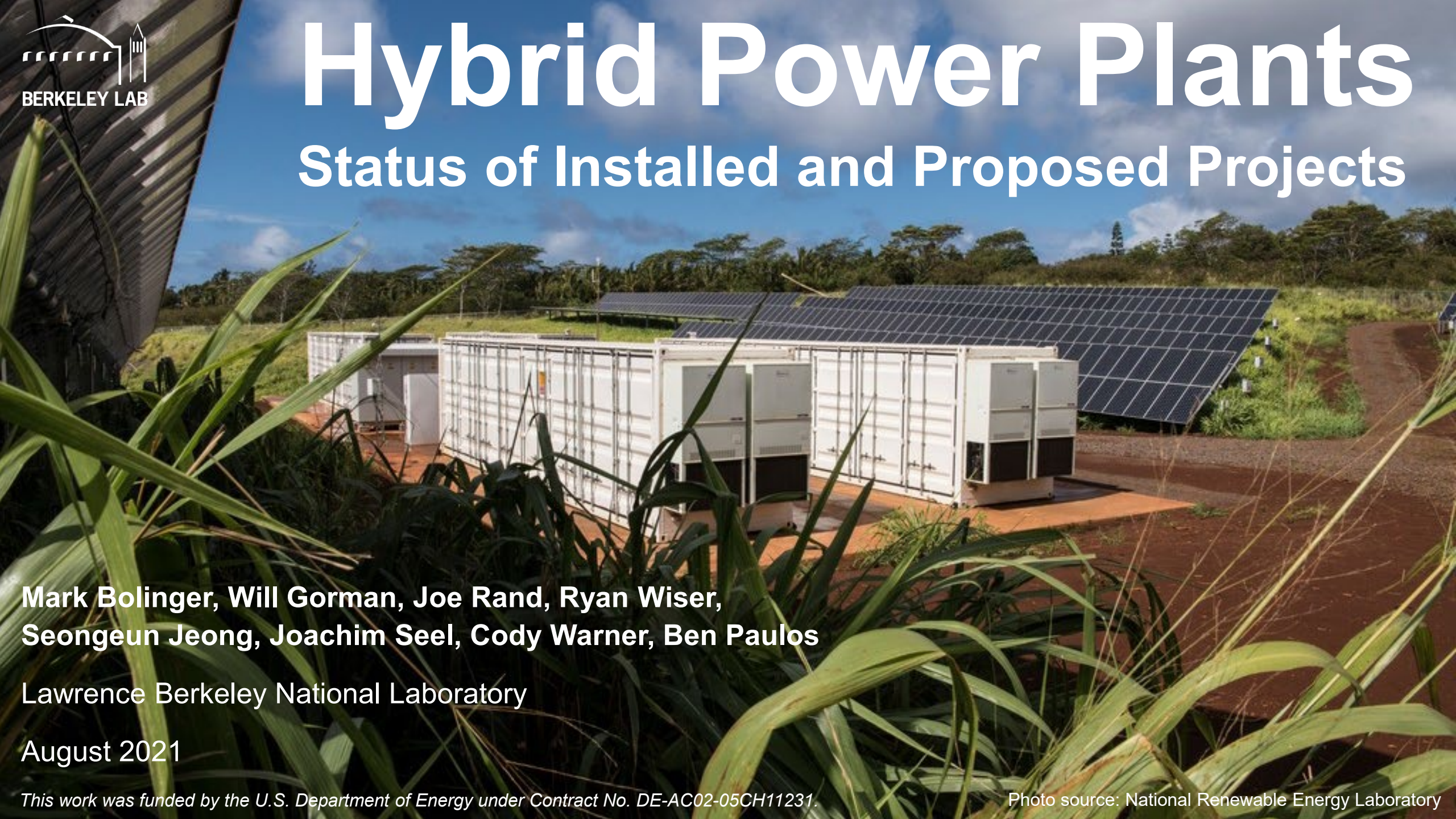

Hybrid Power Plants

Status of Installed and Proposed Projects

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Lawrence Berkeley National Laboratory

August 2021

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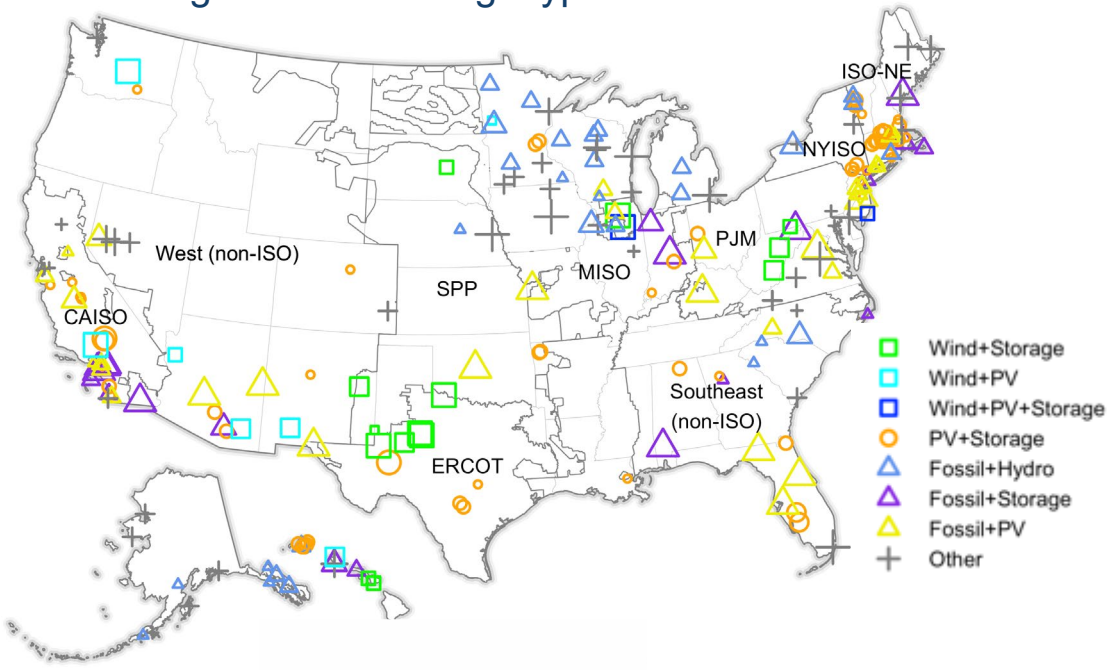
Photo source: National Renewable Energy Laboratory

High-Level Findings

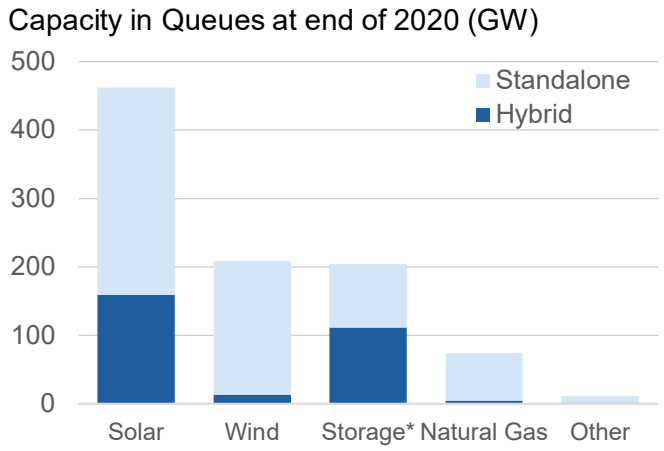
Hybrid / co-located projects exist in many configurations and are distributed broadly across the U.S.

- PV+storage dominates in terms of number of projects (73)
- Fossil hybrids (e.g., fossil+PV, fossil+storage) dominate in terms of generator capacity
- Standalone storage (excluding pumped hydro) capacity exceeds the storage capacity included in existing hybrids
- Storage:generator ratios are higher for PV+storage than for other generator+storage types



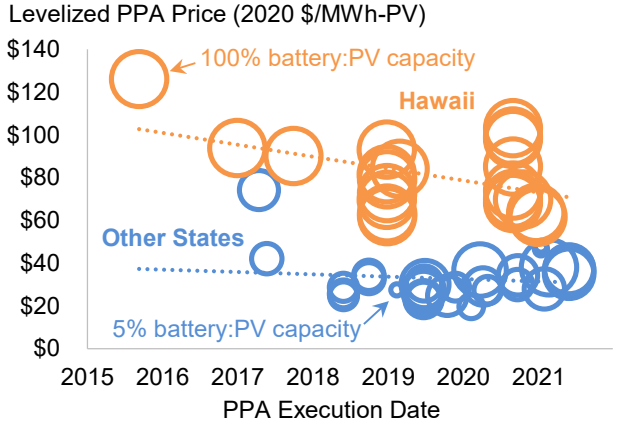
Hybrids comprise a large and increasing share of proposed projects

- 34% (159 GW) of all solar and 6% of wind (13 GW) in interconnection queues are proposed as hybrids
- PV+storage dominates the hybrid development pipeline
- Development interest is concentrated in the West and CAISO



More than 18 GW of proposed PV+storage projects already have an offtake agreement, such as a Power Purchase Agreement (PPA)

- The levelized PPA price from those projects has declined over time
- The cost of adding 4-hour storage to PV increases linearly with the battery:PV capacity ratio from ~$5/MWh-PV at 25% battery:PV capacity to ~$20/MWh at 100%
- Nearly 18 GW of PV+storage projects also already have signed interconnection agreements



Presentation Content

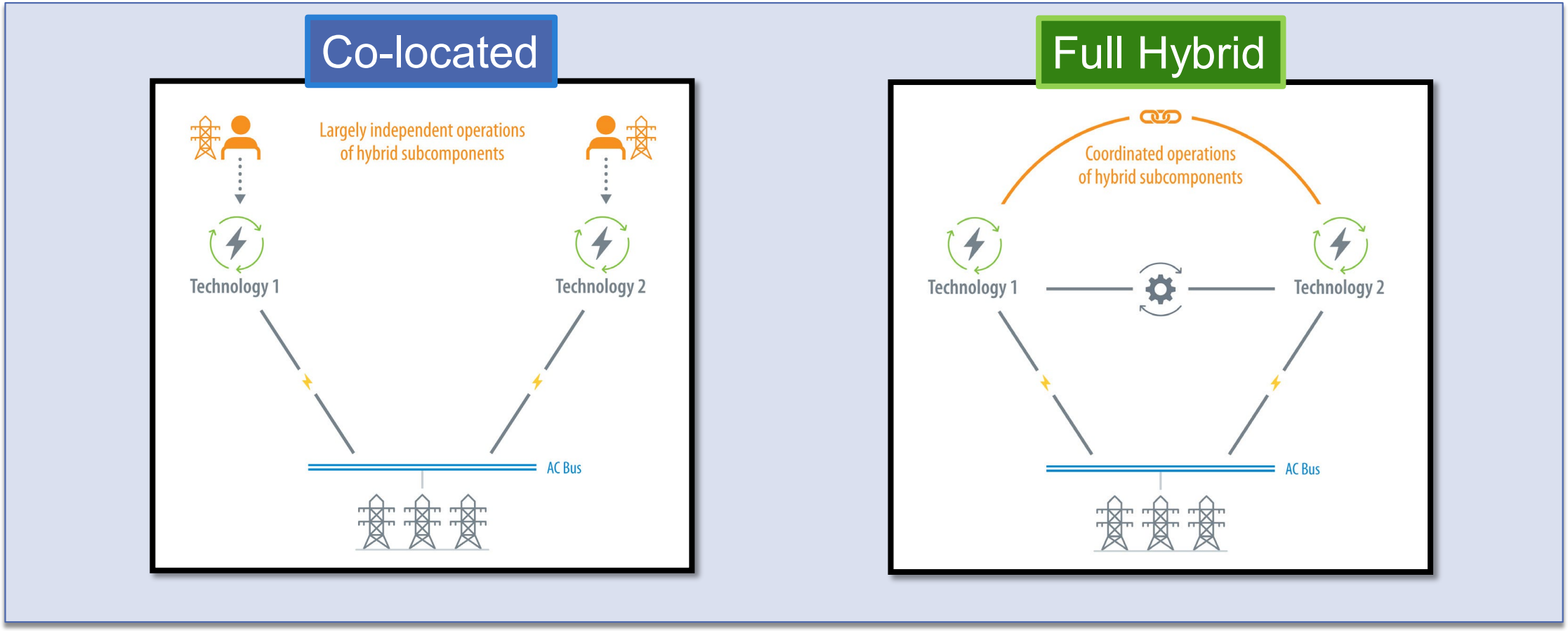
Existing hybrid projects:
installed power plants at end of 2020

Longer-term pipeline:
interconnection queues at end of 2020

Nearer-term pipeline:
PV+battery plants that have secured offtake

Presentation Scope

Scope includes **co-located** plants that pair two or more generators and/or that pair generation with storage at a single point of interconnection, and also **full hybrids** that feature co-location and co-control. **'Virtual' hybrids** are excluded, as are **smaller** (often behind-the-meter) projects not otherwise visible in data sources used here.

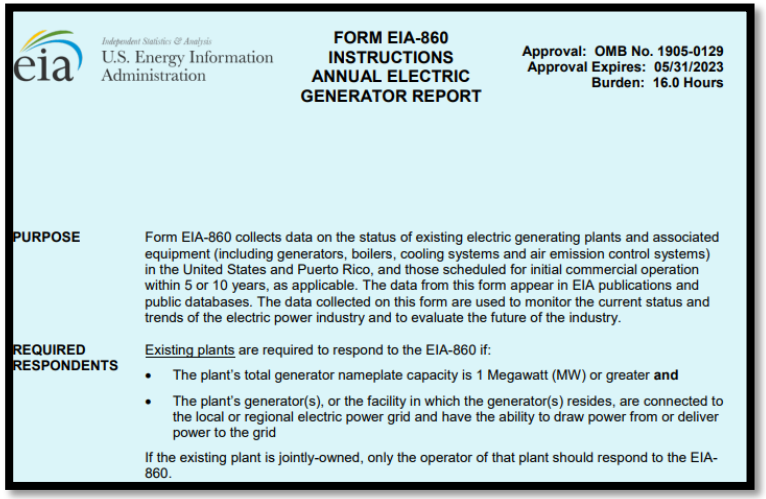


Source: U.S. Department of Energy. 2021. Hybrid Energy Systems: Opportunities for Coordinated Research.

Existing Hybrid Projects: Installed by end of 2020

Methods and Data Source

- Form **EIA-860 2020 early release**
  - Generator specific information for power plants with **>1 MW combined** capacity
  - Very limited amount of spot checking for corrections to EIA data
- Hybrids identified by having the **same EIA ID**
  - **Suggests co-location of generators** at one plant / point of interconnection, but not necessarily co-controlled generators
  - Virtual hybrids cannot be identified; smaller plants excluded
- Challenges and Limitations:
  - Difficult to separate behind-the-meter/micro-grid resources from front of the meter resources
  - EIA ID does **not identify all hybrids or co-located plants** as some co-located plants could have different IDs
    - Limited spot checking of missed hybrids using ABB Velocity Suite's dataset to find co-located plants with different EIA IDs
  - **Exclude dual fuel and CSP units** which use the same prime mover technology (e.g. steam turbine) but have the capability to change fuels (e.g. oil/gas plants, SEGS, Ivanpah, Solana, Martin solar thermal power plants)



eia Independent Statistics & Analysis U.S. Energy Information Administration

FORM EIA-860
INSTRUCTIONS
ANNUAL ELECTRIC
GENERATOR REPORT

Approval: OMB No. 1905-0129
Approval Expires: 05/31/2023
Burden: 16.0 Hours

PURPOSE

Form EIA-860 collects data on the status of existing electric generating plants and associated equipment (including generators, boilers, cooling systems and air emission control systems) in the United States and Puerto Rico, and those scheduled for initial commercial operation within 5 or 10 years, as applicable. The data from this form appear in EIA publications and public databases. The data collected on this form are used to monitor the current status and trends of the electric power industry and to evaluate the future of the industry.

