# *Interconnection Innovation eXchange: A Roadmap for Unlocking Queue Backlogs*

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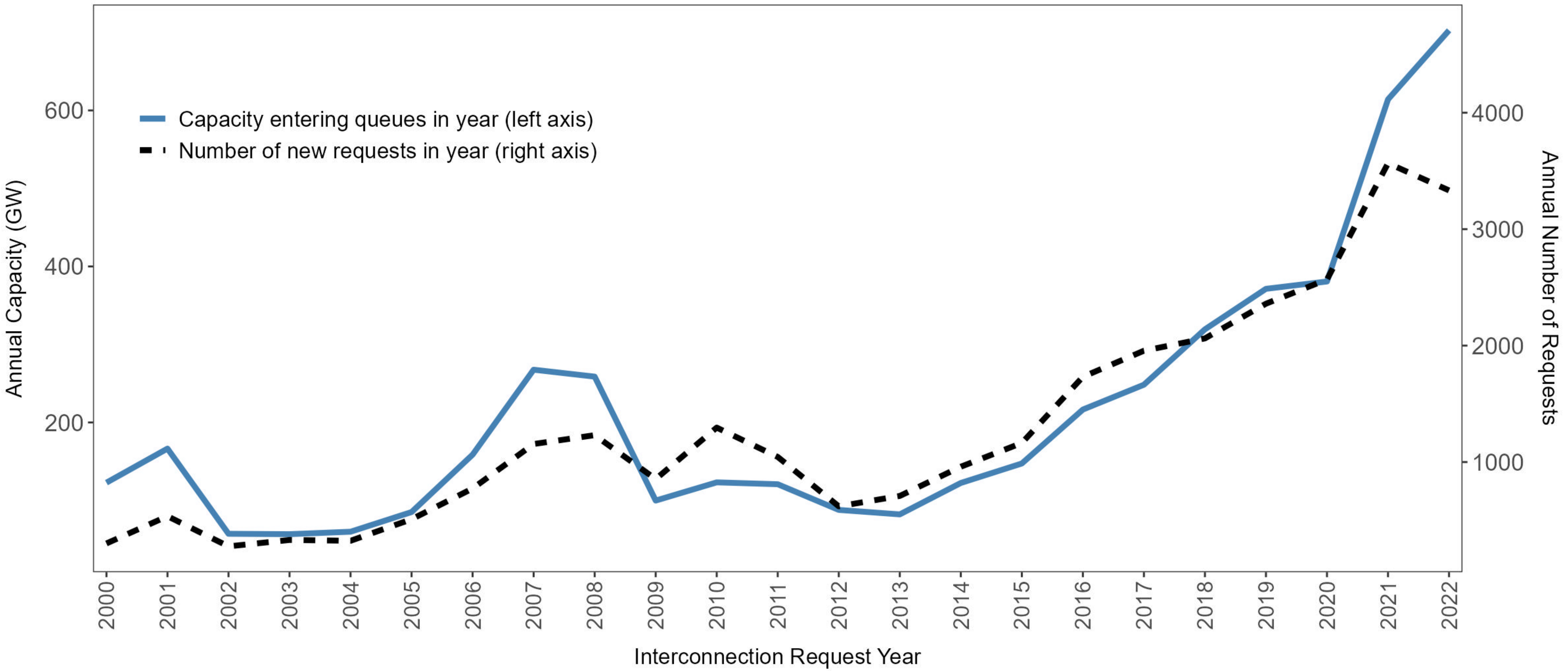
# Outline

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

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

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

# There has been a substantial increase in annual interconnection requests (both in terms of number and capacity) since 2013; over 700 GW added in 2022 alone

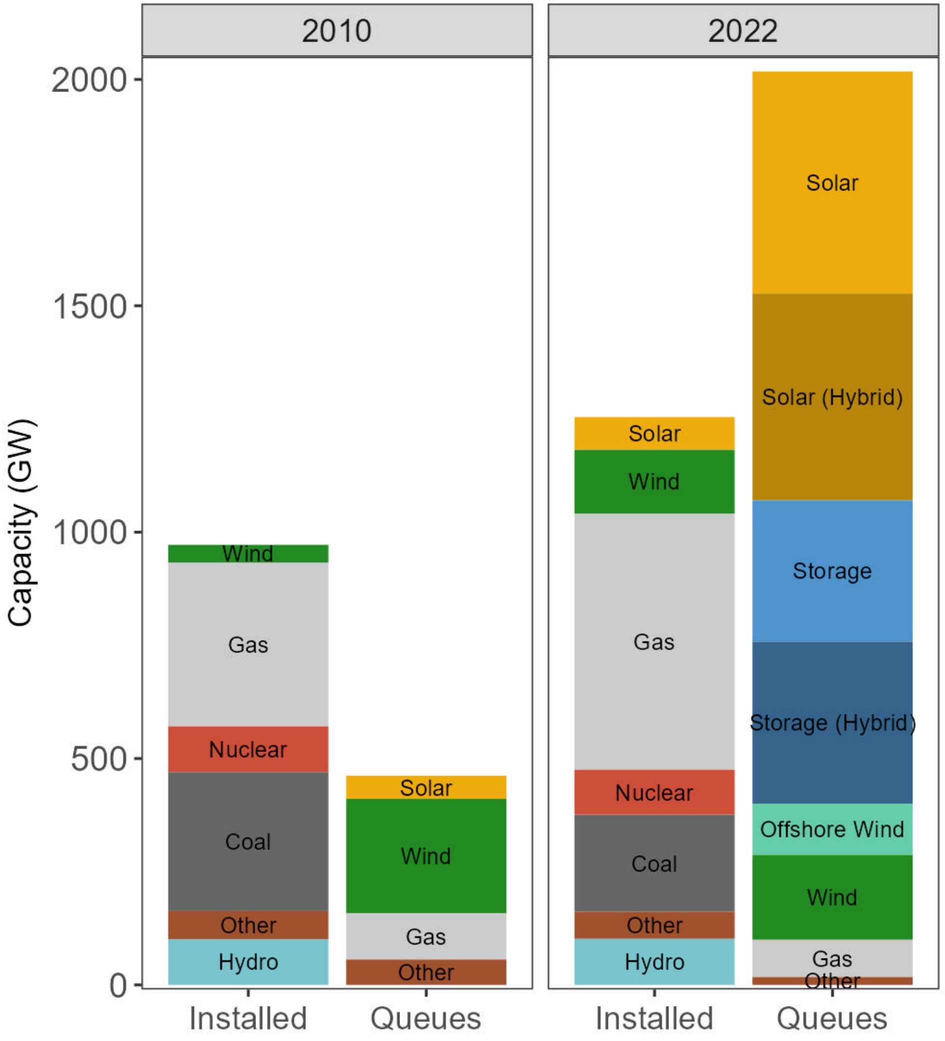



Decrease in new requests in 2022 likely driven by "pauses" on new requests in CAISO and PJM (see slide 7).

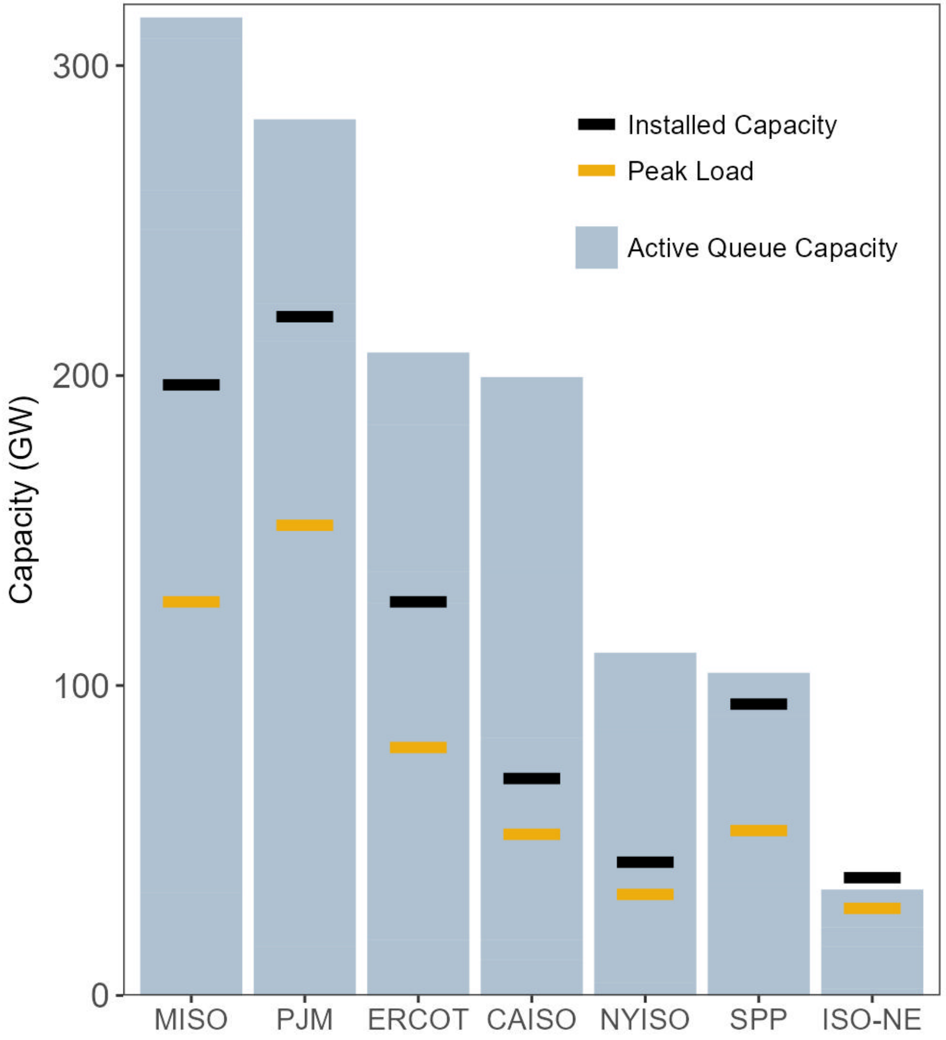
*Notes: (1) This total annual volume includes projects with a queue status of "active", "suspended", "withdrawn", or "operational".*
*(2) All values – especially for earlier years – should be considered approximate.*

# Active capacity in queues (~2,040 GW) exceeds installed capacity of entire U.S. power plant fleet (~1,250 GW), as well as peak load and installed capacity in most ISO/RTOs

*Entire U.S. Installed Capacity vs. Active Queues*




*RTO Installed Capacity & Peak Load vs. Active Queues*

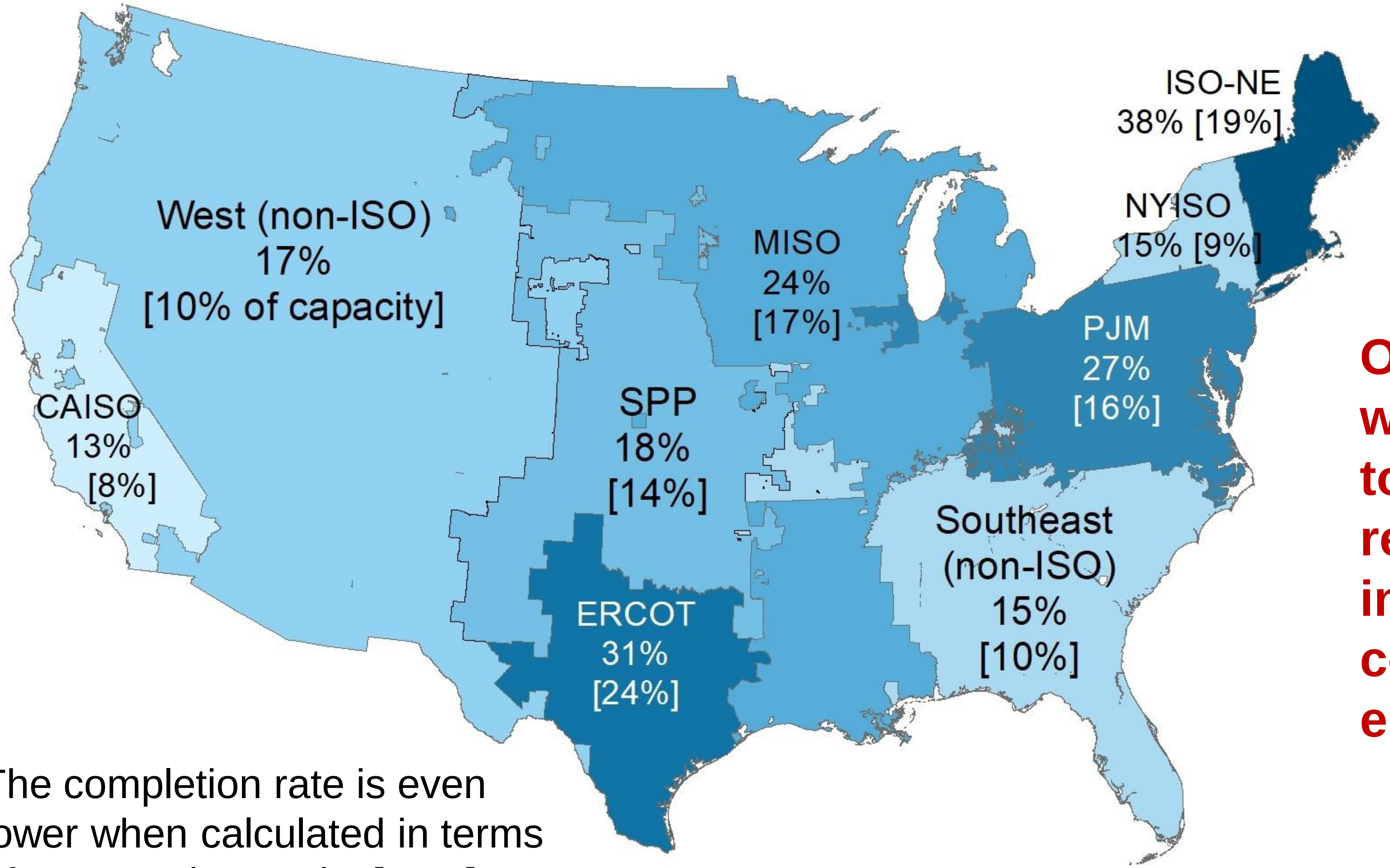



Comparisons of queue capacity to installed capacity or peak load should also consider generators' contributions to resource adequacy, for example their "effective load carrying capability" (ELCC). As variable resources, solar and wind contribute a smaller percentage of their nameplate capacity to resource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

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

*Notes: (a) Hybrid storage in queues is estimated for some projects. (b) Total installed capacity from EIA-860, December 2022. (c) RTO installed capacity from FERC Annual State of the Markets Report ([https://www.ferc.gov/media/report-2021-state-markets](https://www.ferc.gov/media/report-2021-state-markets)). Peak load data from RTO websites.*

# Only 21% of projects that applied for interconnection prior to 2018 have been built – 72% have been withdrawn (7% are still actively trying!)




