Renewable Integration

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STATUS

Industry in the midst of unprecedented change

- Driven by fast-growing mix of interrelated issues

Federal Election Impacts

Existing 50% goal

Gas Storage Challenges

NEW 100% goal

Community Choice

Grid Modernization

Regional Collaboration

Consumer-owned Power

Fossil Plant Retirements

Transmission & Distribution Systems Interface

Power industry transformation

Wind

- Unpredictable Output
- 4,773 MW Peak – April 24, 2016
- 6,087 MW Installed Capacity

Solar Thermal / Photo Voltaic

- Semi – Predictable Output
- 9,868 MW Peak – April 21, 2017
- ≈ 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

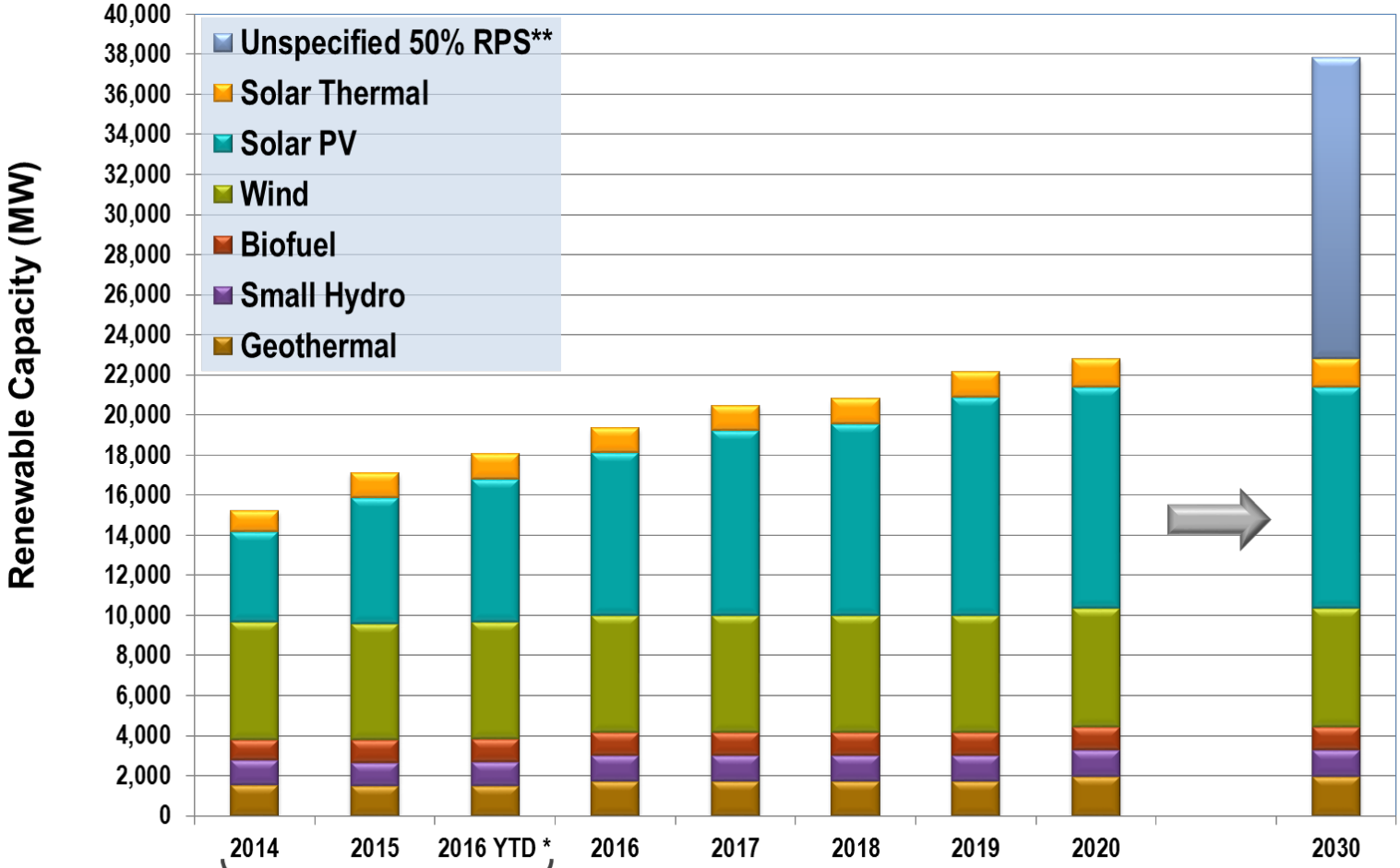
Main Drivers:

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

Goals:

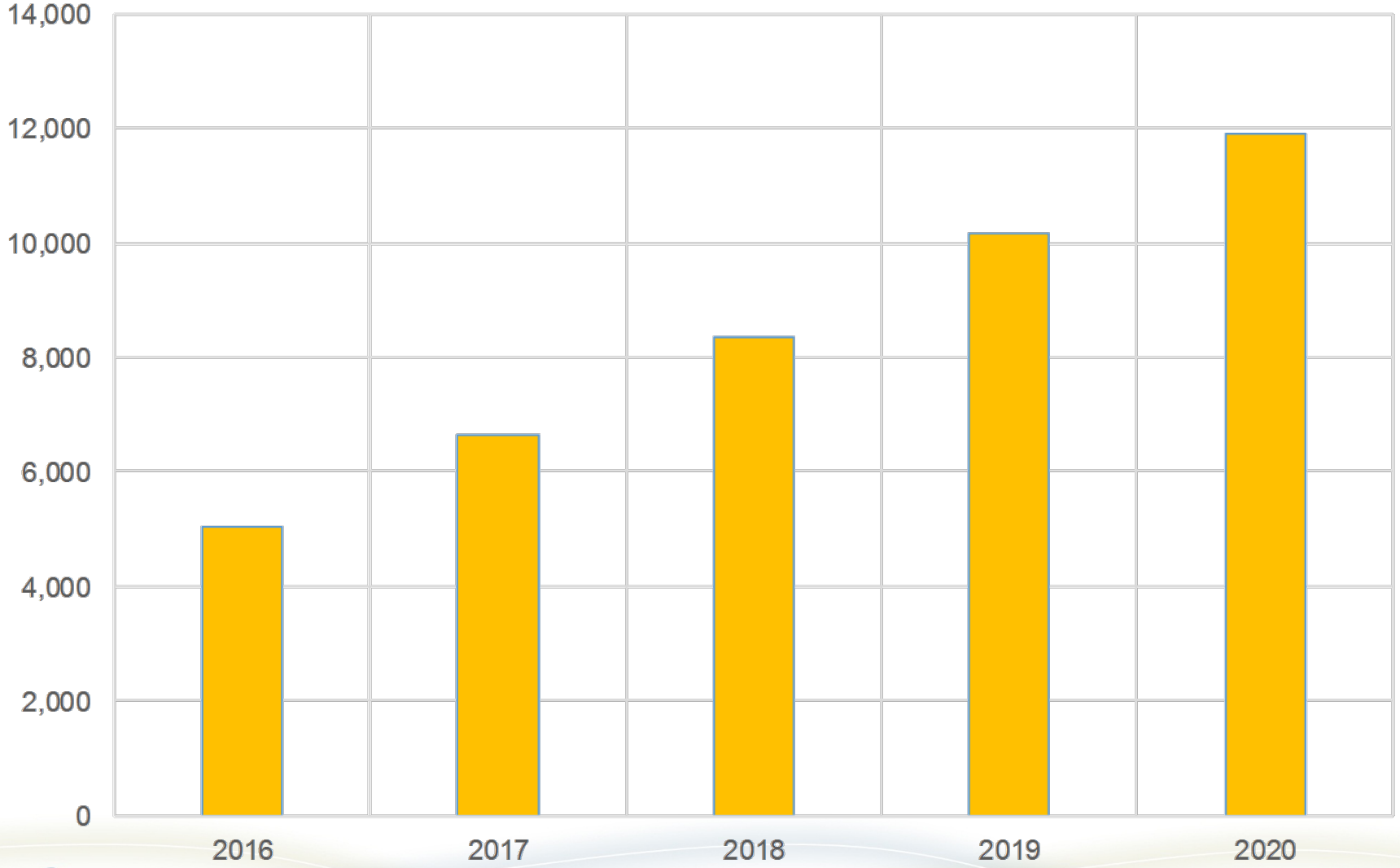
- ✓ Higher expectation of reliability
- ✓ Higher expectation of security
- ✓ Smart Grid
- ✓ Situational awareness through Visualization