REQUIRED RESPONDENTS

Existing plants are required to respond to the EIA-860 if:

- The plant's total generator nameplate capacity is 1 Megawatt (MW) or greater **and**
- The plant's generator(s), or the facility in which the generator(s) resides, are connected to the local or regional electric power grid and have the ability to draw power from or deliver power to the grid

If the existing plant is jointly-owned, only the operator of that plant should respond to the EIA-860.

Hybrid / co-located projects of various configurations exist as of the end of 2020, but market remains limited in overall size (1)

226 projects, 29.4 GW of generating capacity, 0.8 GW storage capacity

Installed at end of 2020	# projects	Gen 1* (MW)	Gen 2* (MW)	Gen 3* (MW)	Storage capacity (MW)	Storage energy (MWh)	Storage: generator ratio	Duration (hrs)
PV+Storage	73	992	0	0	250	658	25%	2.6
Wind+Storage	14	1,425	0	0	198	122	14%	0.6
Wind+PV	7	586	267	0	0	0	0%	n/a
Wind+PV+Storage	2	218	21	0	34	15	14%	0.4
Fossil+PV	34	9,143	229	0	0	0	0%	n/a
Fossil+Storage	21	4,003	0	0	281	353	7%	1.3
Fossil+PV+Storage	4	716	12	0	5	10	1%	1.9
Fossil+Hydro	29	629	81	0	0	0	0%	n/a
Fossil+Wind+PV	4	286	47	4	0	0	0%	n/a
Fossil+Wind	9	57	27	0	0	0	0%	n/a
Nuclear+Fossil	4	6,480	1,355	0	0	0	0%	n/a
Biomass+Hydro	9	327	54	0	0	0	0%	n/a
Biomass+PV	4	102	8	0	0	0	0%	n/a
Hydro+Storage	5	209	0	0	22	31	11%	1.4
Geothermal+PV	2	85	18	0	0	0	0%	n/a
Geothermal+PV+CSP	1	47	22	2	0	0	0%	n/a

Sources: EIA 860 2020 Early Release, Berkeley Lab

Note: **Pumped hydro** is not considered a hybrid resource for the purpose of this compilation. The hydro plants noted in the table pair hydropower with other technologies.

**Gen order determined by name order in first column, storage capacity broken out separately*

Four categories were dropped from this table due to having limited sizes: (1) Fossil+Wind+Storage, (2) Fossil+Wind+PV+Storage, (3) Biomass+Storage, and (4) Nuclear+Hydro

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Hybrid / co-located projects of various configurations exist as of the end of 2020, but market remains limited in overall size (2)

PV Hybrids / Co-Located Projects

- PV+Storage dominates: 73 plants, 992 MW PV, 250 MW/650 MWh of storage
- Fossil+PV is common (34 projects) but involves minor amount of PV (229 MW) added to fossil units (9,143 MW), including 3 coal plants totaling 5 GW at point of interconnection

Wind Hybrids / Co-Located Projects

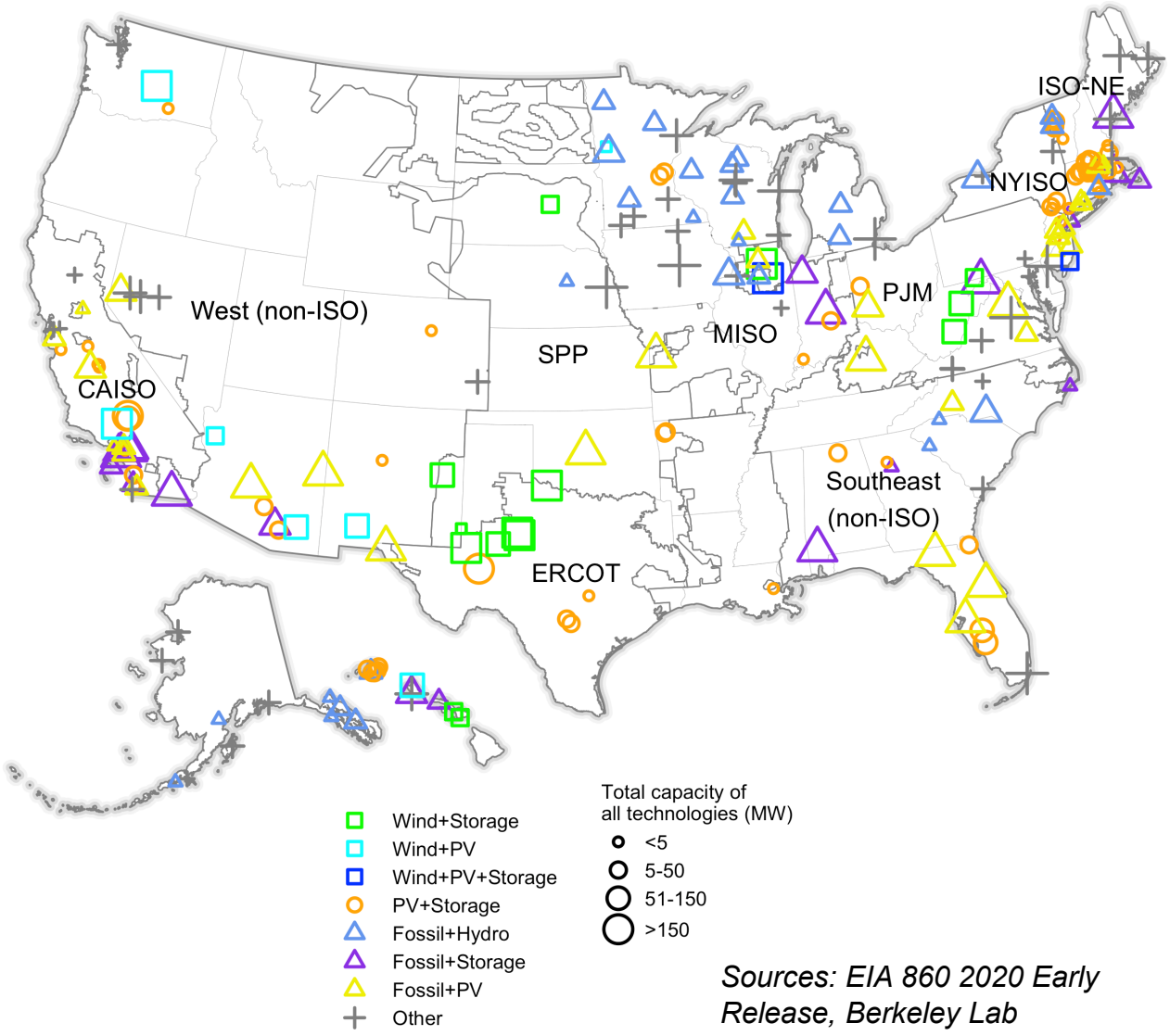
- Wind+Storage dominates wind hybrids: 14 plants, 1,425 MW wind, 198 MW/122 MWh of storage
- Configurations that include fossil involve minor amounts of wind

Fossil Hybrids / Co-Located Projects

- Fossil+PV is most common: small amount of PV added to larger fossil units (9,143 MW)
- Fossil+Storage also relatively common (21 projects, 4,000 MW fossil, 281 MW/353 MWh of storage)

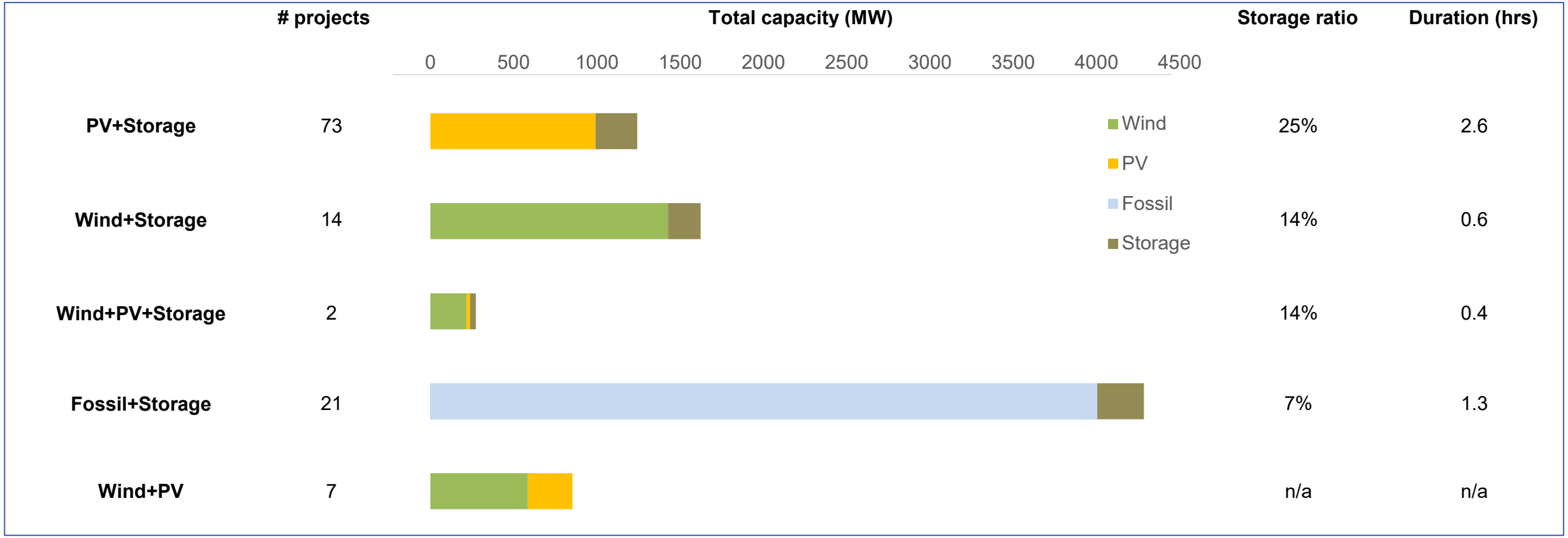
Geothermal, Hydropower, Biomass, Nuclear Hybrids / Co-located Projects

- Multiple configurations, with Nuclear+Fossil involving the most capacity



Sources: EIA 860 2020 Early Release, Berkeley Lab

Most existing hybrid projects are PV+Storage, and these projects include almost twice as much storage energy as any other hybrid pairing that includes storage



Notes: Not included in the figure are 111 other hybrid / co-located projects with other configurations; details on those projects are provided in the table on slide 7. ***Storage ratio*** *defined as total storage capacity divided by total generation capacity within a type.* ***Duration*** *defined as total MWh of storage divided by total MW of storage within a type.*

Sources: EIA 860 2020 Early Release, Berkeley Lab

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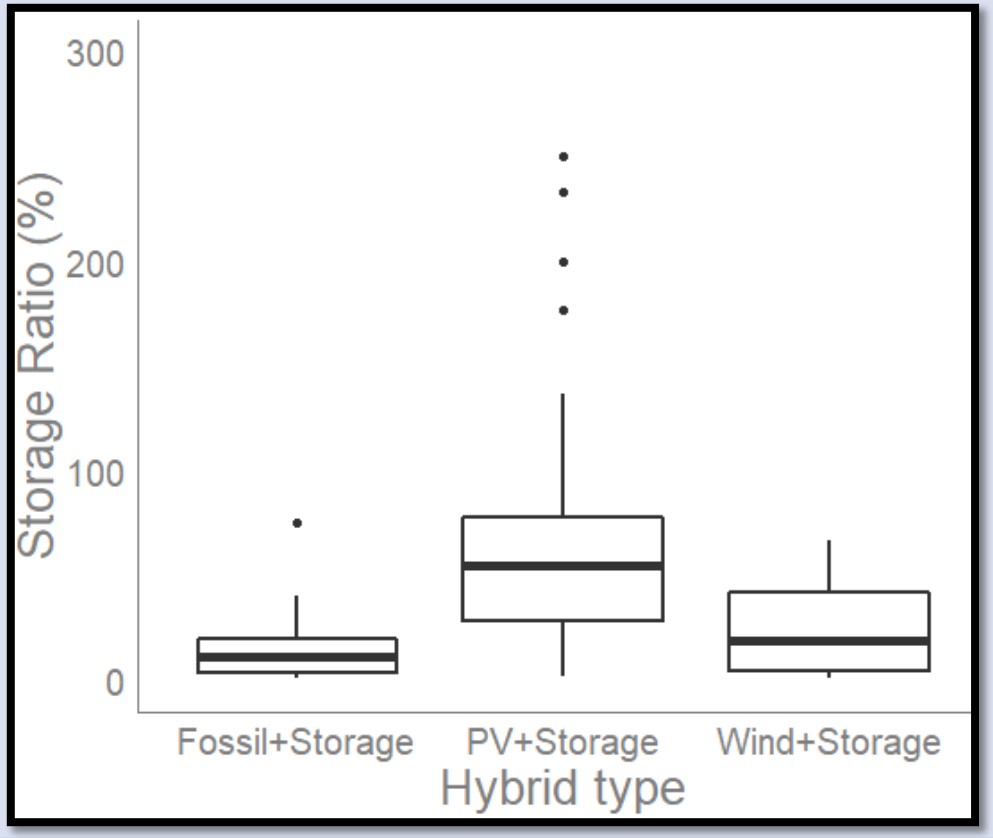
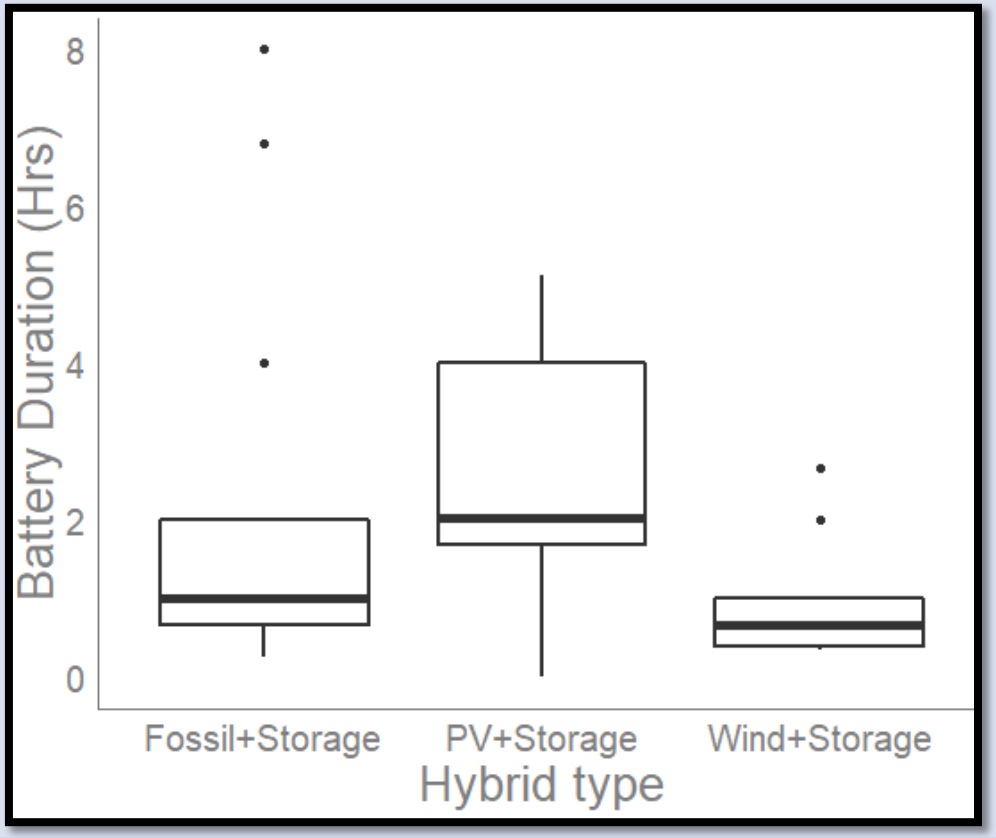
Higher storage-to-generator ratios and longer durations means PV+Storage hybrids feature the most storage energy

