Title

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Publication Date

2024-01-21

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Queued Up:

Characteristics of Power Plants Seeking Transmission Interconnection As of the End of 2022

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April 2023

This work was funded by the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Contents

What are interconnection queues?

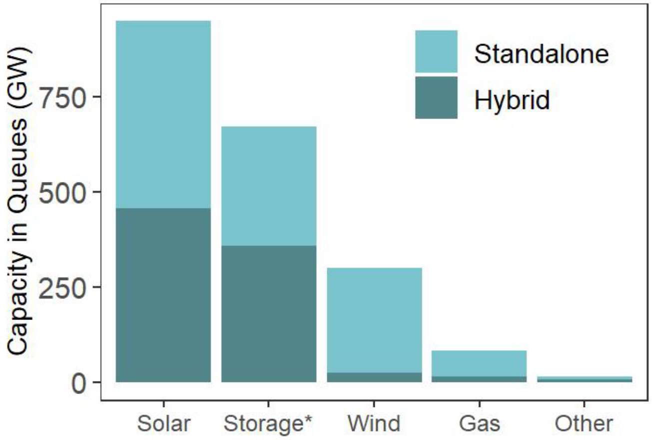
Utilities and regional grid operators (a.k.a., ISOs or RTOs) require projects seeking to connect to the grid to undergo a series of studies before they can be built. This process establishes what new grid system upgrades may be needed before a project can connect to the system and then estimates and 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 download the data used for this analysis and to access an interactive data visualization tool

High-Level Findings

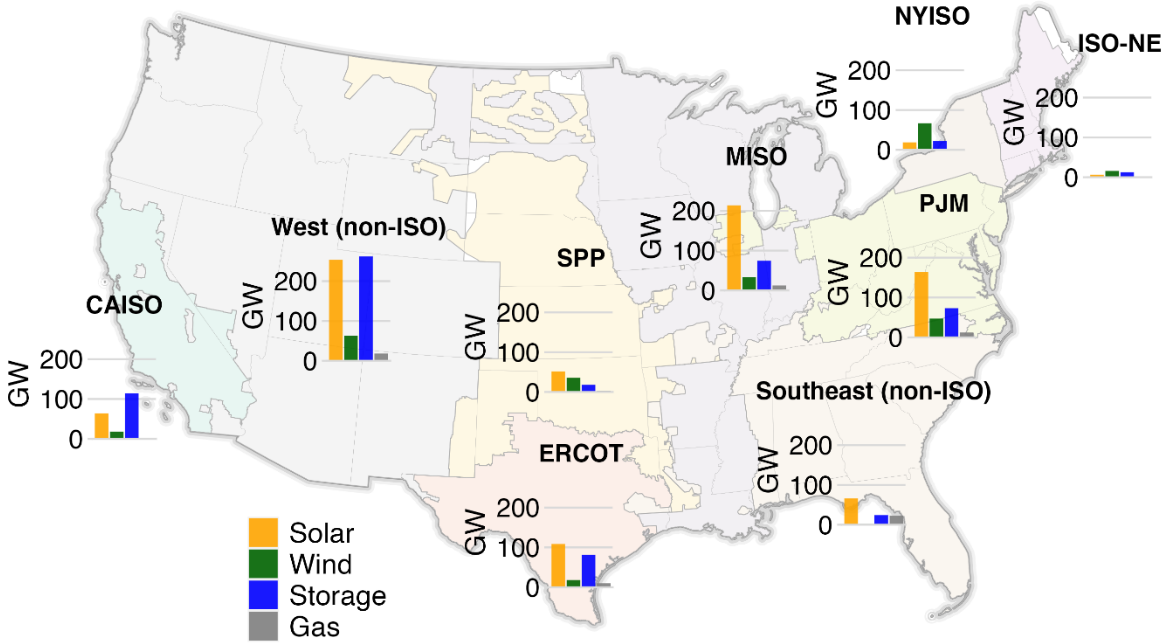
Developer interest in solar, storage, and wind is strong

- Over 10,000 projects representing 1,350 gigawatts (GW) of generator capacity and 680 GW of storage actively seeking interconnection
- Most (~1260 GW) proposed generation is zero-carbon
- Hybrids comprise a large share of proposed projects



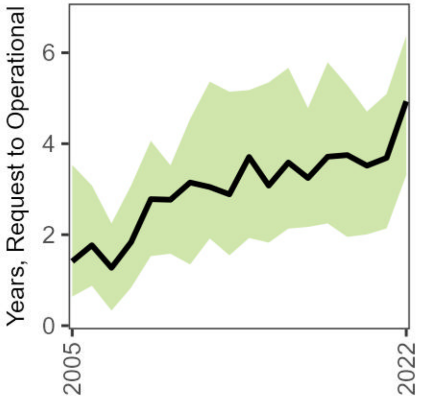
Proposed capacity is widely distributed across the U.S.

- Substantial proposed solar capacity exists in most regions of the U.S.; 947 GW of solar active in queues
- Wind capacity is highest in NYISO, the non-ISO West, PJM, and SPP, with increasing share of offshore projects
- Storage is primarily in the West and CAISO, but also strong in ERCOT, MISO, and PJM; much in hybrid configurations
- Only 82 GW of gas capacity active in the queues, less than 10% of active solar capacity



Completion rates are generally low; wait times are increasing

- Only ~21% of projects (14% of capacity) requesting interconnection from 2000-2017 reached commercial operations by the end of 2022



- Completion rates are even lower for wind (20%) and solar (14%)
- The average time projects spent in queues before being built has increased markedly. The typical project built in 2022 took 5 years from the interconnection request to commercial operations[1], compared to 3 years in 2015 and <2 years in 2008.

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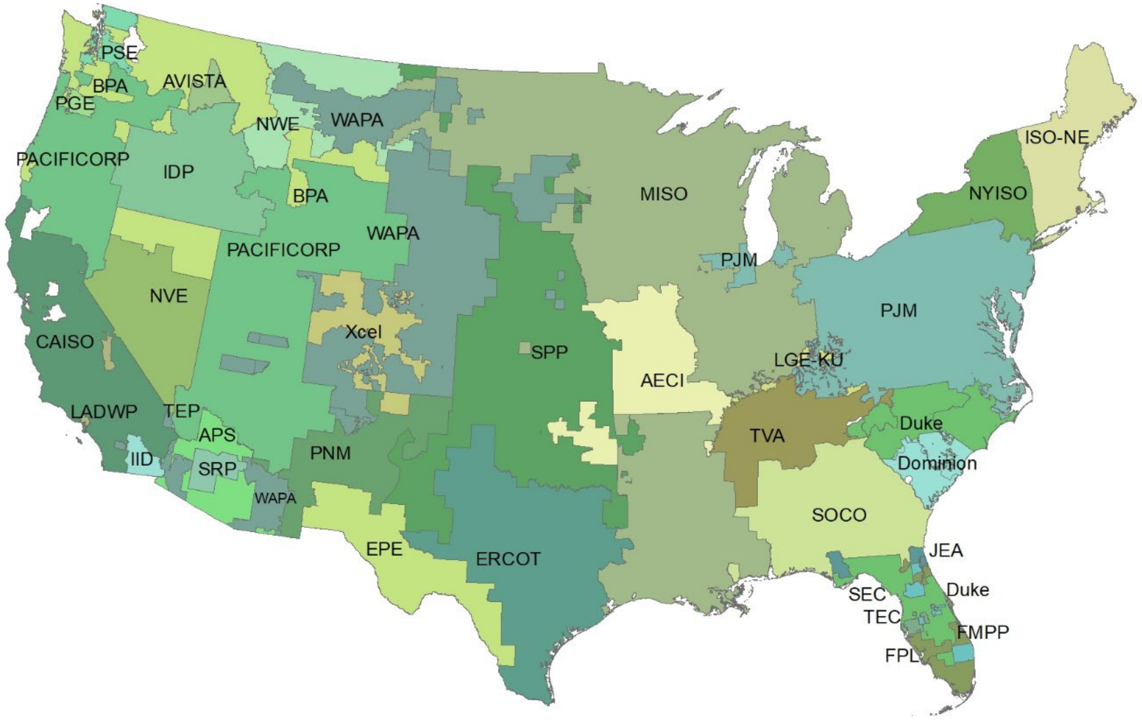
1. In-service date was only available for 58% of all operational projects

Methods and Data Sources

- 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

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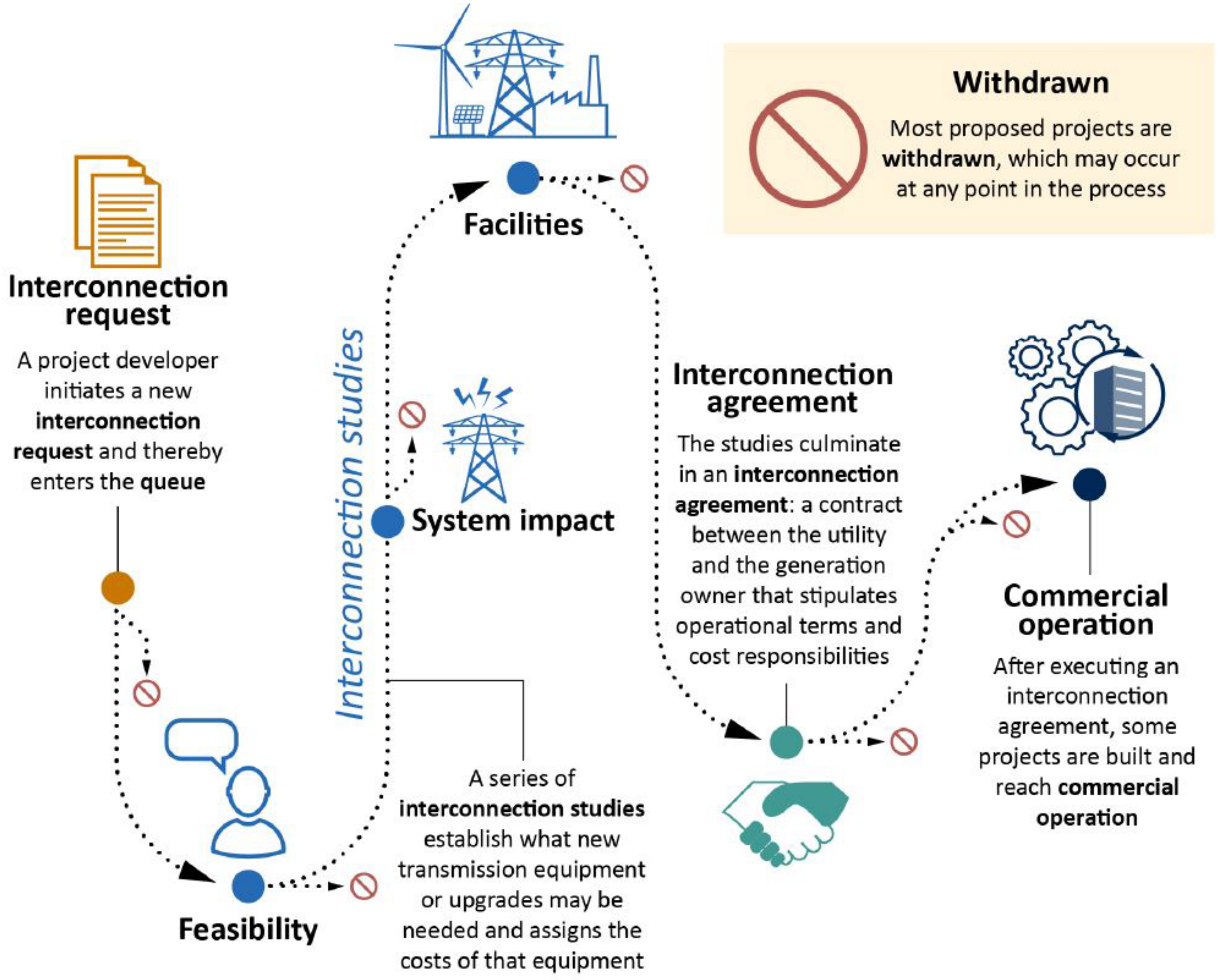
Typical Interconnection Study Process and Timeline

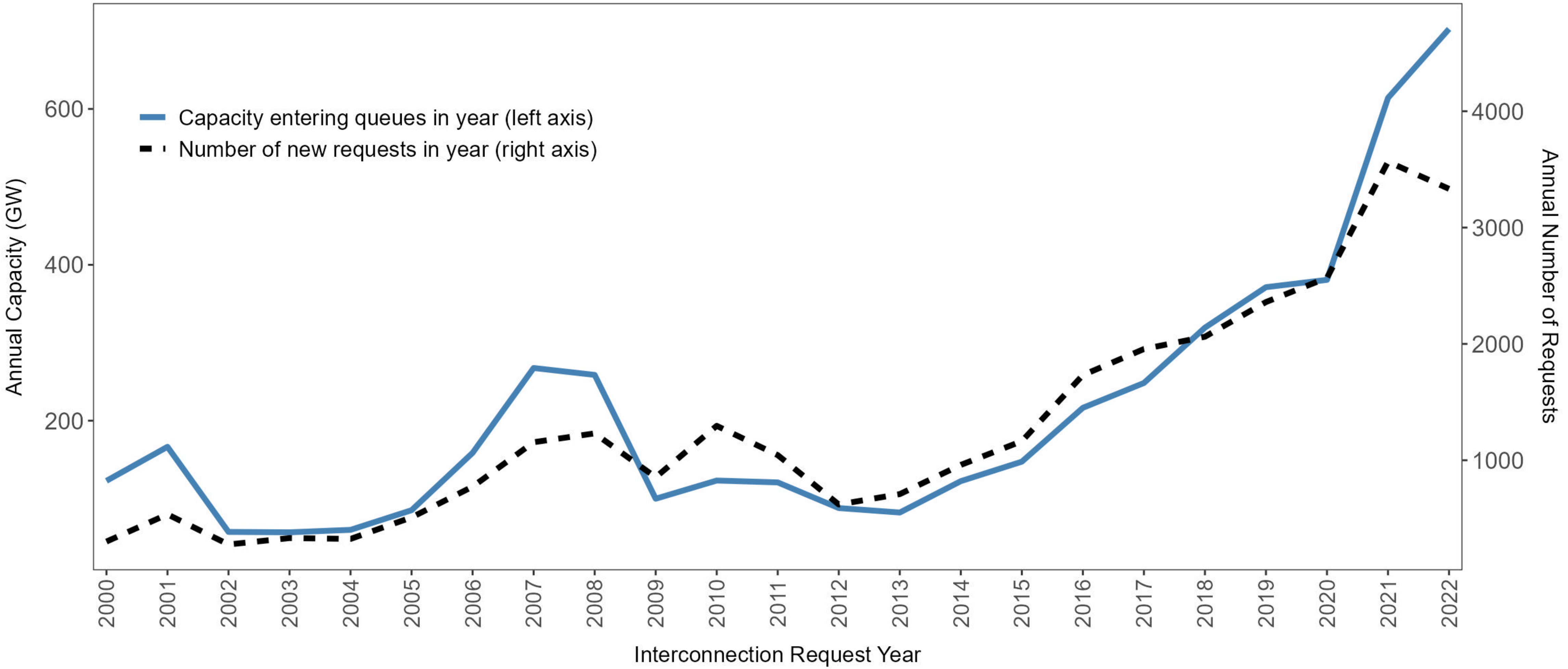
- A project developer initiates a new ***interconnection request (IR)*** and thereby enters the ***queue***
- A series of ***interconnection studies*** establish what new transmission equipment or upgrades may be needed and assigns the costs of that equipment
- The studies culminate in an ***interconnection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



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

Notes: These steps are in accordance with Federal Energy Regulatory Commission (FERC) approved open-access transmission tariffs and generator interconnection procedures. Image from Government Accountability Office report GAO-23-105583: Utility-Scale Energy Storage, used with permission.

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 9).

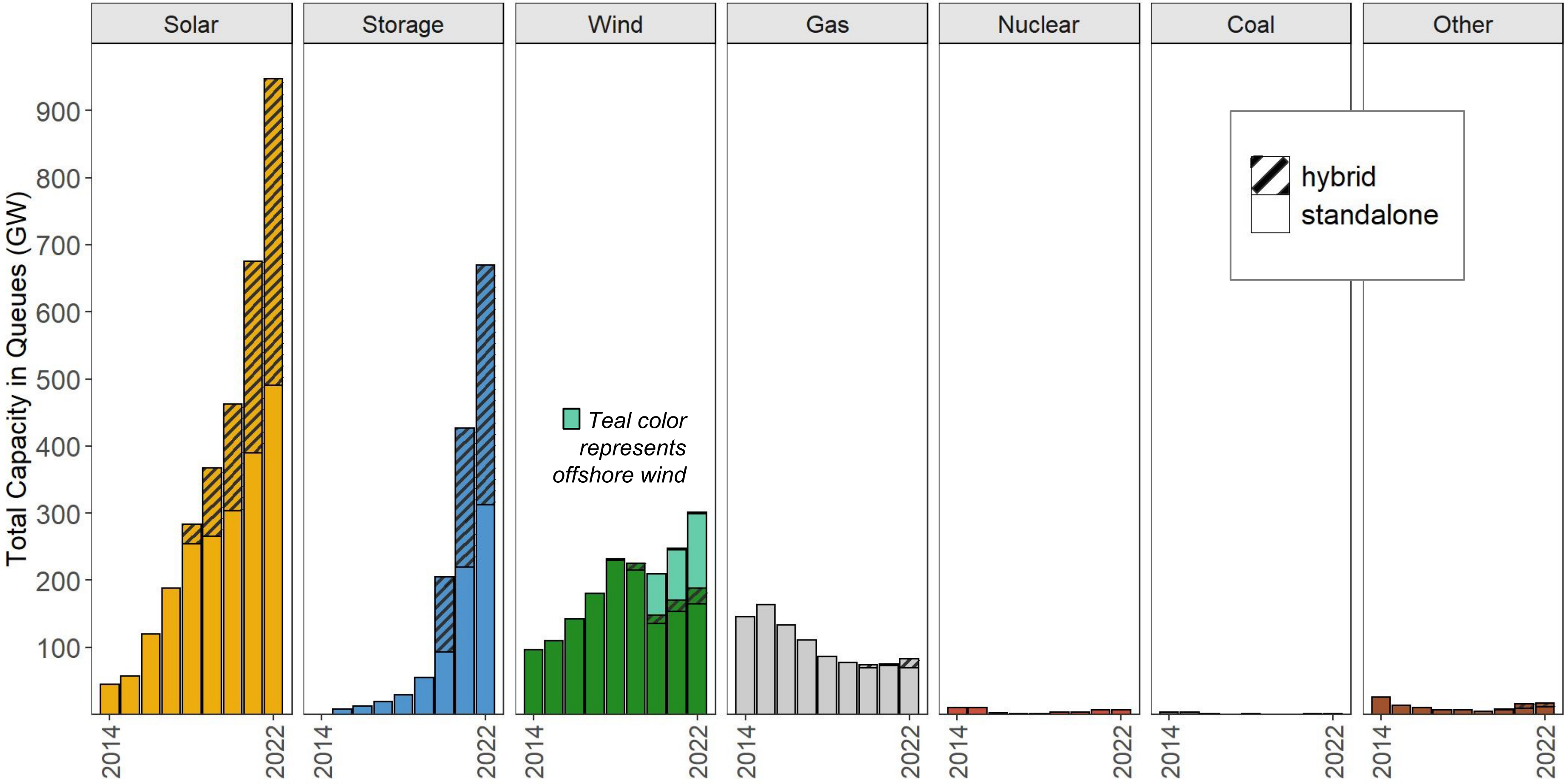
Notes: (1) This total annual volume includes projects with a queue status of "active", "suspended", "withdrawn", or "operational".
(2) All values – especially for earlier years – should be considered approximate.

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

Includes data from all 7 ISOs and 35 non-ISO utilities, totaling 10,262 proposed projects

Region	*n* (Active)
CAISO	495
ERCOT	902
ISO-NE	350
MISO	1,734
NYISO	459
PJM	3,042
SPP	571
Southeast (non-ISO)	830
West (non-ISO)	1,879

Over 2,000 GW (2 TW) of generation & storage capacity active in queues; Especially strong developer interest in solar (~947 GW) and storage (~680 GW), including hybrids



- "**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.*

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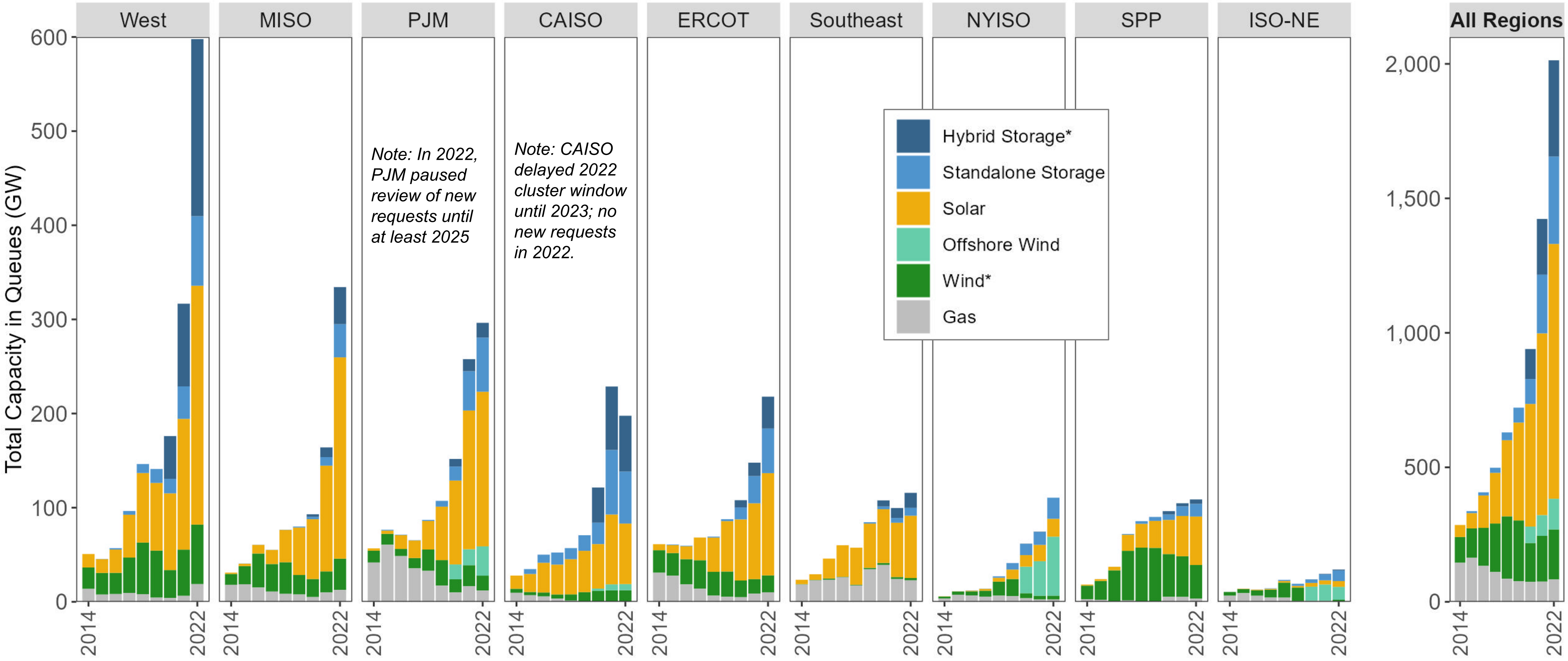
Active queue capacity highest in the non-ISO West (598 GW), followed by MISO (339 GW) and PJM (298 GW). Solar and storage requests are booming in most regions.



