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Queued Up:

Characteristics of Power Plants Seeking Transmission Interconnection As of the End of 2020

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Photo source: National Renewable Energy Laboratory

Contents

What are interconnection queues?

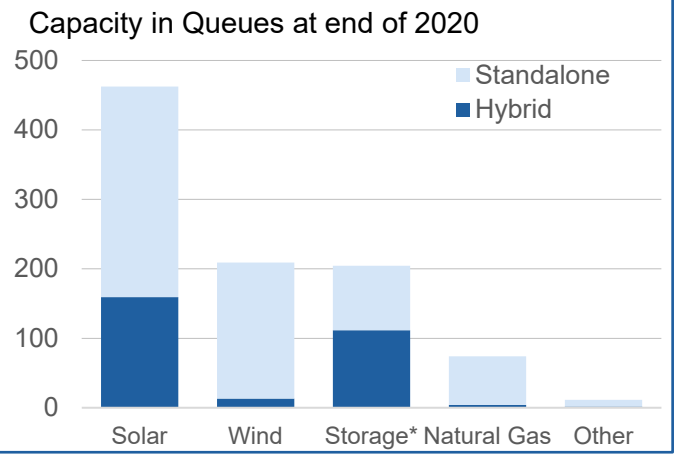
Utilities and regional grid operators (a.k.a., ISOs or RTOs) require projects seeking to connect to the grid to undergo a system impact study before they can be built. This process establishes what new transmission equipment or upgrades may be needed before a project can connect to the system and assigns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

Visit https://emp.lbl.gov/publications/queued-characteristics-power-plants to download the data used for this analysis and to access an interactive data visualization tool

High-Level Findings

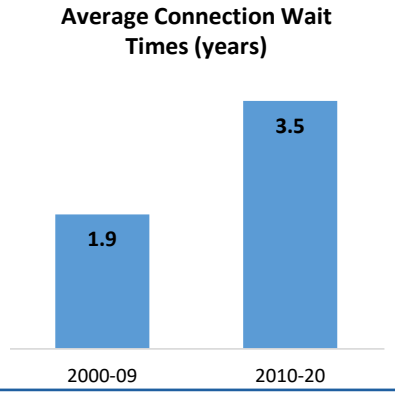
Developer interest in solar, wind, storage, and gas is strong

- Over 755 GW of generator capacity and 200 GW of storage currently seeking interconnection
- Most (~680 GW) proposed generation is zero-carbon
- Hybrids now comprise a large – and increasing – share of proposed projects



Completion rates are generally low; wait times may be increasing

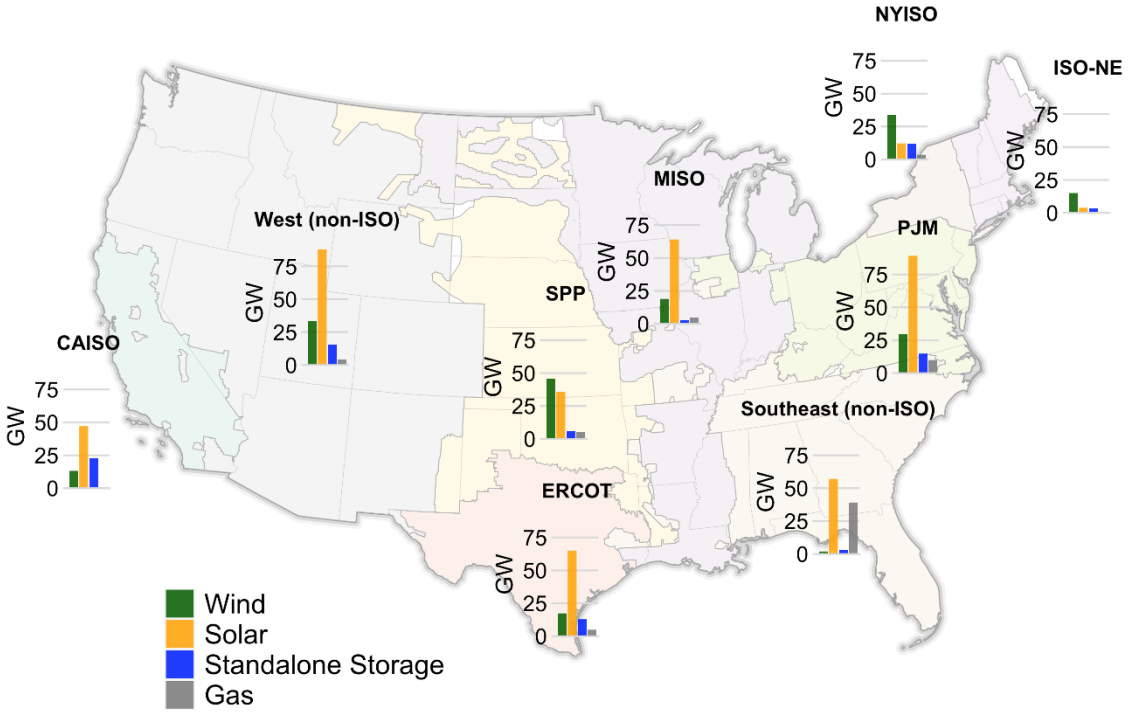
- For five ISOs where data were available, only ~24% of projects in the queues reached commercial operations



- Completion rates are even lower for wind (19%) and solar (16%)
- For four ISOs where data were available, the time projects spent in queues before being built increased from ~1.9 years for projects built in 2000-2009 up to ~3.5 years for those built in 2010-2020.

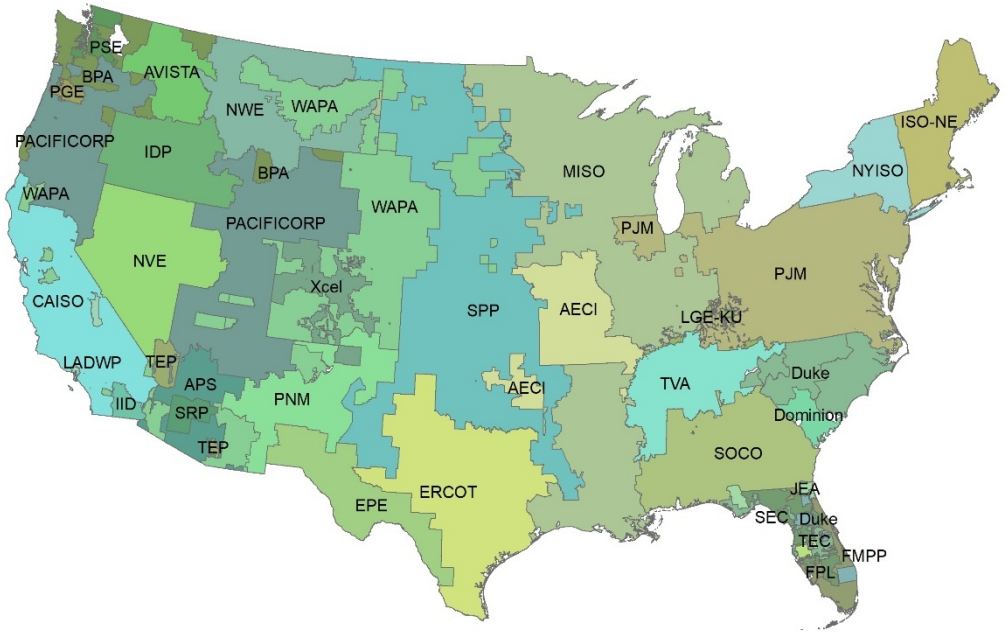
Proposed capacity is widely distributed across the U.S.

- Substantial proposed solar capacity exists in most regions of the U.S.
- Wind capacity is highest in SPP, NYISO, and the non-ISO West, with increasing share of offshore projects
- Proposed gas is primarily in the Southeast and PJM
- Storage is primarily in CAISO and the West



Methods and Data Sources

- Data for “active” projects 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 all projects in queues through the end of 2020
  - Sample includes 5,639 “active” projects
- “Completed” and “Withdrawn” project data were only available for 5 ISOs (CAISO, ISO-NE, MISO, NYISO, PJM)
  - Sample includes 1,706 “completed”, and 6,896 “withdrawn” projects.
- Hybrid / co-located projects were identified and categorized
  - Storage capacity for hybrids (i.e., broken out from generator capacity) was not available in all queues
- Note that being in an interconnection queue *does not guarantee* ultimate construction: majority of plants are not subsequently built



Coverage area of entities for which data was collected
Data source: Homeland Infrastructure Foundation-Level Data (HIFLD)

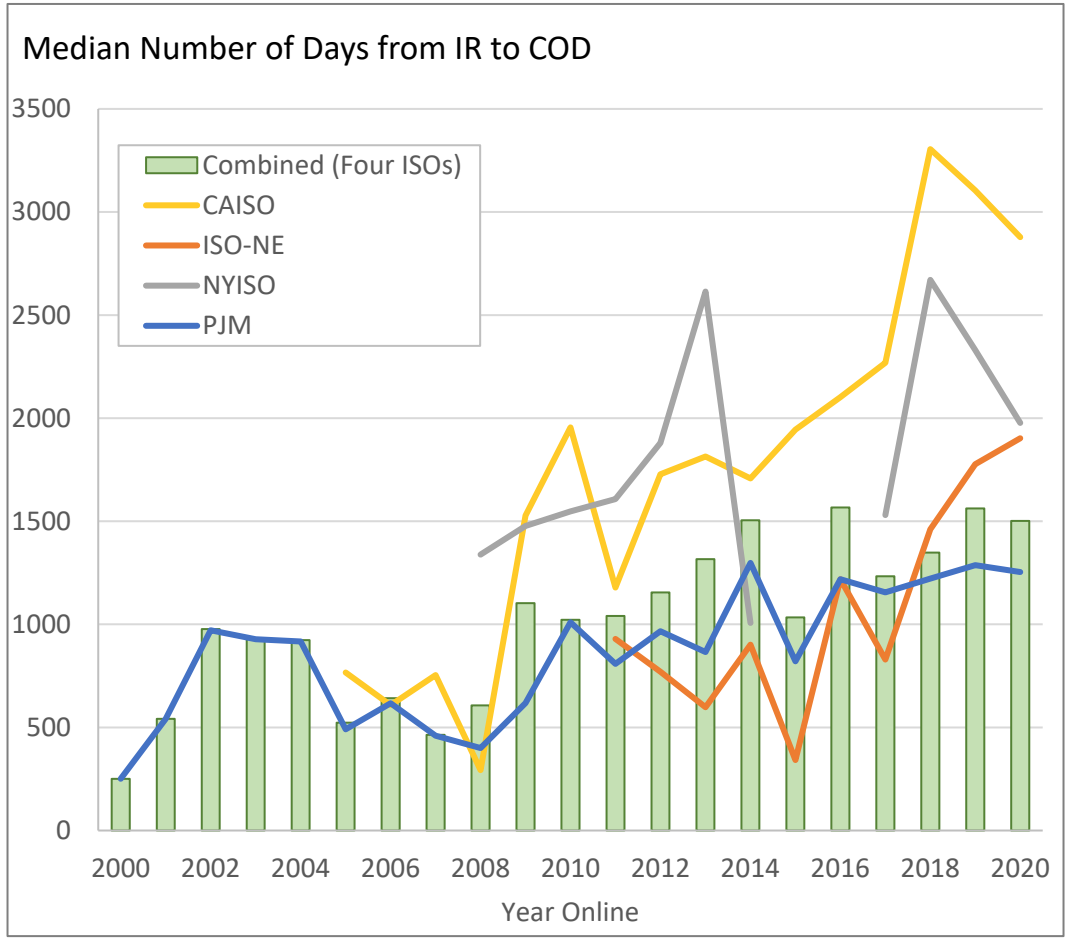
Completed and Withdrawn Projects

Completed and withdrawn data were available from 5 ISOs, and total 1,706 completed projects and 6,896 withdrawn projects.