PV+Storage median storage to generation ratio is highest at 55%



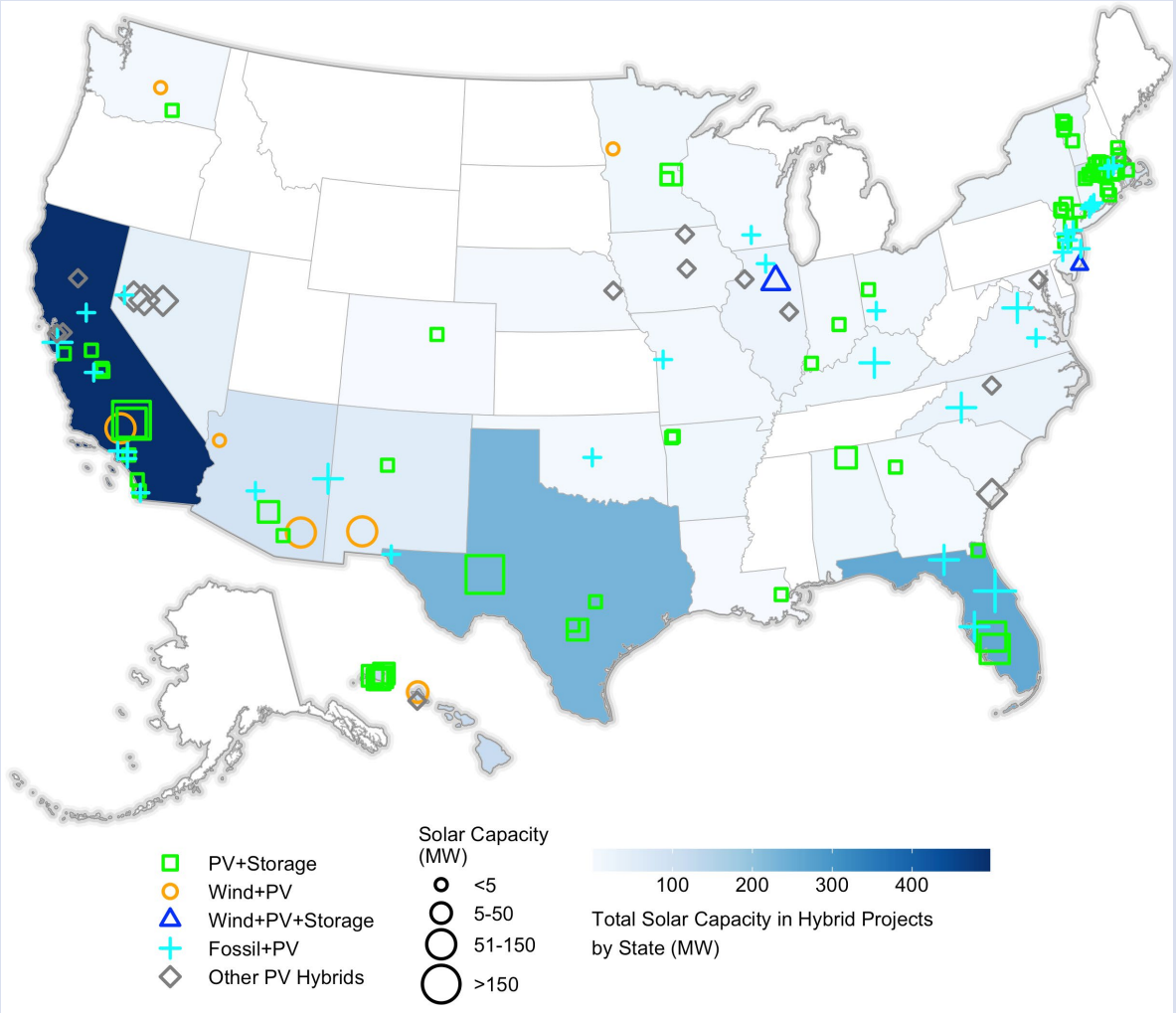
PV+Storage median storage duration is highest at 2 hours



Sources: EIA 860 2020 Early Release, Berkeley Lab

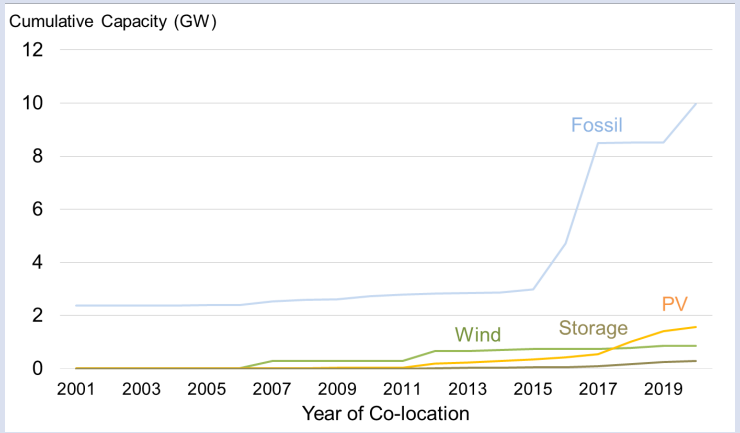
PV+Storage dominates the various PV+ hybrid configurations in terms of number of projects, PV capacity, and storage energy

Online PV Hybrid / Co-located Projects



Growth in PV Hybrid / Co-located Projects over Time

depicts amount of PV and other types of generation and storage being paired with PV, over time

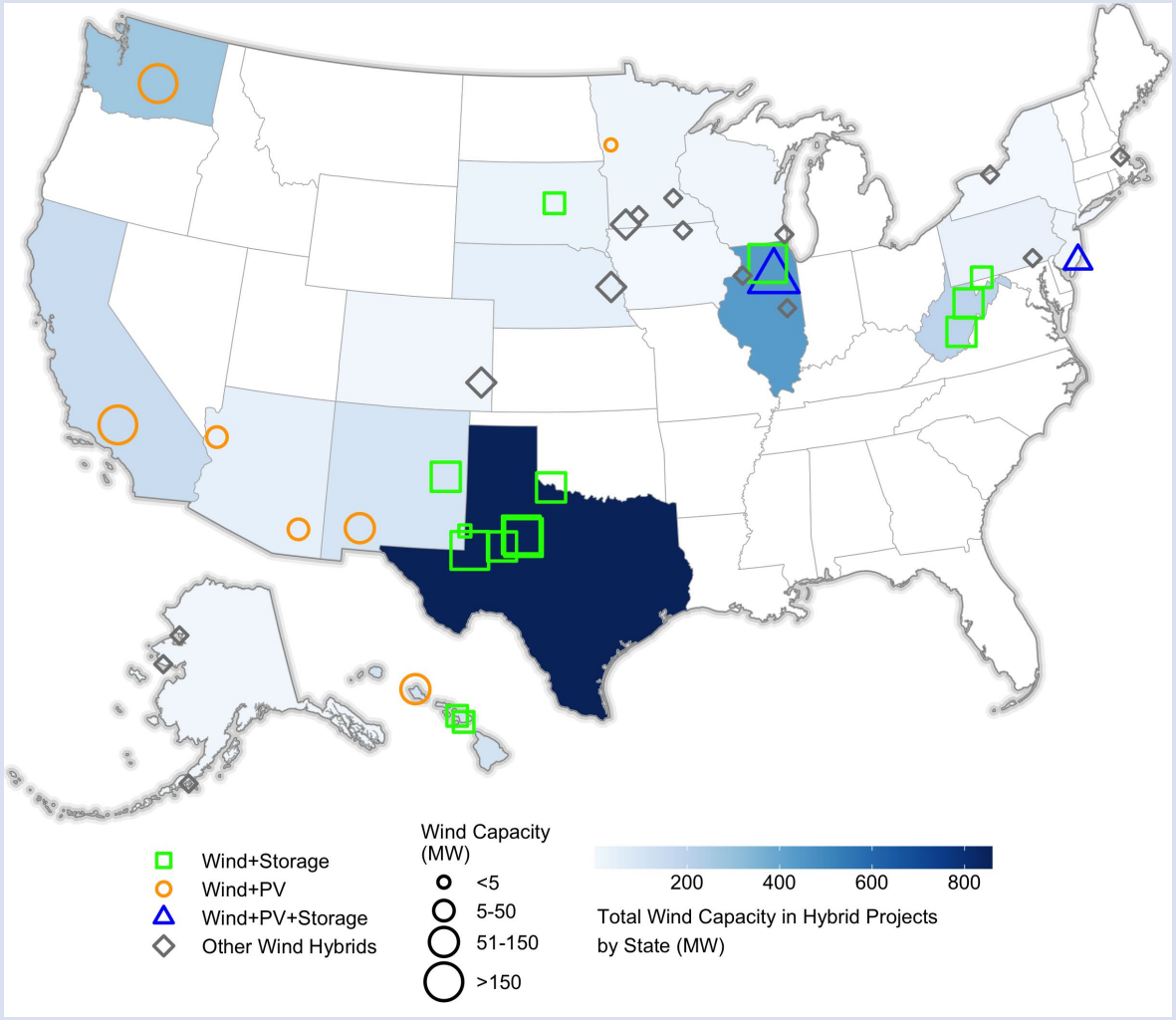


Note: Fossil+PV involve minor amount of PV added to larger fossil units at the point of interconnection: thus, the fossil category dominates this figure

Sources: EIA 860 2020 Early Release, Berkeley Lab

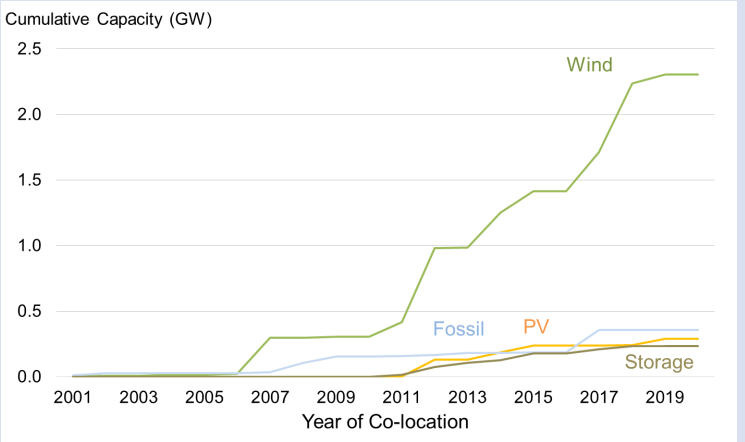
Wind+Storage dominates the various Wind+ hybrid configurations in terms of number of projects, wind capacity, and storage energy

Online Wind Hybrid / Co-located Projects



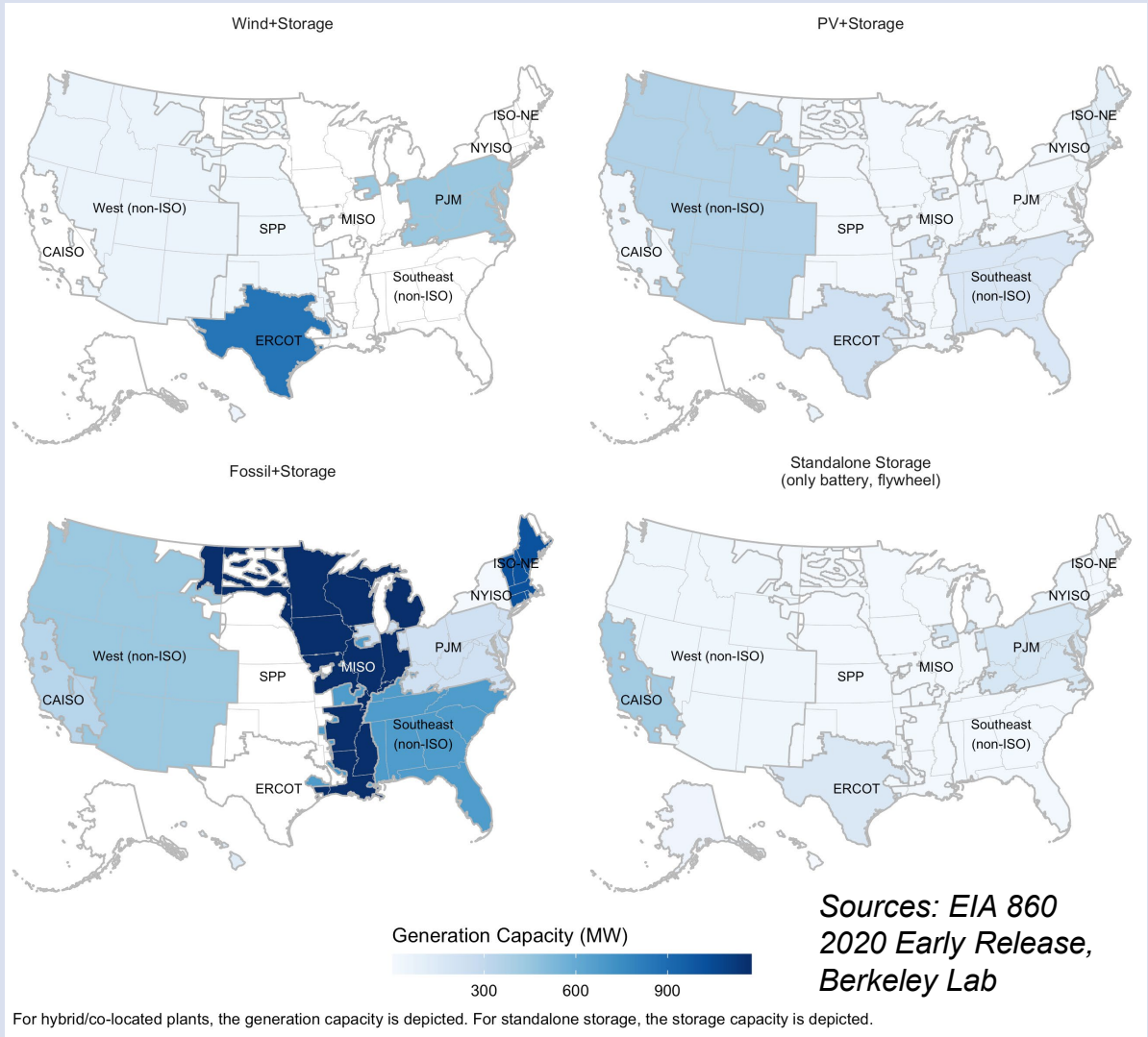
Growth in Wind Hybrid / Co-located Projects over Time

depicts amount of wind and other types of generation and storage being paired with wind, over time



