CAISO BESS Update

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Focus areas

Essential Reliability Services

- Frequency Support
- Ramping and Balancing
- Voltage Support

Other Challenges

Primary Frequency Support

- Positive:
  - Response can be very accurate (and timely) compared with other fuel types
    - Assumes inverter controller settings are in accordance with binding guidelines
      - Outreach to resources has resolved many issues

- Challenges:
  - Droop calculations are not consistent for many BESS resources
    - IEEE 2800 vs Interconnection Agreements vs Regional/National Regulatory standards
  - PFR should be the primary Control Mode
  - Some Co-Located resources are pushing back against having the right droop settings

- Impact:
  - Wrong PFR logic can create a disturbance

Ramping and Balancing

- Positive:
  - Response can be very timely compared with other fuel types
    - Very beneficial during solar ramp up and ramp down periods
    - Assumes inverter controller settings are in accordance with binding guidelines

- Challenges:
  - Expected State of Charge (SOC) of BESS is often dependent on other IBR resources
    - Solar – Cloudy Day can influence BESS effectiveness
  - Ramp rates may need to be reduced to avoid oscillations
  - BESS charge/discharge range is typically between 90% and 10%

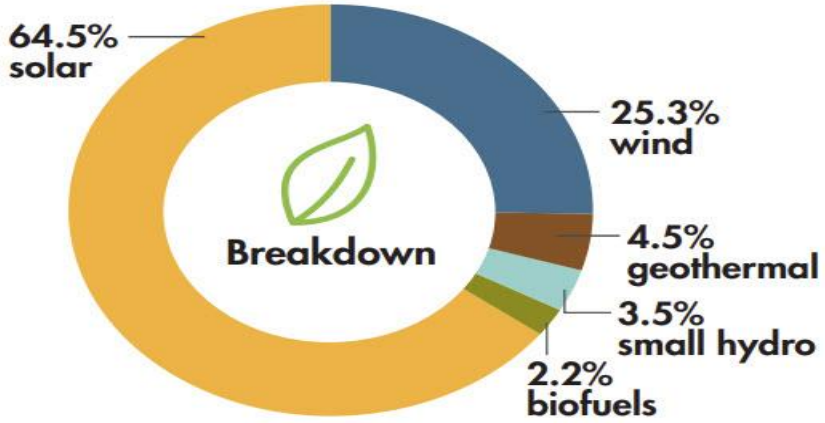
- Impact:
  - Management of BESS SOC during Increased System Variability Periods is essential

Storage Role in resource mix of CAISO

Installed battery capacity
12,896 MW
As of 05/31/25; subject to change.

Nearly all is lithium-ion and 4-hour duration

Installed renewable resources *(as of 06/09/2025)*



	Megawatts
Solar	21,340
Wind	8,373
Geothermal	1,505
Small hydro	1,146
Biofuels	725
TOTAL	**33,089**

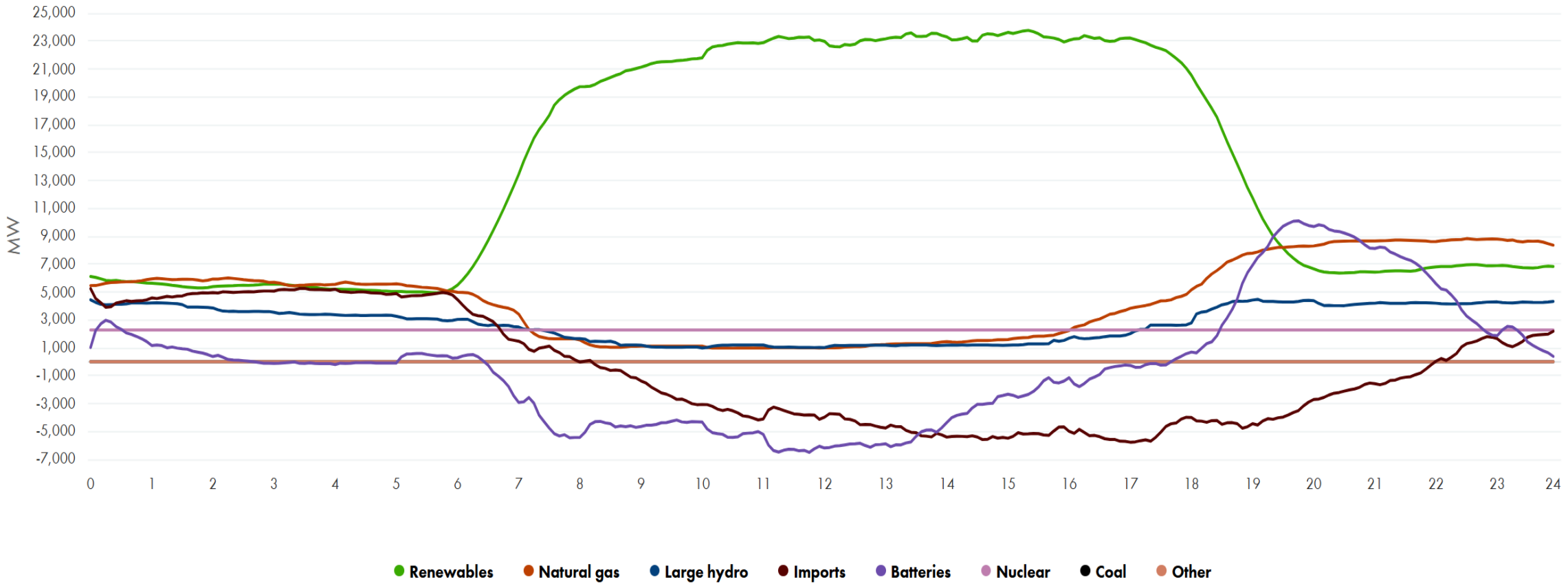
Rooftop solar is not connected to the high-voltage transmission system, but they affect the ISO's markets and grid operation.
Rooftop solar is at approximately 20,000 MW