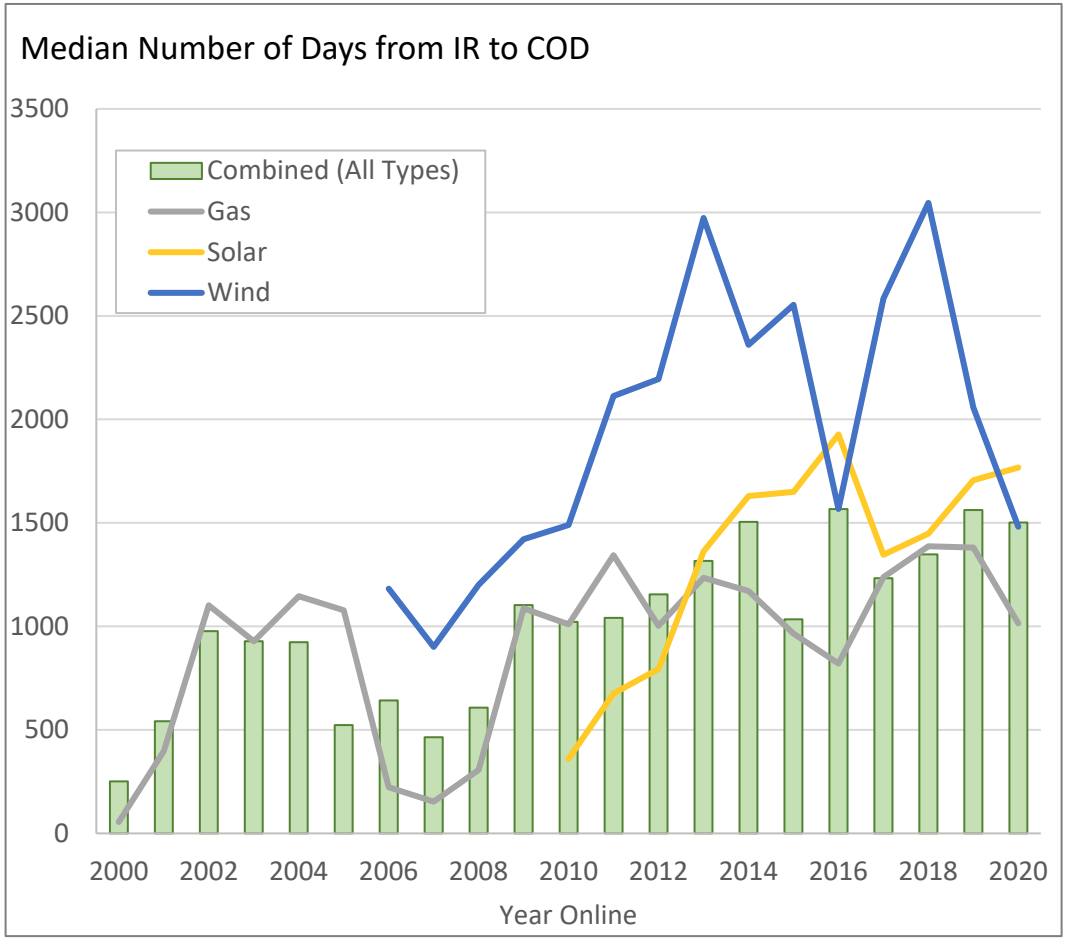
ISO	*n* (Completed)	*n* (Withdrawn)
CAISO	179	1,381
ISO-NE	84	377
MISO	407	1,591
NYISO	86	563
PJM	950	2,984

The time from interconnection request (IR) date to commercial operations date (COD) is increasing for some regions and generator types; typically longer for CAISO and for wind

Completed Projects: Time in Queue, by ISO



Completed Projects: Time in Queue, by Resource

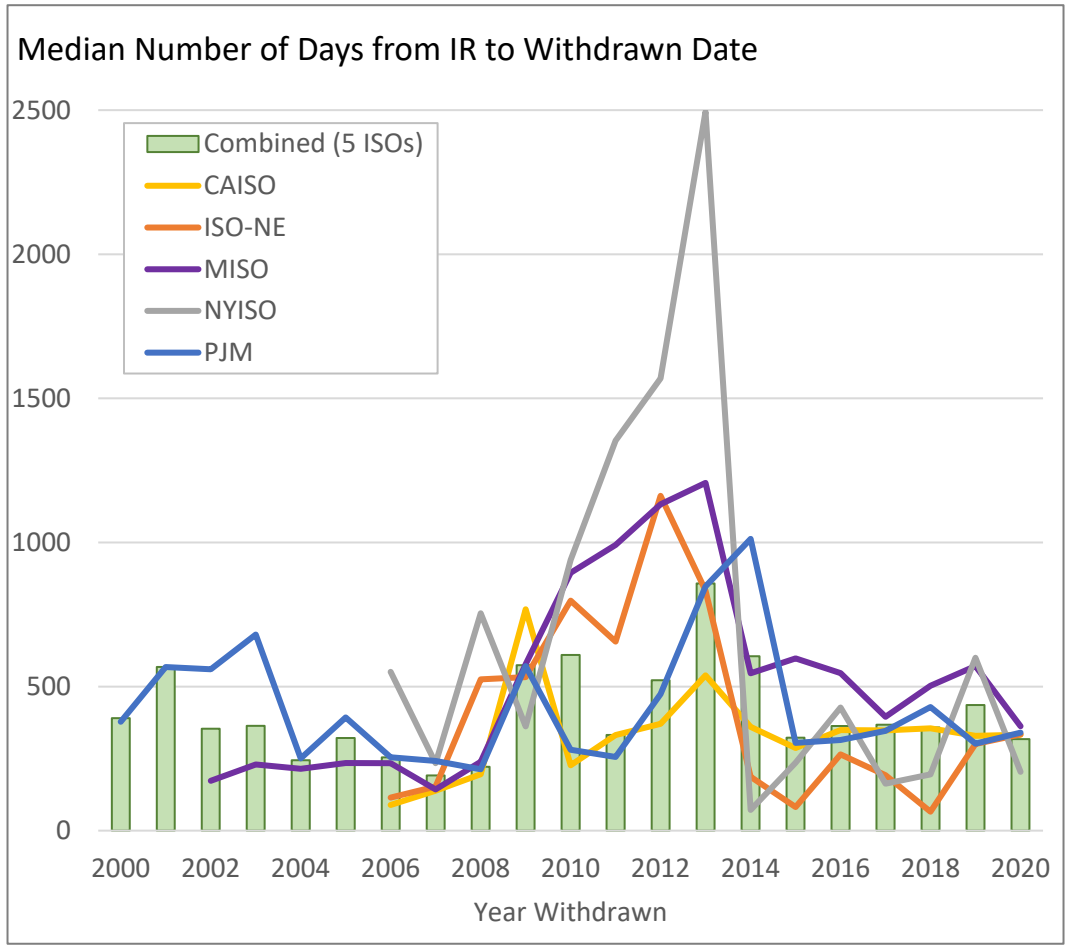


Year	Completed Projects
2000	10
2001	20
2002	27
2003	23
2004	28
2005	25
2006	37
2007	49
2008	69
2009	52
2010	60
2011	81
2012	76
2013	82
2014	72
2015	114
2016	134
2017	82
2018	88
2019	71
2020	73

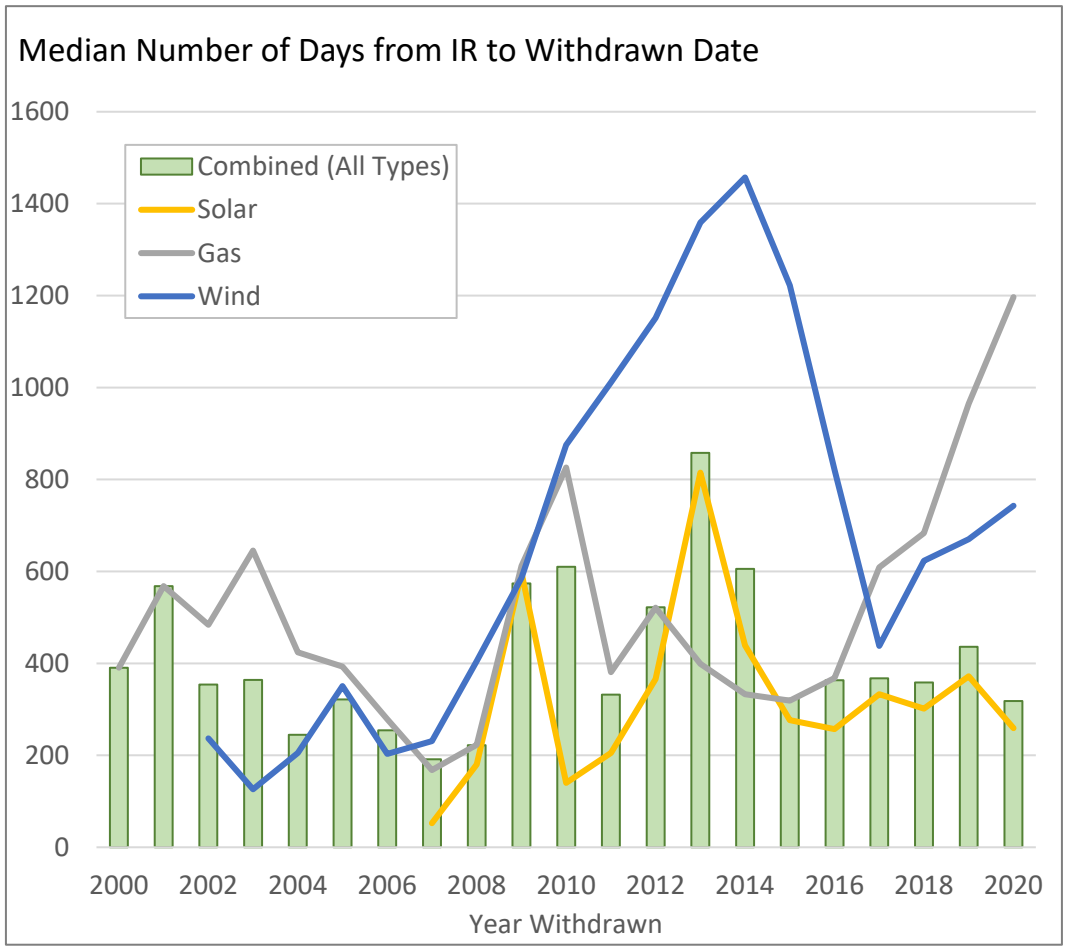
Notes: (1) Data on completed projects were only collected for five ISOs, though only the four shown provided COD. (2) Data are only shown where sample size is >3 for each year. (3) "Time in queues" is calculated as the number of days from the queue entry date to the commercial operations date

Trends are less evident in time from interconnection request to withdrawn date, though a series of queue reforms from 2010-2012[1] *may* have helped reduce backlog

