



Renewable Integration in the Western US

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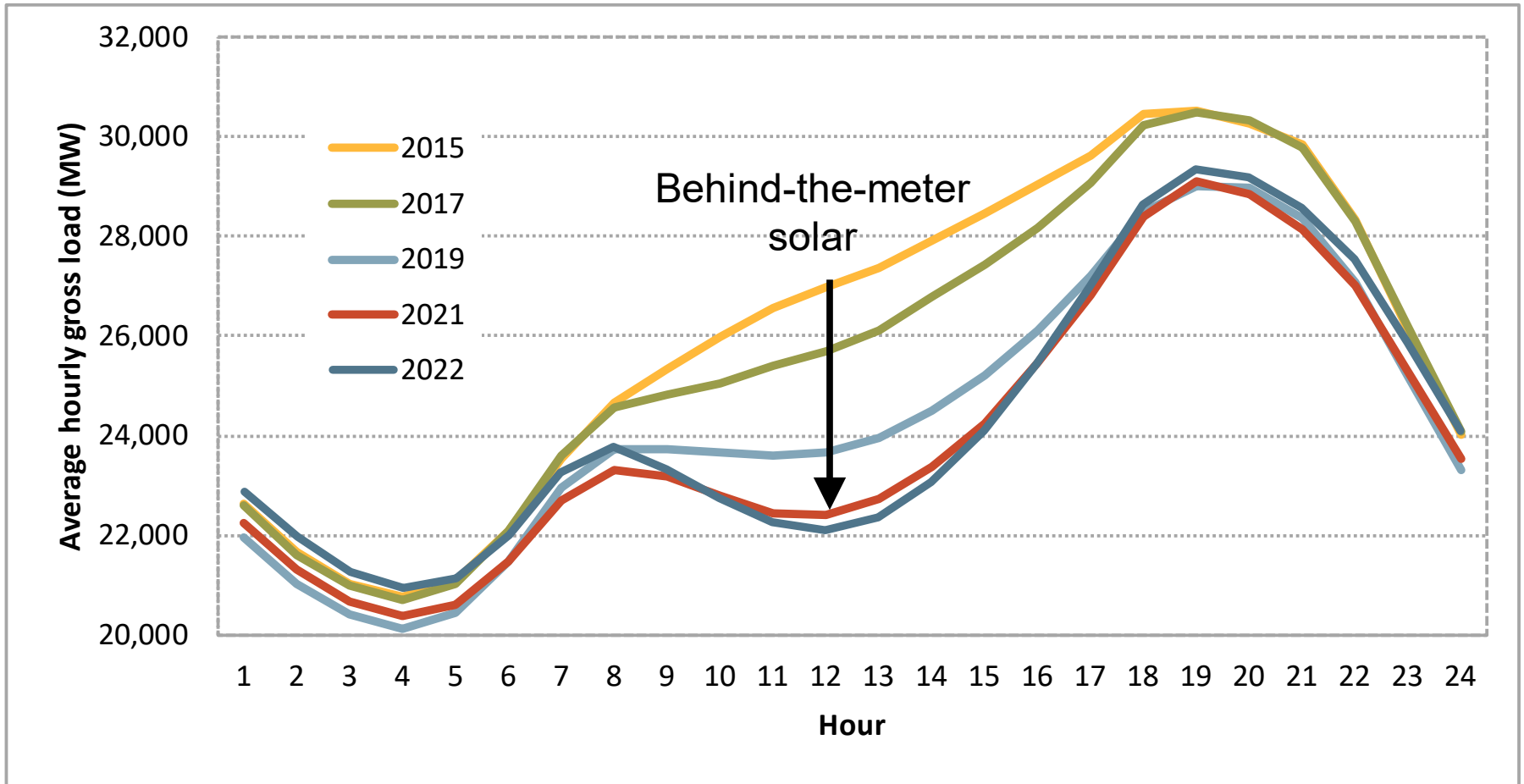
Las Vegas, Nevada

