



Integrating battery energy storage in electric markets and operations

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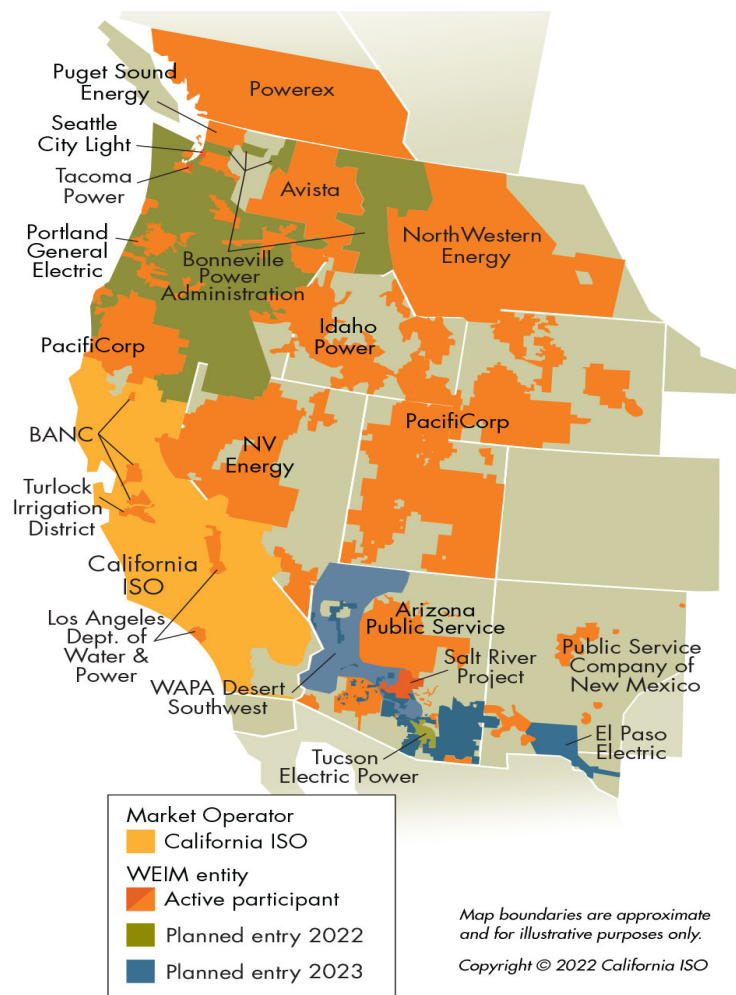
2023 ELECTRICITY MARKET EXCHANGES (EMX)

