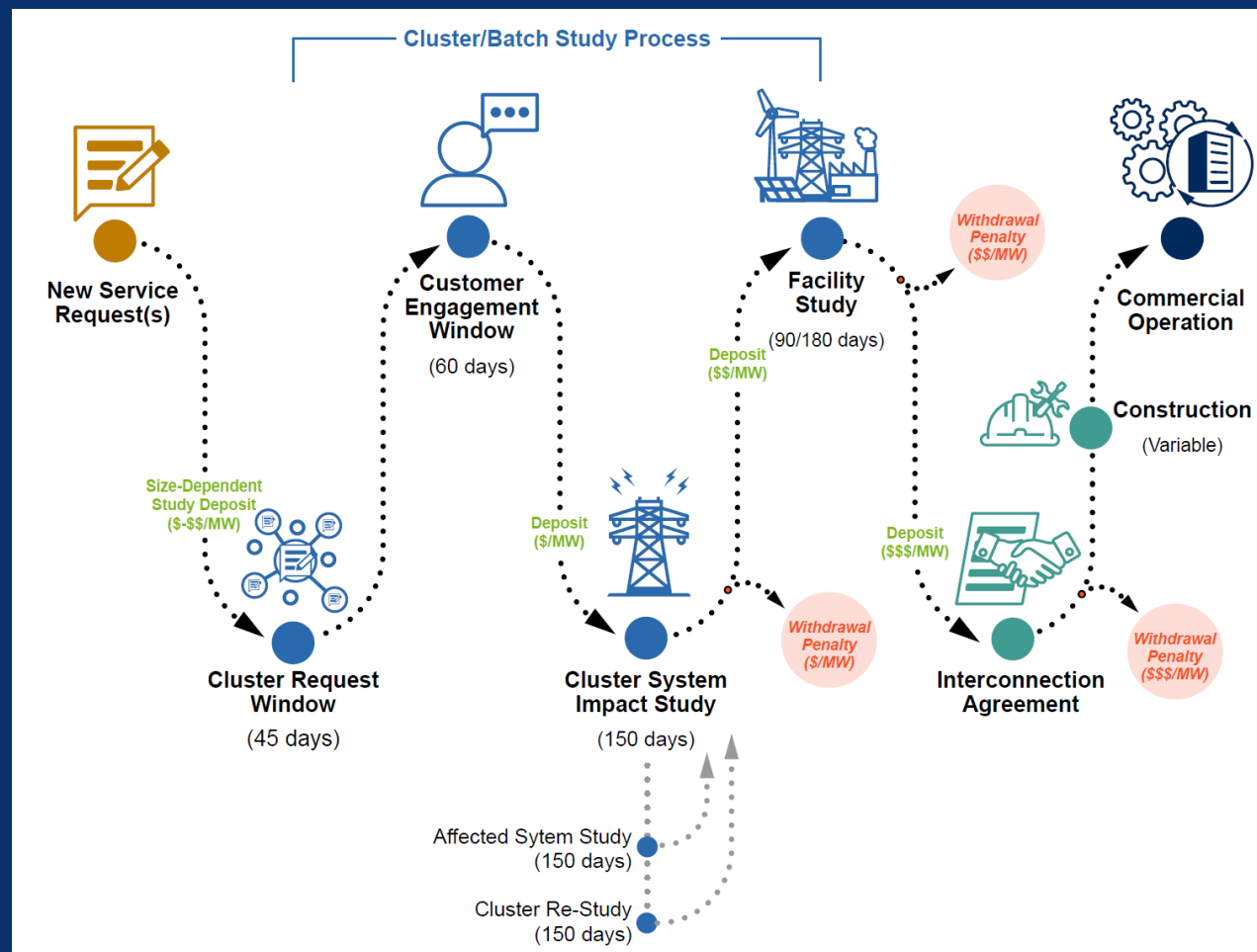


Late-stage withdrawals can be more costly for developers (sunk costs, deposits) and can trigger re-studies for other projects in the queue, increasing delays.

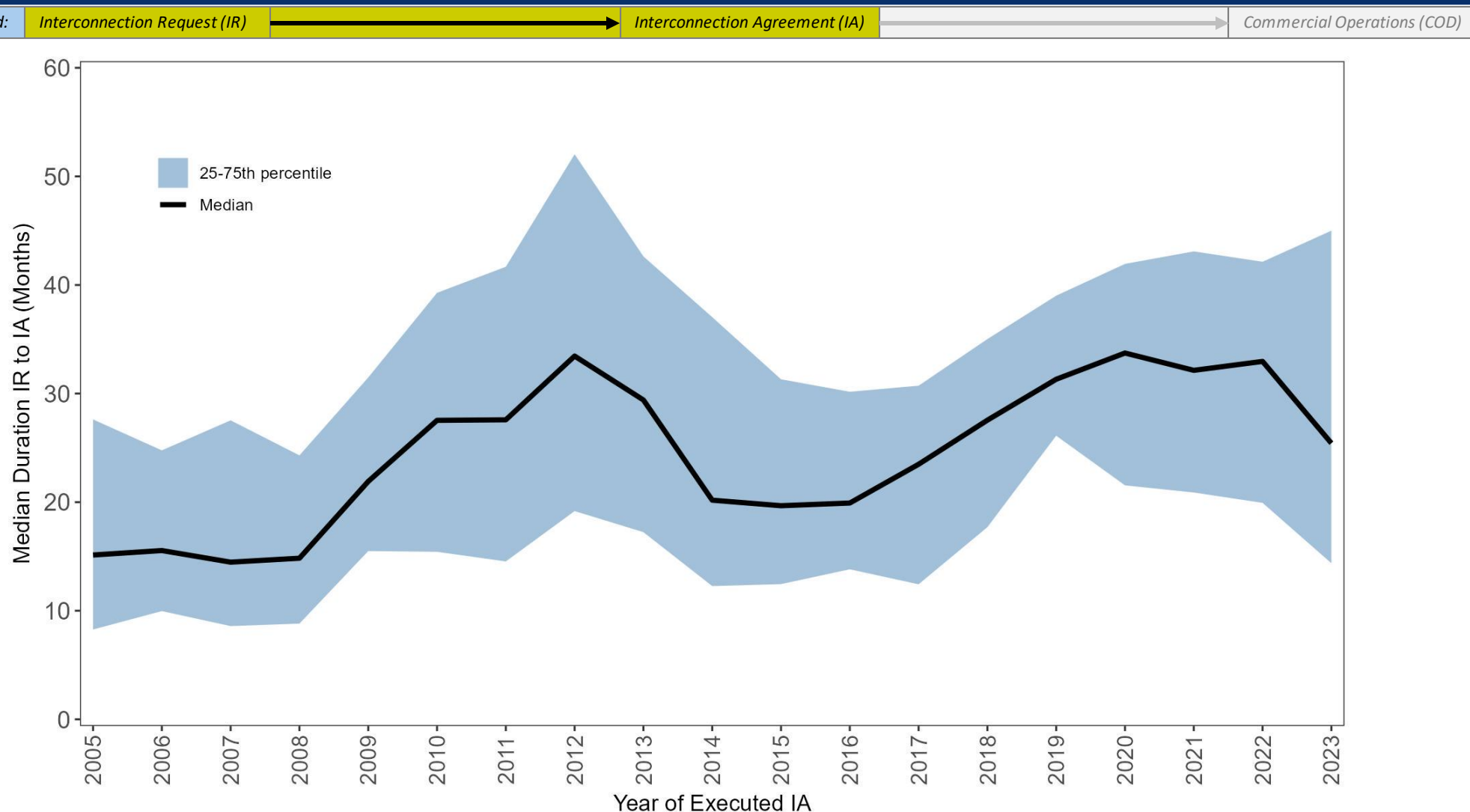


Note: Only includes data for entities that provide study phase for withdrawn projects and comprehensive status information (4 ISOs and 10 non-ISO balancing areas).

