California ISO

Grid of the Future

Johannesburg, South Africa

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California ISO is a federally regulated nonprofit organization

Responsibilities include:

- Maintaining reliability on the grid
- Managing the flow of energy
- Overseeing the transmission planning process
- Operating the wholesale electric market
- Driving innovation and supporting state and federal policy goals

For much of the western U.S., the ISO:

- Operates the Western Energy Imbalance Market (WEIM)
- Serves as Reliability Coordinator (RC West)

California ISO facts

As a federally regulated nonprofit organization, the ISO manages the high-voltage electric grid in California and a portion of Nevada

52,061 MW record peak demand (Sept. 6, 2022)

$739 billion annual market (2022)

224.8 million megawatt-hours of electricity delivered (2020)

76,184 MW power plant capacity

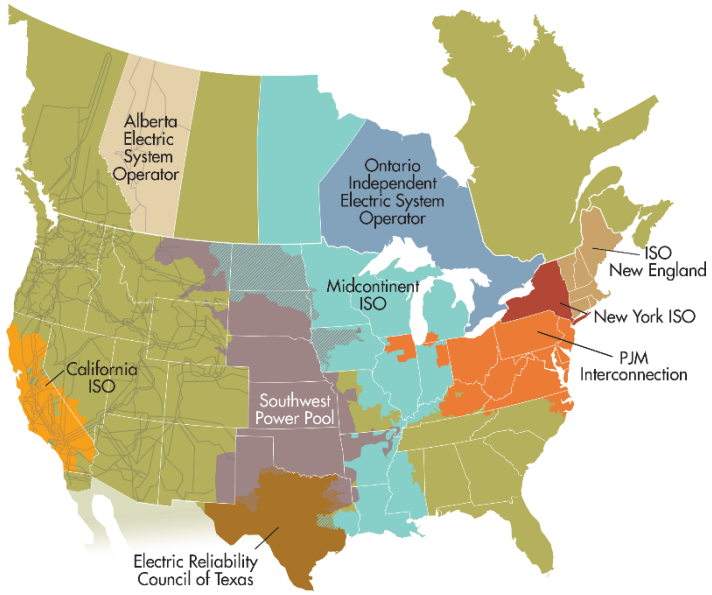
Source: ISO's Masterfile August 2023

1,119 power plants

Source: California Energy Commission

32 million people served

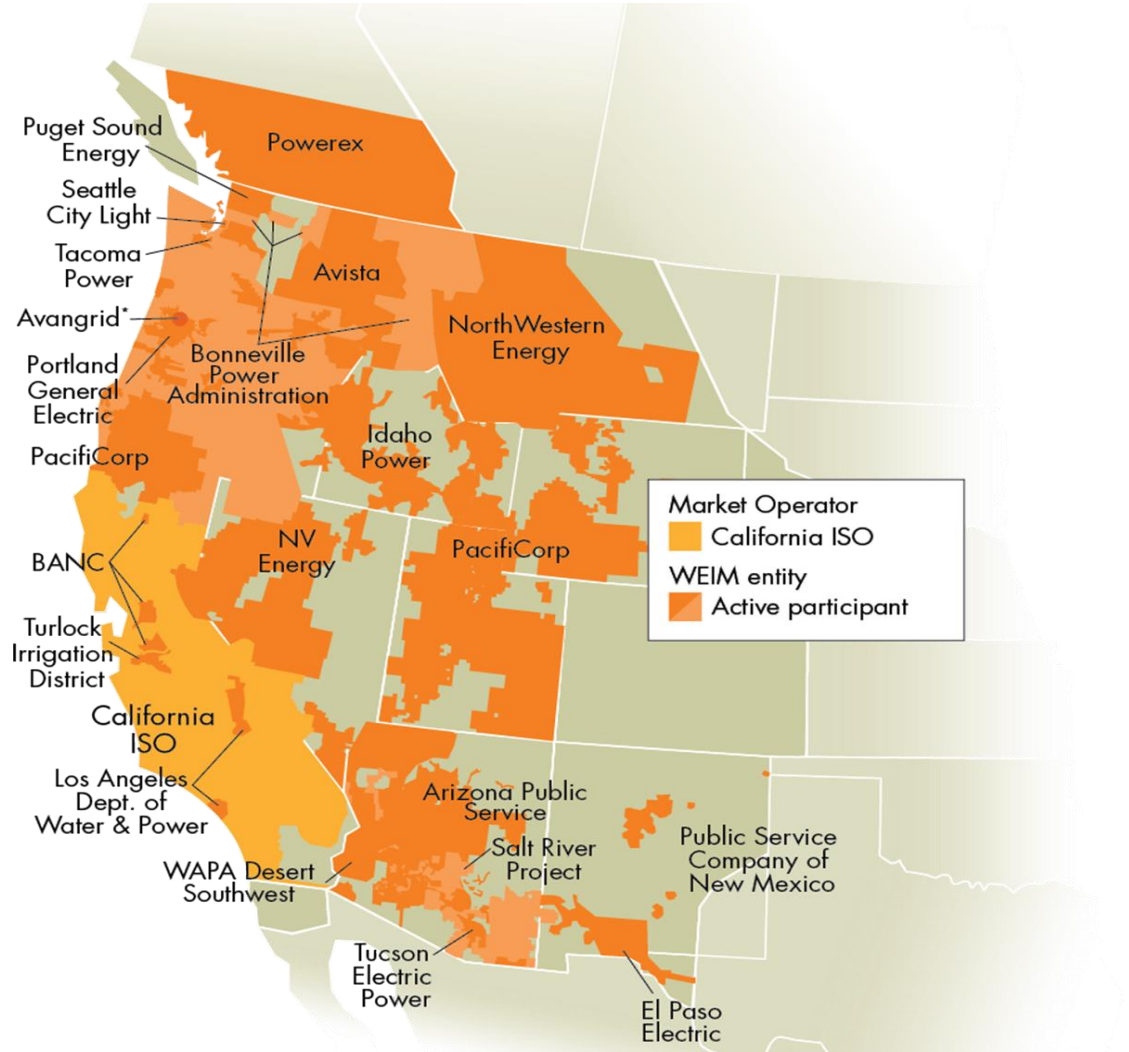
One of **9** ISO/RTOs in North America



Western Energy Imbalance Market (WEIM)

Since its launch in 2014, the WEIM has enhanced grid reliability, generated billions of dollars in benefits for participants, and improved the integration of renewable energy resources

- 22 participating entities
- Gross benefits exceeds $4.2 billion as of July 31, 2023
- Reduced about 878,000 metric tons of CO_2 as of July 31, 2023



*Avangrid office; generation-only BAA with distribution across multiple states.
Map boundaries are approximate and for illustrative purposes only.