April 17 2023

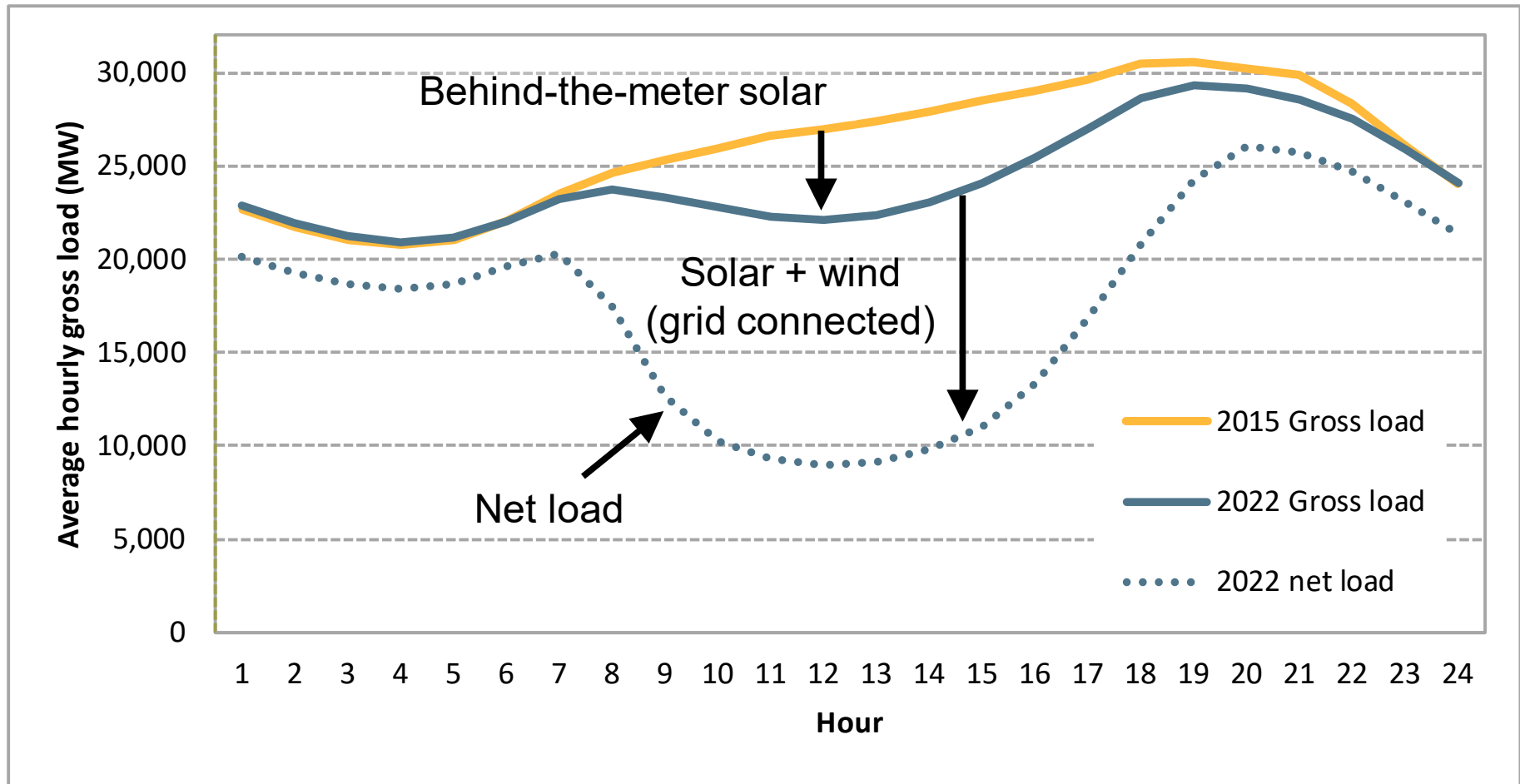
Managing large scale renewable integration

- Infrastructure
 - New transmission upgrades
 - Interconnection rules
- Resource adequacy rules
 - How to count renewables as capacity
 - For all capacity, new focus on net peak hours (HE 18-22) vs gross peak hours
- Regional integration
- Market processes
 - Ability to decrement wind/solar through market bids
 - New ramping products (real-time and day-ahead)
 - Manual actions (upward load bias, out-of-market dispatch)
- Storage technologies (batteries)

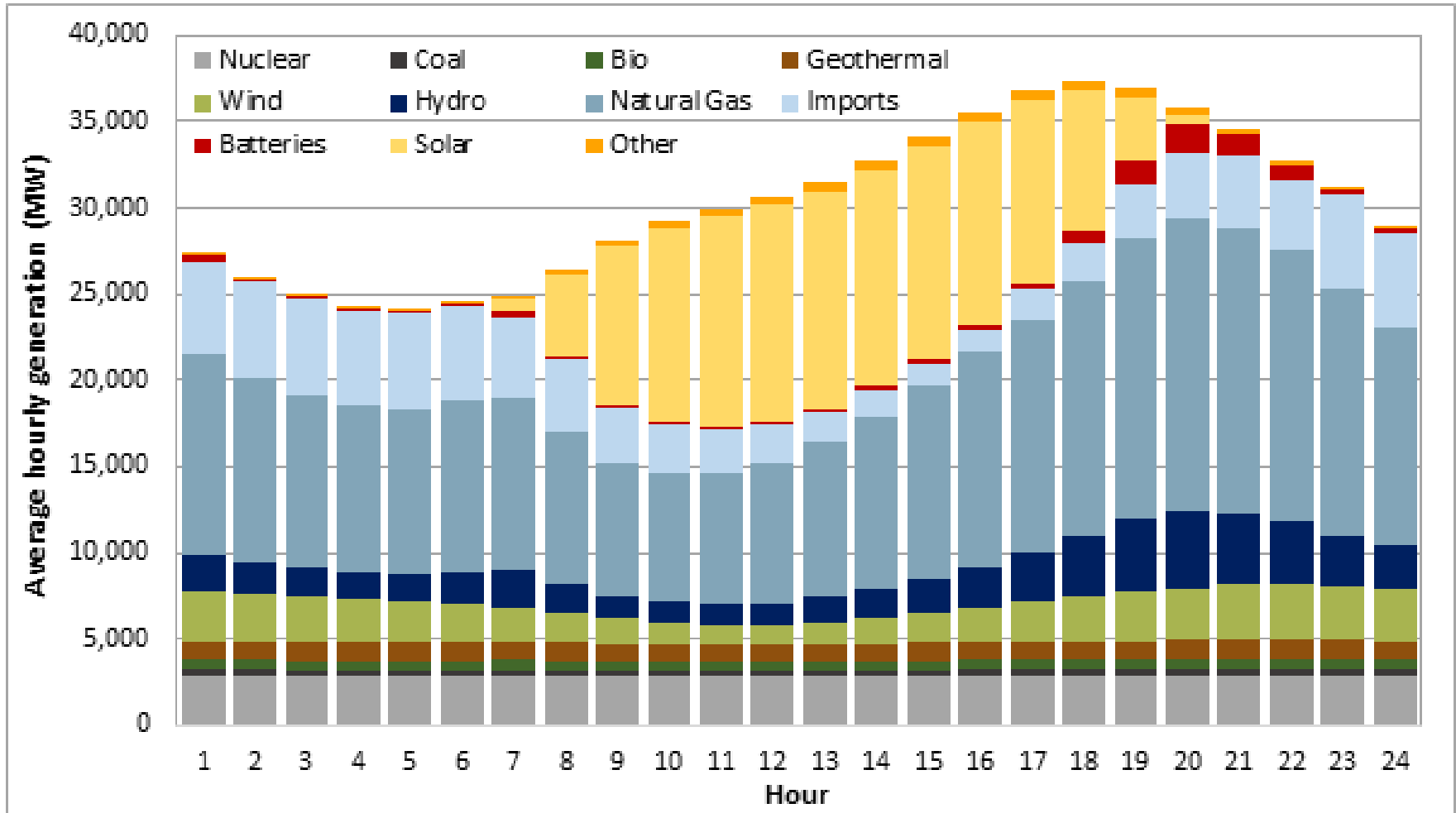
CAISO system load has been re-shaped by significant behind-the-meter solar over last decade.