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

The completion rate is even lower when calculated in terms of proposed capacity [14%]

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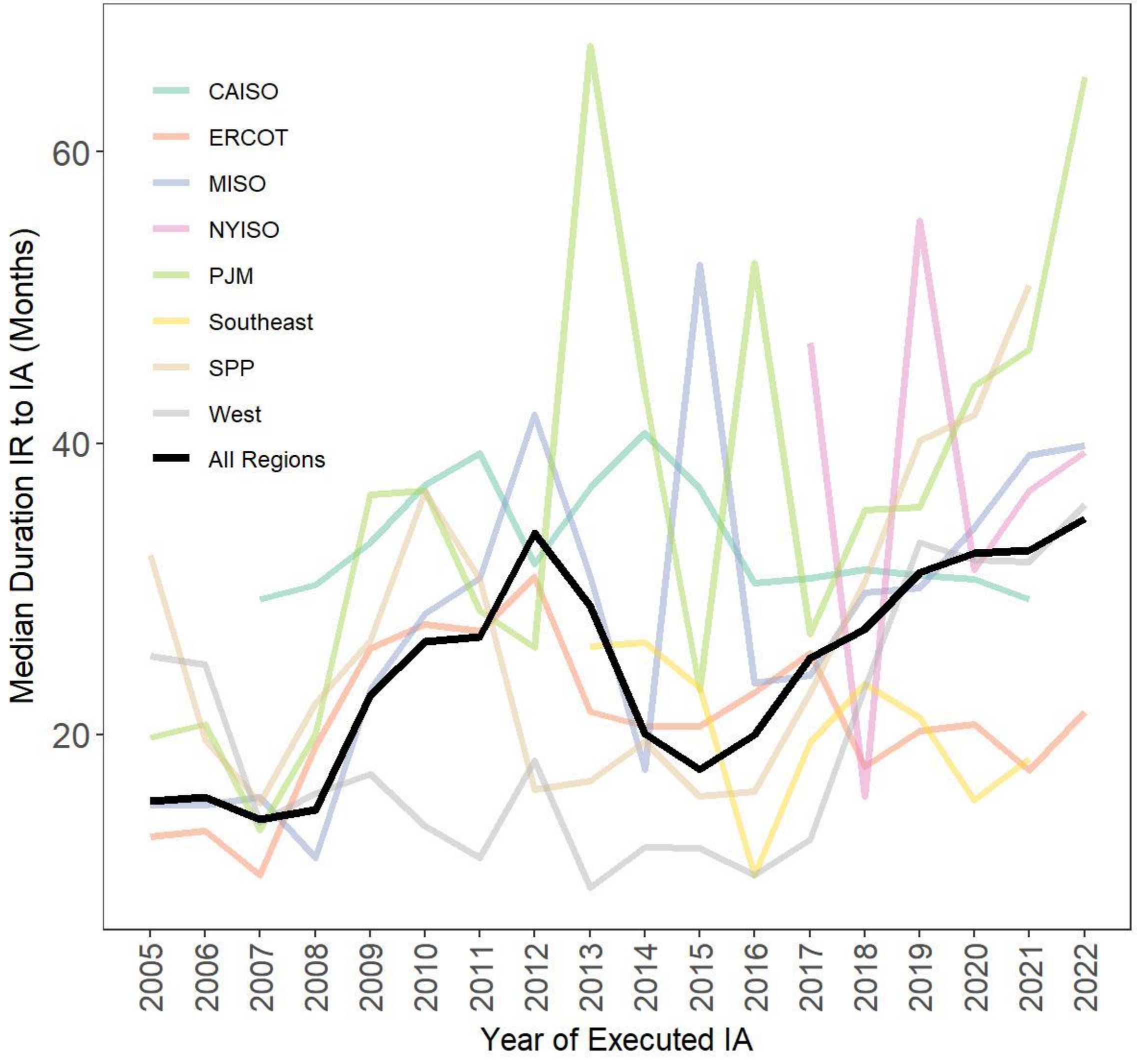
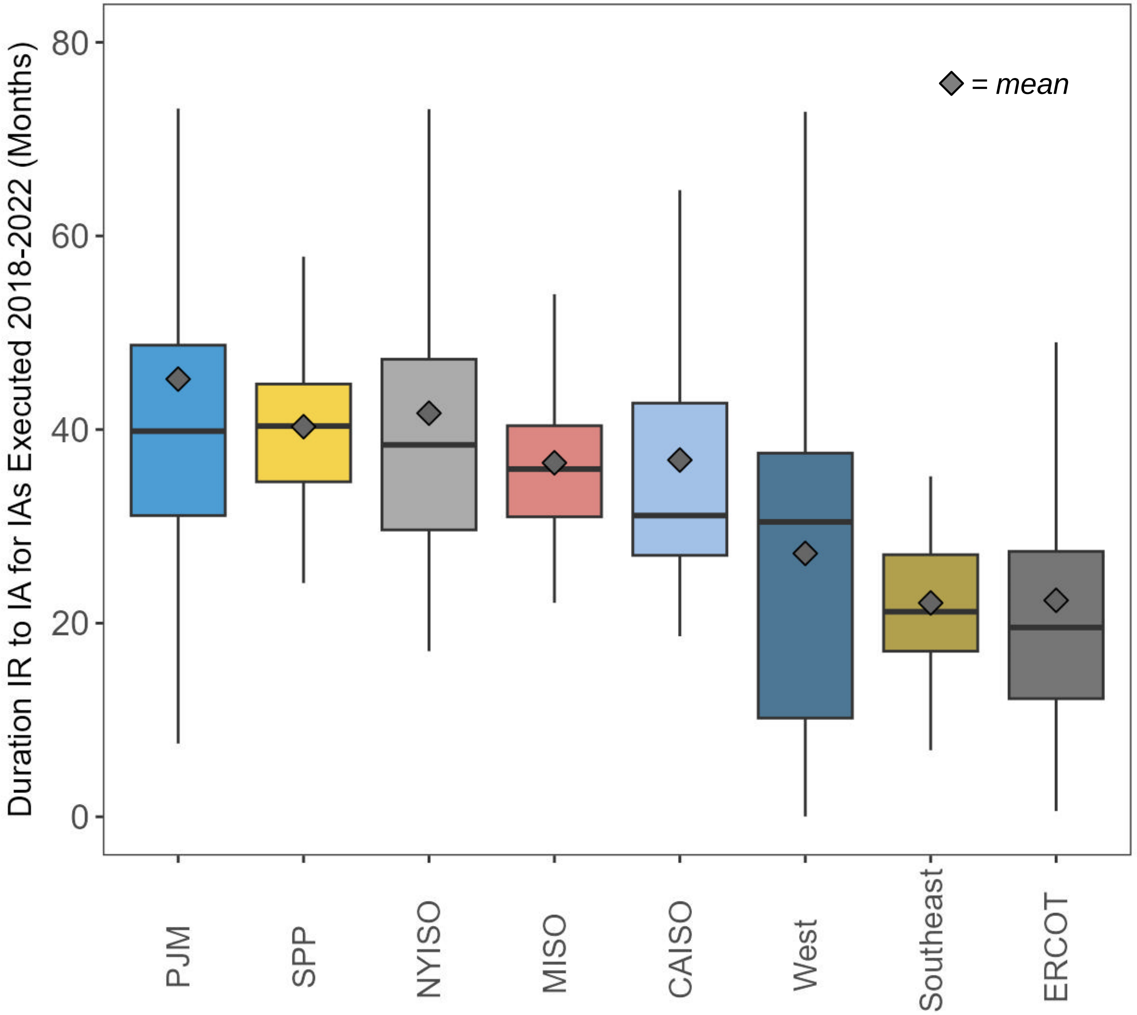
*Source: Berkeley Lab, "Queued Up". 2023*

# Evidence of a Problem #1: Increasing Timelines

# Study duration is increasing in many regions, exceeding 3 years in PJM, SPP, NYISO, and MISO for IAs executed from 2018-2022; ERCOT and Southeast are notably faster

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




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

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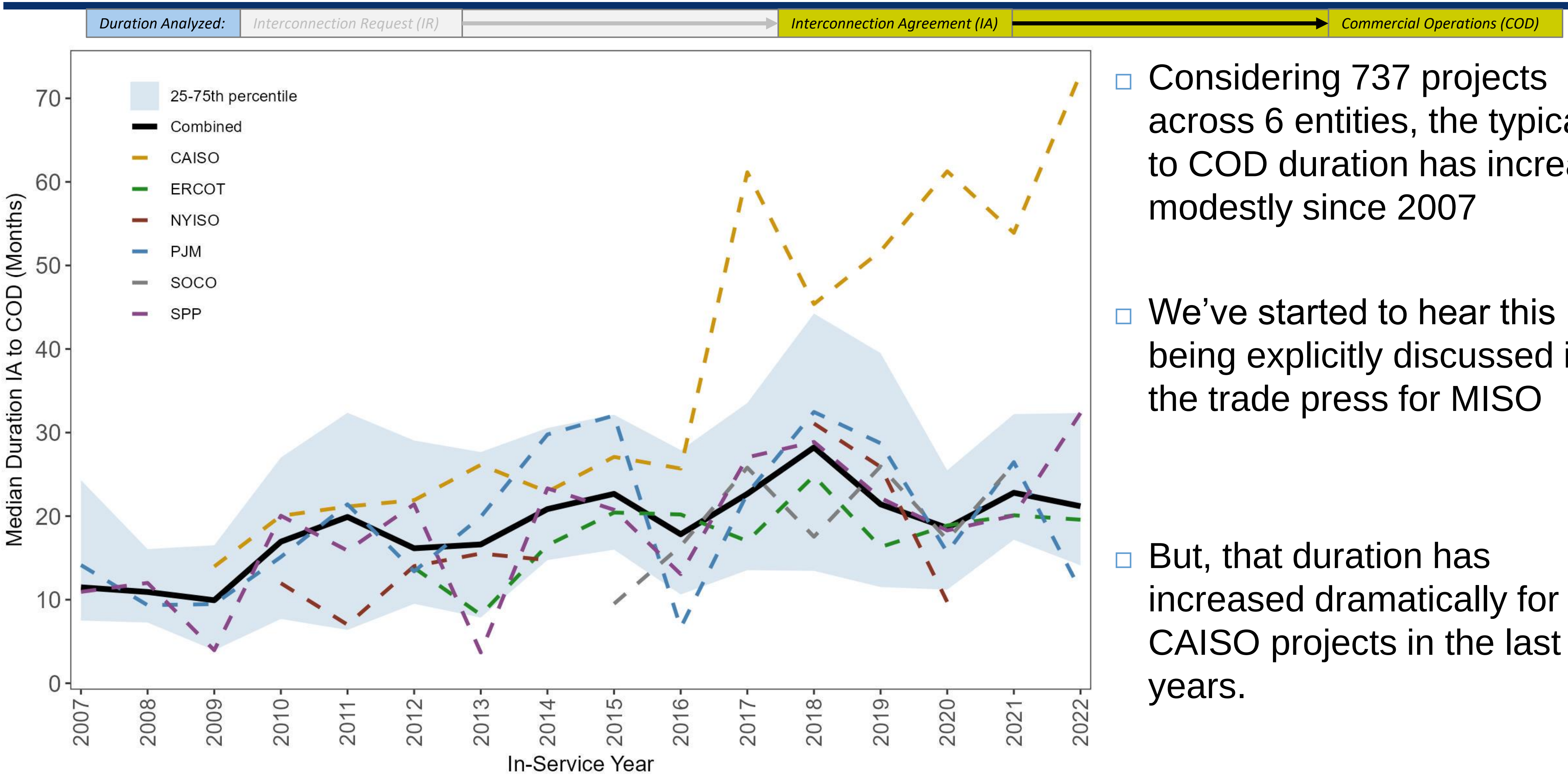
# Some delays are also evident *outside of the interconnection process*: procurement / offtake, local permitting, construction, supply chain, etc.




- Considering 737 projects across 6 entities, the typical IA to COD duration has increased modestly since 2007
- We’ve started to hear this being explicitly discussed in the trade press for MISO
- But, that duration has increased dramatically for CAISO projects in the last 5 years.

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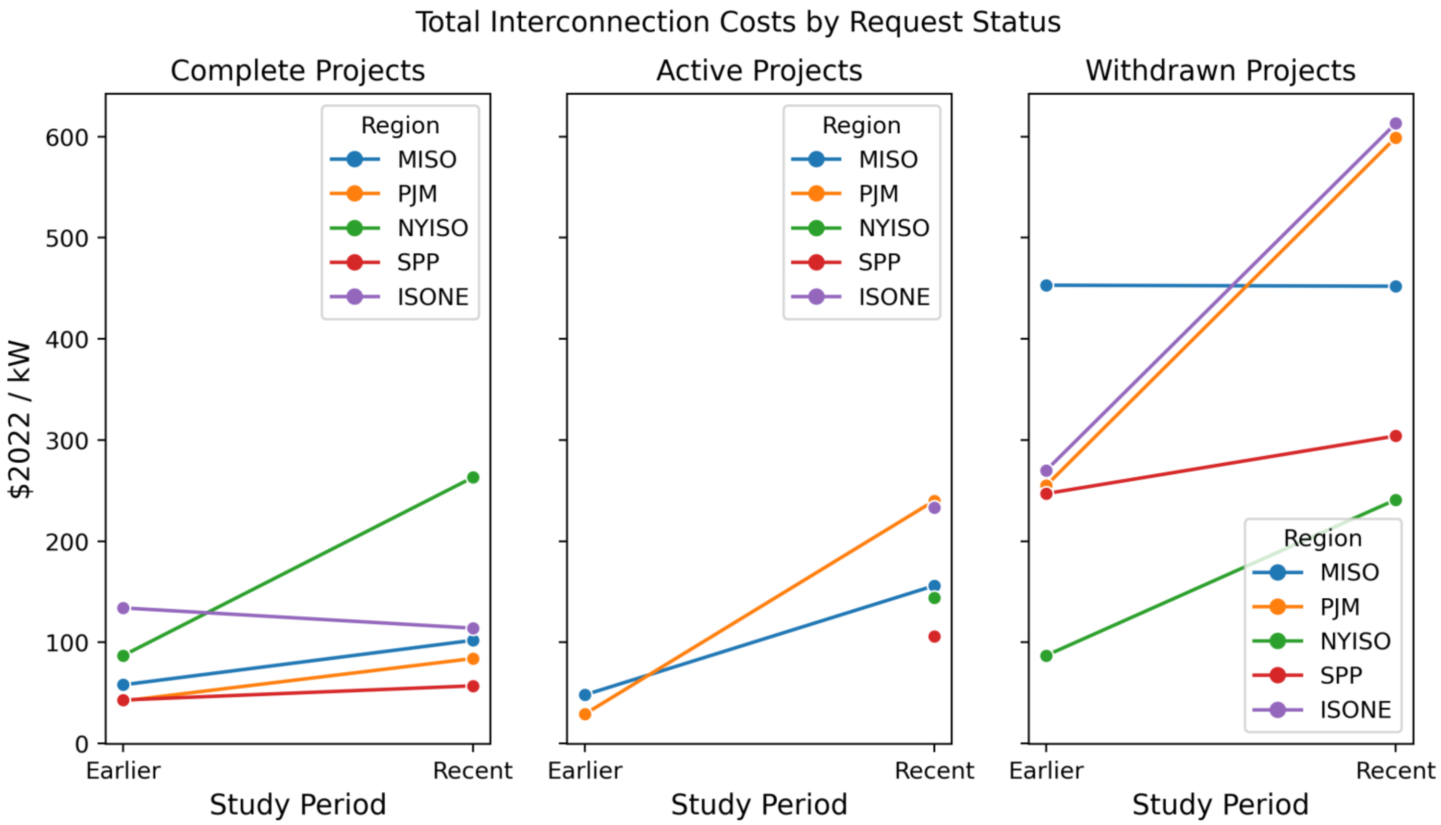
*Notes: (1) Data were only available for 737 projects across 5 ISO/RTOs and one utility (Southern Company), out of 3,846 total “operational” projects in the full dataset. (2) Not all data used in this analysis are publicly available.*

# Evidence of a Problem #2: Increasing Cost to Connect

# Interconnection costs have grown over time in all studied regions, driven primarily by broader network upgrades (not local interconnection costs)

## Average Interconnection Costs




| Region | "Earlier" period | "Recent" period |
|---|---|---|
| MISO | (2000-) 2018 | 2019-2021 |
| SPP | 2010-2019 | 2020-2022 |
| PJM | 2000/2017 - 2019 | 2020-2022 |
| NYISO | 2006-2016 | 2017-2021 |
| ISO-NE | 2010-2017 | 2018-2021 |

- Average interconnection costs have grown across regions and request types:
  - Often doubling for projects that have ***completed*** all studies
  - increasing even more for ***active*** projects currently moving through the queues.
  - Projects that ***withdraw*** have the highest interconnection costs

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# A "wicked" problem: multifaceted drivers of interconnection backlogs

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

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

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

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

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

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# A Sneak Preview of the i2X Program Roadmap:

## Opportunities for Reforms and Solutions

# DOE's Interconnection Innovation e-Xchange (i2X)

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

## Stakeholder Engagement

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

## Data & Analytics

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

## Strategic Roadmap

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

## Technical Assistance

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


Focus today

# Setting up the context and purpose of the roadmap

- We aimed to ***harmonize and develop solutions*** that could provide a more comprehensive, rather than piecemeal, set of reforms

