



Memorandum

To: ISO Board of Governors and WEIM Governing Body

From: Eric Hildebrandt, Executive Director, Market Monitoring

Date: July 10, 2024

Re: Department of Market Monitoring report

This memorandum does not require ISO Board of Governors or WEIM Governing Body action.

EXECUTIVE SUMMARY

This memo summarizes key findings of an upcoming special report on performance of battery storage resources by the Department of Market Monitoring (DMM).

- **Battery storage capacity has grown from about 500 MW in 2020 to over 11,000 MW** in the CAISO balancing area, and now represents about 12 percent of the installed generation in the California ISO balancing area.
- **The Western Energy Imbalance Market (WEIM) includes about 3,500 MW of participating battery capacity** as of June 2024. This is a nearly three-fold increase in battery capacity in the WEIM since June 2023.
- **Batteries account for a significant portion of energy and capacity during the late afternoon and early evening when net loads are highest.** During hours 17 to 21, batteries provided about 5.6 percent of system energy in 2023.
- **Batteries account for a significant portion of load during peak solar hours.** From hours-ending 10 to 13, battery charging accounted for around 8.3 percent of load in the California ISO balancing area in 2023. This additional load from batteries has helped reduce the need to curtail or export surplus solar energy from the ISO at very low prices.
- **Net market revenue for batteries decreased from about \$103/kW-yr in 2022 to \$78/kW-yr in 2023.** This decrease was driven largely by lower energy prices and lower loads than in 2022.
- **Bid cost recovery payments for batteries increased by 16 percent in 2023** and these payments represent 7 percent of batteries' total net market revenues. In 2023, battery resources received 10 percent of all bid cost recovery paid to resources in the California ISO balancing area. DMM continues to recommend enhancements to the market design of bid cost recovery for batteries.

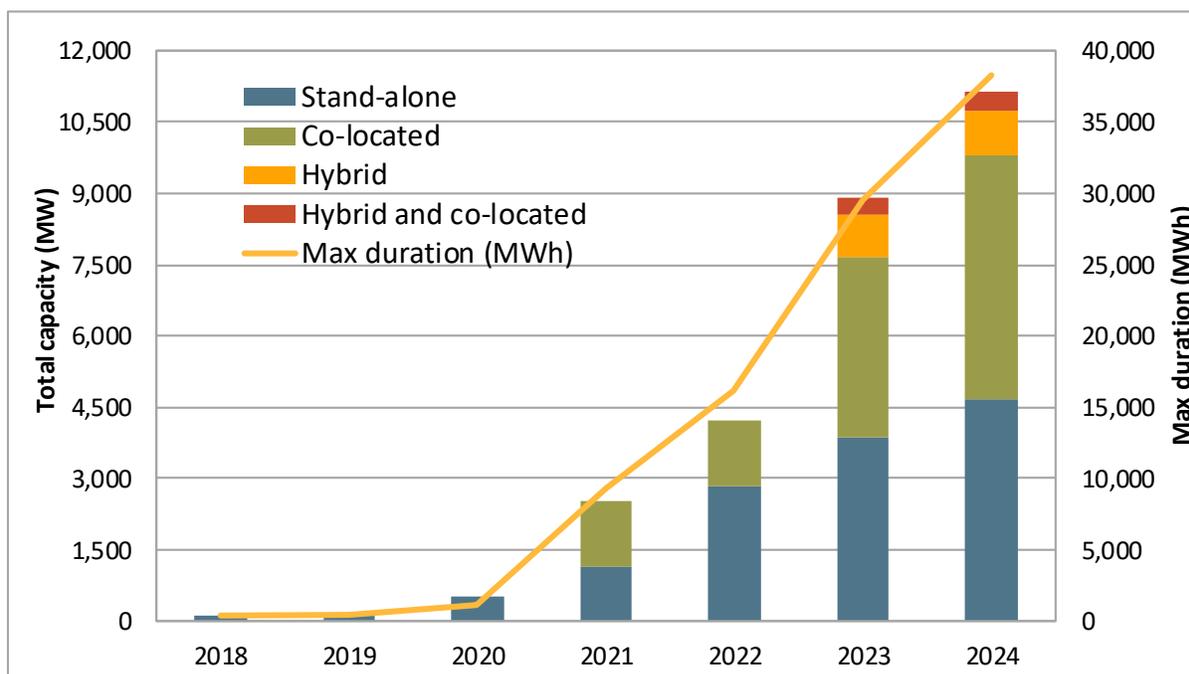
Additional details and analysis of battery resources are provided in this memo. More analysis will be included in an upcoming DMM special report on batteries.