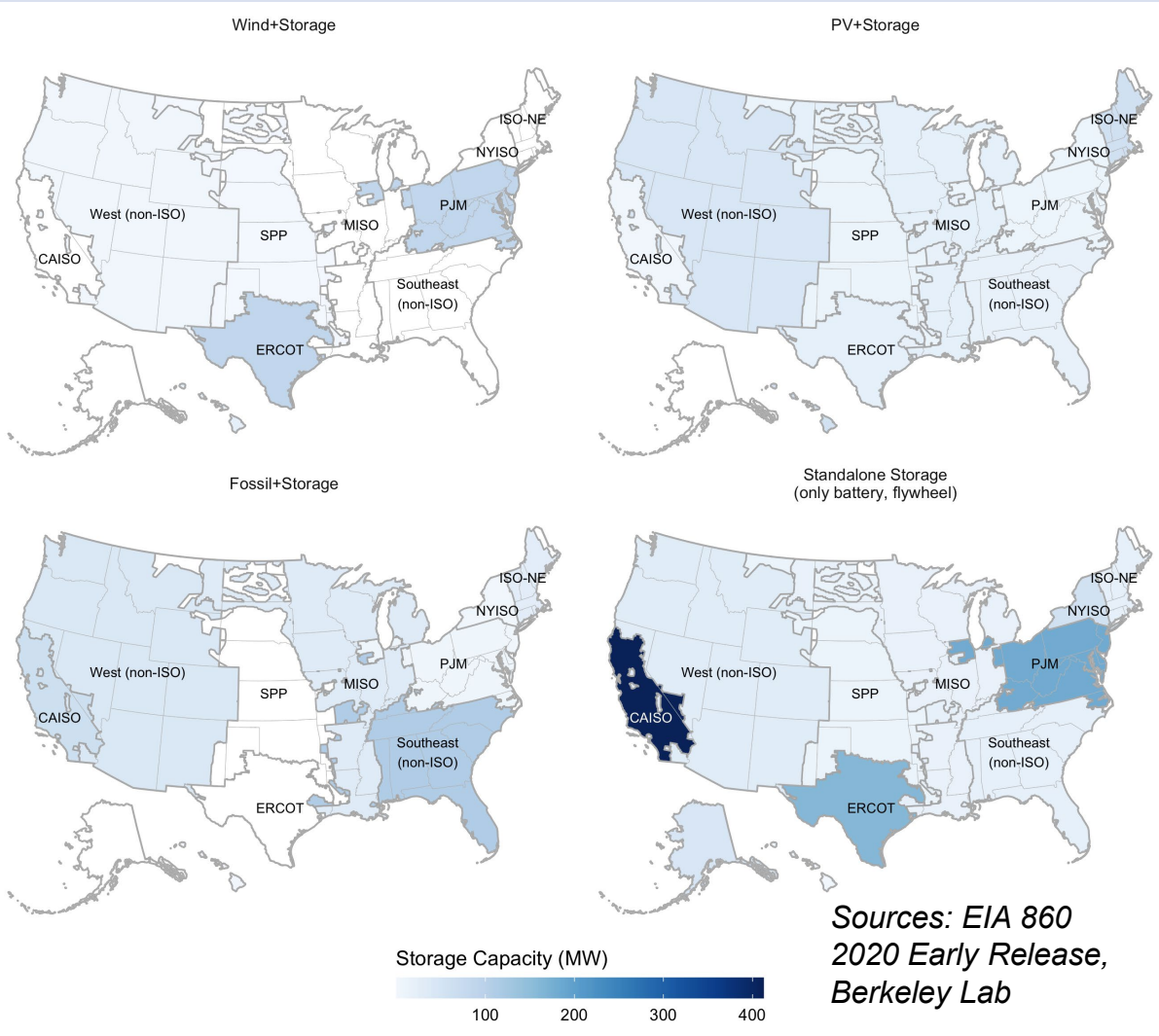
Sources: EIA 860 2020 Early Release, Berkeley Lab

Generator + storage hybrid / co-located projects at end of 2020, compared to subset of standalone storage technologies



- **Wind+storage** plants located primarily in ERCOT and PJM so far
- **PV+storage** plants located primarily in non-ISO West, ERCOT, and Southeast
- **Fossil+storage** plants located primarily in MISO and ISO-NE
- **Standalone storage** (ex. pumped hydro) largely in CAISO, PJM, ERCOT

Standalone storage (even excluding pumped hydro) capacity exceeds the storage capacity included in existing hybrids



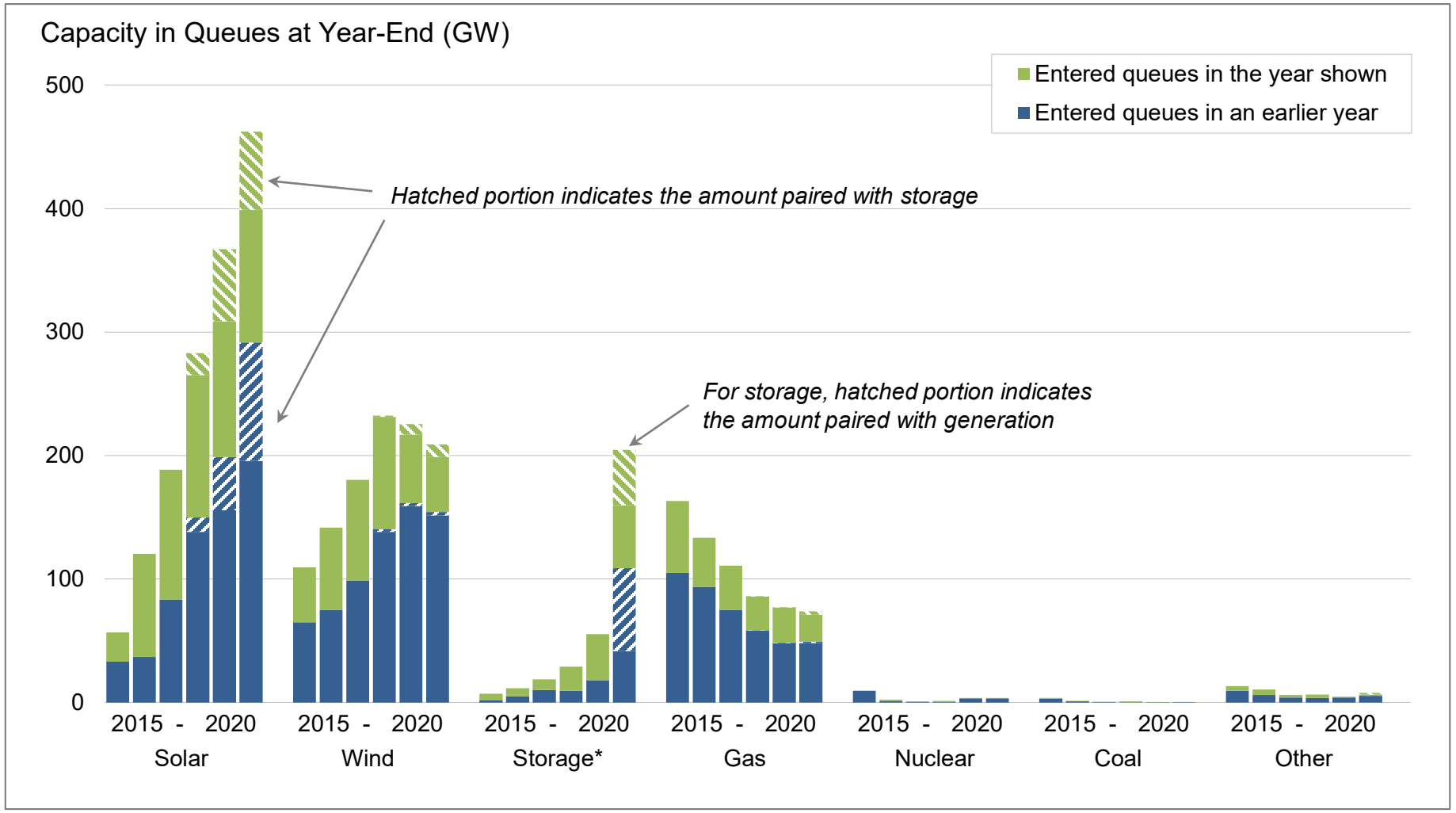
- Standalone storage capacity (battery and flywheel, excluding pumped hydro) **is greatest** in CAISO, PJM, ERCOT
- Standalone storage capacity **exceeds** storage capacity included in wind+storage, PV+storage, and fossil+storage hybrids
- Storage capacity included in hybrids **is located roughly in proportion** to where the hybrid plants are located

Longer-term Pipeline: Interconnection queues at end of 2020

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
- Hybrid / co-located projects identified via either of these two methods:
  - “Generator Type” field includes multiple types for a single queue entry (row)
  - Two or more queue entries (of different generator types) that share the same point of interconnection and sponsor, queue date, ID number, and/or COD
- Storage capacity for hybrids (i.e., broken out from generator capacity) was only available for a subset of proposed hybrid projects
  - For the remainder, storage capacity was estimated using known storage:generator ratios from other projects
- Note that being in an interconnection queue does not guarantee ultimate construction: majority of plants are not subsequently built

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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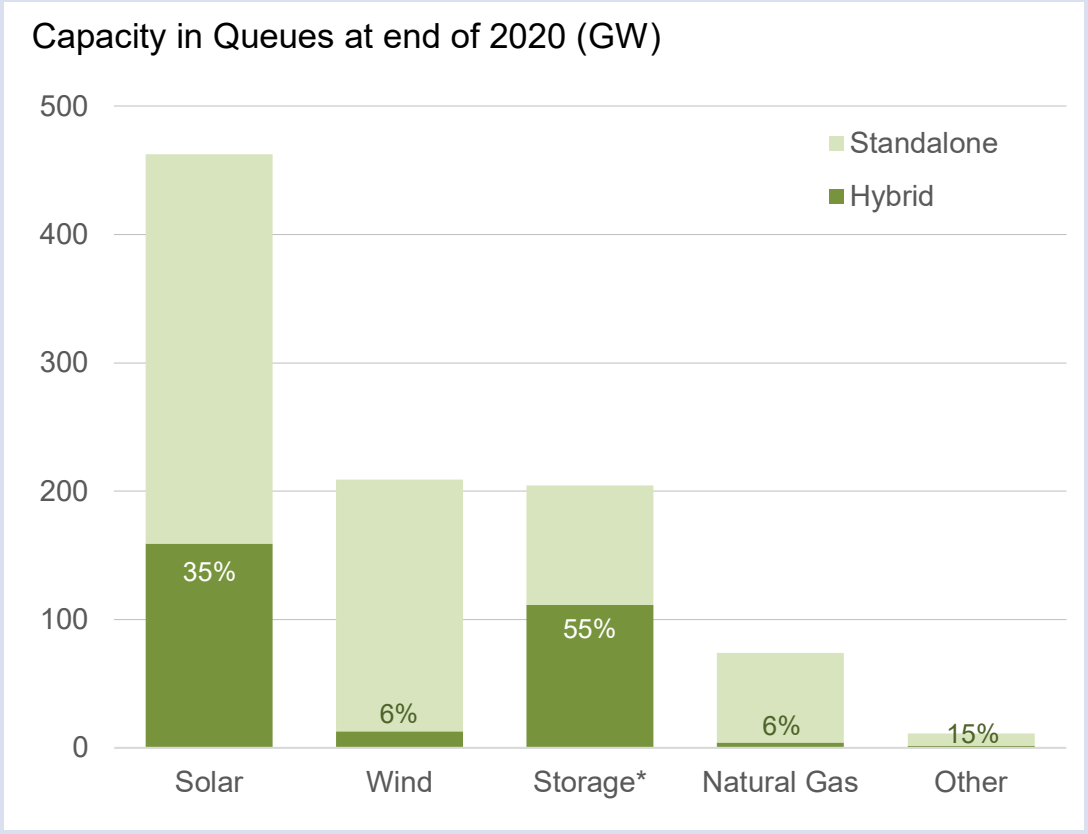
Numerous hybrid configurations exist in the queues, but Solar+Battery is dominant in both number of projects and total capacity

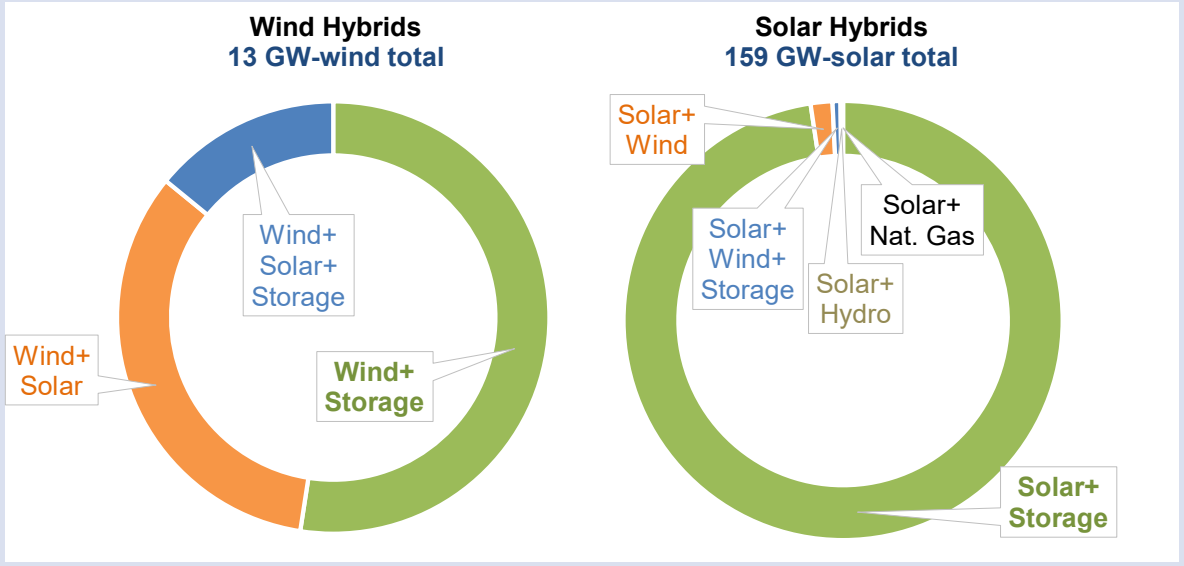
Hybrid Type	Number of Projects	Generator(s) Capacity (MW)
Solar+Battery	830	155,483
Solar+Wind	12	6,982
Wind+Battery	21	6,938
Solar+Wind+Battery	7	2,795
Gas+Battery	7	2,109
Gas+Solar	12	2,052
Other+Battery	2	1,032
Solar+Hydro	1	200
Gas+Solar+Battery	2	unknown
Pumped Storage+Wind+Solar	1	unknown
Other+Other Storage	1	unknown
TOTAL	896	177,591

- Almost 93% of all hybrid projects are Solar+Battery, representing nearly 88% of all known hybrid capacity in the queues
- The next two largest configurations - Solar+Wind and Wind+Battery - each account for only 4% of known hybrid capacity in the queues