Generator Recent Enhancements and Future Innovations

June 20-21, 2023

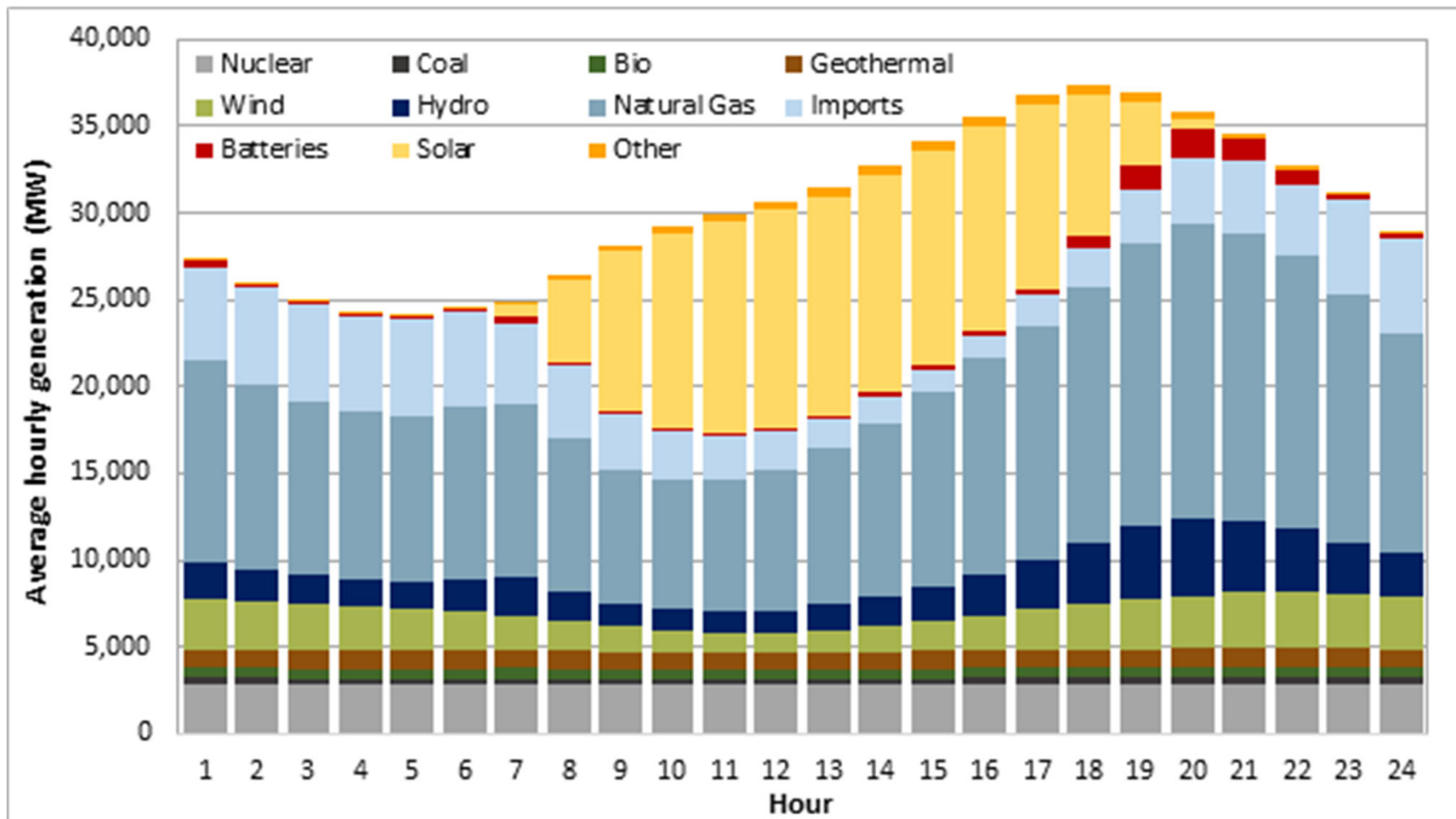
CAISO Public

CAISO has achieved regional integration through the real-time Western Energy Imbalance Market (WEIM)