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

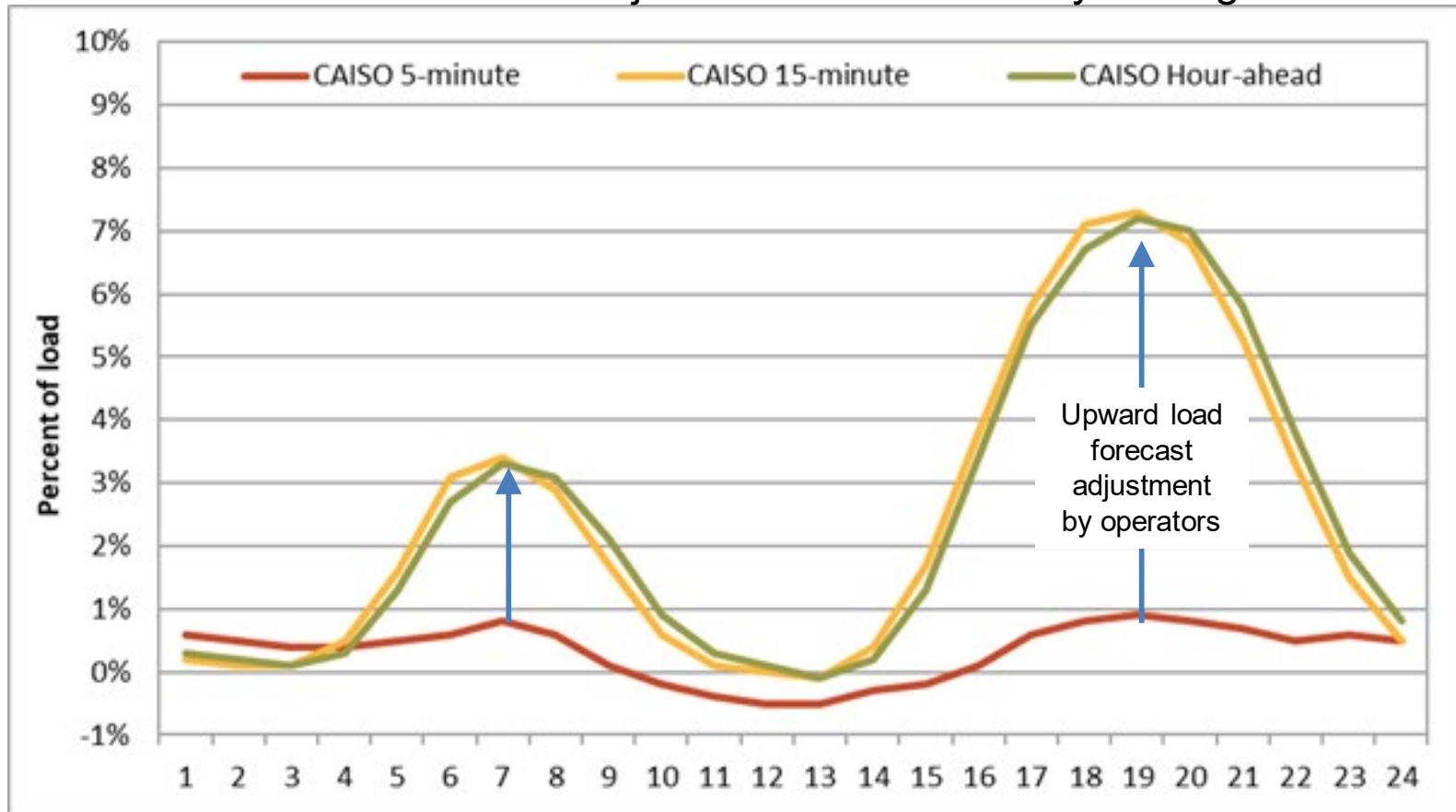


CAISO fuel mix comprised of about 30% solar and wind in 2022 (excluding “behind-the-meter” solar)

