

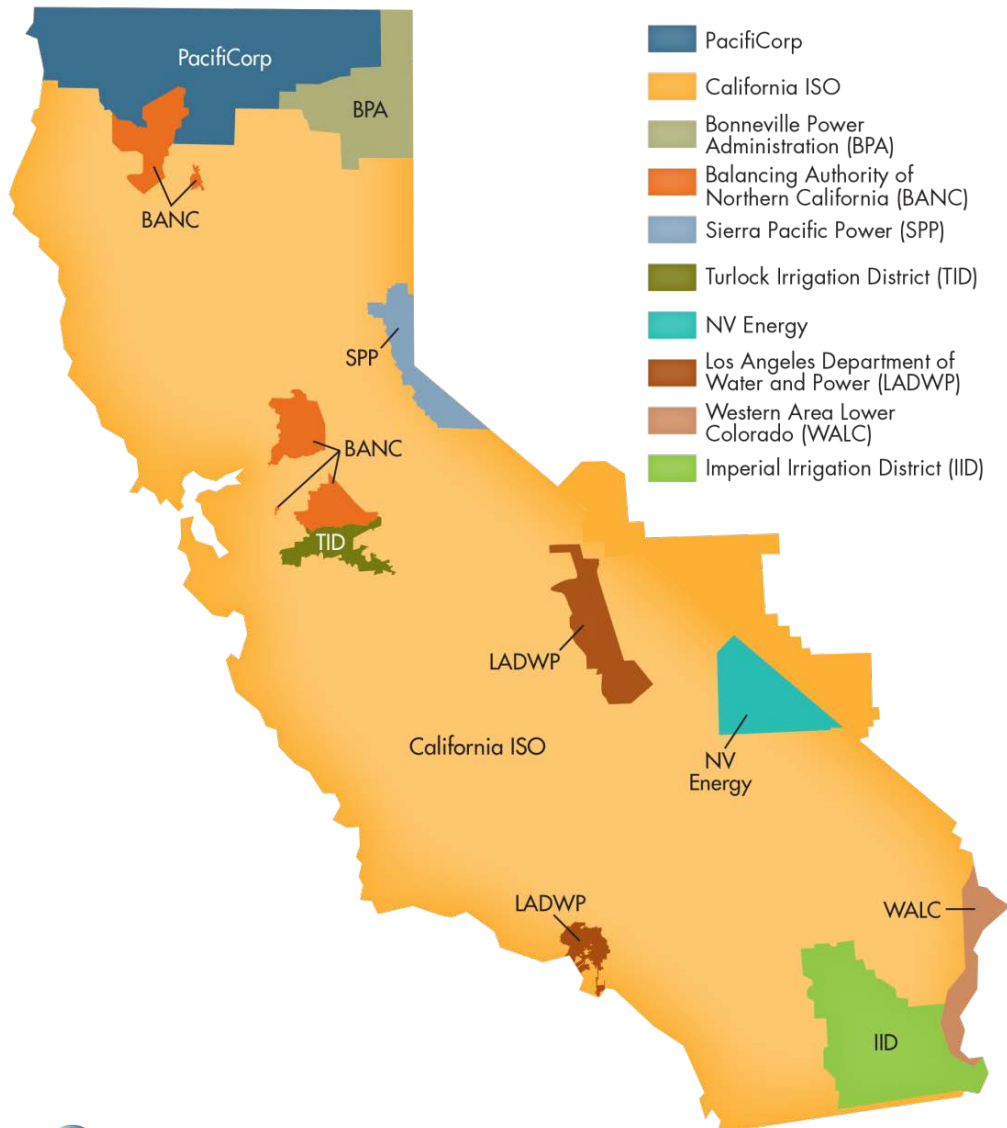


Regional Impact of Renewables

Mark Rothleder
Vice President, Market Quality and Renewable Integration

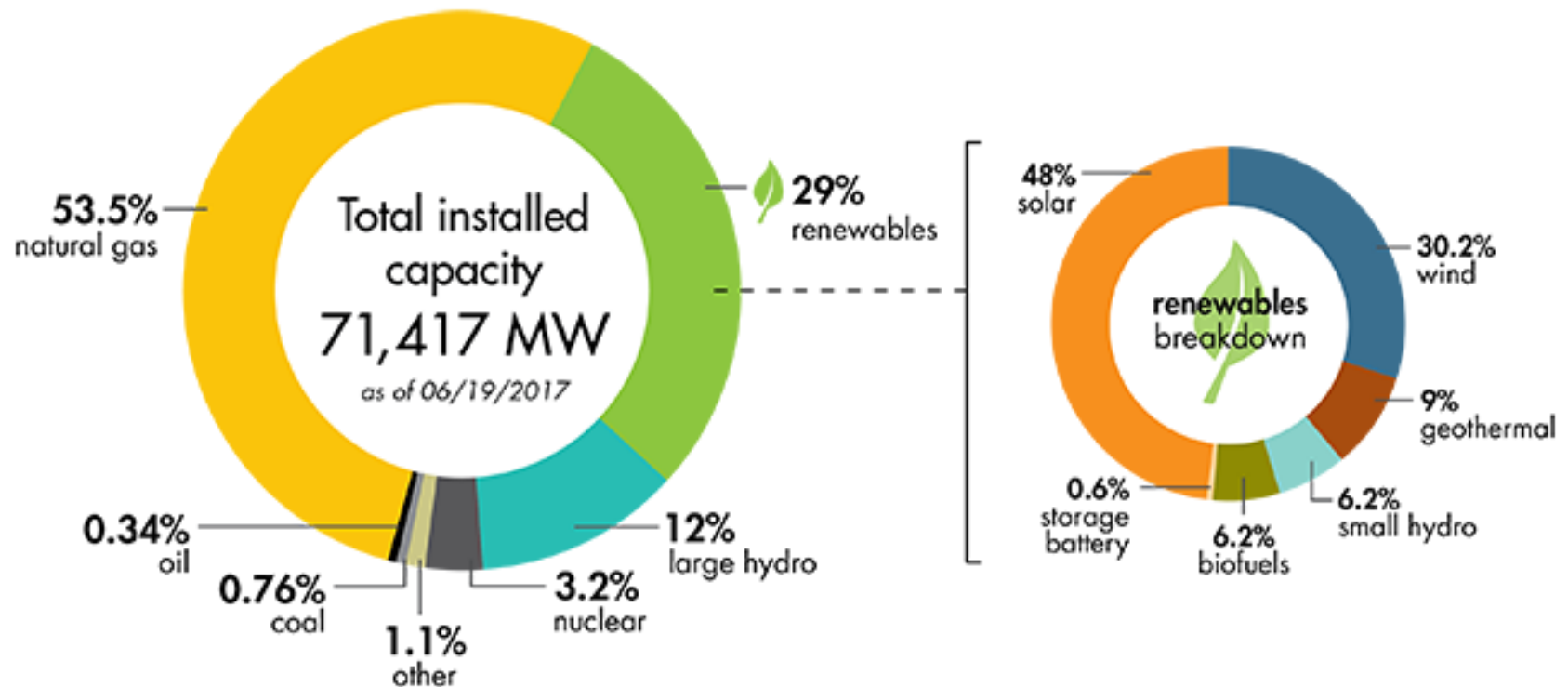
Gas/Electric Partnership Conference
Houston, TX
February 1, 2018