Evidence of a Problem #2: Increasing timelines



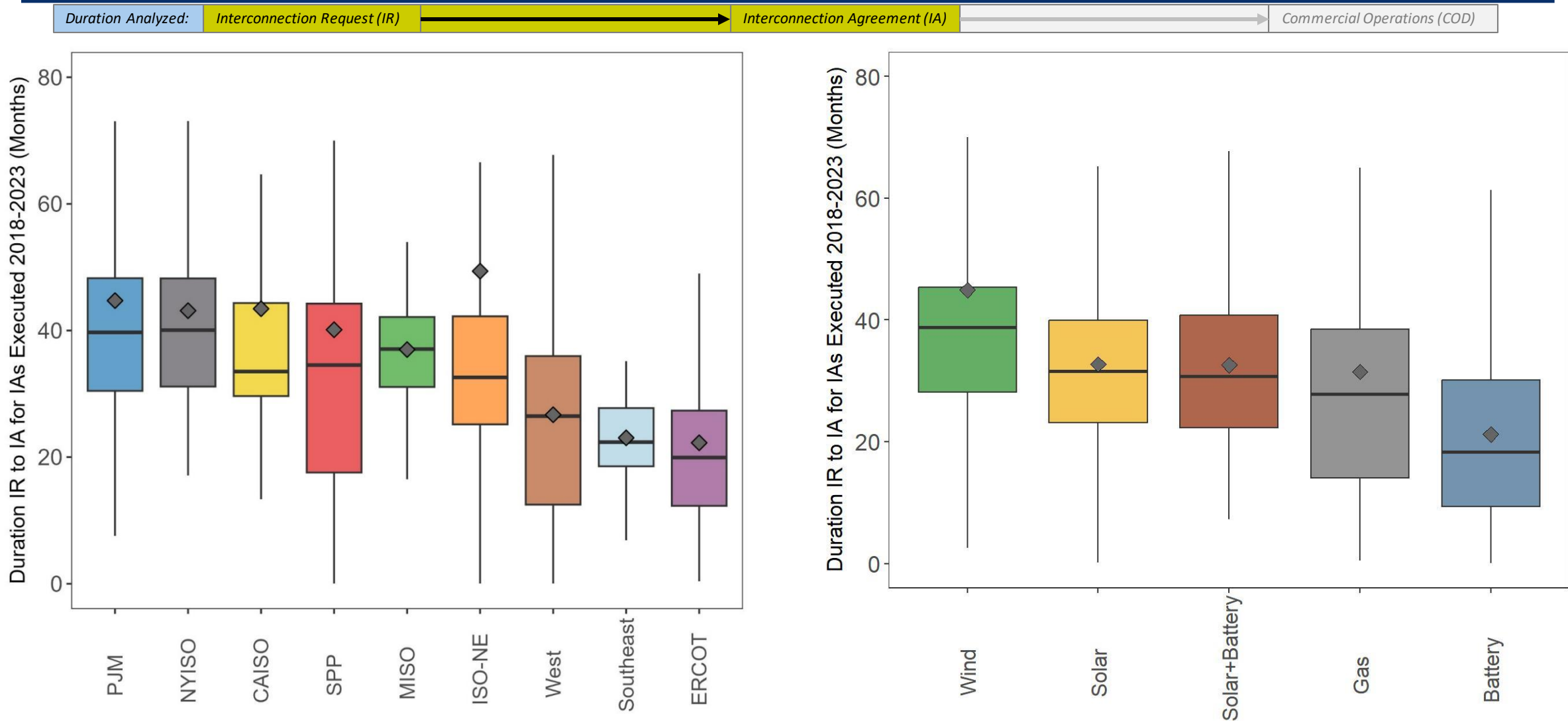
Duration from interconnection request to interconnection agreement had increased recently, but moderated slightly in 2023 (note: 2023 data sample is dominated by ERCOT and West¹)



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 (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.

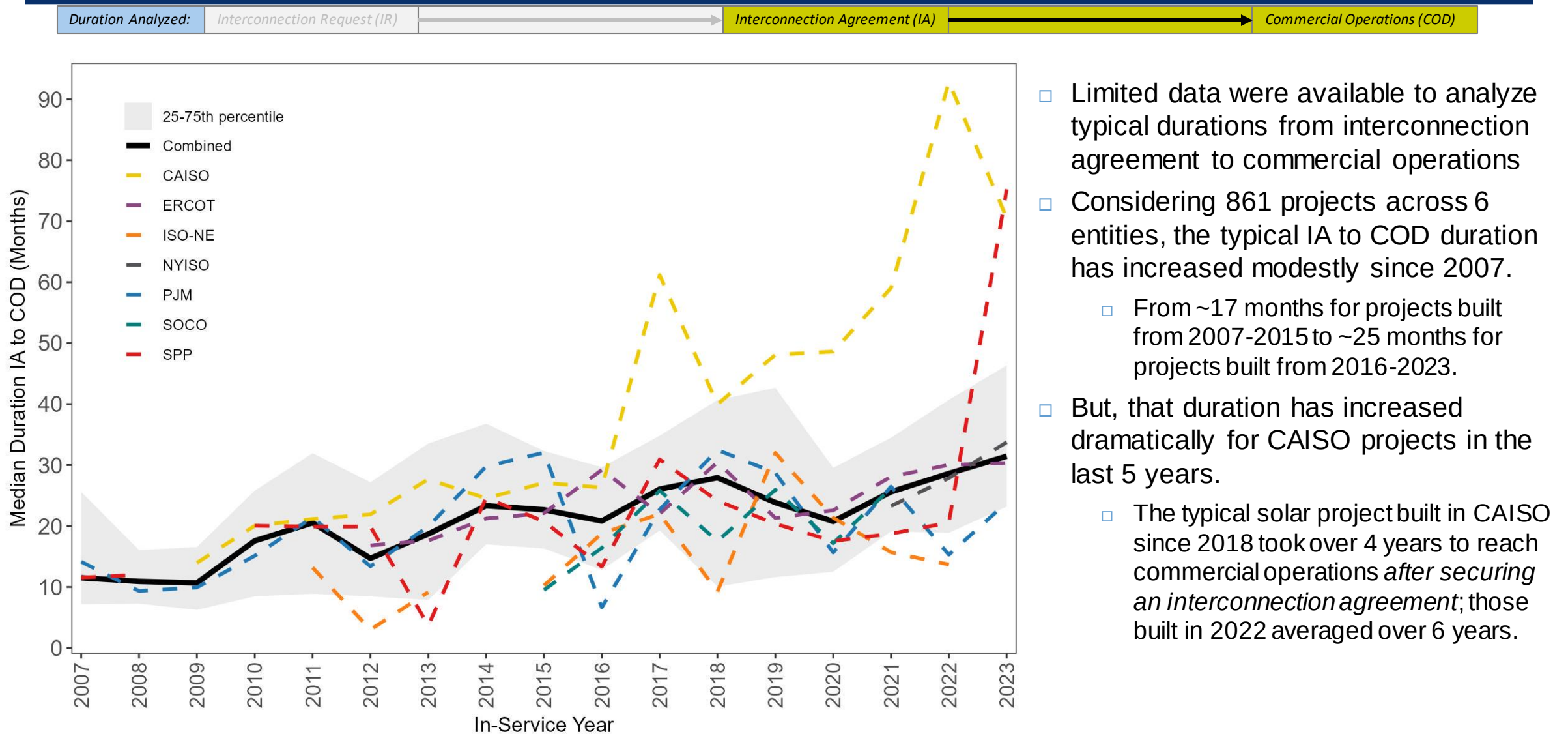
IR to IA duration is typically longest FERC-jurisdictional ISOs; ERCOT is fastest