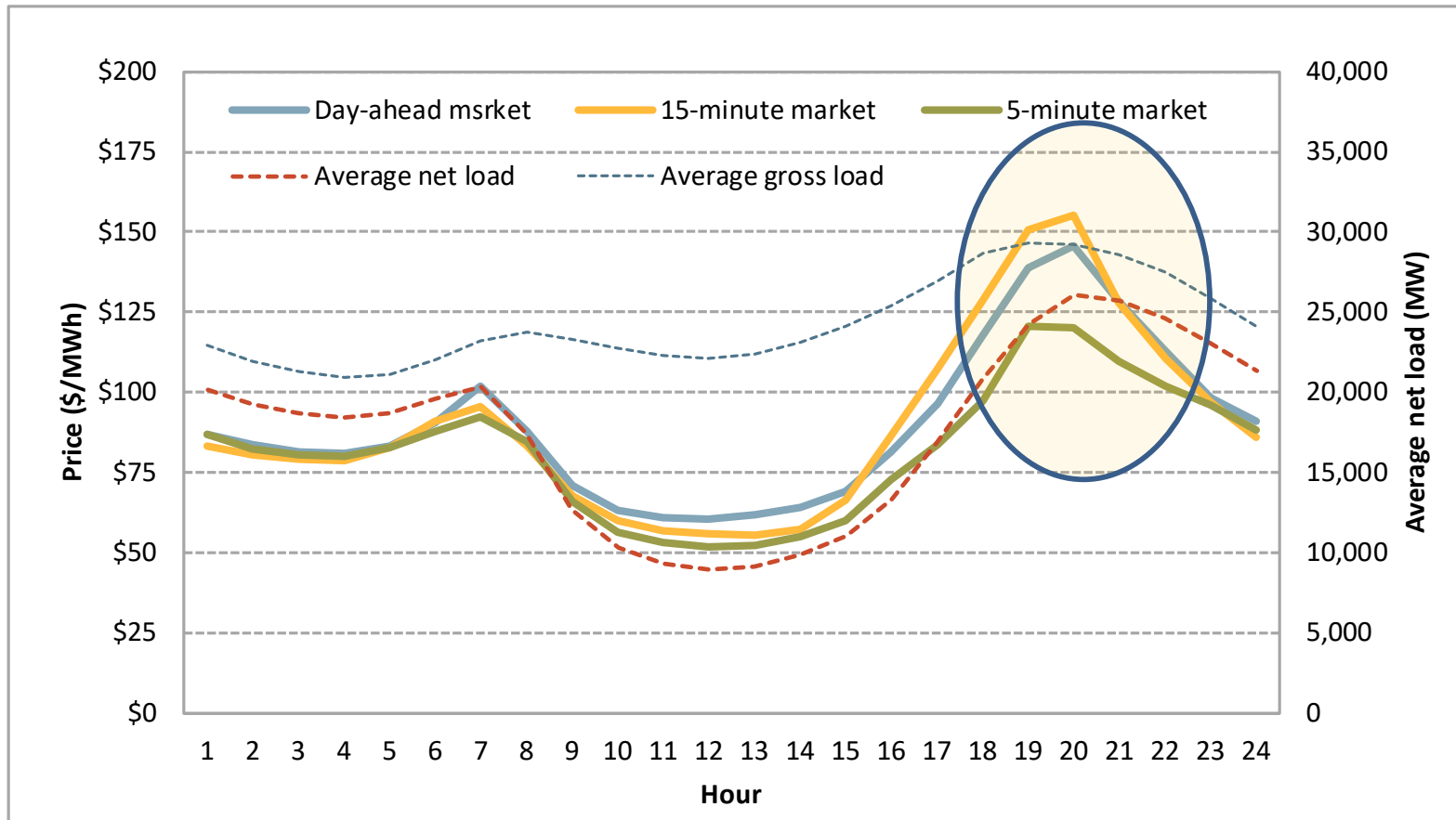


Operators adjust load forecast upward significantly in the hour-ahead and 15-minute markets to ensure more supply for uncertainty and ramping.