CAISO by the numbers



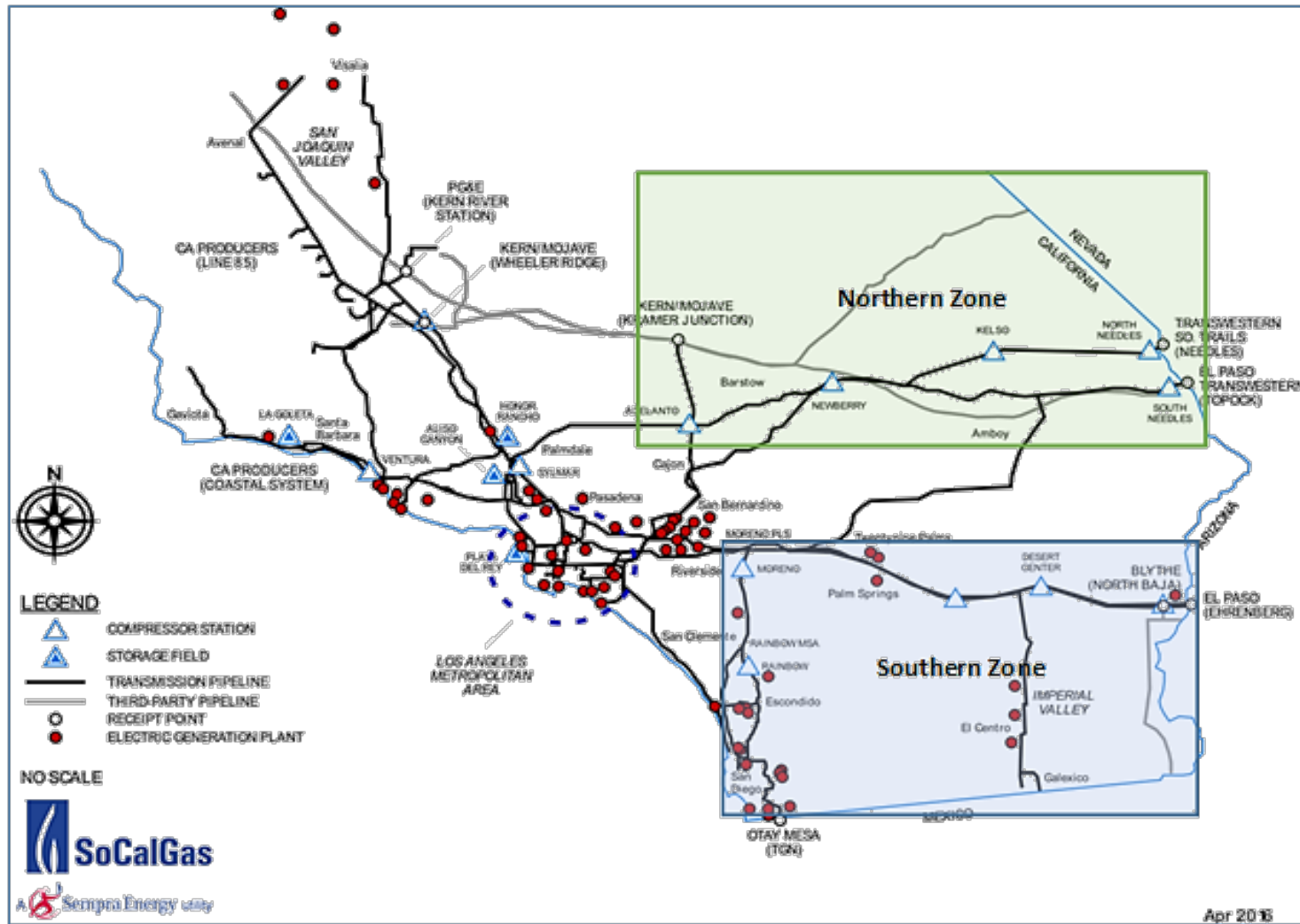
- Serves 80% of state
- 30 million consumers
- 26,000 miles of wires
- 72,000 MW plants
- 27,000 market transactions per day
- \$9 billion market

ISO Resource Mix



Note: "Installed capacity" refers to the total amount of generation capacity, but does not reflect the total generation available for dispatch at any given time.

Gas storage plays an important role in maintaining gas and electric reliability in southern California



Electric industry in the midst of unprecedented change - *Driven by fast-growing mix of interrelated issues*



Power industry transformation



Wind

- Unpredictable Output
- **4,990 MW Peak – May 16, 2017**
- 6,087 MW Installed Capacity



Solar Thermal / Photo Voltaic

- Semi – Predictable Output
- **9,914 MW Peak – June 17, 2017**
- \approx 10,000 MW Installed Capacity

* Simultaneous wind and solar has exceeded 13,000MW on April 23, 2017



Roof Top Solar

- Semi – Predictable Output
- Behind the meter – Residential
- 5,000+ MW Estimated Capacity