California is pursuing a low carbon future

- Ambitious renewable energy goals

33% by 2020 → 60% by 2030 → 100% zero-carbon by 2045

- Deep greenhouse gas (GHG) reduction goals

2020 Target	2030 Target	2050 Target
Reduce GHG emissions to 1990 levels	40% below 1990 levels	80% below 1990 levels

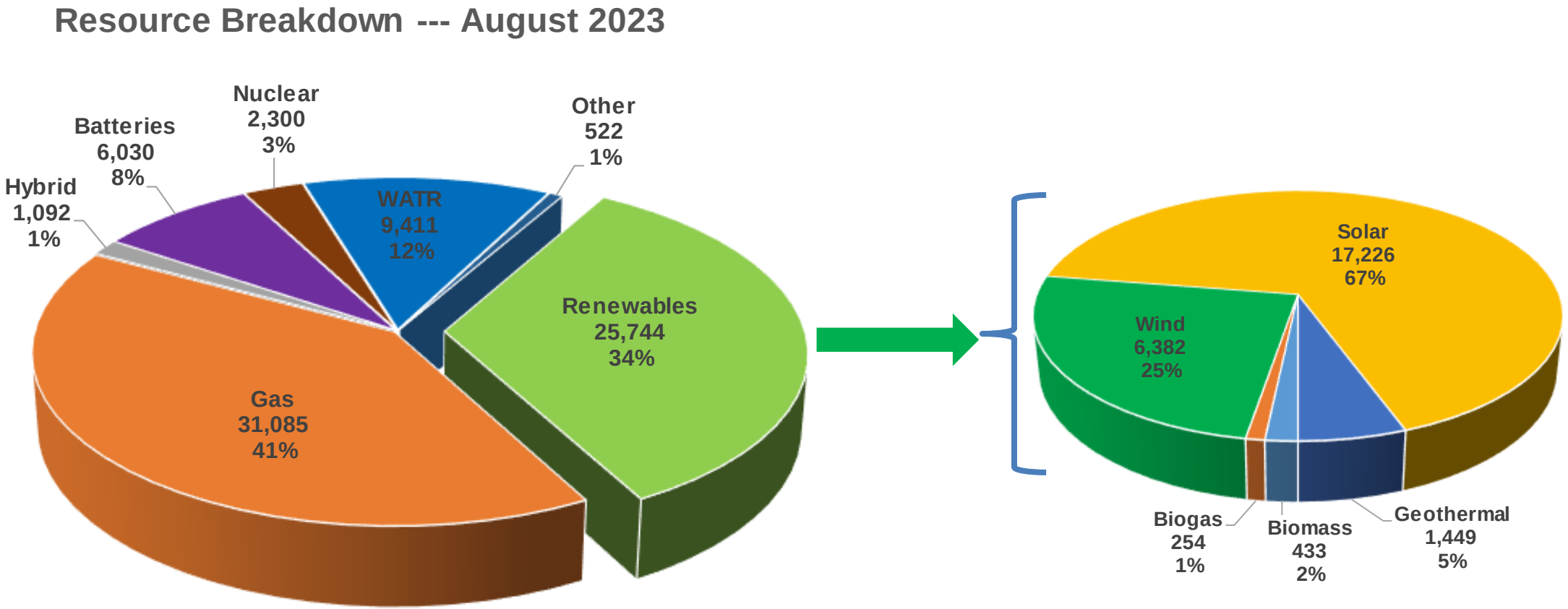
- Robust electric vehicles goal: 1.5 million by 2025
- 14,300 MW of distributed generation by end of 2023
- 6 GW of battery storage by end of 2023

→ **Decarbonization is creating opportunities to develop a high renewables and high DER energy service industry**