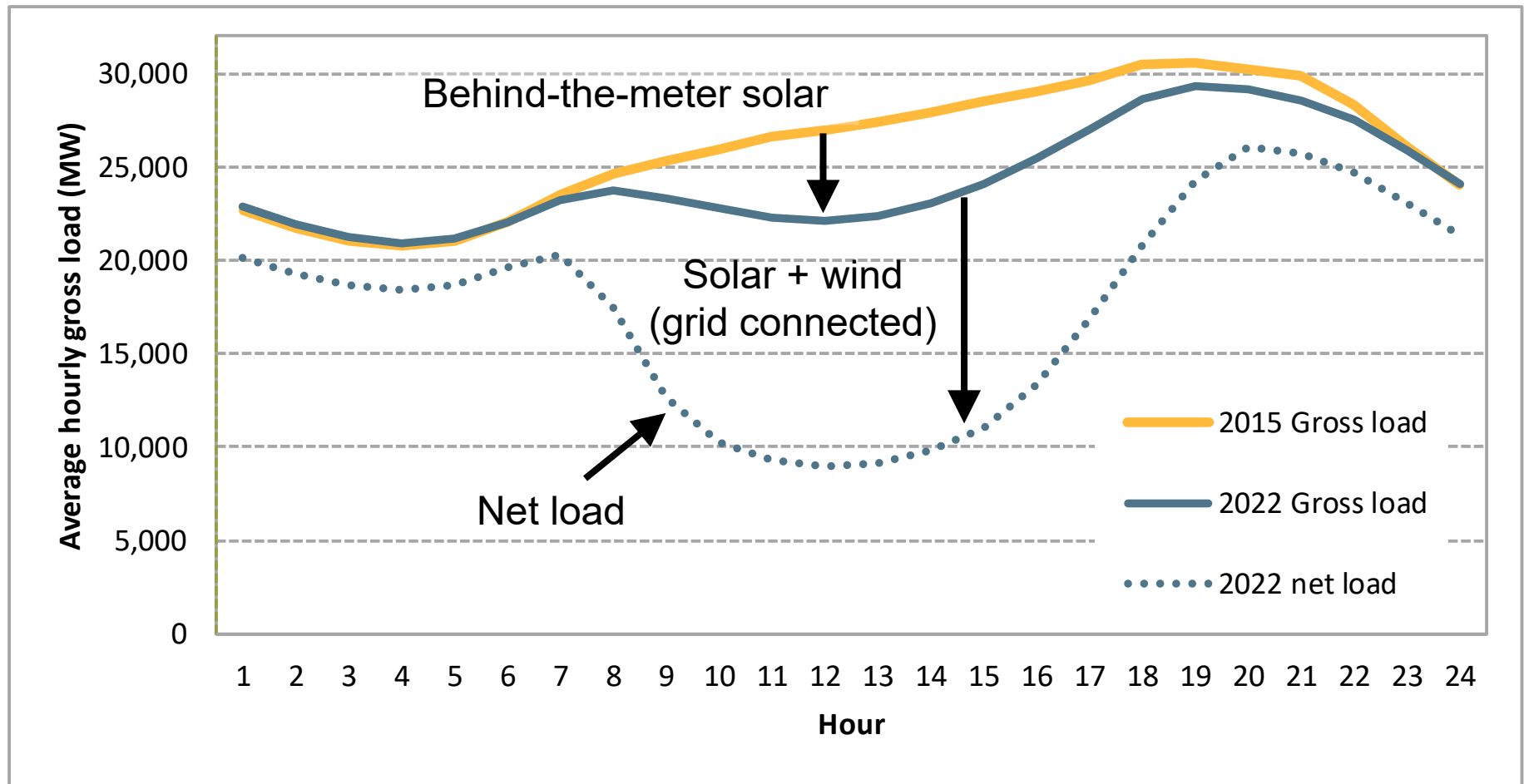


BAA	Peak load		Load during WEIM system peak (06-Sep-22)	
	Date	Load (MW)	Load (MW)	Percentage
CISO	6-Sep-22	49,312	49,269	37.9%
PACE	6-Sep-22	9,408	9,408	7.2%
NEVP	12-Jul-22	8,867	8,682	6.7%
BCHA	19-Dec-22	11,899	7,800	6.0%
BPAT	22-Dec-22	10,941	7,305	5.6%
SRP	11-Jul-22	7,512	6,850	5.3%
AZPS	11-Jul-22	7,373	6,720	5.2%
LADWP	6-Sep-22	6,041	5,941	4.6%
BANC	6-Sep-22	4,744	4,710	3.6%
PGE	2-Jun-22	4,354	3,481	2.7%
IPCO	3-Aug-22	3,793	3,413	2.6%
PACW	23-Feb-22	3,976	3,234	2.5%
PSEI	22-Dec-22	5,017	2,950	2.3%
TEPC	11-Jul-22	2,890	2,462	1.9%
PNM	19-Jul-22	2,617	2,163	1.7%
NWMT	22-Dec-22	2,016	1,586	1.2%
AVA	22-Dec-22	2,206	1,562	1.2%
SCL	22-Dec-22	1,863	1,109	0.9%
TIDC	6-Sep-22	728	722	0.6%
TPWR	24-Mar-22	1,310	505	0.4%
Total			129,872	