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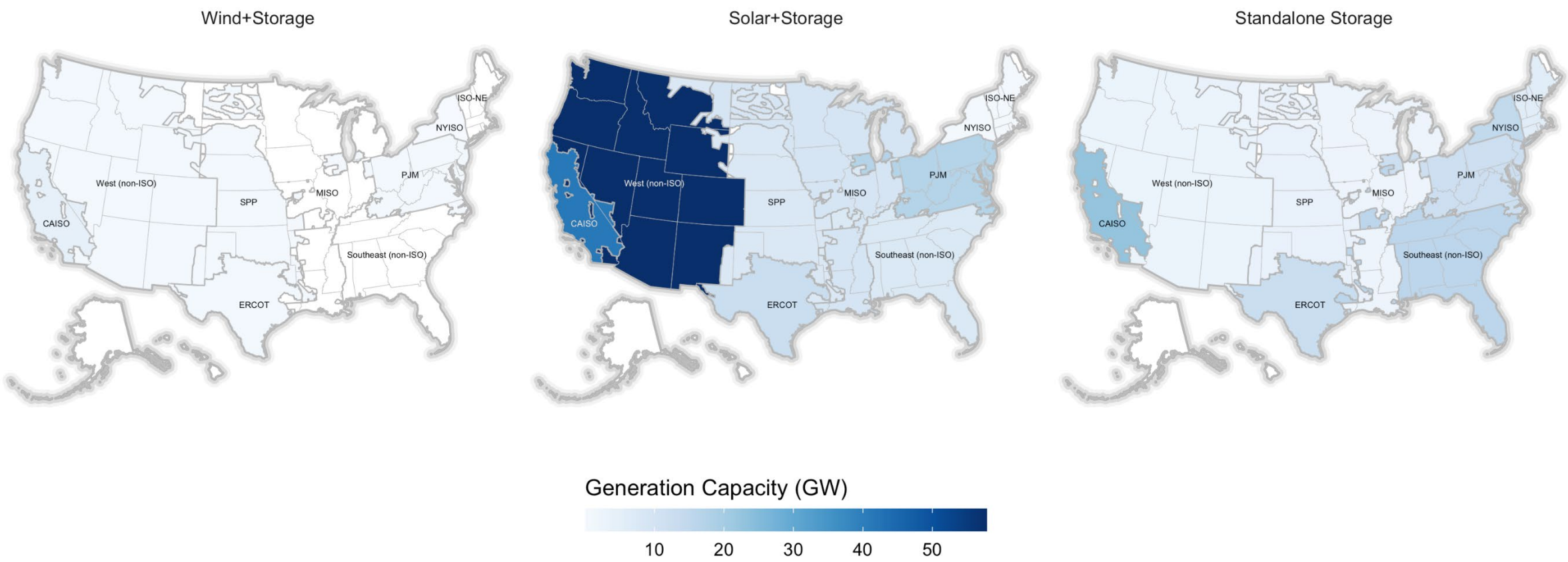
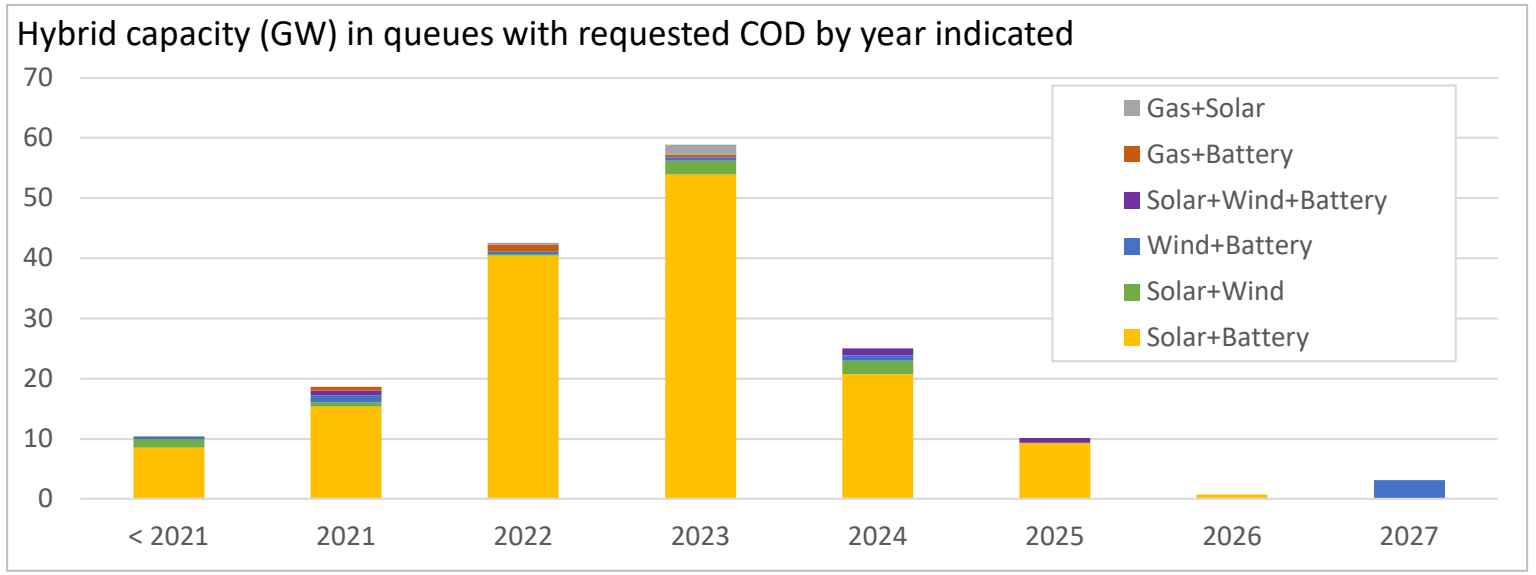
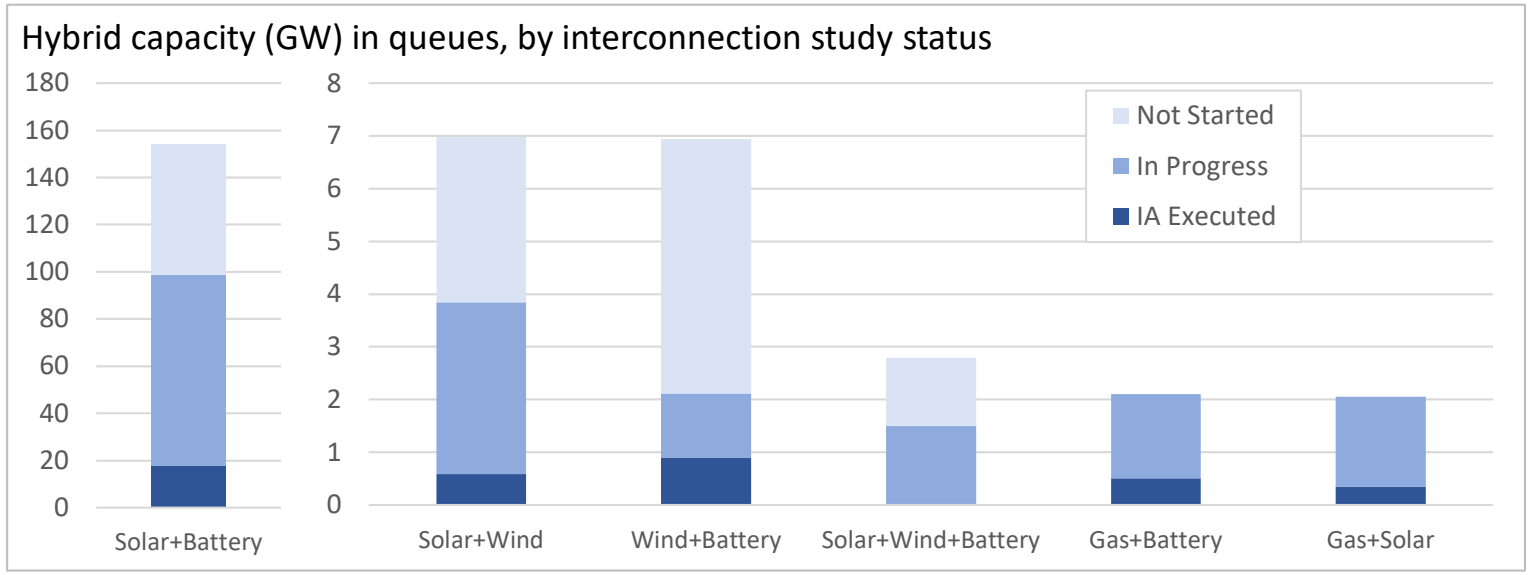
Solar+storage is dominant hybrid type in queues, wind+storage is much less common; CAISO & West of greatest interest so far



Note: Not all of this capacity will be built

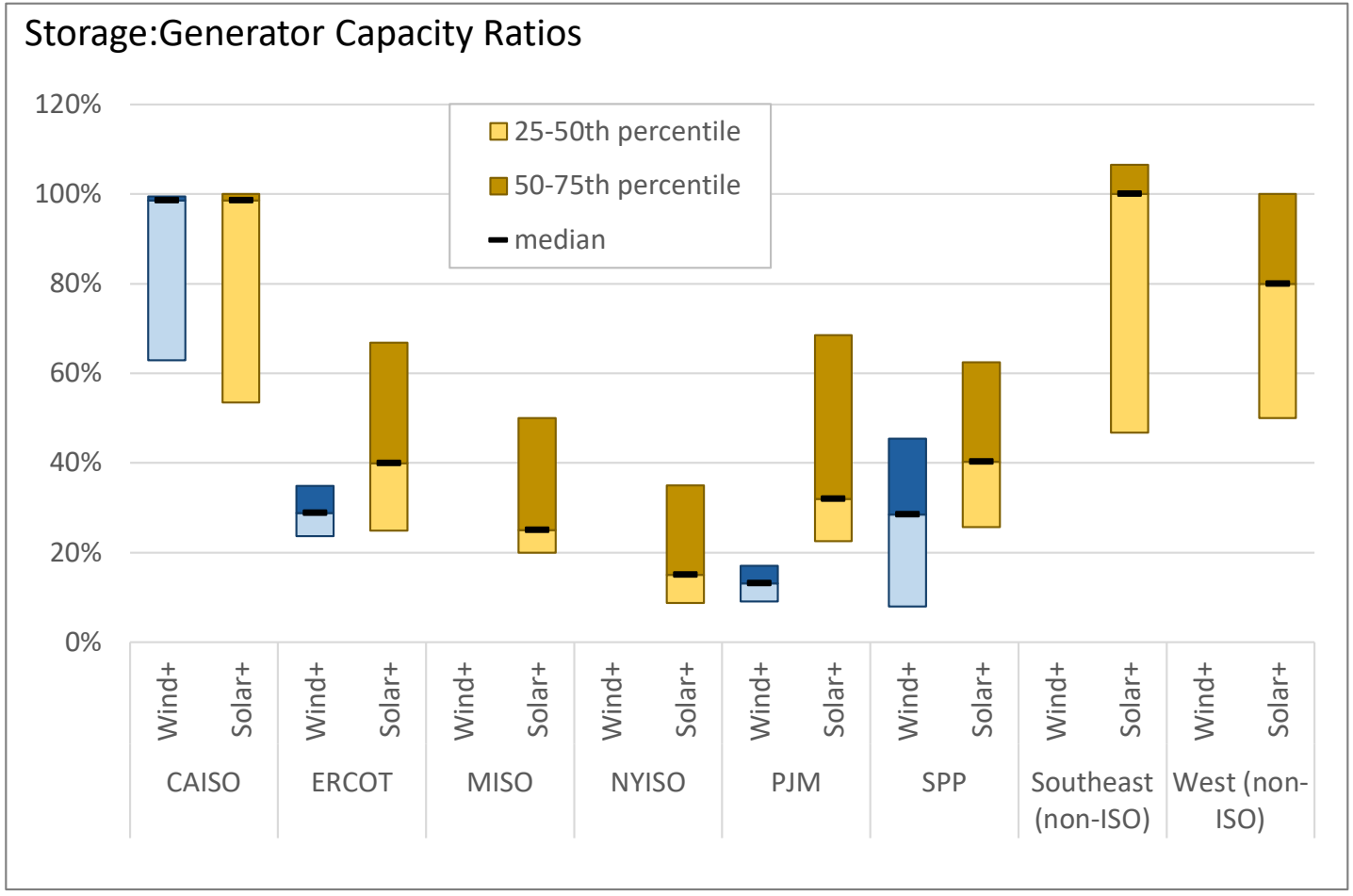
The majority (75%) of hybrid (generator) capacity in the queues has requested to come online by the end of 2023; 11% has an executed interconnection agreement (IA)





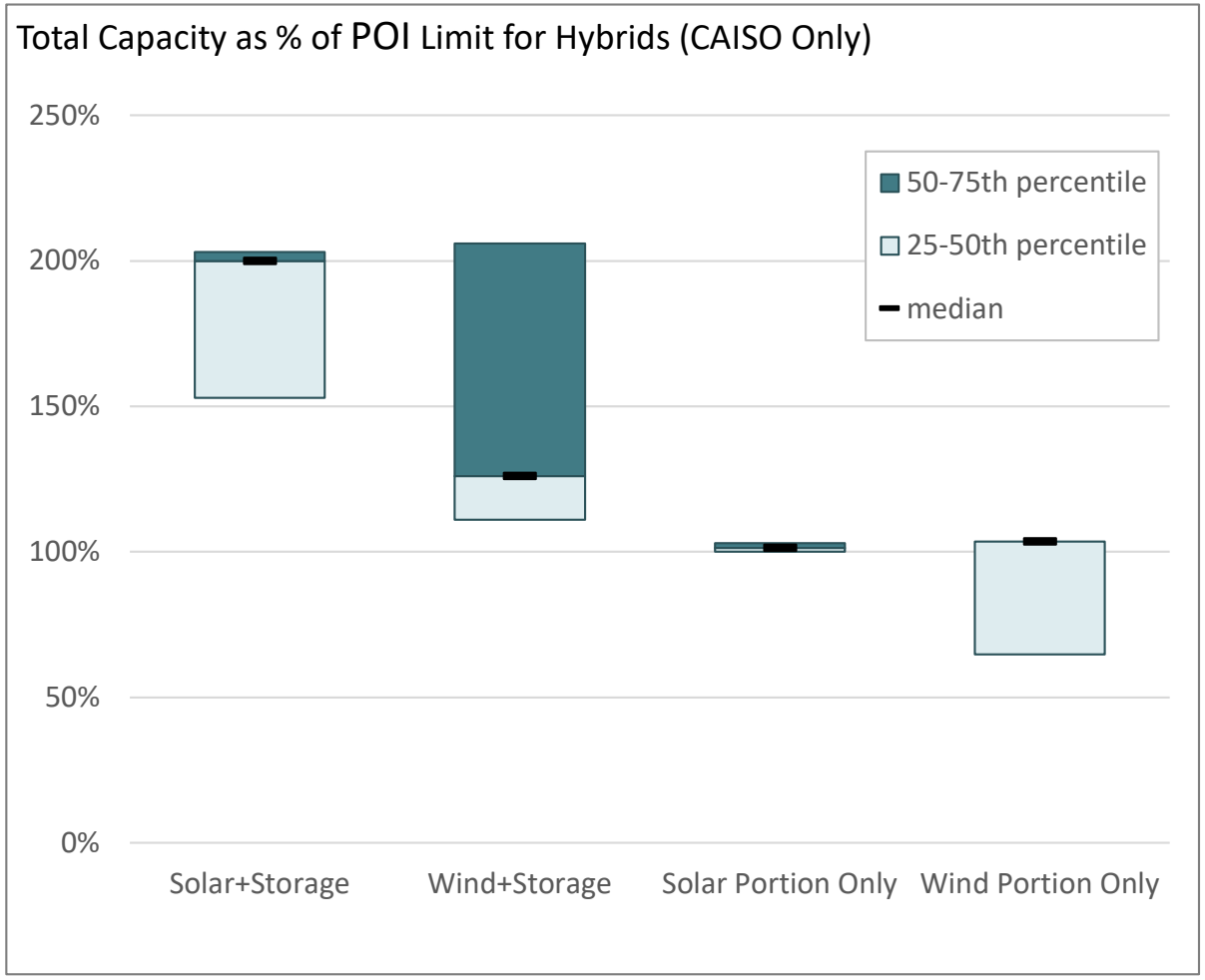
- Nearly all hybrid capacity in the queues is requesting to come online before 2026
- Solar+Battery dominates requested hybrid capacity additions through 2026
- Nearly 20 GW of Solar+ Battery has an executed IA, compared to <1 GW of each of the other hybrid types
- Proportions of interconnection status are similar across types

Solar+storage projects typically feature a higher storage contribution than wind+storage



- 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.
- The ratios shown here for proposed projects are higher than those for existing projects of the same type.