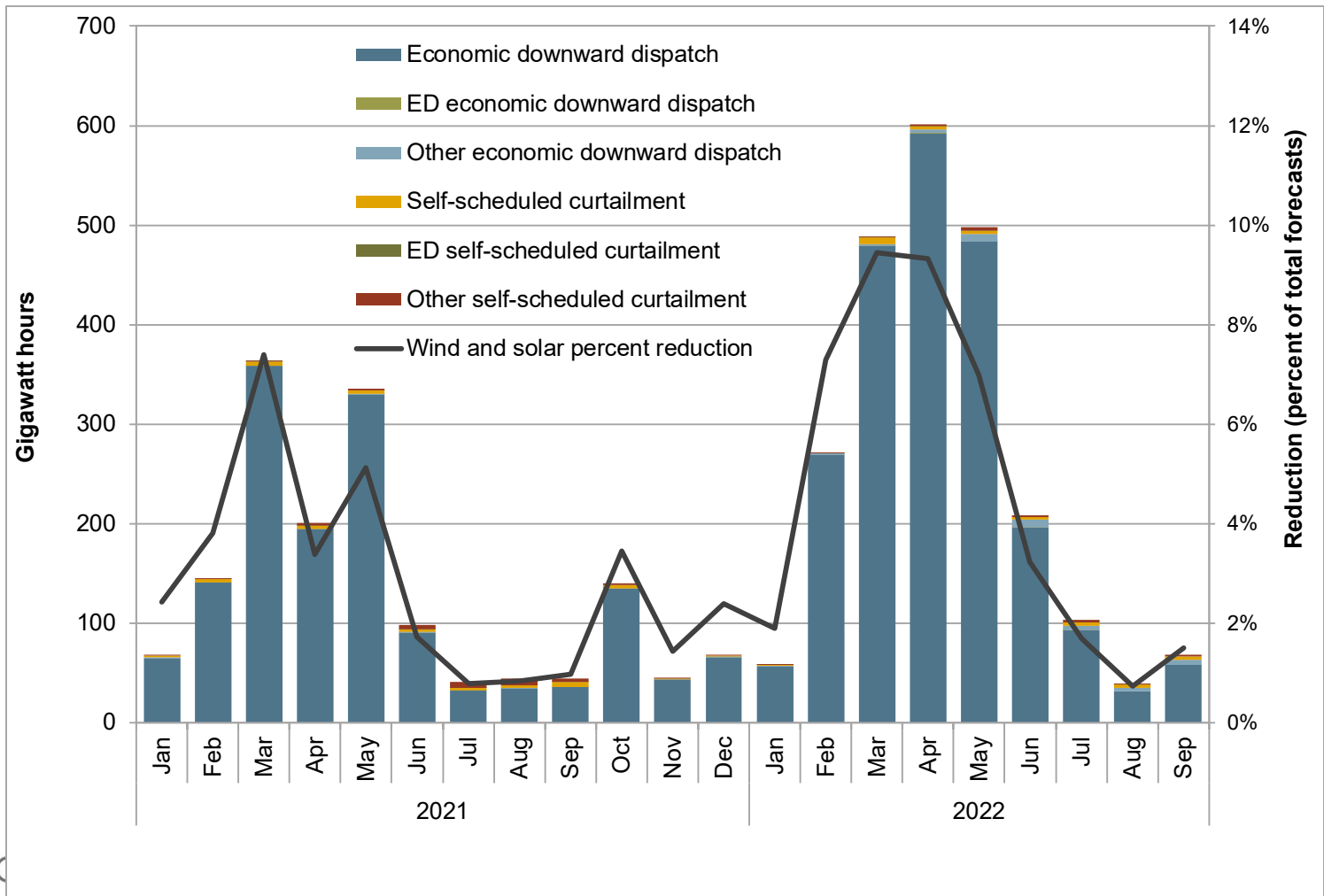
Load forecast adjustments - 2022 hourly averages



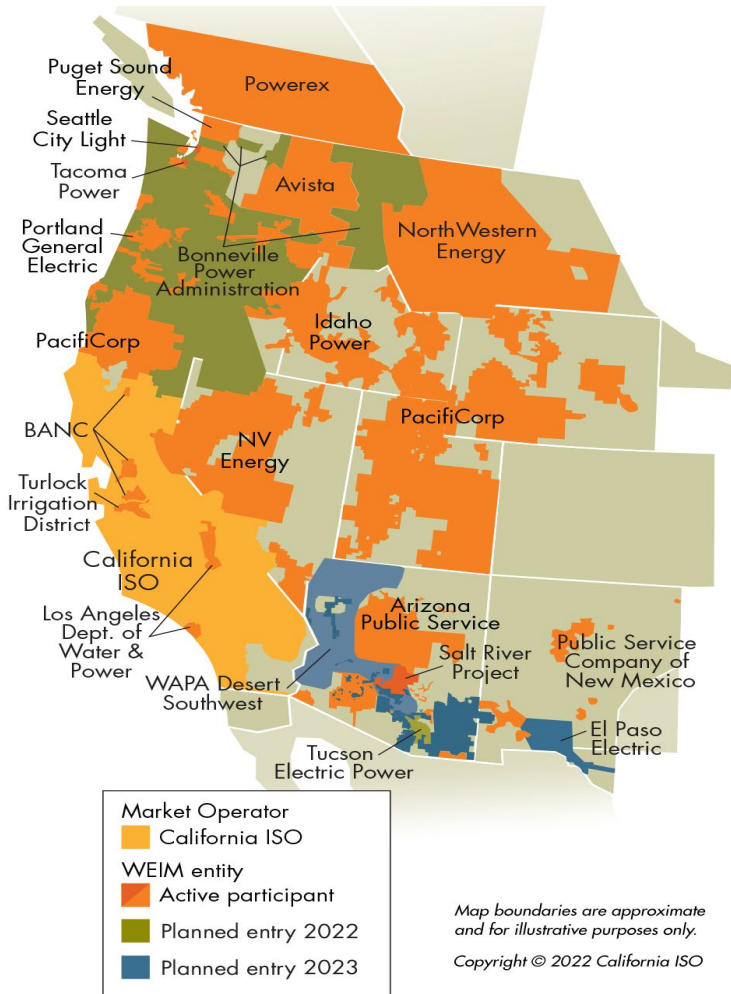
Prices in peak “net load” hours (HE 18-22) reflect operator interventions to manage net load uncertainty and ramping needs



About 4.3% of solar and wind energy was curtailed in 2022 – almost all through market bids.