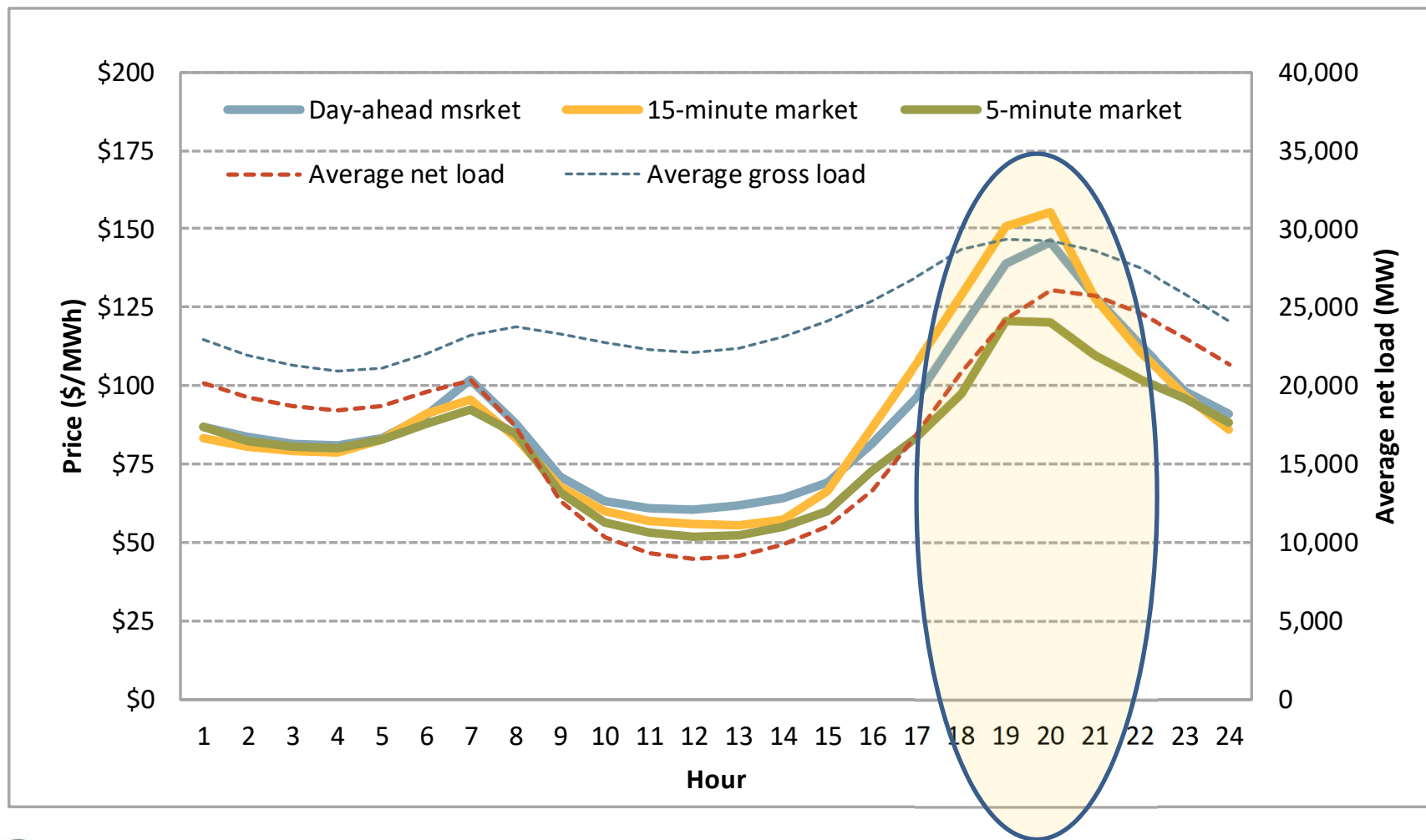
CAISO fuel mix comprised of about 30% solar and wind in 2022 (excluding “behind-the-meter” solar)