Withdrawn Projects: Time in Queue, by ISO



Withdrawn Projects: Time in Queue, by Resource



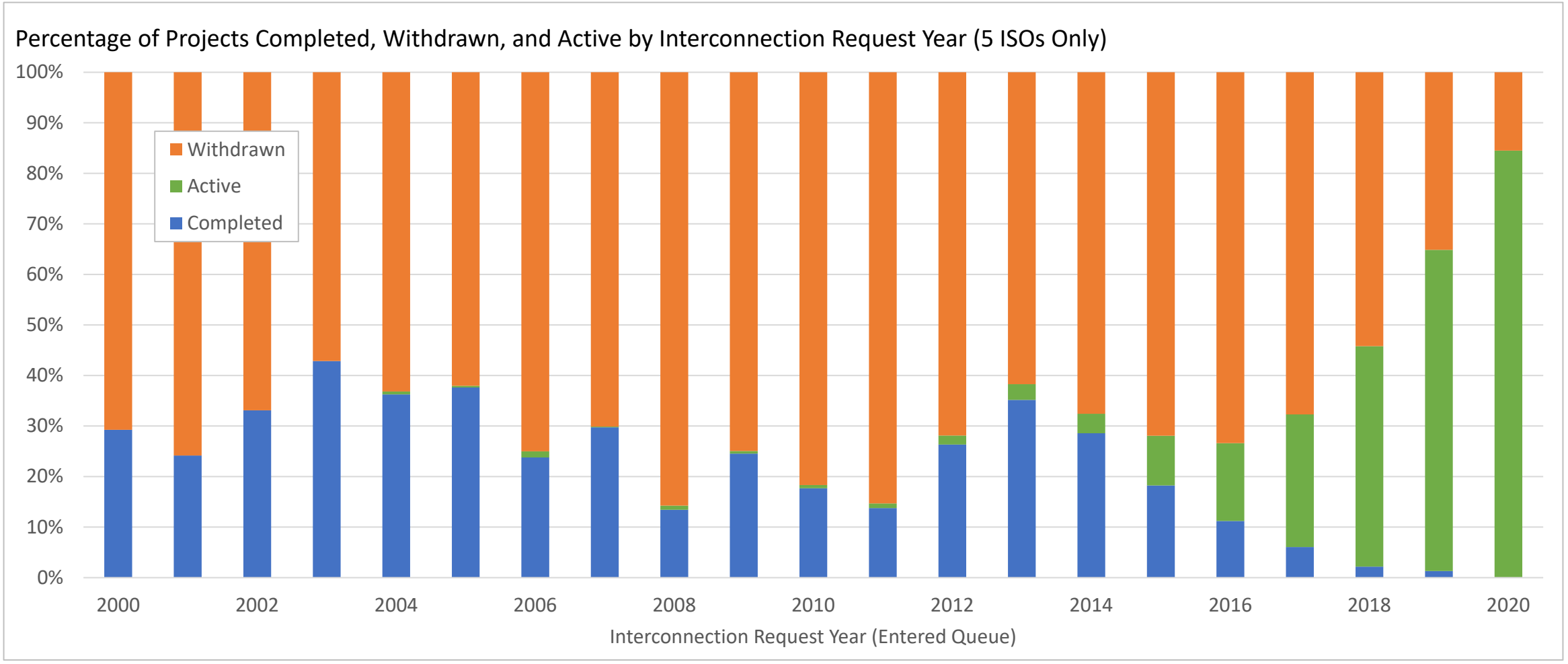
Year	Withdrawn Projects
2000	12
2001	14
2002	97
2003	103
2004	74
2005	76
2006	93
2007	111
2008	371
2009	294
2010	325
2011	544
2012	653
2013	363
2014	308
2015	348
2016	374
2017	540
2018	467
2019	695
2020	729

1. Americans for a Clean Energy Grid. *Disconnected: The Need for a New Generator Interconnection Policy.* January, 2021.

Notes: (1) Data on withdrawn projects were only collected for the five ISOs shown. (2) Data are only shown where sample size is >3 for each year. (3) "Time in queues" is calculated as the number of days from the queue entry date to the date the project was withdrawn from queues.

Across the five ISOs studied, just 24% of projects proposed from 2000-2015 have reached commercial operations

The completion rate may have increased temporarily after 2010-2012 queue reforms[1] but appears to be declining for projects proposed from 2014-2016. Trends for projects proposed in 2017 and after cannot yet be determined.

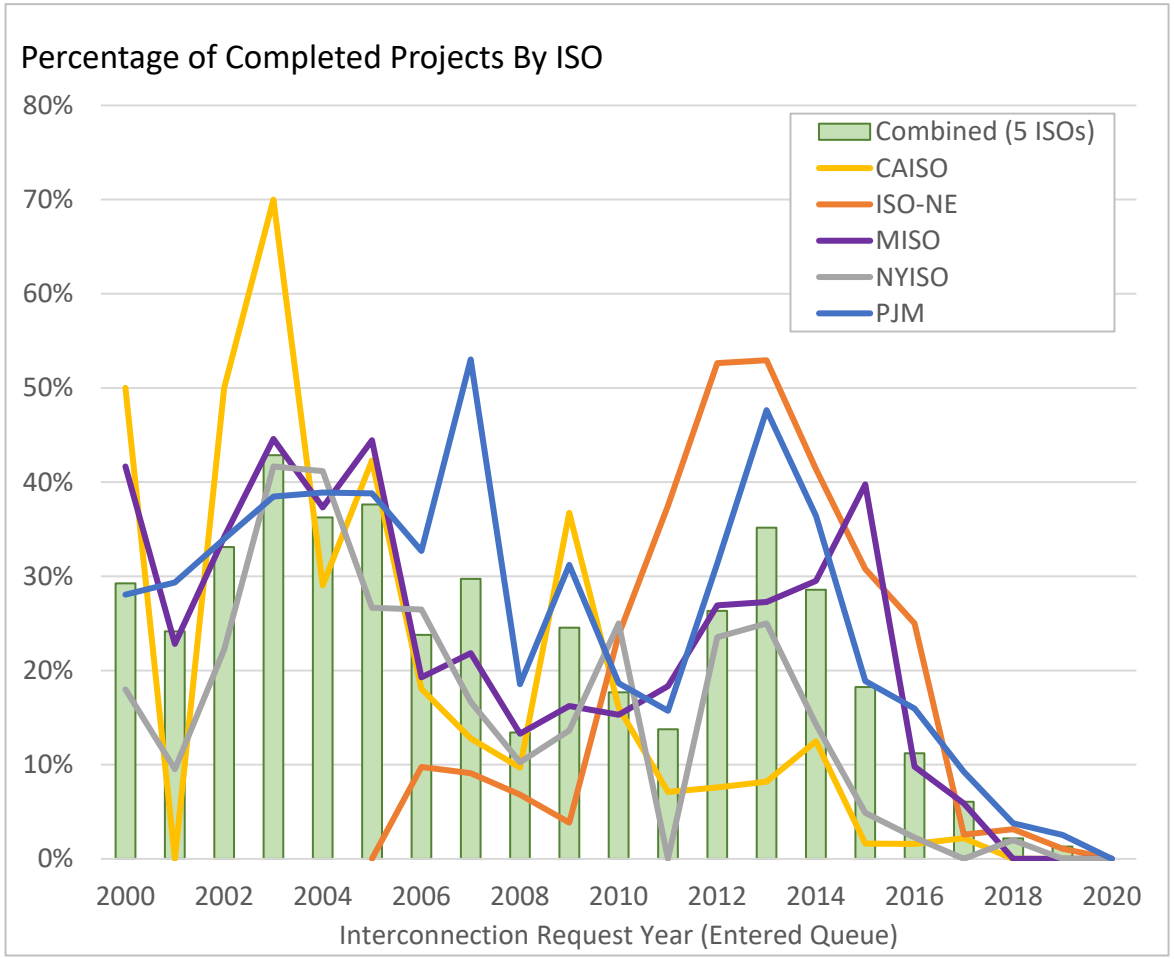


1. Americans for a Clean Energy Grid. *Disconnected: The Need for a New Generator Interconnection Policy.* January, 2021.

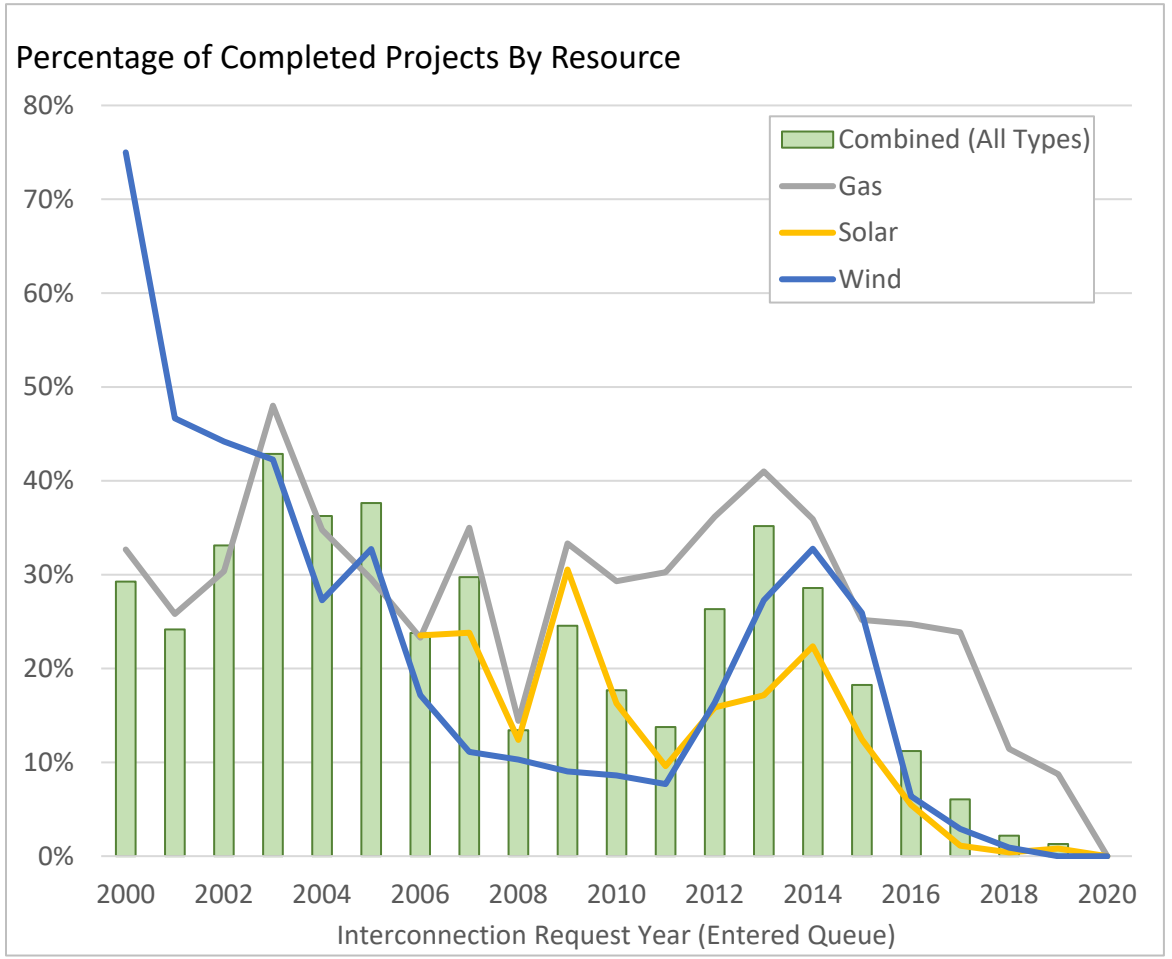
Note: Only includes data from five ISOs: CAISO, MISO, PJM, NYISO, ISO-NE

Increase in completion rates for projects proposed in 2012-2014 is visible across several ISOs; wind (19%) and solar (16%) have lower completion rates from 2000-2015 than other types

Completion percentage by ISO:



Completion percentage by resource:



Note: Only includes data from five ISOs: CAISO, MISO, PJM, NYISO, ISO-NE

Active Projects in Interconnection Queues

Includes data from all 7 ISOs and 35 non-ISO utilities, totaling 5,639 proposed projects