Wind projects typically face longer timelines, batteries fastest



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).

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



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.

Evidence of a Problem #3: Increasing cost to connect

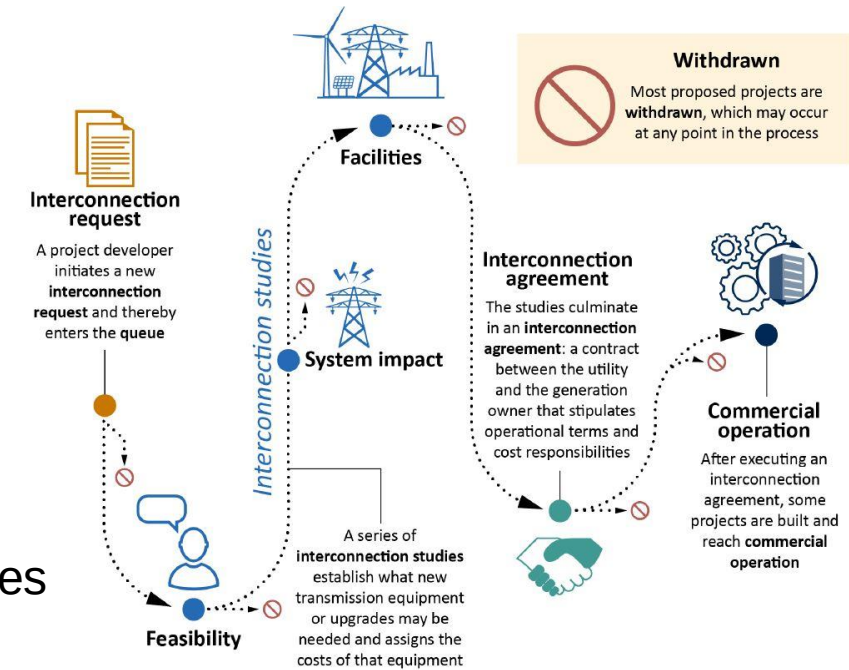
ISO-specific briefings and underlying project cost data available at
https://emp.lbl.gov/interconnection_costs

Motivation for Interconnection Cost Trends Analysis

- A critical knowledge gap:
 - As interconnection requests balloon, have associated interconnection costs increased as well?
 - Are interconnection costs a serious entrance barrier for low-carbon generation?
 - Interconnection cost data are not easily accessible
 - Information barrier for developers and other stakeholders resulting in less efficient interconnection process
 - Reliable interconnection cost estimates can only be obtained by entering the queue, not as pre-request information
 - Interconnection cost estimates are rarely provided in an easily digestible format
 - i2X team initiated request for EIA to collect comprehensive data on ongoing basis
- Regulatory agencies like FERC and legislators don't have clear understanding of cost dynamics, impeding effective policies.

Berkeley Lab Provides Interconnection Cost Data + Analysis: Methods

- ❑ Collected robust sample of 2500+ interconnection cost estimates in 2022/2023
- ❑ Regional coverage:
 - ▣ Project-level costs: SPP, MISO, PJM, NYISO, and ISONE
 - ▣ Cluster-level costs: CAISO
- ❑ Cost data are only a subsample of all projects in the queues:
 - ▣ Interconnection studies are often not yet available for recent queue entrants
 - ▣ RTOs often remove cost publications for older projects
 - ▣ Some projects may withdraw before cost estimates are released
 - ▣ Focus on new and unique generators (not uprates of existing projects)
- ❑ Interconnection cost data are often only available in interconnection studies
 - ▣ Require manual scraping: 400-500 person-hours per region
- ❑ Temporal coverage: 2000-2023
 - ▣ Costs indexed by interconnection study year (not queue entry), real \$2022-terms/kW_{AC} (GDP deflator conversion)
 - ▣ Using most recent cost estimate available at time of data collection (mostly spring-summer 2022)