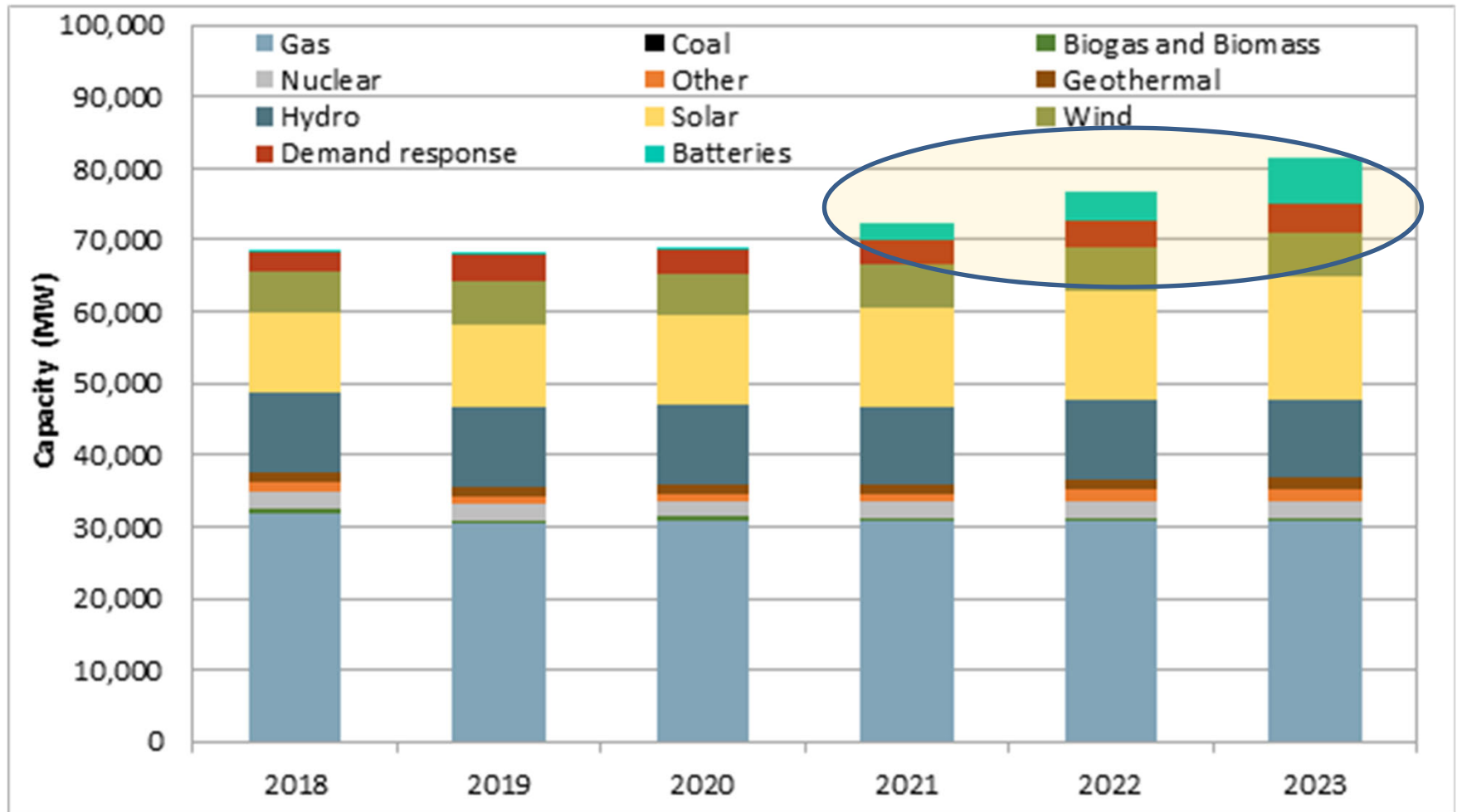
CAISO operation and market now focused on “net load” (system load minus solar+wind output)