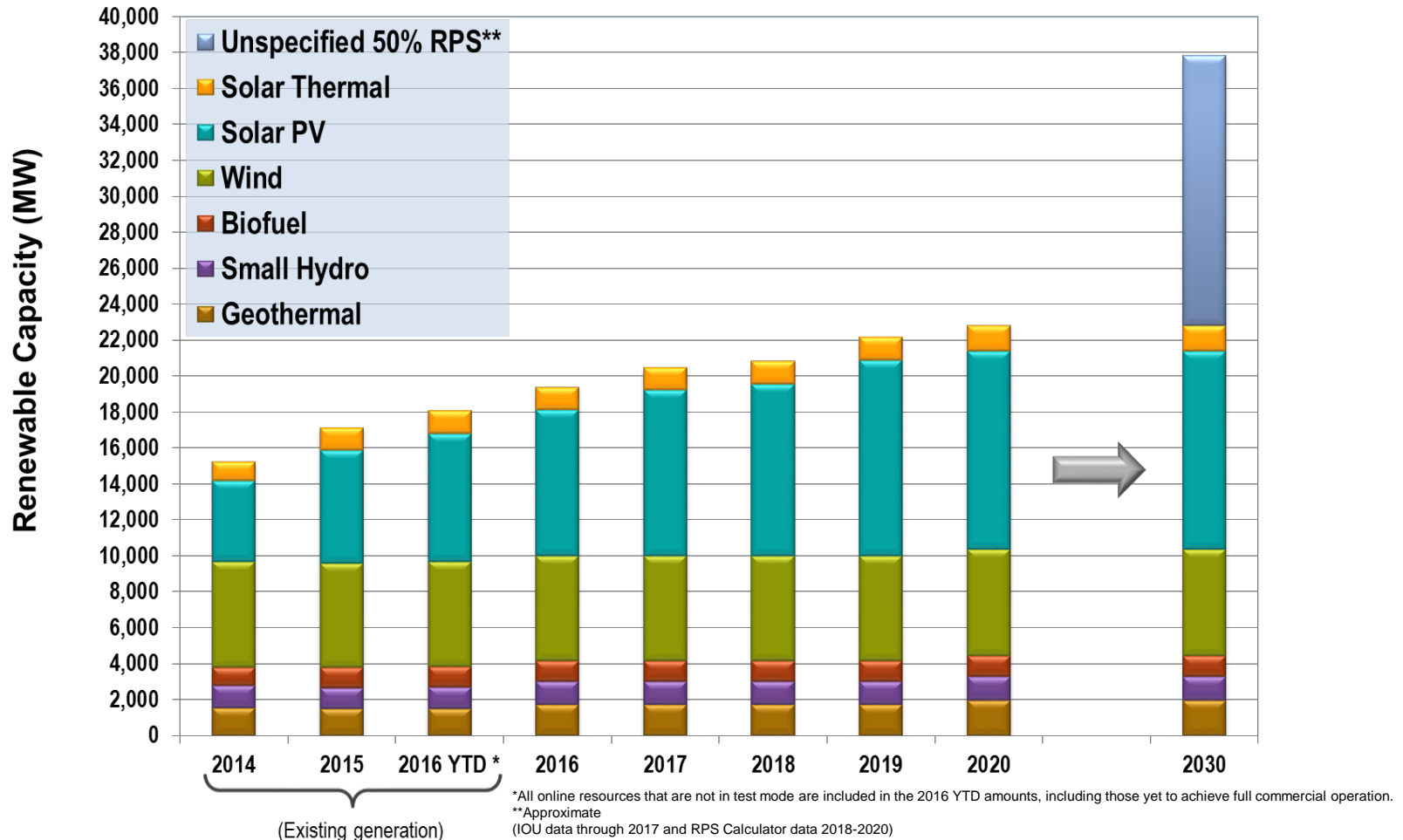
Main Drivers:

- ✓ California RPS
- ✓ GHG reduction
- ✓ Once-through-Cooled plants retirement

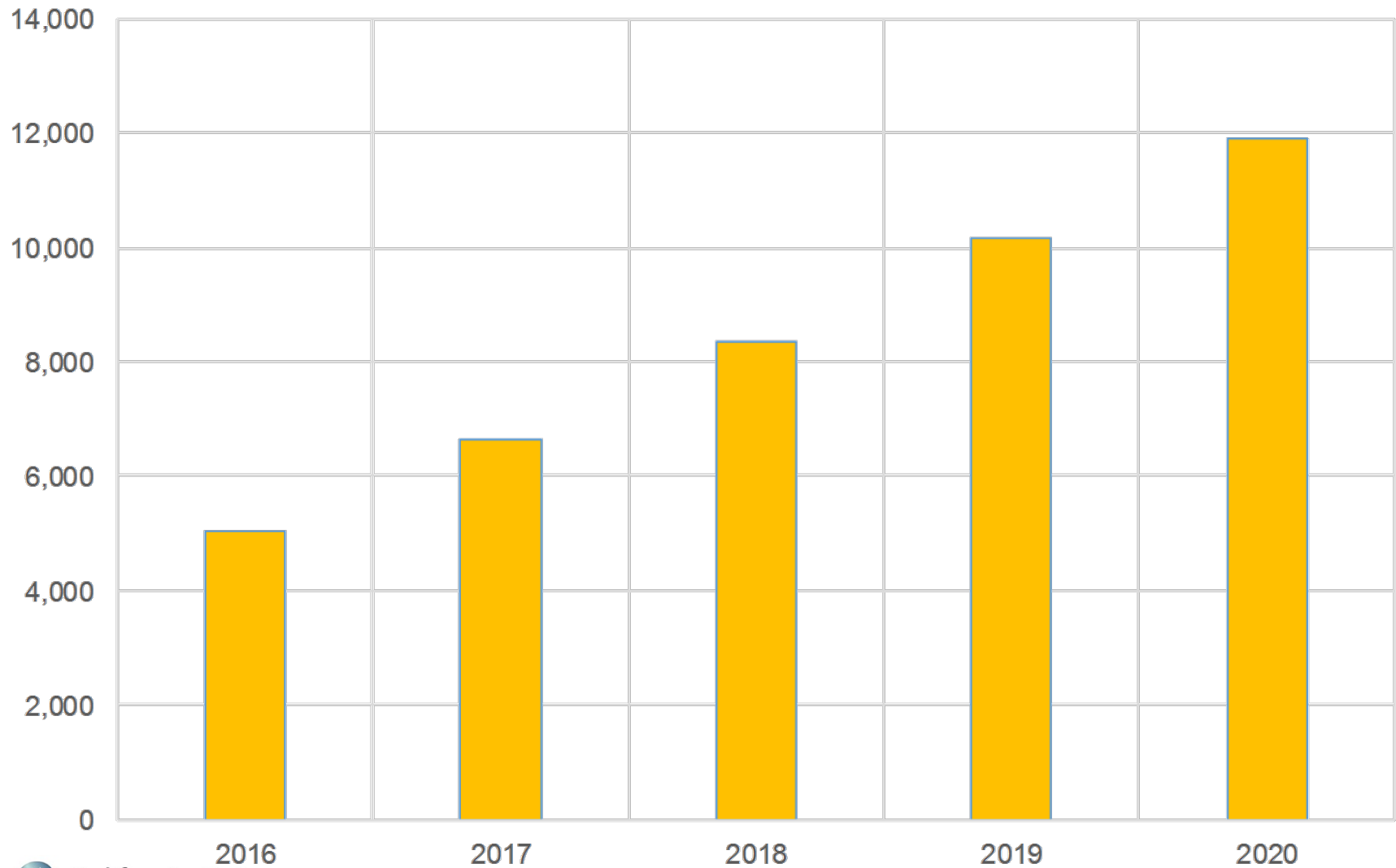
Goals:

- ✓ Higher expectation of reliability
- ✓ Higher expectation of security
- ✓ Smart Grid
- ✓ Situational awareness through Visualization

Approximately 4,000 MW of additional transmission-connected renewables by 2020 and an additional 10,000 to 15,000 MW by 2030

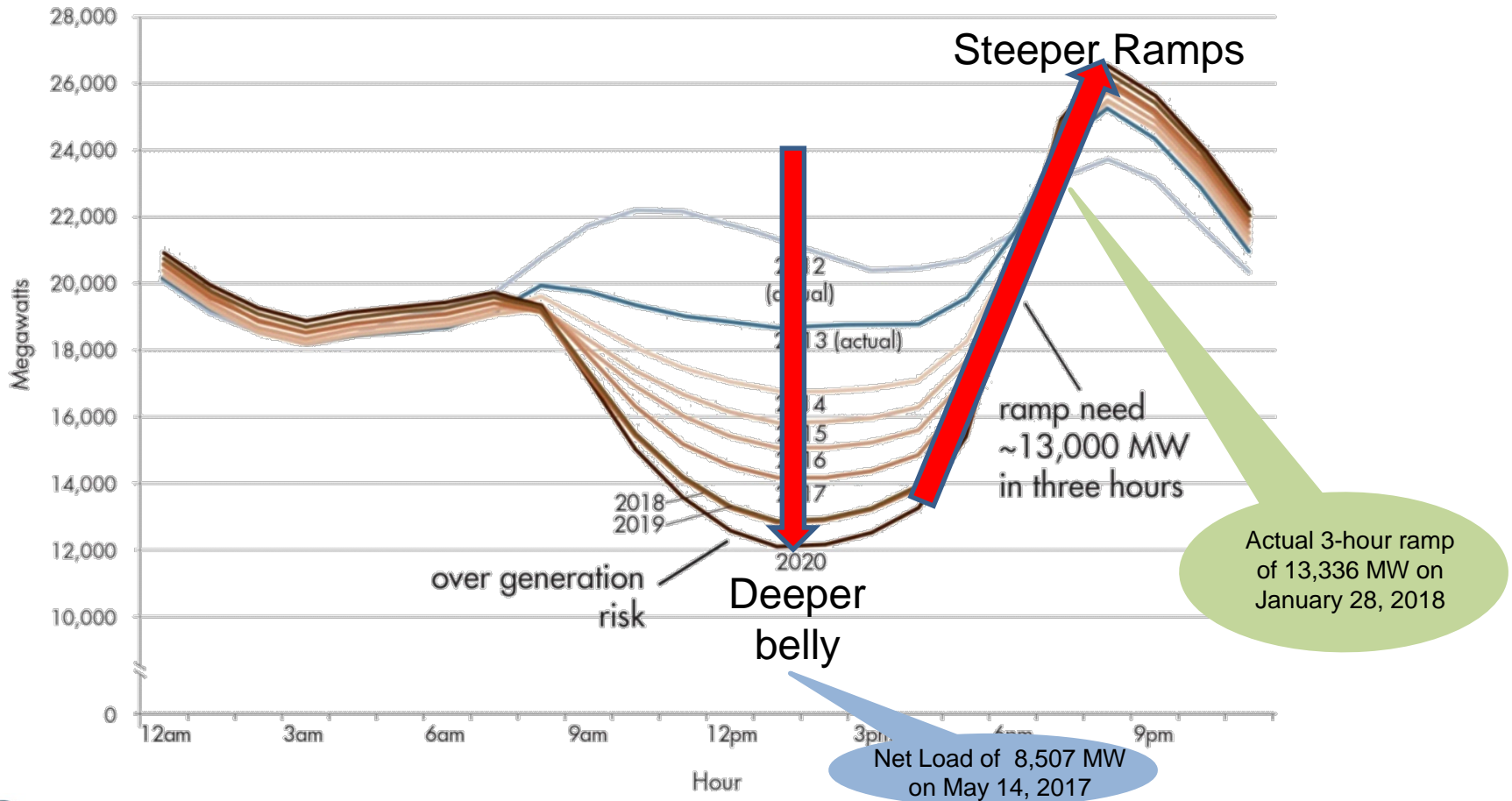


Behind the meter solar PV build-out through 2020

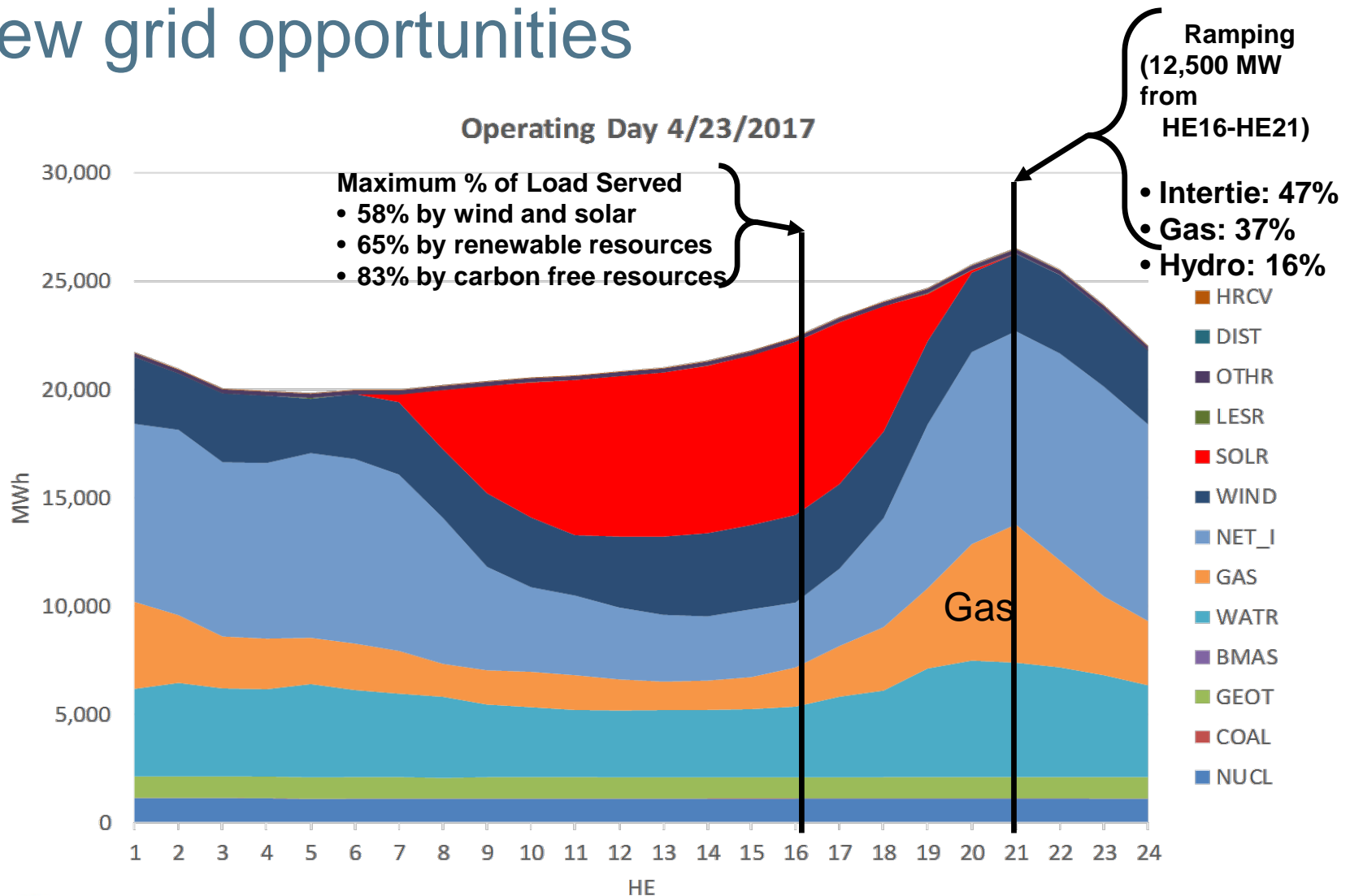