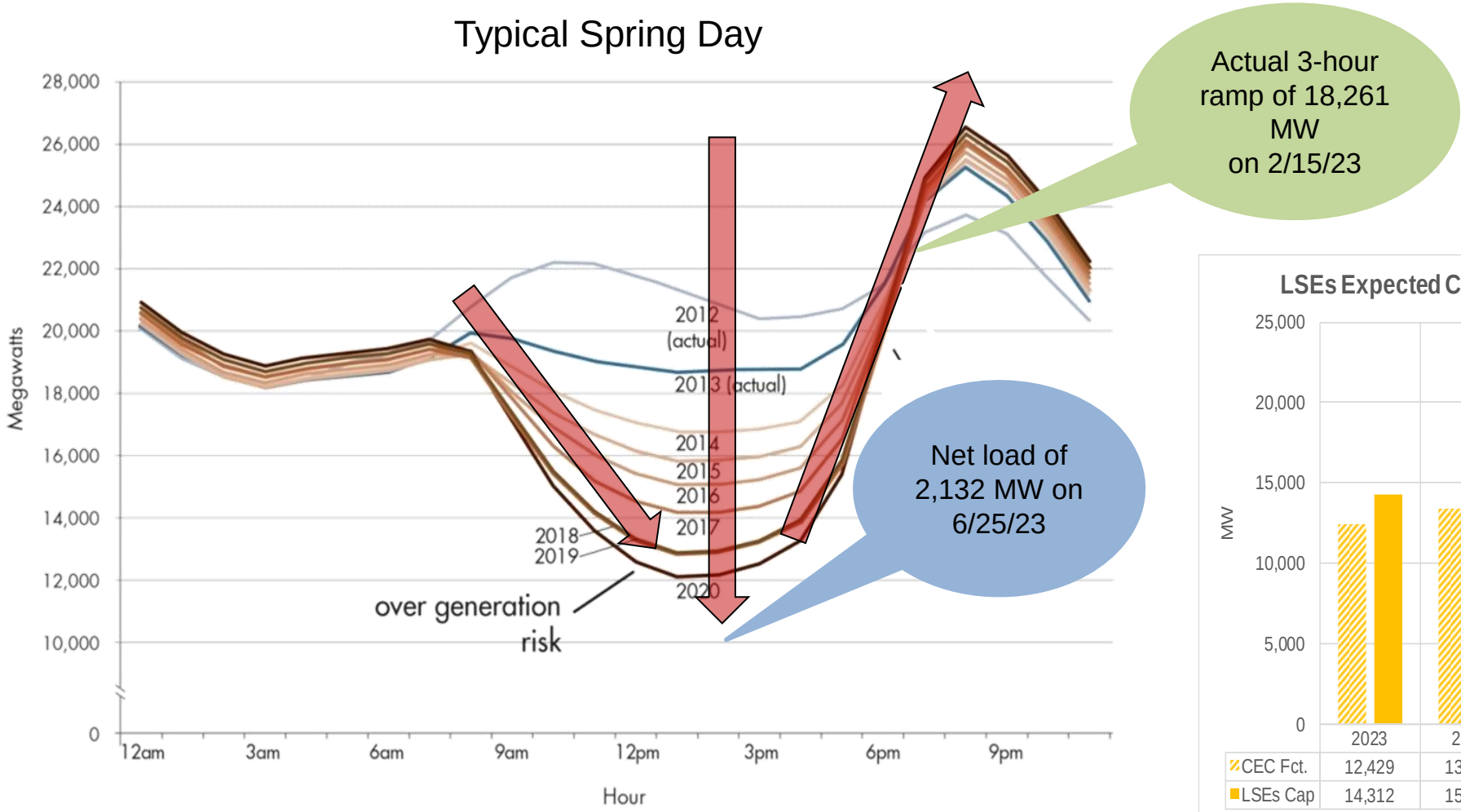
Managing power through new technologies and consumer programs

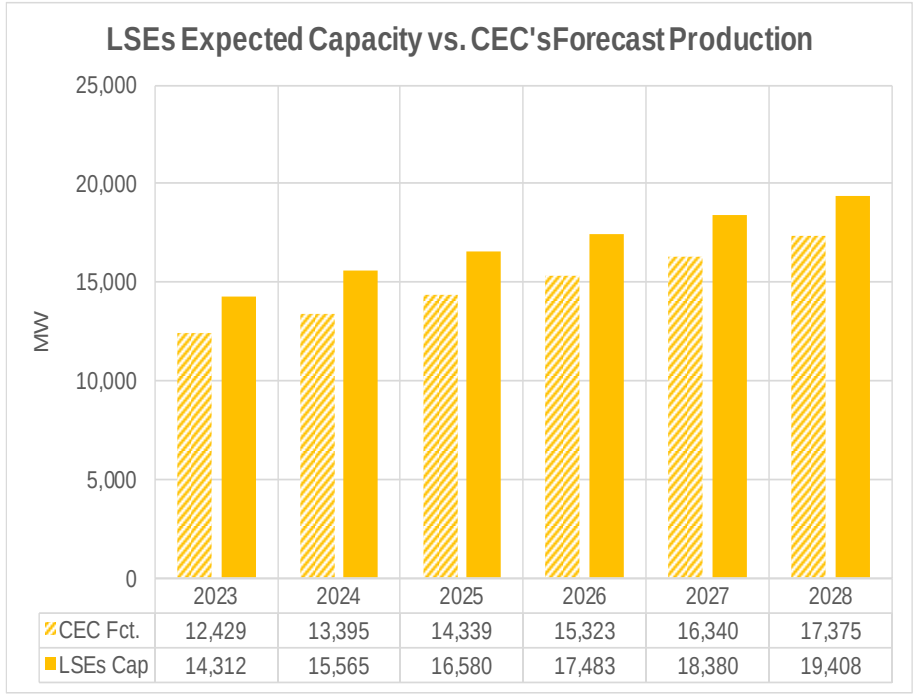
- As more renewable energy is integrated on the electric system, oversupply conditions often occur during the middle of the day
- To avoid curtailment, excess renewable energy must be stored
- Several new technologies and consumer programs have been developing including:
  - Storage/batteries (ISO is agnostic to resource technology)
  - Demand response
  - Time-of-use rates
  - Hydrogen fuel
  - Offshore wind and wave technology
  - Underground compressed air
  - Electric vehicles
  - Other Emerging Technologies

As of August 2023, the CAISO's resource capacity breakdown was 76,184 MW with renewable resources making up 34%



Actual net-load and 3-hour ramps are several years ahead of ISO's original estimate