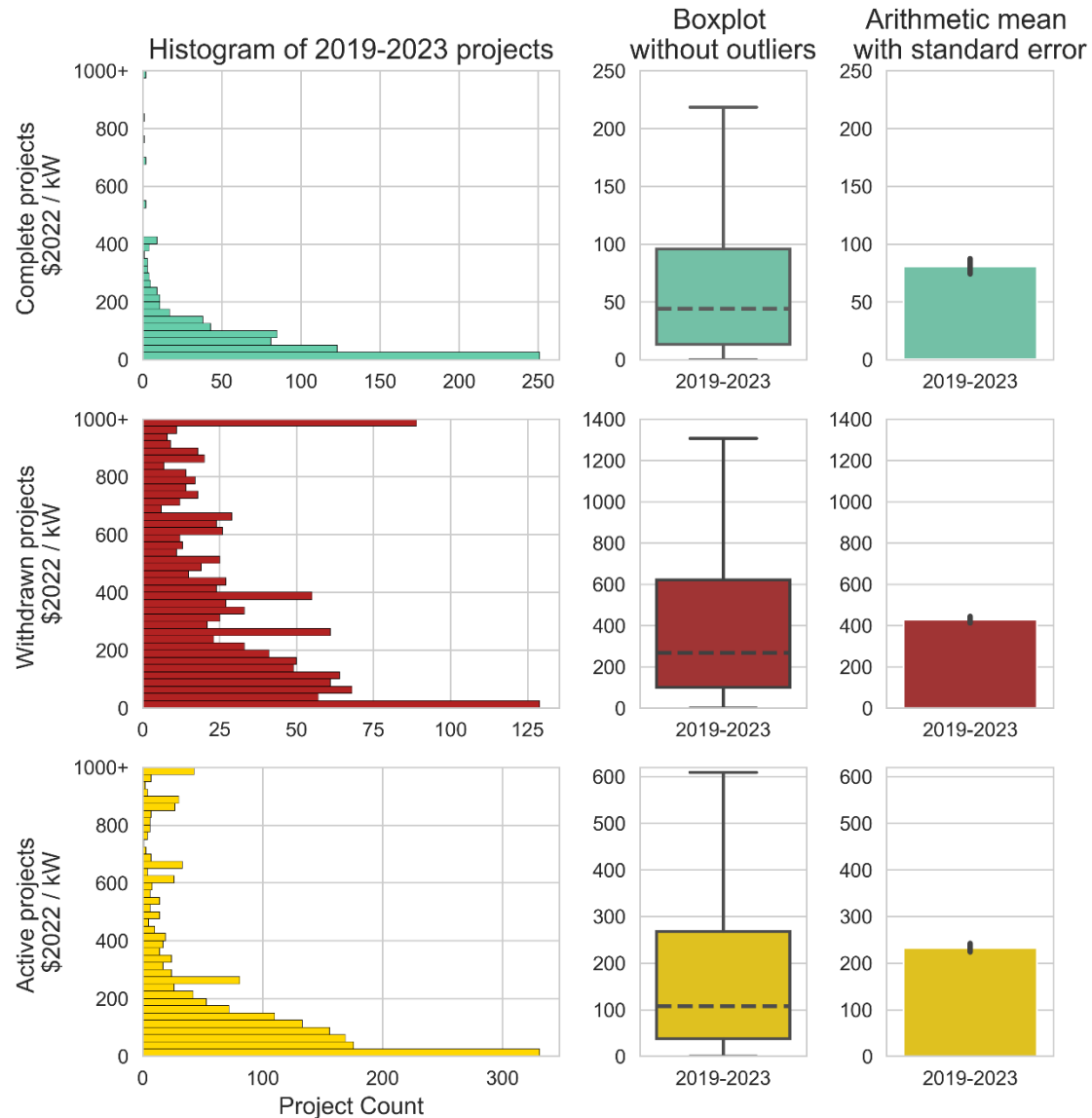


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ISO-specific briefings and underlying cleaned cost data collections available at

https://emp.lbl.gov/interconnection_costs

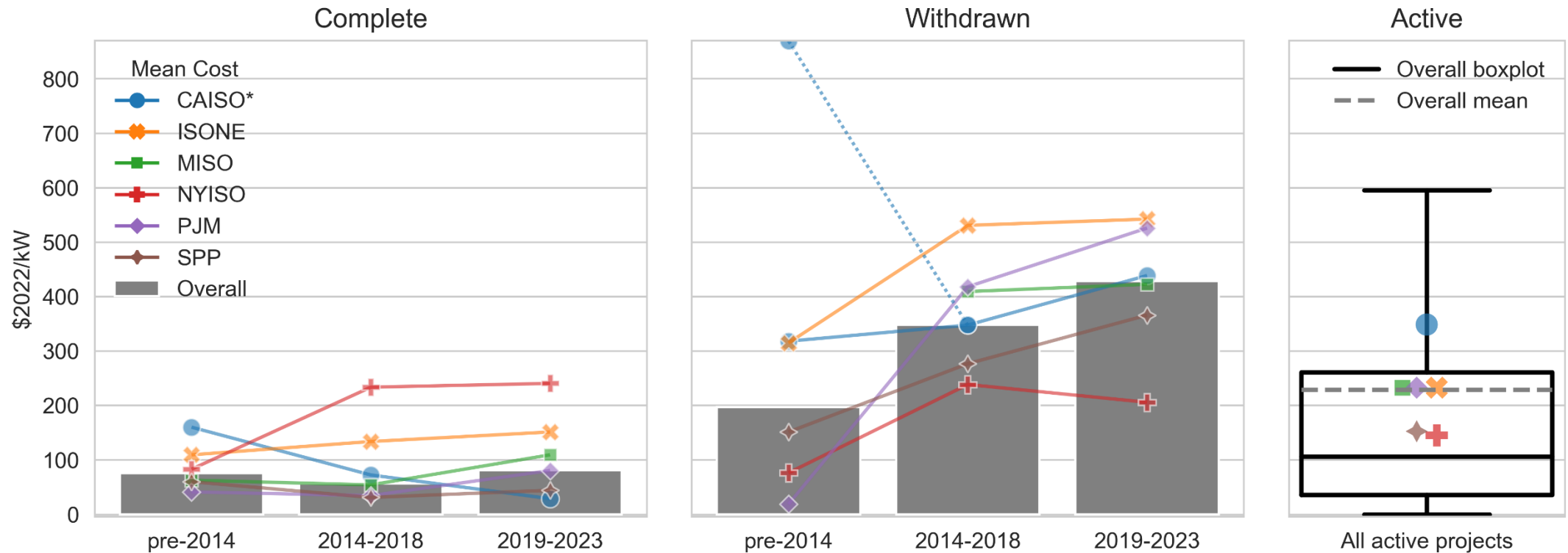
Interconnection costs have a wide distribution



- Cost data often do not have normal distribution:
 - ▣ Many projects with very low interconnection costs
 - ▣ Some projects with very high interconnection costs that influence sample mean
- Most trends presented today also hold when looking at typical (median) projects:
 - ▣ For example, median total interconnection costs have also risen over time for each respective request status

Interconnection costs have grown over time, particularly for projects that withdraw