POI limits are typically based on generator capacity (at least in CAISO)

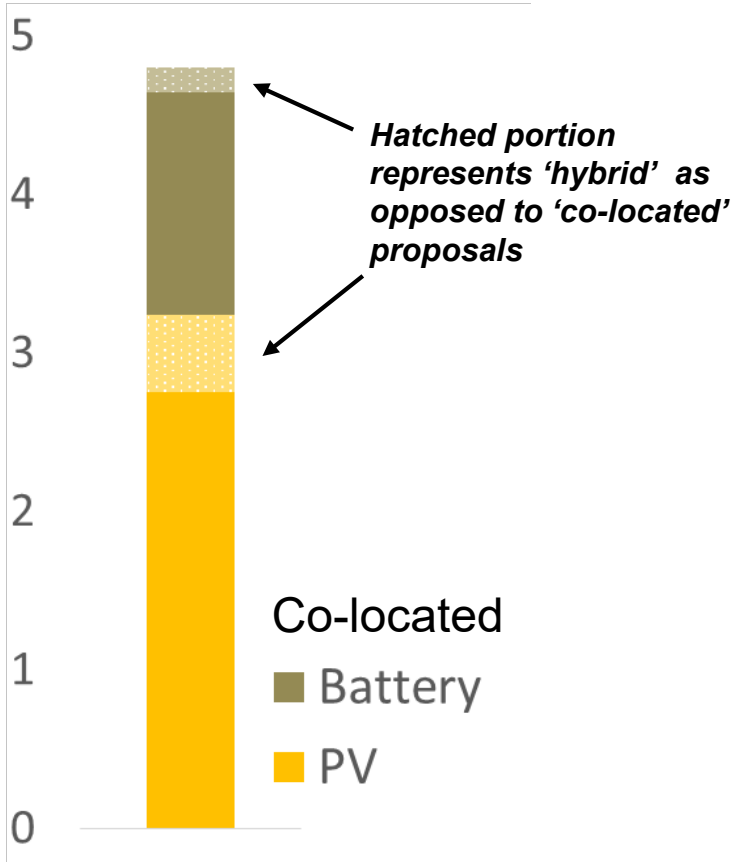


- Point of interconnection (POI) capacity limits were only provided in CAISO's queue
- For solar+storage projects, the solar capacity alone equals or exceeds the POI limit in 91% of projects, and the median combined (solar+storage) capacity is double (200%) the POI limit
- For wind+storage projects, 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

CAISO data on near-term solar+storage pipeline suggests popularity of 'co-location' rather than 'hybrid' model

- **Co-located model** involves distinct modeling and dispatch instructions for individual resources behind shared interconnection
- **Hybrid model** involves single bidding approach for multiple resources behind shared interconnection (e.g. no separate renewable resource forecast and dispatch)
- Difficult to evaluate how near-term pipeline correlates with the significantly larger queue of projects
  - Near-term pipeline projects are **more certain** than interconnection queue projects
  - However, there are roughly **80 GW** in the CAISO queue compared to the **5 GW** near-term pipeline of projects shown in graph to the right

CAISO expected solar+storage capacity by 2024 (GW)



Note: For further reading on participation models, see section 5 of prior LBNL report: https://emp.lbl.gov/publications/motivations-and-options-deploying

Source: CAISO. 2021. Forecasting Evolution with Hybrid Resources from the ISO Point of View.

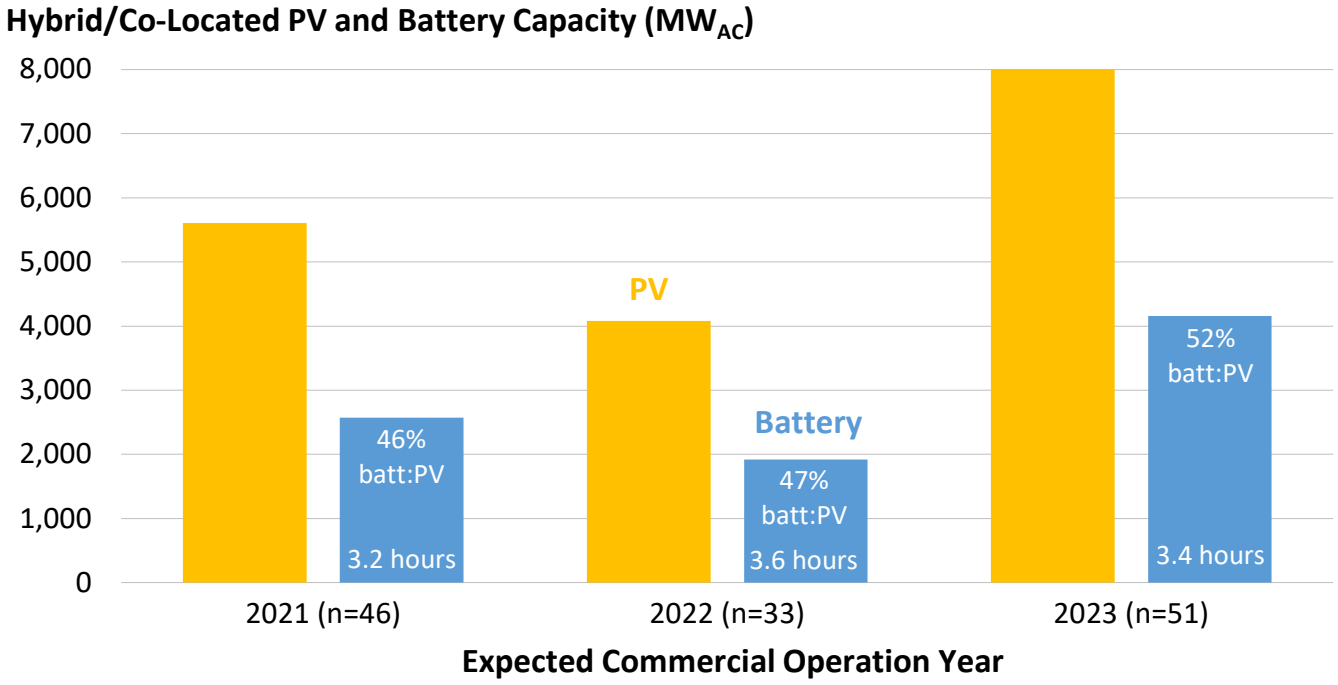
Nearer-term Pipeline:
PV+battery plants in development that have secured offtake

This section digs deeper for more plant-level detail than the queues provide

- The queue data presented in the previous section has the advantage of being comprehensive (in that entering the queues is a necessary step in the development process), but also has some limitations:
  - The queues don't provide much plant-level detail besides capacity, location, and desired interconnection date
  - Many projects in the queues are speculative (low completion rate)
- To get a better sense of what the near-term pipeline looks like, we track data on PV+battery hybrids that have announced offtake arrangements
  - Limited to PV+battery projects, given that they make up the vast majority of hybrid activity to date
  - Includes both IPP-owned projects with power purchase agreements (PPAs) and utility-owned projects
  - Securing an offtaker is a critical step towards raising financing—providing greater confidence that we're looking at "real" rather than "speculative" projects
- We focus on PV+battery plants where the PV capacity is at least 5 MW_{AC} and the battery duration is at least 1.0 hour (weeding out small plants with limited storage)

Sample of 134 projects in 19 states totaling 18.6 GW_{AC} of PV and 9.2 GW_{AC} of batteries reveals longer storage durations and higher battery-to-PV capacity ratios

State	Sample Count	Capacity (MW_{AC}) PV	Capacity (MW_{AC}) Battery	Battery Storage Duration	Battery Storage MWh	Battery:PV Capacity
AR	1	100	10	3.0	30	10%
AZ	13	691	578	3.6	2,083	84%
CA	39	5,418	3,203	3.8	12,173	59%
CO	5	652	256	4.0	1,017	39%
FL	3	170	439	2.2	960	259%
GA	2	409	108	2.0	221	26%
HI	18	702	702	4.1	2,863	100%
IN	3	735	165	3.0	495	22%
KY	1	173	30	4.0	120	17%
MO	3	30	9	4.0	34	28%
MS	2	400	100	4.0	400	25%
NC	1	5	10	1.0	10	200%
NE	1	9	1	2.0	2	12%
NM	7	861	435	3.9	1,710	51%
NV	13	2,974	1,663	4.0	6,667	56%
NY	6	1,093	90	4.0	360	8%
TX	11	3,358	1,029			31%
VA	2	37	14	3.7	52	38%
WI	3	750	350	4.0	1,400	47%
Total	**134**	**18,565**	**9,191**	**3.4**	**30,597**	**50%**



Overall weighted-average battery duration of 3.4 hours and battery:PV capacity of 50% is higher than the 2.6 hours and 25% for existing plants shown earlier (on slides 7 and 9)

- Most battery capacity is in CA, NV, TX, HI; most projects expecting to reach COD pre-2024
- Could not find battery duration for all TX projects (but short in some cases: 1.0-1.4 hours)
- See Appendix for details on individual plants

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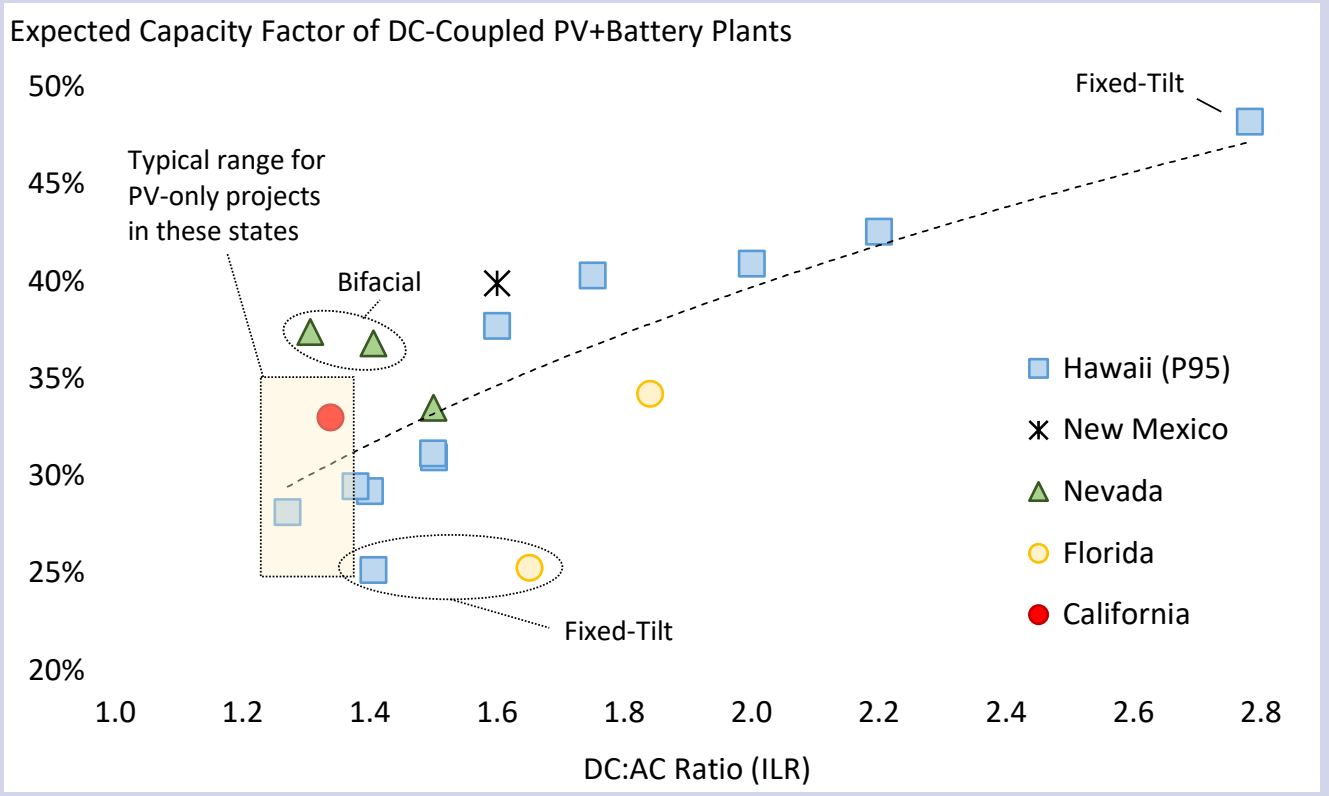
A subset of DC-coupled plants will employ very high DC:AC ratios and store the otherwise-clipped power, leading to higher AC capacity factors

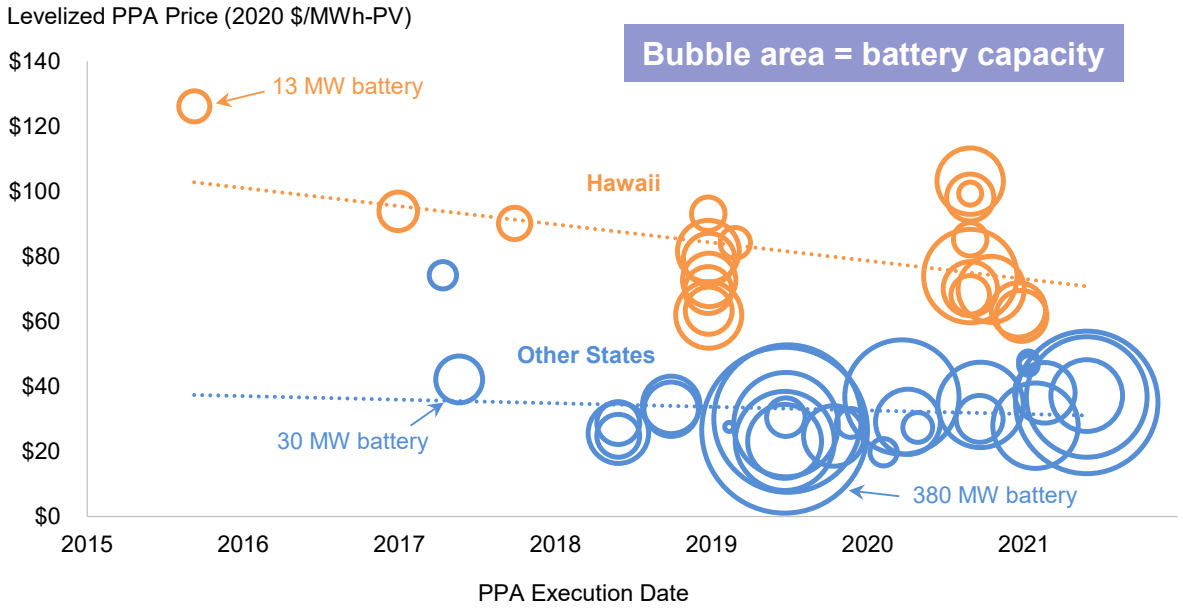
- For PV-only (no storage) plants with single-axis tracking, we typically see DC:AC of ~1.3 and AC capacity factors that top out at ~35% for the very best sites (see utilityscalesolar.lbl.gov)
- But for DC-coupled PV+battery plants, we sometimes see much higher DC:AC and expected AC capacity factors >40% (see graph)