- Solutions identified are a collection of ***possible strategies***

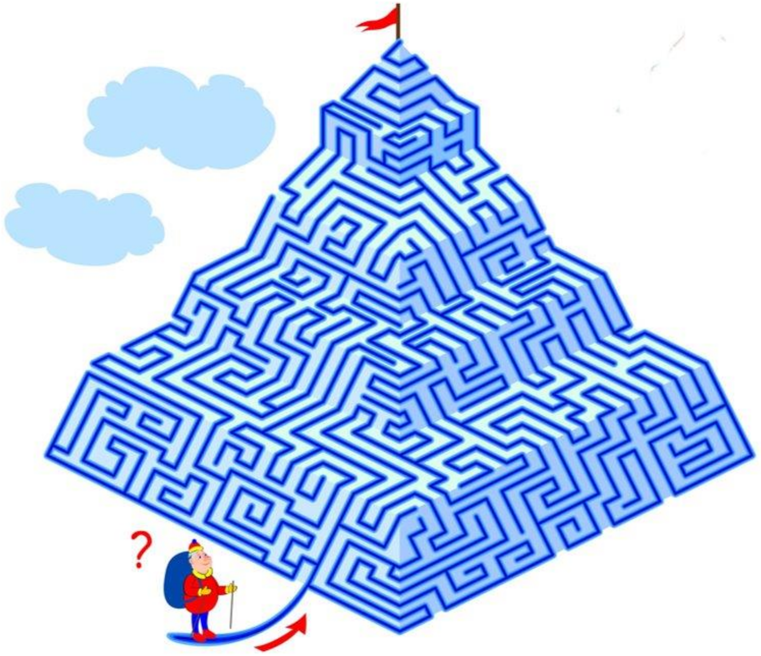
  → NOT rigid package of prescriptive fixes

- Some solutions ***are complementary*** to each other (i.e. needed to be implemented in tandem)

- Others ***are exclusive*** (i.e. adopting one might obviate the need of another)

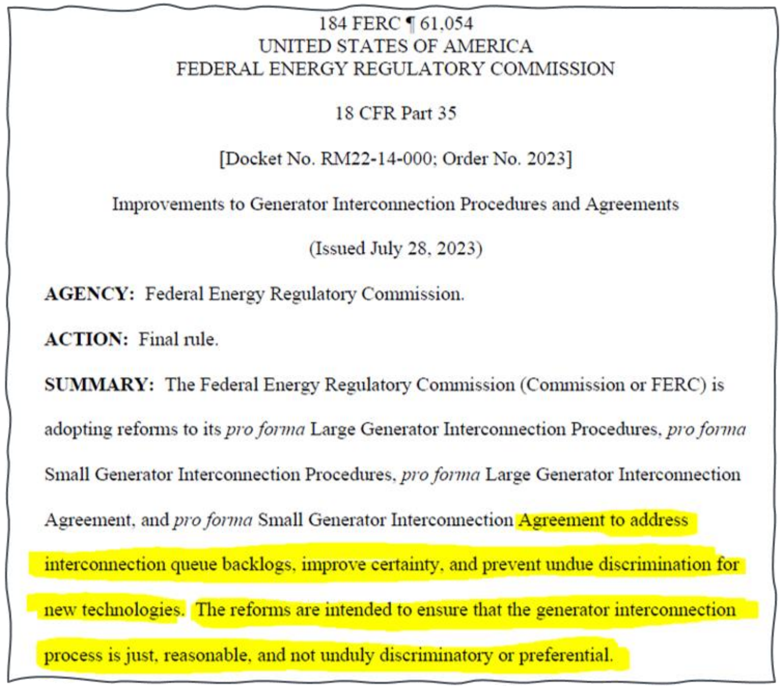
- Some ***regions have adopted*** a subset of these ideas already, and we try to highlight those efforts in the roadmap, where possible

*Roadmap aims to be a starting point for discussions around pathways and solutions*



# As we were developing the roadmap, FERC issued Order 2023

- Notable ***all commissioners agreed*** to support the order
- BUT -- interconnection reform has been happening for at least the ***last 20 years*** (Order 2003, 2006, ISO/RTO reforms in the late 2000s)
- Items like cluster studies and some "first ready, first served" milestones had ***been already implemented*** by some large ISOs / BAs already.
- Still an important step towards industry-wide standardization
- Roadmap contains some solutions that ***relate and align with this order***, but also introduces additional ideas to support longer-term interconnection process evolution



184 FERC ¶ 61,054
UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

18 CFR Part 35

[Docket No. RM22-14-000; Order No. 2023]

Improvements to Generator Interconnection Procedures and Agreements

(Issued July 28, 2023)

**AGENCY:** Federal Energy Regulatory Commission.

**ACTION:** Final rule.

**SUMMARY:** The Federal Energy Regulatory Commission (Commission or FERC) is adopting reforms to its *pro forma* Large Generator Interconnection Procedures, *pro forma* Small Generator Interconnection Procedures, *pro forma* Large Generator Interconnection Agreement, and *pro forma* Small Generator Interconnection Agreement to address interconnection queue backlogs, improve certainty, and prevent undue discrimination for new technologies. The reforms are intended to ensure that the generator interconnection process is just, reasonable, and not unduly discriminatory or preferential.

FERC Chair Willie Phillips at his press conference on July 27, 2023, after the commission ***unanimously approved*** Order 2023.

# The roadmap is organized around four main interconnection goals

| Goal #1: Increase Data Access and Transparency | Goal #2: Improve Process and Timing | Goal #3: Promote Economic Efficiency | Goal #4: Maintain a Reliable Grid |
|---|---|---|---|
| • Highlight improvements that ***go beyond*** FERC Order 845 and 2023<br>• Facilitate screening, optimal siting, and automation<br>• Enhance equitable outcomes by enabling ***benchmarking, tracking and auditing*** of processes and reform performance | • Key focus areas<br>  • Queue Management<br>  • Affected System Studies<br>  • Workforce Development<br>• Balance tradeoff between ***rationing queue space and maintaining open access***<br>• Development of ***fast tracks***<br>• Increase collaboration between neighboring BAs<br>• Focus on ***workforce expansion and retention*** | • Key focus areas<br>  • Cost Allocation<br>  • Coordination btwn IX and TP<br>  • Interconnection Studies<br>• Identify ***proactive transmission*** investment funding opportunities<br>• Explore novel interconnection service options (***energy-only***)<br>• Harmonize ***study methods and transmission mitigation options*** given the changing generation mix | • Key focus areas<br>  • Interconnection Models and Tools<br>  • Interconnection Standards<br>• Foundation to manage ***high penetration rates of IBRs*** and minimize disturbances<br>• Development and collection of appropriate ***EMT models***<br>**Not covered in this presentation** |

# Goal #1: Increase Data Access and Transparency

## Solutions

## Activities

| Solutions | Federal entities (e.g. FERC/EIA) | Transmission Providers (e.g. ISOs, BAs) | Interconnection Customers (e.g. Developers) | Research community (e.g. Academia, DOE) |
|---|---|---|---|---|
| Improve the scope/quality of **data on projects already in interconnection queues**<br>*Implementation timeframe: short-term* | -Expand and improve **data reporting requirements**<br><br>-Aggregate, organize, and publish interconnection data | -Collect and organize data as needed<br><br>-**Automate data compilation** and reporting<br><br>-Share data management best practices with peers<br><br>-Identify IT infrastructure need | -Develop tools to leverage data to improve pre-request screening | -Support data collection, compilation, and synthesis<br><br>-Increase scope, depth, and frequency of data analysis<br><br>- Engage with FERC, developers, transmission providers to **determine data needs** |
| Enhance the accuracy/timeliness of **interconnection study models and modeling assumptions** that are made available<br>*Implementation timeframe: medium-term* | -Expand and improve requirements for study data<br><br>-Review and update guidelines for **CEII data access** | -Explore opportunities for automating study data updates<br><br>-Engage with market participants to determine additional information needs<br><br>-Integrate **data updates with queue cycles** and transmission plan updates | -Develop or support development of open-source study models<br><br>-Engage with transmission providers to determine additional information needs | - Develop or support the development of open-source models |
| **Develop tools** to visualize transmission and interconnection data<br>*Implementation timeframe: medium-term* | | - Develop and support development of visualization tools<br><br>- Convene stakeholders | - Propose additional visualization tools and metrics | - Propose additional visualization tools and metrics<br><br>- Support **software development** |

# In total, there are more than 30 solutions identified in the roadmap

## (Select) Solutions for Goal #2

**Continue to automate** parts of the interconnection process (e.g. data input and validation, some customer communications)
*Implementation timeframe: short-term*

Create new and expand **fast-track options** for interconnection (e.g. surplus, generator replacement, energy-only)
*Implementation timeframe: medium-term*

Consider **market-based approaches** to rationing interconnection access
*Implementation timeframe: long-term*

Increase **voluntary collaboration on affected system studies**
*Implementation timeframe: short-term*

Assess scale of **interconnection workforce growth requirements**
*Implementation timeframe: short-term*

## (Select) Solutions for Goal #3

Ensure that generators have option to connect **without paying for congestion-related** upgrades (energy-only)
*Implementation timeframe: medium-term*

More closely **align interconnection and transmission planning** processes
*Implementation timeframe: medium-term*

Continue to develop **new best practice study methods**, and harmonize methods to adapt to a changing generation mix
*Implementation timeframe: medium-term*

Explore options for generator self-funding of their **own interconnection studies**
*Implementation timeframe: long-term*

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# DOE and the labs will continue to work and analyze interconnection issues – join us!

- The draft roadmap ***will be released shortly*** – we would love comment on the roadmap and additional ideas to incorporate

- i2X will continue in 2024, and we hope for continued ***engagement in Solutions eXchanges***, potentially on specific ideas raised in the roadmap

- DOE and labs are open to ideas on how ***we can and should be working*** on this issue

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## Contact:

Will Gorman (wgorman@lbl.gov)

## More Information:

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

### Acknowledgements:

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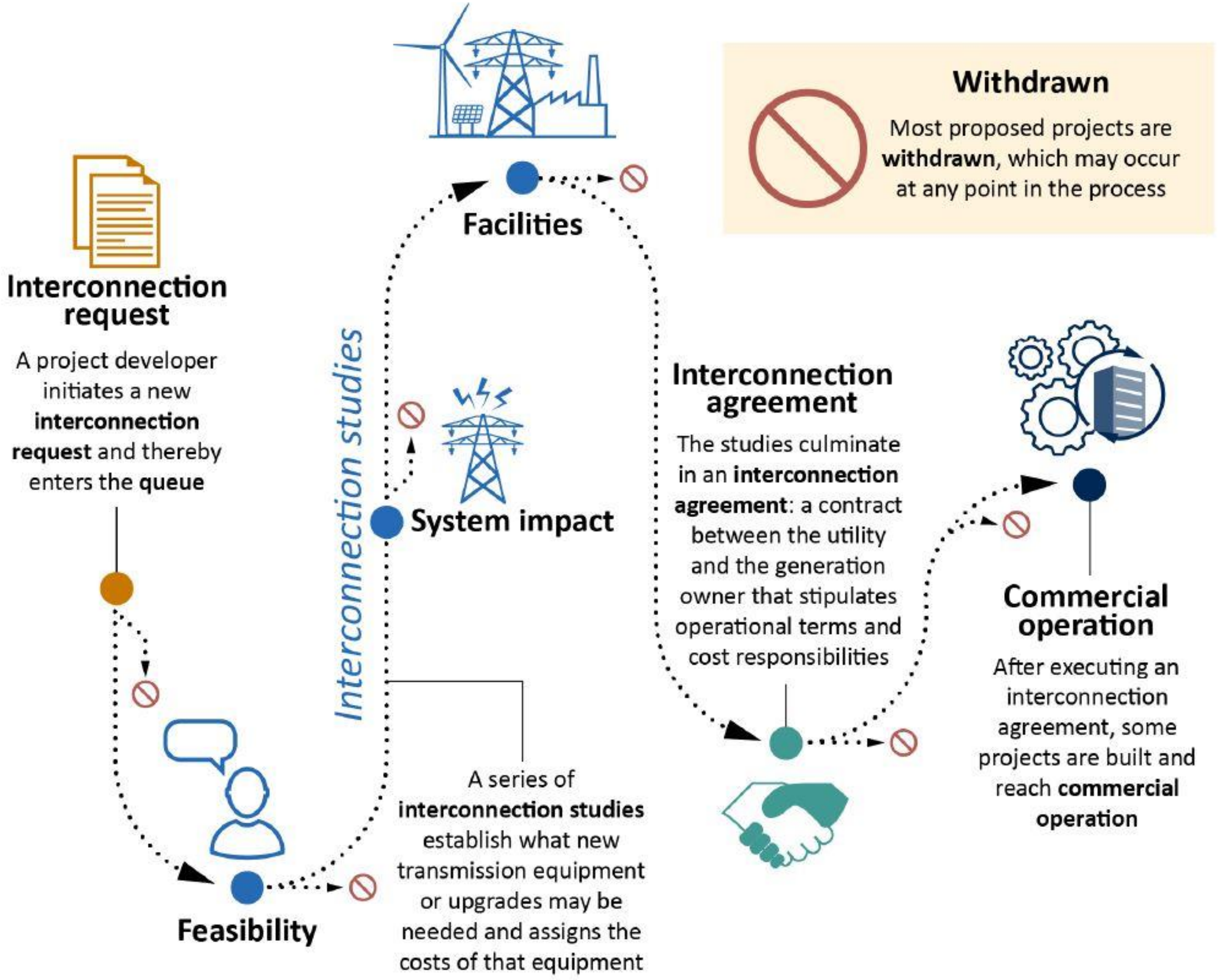
# Appendix Slides

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




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

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

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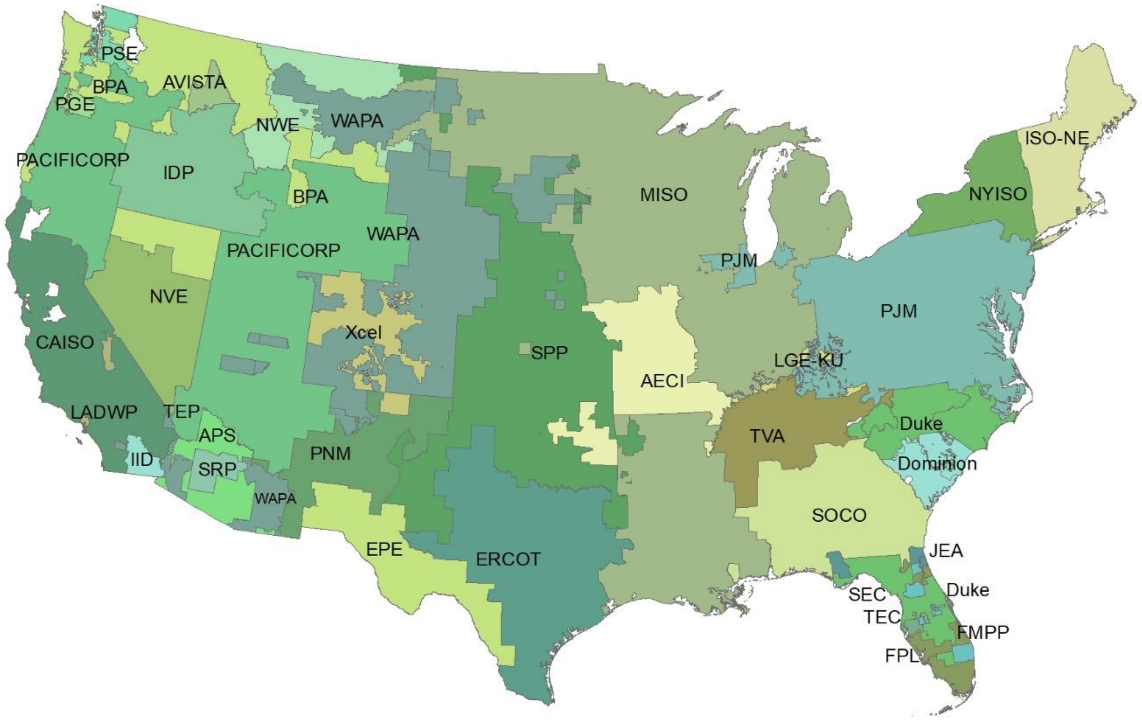
# Methods and Data Sources (Queue Backlogs and Timelines)

- Data collected from interconnection queues for 7 ISOs / RTOs and 35 utilities, which collectively represent >85% of U.S. electricity load
  - Projects that connect to the bulk power system, not behind-the-meter
  - Includes projects in queues through the end of 2022
  - The full sample includes:
    - 3,846 “operational” projects
    - 10,262 “active” projects
    - 374 “suspended” projects
    - 15,672 “withdrawn” projects
- Hybrid / co-located projects were identified and categorized
  - Storage capacity in hybrids (separate from generator capacity) was estimated based on available data for some projects
- Note that being in an interconnection queue *does not guarantee* ultimate construction