Average Interconnection Costs



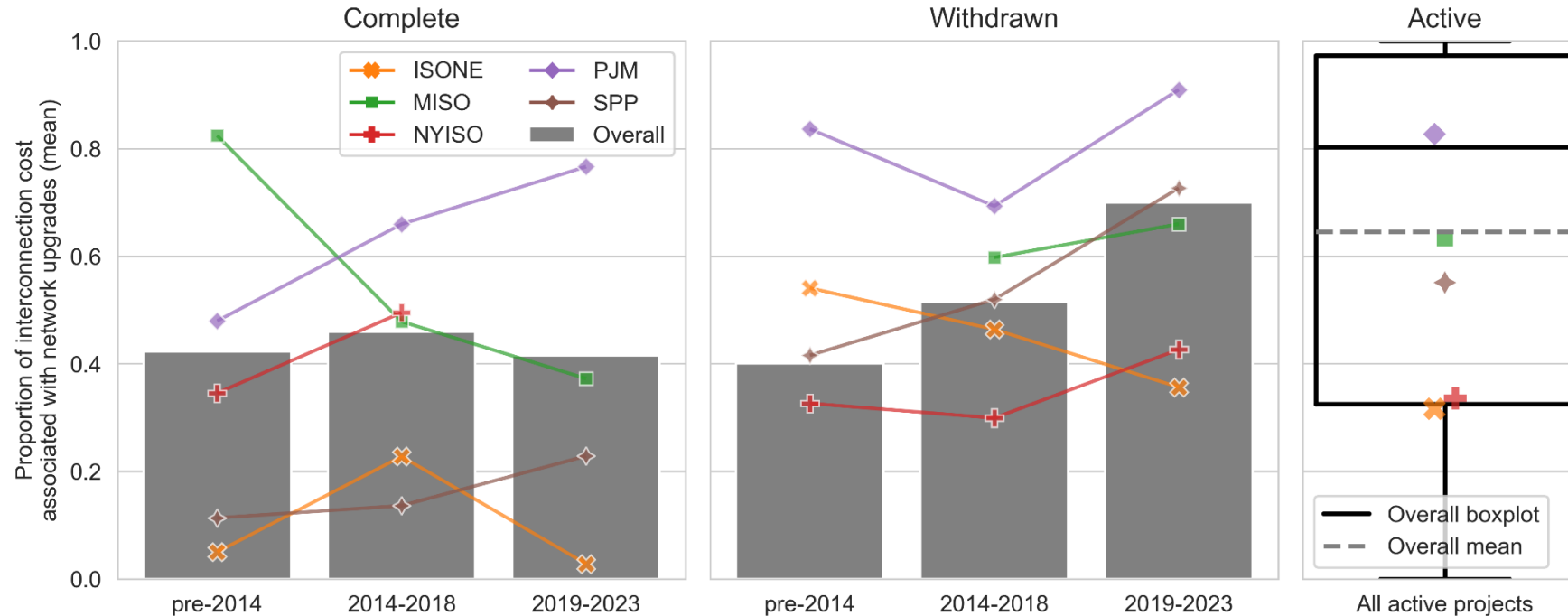
■ Among projects that **complete** all studies, costs have doubled in many regions but declined in CAISO

■ Projects that **withdraw** their interconnection request typically have the highest costs

■ **Active** project costs are consistent with recent trends

Broader network upgrades triggered by new interconnection requests mostly behind recent cost increases among projects that withdraw

Average Network Cost Share of Total Interconnection Costs



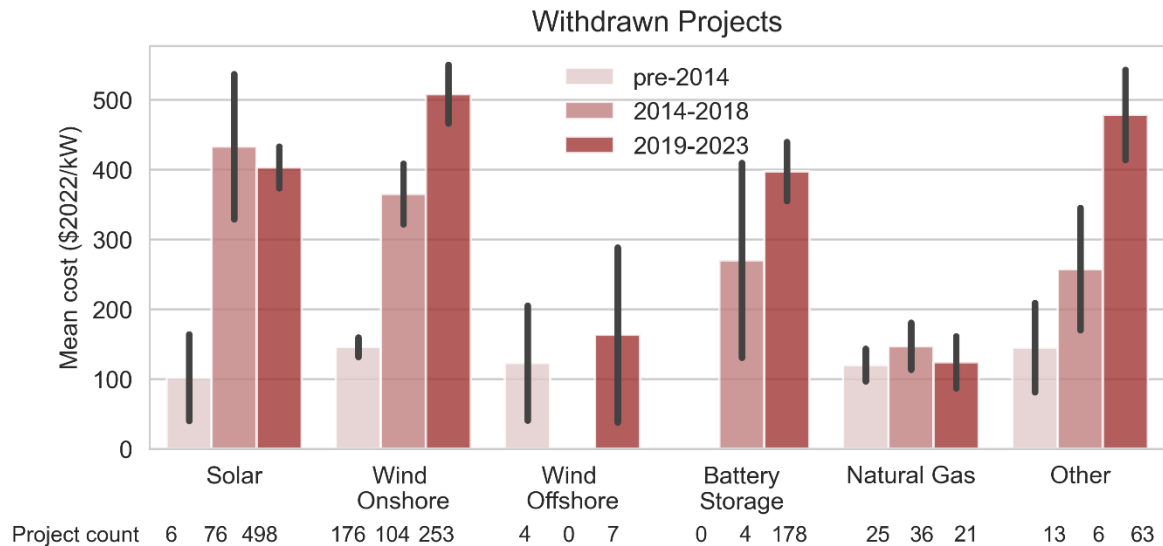
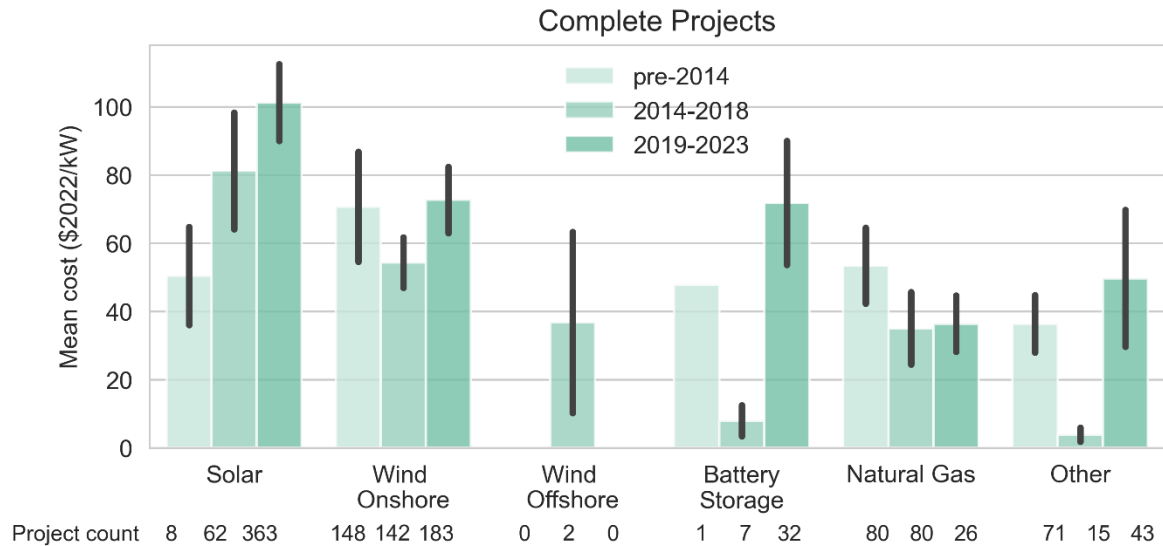
Point of Interconnection (POI) or Interconnection / Attachment Facilities Costs:

- Interconnection station and transmission line extensions
- Often excludes other infrastructure (step-up transformer, spur lines...)

Network Costs:

- Broader transmission network upgrades triggered by reliability or stability violations caused by a new generator.
- May require modest upgrades (breakers) or reconstruction of several high-voltage transmission lines.
- Costs may be shared by multiple generators that contribute to the upgrade and are usually paid for by project developers in the ISOs that we studied.

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%
- Wind costs have greater variation:
 - ▣ Completed: 3%-16% of total project Capex
 - ▣ Withdrawn: 10%-40%
- Storage expensive despite (or because of?) its locational flexibility

Hypothesis:

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

Time for solutions!