Region	*n* (Active)
CAISO	346
ERCOT	527
ISO-NE	263
MISO	580
NYISO	308
PJM	1,541
SPP	498
Southeast (non-ISO)	728
West (non-ISO)	848

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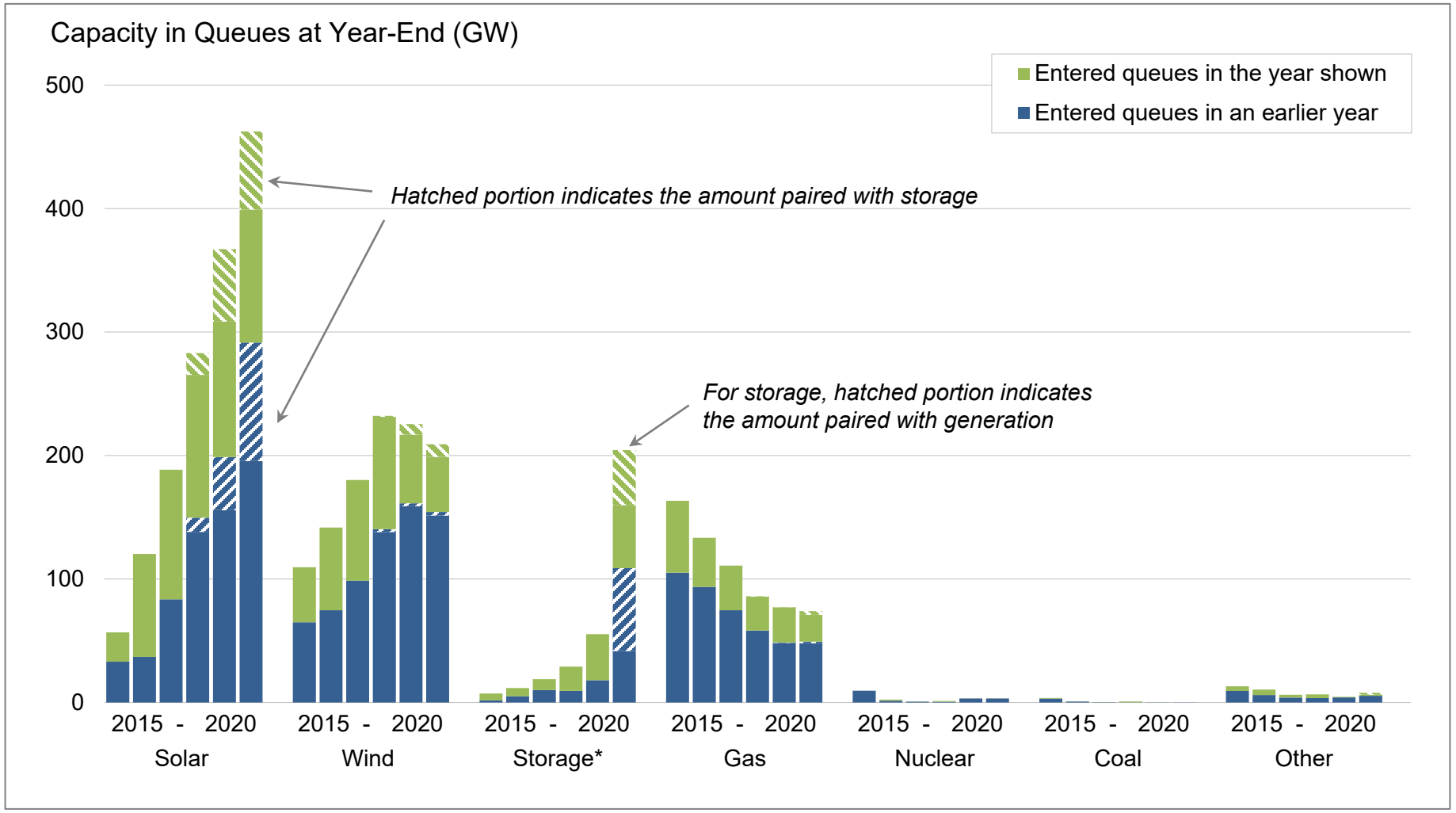
Interconnection queues indicate that commercial interest in solar and storage has grown, including via hybridization; wind and gas have declined



- "**Wind**" includes both onshore and offshore.
- "**Other**" includes
  - Hydropower
  - Geothermal
  - Biomass/biofuel
  - Landfill gas
  - Solar thermal
  - Oil/diesel
- "**Storage**" is primarily (98%) battery, but also includes pumped storage hydro, compressed air, gravity rail, and fuel cell projects.

**Hybrid storage capacity is estimated using storage:generator ratios from projects that provide separate capacity data*
Storage capacity in hybrids was not estimated for years prior to 2020.
Note: Not all of this capacity will be built

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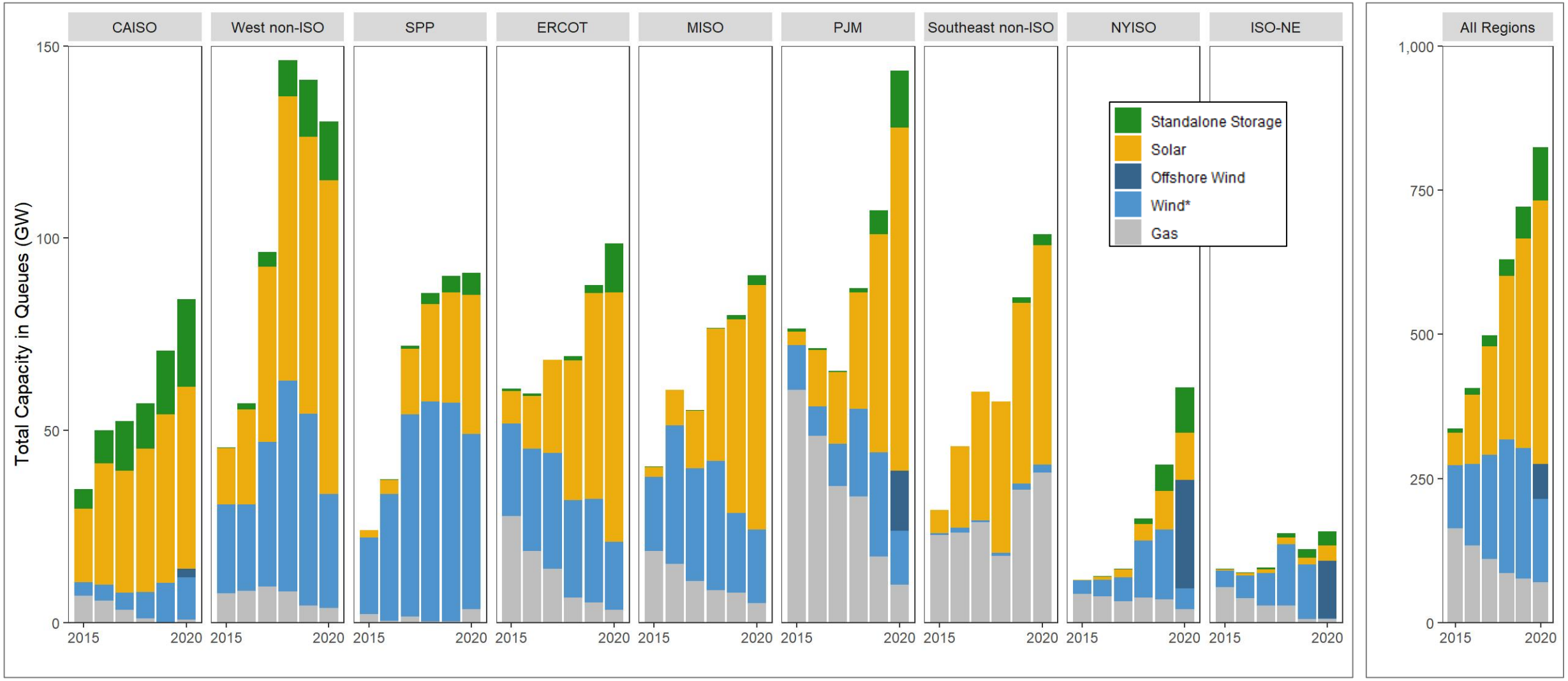
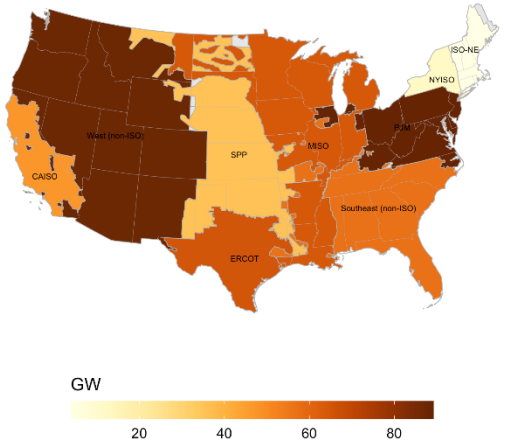
Trends over time vary somewhat by region: Wind capacity has contracted in some regions, solar and storage see consistent growth, gas largely declines



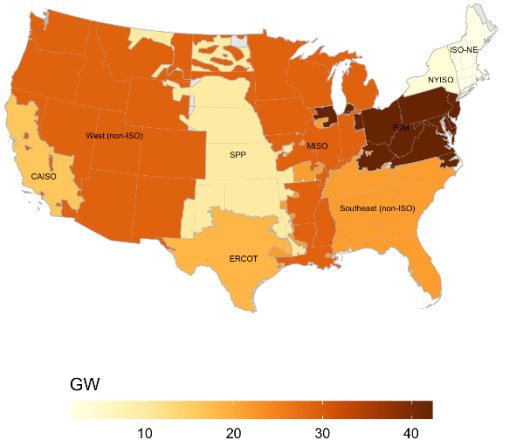
*Wind capacity includes onshore and offshore for all years, but offshore is only broken out starting in 2020.
Notes: (1) Storage capacity only includes standalone storage – storage in hybrid configuration is not included here.
(2) Hybrid generation capacity is included in all generator categories. (3) Not all of this capacity will be built.