*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.*

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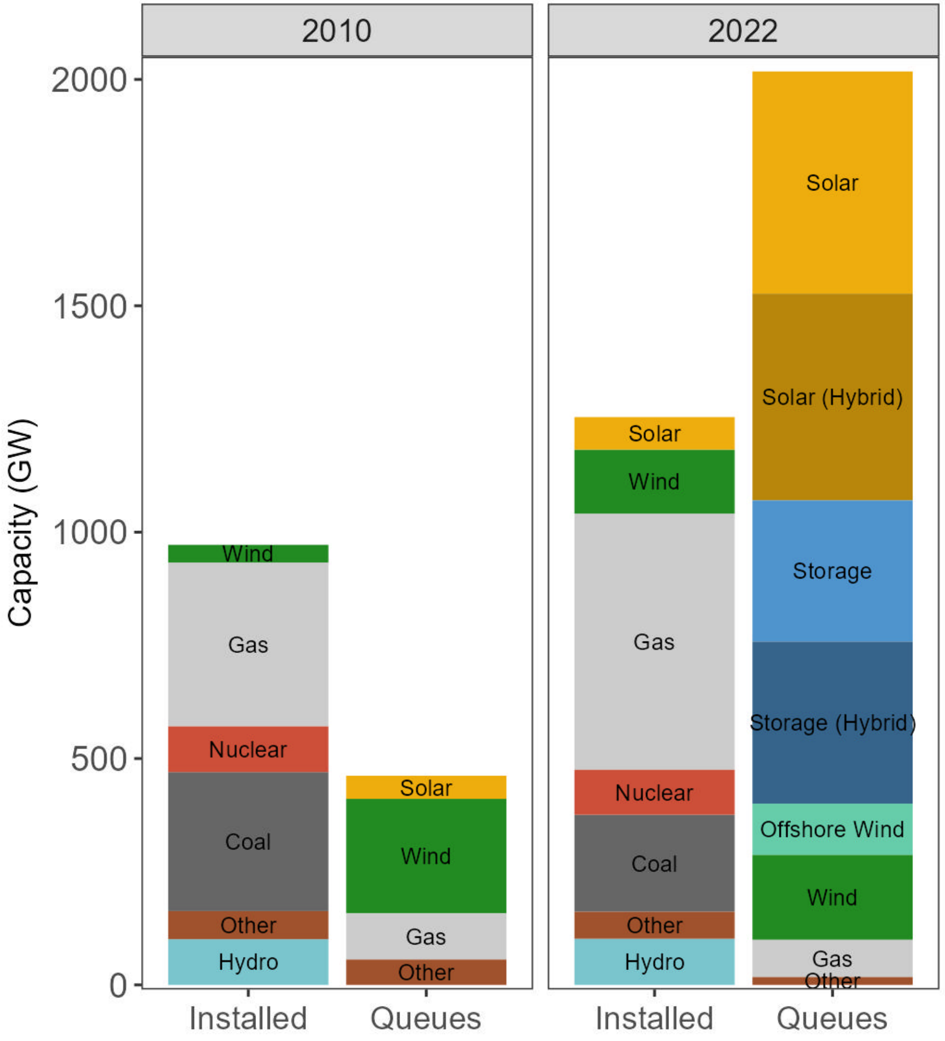
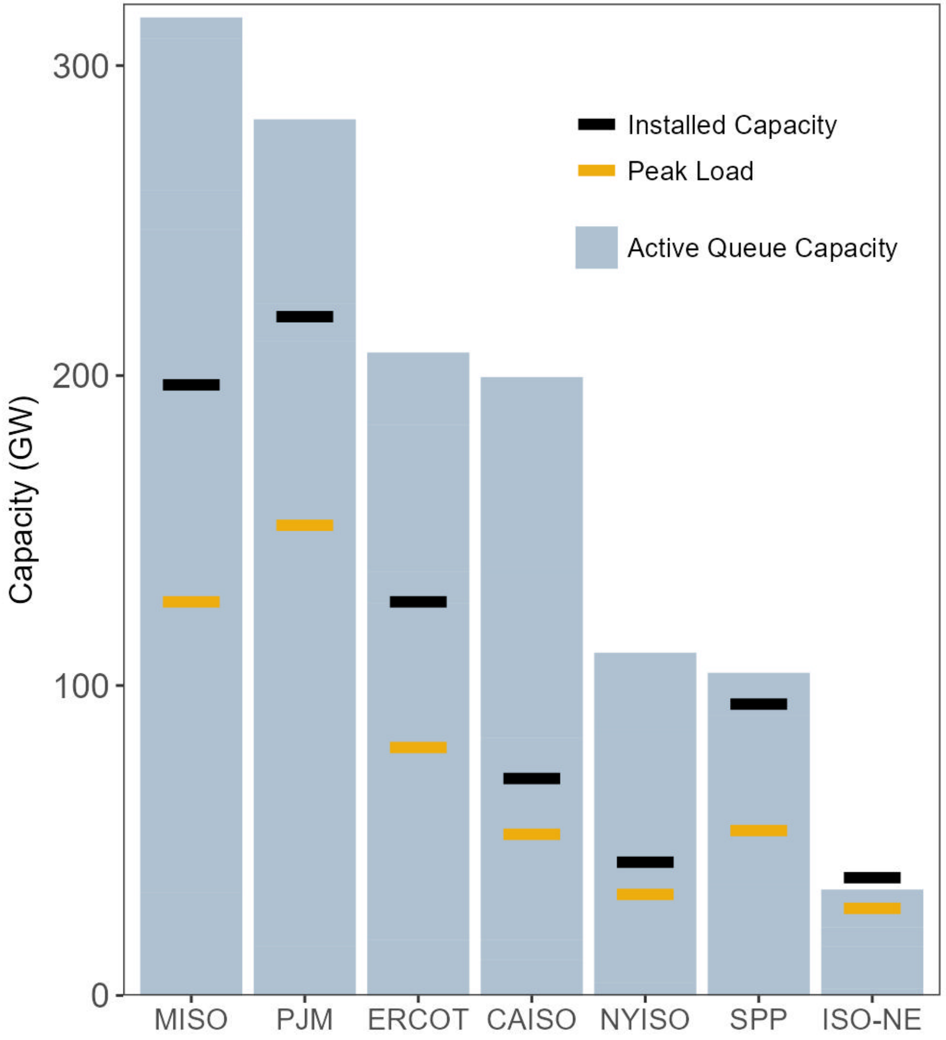
Active capacity in queues (~2,040 GW) exceeds installed capacity of entire U.S. power plant fleet (~1,250 GW), as well as peak load and installed capacity in most ISO/RTOs

Entire U.S. Installed Capacity vs. Active Queues



RTO Installed Capacity & Peak Load vs. Active Queues



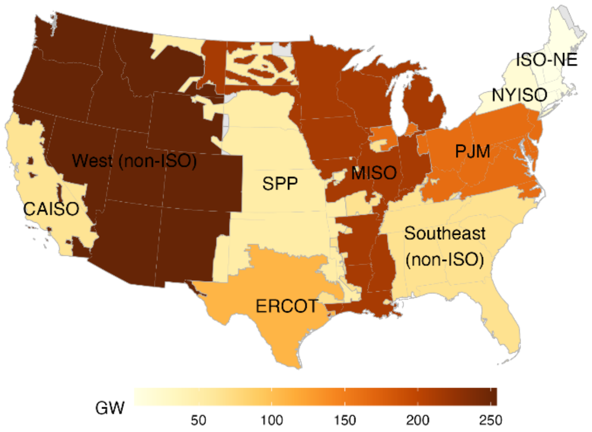
Comparisons of queue capacity to installed capacity or peak load should also consider generators' contributions to resource adequacy, for example their "effective load carrying capability" (ELCC). As variable resources, solar and wind contribute a smaller percentage of their nameplate capacity to resource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

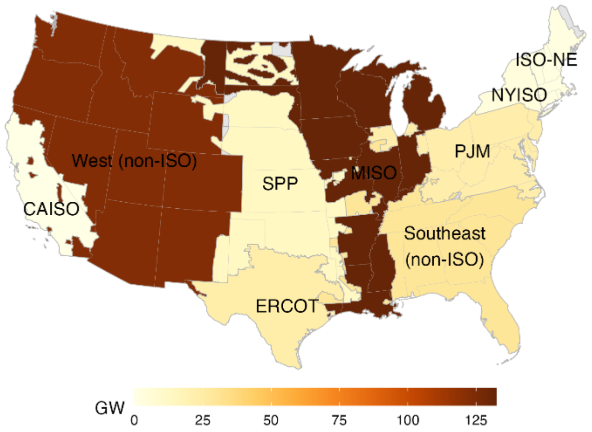
Notes: (a) Hybrid storage in queues is estimated for some projects. (b) Total installed capacity from EIA-860, December 2022. (c) RTO installed capacity from FERC Annual State of the Markets Report (https://www.ferc.gov/media/report-2021-state-markets). Peak load data from RTO websites.

Proposed solar is widespread, with less in SPP and Northeast; Most wind in the West and offshore East Coast; Most storage in the West and CAISO, but expanding; Gas is primarily in the Southeast and West

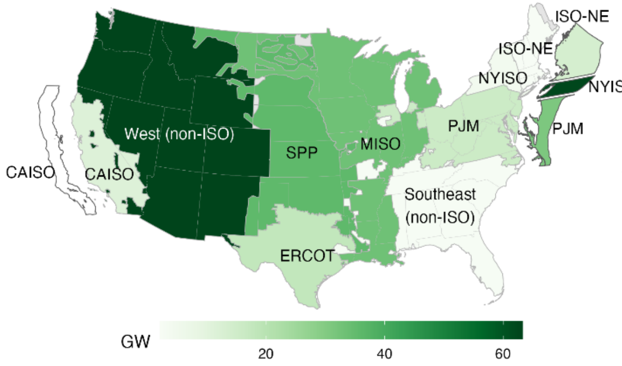
Total Solar Capacity in Interconnection Queues at the end of 2022



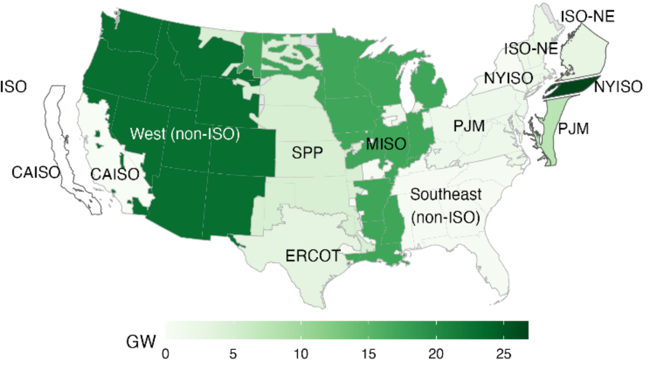
New Solar Capacity Added to Interconnection Queues in 2022



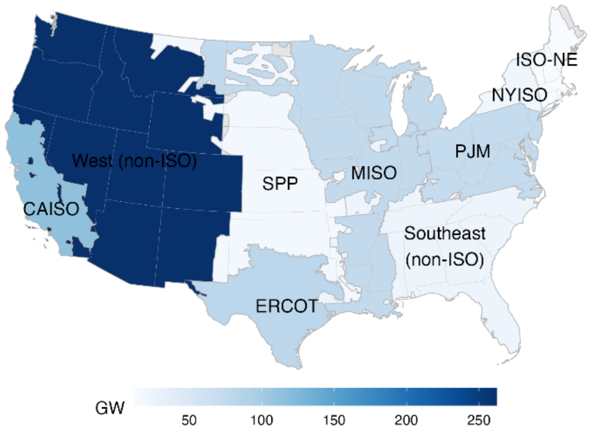
Total Wind Capacity in Interconnection Queues at the end of 2022



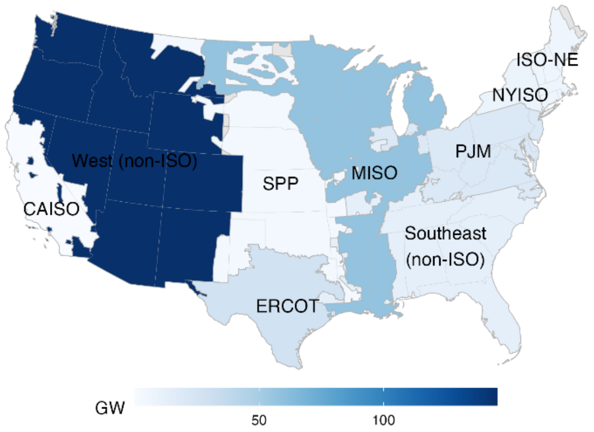
New Wind Capacity Added to Interconnection Queues in 2022



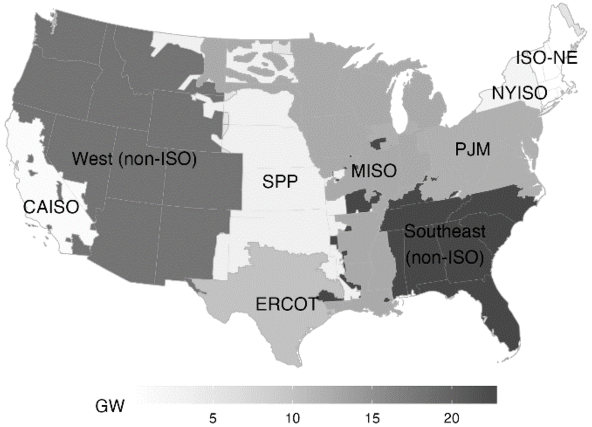
Total Storage Capacity in Interconnection Queues at the end of 2022



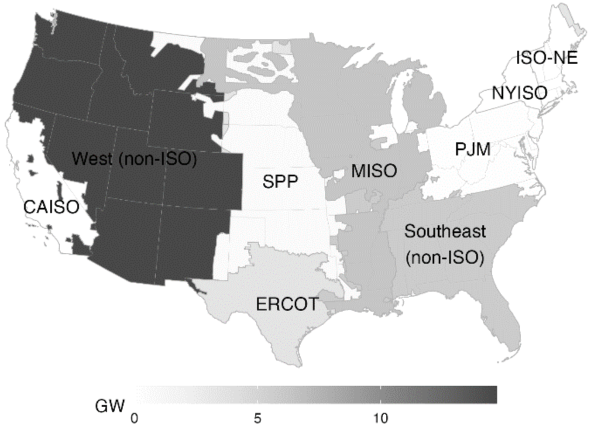
New Storage Capacity Added to Interconnection Queues in 2022



Total Gas Capacity in Interconnection Queues at the end of 2022



New Gas Capacity Added to Interconnection Queues in 2022



Note: Queue capacity mapped by county can be found in appendix slides. See https://emp.lbl.gov/queues to access an interactive data visualization of these maps

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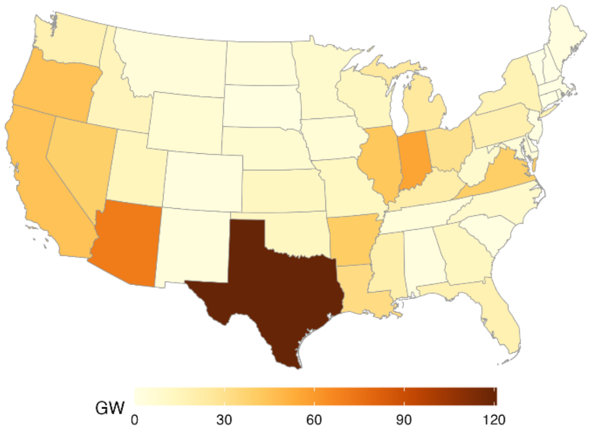
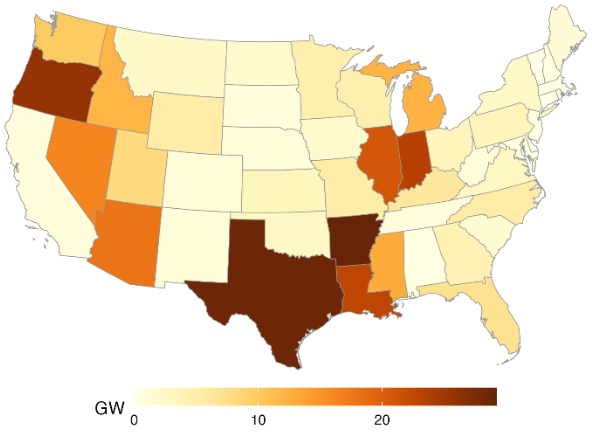
Most proposed solar TX, AZ, IN, CA; proposed wind is mainly offshore, TX, and Great Plains; storage is predominantly in CA, TX, AZ; Proposed gas in TX and Southeast

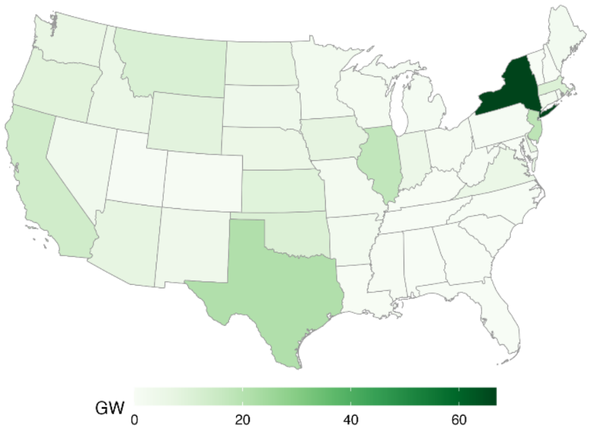
Total Solar Capacity in
Interconnection Queues at the end of 2022



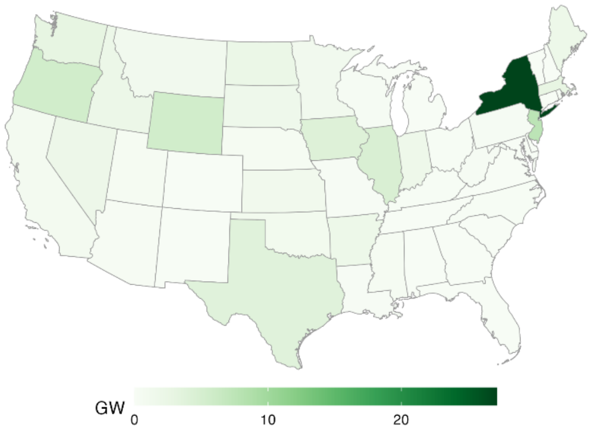
New Solar Capacity Added to
Interconnection Queues in 2022



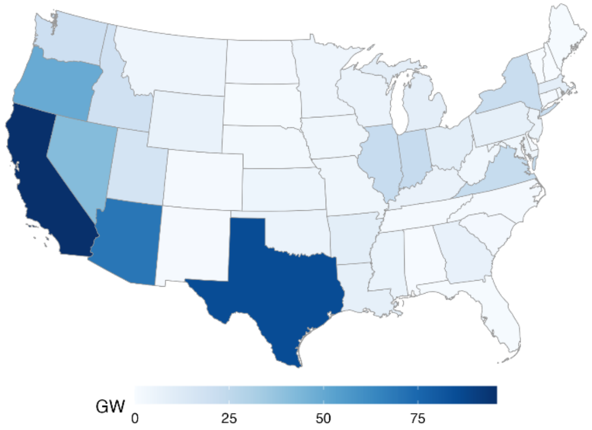
Total Wind Capacity in
Interconnection Queues at the end of 2022



New Wind Capacity Added to
Interconnection Queues in 2022



Total Storage Capacity in
Interconnection Queues at the end of 2022



New Storage Capacity Added to
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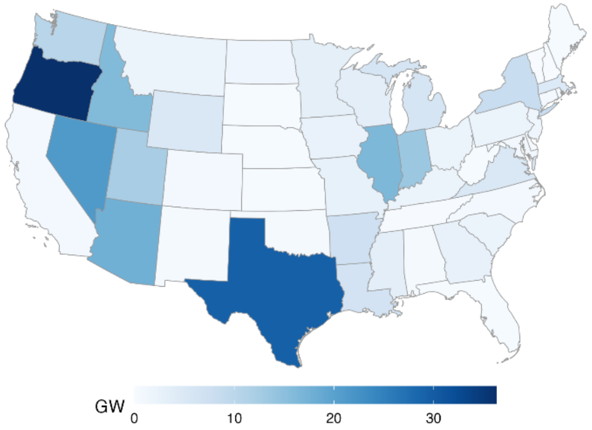
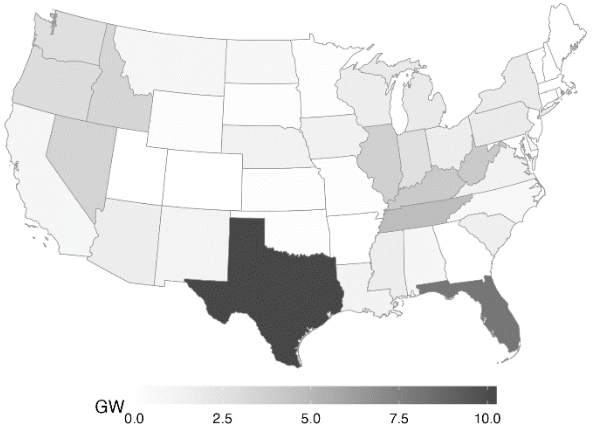