BATTERY STORAGE RESOURCES

California ISO balancing area

Battery storage is the fastest growing resource type in the California ISO balancing area, and now makes up nearly 12 percent of the system’s nameplate capacity. Figure 1 shows the total capacity of battery storage as of June 2024. Battery capacity now totals over 11,100 MW. About 4,700 MW of this capacity is from stand-alone projects and about 5,100 MW from co-located batteries. There is about 1,300 MW of additional battery capacity incorporated in hybrid resources.

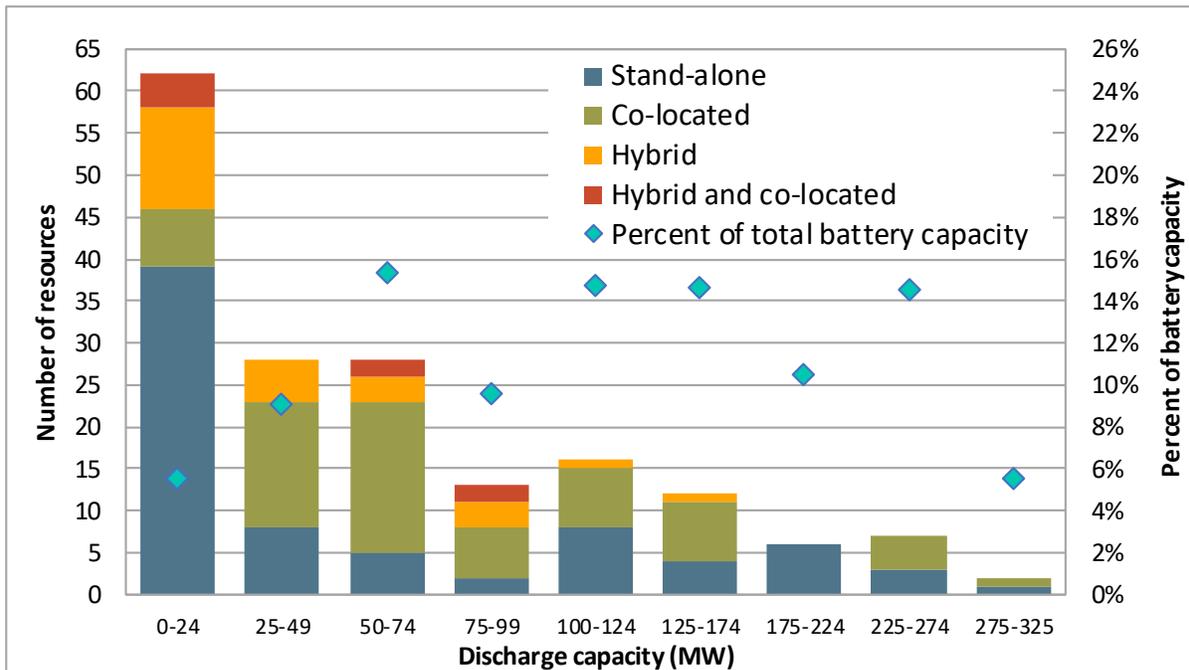
Figure 1. Battery capacity in CAISO balancing area (2018–2024)



The majority of projects waiting to connect to the ISO area grid contain a battery component. As of June 2024, batteries account for about 45 percent of total capacity in the interconnection queue. Almost half of planned new battery capacity comes from projects that combine batteries with generating resources (mainly solar) using the co-located or hybrid connection and modeling options.

The size of active batteries varies widely, ranging from less than 1 MW to 325 MW. **Error! Reference source not found.** Figure 2 shows the size distribution of active battery resources, along with the percentage of active battery capacity represented by each histogram bin. Most batteries in the ISO market have a duration of four hours.

Figure 2. Histogram of battery sizes and types



Western Energy Imbalance Market

The Western Energy Imbalance Market (WEIM) includes about 37 battery resources with 3,500 MW of battery capacity as of June 2024. This is a nearly three-fold increase in battery capacity in the WEIM since June 2023. Batteries now account for about 3 percent of the installed capacity in the WEIM outside of the California ISO balancing area.