Actual net-load and 3-hour ramps are approximately four years ahead of ISO's original estimate

Typical Spring Day

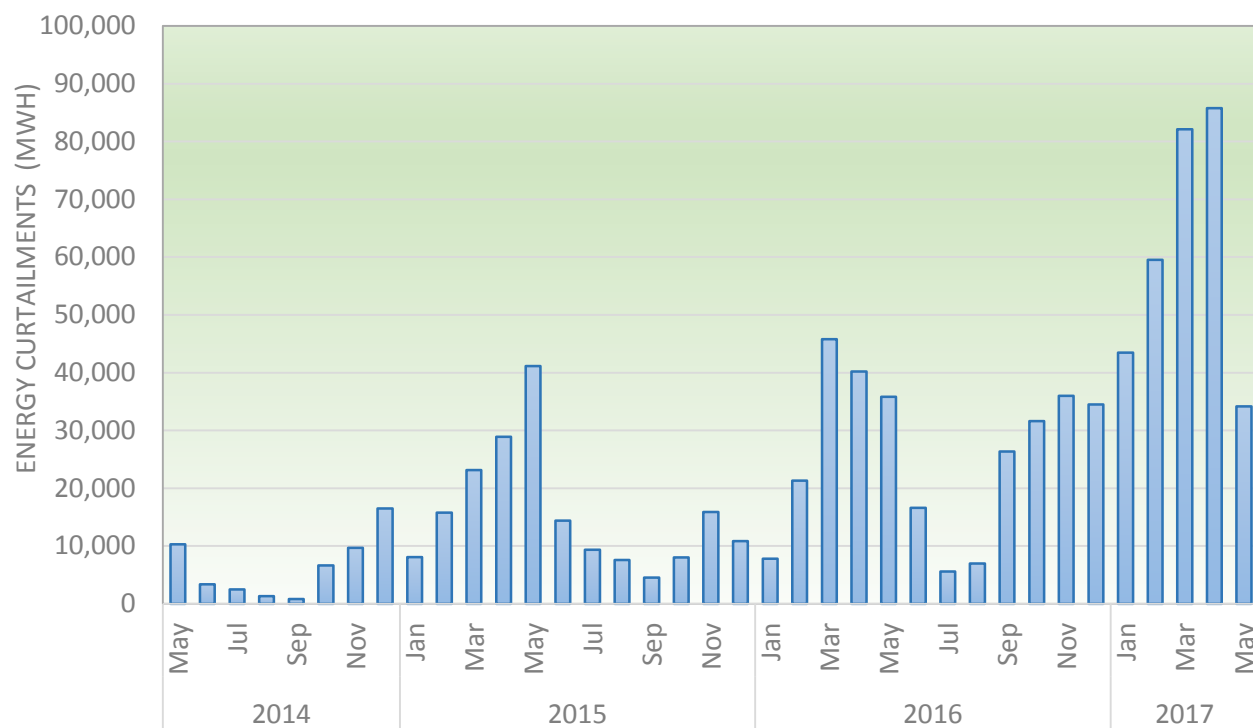


The success of integrating renewables leads to new grid opportunities



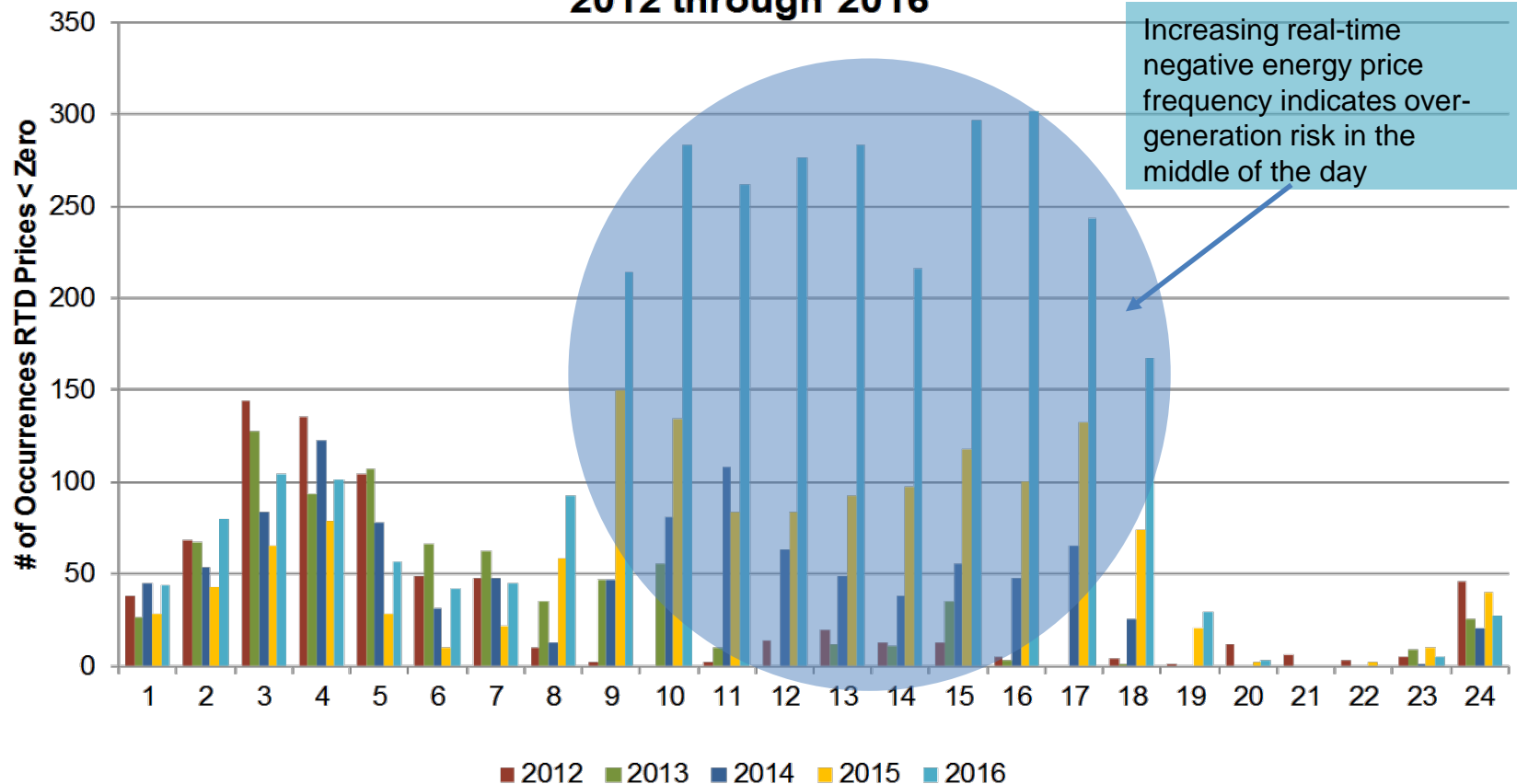
Opportunity 1: Manage oversupply minimize curtailment and realize environmental goals