Total Gas Capacity in
Interconnection Queues at the end of 2022



New Gas Capacity Added to
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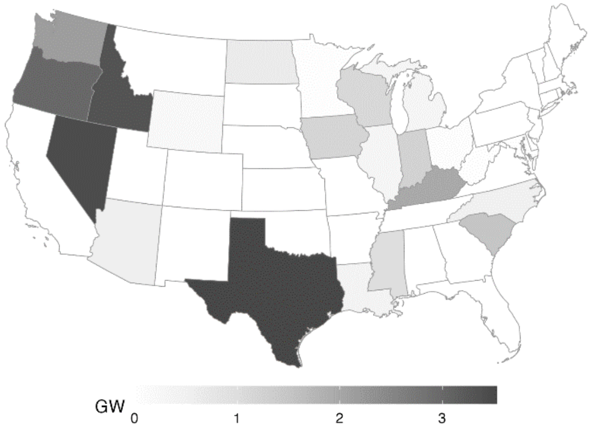
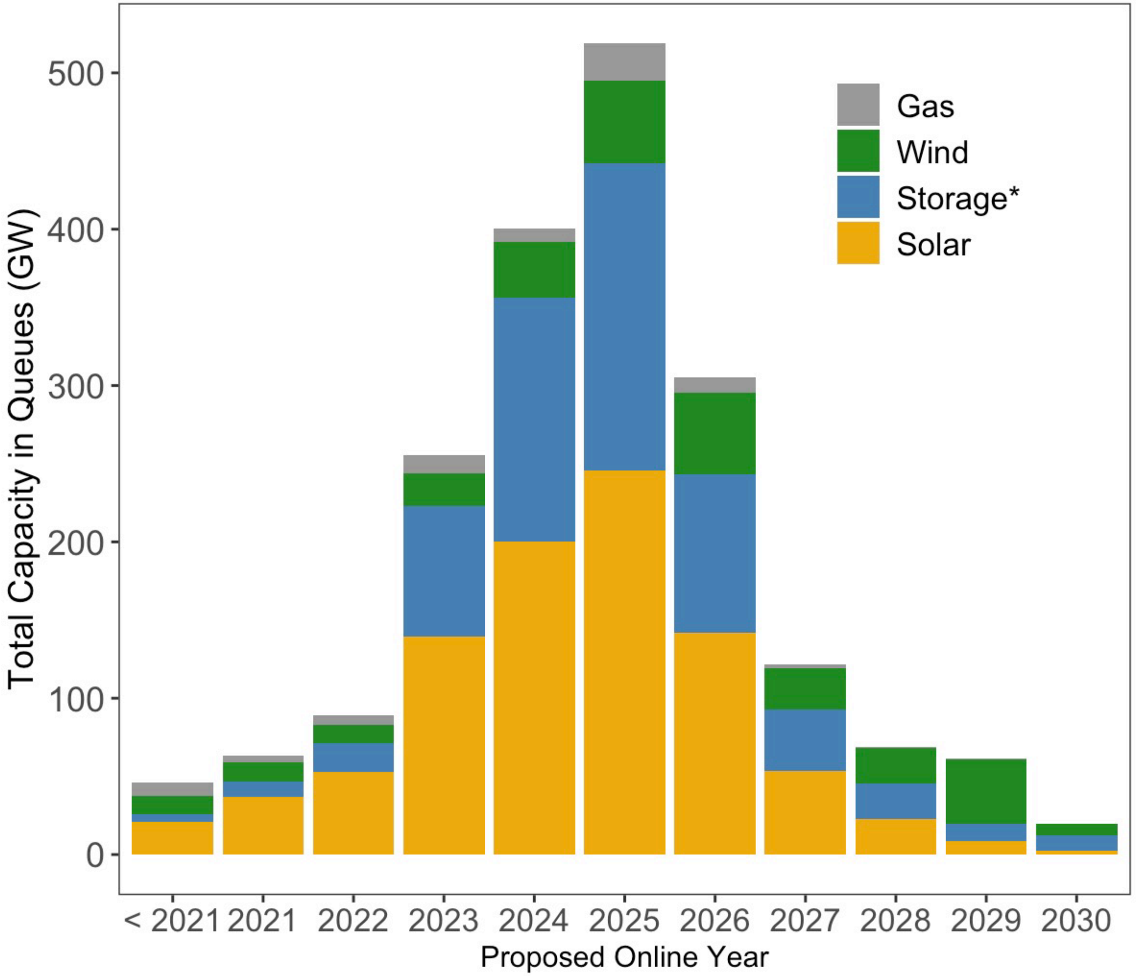
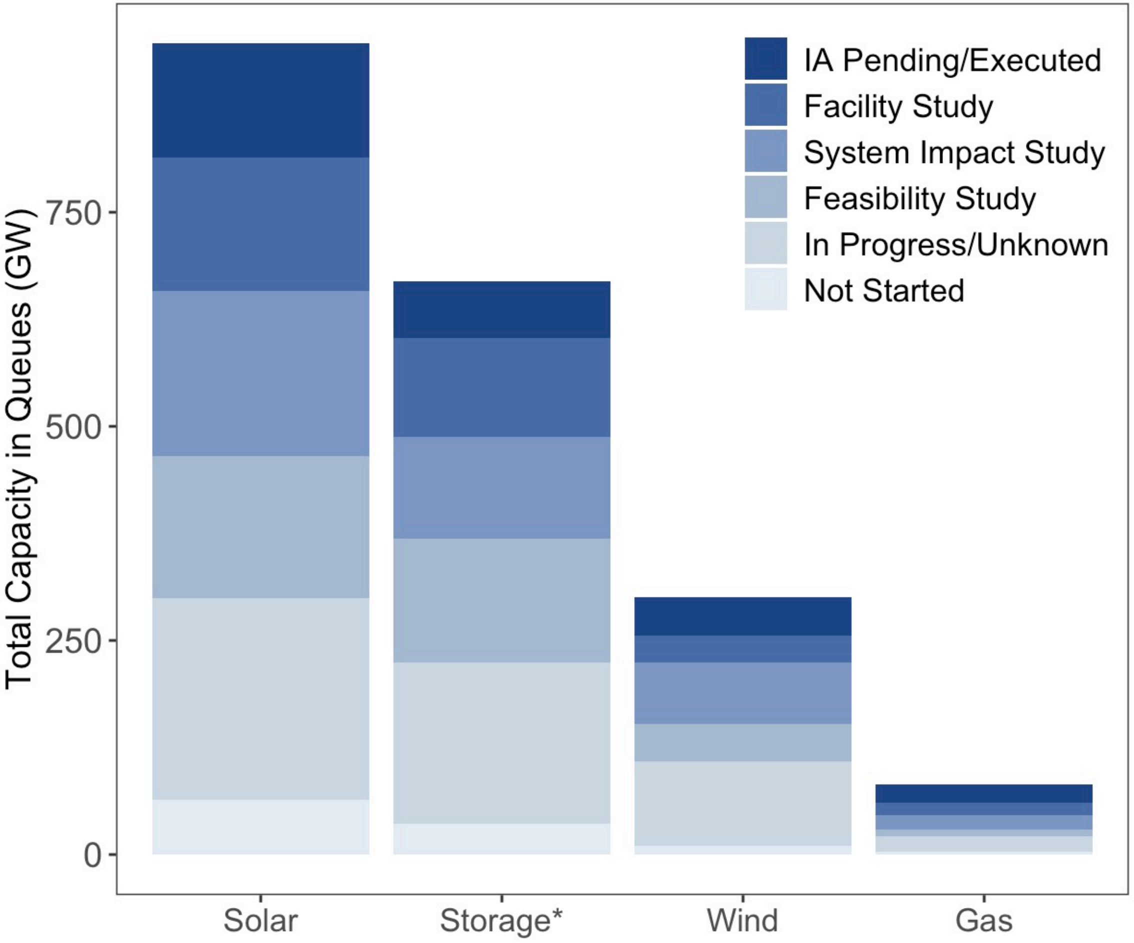


Note: Queue capacity mapped by county can be found in appendix slides. See https://emp.lbl.gov/queues to access an interactive data visualization of these maps

62% (1,262 GW) of total capacity in queues has proposed online date by end of 2025; 13% (257 GW) already has an executed interconnection agreement (IA)

73% of solar (695 GW) is proposed to come online by the end of 2025, compared to 69% of storage (472 GW) and only 48% of wind (145 GW). 14% of solar projects have an IA, compared to 15% of wind and 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, not all queues identify projects under construction*

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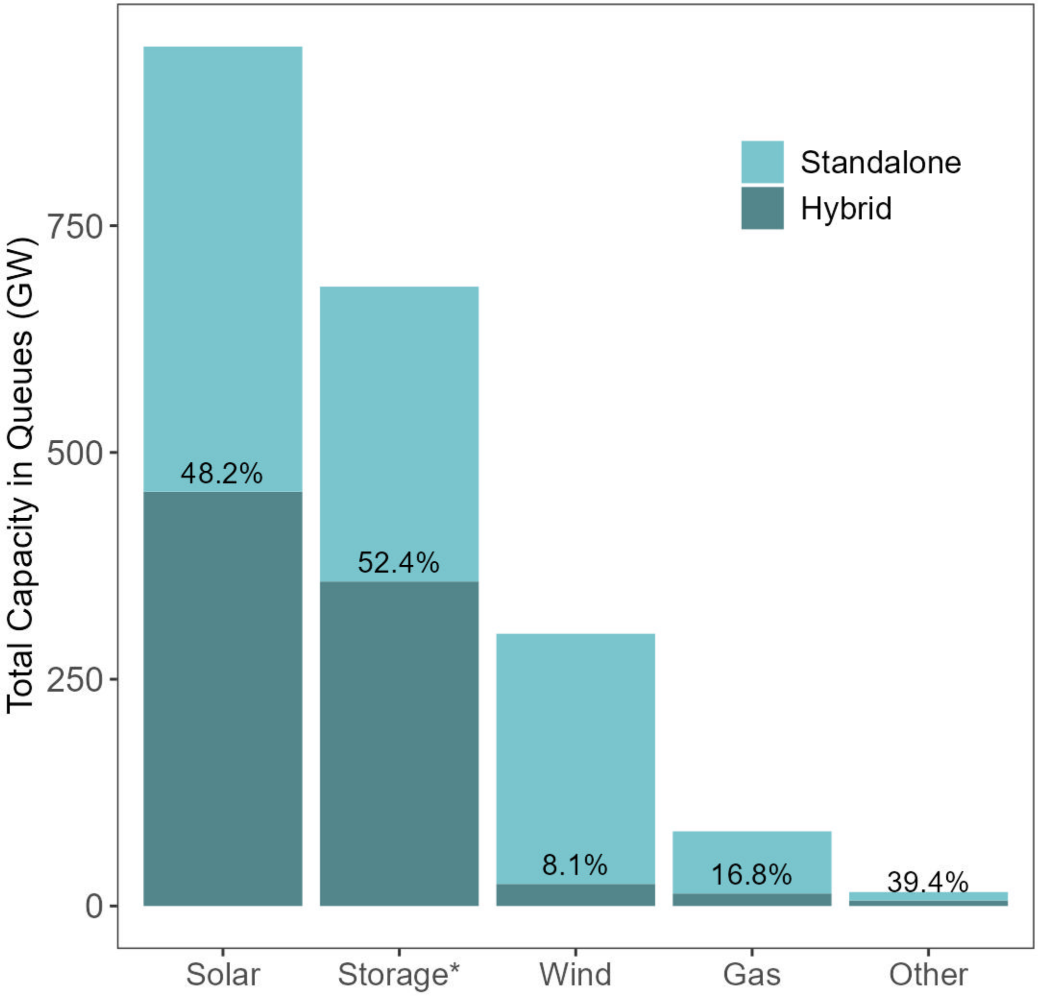
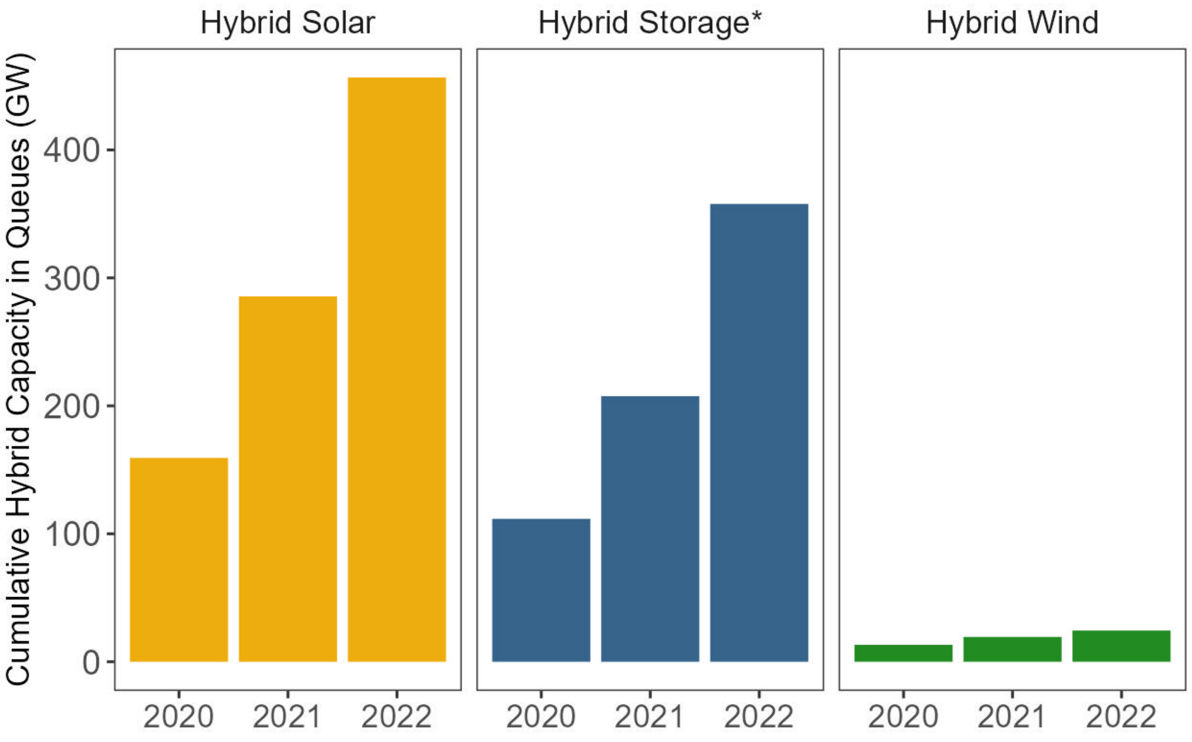
Interest in hybrid plants has increased over time: Hybrids comprise 52% of active storage capacity (358 GW), 48% of solar (457 GW), and 8% of wind (24 GW)



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.

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

Region	% of Proposed Capacity Hybridizing in Each Region			
	Solar	Wind	Gas	Storage
CAISO	97%	45%	15%	53%
ERCOT	42%	4%	3%	42%
ISO-NE	33%	0%	0%	8%
MISO	34%	12%	0%	n/a
NYISO	19%	0%	0%	n/a
PJM	24%	1%	0%	21%
SPP	18%	1%	0%	n/a
Southeast (non-ISO)	21%	0%	0%	n/a
West (non-ISO)	81%	17%	74%	n/a
TOTAL	**48%**	**8%**	**17%**	**n/a**

- **Solar** hybridization relative to total amount of solar in each queue is highest in CAISO (97%) and non-ISO West (81%), and is above or near 20% in all regions
- **Wind** hybridization relative to total amount of wind in each queue is highest in CAISO (45%), the non-ISO West (17%), and MISO (12%), and is less than 5% in all other regions

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Commercially Operational & Withdrawn Projects: Volume and Completion Rates

Operational project data were collected from all 7 ISO/RTOs, and 26 non-ISO utilities, totaling 3,846 projects.

Region	*n* (Operational)
CAISO	199
ERCOT	314
ISO-NE	305
MISO	452
NYISO	88
PJM	1,061
SPP	261
Southeast (non-ISO)	303
West (non-ISO)	863

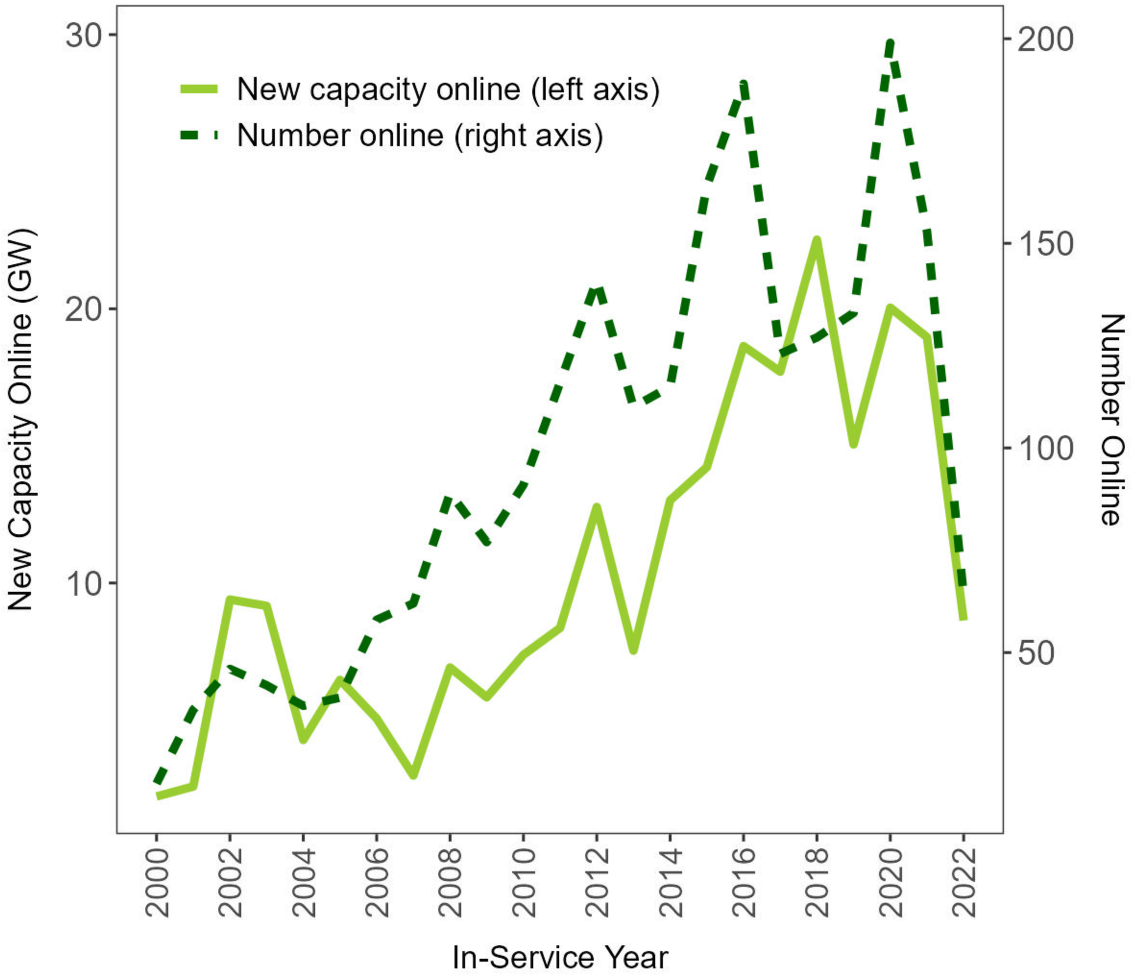
Withdrawn project data were collected from 7 ISO/RTOs, and 31 non-ISO utilities, totaling 15,672 projects.

Region	*n* (Withdrawn)
CAISO	1,580
ERCOT	736
ISO-NE	600
MISO	1,885
NYISO	713
PJM	3,558
SPP	1,135
Southeast (non-ISO)	1,777
West (non-ISO)	3,687

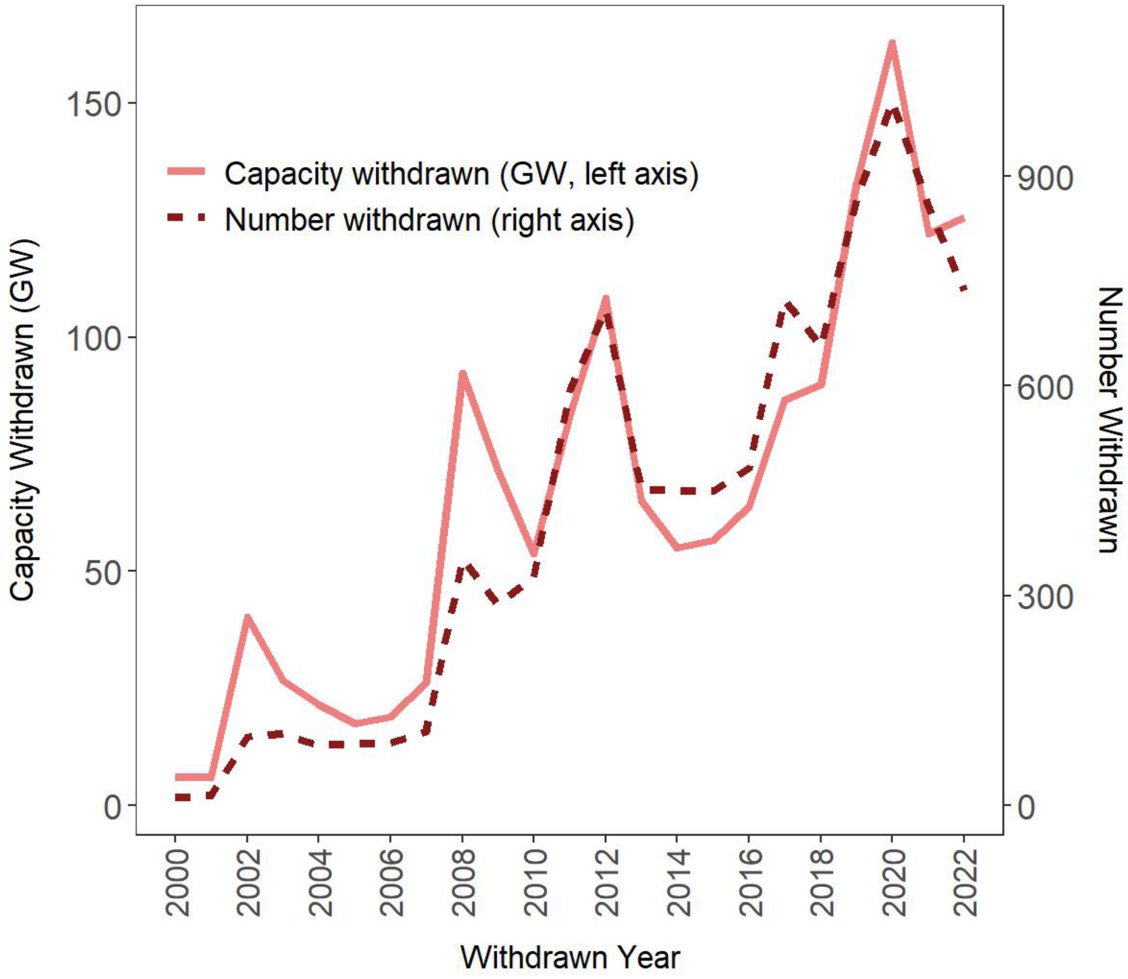
Notes: (1) The number of operational and withdrawn projects with available data may be fewer than the total number of operational or withdrawn projects for each entity. (2) Data were sought from 7 ISO/RTOs and 35 utilities; operational and withdrawn project data are not always available.