Regional: Proposed solar is widespread, with less in SPP and Northeast; Most wind in SPP with new offshore in NY; Most storage in CAISO, West, ERCOT, and PJM; Gas is largely in the Southeast

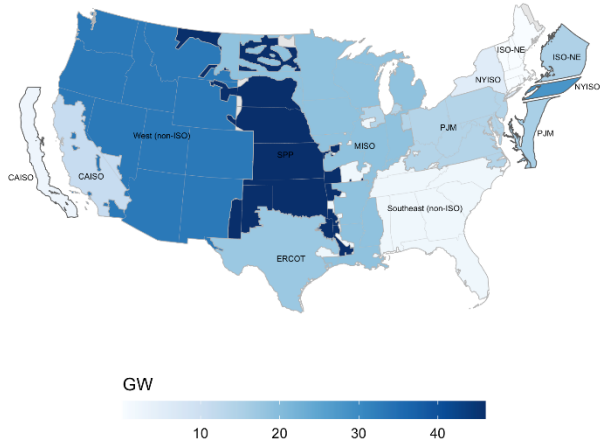
Total Solar Capacity in Interconnection Queues at the end of 2020



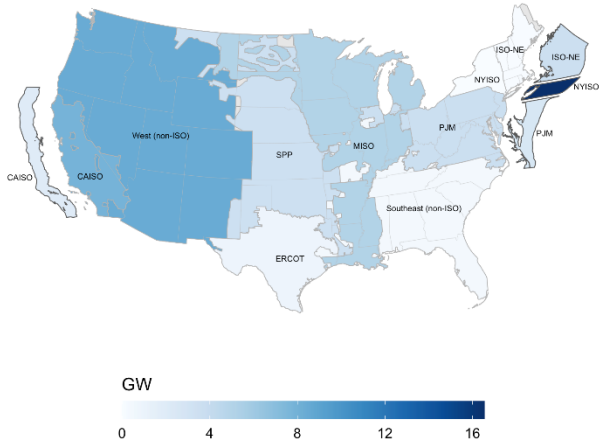
New Solar Capacity Added to Interconnection Queues in 2020



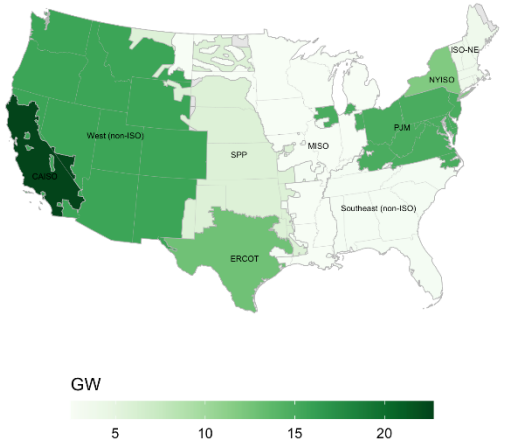
Total Wind Capacity in Interconnection Queues at the end of 2020



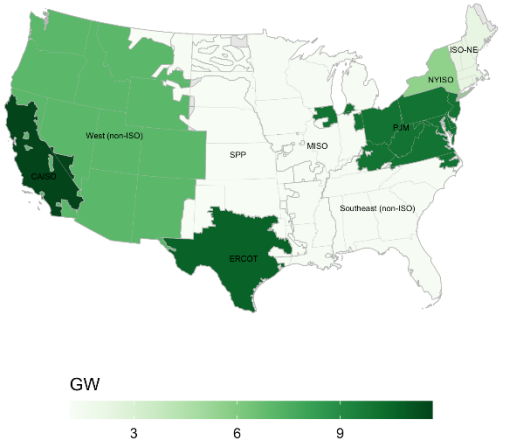
New Wind Capacity Added to Interconnection Queues in 2020



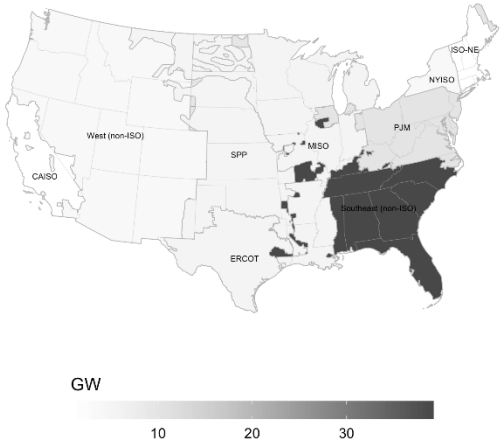
Total Standalone Storage Capacity in Interconnection Queues at the end of 2020



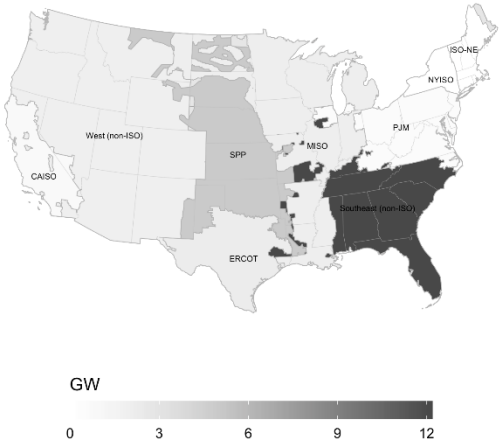
New Standalone Storage Capacity Added to Interconnection Queues in 2020



Total Gas Capacity in Interconnection Queues at the end of 2020

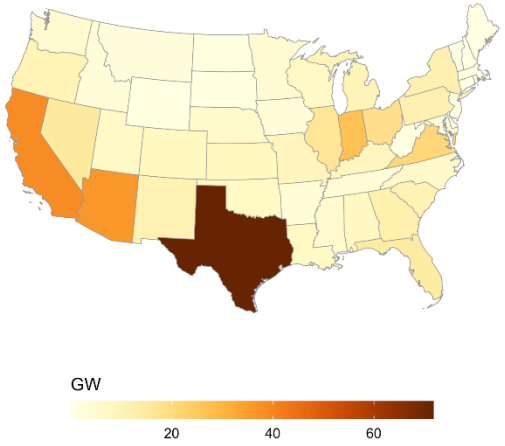


New Gas Capacity Added to Interconnection Queues in 2020

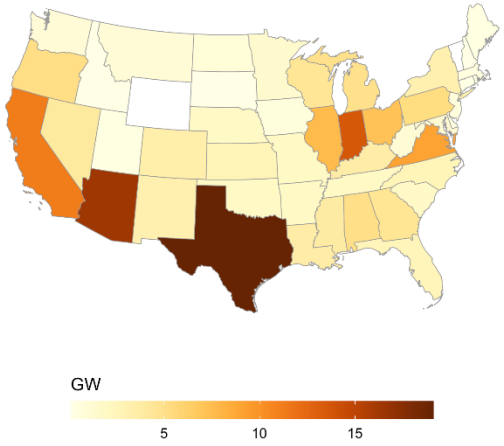


State Level: Most proposed solar TX, AZ, IN; proposed wind in TX, “wind belt”, and CA, with offshore in NY; Storage is mainly proposed in CA, TX, NY; Proposed gas in TX and Southeast

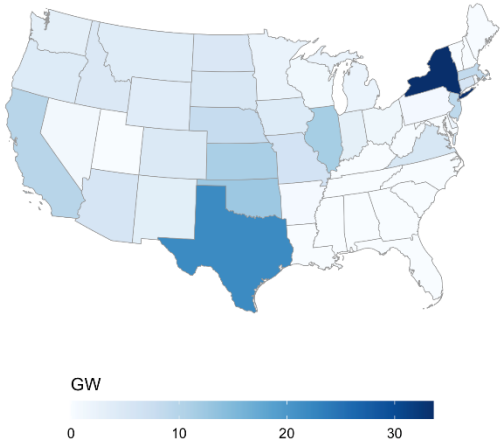
Total Solar Capacity in Interconnection Queues at the end of 2020



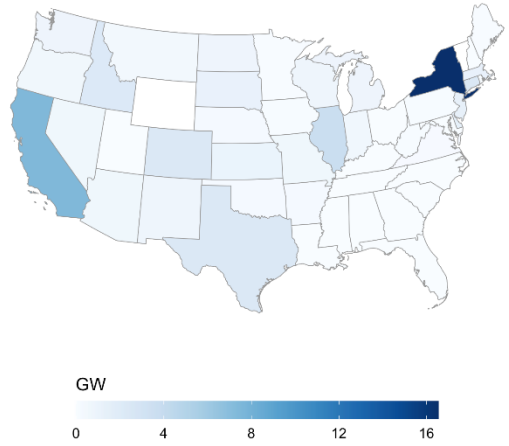
New Solar Capacity Added to Interconnection Queues in 2020



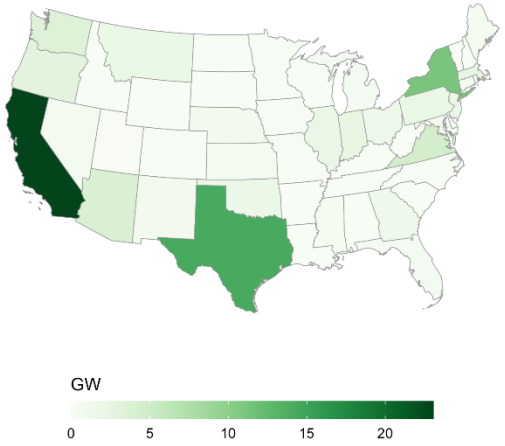
Total Wind Capacity in Interconnection Queues at the end of 2020



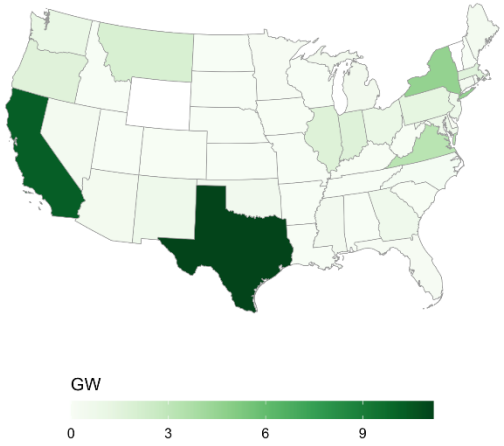
New Wind Capacity Added to Interconnection Queues in 2020



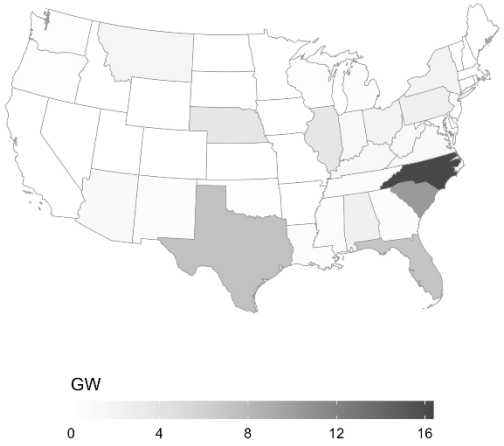
Total Standalone Storage Capacity in Interconnection Queues at the end of 2020



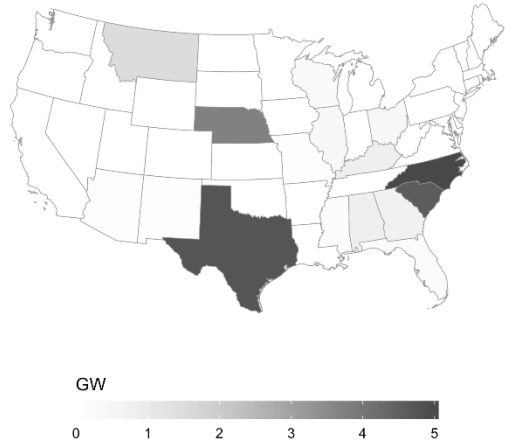
New Standalone Storage Capacity Added to Interconnection Queues in 2020