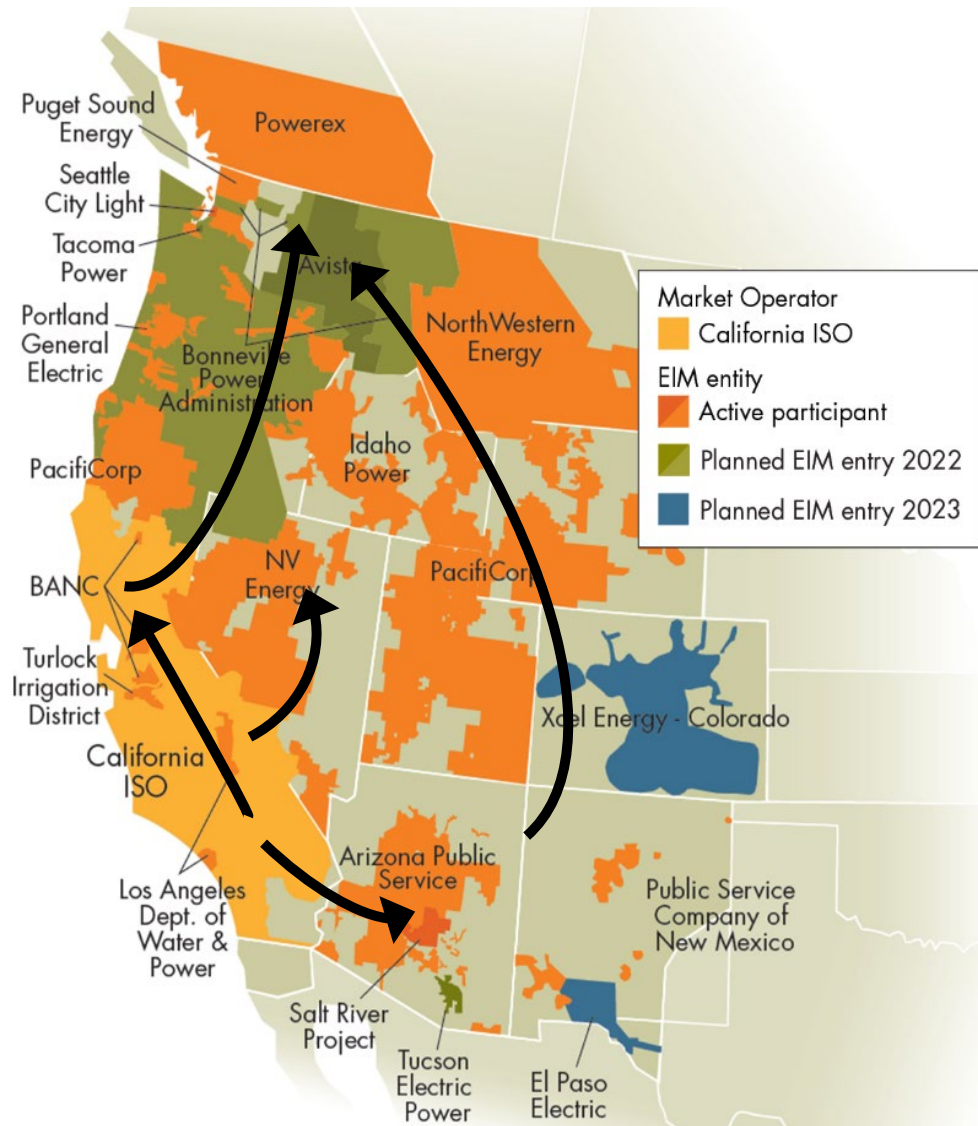
Regional integration through the real-time Western Energy Imbalance Market (WEIM)



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	

Power generally flows out of California and desert southwest during mid-day hours when solar output is high.

Regional integration through the WEIM has avoid curtailment of solar and wind output.