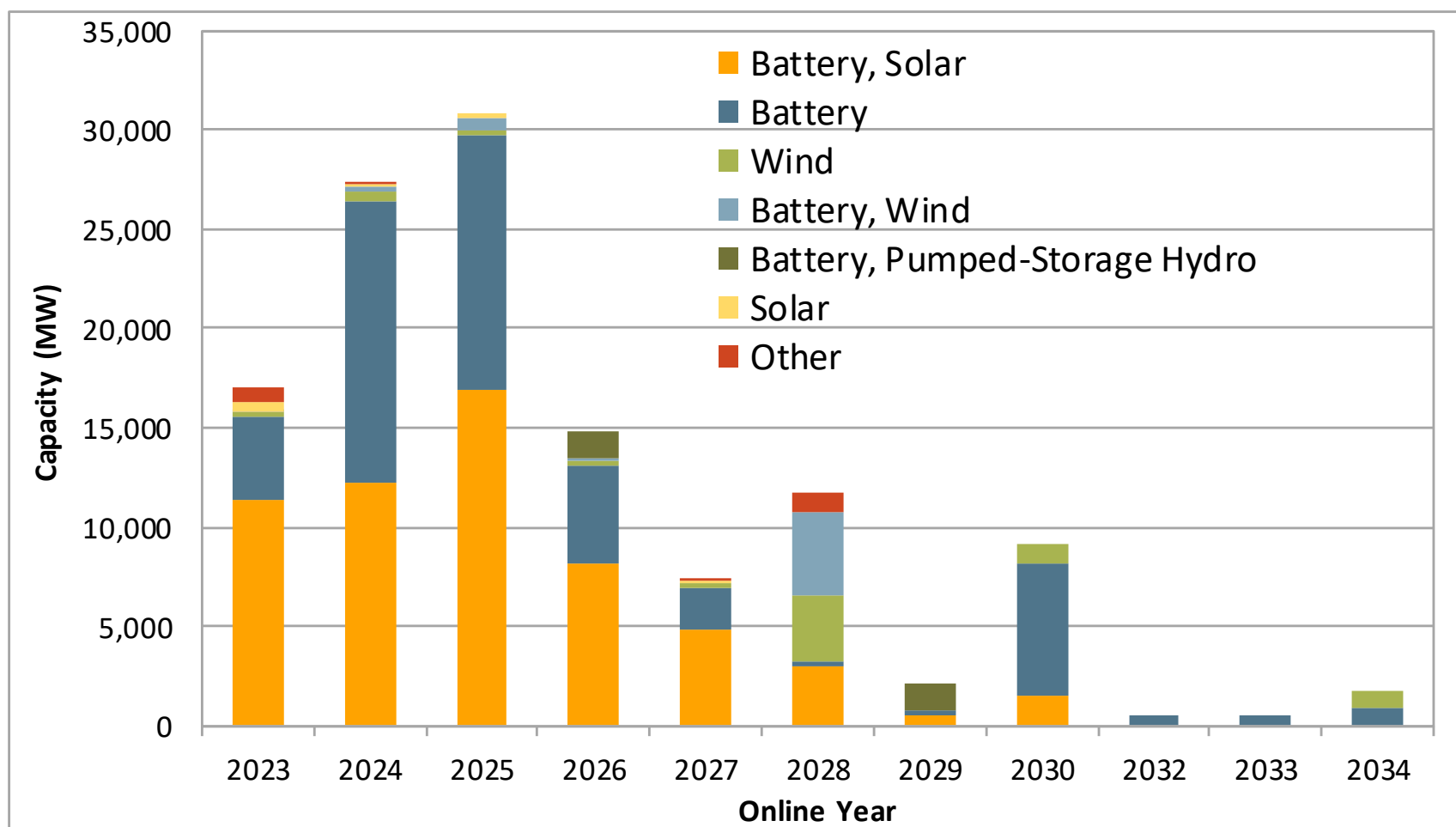
Prices in CAISO markets are now highest during the peak net load hours (18-22) when solar drops.