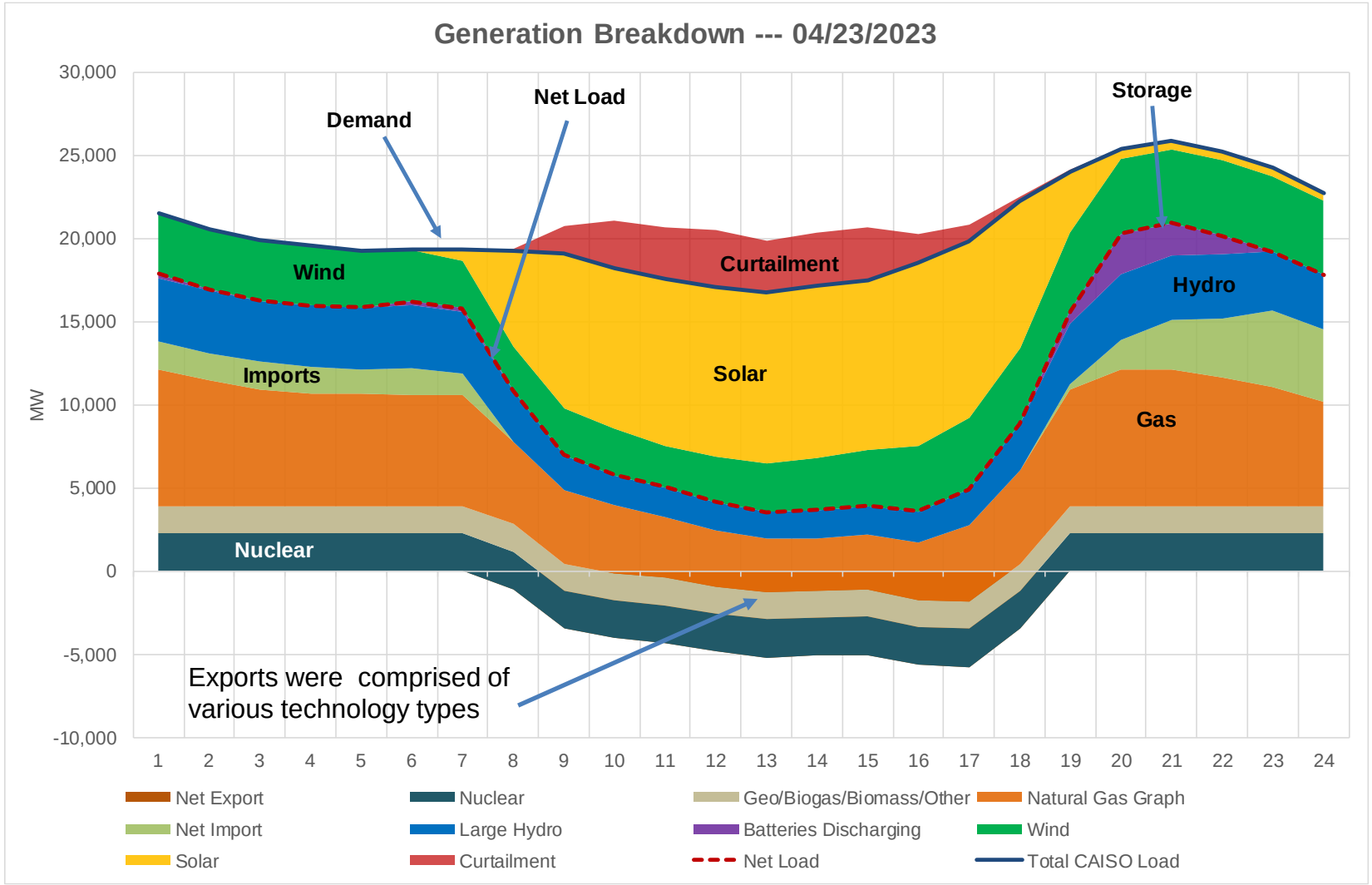


	2023	2024	2025	2026	2027	2028
CEC Fct.	12,429	13,395	14,339	15,323	16,340	17,375
LSEs Cap	14,312	15,565	16,580	17,483	18,380	19,408

Maximum load plus export served by non-carbon resources on Sunday, April 23, 2023 was 108%