- In 2017, approx. 2.6% of potential solar production was curtailed (1.3% of potential renewable production)
- Spring curtailments ran as high as 1,775 MW (approx. 8.8% of energy demand in that hour)
- Current curtailment is manageable. As we approach 50% RPS, curtailments will occur year round and become much larger unless a suite of strategies to contain curtailment are pursued.



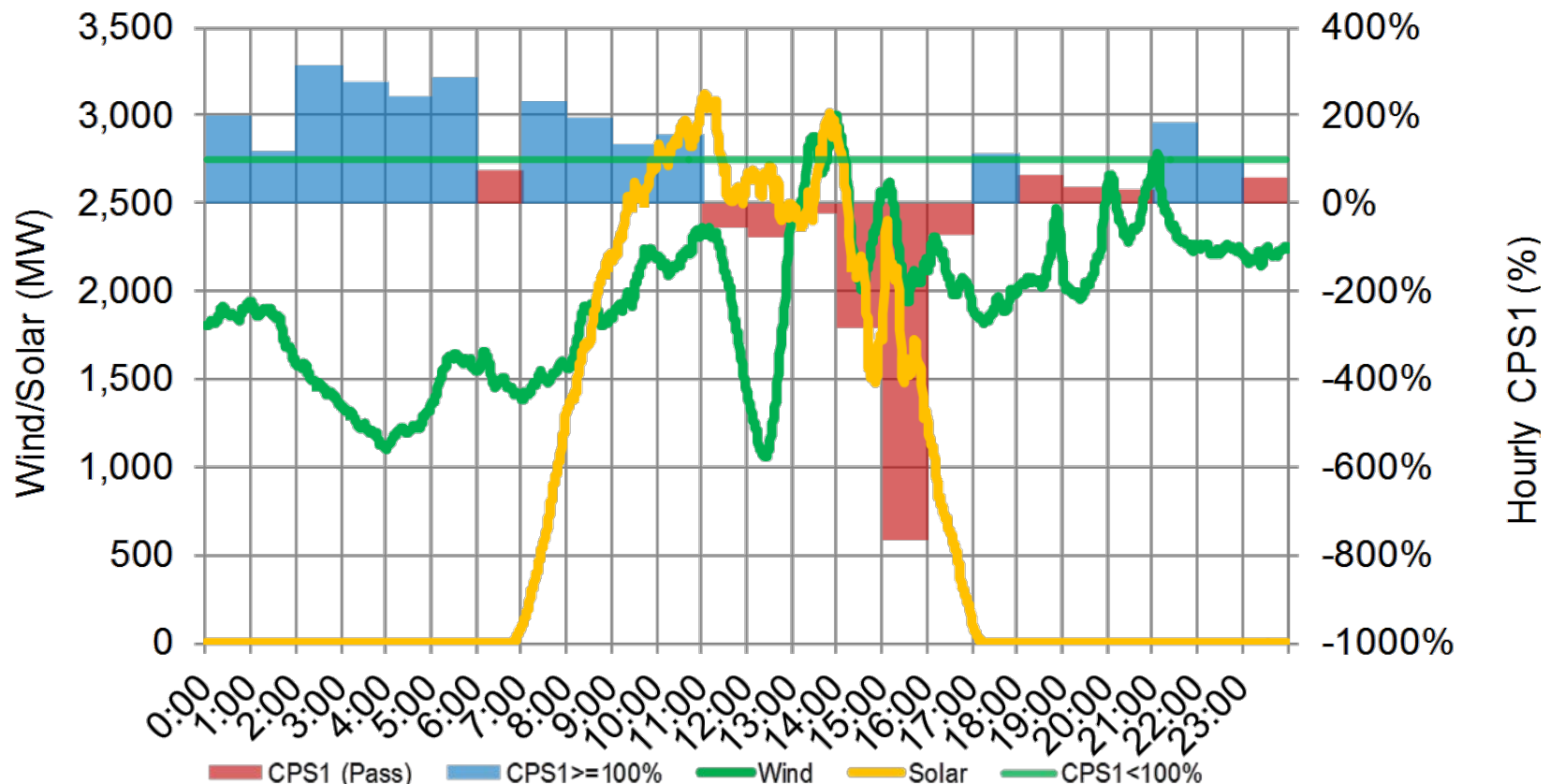
Opportunity 2: New price patterns incentivize innovation in responsive demand and storage

**Distribution of Negative Prices - March, April & May
2012 through 2016**



Opportunity 3: Enhance operational performance during periods of increased supply variability