Figure 3 shows the number of actively participating batteries and their capacity for each WEIM balancing area with active battery resources. As shown in Figure 3, most of this is in the Desert Southwest. About 1,300 MW of this capacity is from stand-alone units, with about 1,700 MW from co-located units. There is about 500 MW of battery capacity in the WEIM that is incorporated as part of hybrid resources.

Figure 3. Active battery capacity by WEIM balancing area (June 2024)

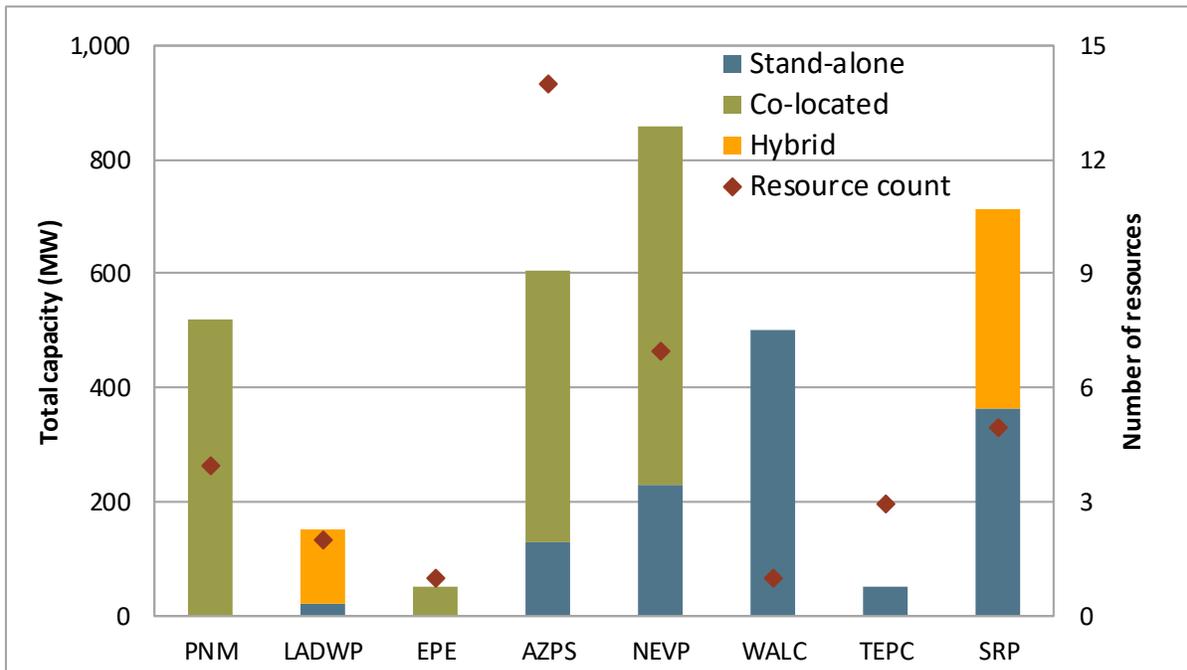
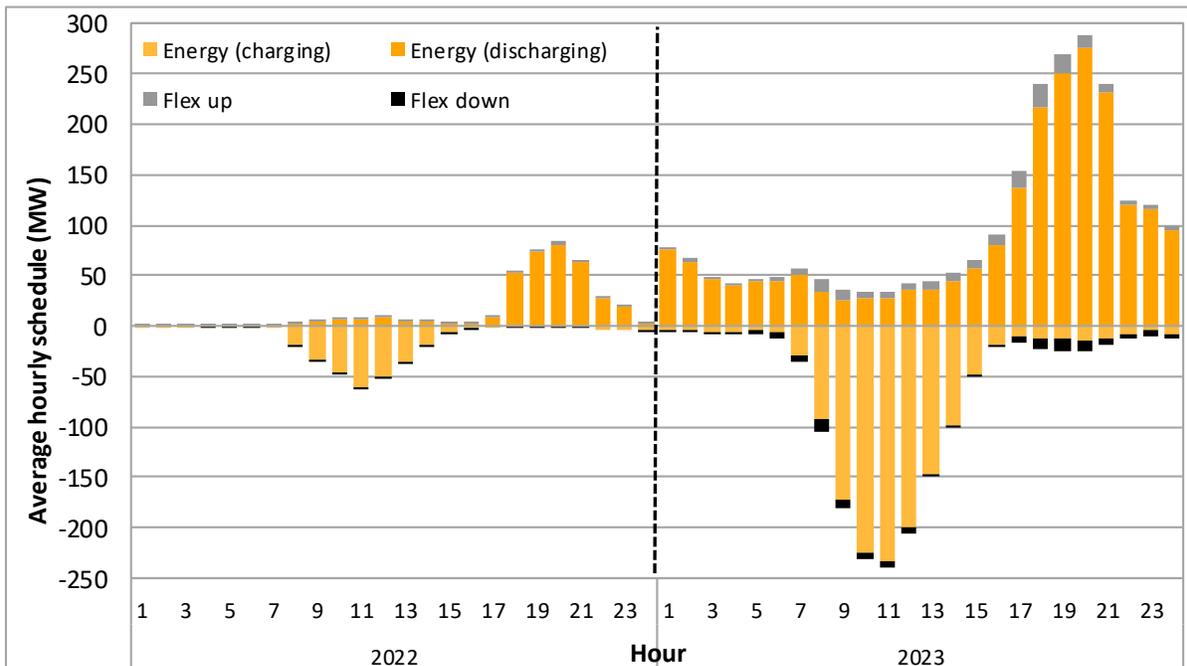