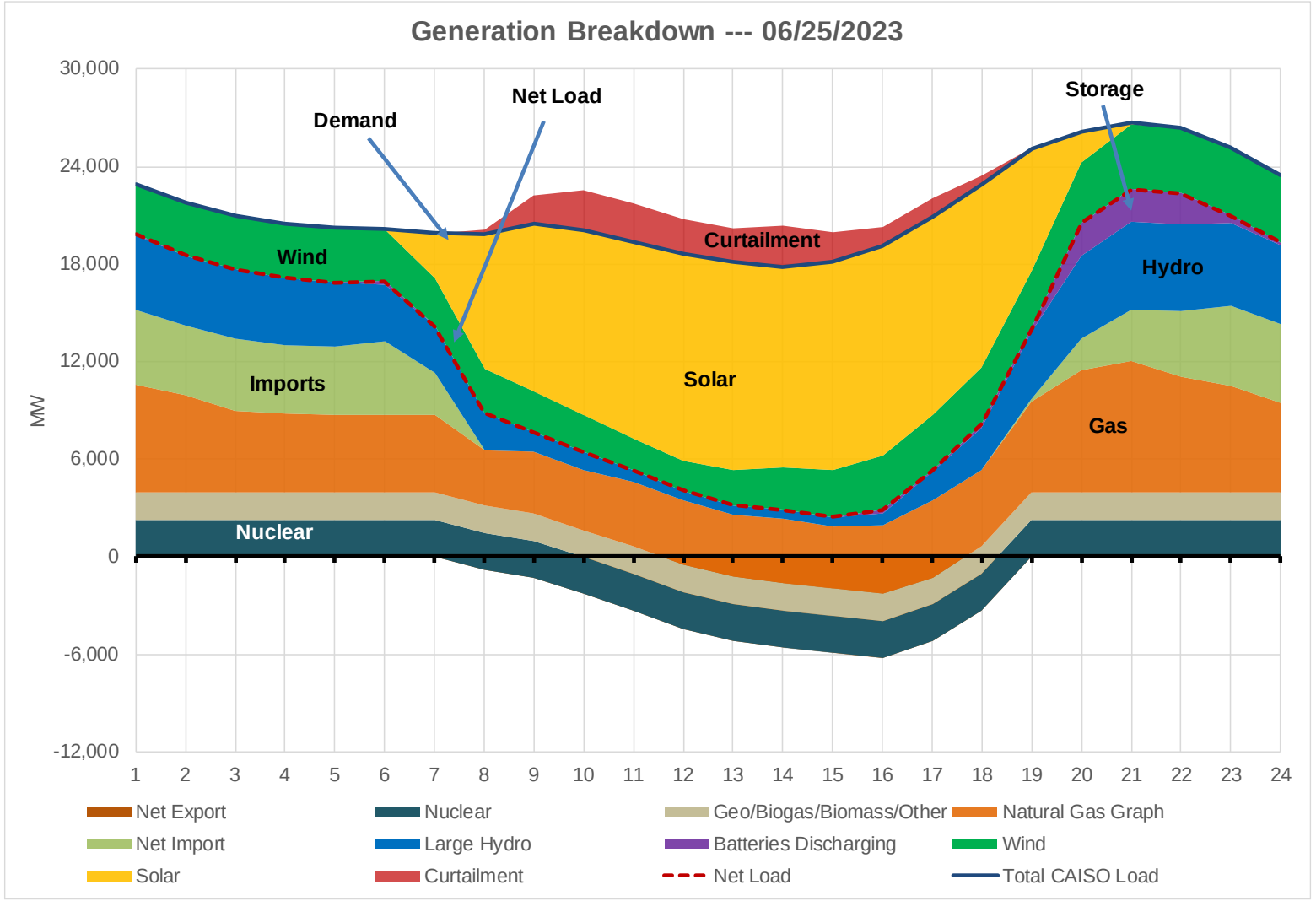
Operational Challenges

- Lack of downward dispatchability during middle of the day
- Relies on imports/exports and DEC bids to balance the system
- Lack of adequate frequency response capability during the middle of the day
- Potential control performance issues due to lack of flexibility
- Need IBRs including storage to provide essential grid services such as:
  - Voltage Control
  - Frequency response/control
  - Active Power Management

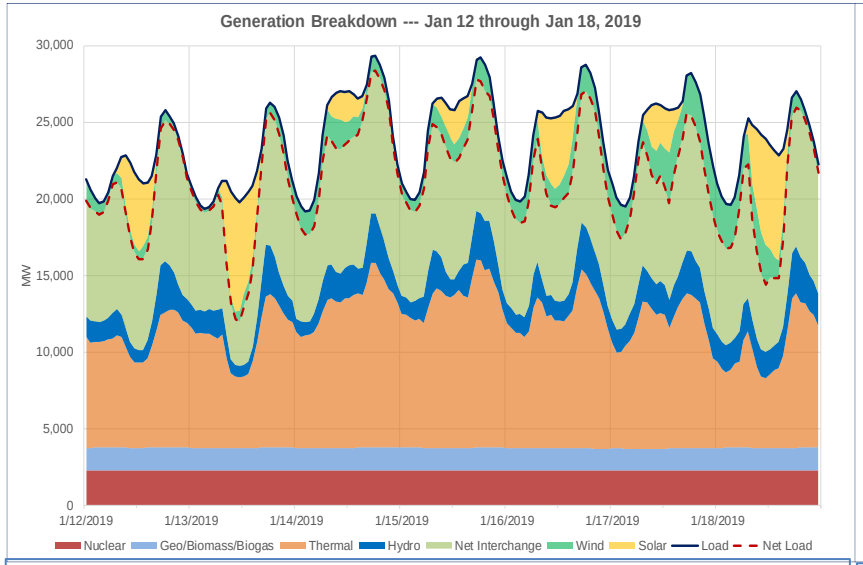


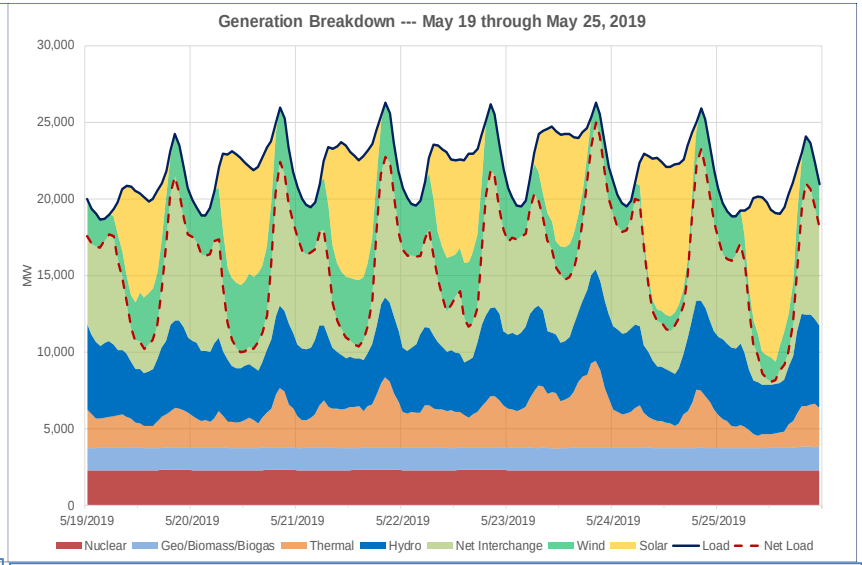
On June 25, 2023 the CAISO served 88 percent of its demand with wind and solar for a short period of time

- CAISO met 88% of its demand with wind and solar
- Production below zero were exported to neighboring balancing authorities
- Exports were comprised of various technology types
- Collaborative efforts are analyzing/evaluating solutions to sustain higher levels of renewables serving demand



Challenges under different operating conditions show the need for IBRs including storage to provide grid services





Cloudy/Rainy Days

- Maximum net import was 9,820 MW
- Maximum hourly solar production was 1,970 MW
- Maximum simultaneous wind/solar was about 3,800 MW and occurred during HE11
- Maximum thermal generation was about 12,000 MW
- Need long-term storage to address extended periods with minimal wind/solar production