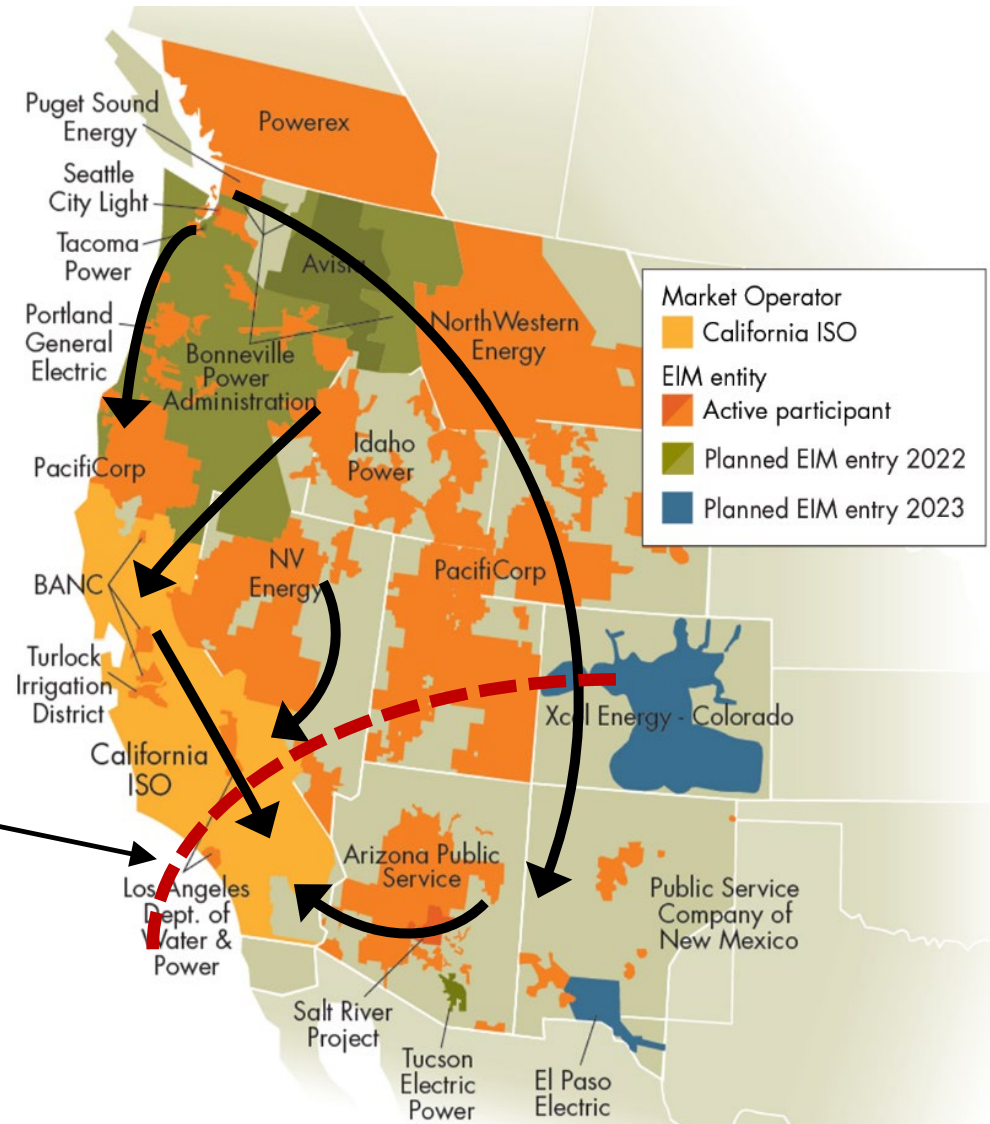


Map boundaries are approximate and for illustrative purposes only.

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Power generally flows into California and desert southwest during net peak hours (hours 18 to 22)

North-to-south flows can be limited by transmission.



Map boundaries are approximate and for illustrative purposes only.

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Flexible ramping product

- Began as non-priced constraint in real-time market 10 years ago
- Evolved into flexible ramping product implemented 6 years ago
- Procures upward and downward ramping capacity over 15- to 30-minute look ahead in real time market.
- Procured based on demand curve, with maximum demand based on forecast ramping needs plus uncertainty
- Rarely results in positive market price
- Continues to be “enhanced”
 - On Feb 1, CAISO switched from system level procurement to locational procurement

Flexible ramping product (continued)

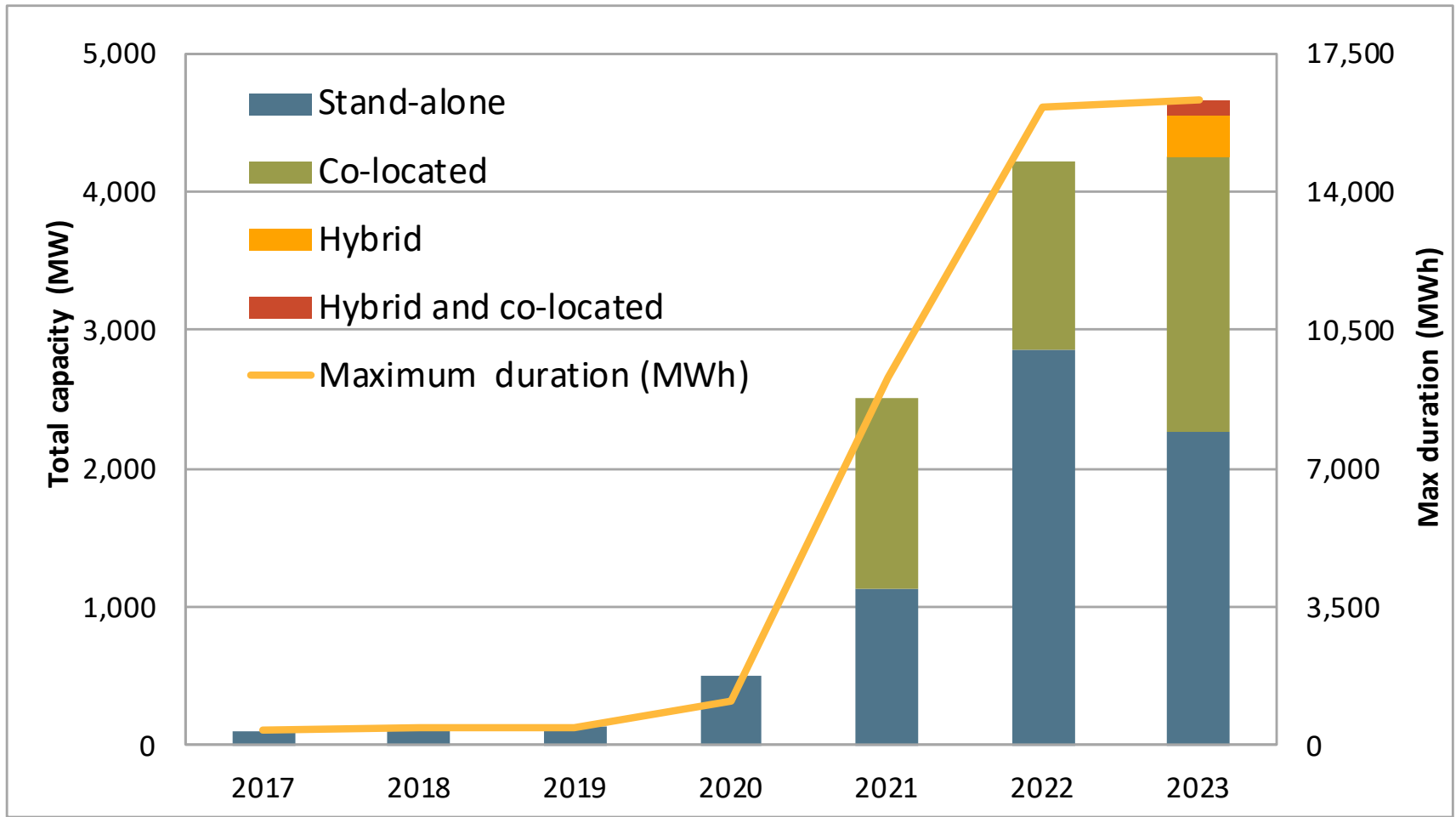
Market Monitors opinion ...