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

Overview of the DOE Transmission Interconnection Roadmap

June 24, 2024

An initiative spearheaded by the Solar Energy Technologies Office and the Wind Energy Technologies Office

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Department of Energy

DOE Releases First-Ever Roadmap to Accelerate Connecting More Clean Energy Projects to the Nation's Electric Grid

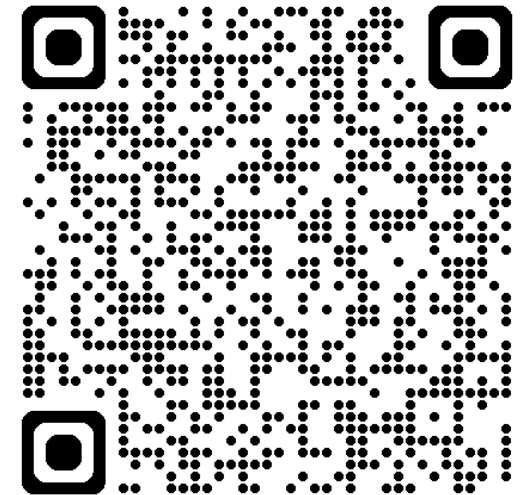
APRIL 17, 2024

[Energy.gov](#) »

DOE Releases First-Ever Roadmap to Accelerate Connecting More Clean Energy Projects to the Nation's Electric Grid

Report Details Recommendations to Streamline Interconnection with Near- to Long-Term Solutions to Add Clean Energy Resources to the Transmission Grid and Boost Our Clean Energy Economy

WASHINGTON, D.C. — The U.S. Department of Energy (DOE) released a [new roadmap](#) outlining solutions to speed up the interconnection of clean energy onto the nation's transmission grid and clear the existing backlog of solar, wind, and battery projects seeking to be built. The Transmission Interconnection Roadmap, developed by DOE's Interconnection Innovation e-Xchange (i2X), serves as a guide for transmission providers, interconnection customers, state agencies, federal regulators, transmission owners, load serving entities (LSEs), equipment manufacturers, consumer advocates, equity and energy justice communities, advocacy groups, consultants, and the research

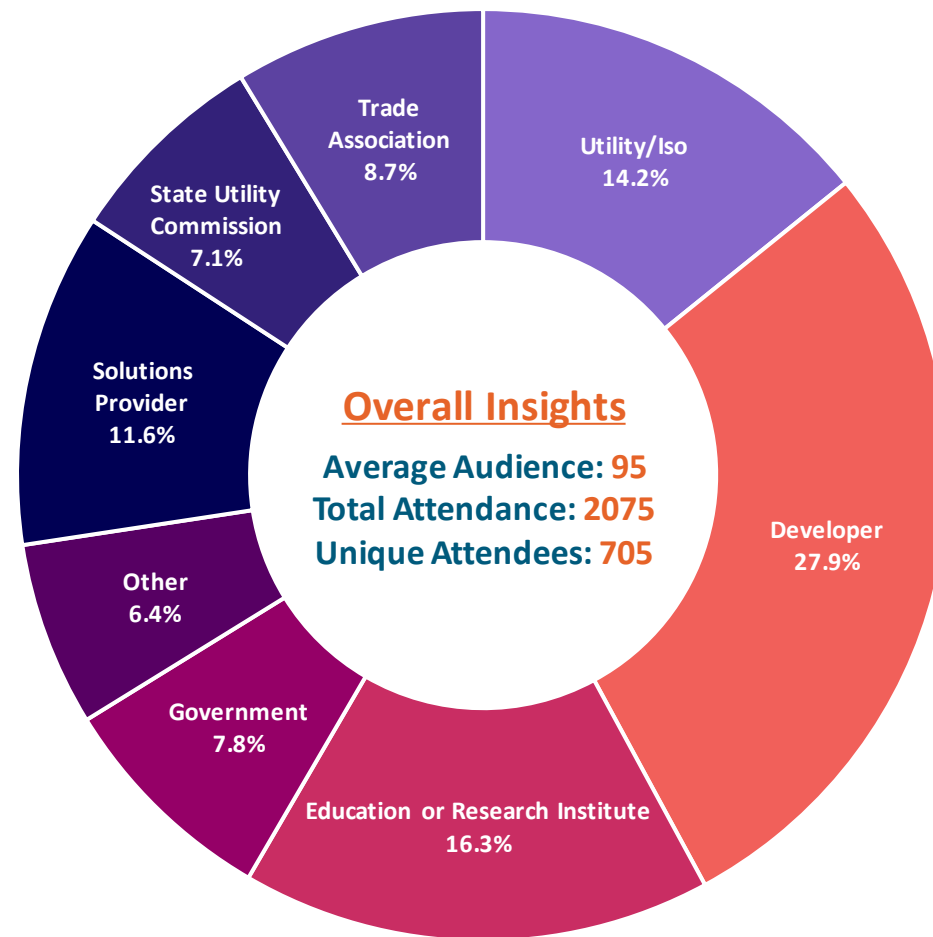


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Transmission Roadmap Development

Roadmap informed by

- Solution e-Xchanges
 - 705 stakeholders from 350 organizations during 22 Solution e-Xchange meetings
 - 20+ public events
- Draft Roadmap
 - Comments from EERE Offices and other DOE offices
 - Request For Information (RFI) Responses on Draft
 - 40 organizations (ISOs/RTOs, utilities, clean energy industries, non-profit organizations)
 - Total of ~280 comments
 - Comments incorporated into the Final



Solution e-Xchange Participation by Stakeholder Group

Major Changes to Roadmap from Draft to Final

- Expanded description of the *role for DOE* (discussed earlier)
- Added context about *FERC Order 2023* and its relationship to key solutions
- Metrics reduced to three with more *aspirational targets*.
- Expanded and better *contextualized key actors* and their roles
- Created separate section on *fair and inclusive interconnection* process
- Expanded connection to *transmission planning*
- Added discussion of *post-interconnection agreement issues*
- *Increased specificity* of several solutions, relying on initiatives provided by RFI comments
- Enhanced cross-referencing of which and how roadmap solutions relate to each other to note *synergies and connectivity of the ideas*