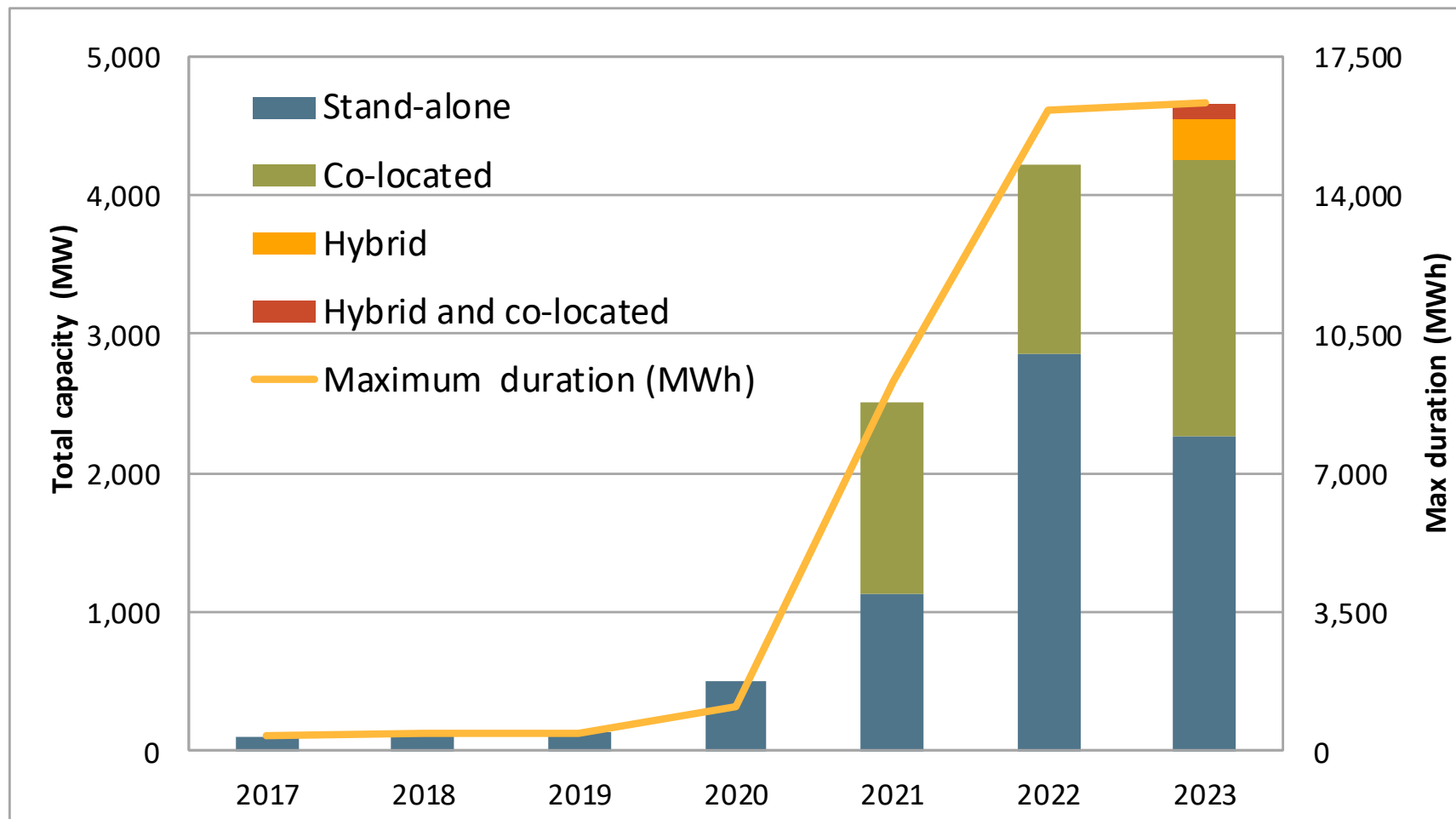
Battery storage has been the main source of new capacity since 2021