Volume (number and capacity) of operational and withdrawn projects are increasing year-over-year, but with a marked decrease in projects coming online in 2022

Operational Projects

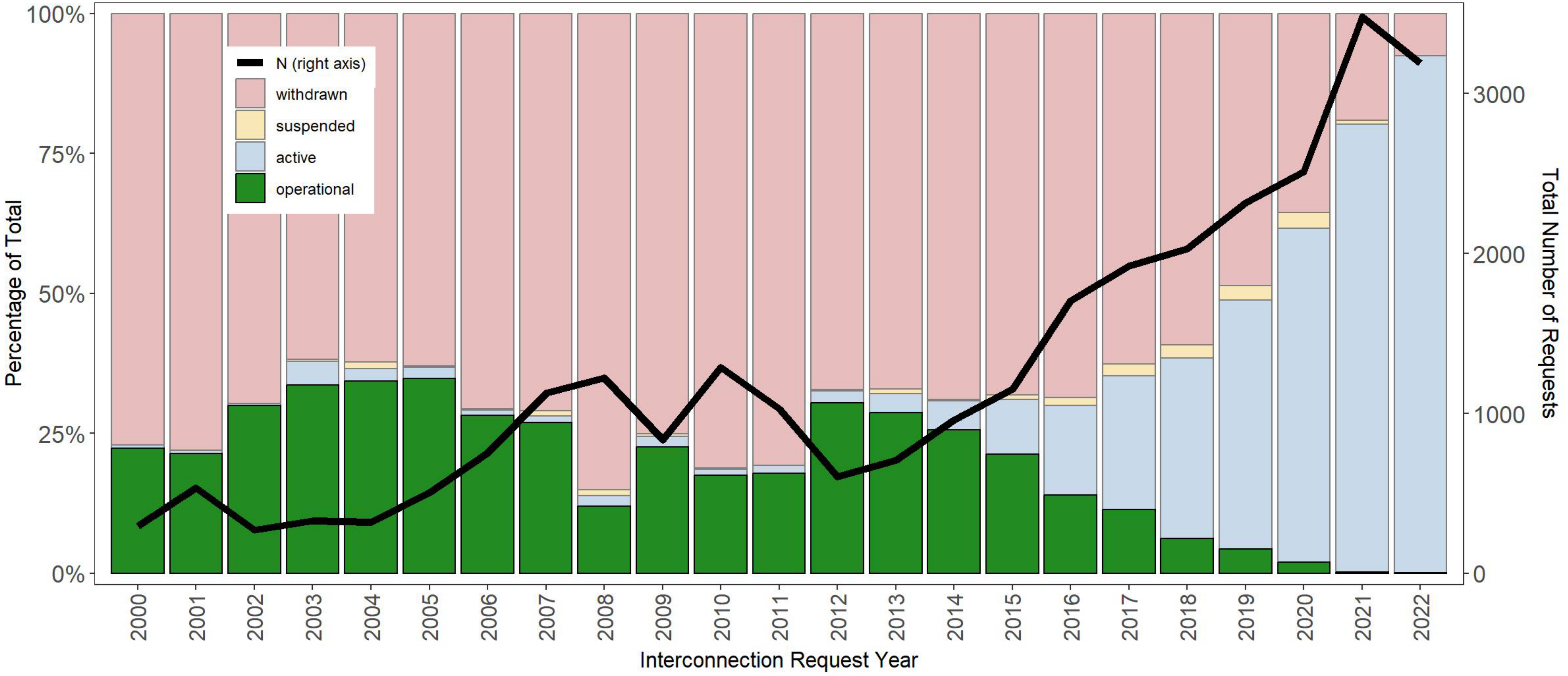


Withdrawn Projects



Note: In-service year only available for 58% of the "operational" project sample; withdrawn year only available for 61% of the "withdrawn" project sample. These figures therefore only include a subset of total data.

Only 21% of all projects proposed from 2000-2017[1] had reached commercial operations by the end of 2022 – 72% had withdrawn from queues



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 2022. (3) Completion rate shown here is calculated by number of projects, not capacity-weighted. (4) Limited to data from 7 ISO/RTOs and 26 utilities.

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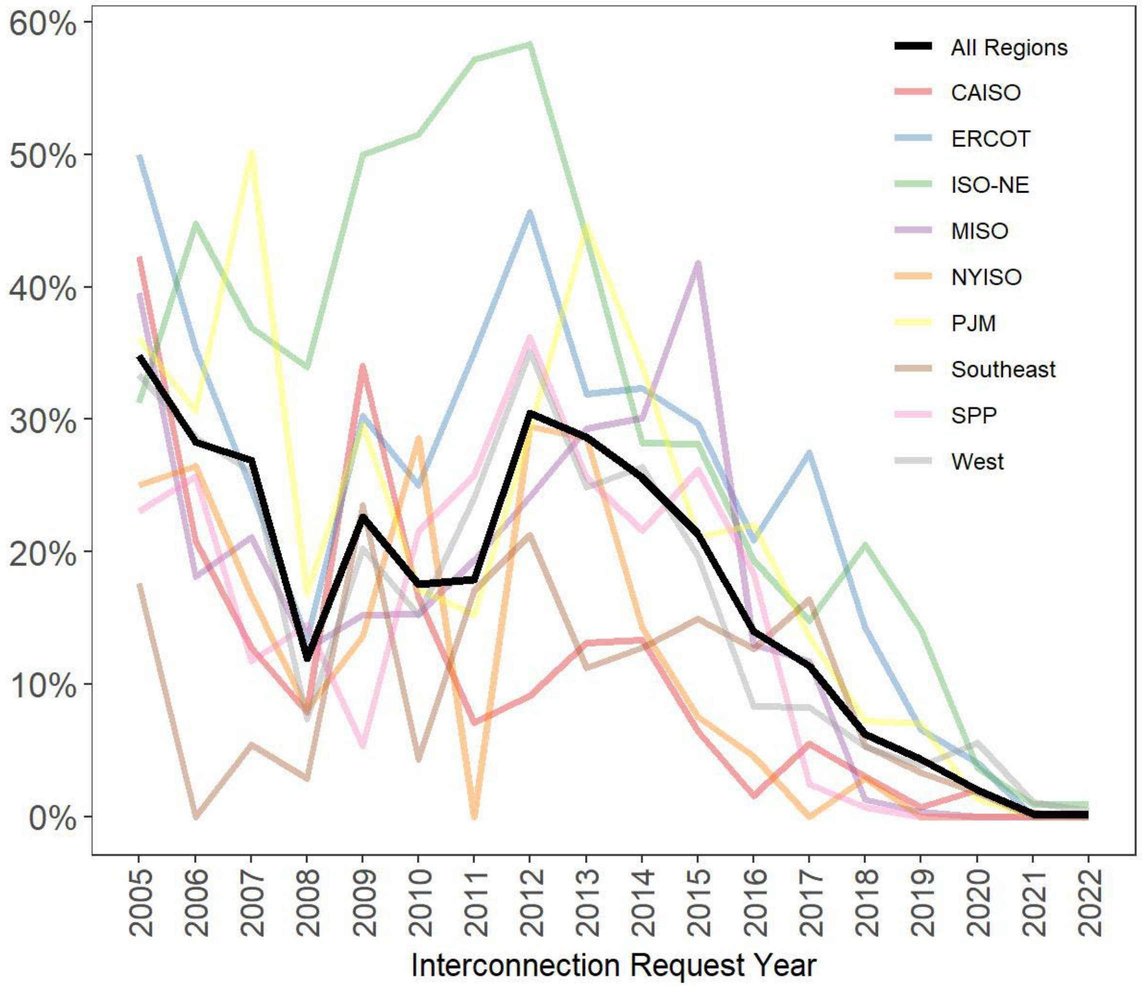
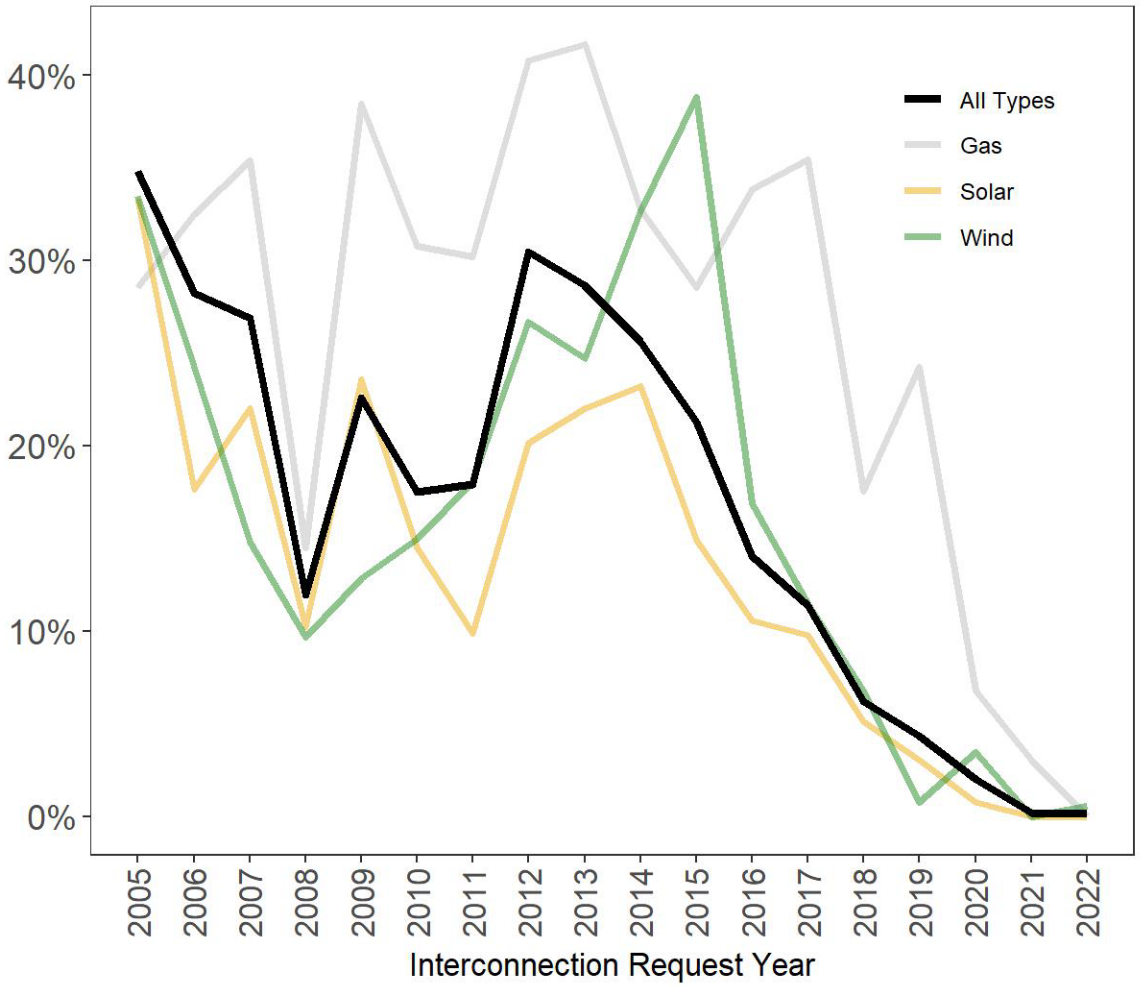
There is considerable variation in completion rates across regions and types; solar (14%) has a lower completion rate from 2000-2017 than other types

Completion percentage by region:



Completion percentage by generator type:



Note: (1) Completion rate shown here is calculated by <u>number</u> of projects online by end of 2022, not capacity-weighted. (2) Calculated as number of projects operational as of EOY 2022 divided by the total number of requests per year. (3) Includes data from 7 ISO/RTOs and 26 utilities.

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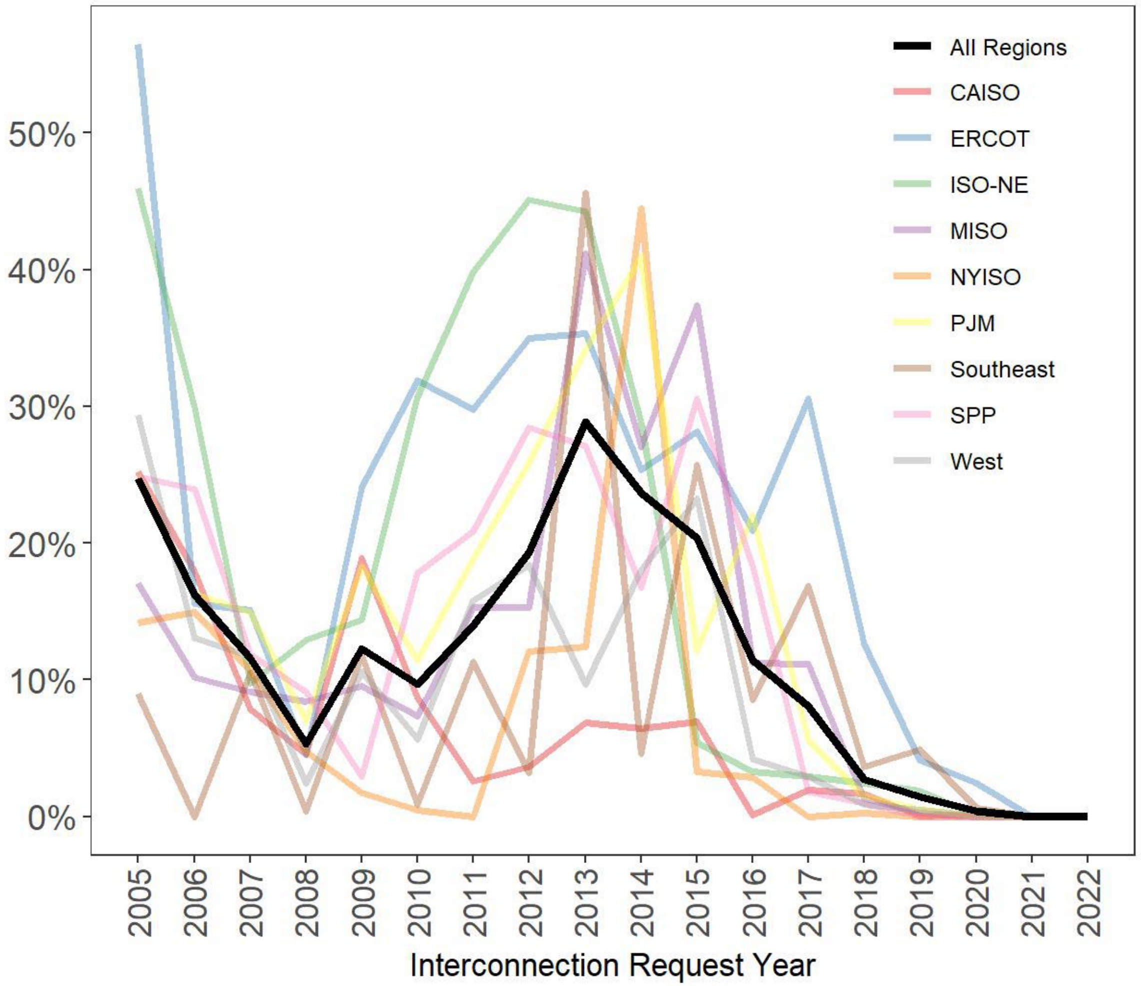
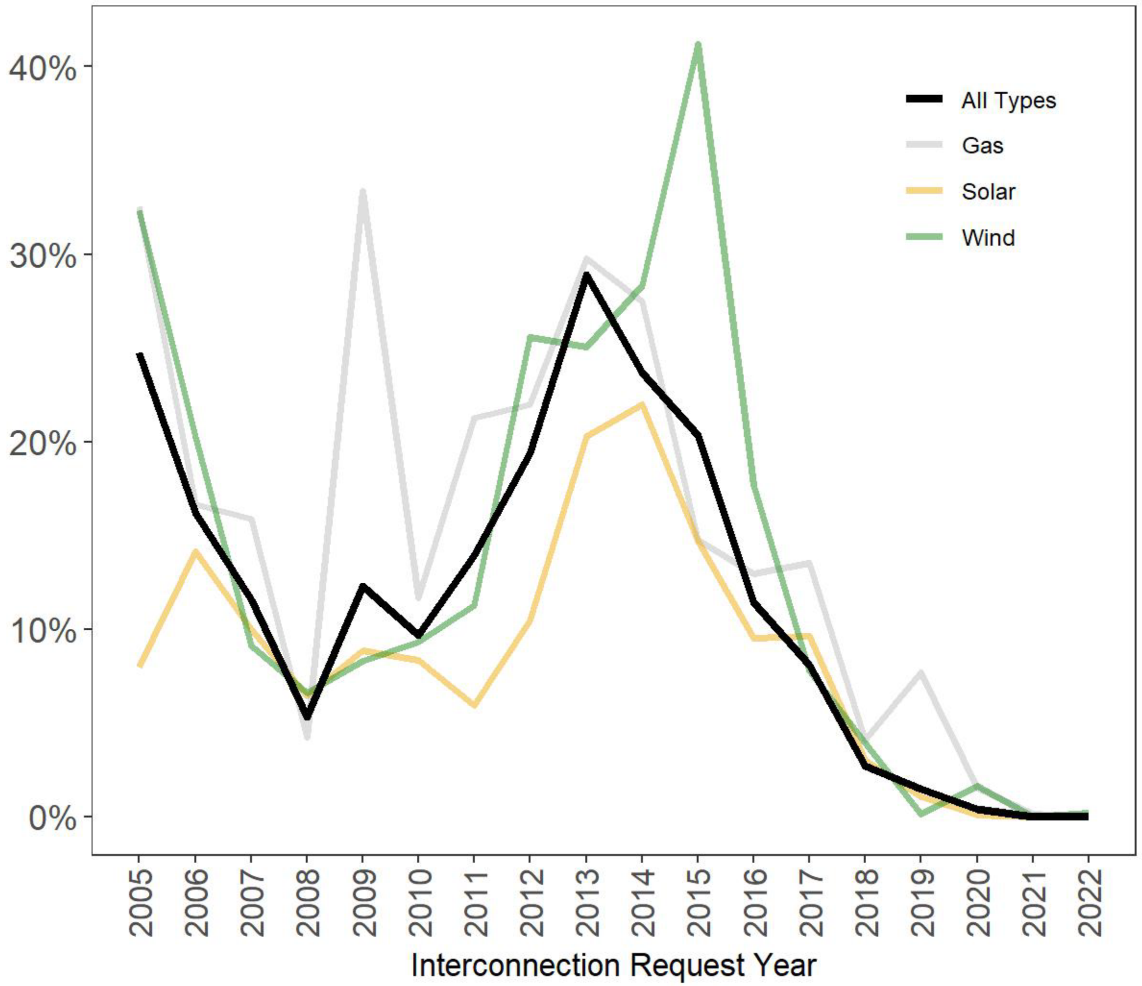
Capacity-weighted completion rates are even lower: Only 14% of all capacity requesting interconnection from 2000-2017 is online; 16% of wind capacity, 10% of solar capacity

Percentage of capacity online by region:

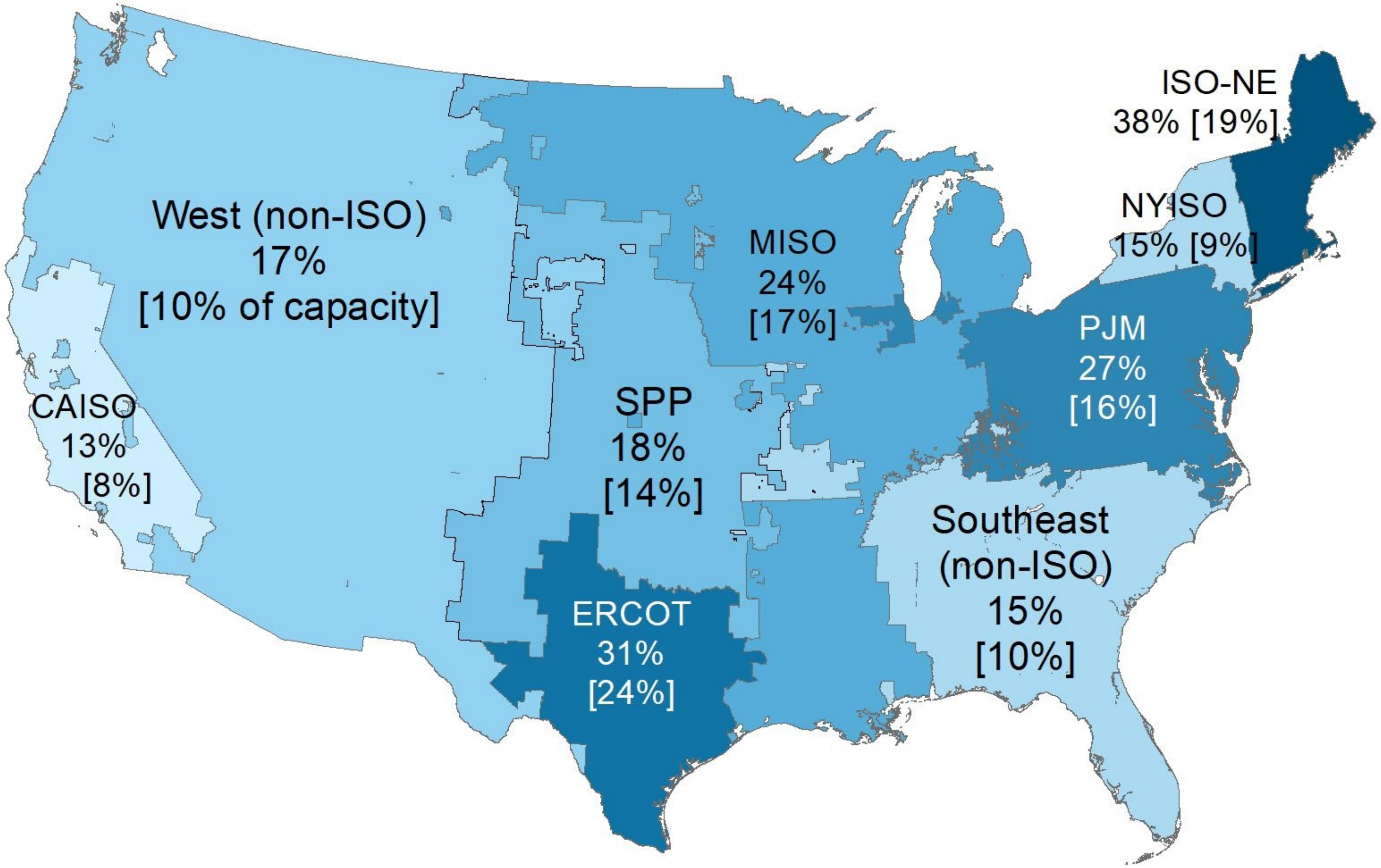


Percentage of capacity online by generator type:



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.