Total Gas Capacity in Interconnection Queues at the end of 2020

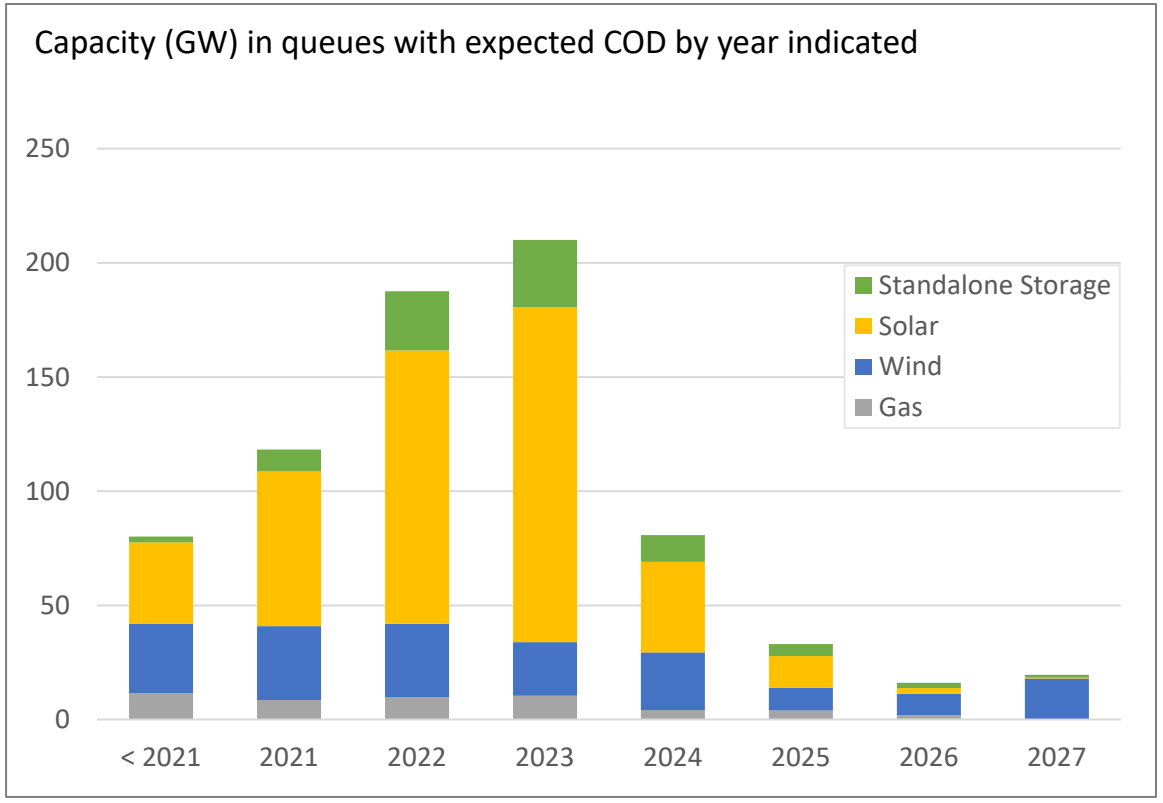


New Gas Capacity Added to Interconnection Queues in 2020

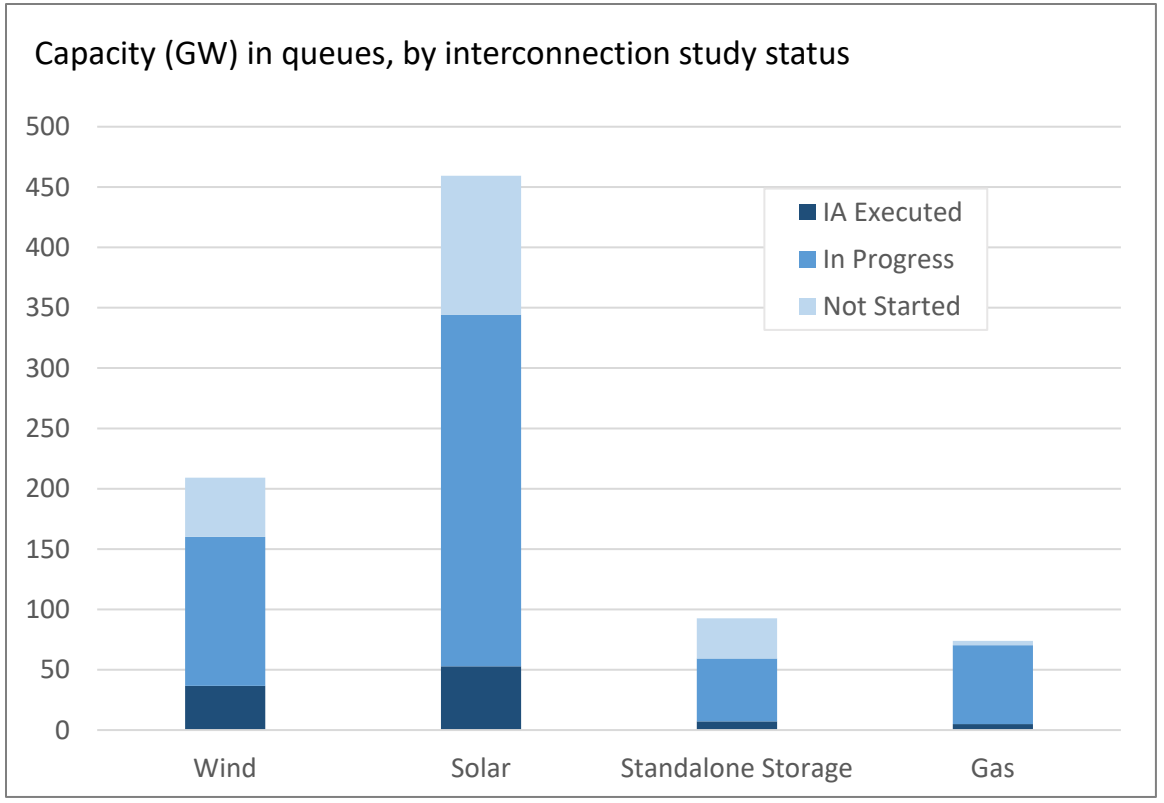


71% (653 GW) of total capacity in queues has expected online date by end of 2023; 13% (117 GW) has an executed interconnection agreement (IA)

Requested online year:



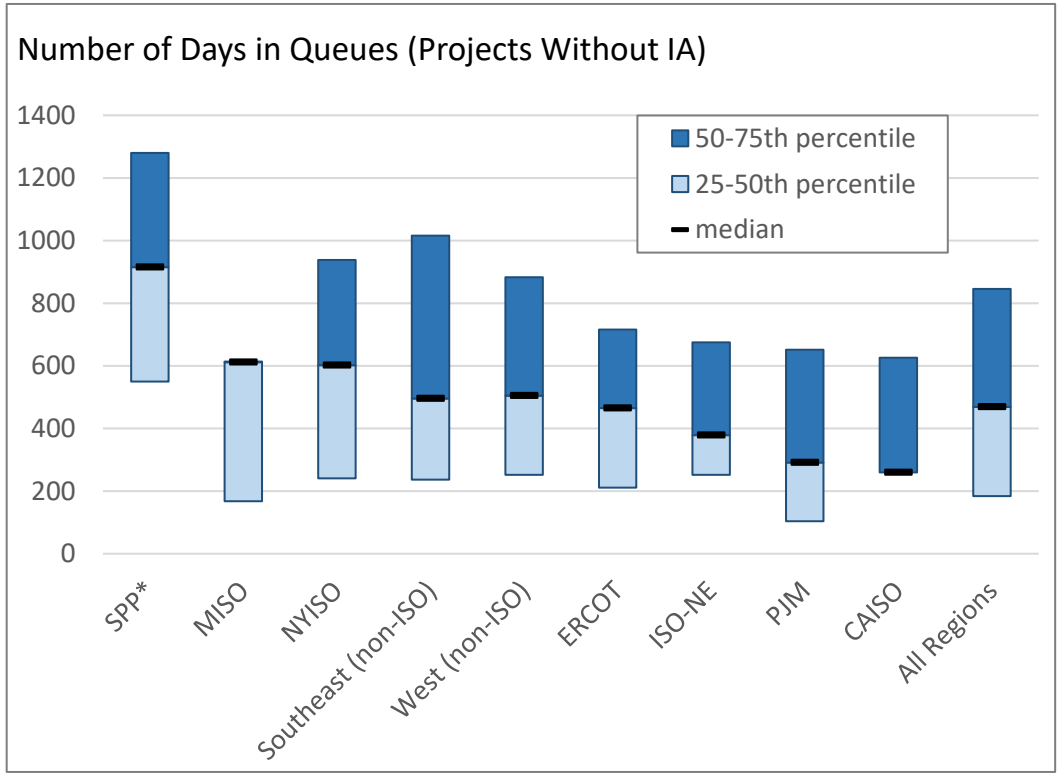
Status of interconnection study:



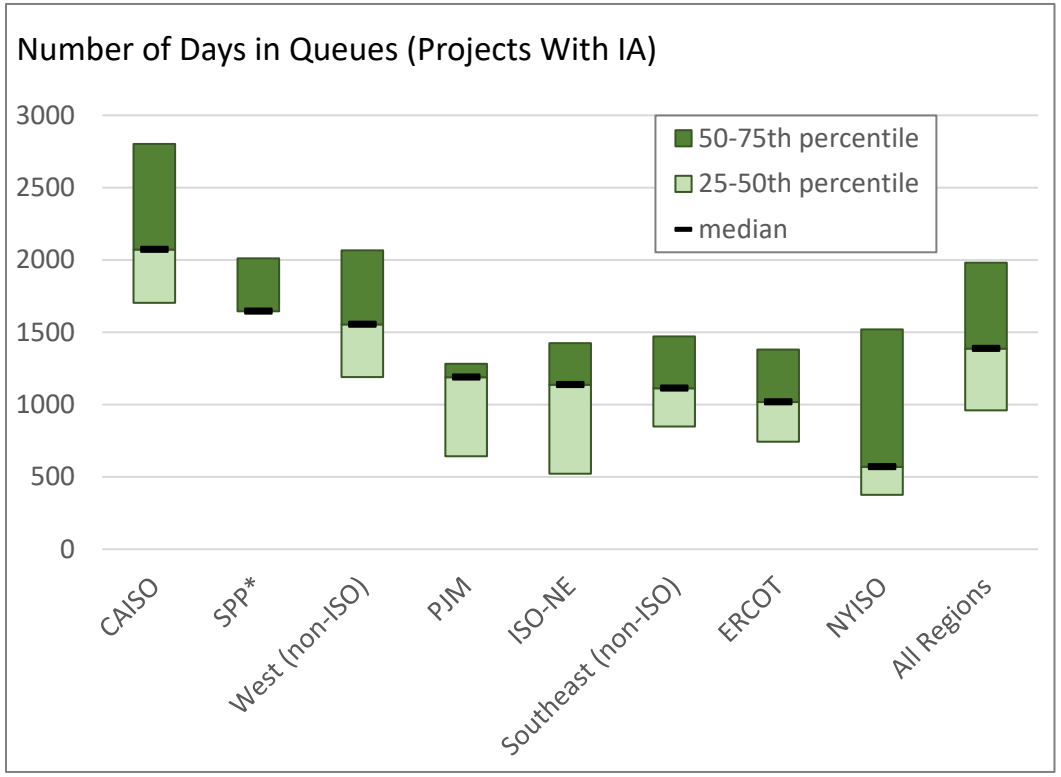
Note: Not all of this capacity will be built

The median project *with* an executed IA (but not yet built) has spent 1,387 days in the queues, over 2.5 years more than the median project *without* an IA (469 days)

Among projects *without* signed IAs, those in SPP (median = 915 days) tend to have spent the longest time in the queues, followed by MISO (612) and NYISO (602).