Wind/Solar vs. CPS1 --- 01/31/2016

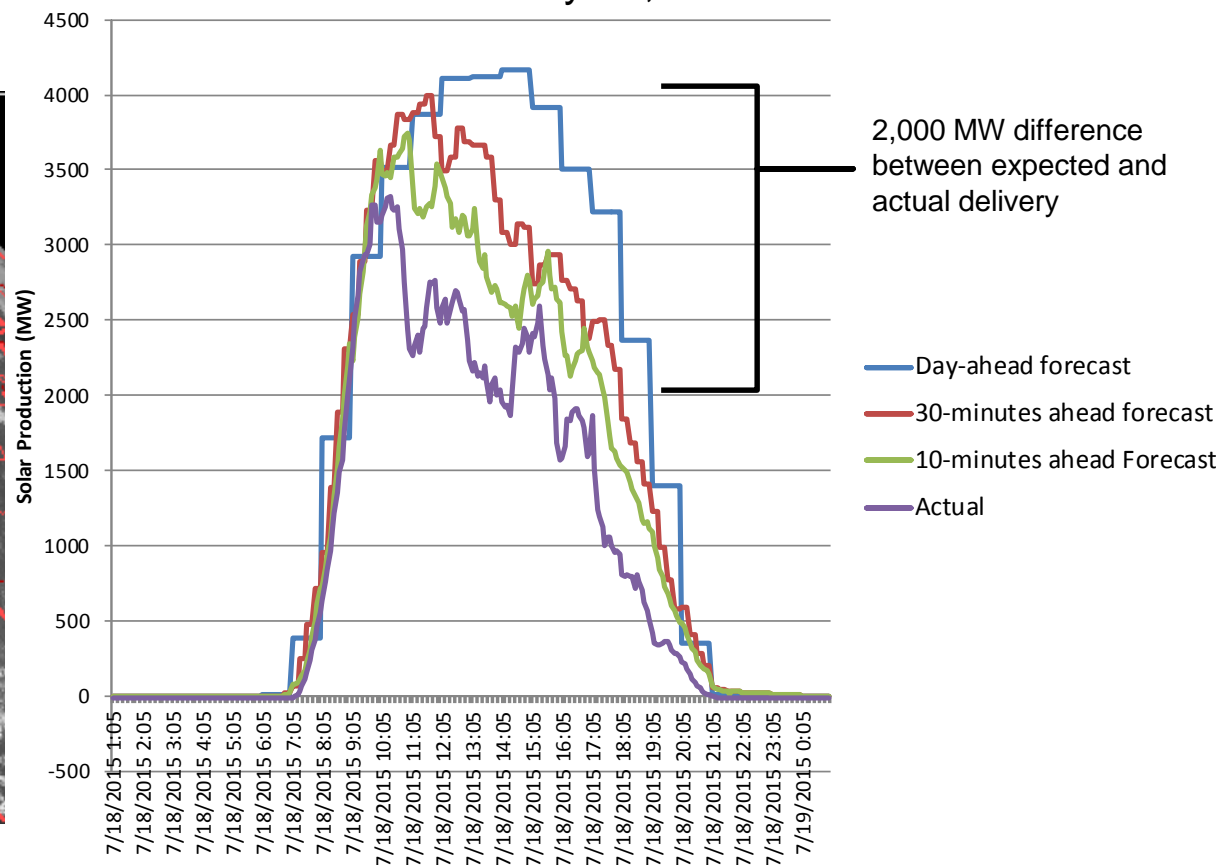
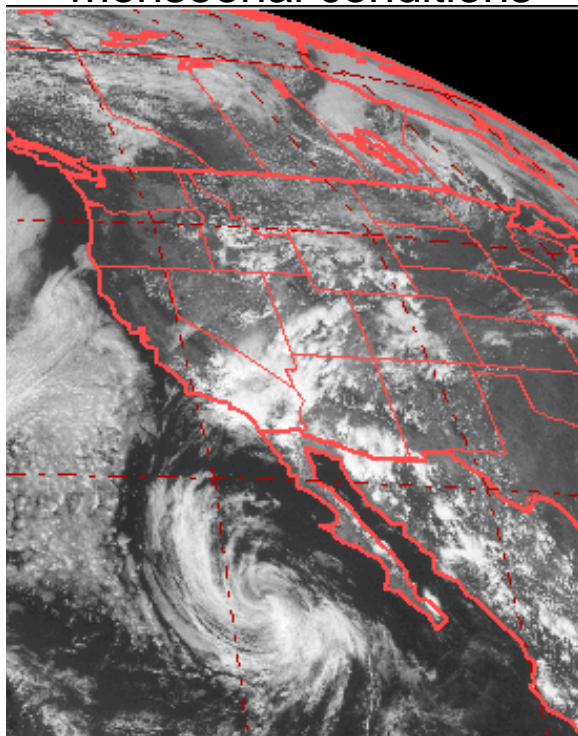


CPS1 is NERC Control Performance Standard which is evaluated on a rolling 12-month average. Over the past few years, the rolling average has been declining as a result of some poor daily performances. Thus, the CAISO need to take measures to enhance daily performance on days with higher variability.

Opportunity 4: Enhance forecasting to manage supply uncertainty

CAISO – Solar Forecast & Actual
July 18, 2015

Example day with
monsoonal conditions



Opportunity 5: Evolve fault resiliency capability

Issue

- Between the months of August and November 2016 there have been seven transmission system faults that occurred in the ISO system, that resulted in the unanticipated loss of inverter based generation
- All transmission line faults cleared in normal tripping time.
- The cause of the inverter based generation loss is under review and remediation measures developed

Action Item

ISO is collaborating with other reliability organizations resources and inverter manufactures to develop and implementing short, medium and long term plan to address this issue

A suite of solutions will be necessary



Storage – increase the effective participation by energy storage resources.



Western EIM expansion – expand the western Energy Imbalance Market.



Demand response – enhance DR initiatives to enable adjustments in consumer demand, both up and down, when warranted by grid conditions.



Regional coordination – offers more diversified set of clean energy resources through a cost effective and reliable regional market.



Time-of-use rates – implement time-of-use rates that match consumption with efficient use of clean energy supplies.



Electric vehicles – incorporate electric vehicle charging systems that are responsive to changing grid conditions.