During Hydro Spill Conditions

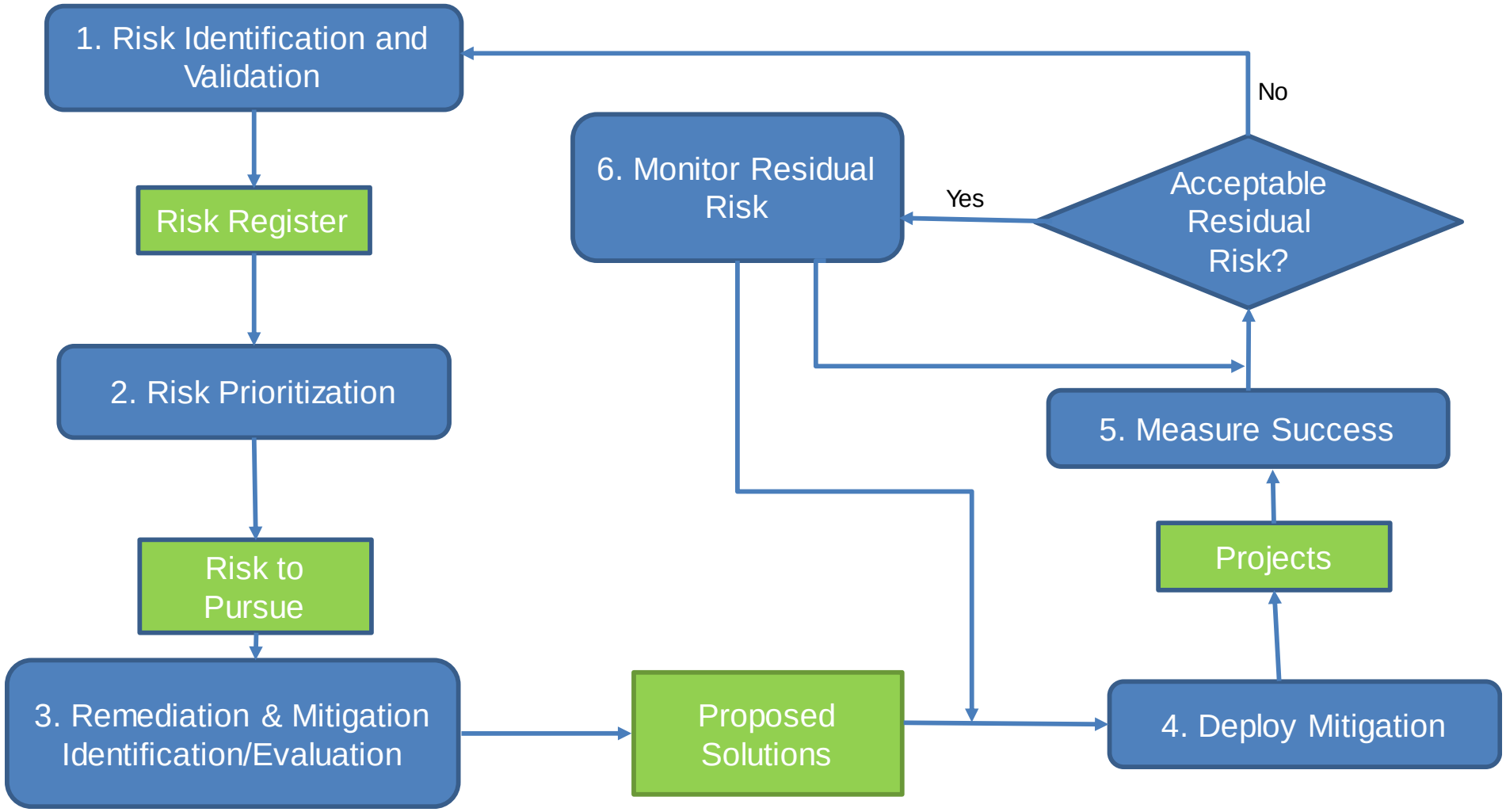
- Rely on gas fleet for most ancillary services
- Typically operate gas fleet at low operating levels to minimize over supply
- Committed gas fleet cannot provide adequate primary frequency response obligation
- Need renewable resources to provide essential grid services
- Need storage devices to provide ancillary services, intra-hour and multiple hour ramping needs

Operational concerns needs to be address as energy and environmental policies drive grid transformation

Risk Profiles

- **Energy Policy** – Ensure reliability as federal, province, state and local communities energy goals work in tandem with end-use electricity users
- **Grid Transformation** – Plan and incorporate advanced tools and grid infrastructure improvements to ensure reliable, resilient and secure integration
- **Resilience to Extreme Events** – Ensure IBRs including energy storage; demand response; micro-grids; and other emerging technologies have the ability to absorb and quickly recover from extreme events
- **Security Risk** - Expansion of emerging technologies is increasing the potential of cyber-attacks and coordinated attacks
- **Critical Infrastructure Interdependencies** – Ensure interdependencies between industries such as gas/electric sector, emerging technologies and DERs are operated reliably

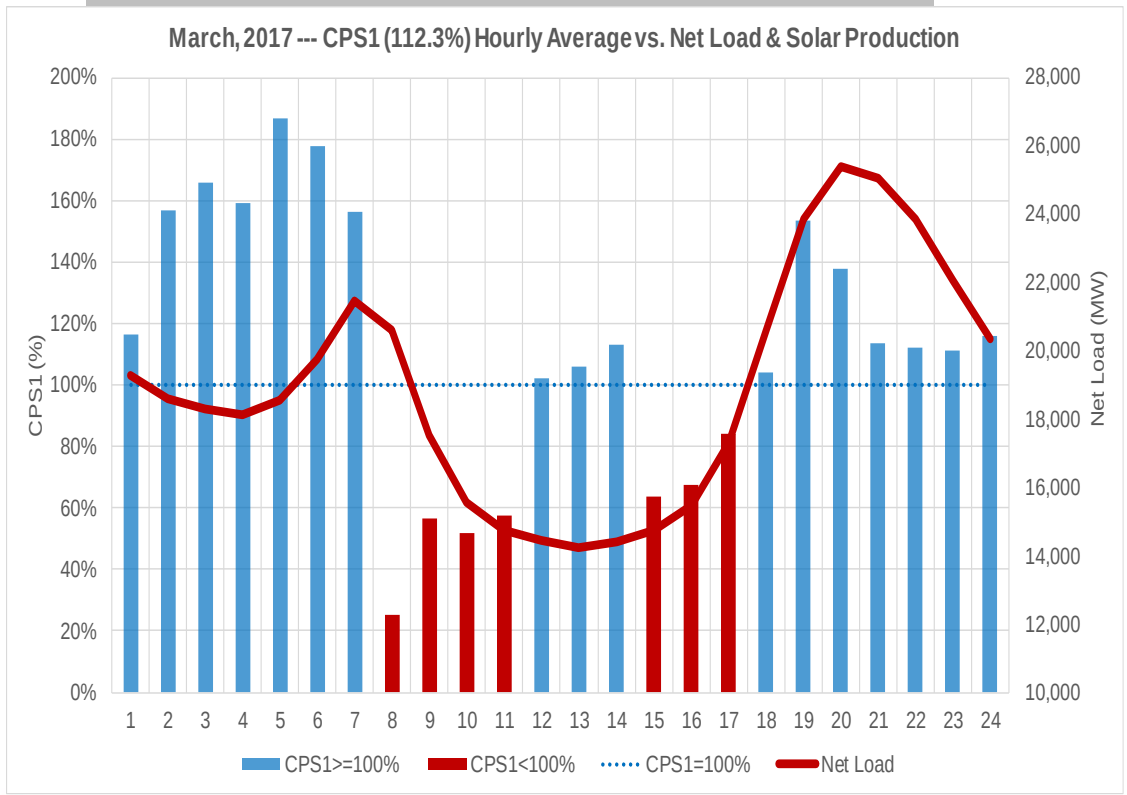
Need to develop a functional risk management framework as more IBRs are integrated into existing resource mix