- Product has not been effective at meeting ramping needs,
 - Operators have increasingly relied on other manual actions to create ramp and defend against uncertainty
- Recent changes to add locational procurement requirements may improve product effectiveness and prices.
- To be really effective, the product needs to be based on longer time horizon
 - e.g. 2 to 3 hours in advance vs 15 to 30 minutes

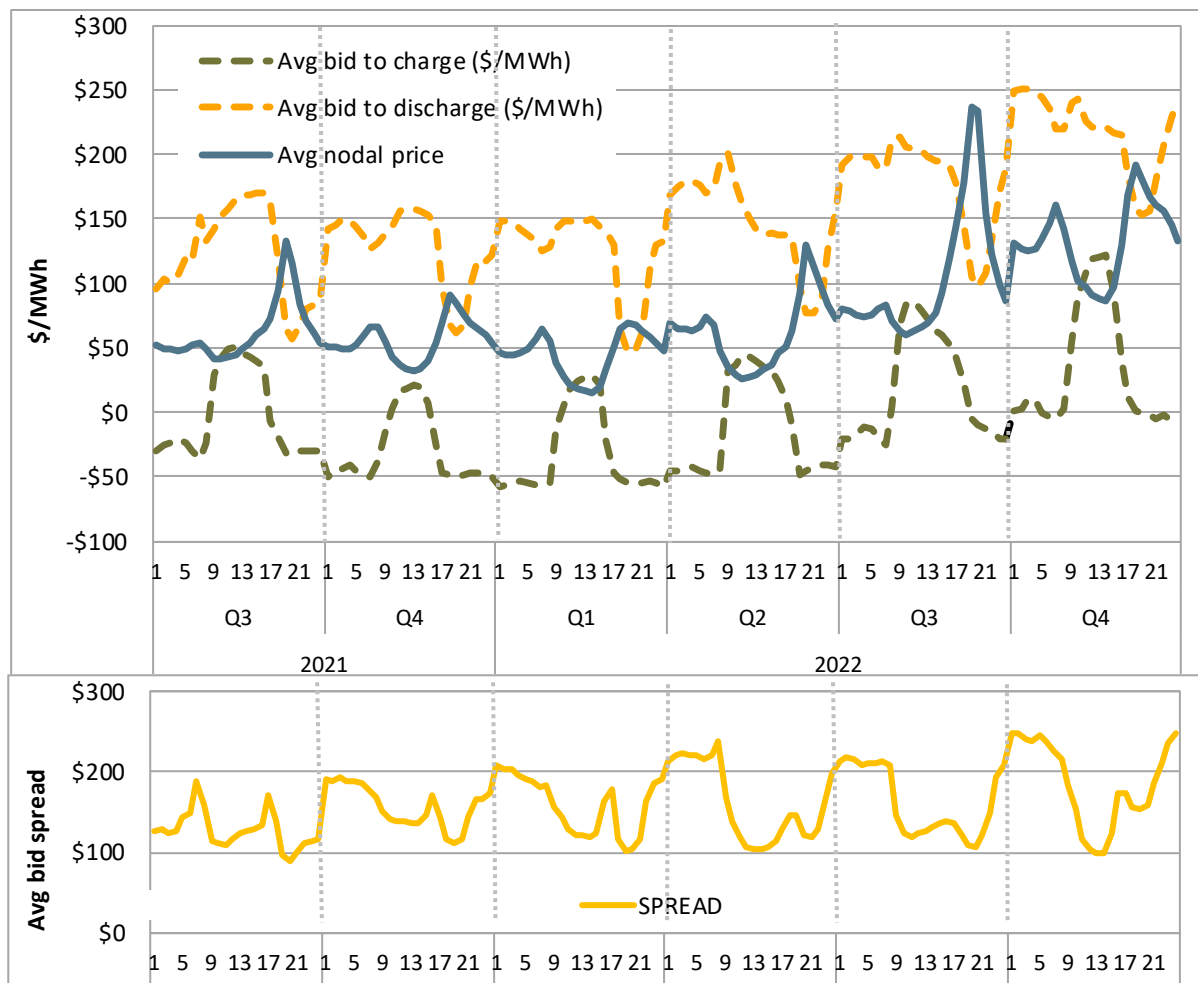
Manual actions by grid operators remain very important for managing uncertainty and ramping needs

- Day-ahead residual unit commitment (RUC) process
 - Operators adjust load used in RUC process up significantly many hours/days.
 - This load adjustment can cause more units to be committed and fewer exports to clear in RUC process
- Direct manual dispatches
 - Commitment of gas-fired units
 - Ramp up gas-fired units up to higher operating level in late afternoon
 - Maintain state-of-charge of batteries in hours prior to net peak
- Upward adjustment (or bias) of load forecast used in hour-ahead and 15-minute real-time dispatch process
 - Helps position units to operate at higher levels in advance
 - Can cause more imports and fewer exports to clear hour-ahead scheduling process
- Battery capacity prevented from discharging before early evening hours by operators on very high load days

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



Batteries bid to charge in low priced hours and discharge during higher priced net peak hours (HE 18-22)



Batteries provided average of 4.4% of energy during hour ending 20 during 2022.