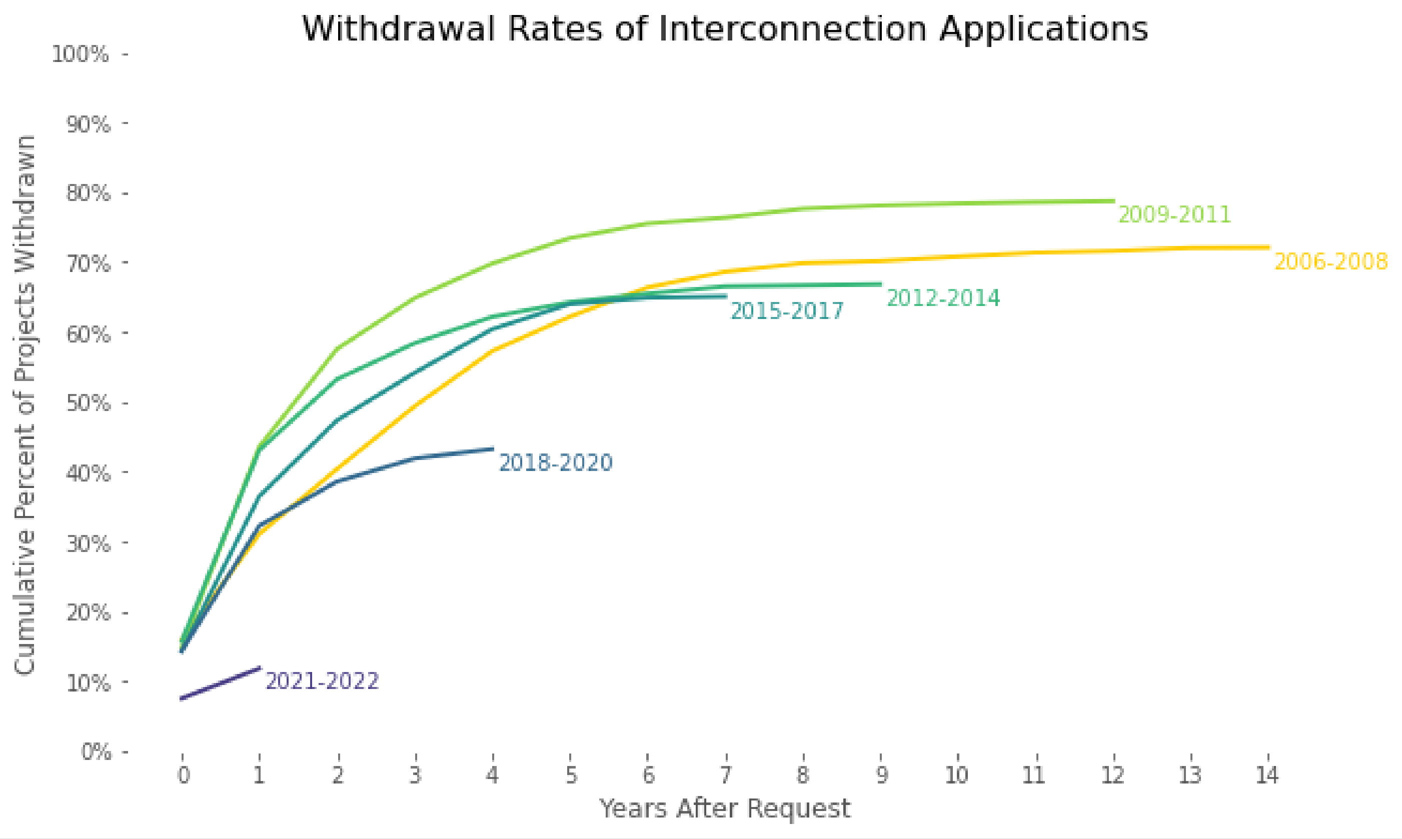
The share of projects requesting interconnection from 2000-2017 that have reached COD is relatively low across regions: Only ISO-NE and ERCOT exceed 30% completion



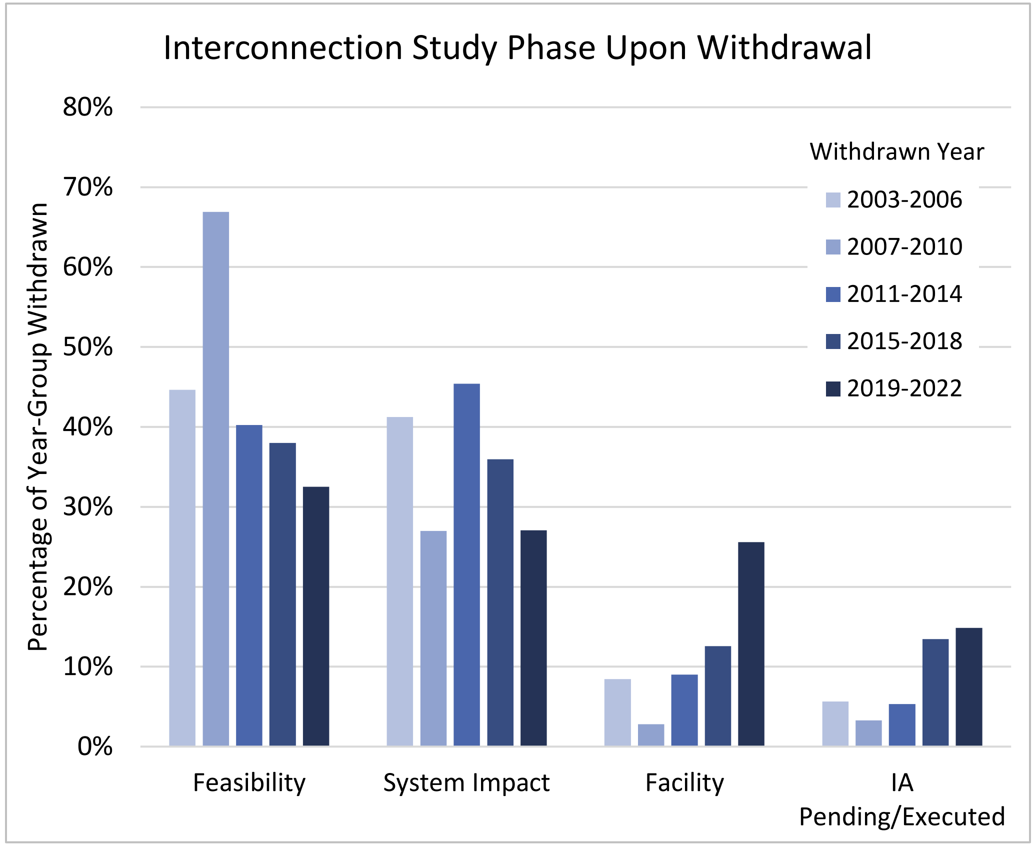
- Capacity-weighted completion rates are even lower; shown in brackets [%]
  - ERCOT is the only region with >20% of capacity reaching commercial operation date (COD)
- For interconnection requests from 2000-2017, ISO-NE (37%) and ERCOT (31%) had the highest project completion percentages, with CAISO (13%) and NYISO (15%), and the Southeast (15%) 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 2000-2017. (3) Includes data from 7 ISOs and 26 utilities.

More recently proposed projects are taking longer to make the decision to withdraw as study durations lengthen; later-stage withdrawals are becoming more common



Final outcome (i.e., withdrawn or operational) for many projects entering the queues in recent years may not yet be determined (i.e., they are still "active"); cumulative percent withdrawn will increase over time.



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.

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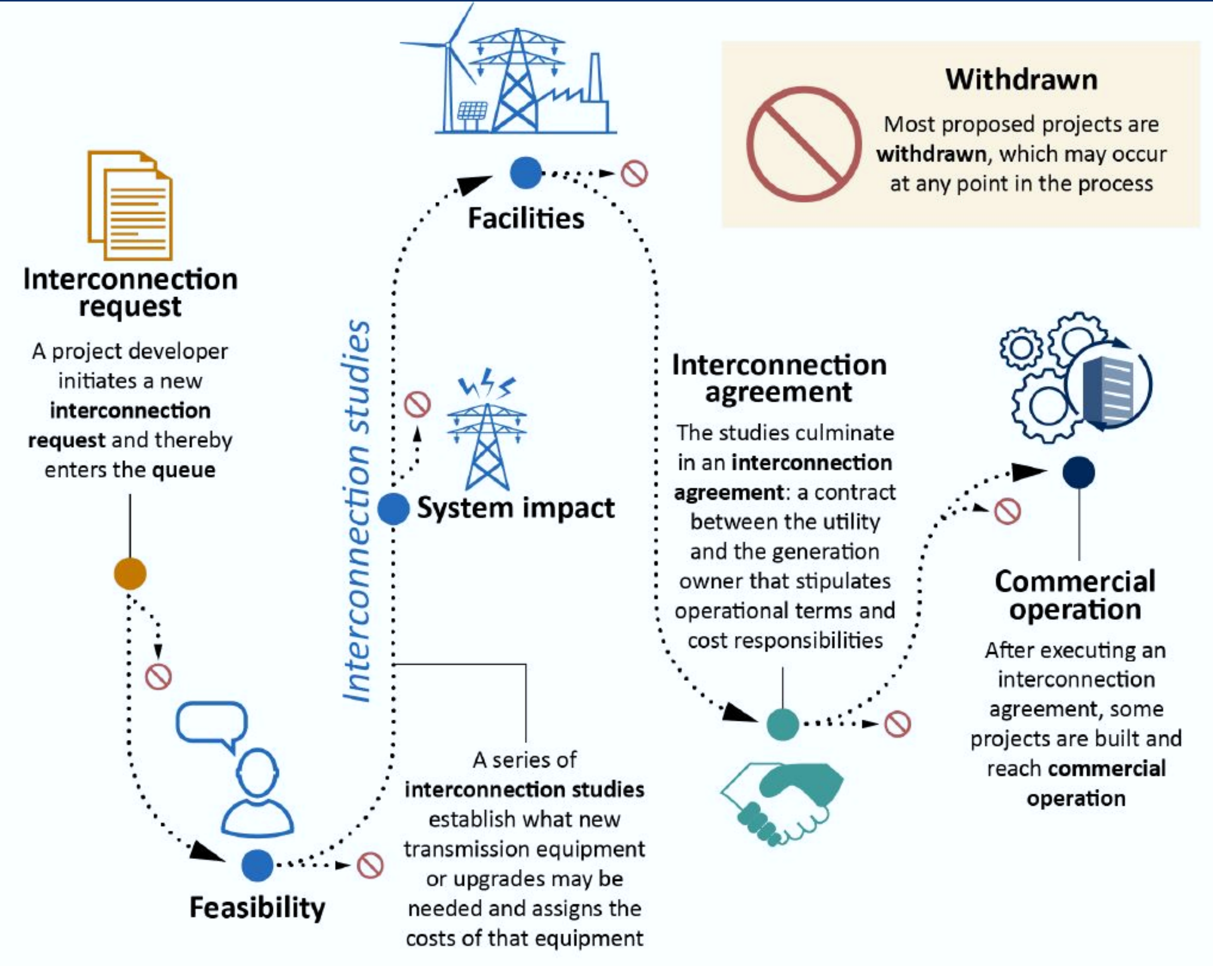
Notes: (1) Withdrawal rate calculation shown here only includes entities and years with "complete" data on withdrawn dates – i.e., withdrawn date is populated for >90% of withdrawn projects for each entity by year included. (2) Study phase only available for 56% of all withdrawn projects

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)
- Duration from IR to proposed online date

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

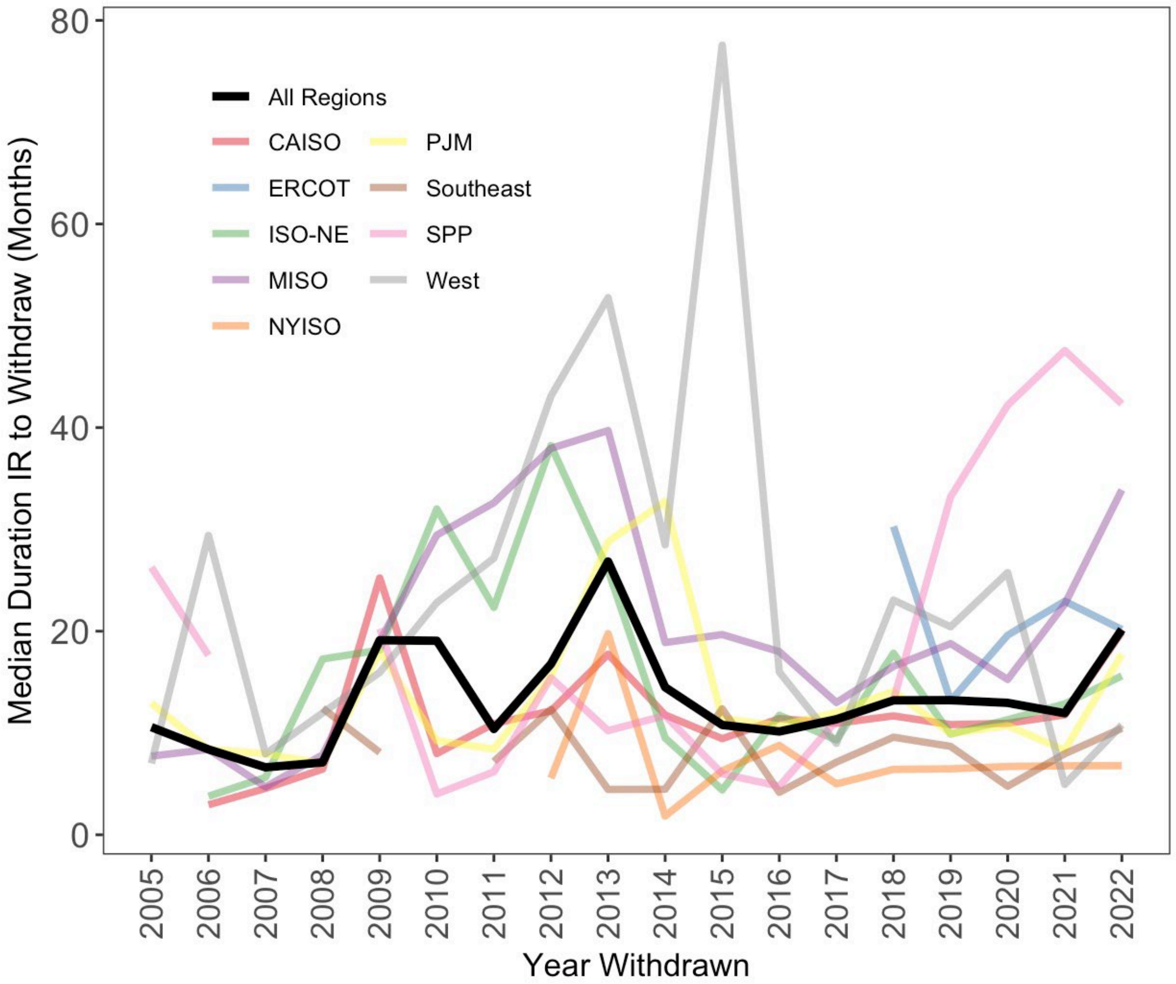


Source: Derived from image courtesy of Lawrence Berkeley National Laboratory and used with permission. | GAO-23-105583

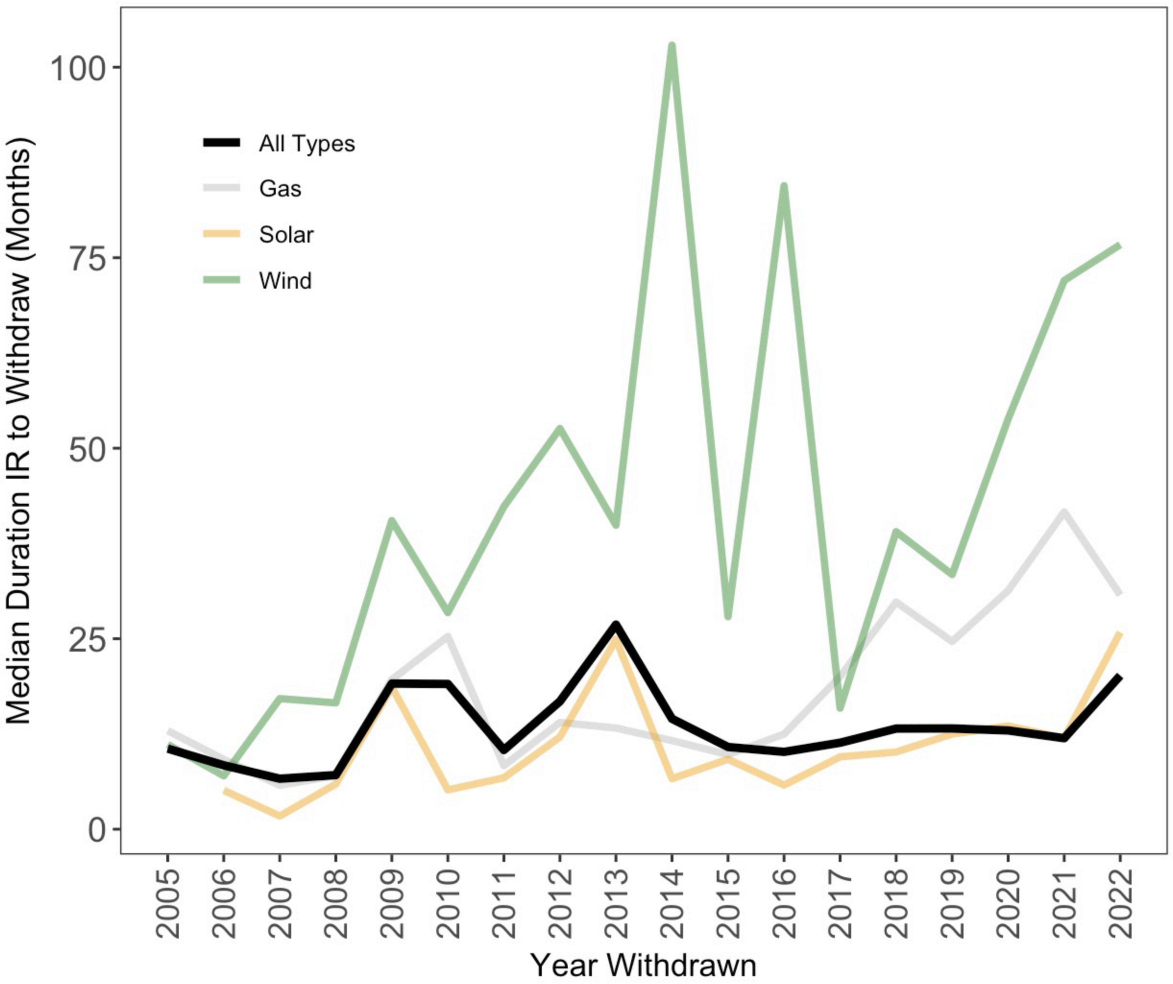
The median duration from request to withdrawn date ticked up in 2022; wind projects typically spend more time in queues than gas or solar prior to withdrawing

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

Median Duration from Interconnection Request to Withdrawn Date, by Region

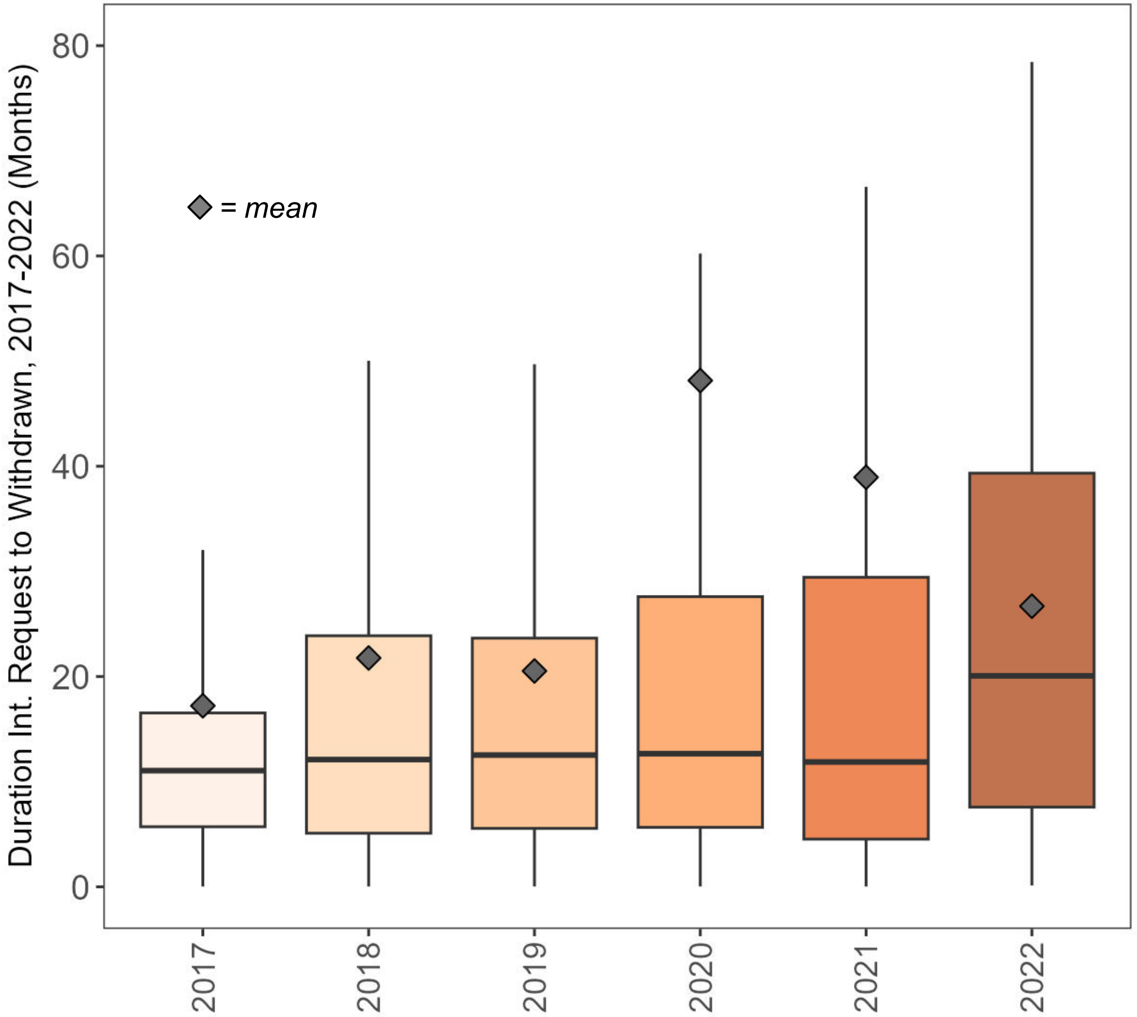


Median Duration from Interconnection Request to Withdrawn Date, by Generator Type