Framing the Interconnection Roadmap

Context and Scope of Roadmap

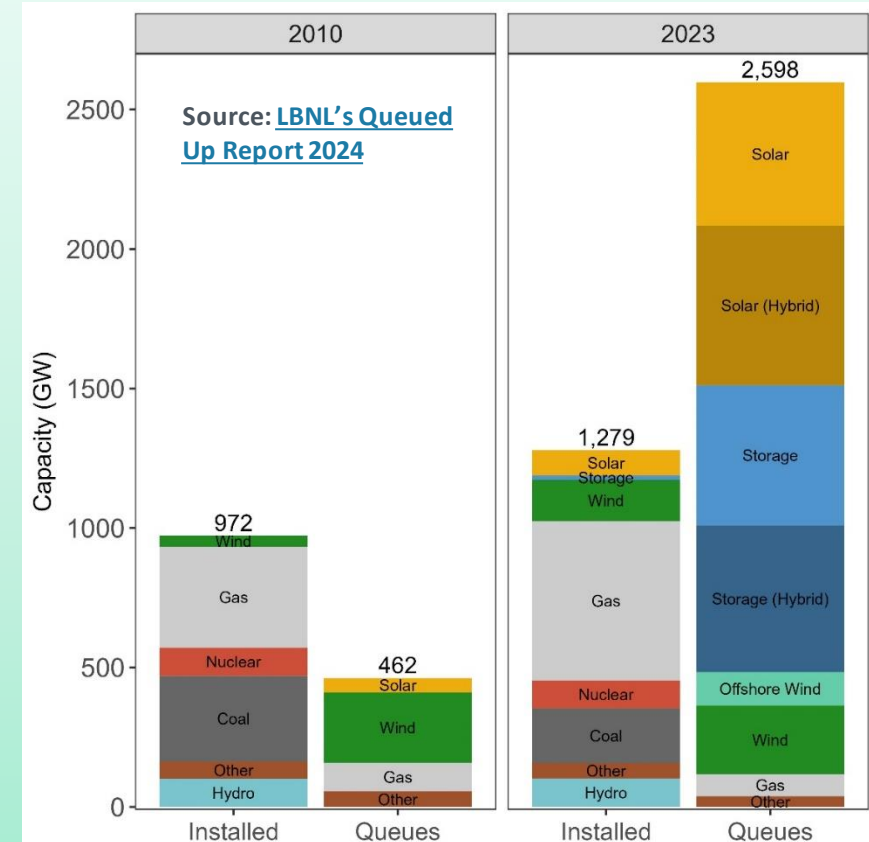
The Need for Reform

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

Synergistic with Ongoing FERC Initiatives

- Solutions in the roadmap are intended to complement and support Order 2023.
- Include challenges and opportunities related to Order 2023 implementation
- But also incorporate ideas not raised in Order 2023 to provide comprehensive vision for longer-term process evolution.

Entire U.S. Installed Capacity vs. Active Queues



Source: [LBNI's Queued Up Report 2024](#)

Transmission Roadmap Key Components and Implementation Actors

35 solutions organized in four goals

Solutions with different 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)

Solutions describe collaborative actions among key 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

Measurable 2030 success targets

DOE has multiple potential roles in enabling Roadmap implementation

Convene Stakeholders

Provide Technical Support

Fund Research and Innovation

Evaluate Progress

Measurable Success Targets for 2030

Interconnection processes align well with Federal, state, and customer's decarbonization goals



Reduced interconnection process time
Average time from request to agreement

Target Value by 2030

< 12 months

Recent Value

33 months (2022)



Lowered cost uncertainty
Standard deviation of interconnection costs

< \$150/kW

\$551/kW (2020-2021)



Increased Completion rates
Completion rate for projects that entered facility study phase

> 70%

45% (2016)



Maintained system reliability
Number of system disturbances due to modeling inaccuracy

Zero

4 (2022)

Four Interconnection Goals with 35 Solutions

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

- Solutions are a collection of strategies rather than a rigid package of prescriptive fixes.
- Some solutions are complementary: to be effective, they would need to be implemented in tandem with others.
- Other solutions are exclusive: adopting one might obviate the need for another.
- Solutions may be topically specific (e.g., Cost Allocation)

Roadmap does not assess the costs of implementing the solutions.

Goal 1: Data Access and Transparency

Challenge: Inadequate access to information is contributing to high volumes of interconnection requests, high withdrawal rates, and processing delays. How can improvements to data access and transparency support interconnection stakeholders?

Objectives

Key Tradeoff: Providing information to promote transparency, which take time and resources to implement, and which need to abide by security and confidentiality concerns

- Enable tracking and auditing of process performance
- Facilitate screening, optimal siting, and automation
- Improve the predictability of interconnection studies
- Reduce barriers to assess proposed projects



Example Solutions

- a. Improve the scope, accessibility, quality, and standardization of **data on projects already in interconnection queues** (short-term)
- b. Enhance the scope, timeliness, accuracy, and consistency of **interconnection study models and modeling assumptions** (medium-term)
- c. **Develop tools** to manage, analyze, and visualize transmission and interconnection data (medium-term)

Goal 2: Improve Process and Timeline

Challenge: Backlogs and delays are the result of rapid growth in interconnection requests and inefficiencies in process. What changes can be made to handle larger quantities of requests while reducing study process timelines and maintaining access?

Topical Area

Queue Management

Key tradeoff: **rationing quantity** of proposed projects while **maintaining competition** and open access industry principles



Example Solutions

- **Automate** data input, study validation, and customer communications (short-term)
- Better utilize **fast-track options** for interconnection (medium-term)
- Consider **market-based approaches** to rationing (long-term)

Affected System Studies

Key tradeoff: creating more **consistent and harmonized** interregional processes while **maintaining independence** of individual balancing areas



- Increase **collaboration and standardization** on affected system studies (short-term)
- Develop processes for **joint transmission planning** efforts on neighboring affected systems (medium-term)

Goal 2: Improve Process and Timeline

Challenge: Backlogs and delays are the result of rapid growth in interconnection requests and inefficiencies in process. What changes can be made to handle larger quantities of requests while reducing study process timelines and maintaining access?

Topical Area

Inclusive and Fair Process

Key tradeoff: Providing **targeted support** for stakeholders that do not start with the same tools and resources **without ignoring open access** principles



Example Solutions

- Incorporate **equity goals in transmission planning** and valuation (short-term)
- Provide **independent engineering, admin, and legal services** to support interconnection process navigation (medium-term)

Workforce Development

Key tradeoff: Focus on **growing and retaining workers** while acknowledging challenge of **competition for interconnection skills** amongst interconnection-focused employers



- Assess **scale of interconnection workforce** growth requirements (short-term)
- Upskill the **existing workforce** (short-term)
- Grow workforce via **outreach, career counseling, apprenticeships, and new curriculum** (medium-term)

From which topic area are you most excited to implement solutions?

a) Queue management

- e.g., readiness requirements, automation, fast-track development, interconnection rationing

b) Affected systems studies

- e.g., regional collaboration and joint planning with neighboring systems

c) Inclusive and fair process

- e.g., equity goals in transmission planning, technical assistance for underserved interconnection customers

d) Workforce development

- e.g., continuing education, workforce expansion

Goal 3: Promote Economic Efficiency

Challenge: Interconnection and transmission planning are closely related, though often not closely coordinated. How can coordination be improved to keep costs low for consumers and more fairly allocate costs?

Topical Area

Example Solutions

Cost Allocation

Key tradeoff: Balancing **uncertain interconnection cost outcomes** with the need to provide appropriate **incentives for resource siting** and efficient use of current transmission system

- Ensure generators have **option to be re-dispatched** rather than paying for network upgrades (medium-term)
- **Explore delinking** interconnection processes from network upgrades (long-term)

Planning Coordination

Key tradeoff: Transmission facilities not selected through **long-term planning** could be triggered by **less efficient interconnection processes**

- Align **data inputs, assumptions, and process timing** between interconnection and transmission planning (medium-term)

Interconnection Studies

Key tradeoff: Changing generation mix requires **study method updates**, which take **time and resources** to implement

- Evaluate **all effective mitigation options**, including alternative transmission technologies (short-term)
- Consider allowing interconnection customers to **provide own interconnection study** (long-term)

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

Challenge: In recent years there has been a series of disturbance events leading to inverter-based resource (IBR) disconnection. How do we build the foundation to manage high penetration rates of IBRs & minimize disturbances?