Figure 4. Average hourly battery schedules in WEIM balancing area (2022–2023)



As shown in Figure 4, batteries in the WEIM have similar schedules as batteries in the California ISO balancing area (i.e., primarily charging in the morning and early afternoon hours, then discharging in the evening). WEIM batteries do not have ancillary service schedules, since ancillary services are not scheduled through the market in WEIM balancing areas.

Scheduling of batteries

Figure 5 shows average hourly schedules in 2023 for the two main types of battery resources: stand-alone and co-located batteries. Both types of batteries can be optimally scheduled for both energy and ancillary services through the ISO 24-hour day-ahead market optimization. Batteries can then be re-dispatched in the real-time market based on real-time bids and prices.

Co-located batteries are subject to several special market constraints, including the aggregate capability constraint (ACC), which ensures that dispatch instructions to co-located resources behind a common point of interconnection do not exceed interconnection limits. The ACC can also restrict a battery's regulation awards.

As shown in Figure 5, despite these extra market constraints imposed on co-located battery participation, co-located batteries tend to have similar schedules to stand-alone batteries. Overall, in 2023:

- Batteries provided about 5.6 percent of system energy during hours 17 to 21.
- From hours-ending 10 to 13, battery charging accounted for around 8.3 percent of load in the California ISO balancing area in 2023. This additional load from batteries has helped reduce the need to curtail or export surplus solar energy from the balancing area at very low prices.
- About 16 percent of battery capacity was scheduled for downward regulation, which provided about 63 percent of the total downward regulation in the ISO.
- About 8 percent of battery capacity was scheduled for upward regulation, meeting about 80 percent of upward regulation.

Figure 6 shows average hourly real-time (15-minute market) schedules of all hybrid resources in 2023. Hybrid resources have a single bid curve that applies to all their component parts and receive one dispatch instruction from the ISO. The hybrid resource operator self-optimizes the components of its resource to meet that dispatch instruction.

Most energy scheduled from hybrids occur during the afternoon when solar is abundant. Then, in the evening when solar is unavailable, hybrids can still discharge energy that they have stored in battery components during the day.

In 2023, hybrids received very few market awards to charge from the grid, and mostly charged from on-site renewables. Only about 37 percent of hybrid resources had operational capabilities that would make them eligible to charge from the grid.