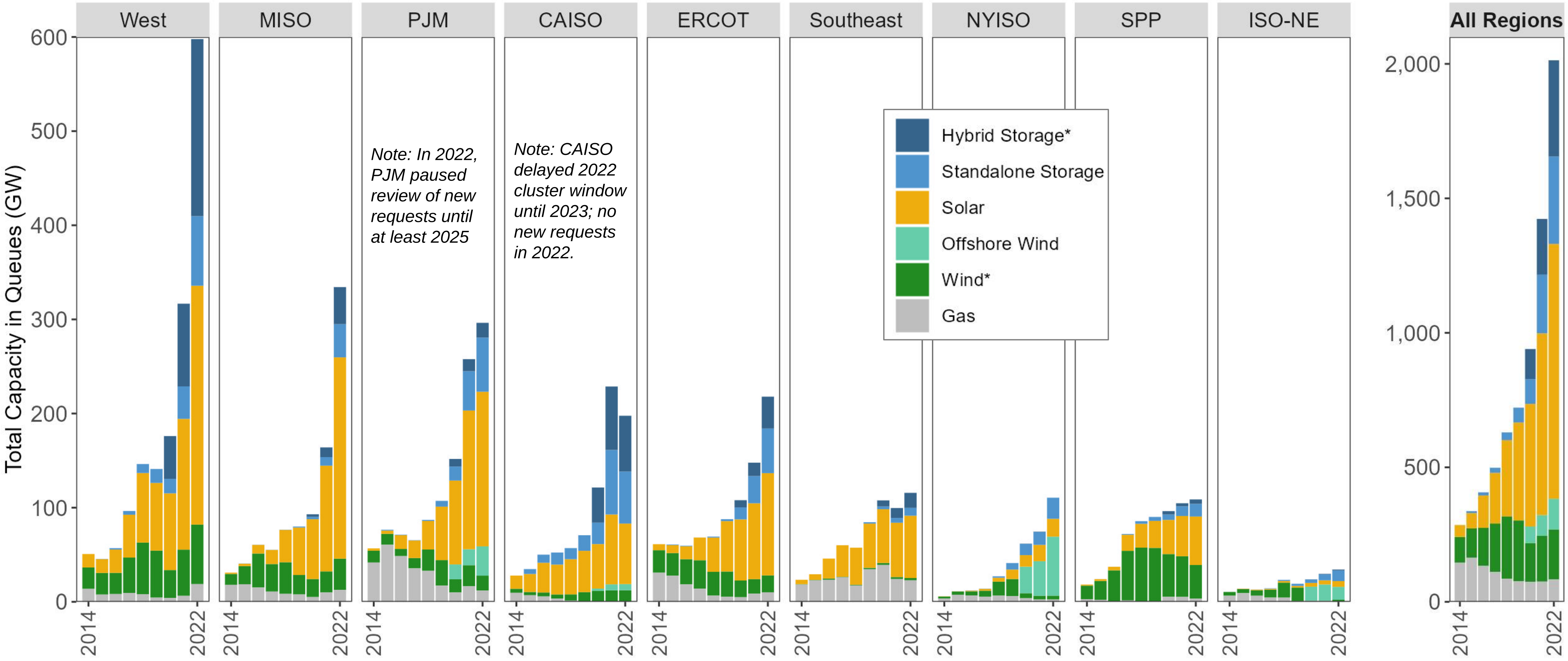



*Coverage area of entities for which data was collected*
*Data source: Homeland Infrastructure Foundation-Level Data (HIFLD)*
*A full list of included balancing areas can be found in the Appendix*
*Note that service areas can overlap*
*No data collected for Hawaii or Alaska*

# Balancing Areas Included In Data:

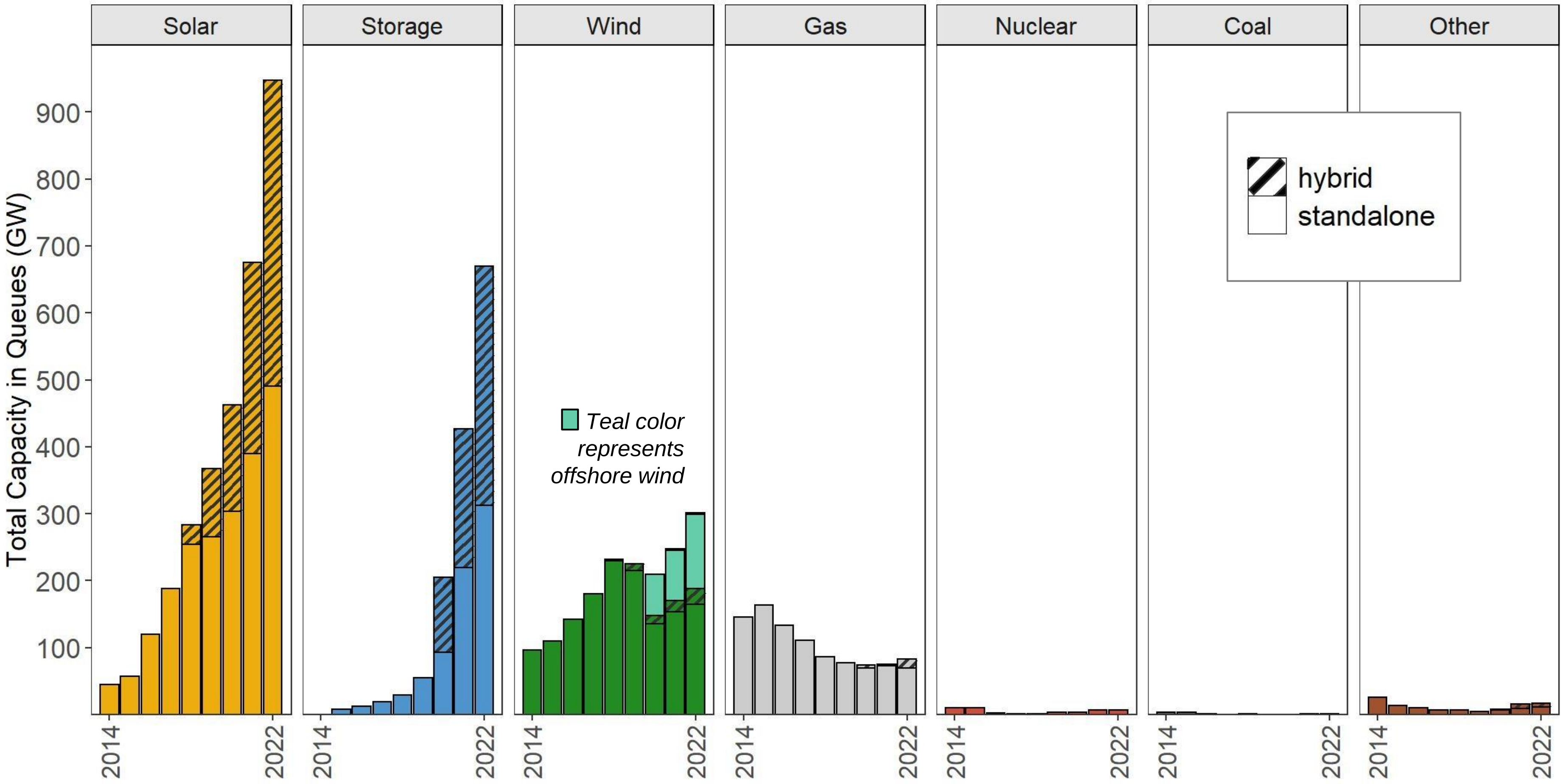
| ISO/RTOs | Other (non-ISO) Transmission Operators | | | | |
|---|---|---|---|---|---|
| PJM | Southern Company | Associated Electric Coop. | LG&E & KU Energy | Portland General Electric | Public Service Co. of NM |
| MISO | Tennessee Valley Authority | PSCO | Salt River Projects | Idaho Power | Avista |
| ERCOT | Duke/Progress | Santee Cooper | NV Energy | Florida Municipal Power Pool | El Paso Electric |
| SPP | WAPA | Georgia Transmission Corp. | Navajo-Crystal | Tri-State G&T | Imperial Irrigation District |
| NYISO | Florida Power & Light | Arizona Public Service | Dominion | Jacksonville Electric Authority | Platte River Power Authority |
| CAISO | Bonneville Power Admin. | LADWP | Puget Sound Energy | Tucson Electric Power | Black Hills Colorado |
| ISO-NE | PacifiCorp | Seminole Electric Coop. | Tampa Electric Co. | NorthWestern | Cheyenne Light Fuel & Power |

# Active queue capacity highest in the non-ISO West (598 GW), followed by MISO (339 GW) and PJM (298 GW). Solar and storage requests are booming in most regions.




*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.*

# Especially strong developer interest in solar (~947 GW) and storage (~680 GW); Hybrid plants represent a large fraction of proposed solar and storage

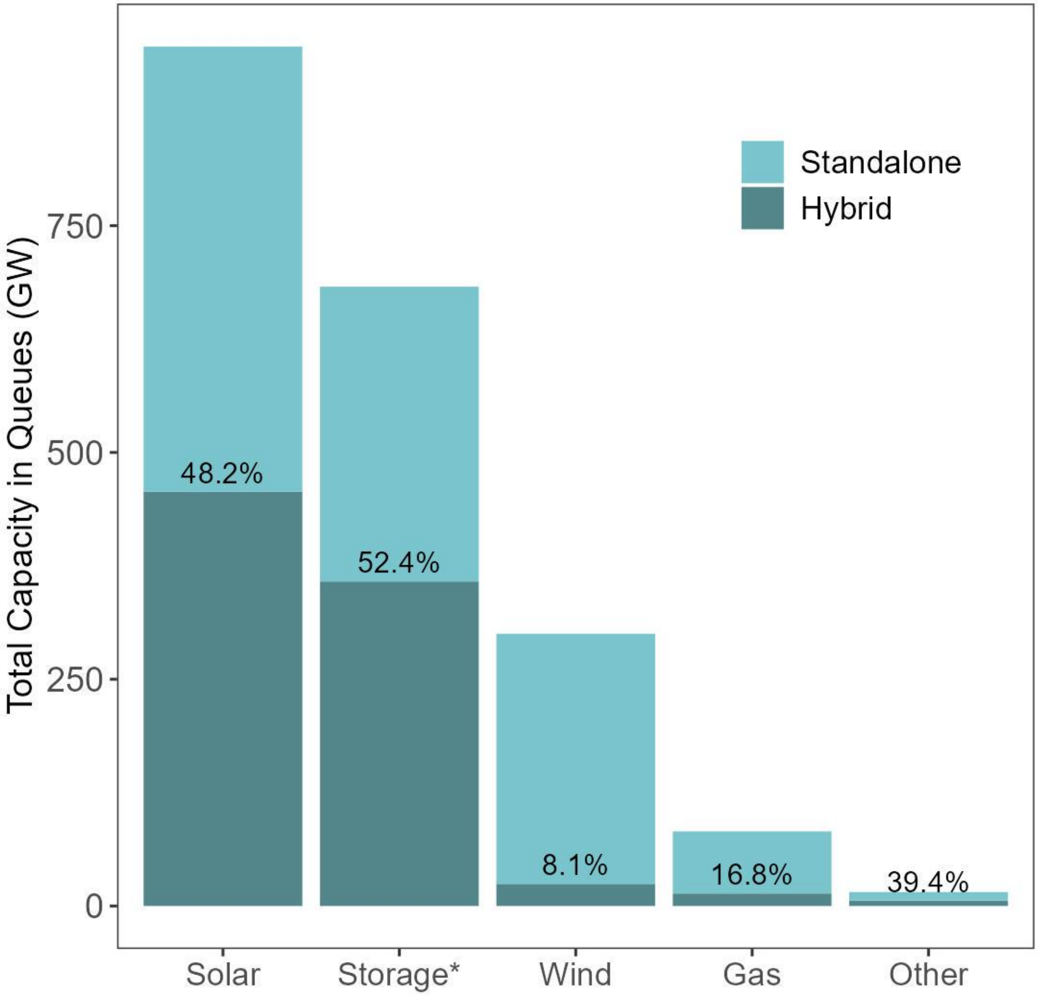



- "**Wind**" includes both onshore and offshore.
- "**Other**" includes
  - Hydropower
  - Geothermal
  - Biomass/biofuel
  - Landfill gas
  - Solar thermal
  - Oil/diesel
- "**Storage**" is primarily (99%) battery, but also includes pumped storage hydro, compressed air, gravity rail, and hydrogen.

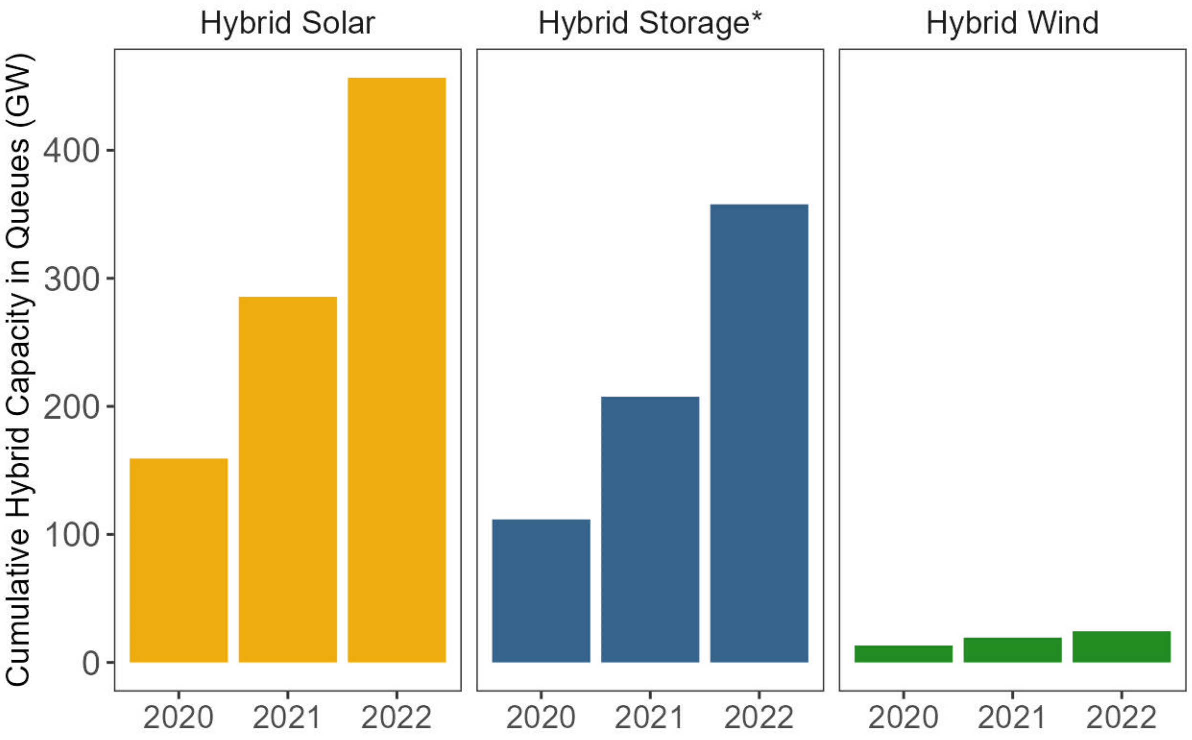
*See https://emp.lbl.gov/queues to access an interactive data visualization tool.*

*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.*

# Interest in hybrid plants has increased over time: Hybrids comprise 52% of active storage capacity (358 GW), 48% of solar (457 GW), and 8% of wind (24 GW)