Example of the risk framework processes showing hourly control performance improvements with integration of high levels of IBRs

March 2017

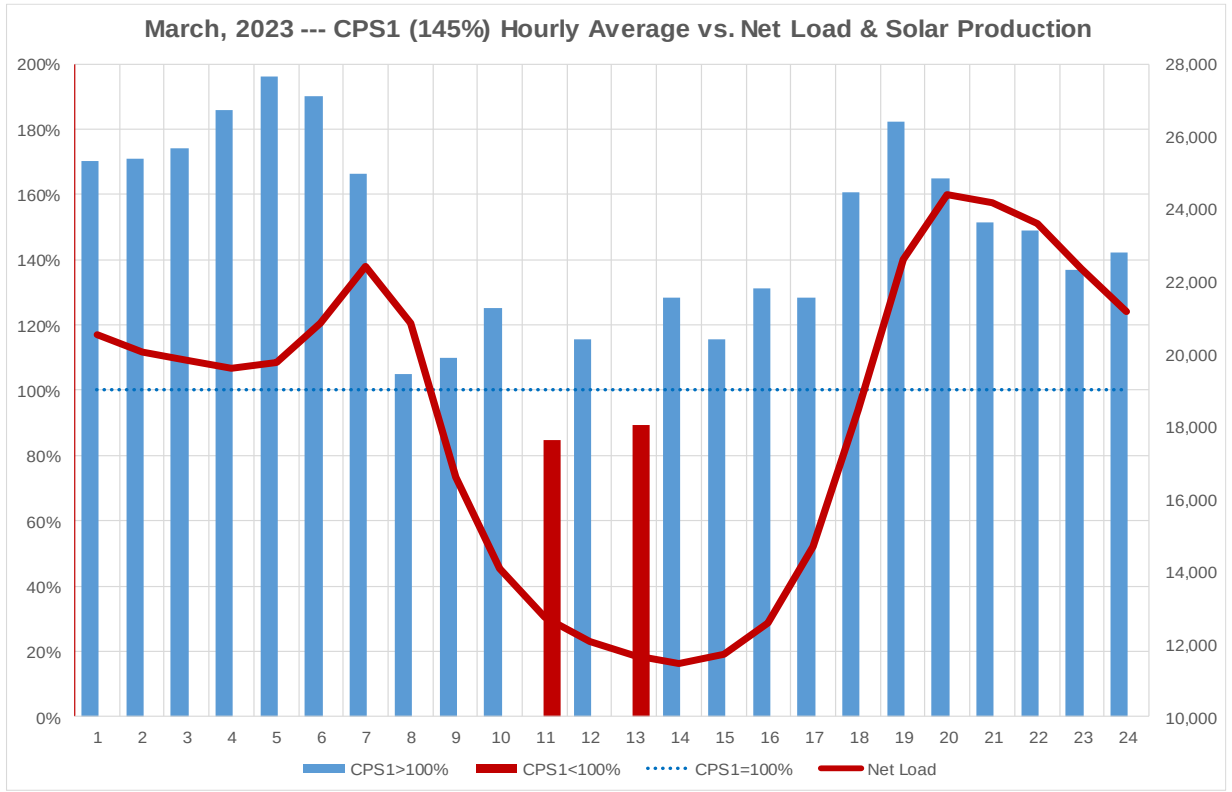
- Pronounced operational challenges during sunrise and sunset
- Challenges maintaining hourly CPS1 scores above 100%



March 2023

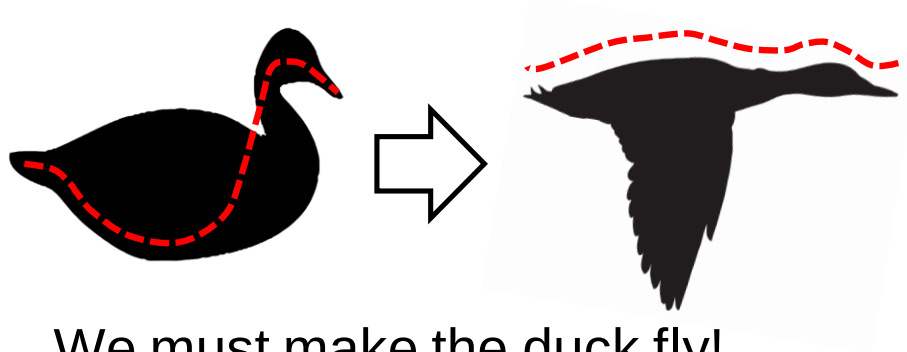
Better hourly control due to:

- Increased regulation procurement
- Better utilization of the ties
- Storage devices
- Persistence forecast



What is the “Duck” telling us?