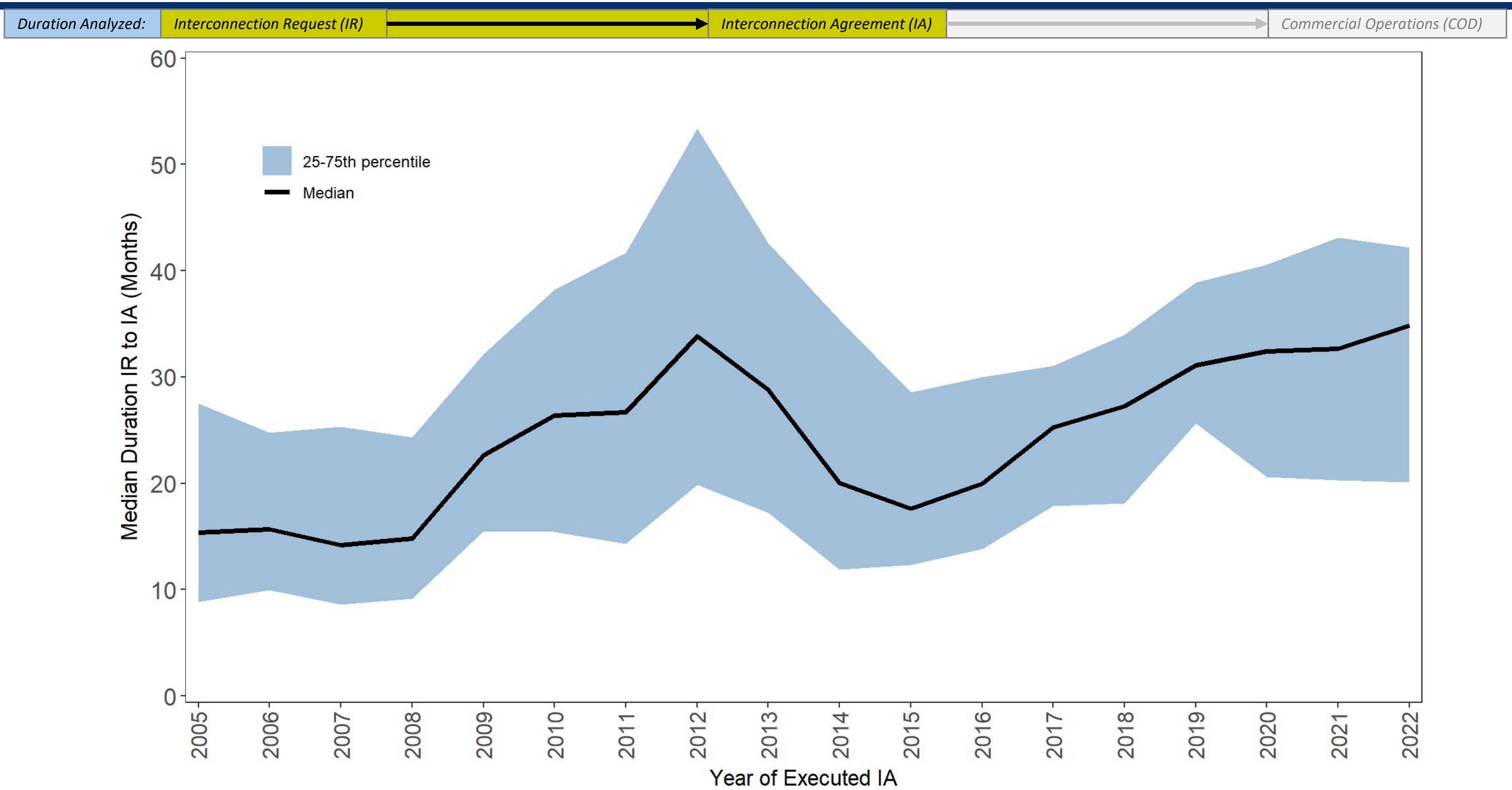
Notes: (1) Withdrawn date was available for 6,323 projects from 5 ISOs and 6 utilities. (2) Duration is calculated as the number of months from the queue entry date to the date the project was withdrawn from queues.

Although median withdrawal duration has been relatively consistent over time, the *mean* withdrawal duration and distributions have edged higher in recent years



- This trend implies that some recently-withdrawn projects are waiting longer in the queues before making the determination to withdraw
- This corroborates the findings on cumulative withdrawal rates and late-stage withdrawals illustrated on Slide 22
- 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

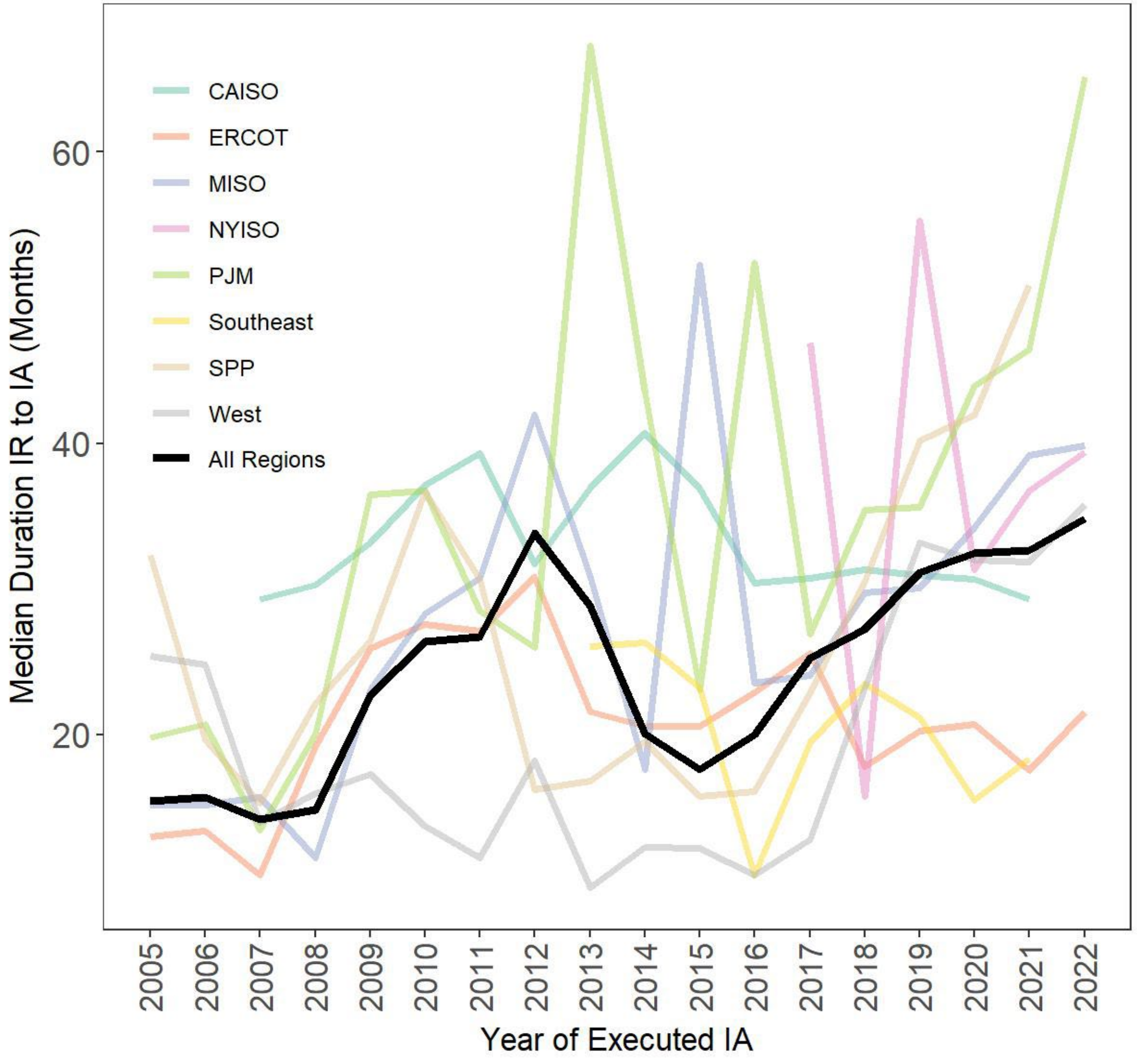
After falling from a 2012 peak, the typical duration from interconnection request (IR) to interconnection agreement (IA) increased sharply since 2015, reaching 35 months in 2022

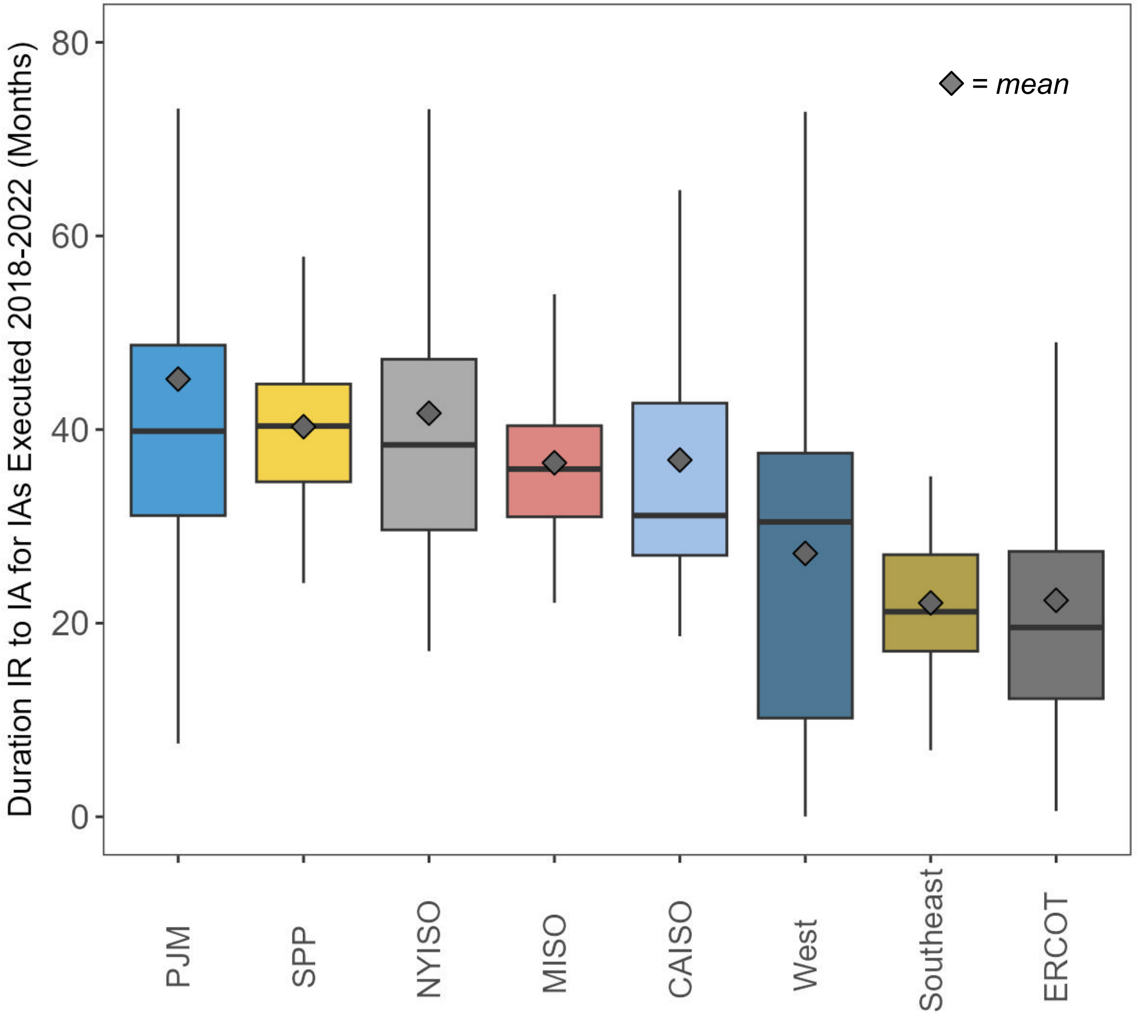


Notes: (1) Sample includes 3,348 projects from 6 ISO/RTOs and 5 non-ISO utilities with executed interconnection agreements since 2005. (2) Not all data used in this analysis are publicly available.

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)*

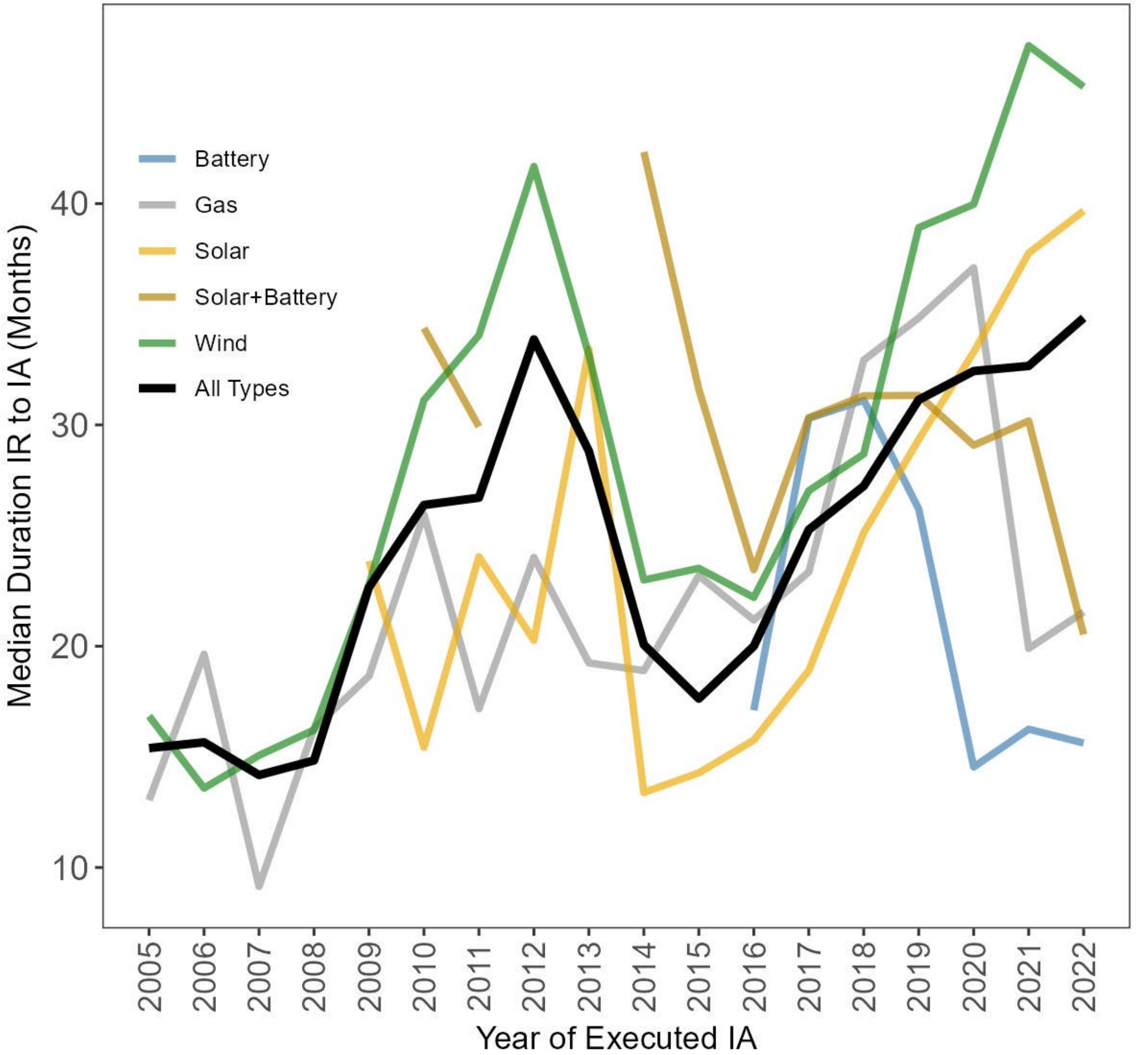


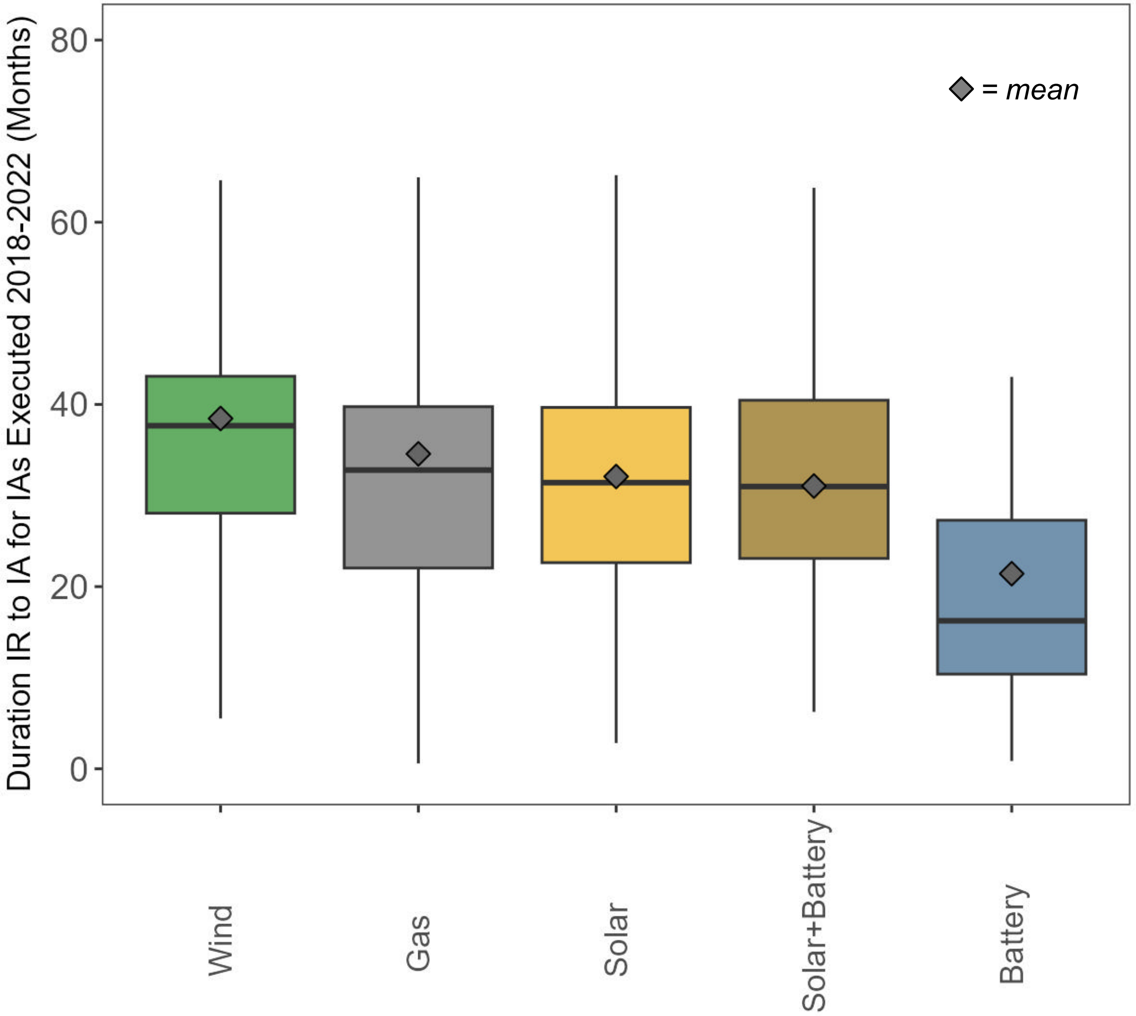


Notes: (1) Data are only shown where sample size is >2 for each region and year. (2) Not all data used in this analysis are publicly available.
(3) "West" includes PacifiCorp, Public Service Co. of New Mexico, Idaho Power; "Southeast" includes Southern Company, Seminole Electric Cooperative.

Wind projects typically face longer interconnection study timelines; recent battery projects are processed much more quickly

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





Notes: (1) Data are only shown where sample size is >2 for each type and year. (2) Not all data used in this analysis are publicly available.