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

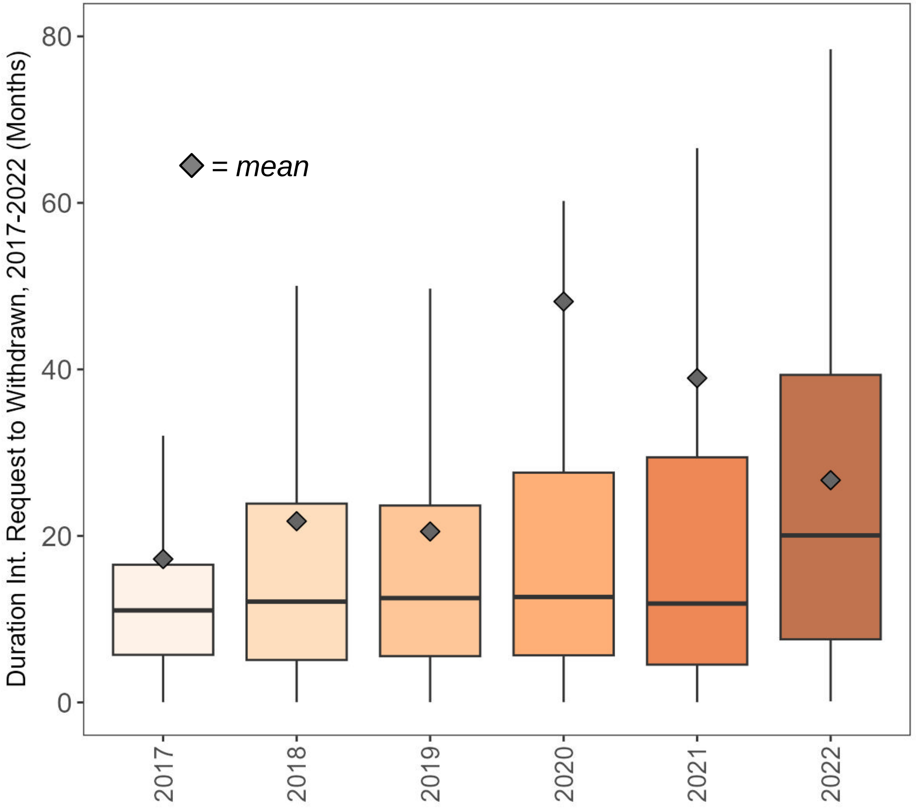


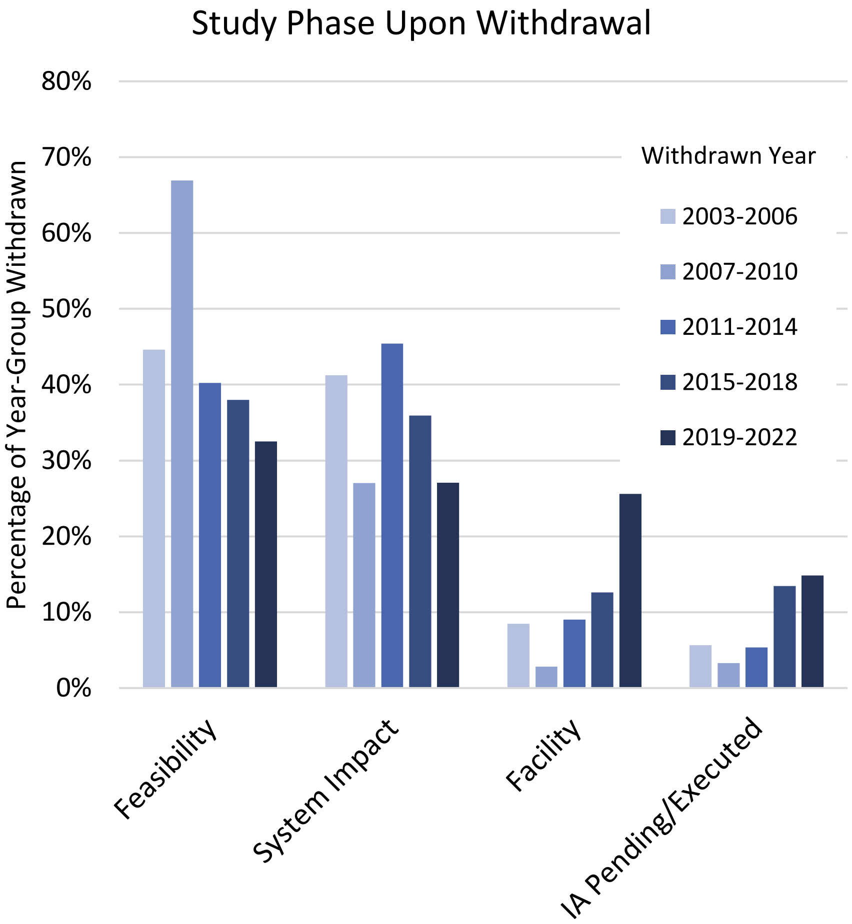

- **Solar Hybrids** include: Solar+Storage (431 GW), Solar+Wind (3 GW), Solar+Wind+Storage (8 GW)
- **Wind Hybrids** include: Wind+Storage (19 GW), Wind+Solar (1 GW), Wind+Solar+Storage (4 GW)
- **Storage Hybrids** may be paired with any generator type; most are paired with solar
- **Gas Hybrids** include: Gas+Solar+Storage (13 GW), Gas+Storage (0.4 GW), Gas+Solar (0.3 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) Hybrid plants involving multiple generator types (e.g., Wind+Solar+Storage) show up in all generator categories, presuming the capacity is known for each type.*

# The mean duration prior to withdrawing has edged higher in recent years; later-stage withdrawals are becoming more common

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

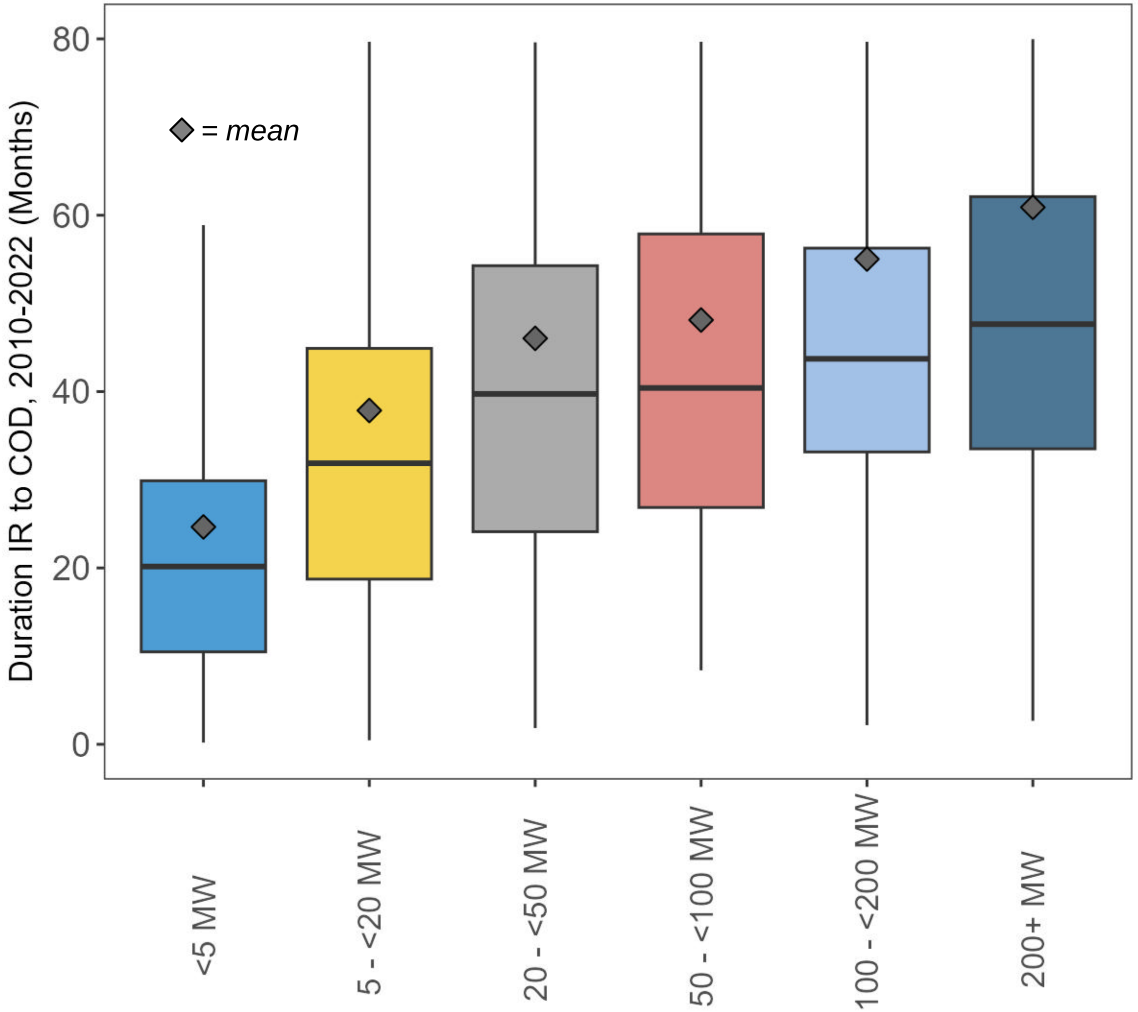



- Some recently-withdrawn projects are waiting longer in the queues before making the determination to withdraw
- Later stage withdrawals can be costly for developers and can disrupt assumptions built into other projects' interconnection studies, necessitating re-studies in some cases and increasing study durations

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

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

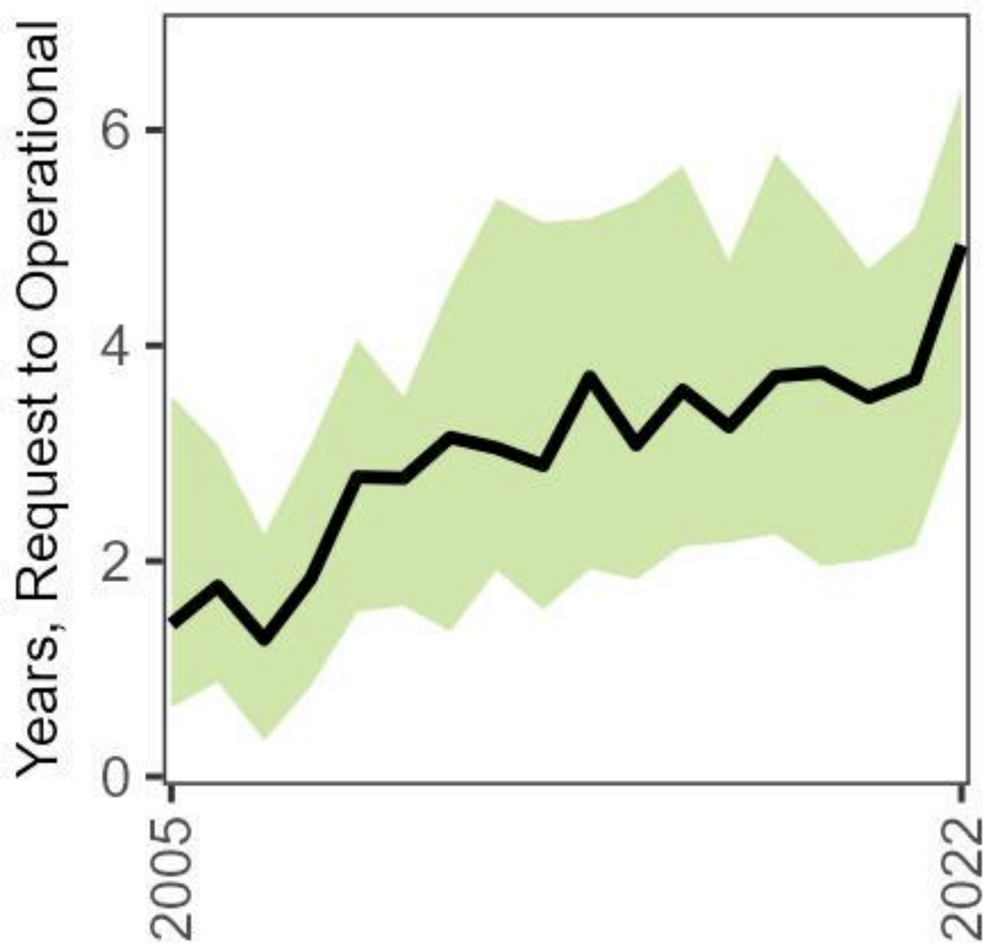



- For the smallest projects in our sample (<5 MW), the median project came online less than 2 years (20 months) after the interconnection request
- The median 5-20 MW project, meanwhile, takes nearly 3 years (33 months) from IR to COD
- Larger projects spend even more time in the interconnection and 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

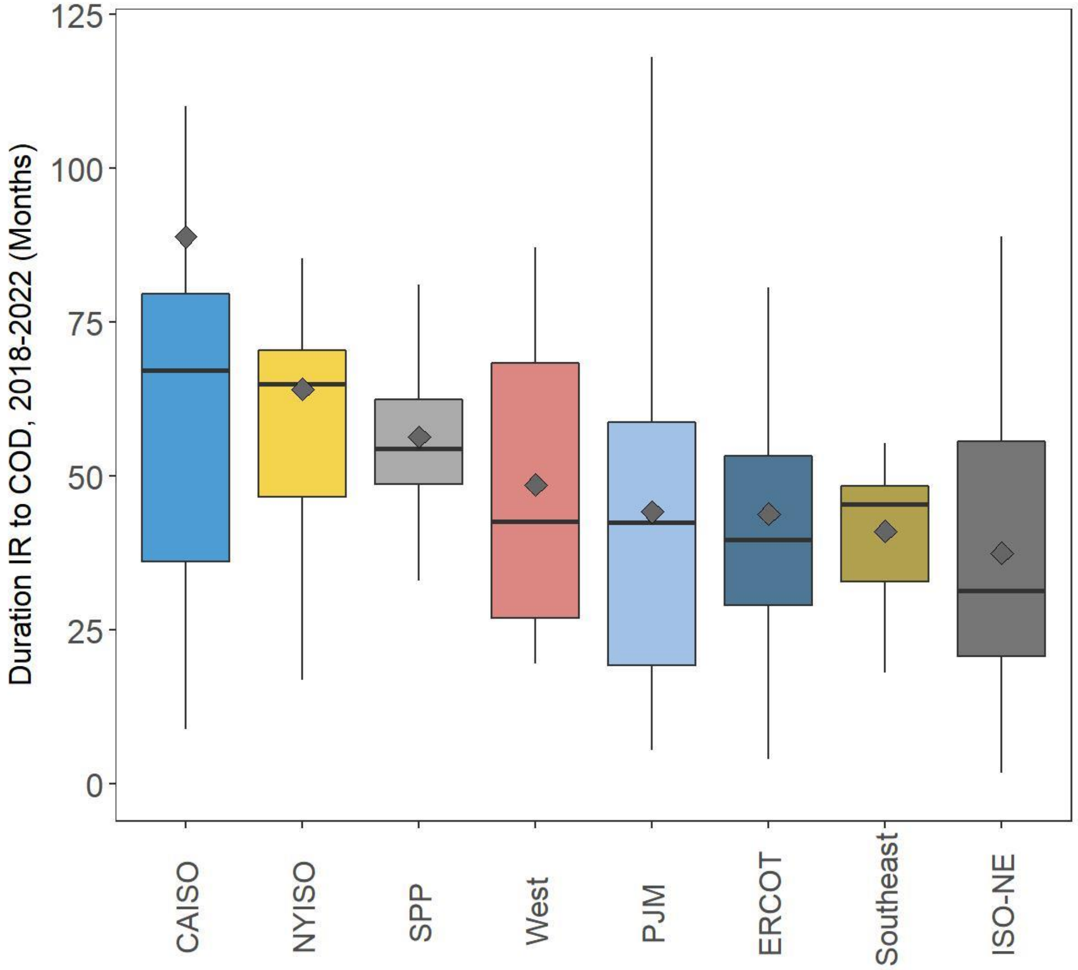
*Notes: (1) Box-plot includes projects reaching commercial operations from 2010-2022. (2) Includes data from 6 ISOs and 5 utilities. (2) Duration is calculated as the number of months from the queue entry date to the in-service date.*

# The median duration from interconnection request to commercial operations date continues to rise, reaching ~5 years for projects completed in 2022; Longest in CAISO