Topical Area

Interconnection Reliability Assessment Models and Tools

Key tradeoff: Providing **accurate and precise resource modeling** without significantly **slowing down the interconnection study** process

Interconnection Standards

Key tradeoff: Providing **clear upfront requirements** that ensure reliability in real-time operations while allowing enough flexibility to **leverage innovation and technology efficiencies**

Example Solutions

- Require **submission of EMT models** and develop screens that determine when EMT studies are necessary (short-term)
 - Develop **study process flow** aligned with project development timelines (medium-term)
 - Advance **computational speeds** of studies (medium-term)
-
- Adopt and implement **IEEE 2800-2022** (short-term)
 - Assess need for new standards to cover **emerging technologies** (medium-term)
 - Evaluate **cyber and physical security** concerns during interconnection (medium-term)

Explore solutions in depth together



July 18 - Increase Data Access and Transparency



September 19 - Promote Economic Efficiency



October 24 - Improve Process and Timeline



December 3 - Maintain a Reliable, Resilient and Secure Grid

i2X Forum for Implementing Reliability Standards for Transmission (i2X FIRST)

i2X FIRST is a series of monthly interactive meetings to facilitate the adoption of new and recently updated standards relevant for interconnected clean energy resources like solar and wind energy.

Upcoming dates:

- June 25 | 11 a.m.- 1 p.m. ET | Virtual
- July 30 | 11 a.m.- 1 p.m. ET | Virtual
- Aug 20 | 11 a.m.- 1 p.m. ET | Virtual



Join . Engage . Collaborate

15-minute Break

Website: energy.gov/i2x
Email: i2x@ee.doe.gov



1

Welcome & Opening Remarks

2

CAISO Interconnection Process

3

LBNL Cost Analysis and Queued Up Report

4

Transmission Roadmap

5

Interactive Exercise: Visioning
Generator Interconnection in 2035

Interactive Exercise – Visioning 2035

Scenario

It's 2027. 70% of CA's electricity comes from renewables and zero-carbon resources (e.g., hydro, nuclear). CA is behind schedule in meeting its goals of 90% by 2035 and 100% by 2045. It takes more than 18 months to secure an interconnection agreement. Clean energy projects with interconnection agreements take at least 36 months to start operations.

Exercise

- Your group identified **seven solutions** outlined in DOE's 2024 Transmission Interconnection Roadmap.
- Discuss your finalized solutions stack and how to implement within 5 years to see impact.

Rules

- Each group needs at least one representative from a stakeholder group.
- You can swap a solution from a list of alternatives (only). No more than seven total solutions.
- You can cut your solution stack to four with one solution in each goal area.
- Be Respectful. Open. Concise. Be "Yes &." Be Fun

Interactive Exercise – Solution Stack

Goal #1. Increase Data Access, Transparency, and Security for Interconnection

- Solution 1.2: Enhance the scope, timeliness, accuracy, and consistency of **interconnection study models and modeling assumptions** that transmission providers make available to interconnection customers.

Goal #2. Improve Interconnection Process and Timeline

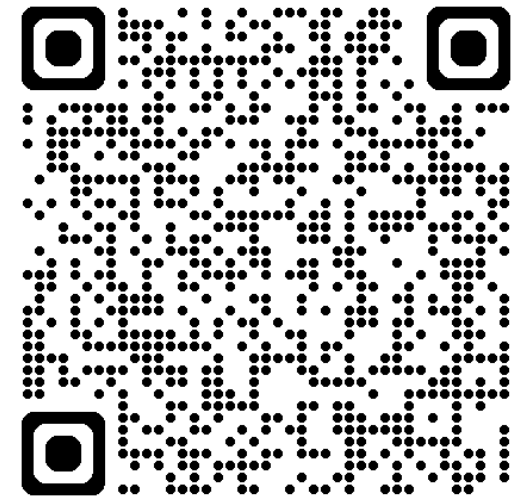
- Solution 2.6: Consider market-based approaches to rationing interconnection access.
- Solution 2.11: Provide access to independent engineering, administrative, and legal services to support the navigation of interconnection processes.

Goal #3. Promote Economic Efficiency in Interconnection

- Solution 3.3: Explore and evaluate potential options for delinking the interconnection process and network upgrade investments to increase up-front interconnection cost certainty.
- Solution 3.7: Explore options to allow interconnection customers to self-fund and provide their own interconnection studies, subject to transmission provider oversight, rules, and requirements.

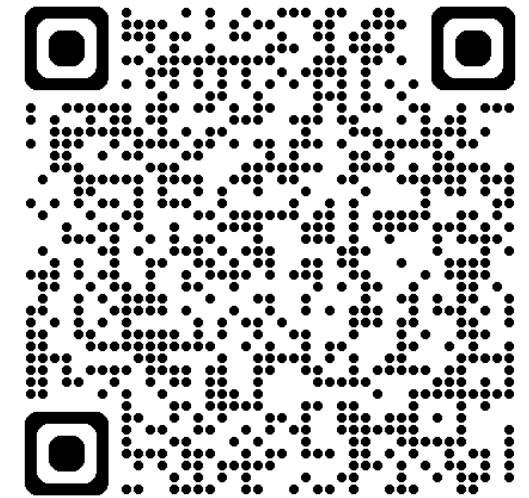
Goal #4. Maintain a Reliable, Resilient, and Secure Grid

- Solution 4.4: Advance the computational speed of interconnection reliability assessments.
- Solution 4.5: Adopt and implement a harmonized and comprehensive set of generation interconnection requirements or standards, consistent with Institute of Electrical and Electronics Engineers (IEEE) Standard 2800-2022.



Questions for discussion

1. Start with the provided solution stack. Do you like to keep all the solutions? Which ones you removed? Which ones you swapped?
2. In your final stack of solutions, where do you see conflicts or synergies? How would you make the solutions more specific to solve conflicts and amplify synergies?
3. What are some of the costs and benefits in these solutions that you like to highlight?
4. How would you implement these solutions? From different stakeholders' viewpoints/ or preferences? What must change in terms of incentives (if any)?



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Interactive Exercise – Let's play

- Introduce yourself
- In each group, pick your role to play. There must be at least one representative:
 1. Federal Energy Regulatory Commission (FERC)
 2. State Energy regulatory authorities
 3. Interconnection service providers
 4. Interconnection Customers
 5. OEM / Service/ Solution Providers
 6. Advocacy groups Public-benefit organization
 7. Research community
 8. Other (e.g., Local, State & Tribal Govs)
- Elect someone from the group to take notes and report out and share
- Bring to the conversation diverse subject matter expertise
 - Tech/Engineering. Regulatory/Markets. Admin process / Organizational change management)
- Have fun and use your creativity, your experience or lack of experience.



Join . Engage . Collaborate

Interactive Exercise

Website: energy.gov/i2x
Email: i2x@ee.doe.gov