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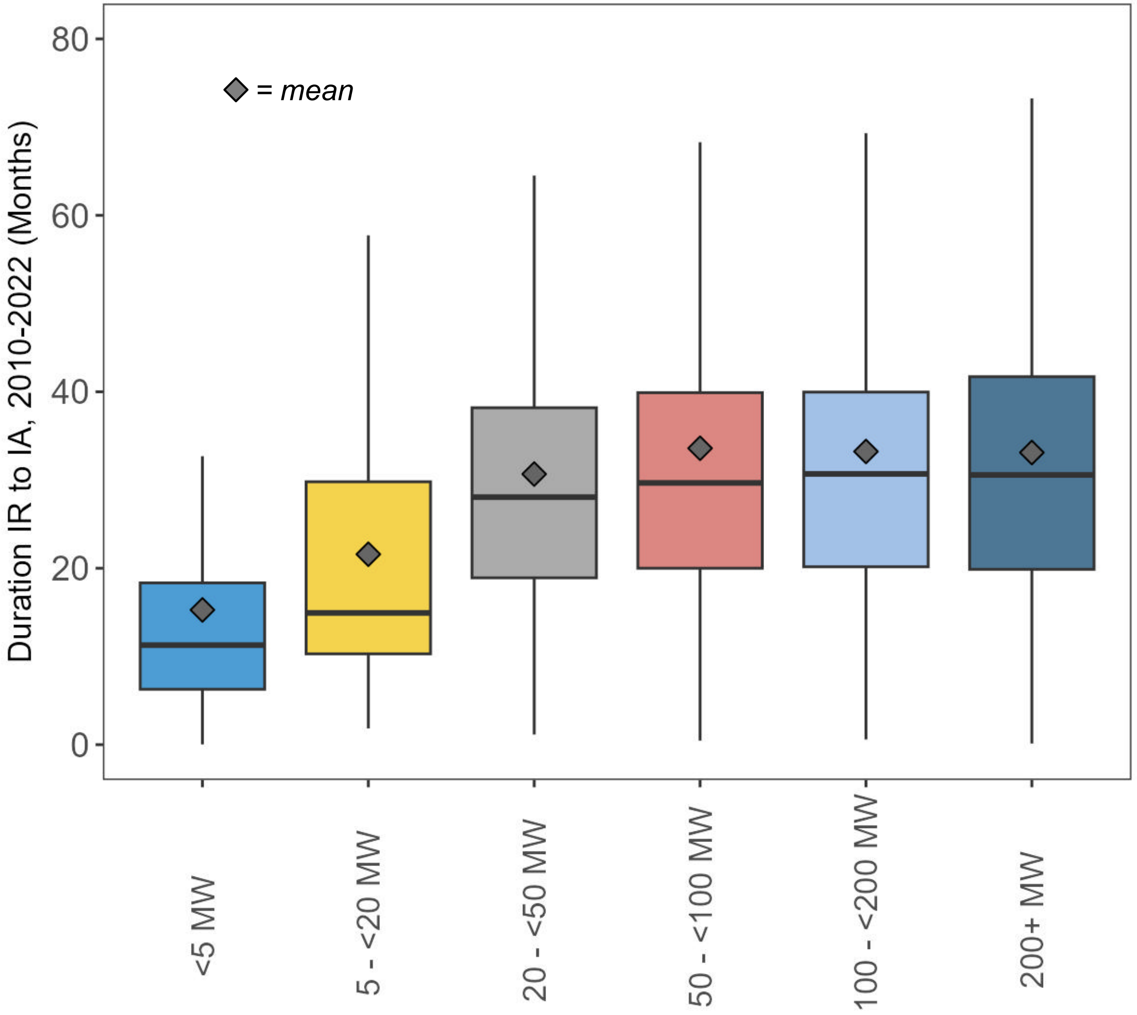
There is a clear step change in IR to IA duration between “small” (<20 MW) and “large” (>20 MW) generator interconnection procedures

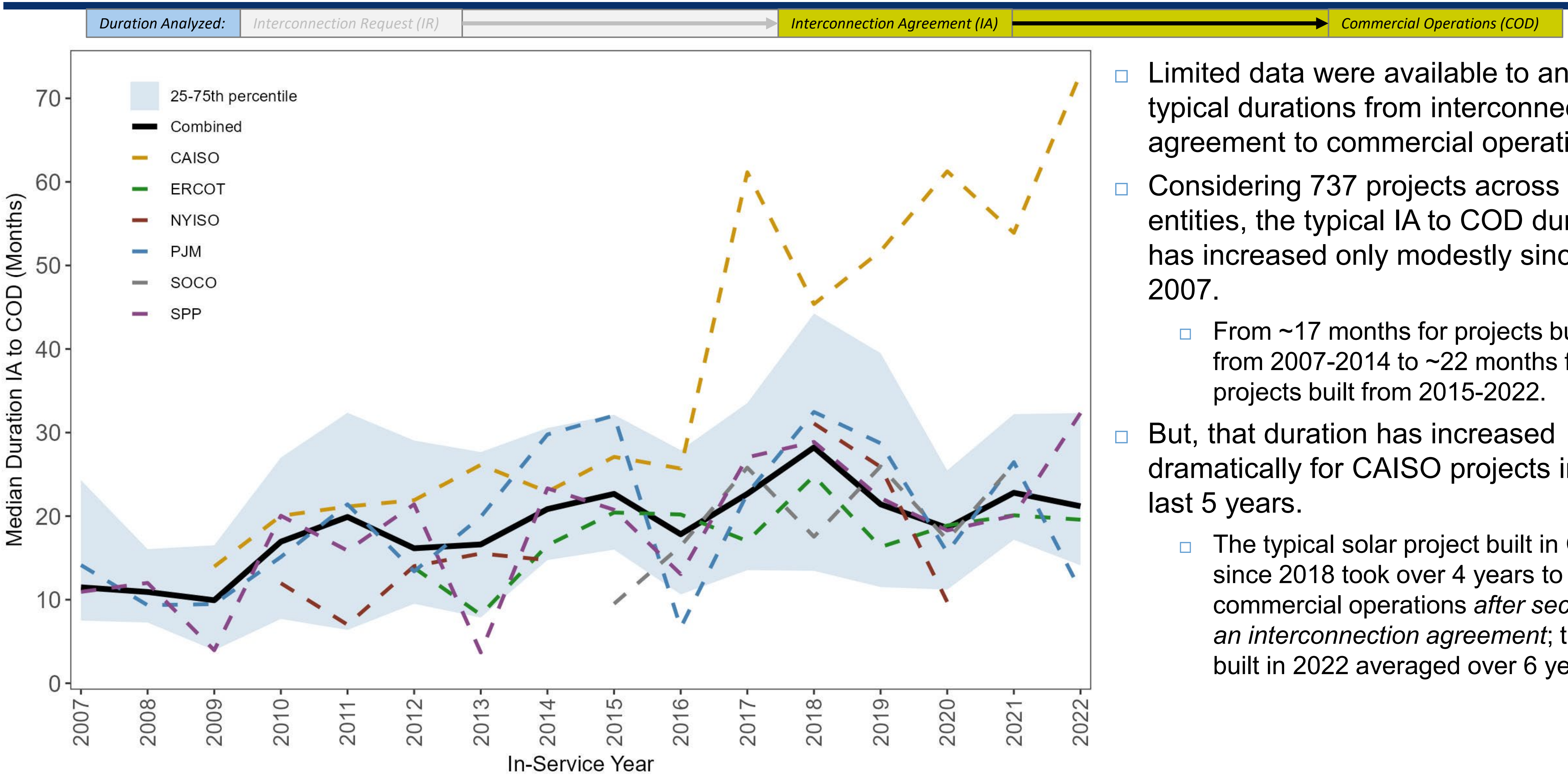
Duration Analyzed: *Interconnection Request (IR)* → *Interconnection Agreement (IA)* → *Commercial Operations (COD)*



- 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.

Typical duration from IA to commercial operations date (COD) has increased modestly since 2007, except in CAISO where recently built solar projects took 4-6 years *after* securing an IA



- Limited data were available to analyze typical durations from interconnection agreement to commercial operations
- Considering 737 projects across 6 entities, the typical IA to COD duration has increased only modestly since 2007.
  - From ~17 months for projects built from 2007-2014 to ~22 months for projects built from 2015-2022.
- 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.

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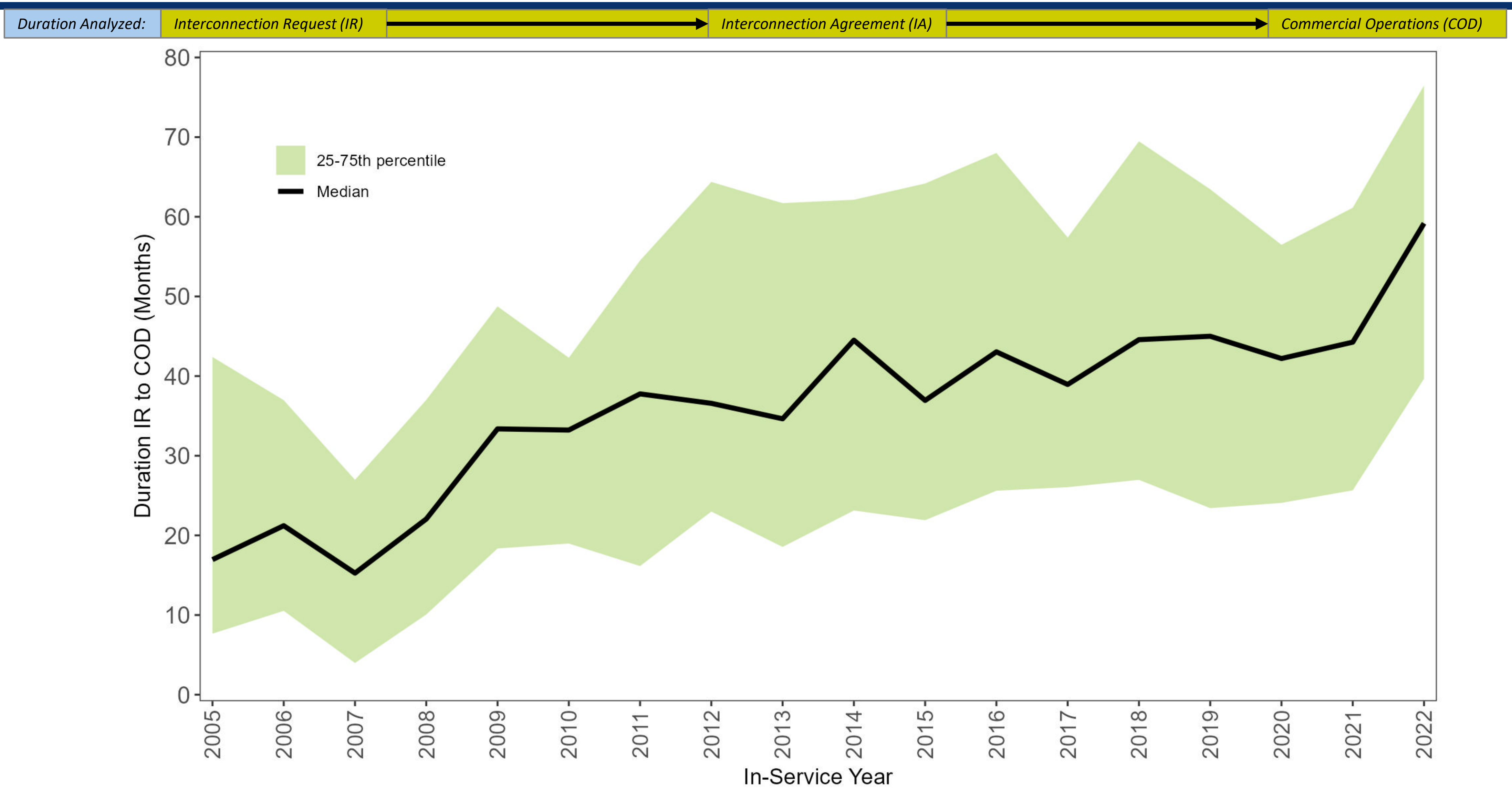
Notes: (1) Data were only available for 737 projects across 5 ISO/RTOs and one utility (Southern Company), out of 3,846 total "operational" projects in the full dataset. (2) Not all data used in this analysis are publicly available.

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

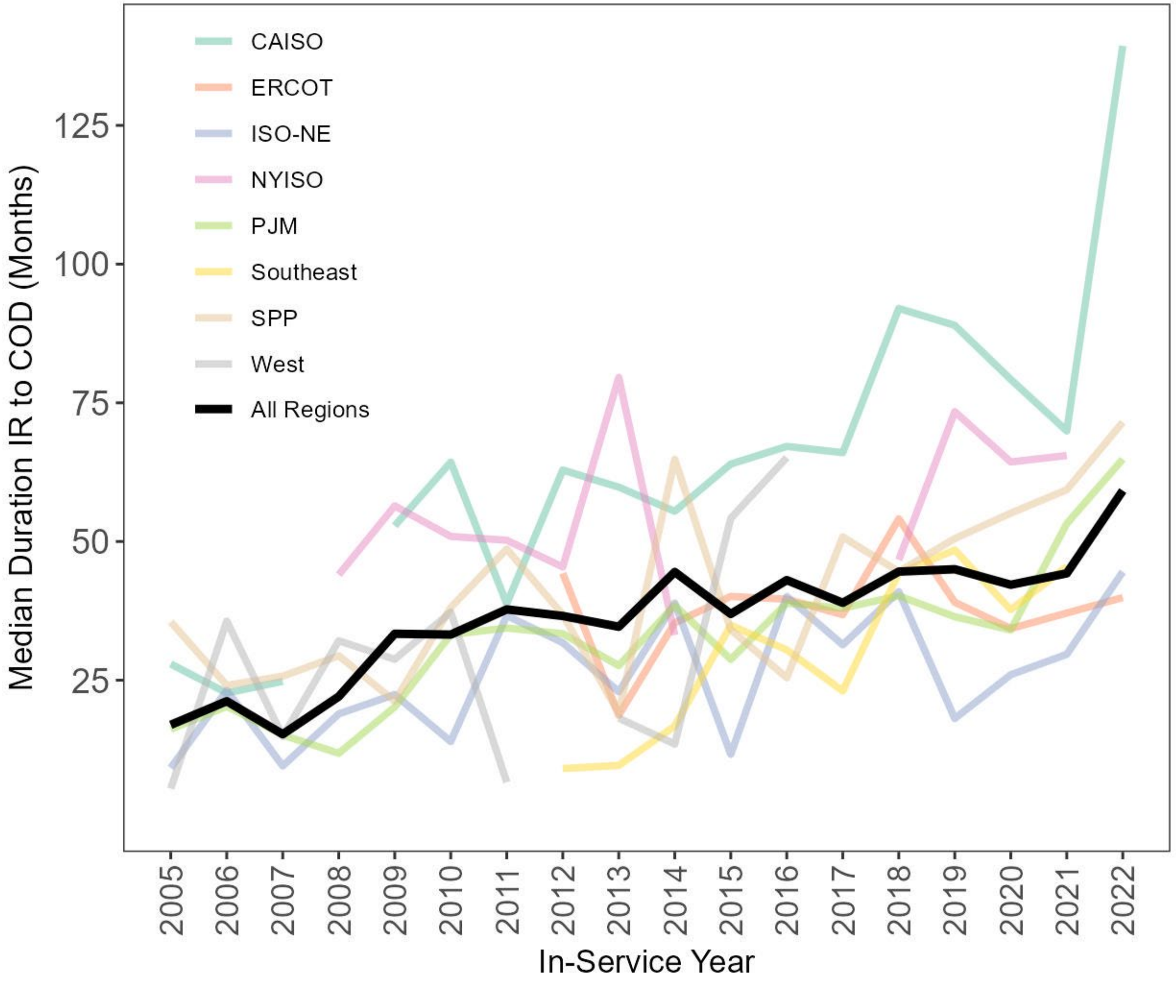


Notes: (1) In-service date was only available for 6 ISOs (CAISO, ERCOT, ISO-NE, NYISO, PJM, SPP) and 5 utilities (Duke, LADWP, PSCo, SOCO, WAPA) representing 58% of all operational projects. (2) Duration is calculated as the number of months from the queue entry date to the in-service date.

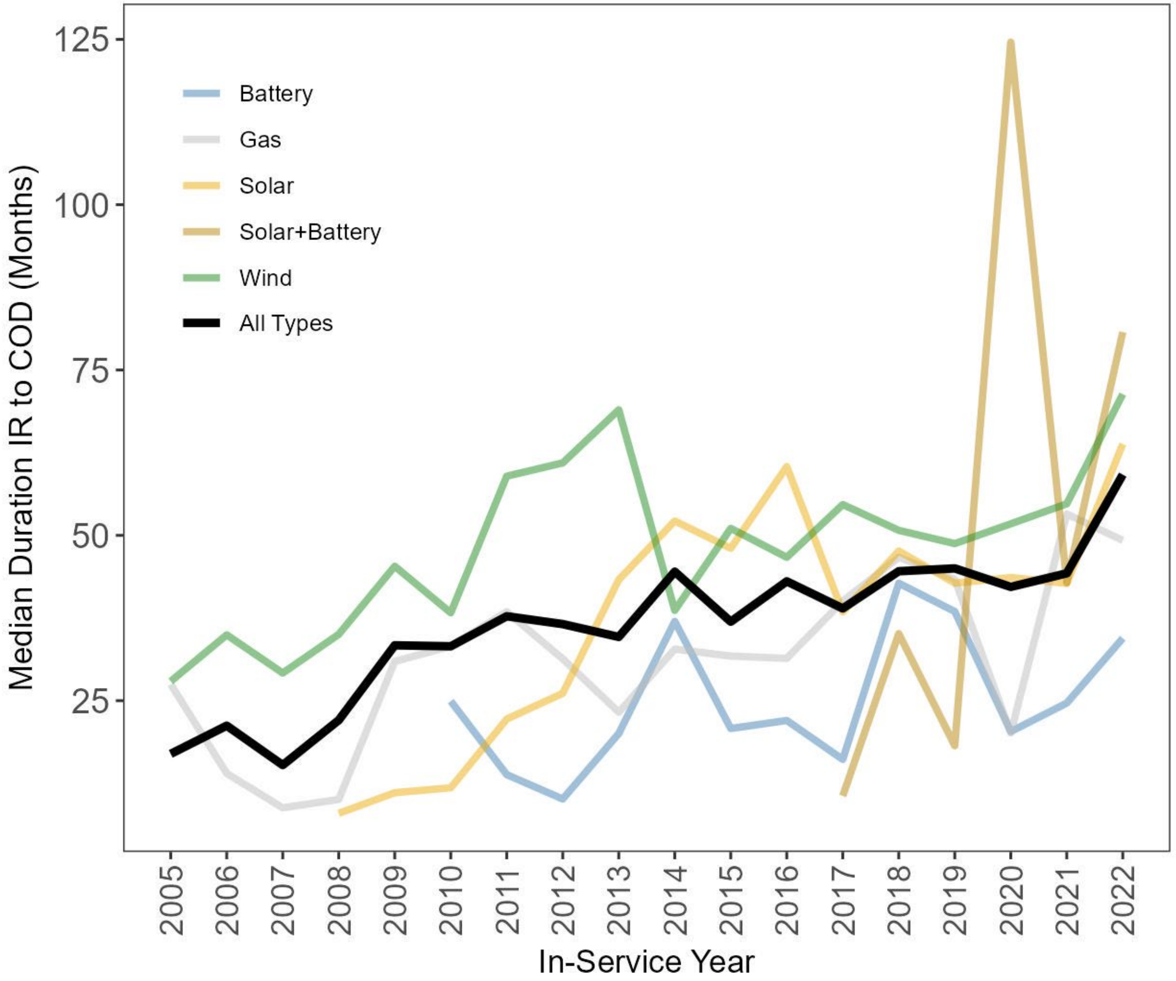
IR to COD timelines are longest in CAISO, NYISO, and SPP; solar and wind projects typically take longer than other types, with standalone battery projects moving fastest to completion

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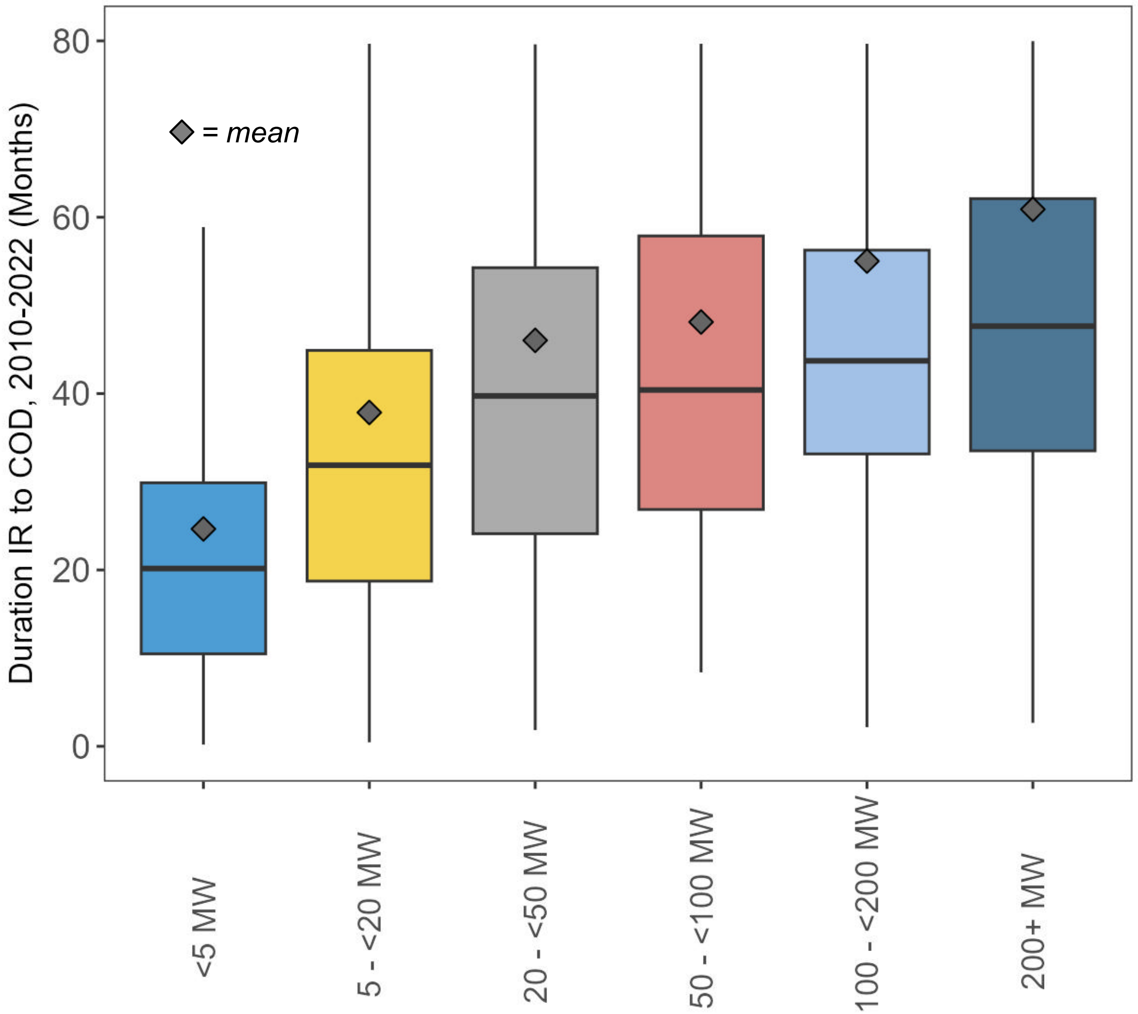
Larger projects have longer development timelines: Typical IR to COD duration increases monotonically by project size (MW)

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.