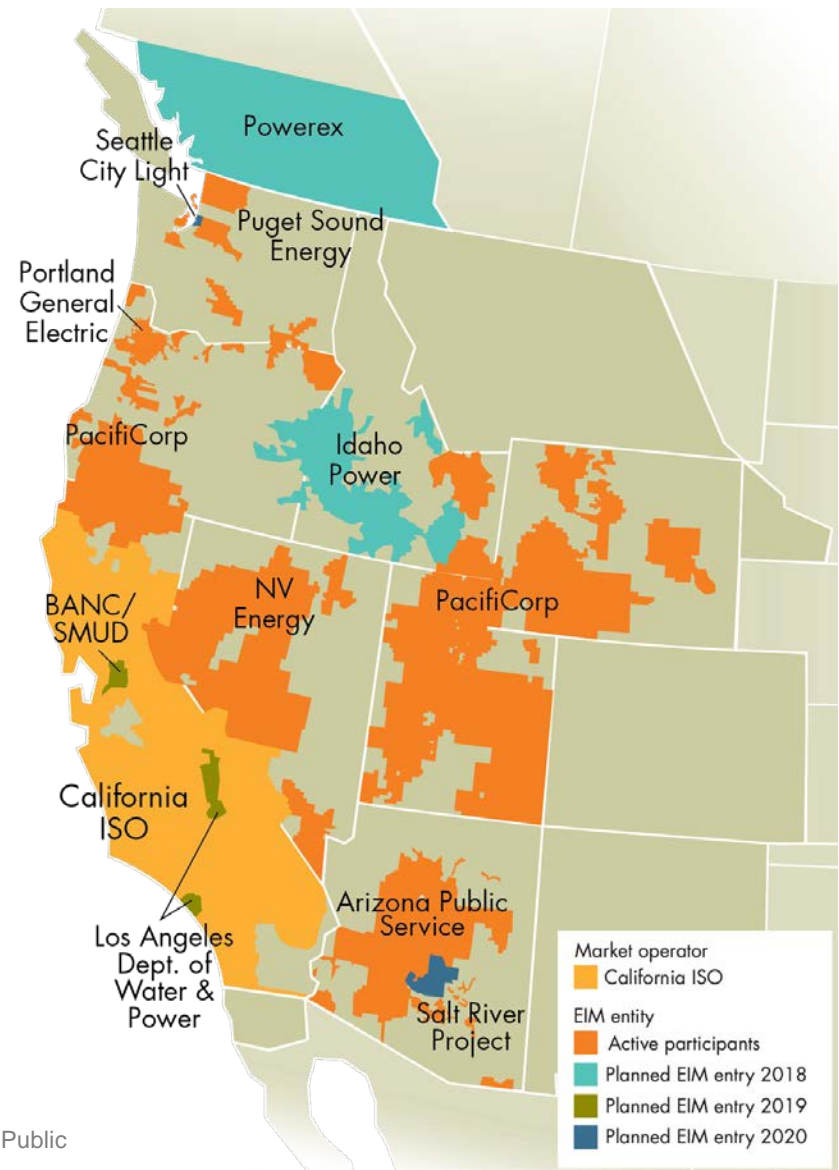
Minimum generation – explore policies to reduce minimum operating levels for existing generators, thus making room for more renewable production.



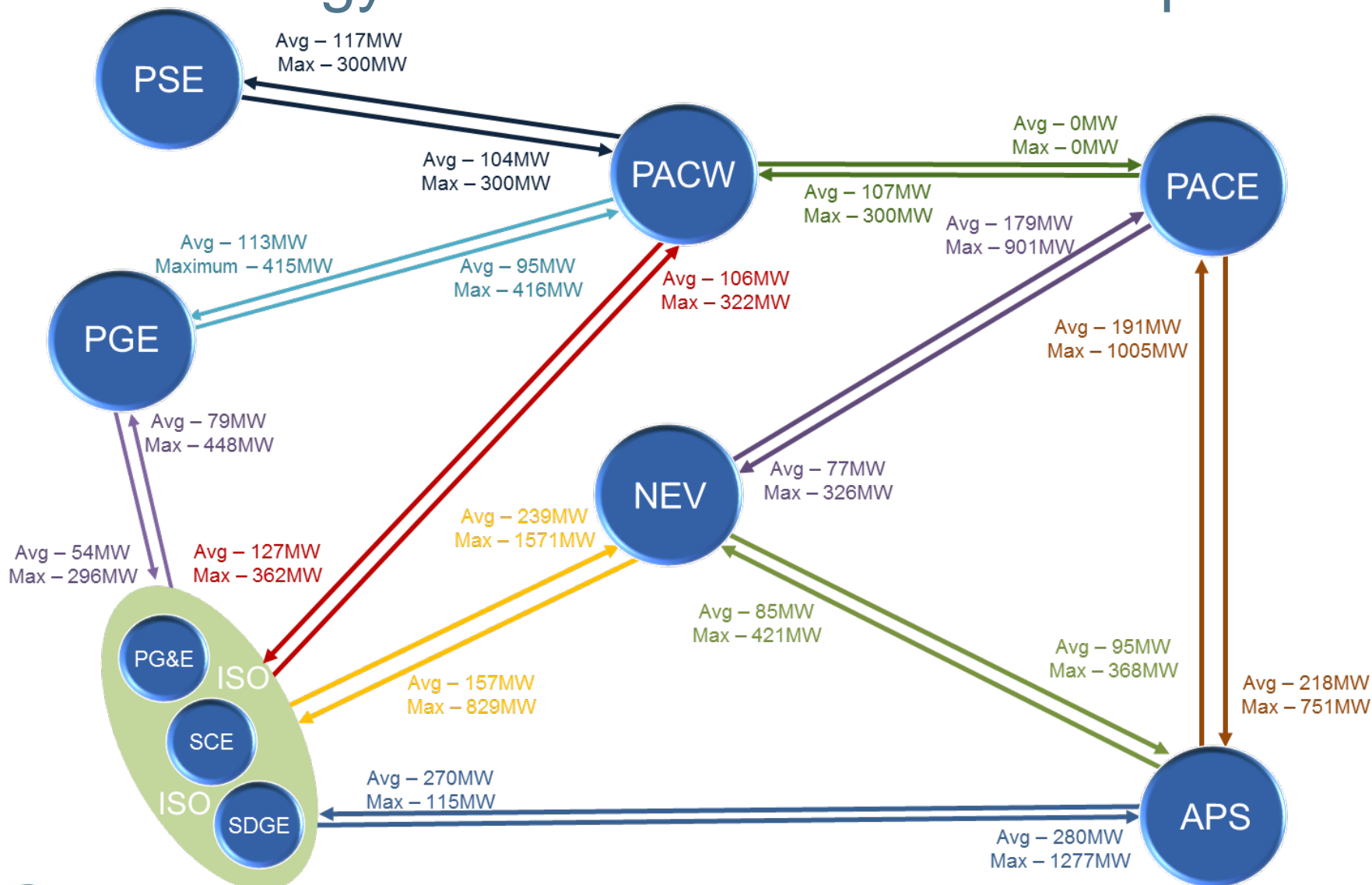
Flexible resources – invest in modern, fast-responding resources that can follow sudden increases and decreases in demand.

The western energy imbalance market continues to grow

- Market Simulation for Idaho is completed; Powerex is in process of finishing.
- Idaho and Powerex will enter parallel operations (none market binding) on February 1st.



Robust energy transfers observed in 4th quarter



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