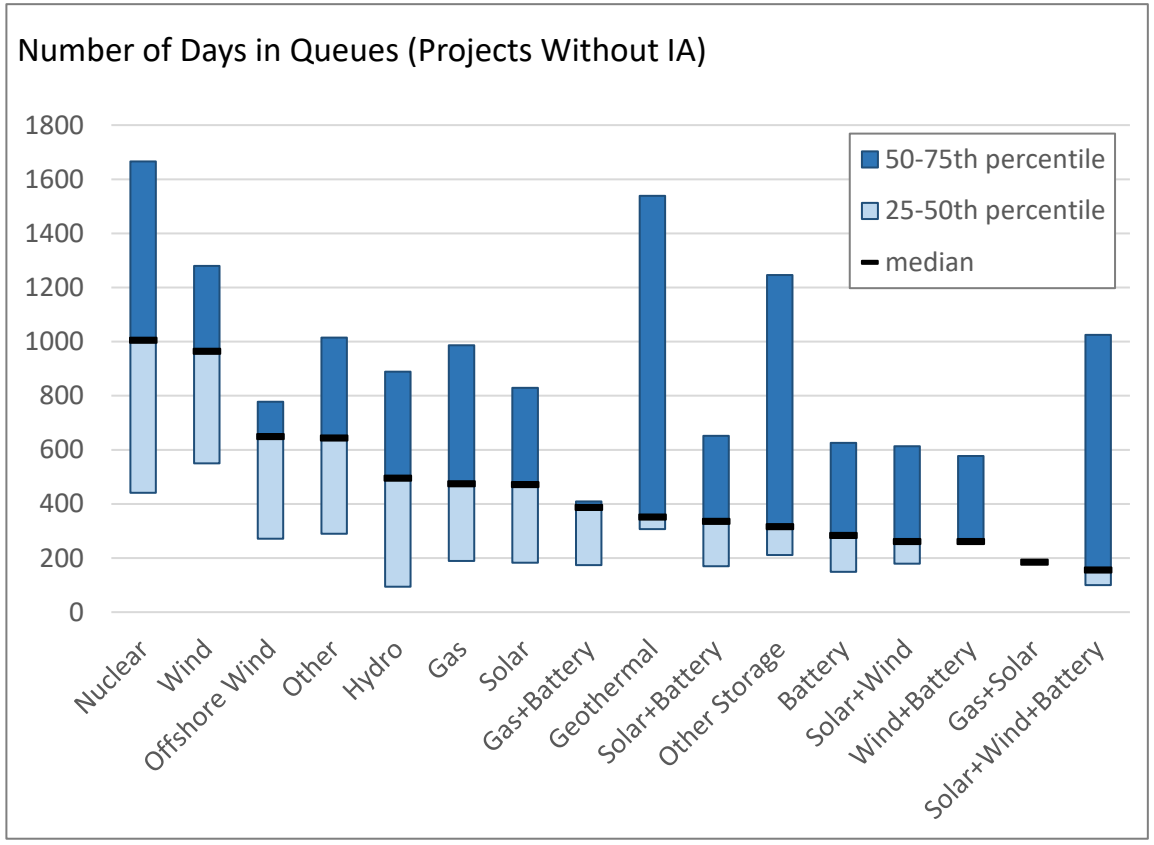
Among projects *with* signed IAs, those in CAISO (median = 2,072 days) tend to have spent the longest time in queues, followed by SPP (1,645), and West (non-ISO) (1,555).



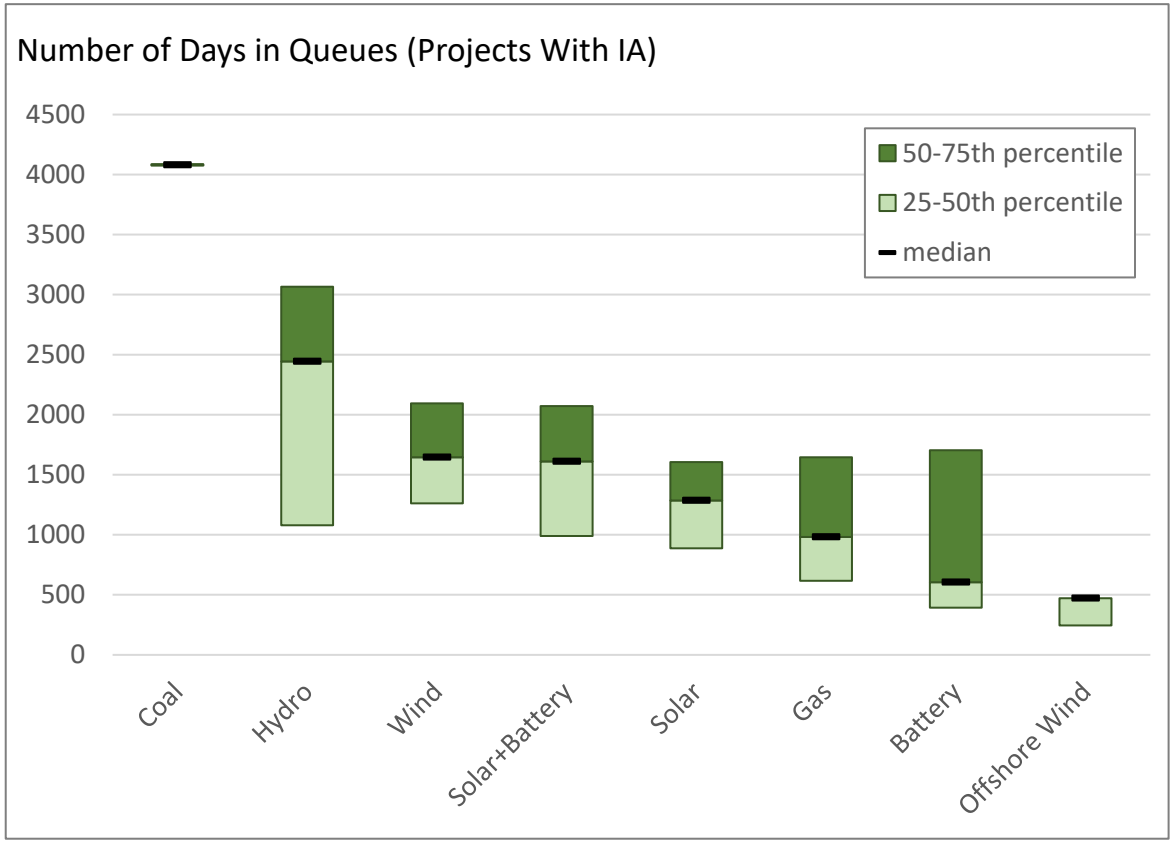
**Exact queue entry dates were not available for SPP, so this analysis assumed June 30 of the entry year.*
Notes: (1) Figures only include regions with at least 5 projects in the category.
(2) "Time in queues" is calculated as the number of days from the queue entry date to December 31, 2020.

Considerable variation also exists between resource types, with coal, hydropower, nuclear, and wind projects spending the longest time in queues

Among projects *without* signed IAs, nuclear projects (median = 1,004 days) tend to have spent the longest time in the queues, followed by wind (964)

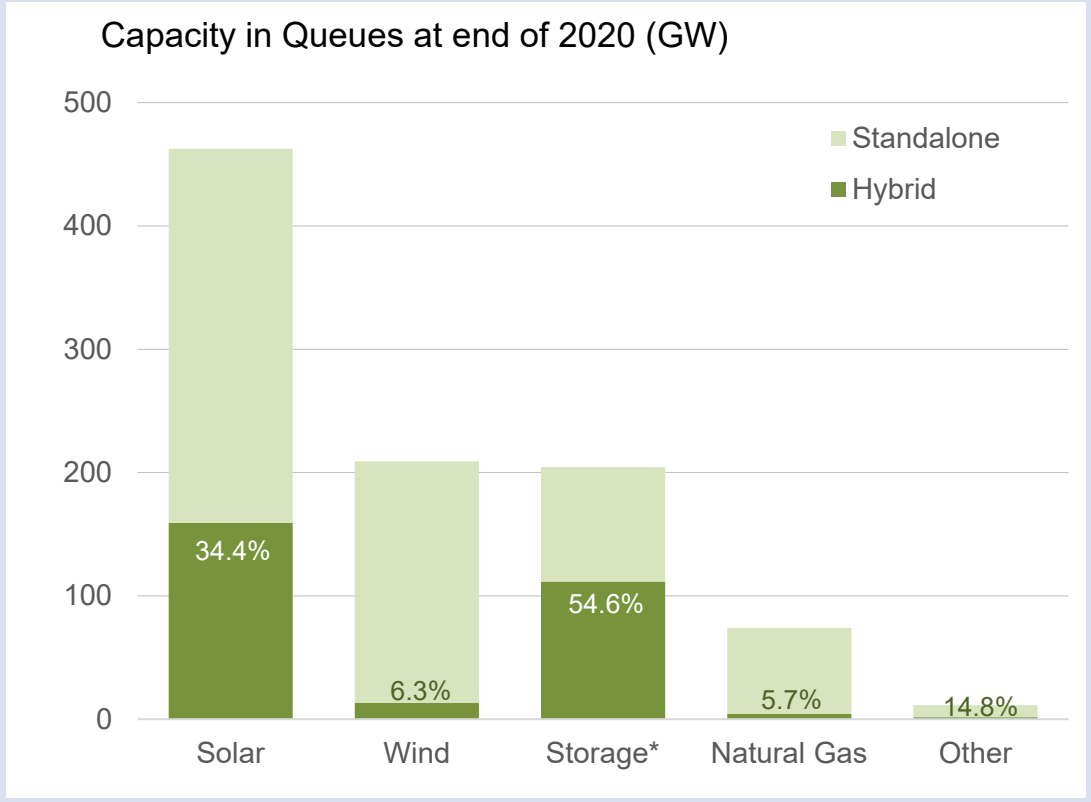


Among projects *with* signed IAs, coal projects (median = 4,081 days) are by far the oldest, followed by Hydropower (2,444 days)

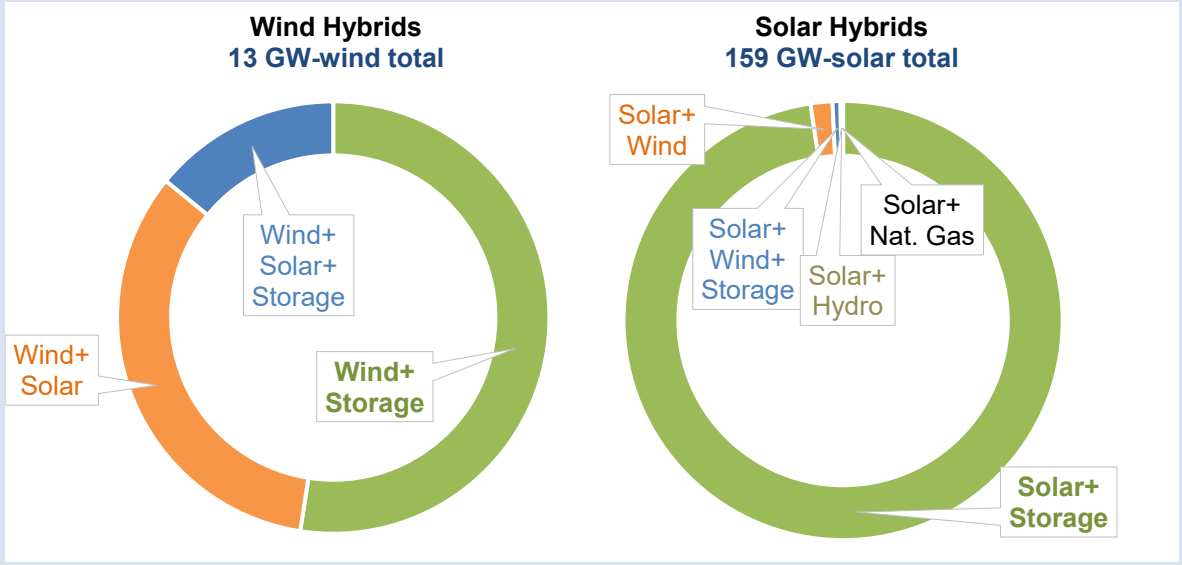


Notes: (1) Figures only include resource types with at least 5 projects in the category.
(2) "Time in queues" is calculated as the number of days from the queue entry date to December 31, 2020.