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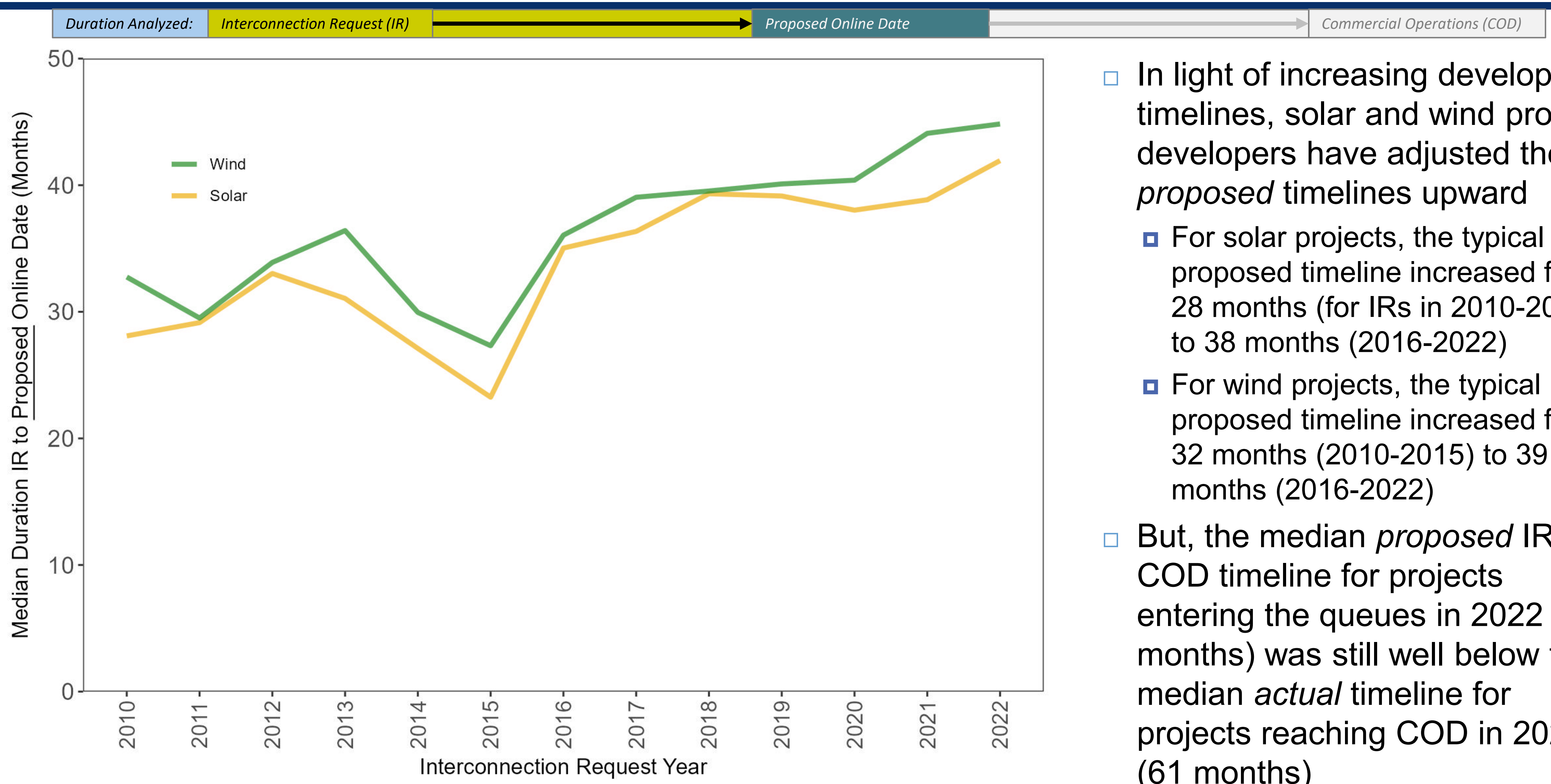
Solar and wind developers' proposed timelines (from IR to *proposed* online date) have trended upward since 2010, accounting for lengthening development times



- In light of increasing development timelines, solar and wind project developers have adjusted their *proposed* timelines upward
  - For solar projects, the typical proposed timeline increased from 28 months (for IRs in 2010-2015) to 38 months (2016-2022)
  - For wind projects, the typical proposed timeline increased from 32 months (2010-2015) to 39 months (2016-2022)
- But, the median *proposed* IR to COD timeline for projects entering the queues in 2022 (42 months) was still well below the median *actual* timeline for projects reaching COD in 2022 (61 months)

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Conclusions

As of the end of 2022, there were over 10,200 projects seeking grid interconnection across the U.S., representing over 1,350 GW of generation and an estimated 680 GW of storage.

- Solar (947 GW) accounts for >70% of all active generator capacity in the queues, though substantial wind (300 GW) and gas (82 GW) capacity is also in development. 113 GW of offshore wind is currently active in the queues.
- Considerable standalone (325 GW) and hybrid (~358 GW[1]) storage capacity has also requested interconnection.
- The combined capacity of solar and wind now active in the queues (~1,250 GW) approximately equals 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 proposed solar, storage, and gas, and 7% of proposed wind; New York has 23% of all proposed wind (mostly offshore); California has 14% of proposed storage.
- Hybrids now comprise a large – and increasing – share of proposed projects, particularly in CAISO and the West. 457 GW of solar hybrids (primarily solar+battery) and 24 GW of wind hybrids are in the queues.
- The majority (62%) of capacity in the queues is proposed to come online before 2025, and some (13%) 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 nearly 4 years for those built in 2018-2022.
  - The typical full interconnection study duration (from IR to IA) has also increased sharply, exceeding 3 years in many regions.
  - 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 ~21% of projects (and only 14% of capacity) requesting interconnection from 2000-2017 have reached commercial operations. As well, late-stage withdrawals may be on the rise.

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 five utilities.

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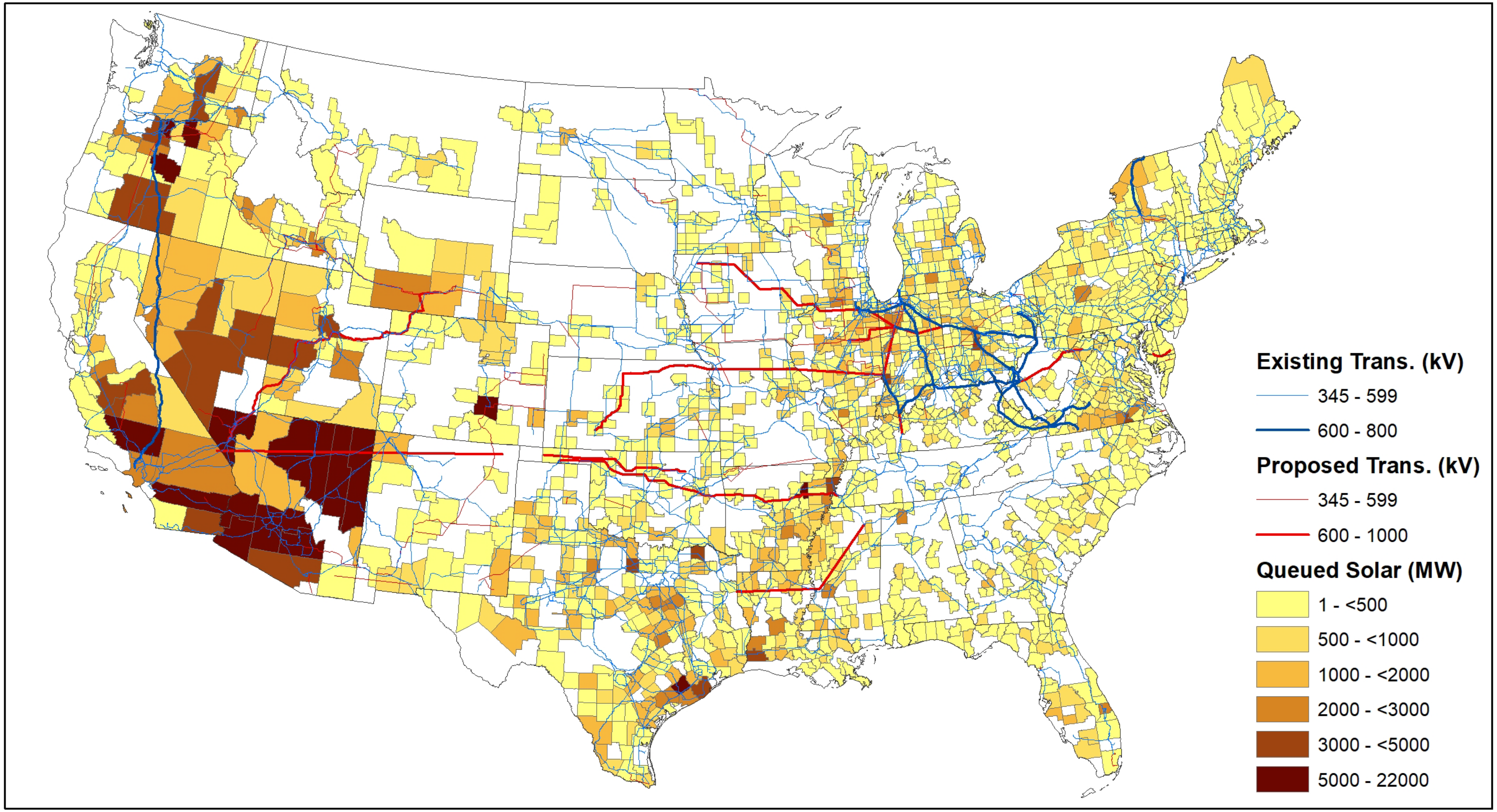
More Information:

- 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 generator 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 Ammar Qusaibaty, Michele Boyd, Juan Botero, Cynthia Bothwell, Jian Fu, Patrick Gilman, Gage Reber, and Paul Spitsen for supporting this project.

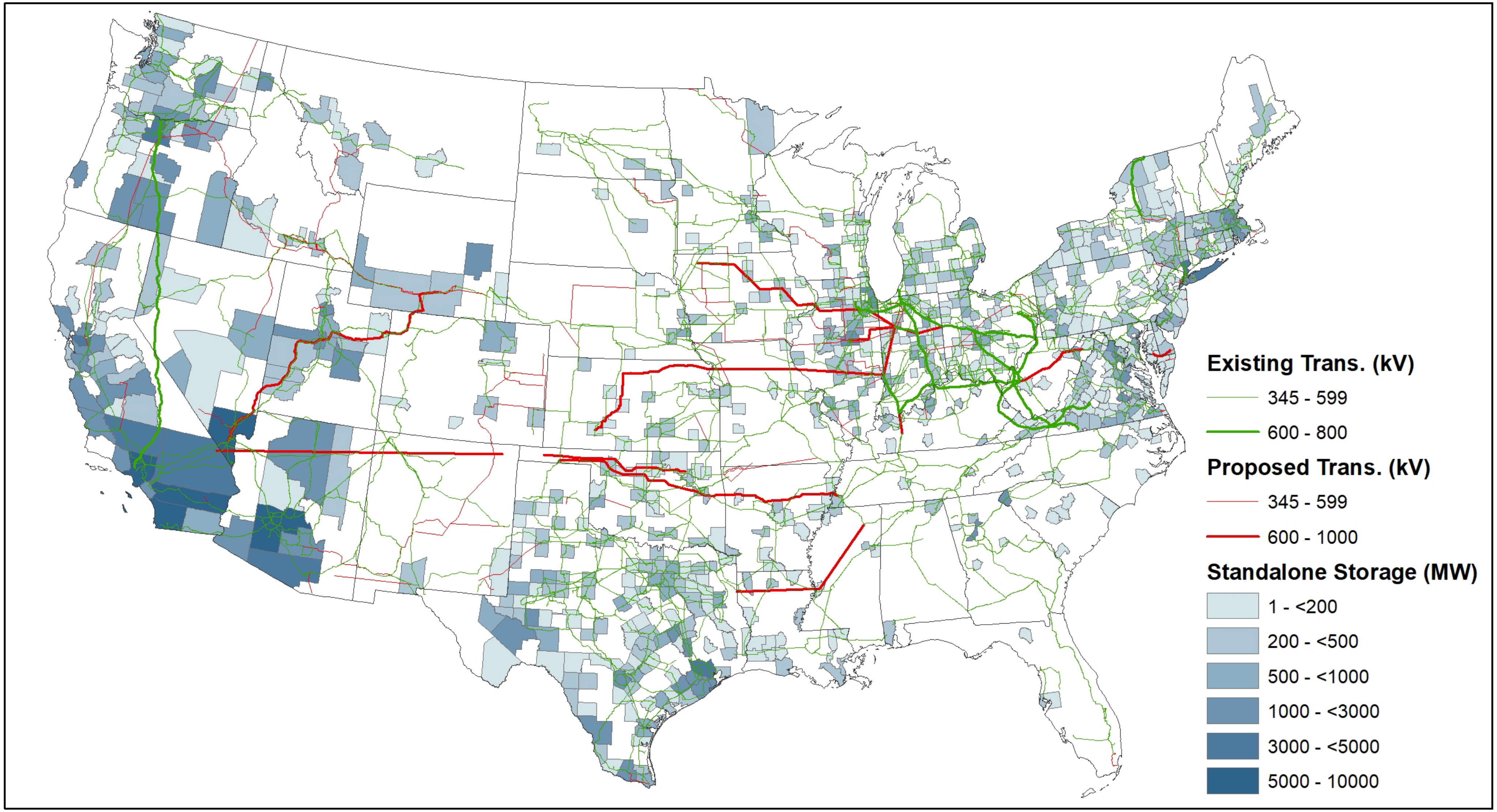
Appendix

Active solar capacity in queues: by county



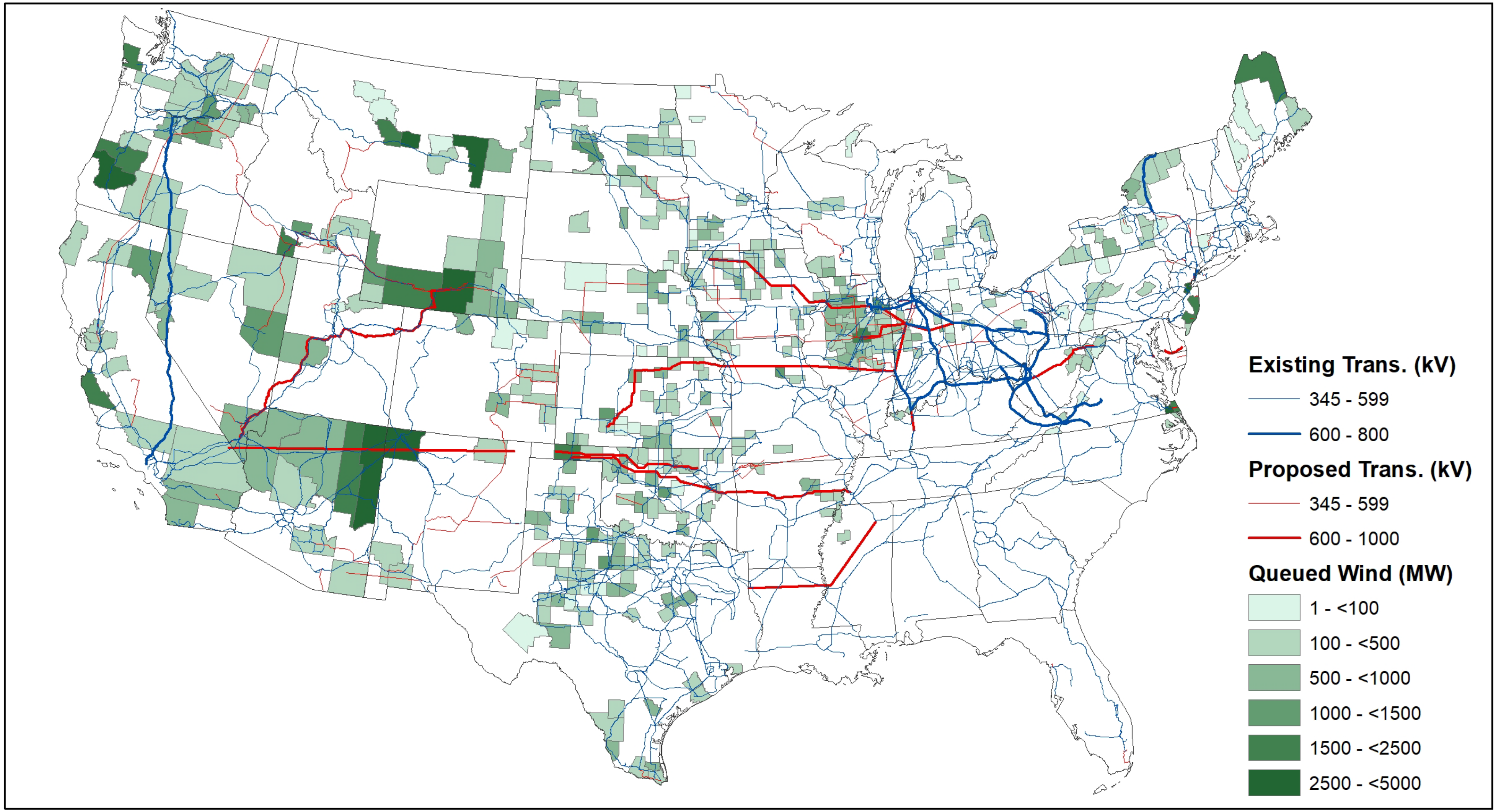
Notes: (1) Includes "active" interconnection requests only. (2) County was missing or could not be determined for 4.6% of active solar requests. (3) Transmission line data from Hitachi Velocity Suite. (4) See https://emp.lbl.gov/queues to access an interactive data visualization of these maps

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 3.4% 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



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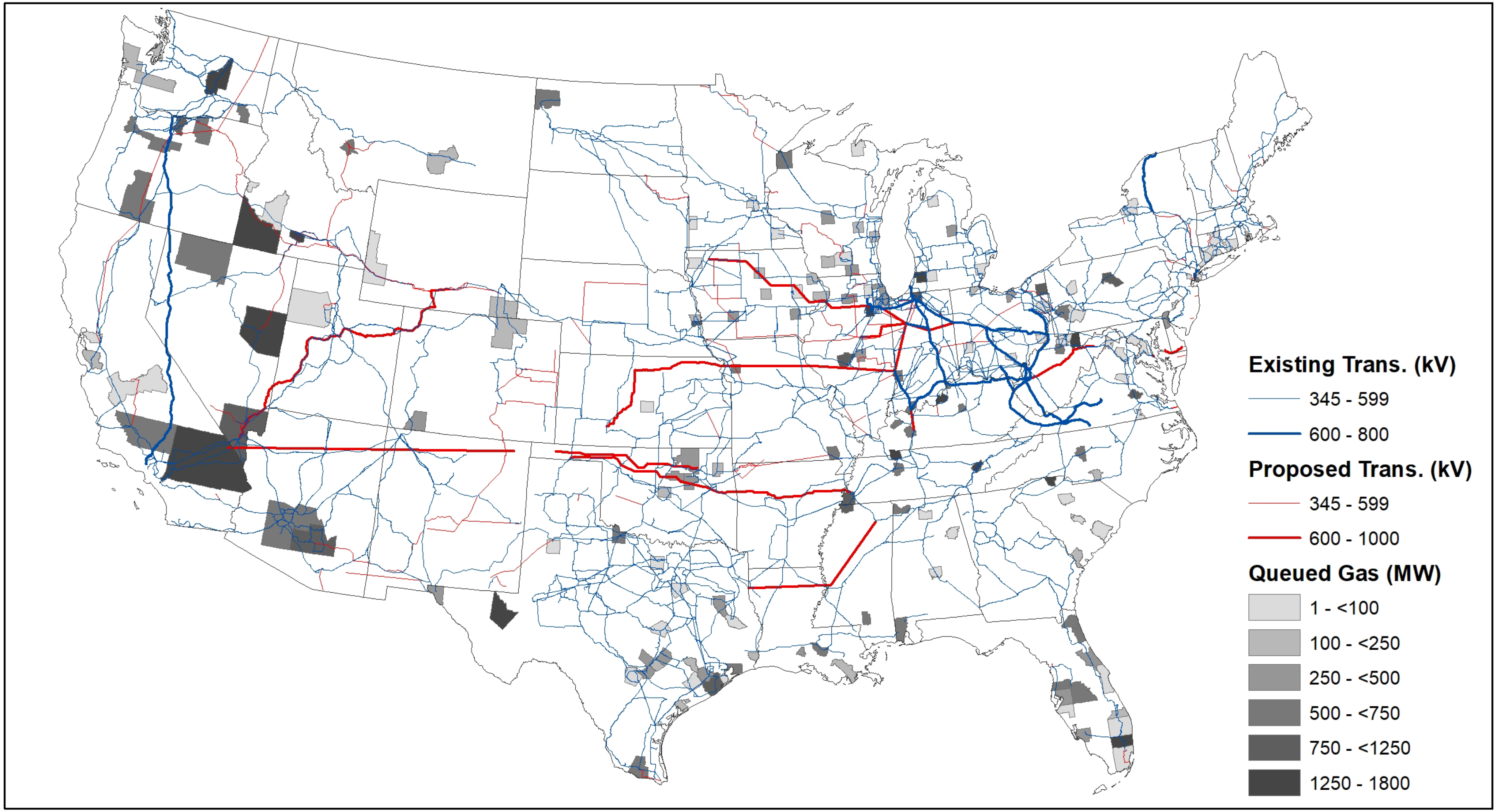
Notes: (1) Includes "active" interconnection requests only. (2) County was missing or could not be determined for 5.5% of land-based wind requests, and 14.6% of offshore wind requests. (3) Transmission line data from Hitachi Velocity Suite. (4) See https://emp.lbl.gov/queues to access an interactive 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 6.1% 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

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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