- Integrating higher levels of renewables is making significant impact on how we meet mid-day demand
- Management of increased oversupply requires economic bids from all resources, including renewables
- Increasing challenges to simultaneously meet evening ramp and most severe contingency
- Need additional solutions such as storage, time of use (TOU) rates, regional collaboration, and flexibility from all resources to shift and shape demand
- Need to maintain sufficient capacity during multiple days of low wind/solar production

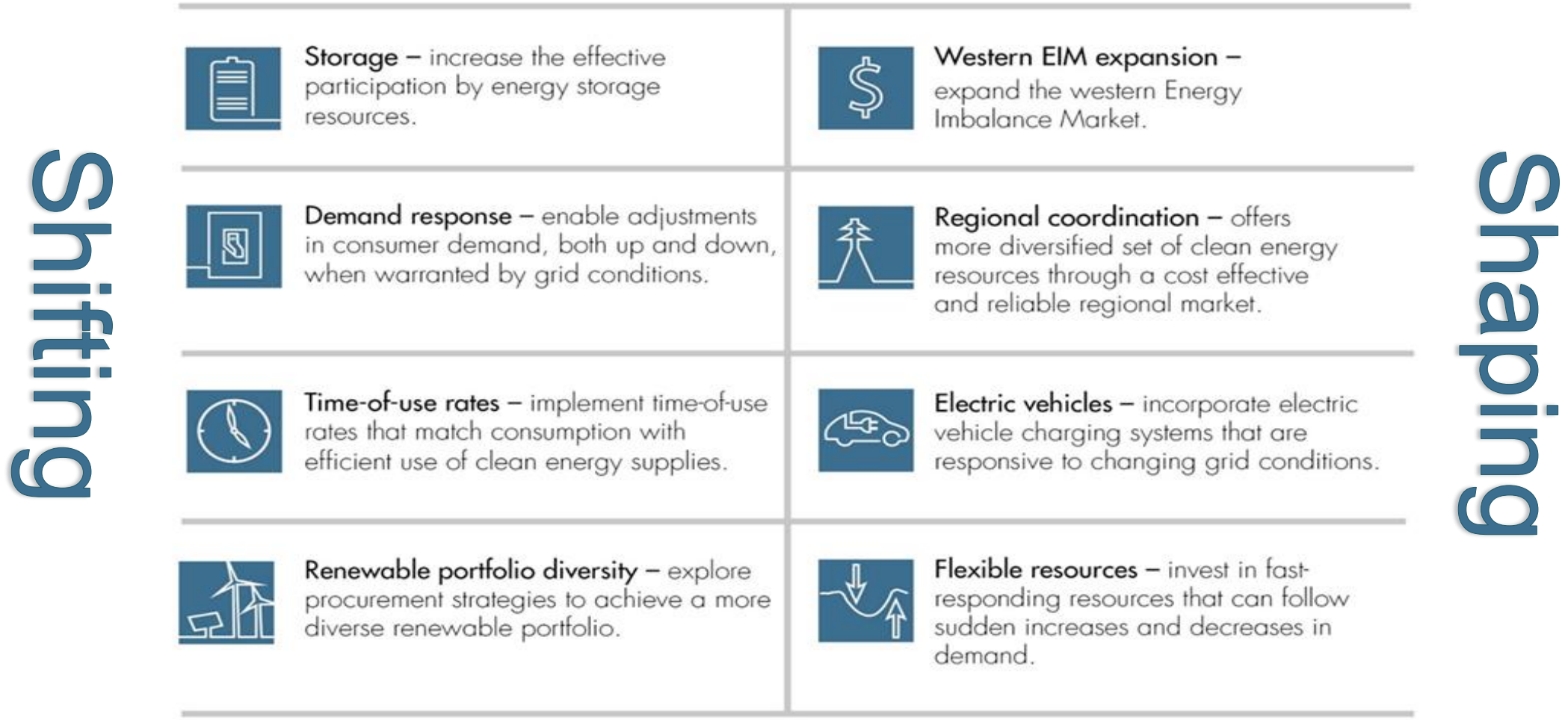


We must make the duck fly!

A healthy grid must counter-act the ill-affects of the sitting “duck curve”

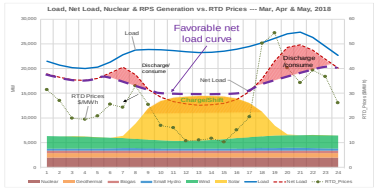
- Volume and speed of solar morning ramp is greater than demand and needs to be managed
- Renewable resources need to follow dispatch instructions similar to other resources

How can IBRs be used to create a more favorable load shape and an operationally sustainable grid?



What are some potential opportunities?

Targeting energy efficiency

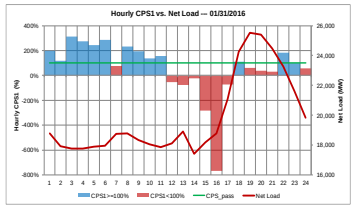


Minimizing curtailment, diversifying VERs portfolio, increasing storage and demand response participation

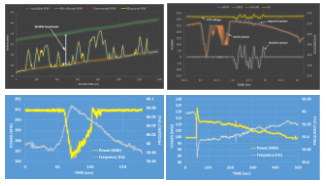
Decarbonizing transportation fleet

Expanding Western EIM enabling economic dispatch of renewables

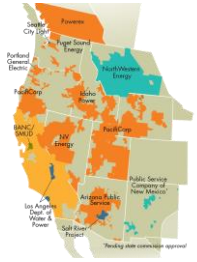
Aligning time-of-use rates with system conditions



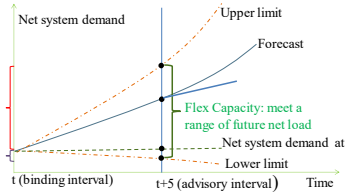
Ensuring compliance with NERC's operational performance standards



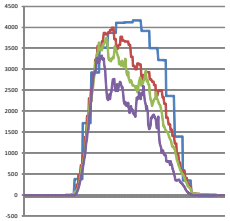
Utilizing Grid/DER resources to provide essential reliability services



Exploring Regional Coordination



Enhancing market products and timelines



Enhancing forecast to better manage supply/demand uncertainty

Questions