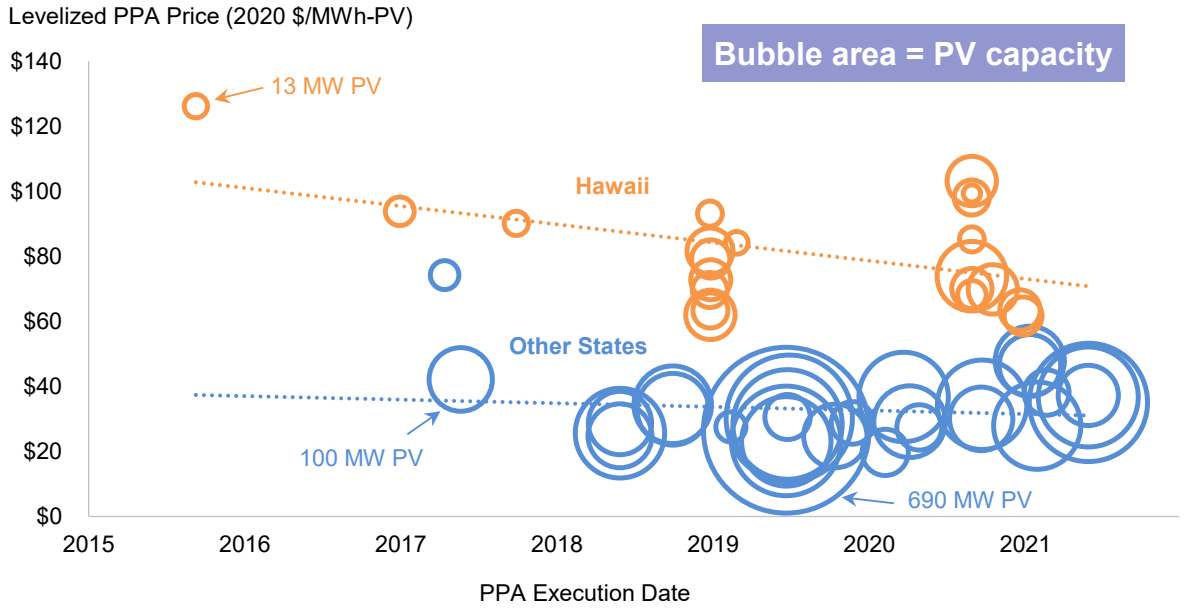
- Graph shows an 18-project sub-sample in 5 states, totaling 1.9 GW_{AC} PV and 1.1 GW_{AC} battery
- Battery:PV capacity ratios in graph range from 5% (Florida) to 100% (all Hawaii), with a mean of 77% (median of 100%)
- Durations in graph range from 2-8 hours, with a mean of 4.2 (median of 4.0 hours)
- **Important note:** Hawaii capacity factors in graph are based on P95 output—a more-typical P50 capacity factor would be even higher (though at very high DC:AC, the P95 is likely closer-than-normal to the P50)



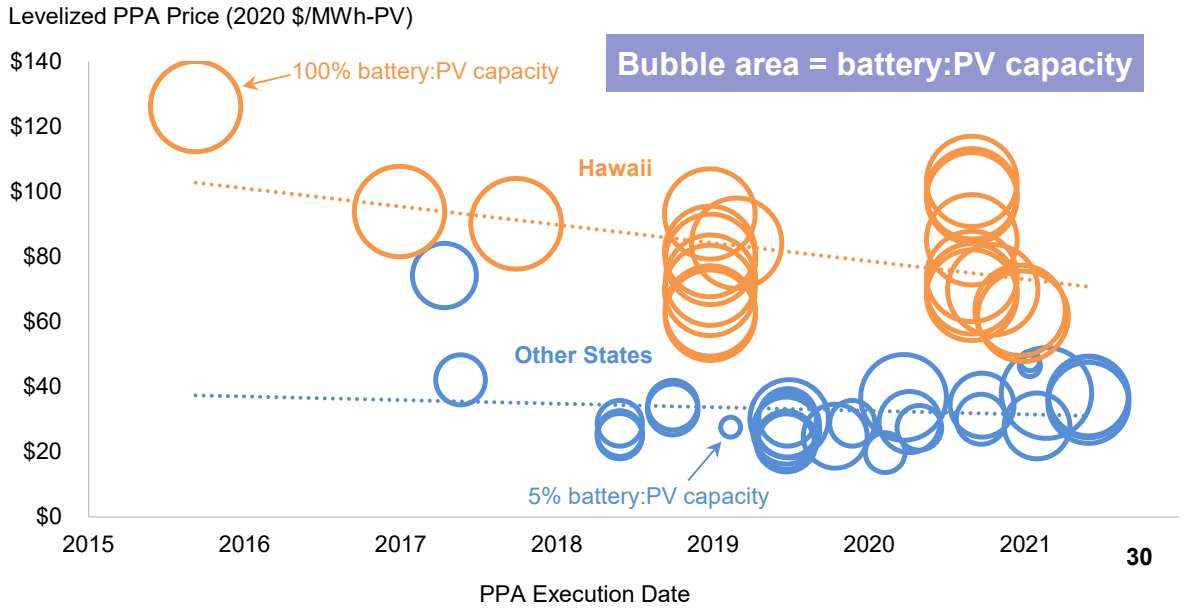
Note: All projects not flagged as fixed-tilt use single-axis tracking

PPA prices for PV+battery have declined over time; Hawaii priced at a premium

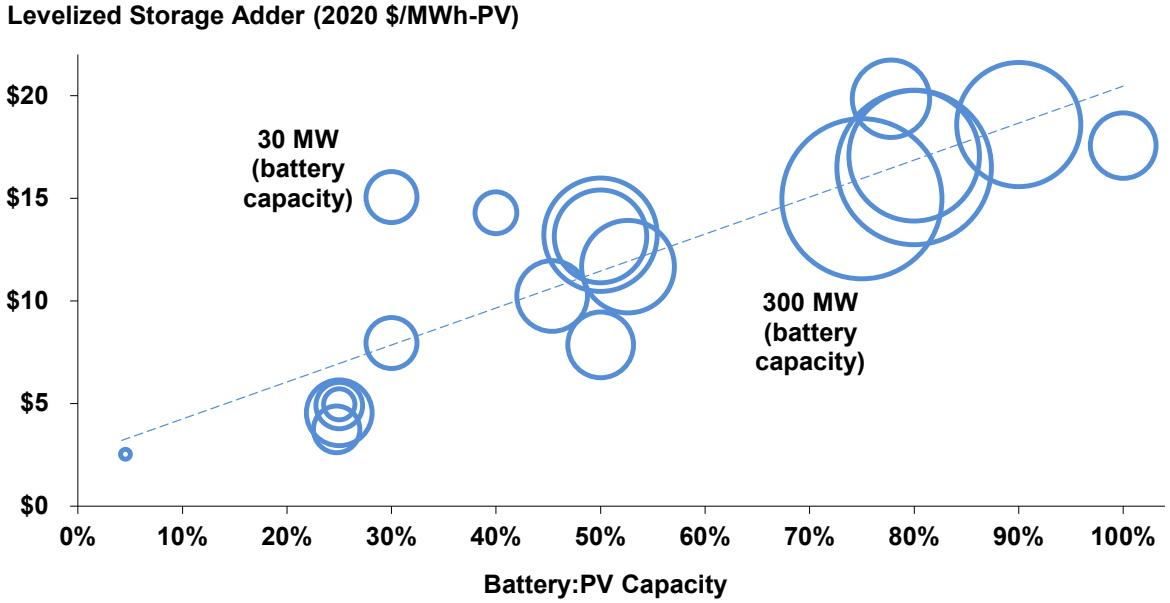


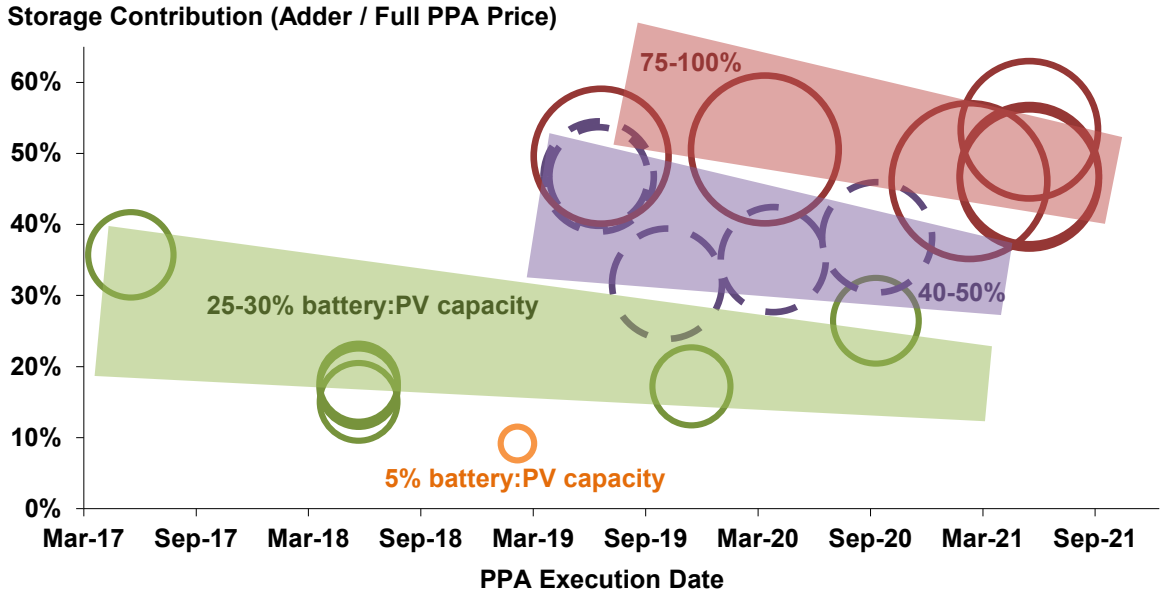


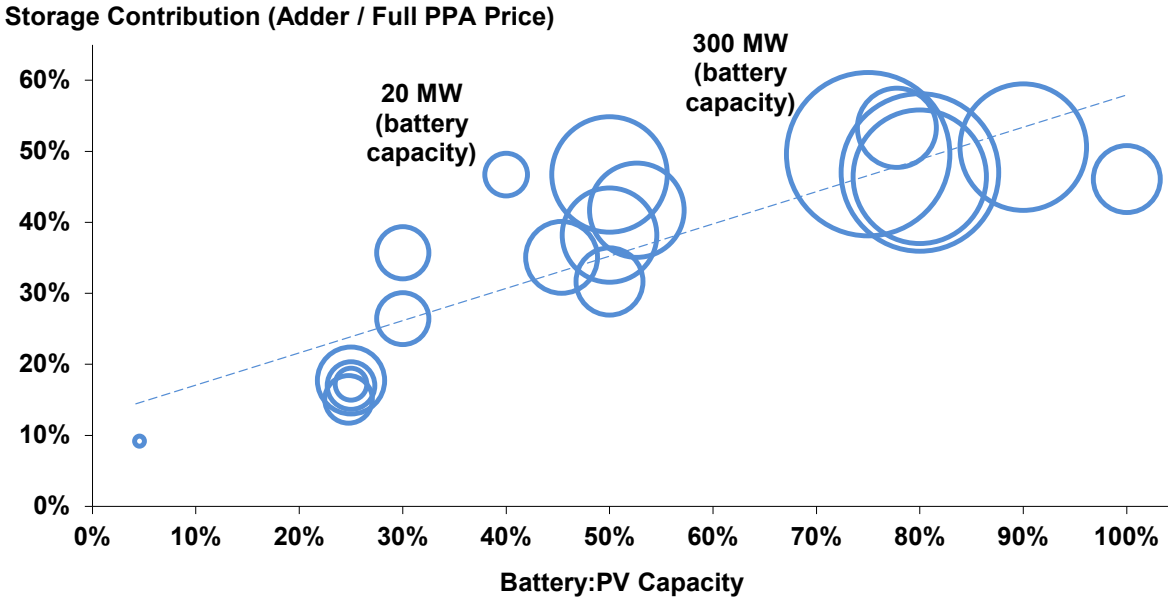
- All three graphs show the same data from a sub-sample of 50 plants; the only difference is what the bubble size represents
- Downward trend over time, particularly in HI, but refinement is complicated by multi-dimensionality of these plants; “Other States” (in blue) are more heterogenous than HI in terms of solar resource
- Battery:PV capacity ratio always at 100% in HI; lower on the mainland
- Battery duration ranges from 2-8 hours; 46 of the 50 plants shown have durations ≥4 hours (other 4 are 3.8, 2, 2, and 2 hours)



PPAs that price the PV and storage separately enable us to calculate a "levelized storage adder"—which depends on the battery:PV capacity ratio







- The "levelized storage adder"—*expressed in the top-left graph in $/MWh-PV, not $/MWh-stored*—increases linearly with the battery:PV capacity ratio: ~$5/MWh-PV at 25% battery:PV capacity, ~$10/MWh at 50%, ~$20/MWh at 100%
- Bottom-left graph presents the storage adder as a percentage of the full PPA price (i.e., storage's contribution to the overall price)
- Top-right graph shows storage's contribution holding fairly steady, and a trend toward larger battery:PV capacity, over time
- Except for the smallest plant (5% battery:PV capacity, 2-hour duration), all other plants shown have 4-hour storage

Conclusions

Conclusions

As of the end of 2020, there were over 29 GW of existing hybrid / co-located projects, and more than 177 GW in the development pipeline across the U.S.

- The overall market for hybrid / co-located projects remains limited. The installed generator capacity for hybrids increased by 2.3 GW from 2019 to 2020. The majority of new 2020 projects—28 out of 38—were PV+storage.
- There are many different hybrid configurations currently operating. PV+storage projects are most common (by count), whereas fossil hybrids (such as fossil+PV or fossil+storage) are dominant in terms of generator capacity.
- Proposed solar+battery capacity accounts for more than 7 times the combined generator capacity of all other proposed hybrid configurations in interconnection queues as of the end of 2020.
- The near-term pipeline for solar+battery projects is particularly strong. Nearly 18 GW of solar+battery projects already have a signed interconnection agreement, and a similar amount have secured an offtaker (note that these two groups likely overlap).
- Storage:generation ratios and storage durations tend to be higher for installed PV+storage plants than for other types, and are higher still for proposed PV+storage projects than for existing plants.
- Hybrid projects have been installed in all regions of the U.S., but current commercial interest is concentrated in CAISO and the non-ISO West.
- For PV+battery projects that have secured offtake agreements, PPA prices have declined over time despite increasing (on the mainland) or stable (in Hawaii) battery:PV capacity ratios.