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



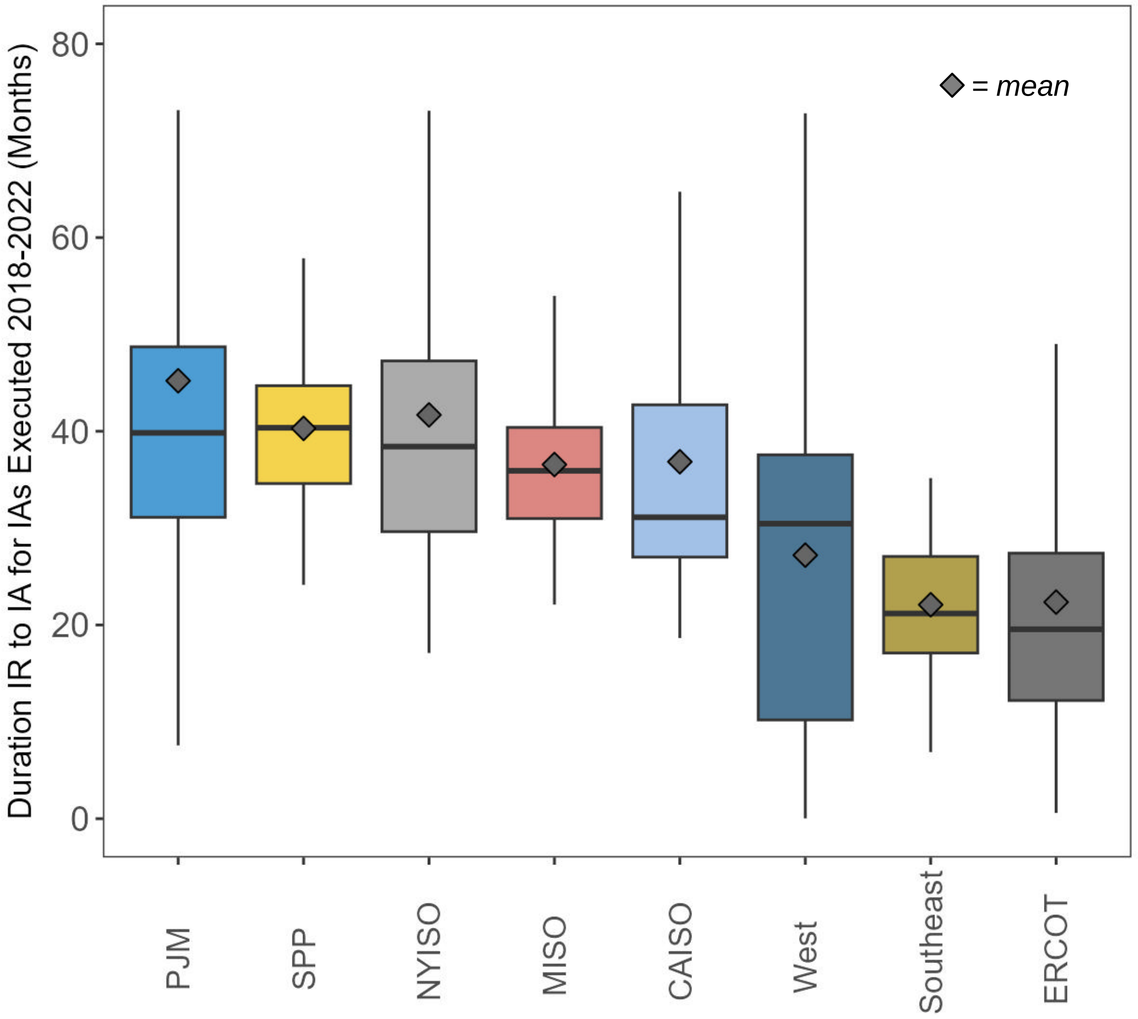

*Duration for projects reaching COD from 2018-2022*

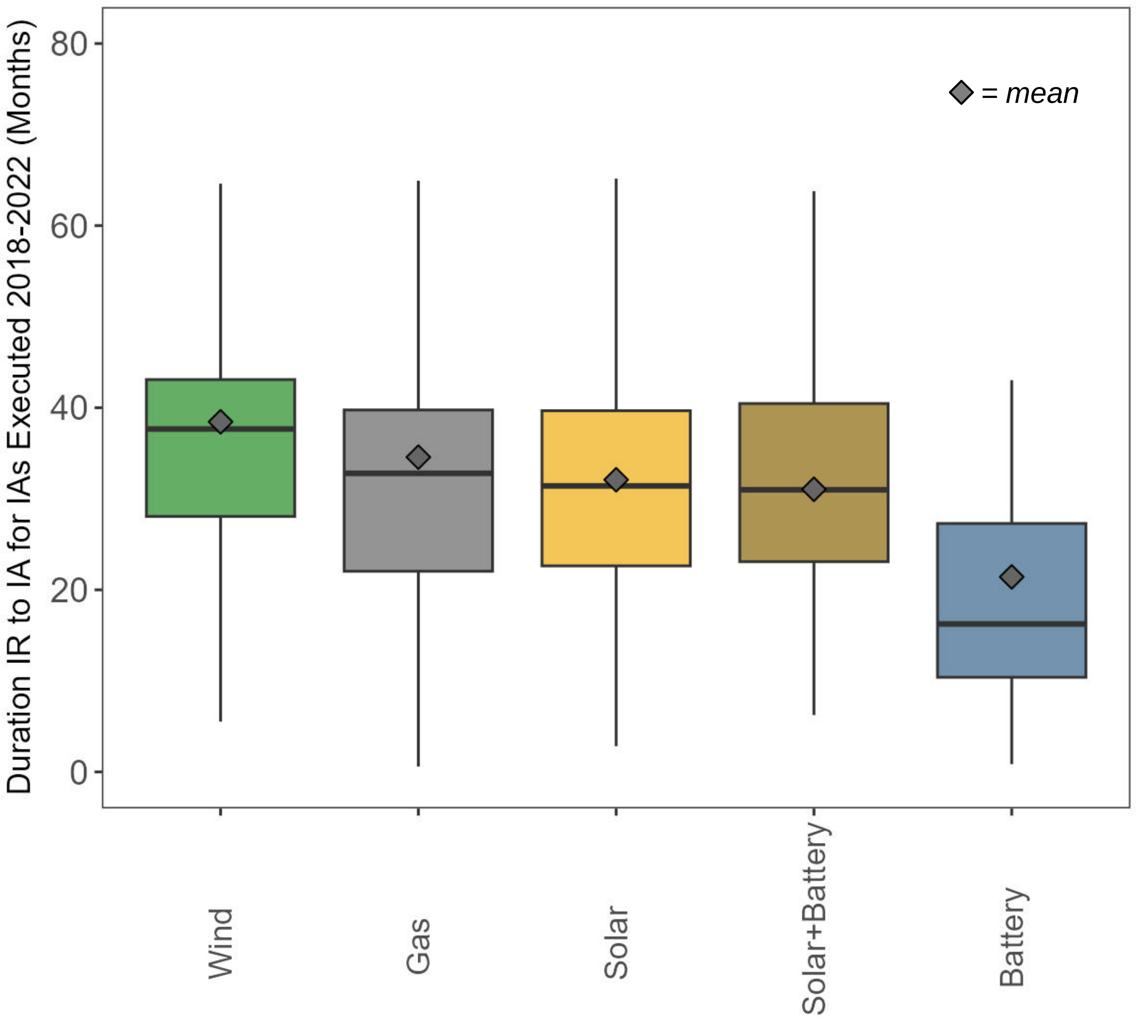



*Notes: (1) In-service date was only available for 6 ISOs (CAISO, ERCOT, ISO-NE, NYISO, PJM, SPP) and 5 utilities (Duke, LADWP, PSCo, SOCO, WAPA) representing 58% of all operational projects. (2) Duration is calculated as the number of months from the queue entry date to the in-service date.*

# Study duration exceeds 3 years in most grid operating regions; ERCOT and Southeast are faster. Battery projects tend to be processed more quickly than other types

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

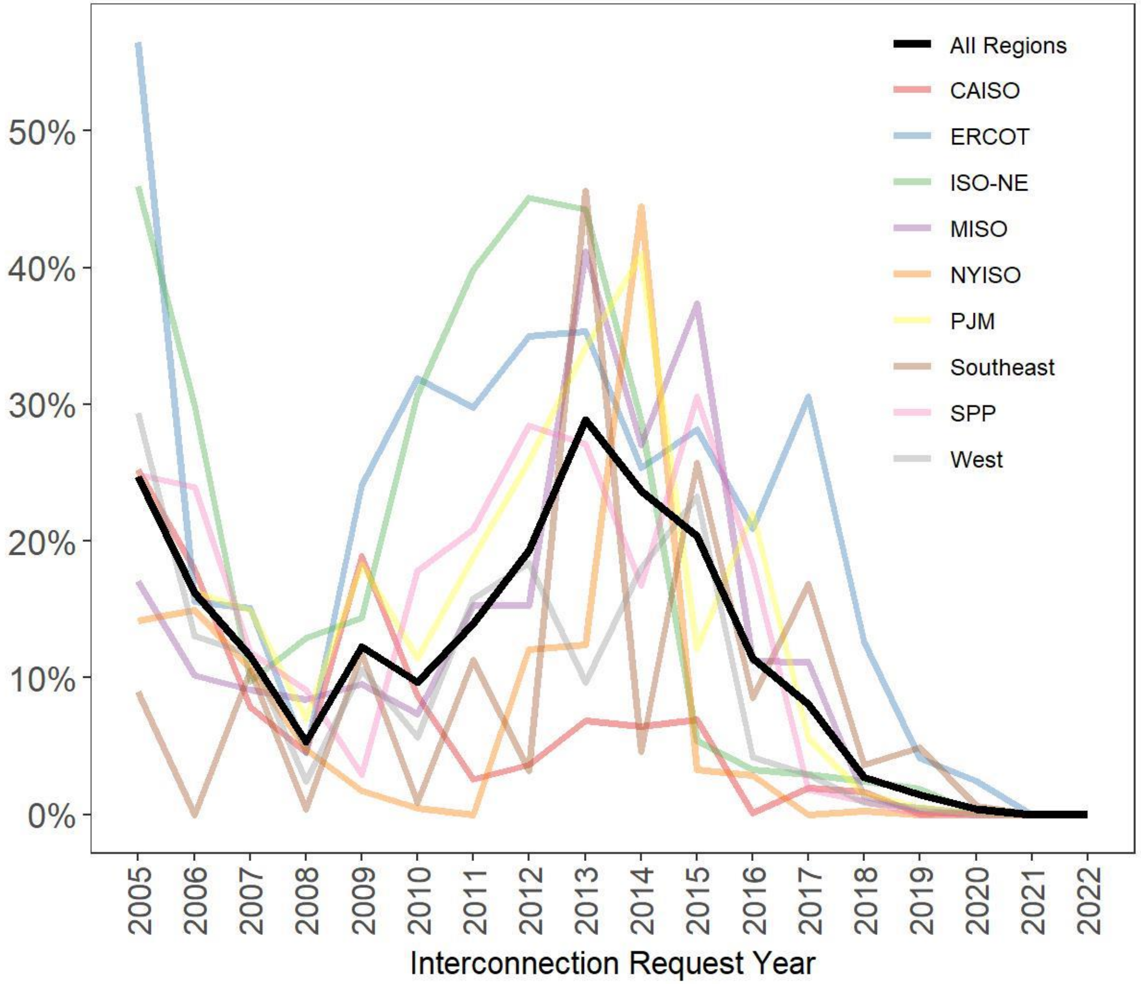


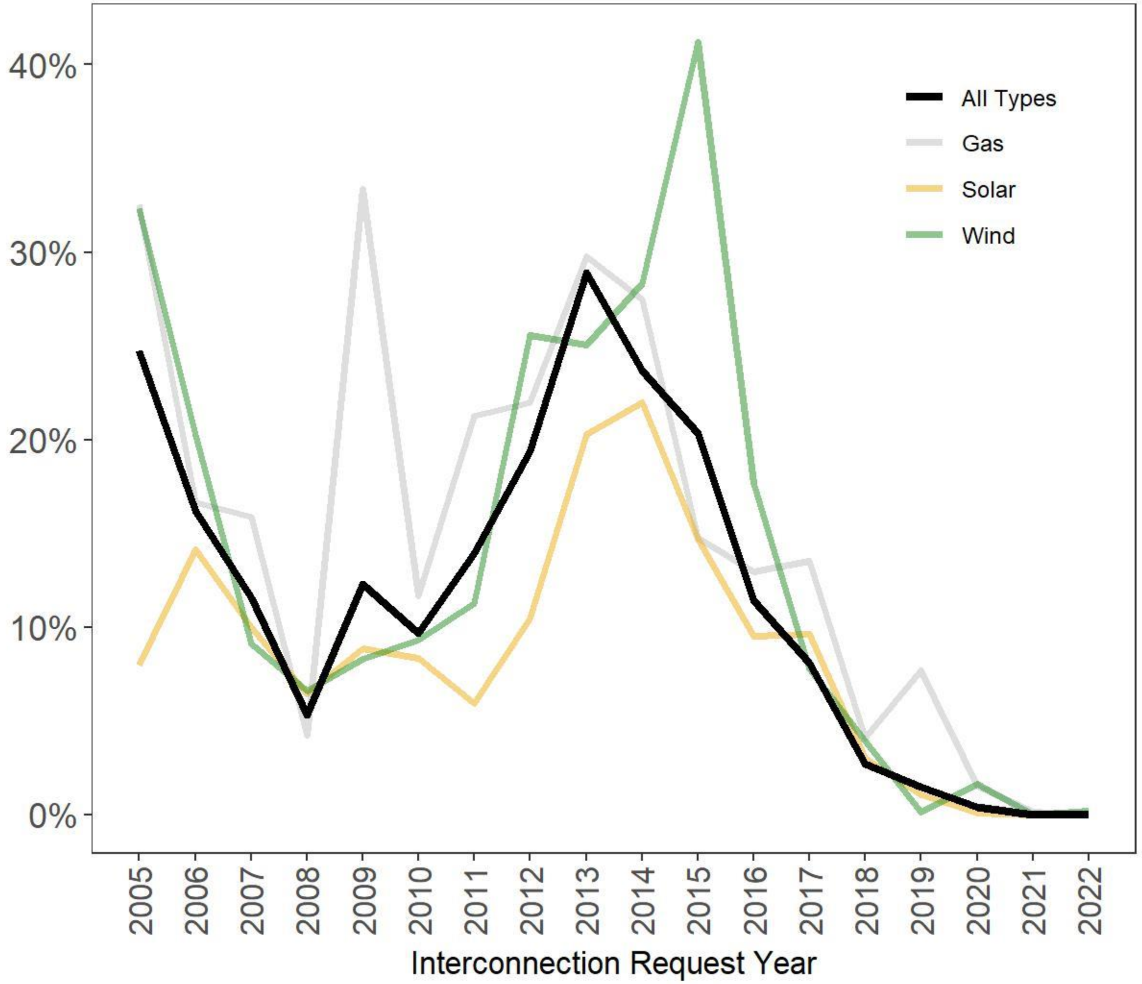

*Notes: (1) Data are only shown where sample size is >2 for each region and year. (2) Not all data used in this analysis are publicly available.*
*(3) "West" includes PacifiCorp, Public Service Co. of New Mexico, Idaho Power; "Southeast" includes Southern Company, Seminole Electric Cooperative.*

# Capacity-weighted completion rates are even lower: Only 14% of all capacity requesting interconnection from 2000-2017 is online; 16% of wind capacity, 10% of solar capacity

Percentage of capacity online by region:




Percentage of capacity online by generator type:

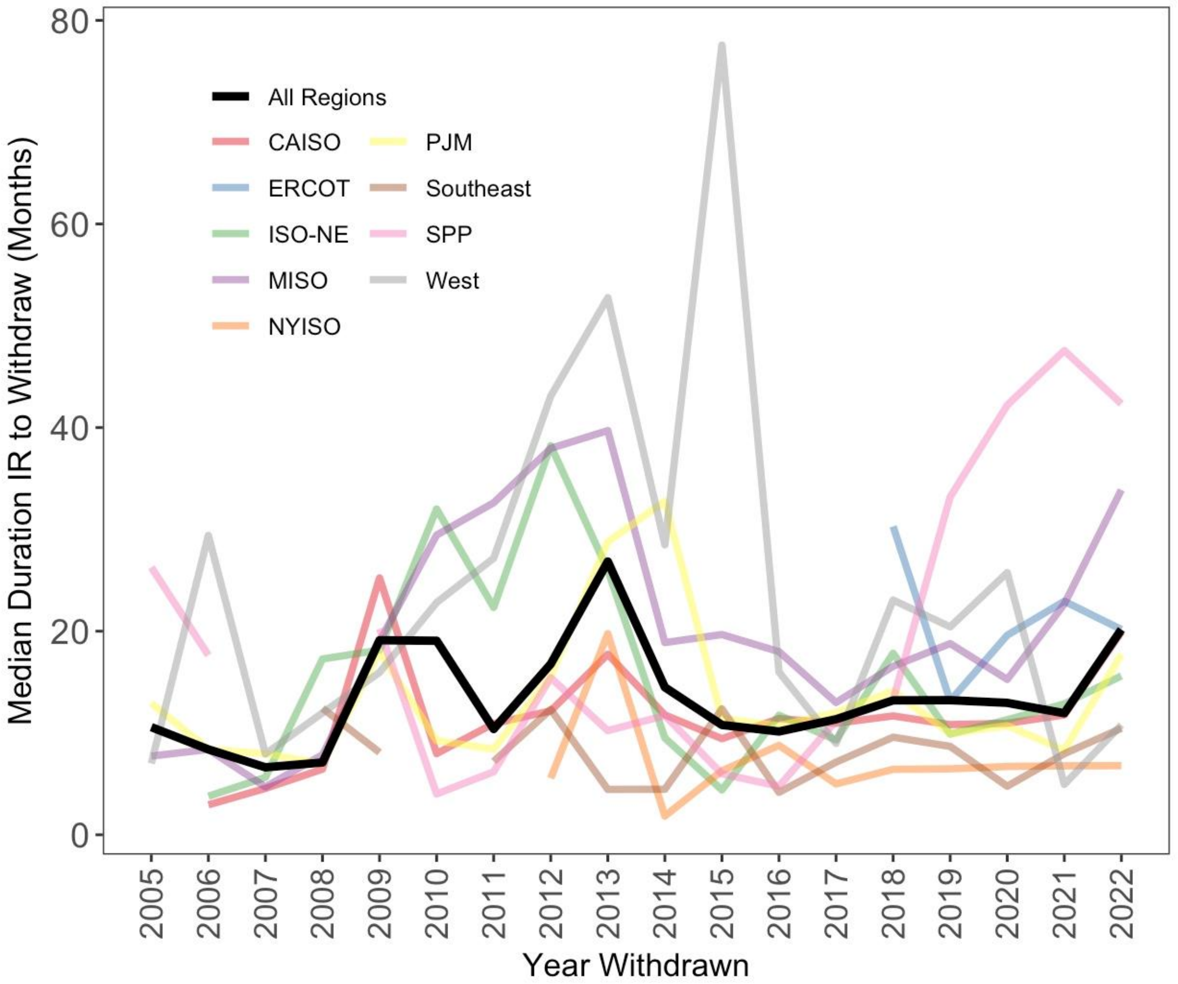



*Notes: (1) Completion rate shown here is capacity-weighted, calculated as the capacity that is online by end of 2022 divided by the total capacity requesting interconnection each year. (2) Includes data from 7 ISO/RTOs and 26 utilities.*