Figure 5. Average hourly schedule of stand-alone and co-located batteries (2023)

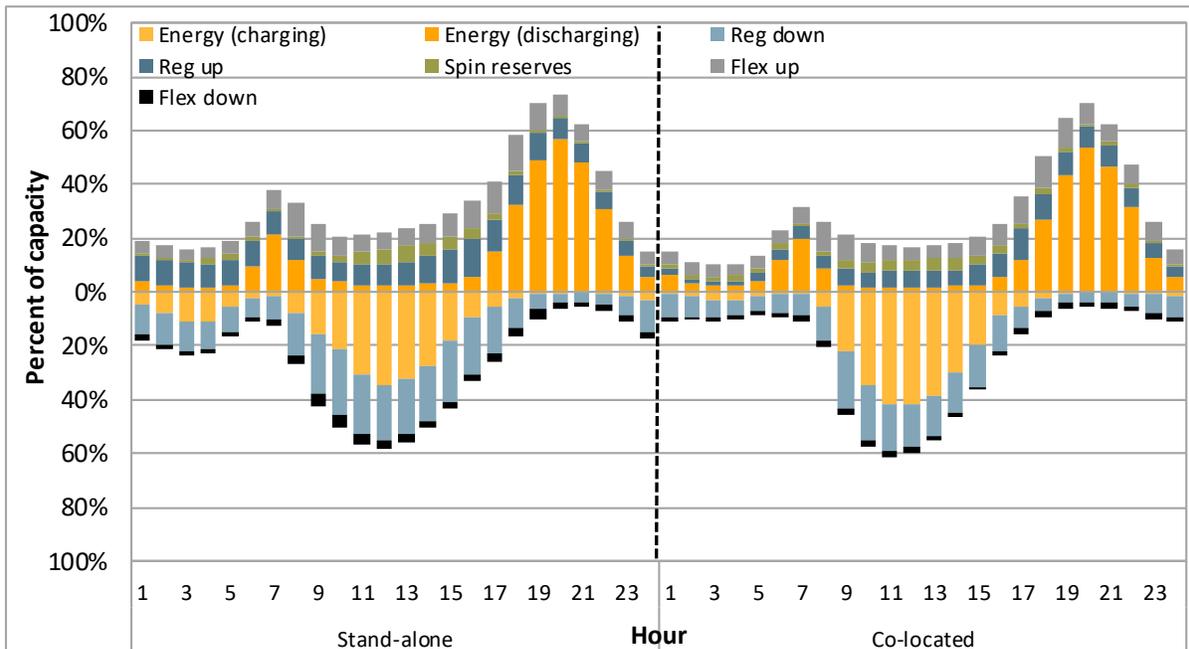
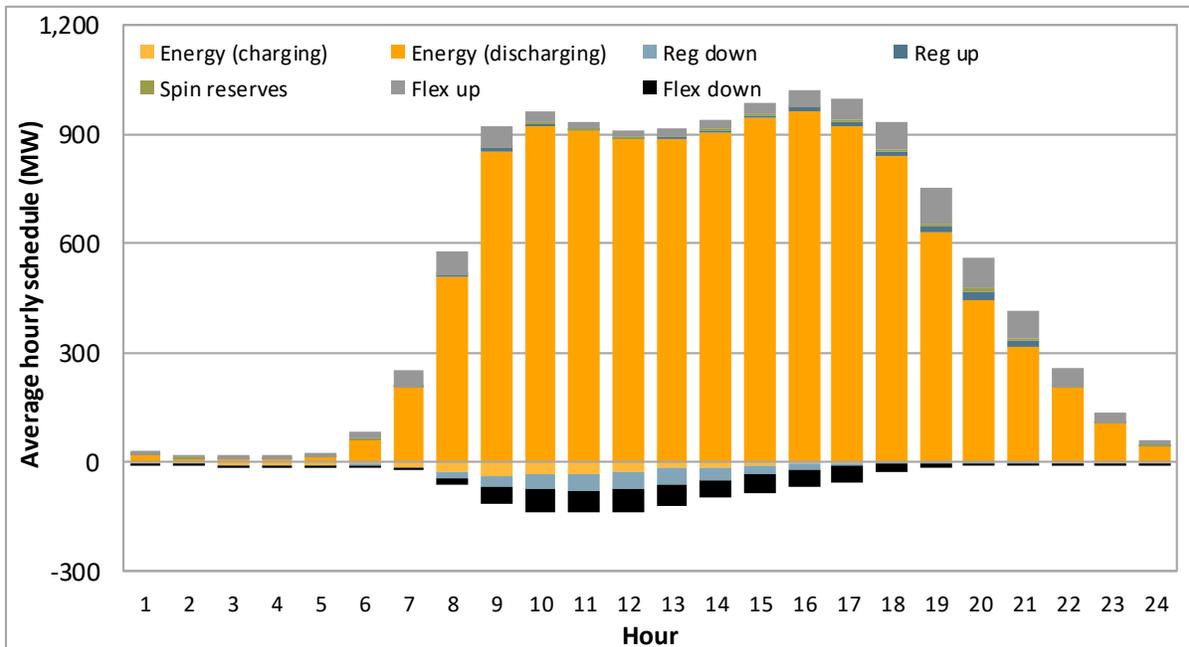