Appendix: Detail of PV+battery projects with offtake (1 of 4)

State	Project Name	Project Sponsor	Power Offtaker	Expected COD (PV/Battery)	Capacity (MW_{AC})		Battery Storage		Battery:PV Capacity
					PV	Battery	Duration	MWh	
AR	Searcy	NextEra / Entergy	Entergy	Dec-21	100	10	3.0	30	10%
AZ	Cotton Center	APS/Invenergy	APS	Nov-11/Dec-22	17	17	3.0	51	100%
AZ	Desert Star	APS/Invenergy	APS	Jun-15/Dec-22	10	10	3.0	30	100%
AZ	Foothills	APS/Invenergy	APS	Mar-13/Dec-22	35	35	3.0	105	100%
AZ	Gila Bend	APS/Invenergy	APS	Oct-14/Dec-22	32	32	3.0	96	100%
AZ	Hyder	APS/Invenergy	APS	Oct-11/Dec-22	16	16	3.0	48	100%
AZ	Hyder II	APS/Invenergy	APS	Jan-13/Dec-22	14	14	3.0	42	100%
AZ	Paloma	APS/Invenergy	APS	Sep-11/Dec-22	17	17	3.0	51	100%
AZ	Mesquite Solar 4	ConEd Development	Modesto Irrigation District	Jul-23	52.5	10	4.0	40	19%
AZ	Sonoran Energy Center	NextEra	Salt River Project	Jul-23	250	250	4.0	1000	100%
AZ	Storey	NextEra	Salt River Project	Jul-23	88	88	3.0	264	100%
AZ	Wilmot	NextEra	TEP	Dec-21	100	30	4.0	120	30%
AZ	Chino Valley	TBD (12/20 RFP	APS	Dec-12/Jul-23	19	19	4.0	76	100%
AZ	Red Rock	TBD (12/20 RFP)	APS	Feb-17/Jul-23	40	40	4.0	160	100%
CA	Aratina	8minute Solar	MBCP and SVCE	Dec-23	200	50	3.0	150	25%
CA	Eland	8minute Solar	LADWP/Glendale	Dec-23	400	300	4.0	1200	75%
CA	Rexford 1	8minute Solar	Clean Power Alliance	Oct-23	300	180	3.0	540	60%
CA	Camino	Avangrid	Riverside	May-22	44	11	4.0	44	25%
CA	Jacumba Valley Ranch	BayWa	San Diego Community Power	Mar-23	90	70	4.0	280	78%
CA	Mustang	Canadian Solar/Goldman Sachs	SCP / MCE	2016/Jul-21	100	75	4.0	300	75%
CA	California Flats 130	Capital Dynamics	Apple/MBCP(RA)	Nov-17/Aug-21	130	60	4.0	240	46%
CA	Arica	Clearway	Clean Power Alliance	Dec-23	93.5	71	4.0	284	76%
CA	Daggett	Clearway Energy	Clean Power Alliance	Mar-23	123	61.5	4.0	246	50%
CA	Daggett 2	Clearway Energy	Clean Power Alliance	Sep-23	65	52	4.0	208	80%
CA	Maverick 6	EDF-RE	CleanPowerSF	Dec-21	100	100	2.0	200	100%
CA	BigBeau	EDF-RE / Masdar	MBCP and SVCE	Dec-21	128	40	4.0	160	31%
CA	Desert Harvest II	EDF-RE / Masdar	SCPPA	Jan-21	70	35	4.0	140	50%
CA	Sonrisa	EDPR	SJCE & EBCE	Dec-22	200	40	4.0	160	20%
CA	Rabbitbrush	First Solar	MBCP and SVCE	Jun-22	100	20	2.5	50	20%
CA	High Desert	Middle River Power	Clean Power Alliance	Aug-21	100	50	4.0	200	50%
CA	Arlington	NextEra	Clean Power Alliance	Oct-22	233	132	4.0	528	57%
CA	Blythe 110	NextEra	PG&E	Apr-16/Aug-21	110	63	4.0	252	57%
CA	Blythe 2	NextEra	SoCalEd	Oct-16/Aug-21	131.2	115	4.0	460	88%
CA	Blythe 3	NextEra	SoCalEd	May-20/Aug-21	136.8	115	4.0	460	84%

Like in Hawaii, many Arizona projects are at parity in terms of PV and battery capacity.

Reflects relatively high solar market share, and perhaps the opportunity to charge up mid-day while being paid (via negative prices in the EIM) to take excess CA solar generation.

Appendix: Detail of PV+battery projects with offtake (2 of 4)

State	Project Name	Project Sponsor	Power Offtaker	Expected COD (PV/Battery)	Capacity (MW_{AC})		Battery Storage		Battery:PV Capacity
					PV	Battery	Duration	MWh	
CA	Crow Creek	NextEra	CleanPowerSF	Dec-23	20	20	3.0	60	100%
CA	McCoy	NextEra	SoCalEd	Jun-16/Aug-21	270.6	230	4.0	920	85%
CA	Proxima	NextEra	Sonoma Clean Power	Dec-23	50	5	4.0	20	10%
CA	Resurgence Solar I	NextEra	Valley Clean Energy	2023/2024	90	75	4.0	300	83%
CA	Resurgence Solar II	NextEra	Clean Power Alliance	Mar-23	48	40	4.0	160	83%
CA	Chalan	Origis	Clean Power Alliance	Dec-23	64.9	25	4.0	100	39%
CA	Vikings Energy Farm	RAI Energy	San Diego Community Power	Jun-23	100	150	4.0	600	150%
CA	RE Slate 2	ReCurrent	MBCP and SVCE	Jun-21	150	45	4.0	180	30%
CA	Crimson	Recurrent/Canadian Solar	Southern California Edison	Aug-22	350	350	4.0	1400	100%
CA	RE Slate	Recurrent/Goldman	5 offtakers	Dec-21	300	140.25	4.0	561	47%
CA	Gibson	ReneSola	Valley Clean Energy	Jul-22	20	6.5	4.0	26	33%
CA	Azalea	Solar Frontier Americas	Clean Power Alliance	Dec-22	60	38	4.0	152	63%
CA	Garland	Southern Power	SoCalEd	Nov-16/Aug-21	205	88	4.0	352	43%
CA	Tranquility	Southern Power	SoCalEd	Sep-16/Aug-21	204	72	4.0	288	35%
CA	Estrella	sPower	Clean Power Alliance	Dec-22	56	28	4.0	112	50%
CA	Raceway	sPower	EBCE	Dec-22	125	80	2.0	160	64%
CA	Sanborn	Terra-Gen	SoCalEd	Aug-21	300	50	4.0	200	17%
CA	Deer Creek	Vesper Energy	Desert Community Energy	Jul-23	50	50	4.0	200	100%
CA	Vega	Zglobal	Amazon	Dec-22	100	70	4.0	280	70%
CO	Colorado Mountain College	Ameresco	Holy Cross Energy	Apr-22	5	5	3.0	15	100%
CO	Rawhide Prairie	DEPCOM Power	PRPA	Mar-21	22	1	2.0	2	5%
CO	Pike	juwi	Colorado Springs	Dec-23	175	25	4.0	100	14%
CO	Neptune	NextEra	Xcel / PSCo	Dec-22	250	125	4.0	500	50%
CO	Thunder Wolf	NextEra	Xcel / PSCo	Dec-22	200	100	4.0	400	50%
FL	Lake Placid	Duke Energy Florida	Duke Energy Florida	Dec-19/Dec-21	45	18	2.0	36	40%
FL	Manatee	NextEra / FPL	FPL	Dec-16/Nov-21	74.5	409	2.2	900	549%
FL	FL Solar 6	Origis	Gainesville Regional Utilities	Dec-22	50	12	2.0	24	24%
GA	Cool Springs	NextEra	Georgia Power	Dec-21	213	68	2.1	140.62	32%
GA	Broken Spoke (Hickory Park)	RWE Renewables	Georgia Power	Dec-21	195.5	40	2.0	80	20%
HI	Ho'Ohana Solar 1	174 Power Global	Hawaiian Electric	Dec-21	52	52	4.0	208	100%
HI	AES Waikoloa Solar	AES	Hawaiian Electric	Jul-21	30	30	4.0	120	100%
HI	Kuihelani Solar	AES	Hawaiian Electric	Jul-21	60	60	4.0	240	100%
HI	Mountain View	AES	Hawaiian Electric	2023	7	7	5.0	35	100%
HI	Waiawa Phase 2	AES	Hawaiian Electric	2023	30	30	8.0	240	100%
HI	West Kaua'i	AES	KIUC	2023	35	35	2.0	70	100%

All Hawaii projects are at parity in terms of PV and battery capacity—see next slide.

Appendix: Detail of PV+battery projects with offtake (3 of 4)

State	Project Name	Project Sponsor	Power Offtaker	Expected COD (PV/Battery)	Capacity (MW_{AC})		Battery Storage		Battery:PV Capacity
					PV	Battery	Duration	MWh	
HI	West Oahu	AES	Hawaiian Electric	Sep-21	12.5	12.5	4.0	50	100%
HI	Mililani I Solar	Clearway	Hawaiian Electric	Dec-21	39	39	4.0	156	100%
HI	Waiawa Solar	Clearway	Hawaiian Electric	Dec-21	36	36	4.0	144	100%
HI	Puako	Engie EPS	Hawaiian Electric	2023	60	60	4.0	240	100%
HI	Kupehau	Hanwha	Hawaiian Electric	Jun-22	60	60	4.0	240	100%
HI	Barbers Point	Innergex	Hawaiian Electric	2023	15	15	4.0	60	100%
HI	Hale Kuawehi	Innergex	Hawaiian Electric	Jun-22	30	30	4.0	120	100%
HI	Kahana	Innergex	Hawaiian Electric	2023	20	20	4.0	80	100%
HI	Paeahu	Innergex	Hawaiian Electric	Jun-22	15	15	4.0	60	100%
HI	Mahi	Longroad	Hawaiian Electric	2023	120	120	4.0	480	100%
HI	Pulehu	Longroad	Hawaiian Electric	2023	40	40	4.0	160	100%
HI	Kamaole	SB Energy	Hawaiian Electric	2023	40	40	4.0	160	100%
IN	Greensboro Solar	NextEra	NIPSCO	Jul-23	100	30	3.0	90	30%
IN	Cavalry Solar	NextEra/NIPSCO	NIPSCO	Dec-23	200	60	3.0	180	30%
IN	Dunns Bridge II	NextEra/NIPSCO	NIPSCO	Dec-23	435	75	3.0	225	17%
KY	Logan County	Silicon Ranch	TVA (Facebook, GM)	Dec-23	173	30	4.0	120	17%
MO	Green City Renewable Energy Center	Ameren Missouri	Ameren Missouri	Dec-21	10	2.5	4.0	10	25%
MO	Richwoods Renewable Energy Center	Ameren Missouri	Ameren Missouri	Dec-21	10	4	4.0	16	40%
MO	Utica Renewable Energy Center	Ameren Missouri	Ameren Missouri	Dec-21	10	2	4.0	8	20%
MS	Clay County, MS	Origis	TVA (Knoxville Utility Board)	Dec-23	200	50	4.0	200	25%
MS	Golden Triangle	Origis	TVA (Facebook)	Oct-23	200	50	4.0	200	25%
NC	Grissom Solar	Pine Gate Renewables	North Carolina EMC	Jun-21	5	10	1.0	10	200%
NE	Norfolk	N Solar	NPPD	Dec-21	8.5	1	2.0	2	12%
NM	Arroyo	Clenera	PNM	Jun-22	300	150	4.0	600	50%
NM	Jicarilla 1	Hecate	PNM	Apr-22	50	20	4.0	80	40%
NM	Buena Vista	NextEra	El Paso Electric	May-22	100	50	4.0	200	50%
NM	Sky Ranch	NextEra	PNM (Facebook)	Dec-23	190	100	4.0	400	53%
NM	San Juan Solar 1	Photosol	PNM	Jun-22	200	100	4.0	400	50%
NM	Angel Fire	Torch Clean Energy	Kit Carson Electric Co-op	Dec-21	6	3	2.0	6	50%
NM	Taos Mesa	Torch Clean Energy	Kit Carson Electric Co-op	Dec-21	15	12	2.0	24	80%
NV	Boulder Solar 3	174 Power Global	NV Energy	Dec-23	128	58	4.0	232	45%
NV	Southern Bighorn	8minute Solar	NV Energy	Sep-23	300	135	4.0	540	45%
NV	Iron Point	Avangrid/Primergy/NV Energy	NV Energy	Dec-23	250	200	4.0	800	80%
NV	Townsite	Capital Dynamics	Munis/Co-op	Dec-21	180	90	4.0	360	50%
NV	Battle Mountain	Cypress Creek	NV Energy	Jun-21	101	25	4.0	100	25%

All Hawaii projects are at parity in terms of PV and battery capacity.

Reflects a need to prevent any utility-scale PV generation from flowing to the grid mid-day, when rooftop systems are at max output, saturating the grid.

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Appendix: Detail of PV+battery projects with offtake (4 of 4)

State	Project Name	Project Sponsor	Power Offtaker	Expected COD (PV/Battery)	Capacity (MW_{AC})		Battery Storage		Battery:PV Capacity
					PV	Battery	Duration	MWh	
NV	Arrow Canyon (Moapa)	EDF-RE	NV Energy	Dec-22	200	75	5.0	375	38%
NV	Chuckwalla	EDF-RE	NV Energy	Dec-23	200	180	4.0	720	90%
NV	Dodge Flat	NextEra	NV Energy	Dec-21	200	50	4.0	200	25%
NV	Fish Springs Ranch	NextEra	NV Energy	Dec-21	100	25	4.0	100	25%
NV	Yellow Pine Energy Center	NextEra	MBCP and SVCE	Dec-22	125	65	4.0	260	52%
NV	Dry Lake	NV Energy	NV Energy	Dec-23	150	100	4.0	400	67%
NV	Hot Pot	Primergy/NV Energy	NV Energy	Dec-24	350	280	4.0	1120	80%
NV	Gemini	Quinbrook/Arevia	NV Energy	Dec-23	690	380	3.8	1460	55%
NY	South Ripley	ConnectGen	NYSERDA	Jun-23	270	20	4.0	80	7%
NY	Moraine	EDF-RE	NYSERDA	Jun-23	94	5	4.0	20	5%
NY	Tracy	EDF-RE	NYSERDA	Jun-23	119	5	4.0	20	4%
NY	Alabama	EDPR	NYSERDA	Jun-24	130	20	4.0	80	15%
NY	Excelsior	NextEra	NYSERDA	Dec-22	280	20	4.0	80	7%
NY	Garnet Energy Center	NextEra	NYSERDA	Jun-23	200	20	4.0	80	10%
TX	Azure Sky Solar	Enel	Home Depot	Jul-21	225	81	1.4	116	36%
TX	Blue Jay	Enel	*partial*	Dec-21	210	51.63			25%
TX	Roadrunner Solar	Enel	*partial*	Dec-19/Dec-21	497	51.06			10%
TX	Roseland	Enel	*partial*	Oct-22	513	51.63			10%
TX	Noble	National Grid (NRG)	Home Depot/NRG/Hershey	Jun-22	275	125	1.0	125	45%
TX	Permian Energy Centre	Orsted	ExxonMobil	May-21	420	40	1.0	40	10%
TX	Danish Fields I-III	Total/Sunchase	Total	Dec-23	603	150.83			25%
TX	Long Point	Total/Sunchase	Total	Dec-23	101.25	100.62			99%
TX	Morrow Lake	Total/Sunchase	Total	Dec-23	204	201.13			99%
TX	Mustang Creek	Total/Sunchase	Total	Dec-23	152.25	150.83			99%
TX	Upton County Solar	Viridity (Ormat)	Austin Energy	Dec-17/Dec-21	157.5	25			16%
VA	Correctional Solar	Dominion	Dominion	Dec-17/Dec-21	20	2	2.0	4	10%
VA	Scott Solar	Dominion	Dominion	Dec-16/Dec-21	17	12	4.0	48	71%
WI	Darien	Invenergy/WEC Energy	We Energies/WPS/MG&E	Dec-23	250	75	4.0	300	30%
WI	Koshkonong	Invenergy/WEC Energy	We Energies/WPS/MG&E	Dec-24	300	165	4.0	660	55%
WI	Paris	Invenergy/WEC Energy	We Energies/WPS/MG&E	Dec-23	200	110	4.0	440	55%

To date, it's been hard to find good information on battery duration for a number of Texas projects.

The 3 TX projects for which duration is available range from 1.0-1.4 hours—i.e., relatively short, perhaps reflecting ERCOT market dynamics and lack of a capacity requirement.

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