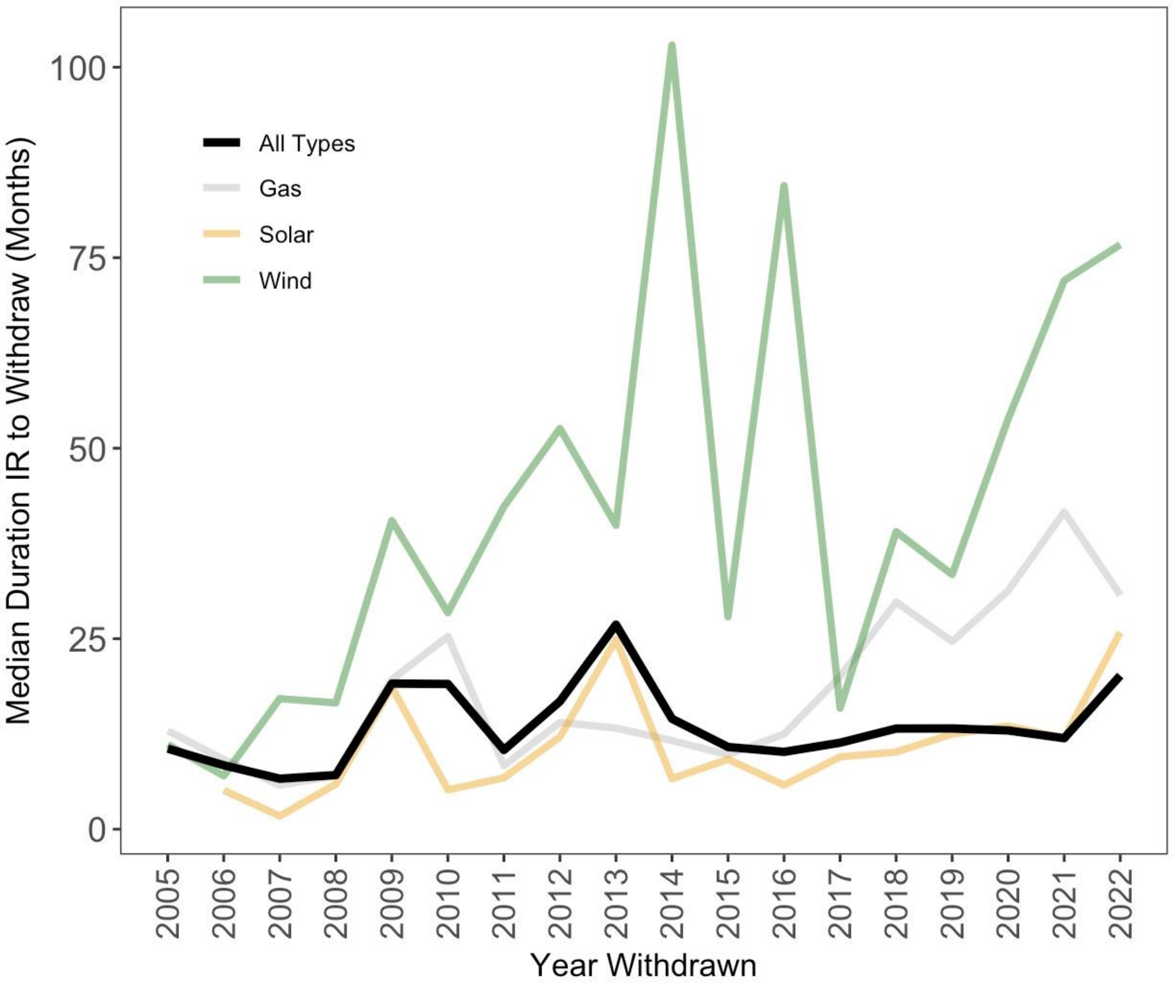
# The median duration from request to withdrawn date ticked up in 2022; wind projects typically spend more time in queues than gas or solar prior to withdrawing

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

Median Duration from Interconnection Request to Withdrawn Date, by Region



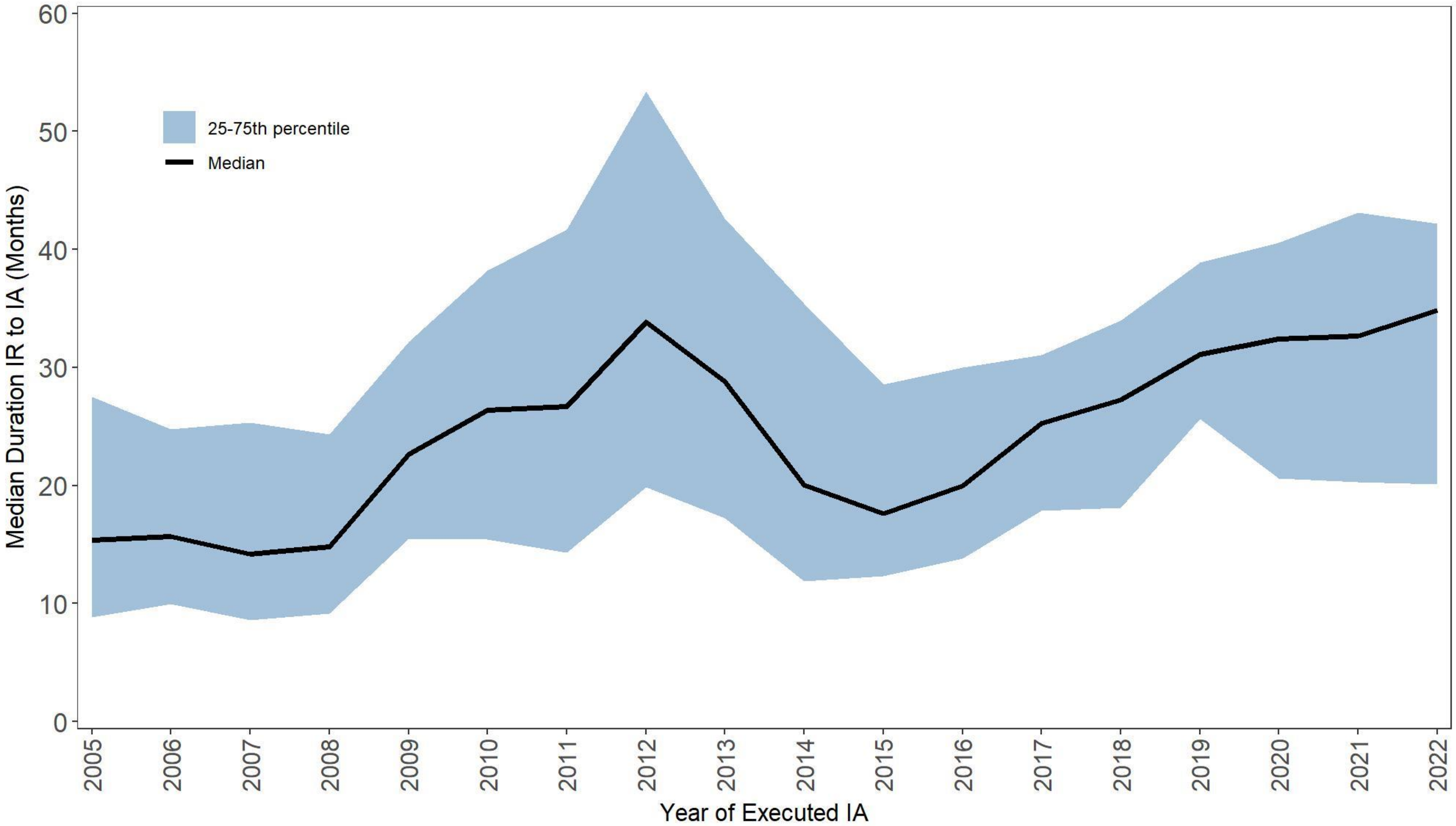

Median Duration from Interconnection Request to Withdrawn Date, by Generator Type




*Notes: (1) Withdrawn date was available for 6,323 projects from 5 ISOs and 6 utilities. (2) Duration is calculated as the number of months from the queue entry date to the date the project was withdrawn from queues.*

# After falling from a 2012 peak, the typical duration from interconnection request (IR) to interconnection agreement (IA) increased sharply since 2015, reaching 35 months in 2022

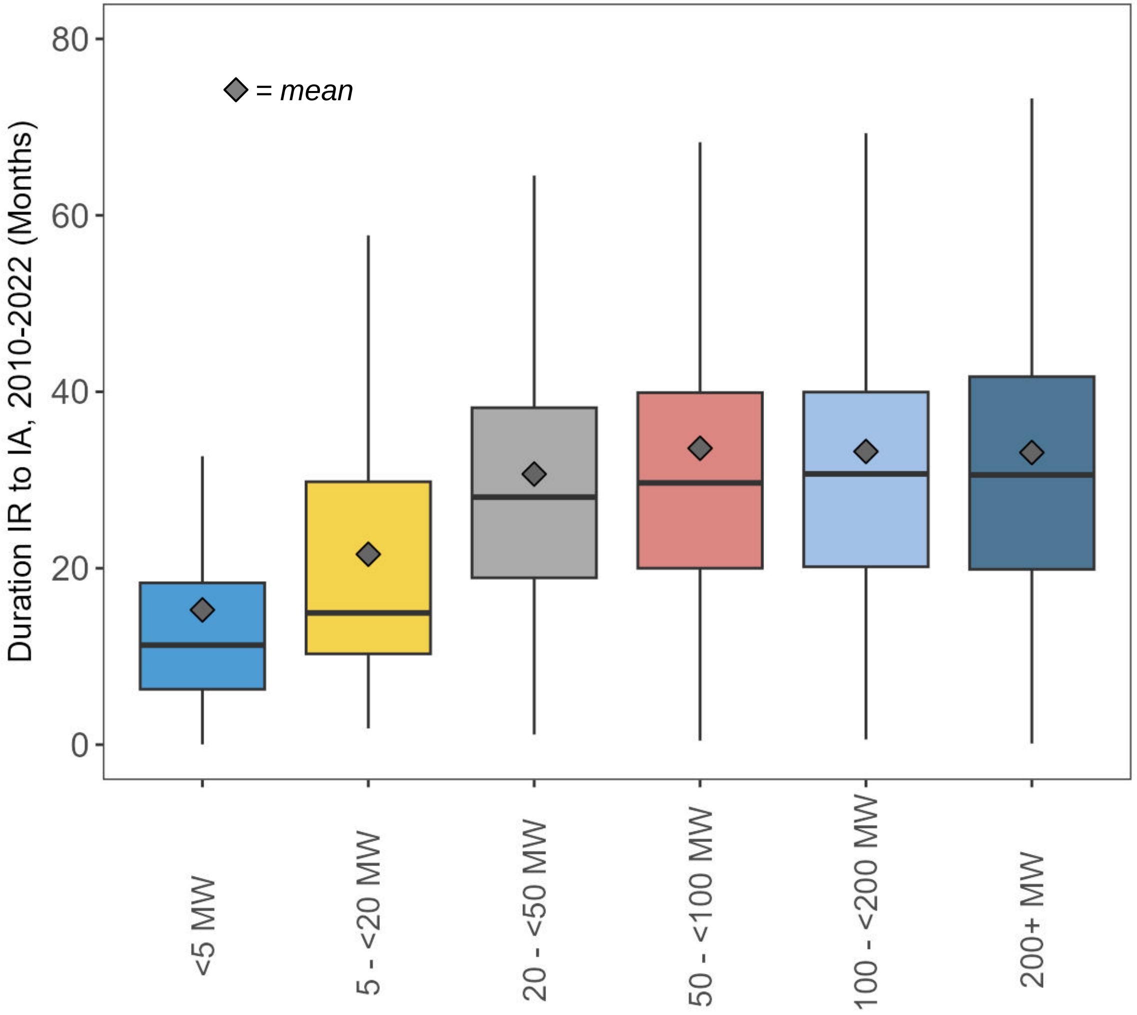
*Duration Analyzed:* | *Interconnection Request (IR)* → *Interconnection Agreement (IA)* → *Commercial Operations (COD)*




*Notes: (1) Sample includes 3,348 projects from 6 ISO/RTOs and 5 non-ISO utilities with executed interconnection agreements since 2005. (2) Not all data used in this analysis are publicly available.*

# 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) |
|---|---|---|---|---|---|



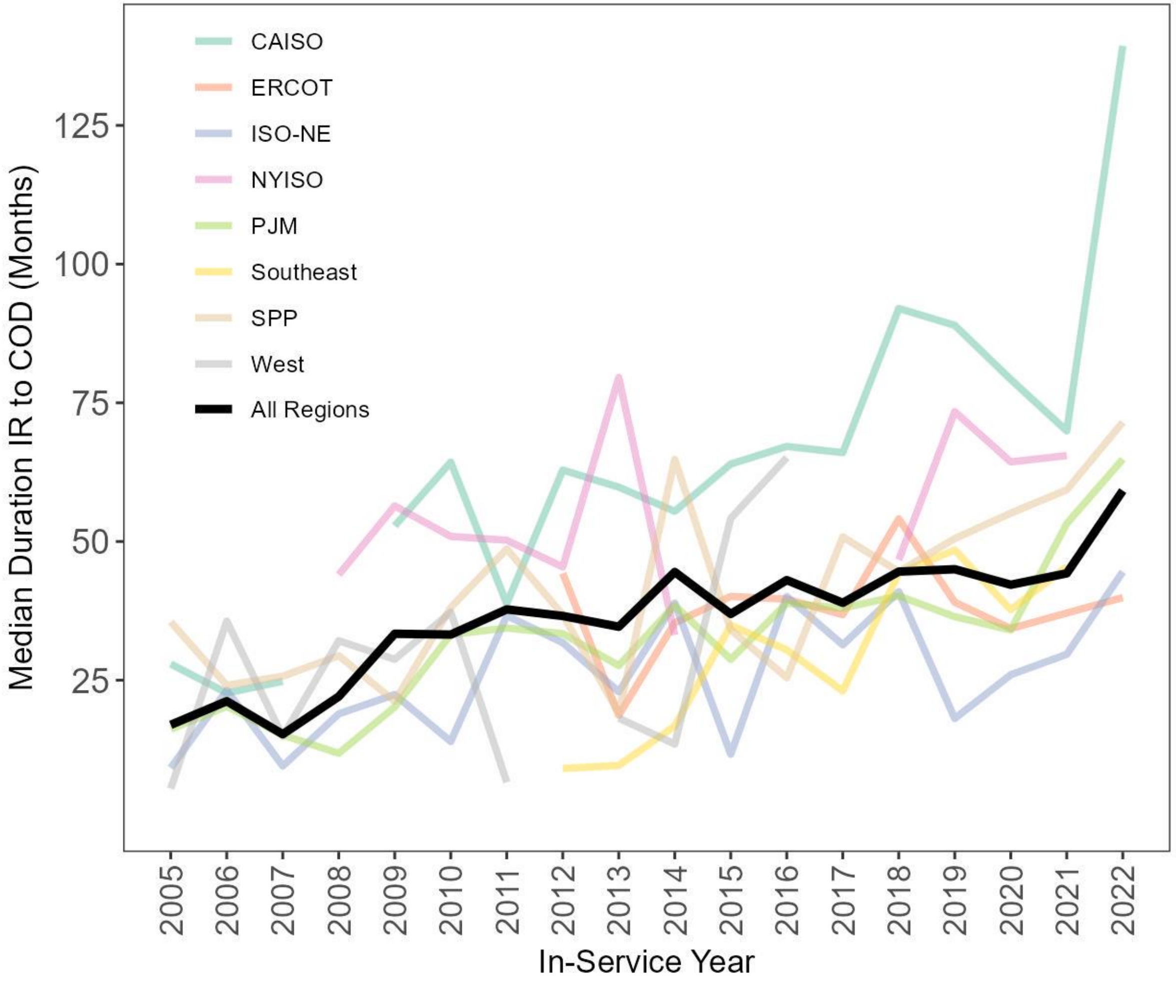

- On average, projects with rated capacity <20 MW complete studies and execute interconnection agreements much faster than larger projects
  - Median is 11 months for projects <5 MW
  - 15 months for projects 5 - <20 MW
- The median duration for projects 20 MW or larger hovers around 30 months across 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) Box-plot includes projects executing interconnection agreements from 2010-2022. (2) Duration is calculated as the number of months from the queue entry date to the interconnection agreement date.*