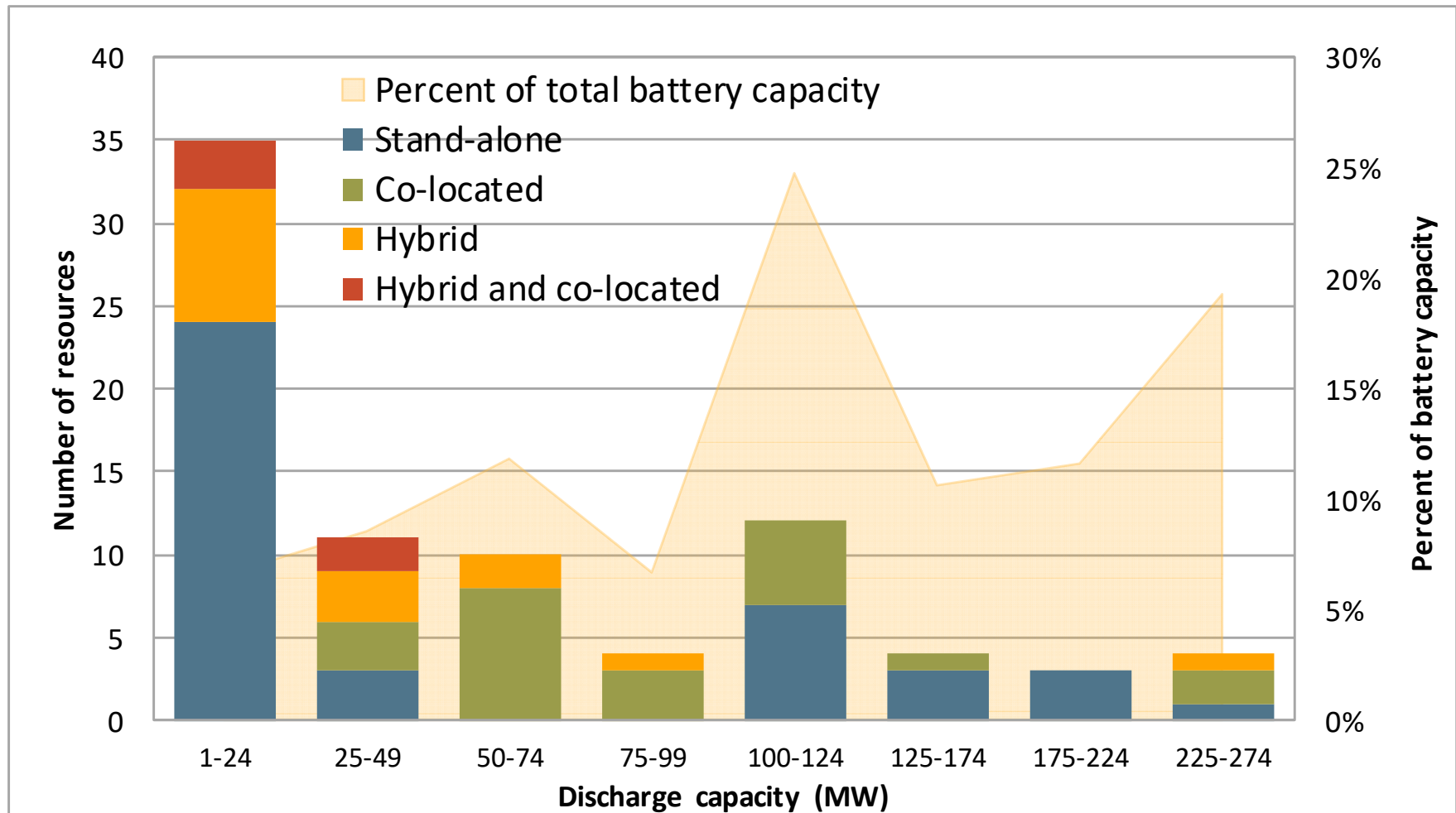
Battery storage and combined solar/battery facilities will continue to be the main source of new capacity



Most batteries being designed so that they can discharge at maximum capacity for 4 hours.



Size of batteries ranges widely – from large batteries on power plant sites to small batteries located near solar farms.



Batteries are modeled and dispatched using a variety of unit characteristics and bids submitted by operators.

- Separate energy bids to charge and discharge
 - Bid prices from 0 MW to maximum charging capacity to charge
 - Bid prices from 0 MW to maximum discharge capacity to discharge
- Batteries also submit ramp rate curves.
- Battery operators may also submit state-of-charge constraints to manage how batteries are dispatched in the market:
 - Initial state-of charge for the day-ahead market (Hour 1)
 - Minimum and maximum state-of-charge limits
 - Real-time end-of-hour state-of-charge range
- Batteries may also bid to provide ancillary services.
 - ISO market software includes constraints that manage state-of-charge to ensure deliverability of ancillary service schedules.