California ISO

Battery Storage is Key to Reliably Meet California's Clean Energy Goals

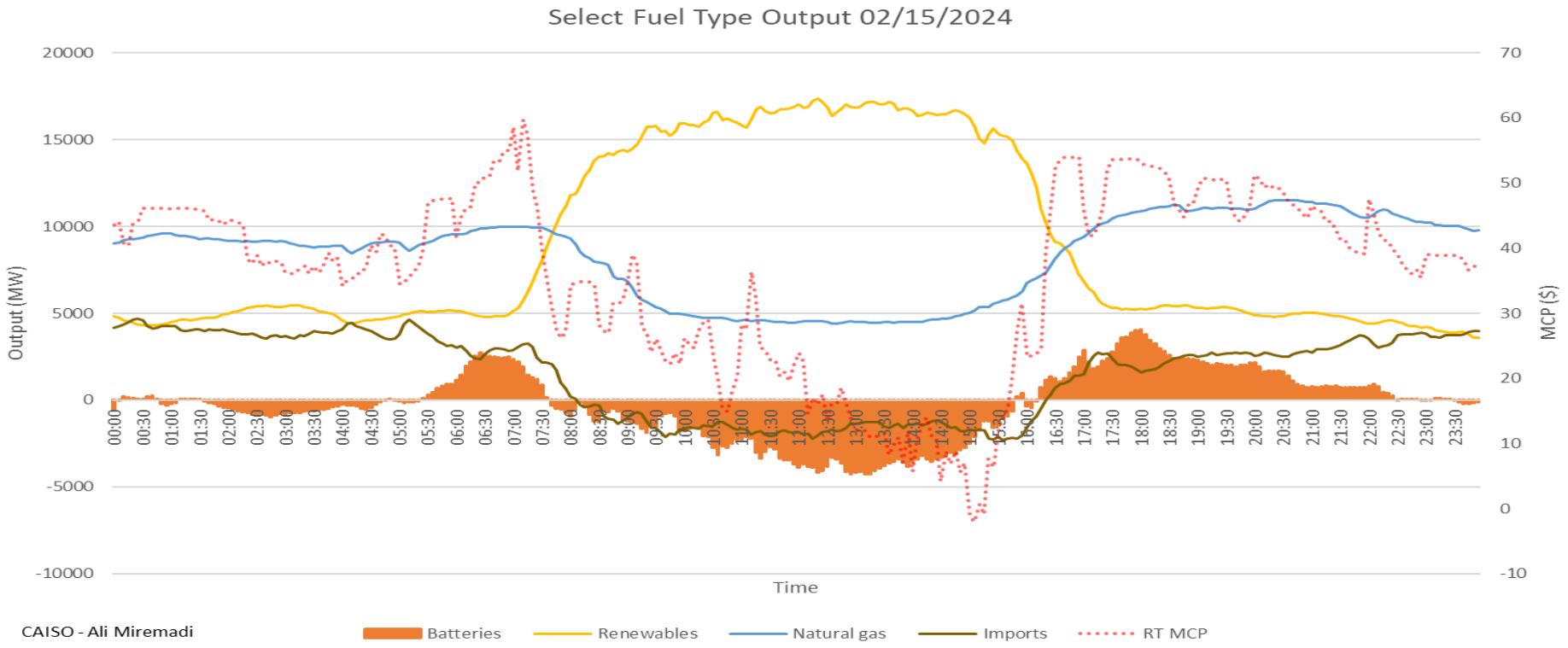
- State energy policy calls for a carbon-free grid by 2045 (SB 100)
  - Energy storage is a major part of the state's resource strategy
- California ISO's grid currently peaks at ~50 GW
  - 12,800+ MW of battery storage already integrated into the market
  - Nearly all are 4-hour duration lithium-ion batteries
  - Anticipate having more than 14 GW of battery storage by EOY
  - More than 1 GW of longer-duration storage by 2026
  - **~45 GW of energy storage by 2045.**

Ramping and Balancing – Supply Trend for 06/08/2025



Steepest 3-Hour Average evening ramp = 23,400MWh set on 04/07/2025

Ramping and Balancing – Storage-Price relationship



Key Services

- Providing dispatchable capacity during net peak after sunset
- Supporting early morning ramp
- Cushioning excess supply during solar hours
- Providing frequency response and other essential reliability services
- Increasing the capacity contribution of co-located solar projects

Voltage Support

- Positive:
  - BESS resources are capable of providing full range of reactive power even when sitting at zero active power output
    - Assumes inverter controller settings are in accordance with binding guidelines
- Challenges:
  - Some battery storage units are having difficulty transitioning from Power Factor mode to Voltage Control mode automatically
  - Lack of coordinated response due to different control settings
  - Some units rely on caps to provide voltage support (manual, slow)
  - Transformer configurations can impact voltage support at the point of interconnection
  - Voltage schedules vary by resource based on location, making validation difficult

Other Challenges

- SOC measuring and estimating accuracy is not optimal due to the non-linear nature of charging/discharging
- Battery cell aging can reduce expected performance over time
- Battery cell imbalance visibility/mitigation requires additional analysis. Active vs Passive balancing using BMS
- Battery fire cause/mitigation/prevention analysis is in progress but not complete

Questions?