Figure 6. Average hourly schedule of hybrid resources with battery storage (2023)



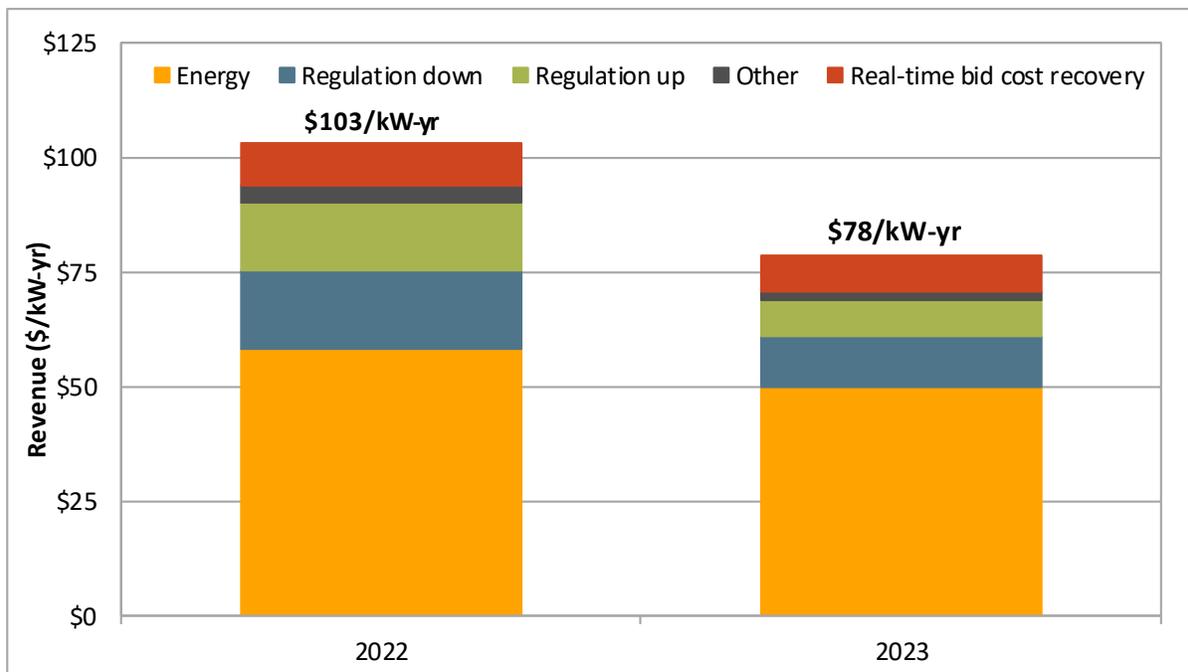
Battery revenues

In 2023, total net market revenues for batteries increased by around 22 percent as a result of increases to the battery fleet. However, net annual market revenues per MW of battery capacity decreased from \$103/kW in 2022 to \$78/kW in 2023 due to lower overall market prices.

Figure 7 shows weighted average revenue from different settlement categories per MW for batteries with a full year of operation. Energy revenues accounted for about 62 percent of battery revenues in 2023, and batteries earn substantial additional revenues from sales of regulation and bid cost recovery payments.

In 2023, bid cost recovery payments to batteries increased by about 16 percent to nearly \$28 million.¹ These payments represent about 10 percent of all bid cost recovery payments in the ISO markets, and represent 7 percent of batteries’ total net market revenues. DMM continues to recommend that the ISO enhance bid cost recovery rules for storage resources to consider state-of-charge limitations and other attributes unique to storage resources.

Figure 7. Average revenue for batteries with a full year of operation



¹ The ISO continues to resettle some bid cost recovery paid to batteries related to the ancillary service state-of-charge constraint. Therefore, final bid cost recovery paid to batteries in 2023 is likely to be lower than this value.