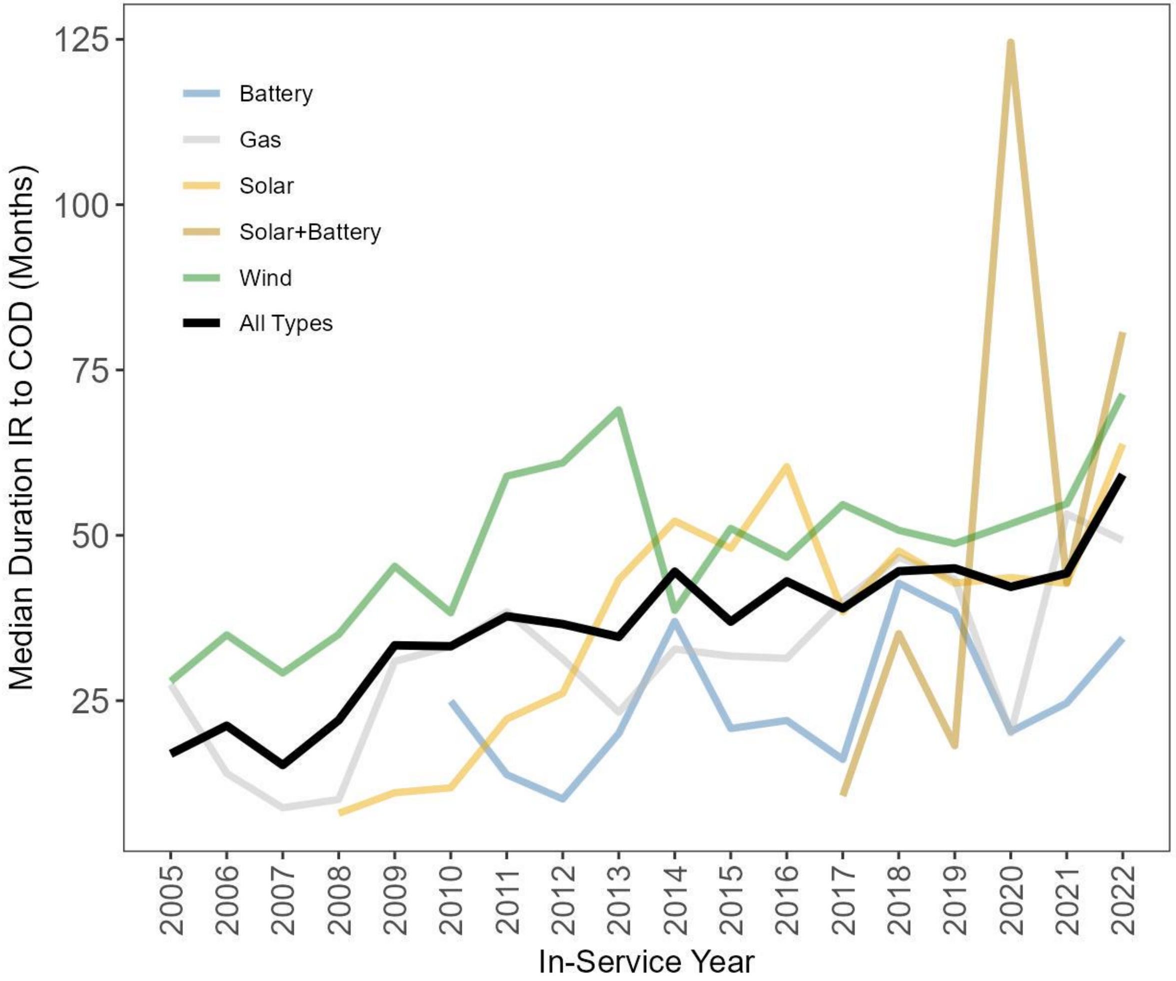
# IR to COD timelines are longest in CAISO, NYISO, and SPP; solar and wind projects typically take longer than other types, with standalone battery projects moving fastest to completion

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

Median Duration from Interconnection Request to Commercial Operations, by Region




Median Duration from Interconnection Request to Commercial Operations, by Generator Type




*Notes: (1) In-service date was only available for 6 ISOs and 5 utilities representing 58% of all operational projects; . (2) Duration is calculated as the number of months from the queue entry date to the in-service date.*

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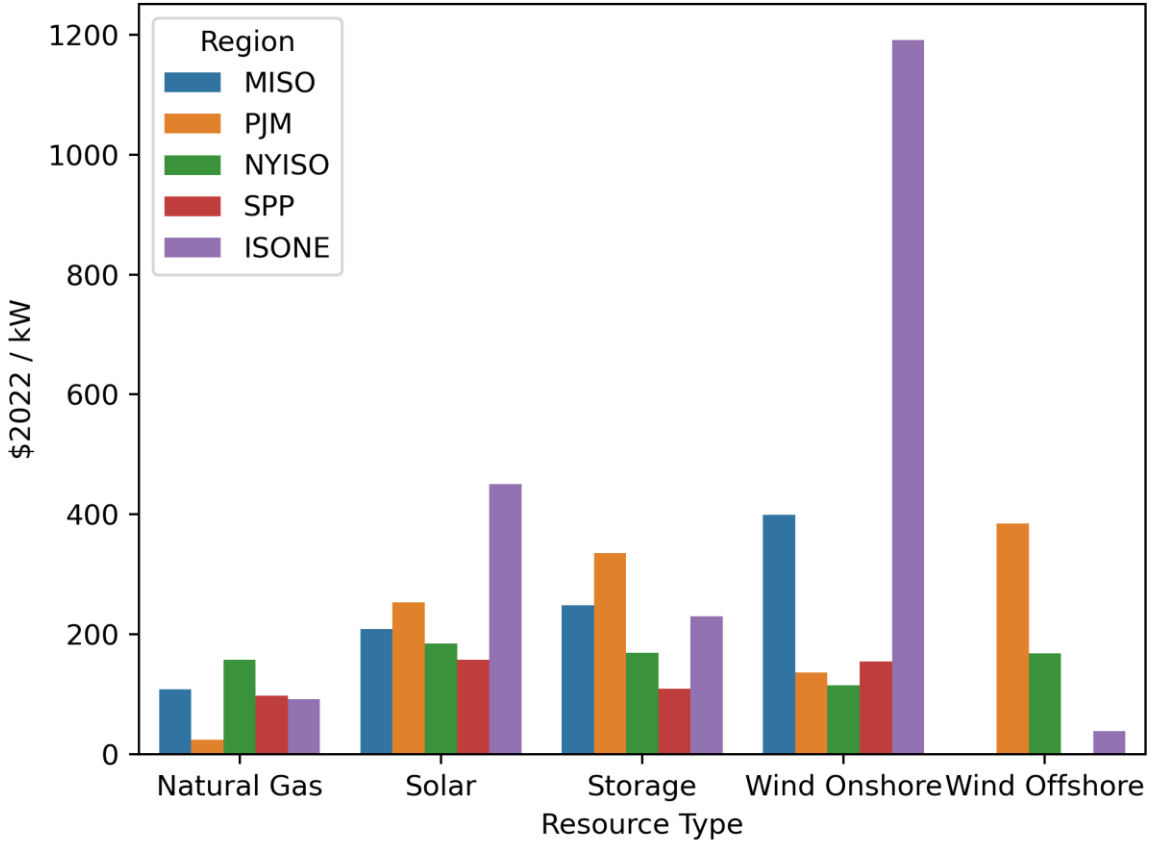
# Renewables and storage often face higher interconnection costs than natural gas

Average Interconnection Costs in Recent Years (includes projects that withdraw application)




*Offshore Wind costs exclude transmission investments offshore*

| | MISO | PJM | NYISO | SPP | ISO-NE |
|---|---|---|---|---|---|
| Years represented | 2018-2021 | 2017-2022 | 2017-2021 | 2010-2022 | 2018-2021 |

- 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.

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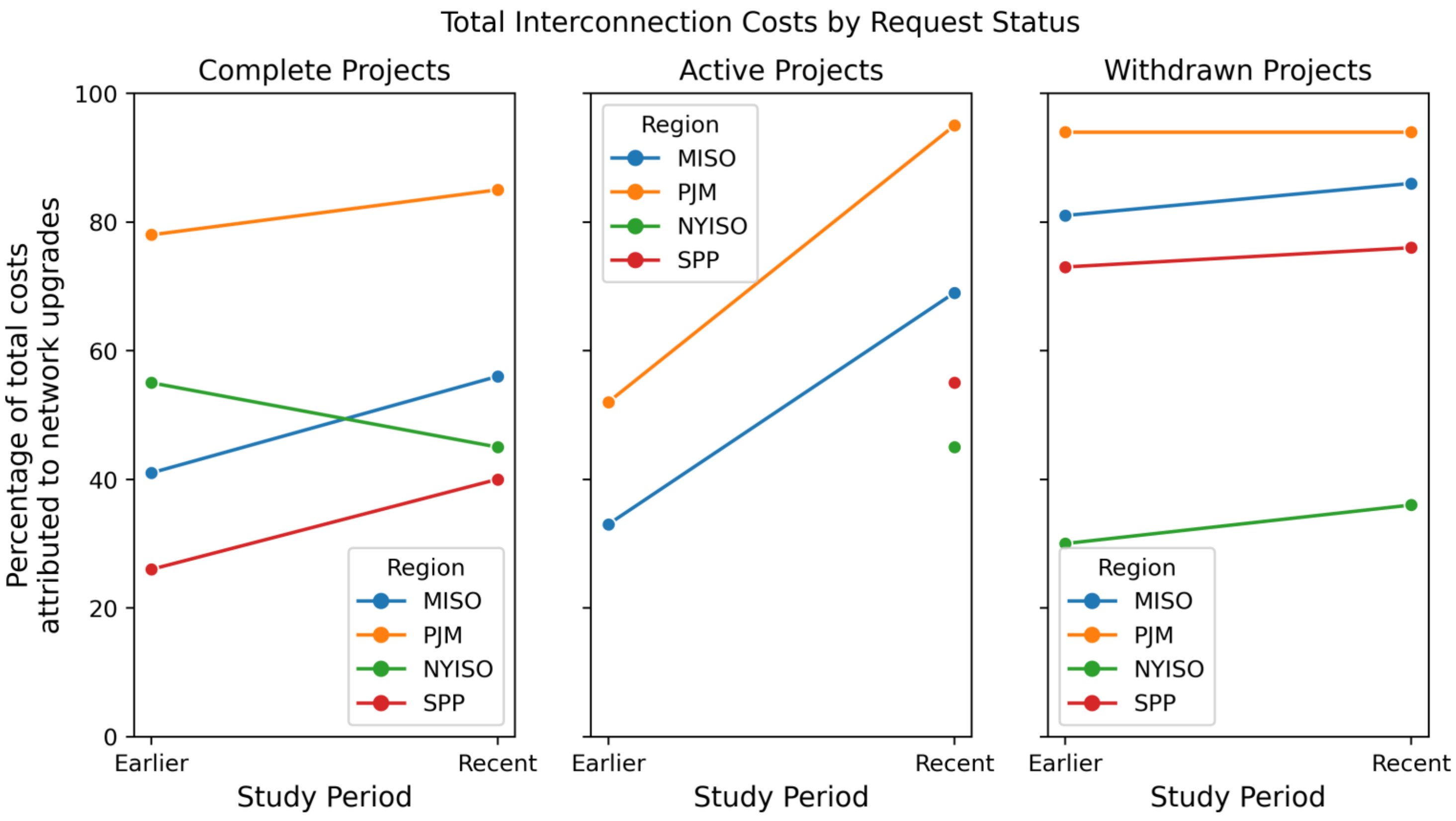
# Broader network upgrades triggered by new interconnection requests mostly behind recent cost increases (not local interconnection costs)

## Average Network Cost Share of Total Interconnection Costs




## Interconnection Cost Components

**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.

| Region | "Earlier" period | "Recent" period |
|---|---|---|
| MISO | 2018 | 2019-2021 |
| SPP | 2010-2019 | 2020-2022 |
| PJM | 2017-2019 | 2020-2022 |
| NYISO | 2006-2016 | 2017-2021 |

# Goal #2: Improve Process and Timing

## (Select) Solutions | Activities

| (Select) Solutions | Federal entities (e.g. FERC/EIA) | Transmission Providers (e.g. ISOs, BAs) | Interconnection Customers (e.g. Developers) | Research community (e.g. Academia, DOE) |
|---|---|---|---|---|
| **Continue to automate** parts of the interconnection process (e.g. data input and validation, some customer communications) | - Identify opportunities for federal funding for automation<br><br>- Encourage transmission providers to identify opportunities for automation | - Identify needs and **priority areas for automation**<br><br>- Identify opportunities for federal funding for automation | - Provide feedback to transmission providers and FERC on priority areas for automation | - Support software development for automation<br><br>- Document needs and priority areas for automation |
| Create new and expand **fast-track options** for interconnection (e.g. surplus, generator replacement, energy-only) | - Consider guidelines for **energy-only fast-tracks** and generator replacement | - Explore technical options for fast-tracking energy-only requests | - **Explore business models** for surplus interconnection service, co-located storage | - Develop approaches for fast-tracking without affecting reliability |
| Consider **market-based approaches** to rationing interconnection access | | -Explore implication of market-based approaches to rationing access<br><br>-Convene stakeholders | -Consider and **propose market-based approaches** to rationing access<br><br>- Participate in new initiatives | -Study implications of market-based approaches to rationing access |
| Increase **voluntary collaboration on affected system studies** | - Encourage voluntary collaboration on affected systems<br><br>- Establish system modeling guidelines and standards to **facilitate coordination** | - Align study methods between affected systems<br><br>- Develop coordinated study processes and/or explore options for **combining host and affected system studies** | | - Carry out case studies demonstrating pros/cons of combining host and affected system studies |
| Assess scale of **interconnection workforce growth requirements** | -Establish clear **reporting requirements**<br><br>-Facilitate data gathering to allow cross-comparisons | -Provide data on **workforce need expectations** | -Provide data on **workforce need expectations** | -Determine data requirements to identify workforce growth<br><br>-Analyze data |

# Goal #3: Promote Economic Efficiency

## (Select) Solutions

## Activities

| (Select) Solutions | Federal entities (e.g. FERC/EIA) | Transmission Providers (e.g. ISOs, BAs) | Interconnection Customers (e.g. Developers) | Research community (e.g. Academia, DOE) |
|---|---|---|---|---|
| Ensure that generators have option to connect **without paying for congestion-related** upgrades (energy-only) | - Consider minimum interconnection standards in the GIP | - Review existing energy-only interconnection service<br><br>- Develop and **integrate minimum interconnection standards**, where absent | - More systematically evaluate energy-only interconnection options | - Review **current approaches to energy-only interconnection**<br><br>- Develop generic minimum interconnection standard |
| More closely **align interconnection and transmission planning** processes | - Encourage interconnection-planning coordination<br><br>- Continue progress on transmission planning reforms | - Ensure **coordinated inputs and assumptions**<br><br>- Convene stakeholders to discuss coordination options | - Participate in and inform stakeholder discussions | - Document emerging practices for coordination |
| Continue to develop **new best practice study methods**, and harmonize methods to adapt to a changing generation mix | - Encourage harmonized study methods<br><br>- Study and propose generic changes in study methods | - Develop new study methods<br><br>- Engage with stakeholders to communicate new methods | - Work with NERC and transmission providers | - Study and **propose generic changes in study methods**<br><br>- Work with software vendors to promote model integration |
| Explore options for generator self-funding of their **own interconnection studies** | - Explore regulations for self-funded studies | - Explore reliability implications for **self-funded studies**<br><br>- Explore rules and regulations for self-funded studies | | |