Interest in hybrid plants has increased: 34% of solar (159 GW) proposed as hybrids, 6% of wind (13 GW) proposed as hybrids (up from 28% and 5% in 2019, respectively)



Solar+Storage and Wind+Storage configurations are more common than other hybrid types



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

Notes: (1) Not all of this capacity will be built; (2) Hybrid plants involving multiple generator types (e.g., wind+PV+storage, wind+PV) 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; proposed wind hybrids dominated by CAISO

Region	% of Proposed Capacity Hybridizing in Each Region			
	Wind	Solar	Nat. Gas	Battery
CAISO	37%	89%	0%	64%
ERCOT	6%	21%	34%	37%
SPP	4%	22%	33%	38%
MISO	5%	18%	0%	n/a
PJM	1%	19%	1%	n/a
NYISO	0%	5%	6%	2%
ISO-NE	0%	12%	0%	n/a
West (non-ISO)	13%	67%	6%	n/a
Southeast (non-ISO)	0%	13%	1%	n/a
TOTAL	**6%**	**34%**	**6%**	**n/a**

- **Solar** hybridization relative to total amount of solar in each queue is highest in CAISO (89%) and non-ISO West (67%), and is above 20% in SPP and ERCOT
- **Wind** hybridization relative to total amount of wind in each queue is highest in CAISO (37%) and non-ISO West (13%), and is less than 7% in all other regions

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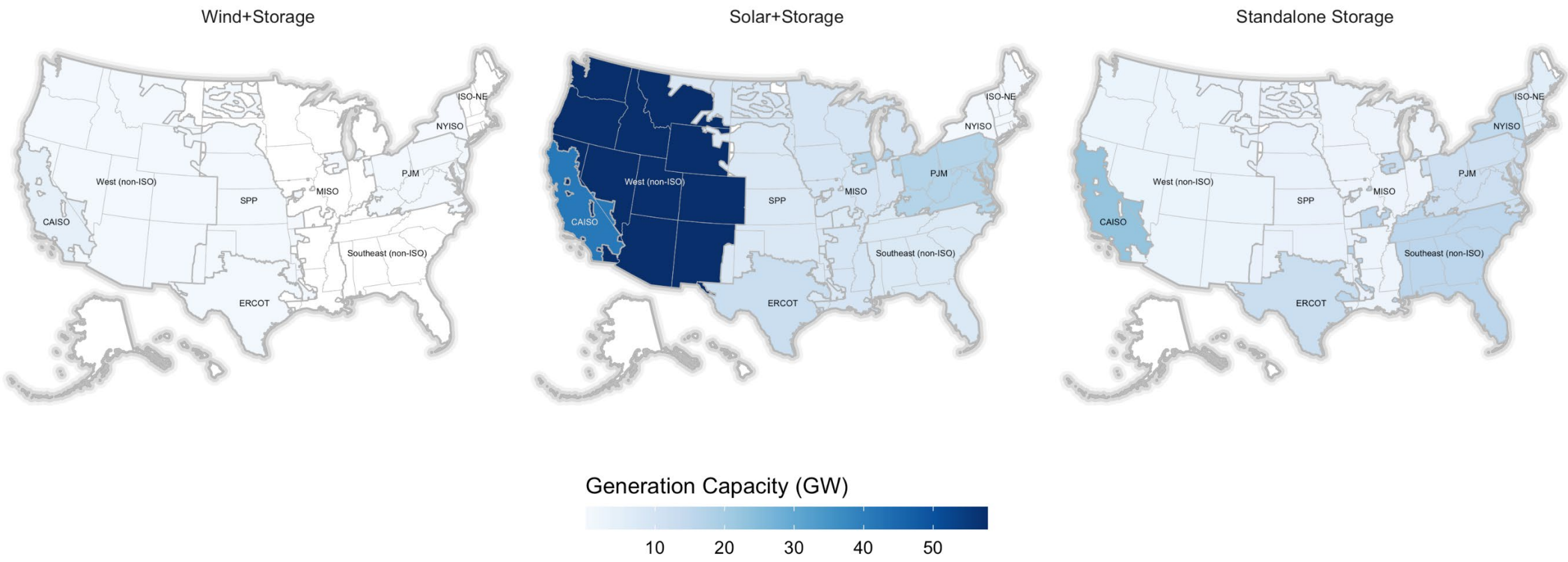
Solar+storage is dominant hybrid type in queues, wind+storage is much less common; CAISO & West of greatest interest so far

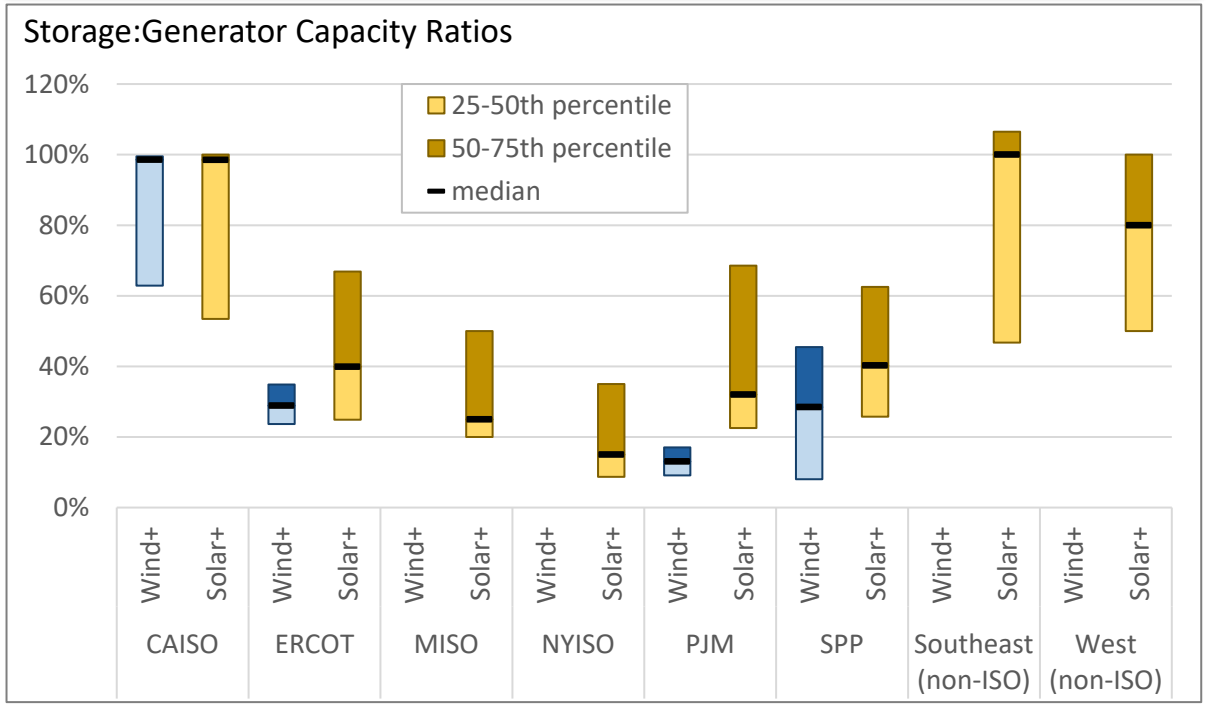


Note: Not all of this capacity will be built

Solar+storage projects typically feature a higher storage contribution than wind+storage; POI limits are typically based on generator capacity (at least in CAISO)

Storage capacity for hybrid projects was provided in a subset of queues. Where available, we calculated the ratio of storage capacity to generator capacity.

Median storage:generator capacity ratio for solar+storage (60%) is higher than for wind+storage (35%), and the ratio is generally higher where solar penetration is higher.

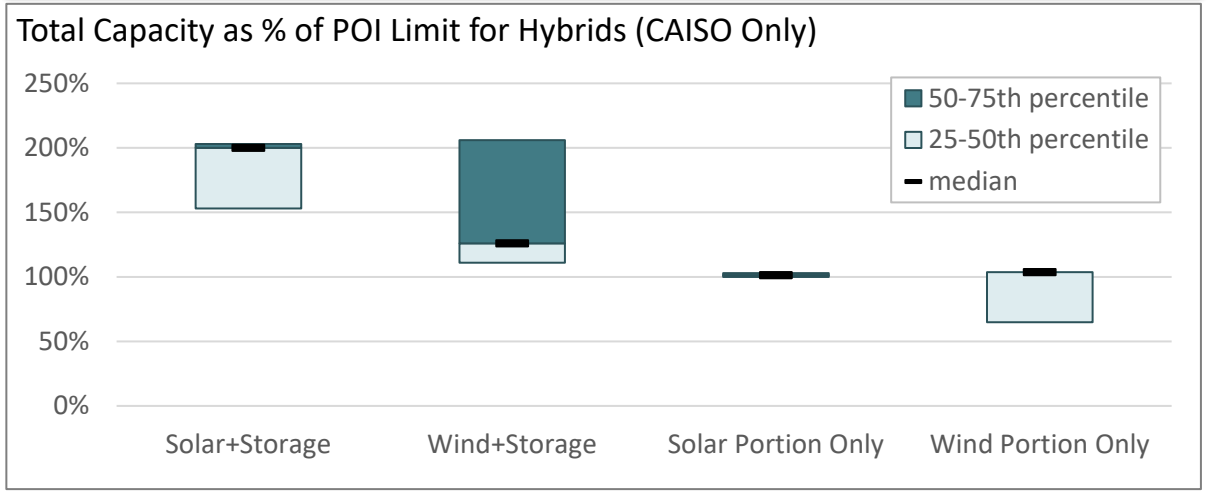


Point of interconnection (POI) capacity limits were only provided in CAISO's queue.

For **solar+storage** projects, the solar capacity alone equals or exceeds the POI limit in 91% of projects, and the median combined (solar+storage) capacity is double (200%) the POI limit.

For **wind+storage** projects, the wind capacity alone equals or exceeds the POI limit in 67% of projects, and the median total (wind+storage) capacity is 126% of the POI limit.

These values suggest that these projects are maximizing their POI limit by using storage to supply power at times when the generator is not generating.



Conclusions

As of the end of 2020, there were over 5,600 projects seeking grid interconnection across the U.S., representing over 755 GW of generation and an estimated ~204 GW of storage.

- Solar (462 GW) accounts for >60% of all active generator capacity in the queues, though substantial wind (209 GW) and gas (74 GW) capacity is also in development. Notably, 29% of the wind capacity in the queues is for offshore projects (61 GW).
- Considerable standalone (89 GW) and hybrid (~112 GW[1]) battery capacity is also in development, along with 4 GW of other storage.
- Growth in proposed solar and storage capacity is consistent across regions. Proposed wind has contracted in some regions, but continues to grow in those with proposed offshore development. Gas is declining in all regions except for non-ISO Southeast.
- Hybrids now comprise a large – and increasing – share of proposed projects, particularly in CAISO and non-ISO West. 159 GW of solar hybrids (primarily solar+battery) and 13 GW of wind hybrids are in the queues.
- The vast majority (71%) of capacity in the queues has requested to come online by the end of 2023, and some (13%) already has an executed interconnection agreement.
- The time projects spend in queues before reaching COD may be increasing. For the four ISOs studied[2], the typical duration from IR to COD went from ~1.9 years for projects built in 2000-2009 up to ~3.5 years for those built in 2010-2020.
- More than half (671 GW) of the estimated 1,100 GW of wind and solar capacity needed to approach a zero-carbon electricity target is already in development[3].
- Ultimately, much of this proposed capacity will not be built. Historically only ~24% of projects in the queues reached commercial operations, and less for wind (19%) and solar (16%). There are growing calls for queue reform to reduce cost, lead times, and speculation.

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Notes: (1) Hybrid battery capacity is estimated using storage:generator ratios from projects that provide separate capacity data. (2) Data on completed projects were only collected for five ISOs, though only the four shown provided COD. (3) See https://gridlab.org/2035-report/

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More Information:
Visit https://emp.lbl.gov/publications/queued-characteristics-power-plants to download the data used for this analysis and to access an interactive data visualization tool