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

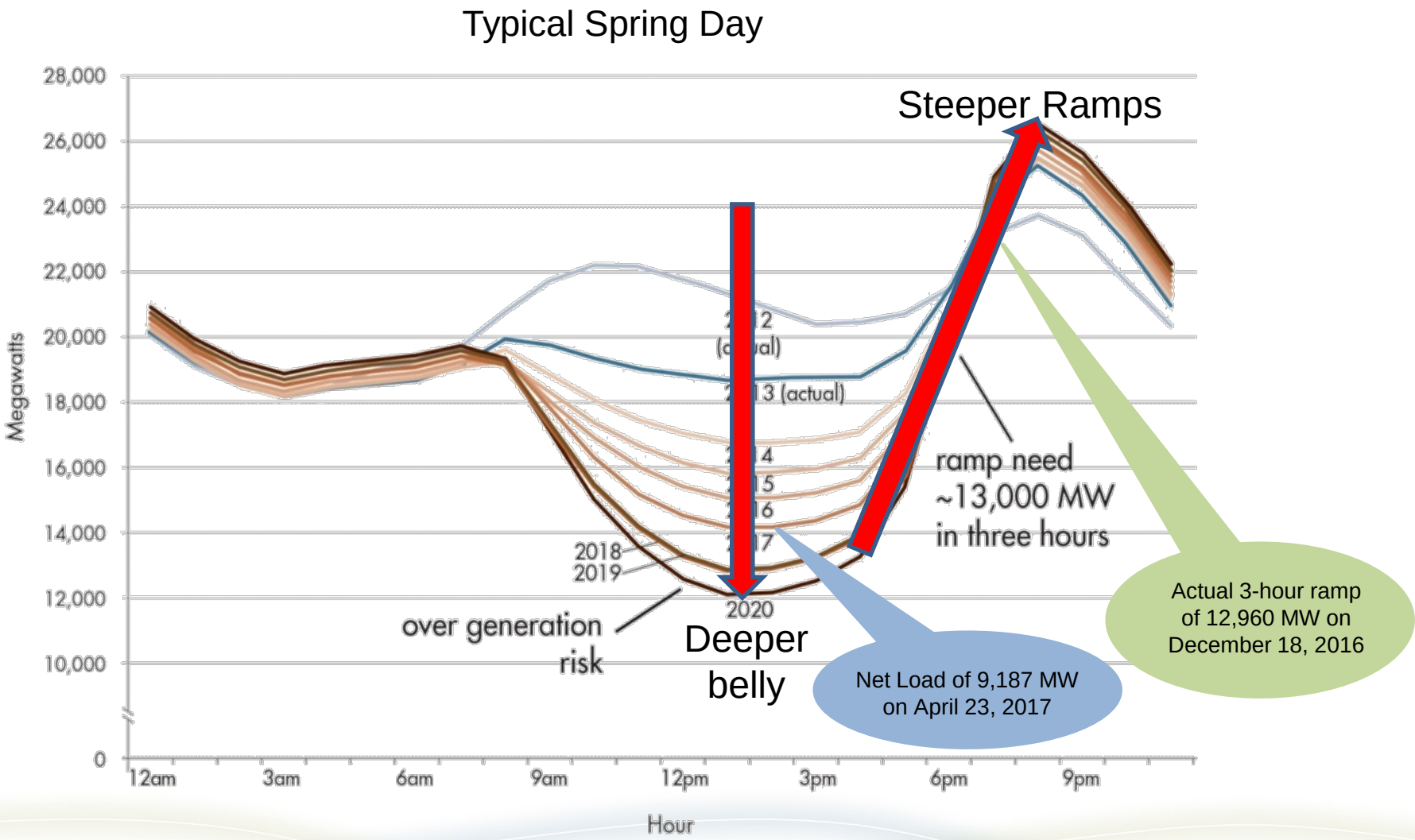


*All online resources that are not in test mode are included in the 2016 YTD amounts, including those yet to achieve full commercial operation.
**Approximate
(IOU data through 2017 and RPS Calculator data 2018-2020)

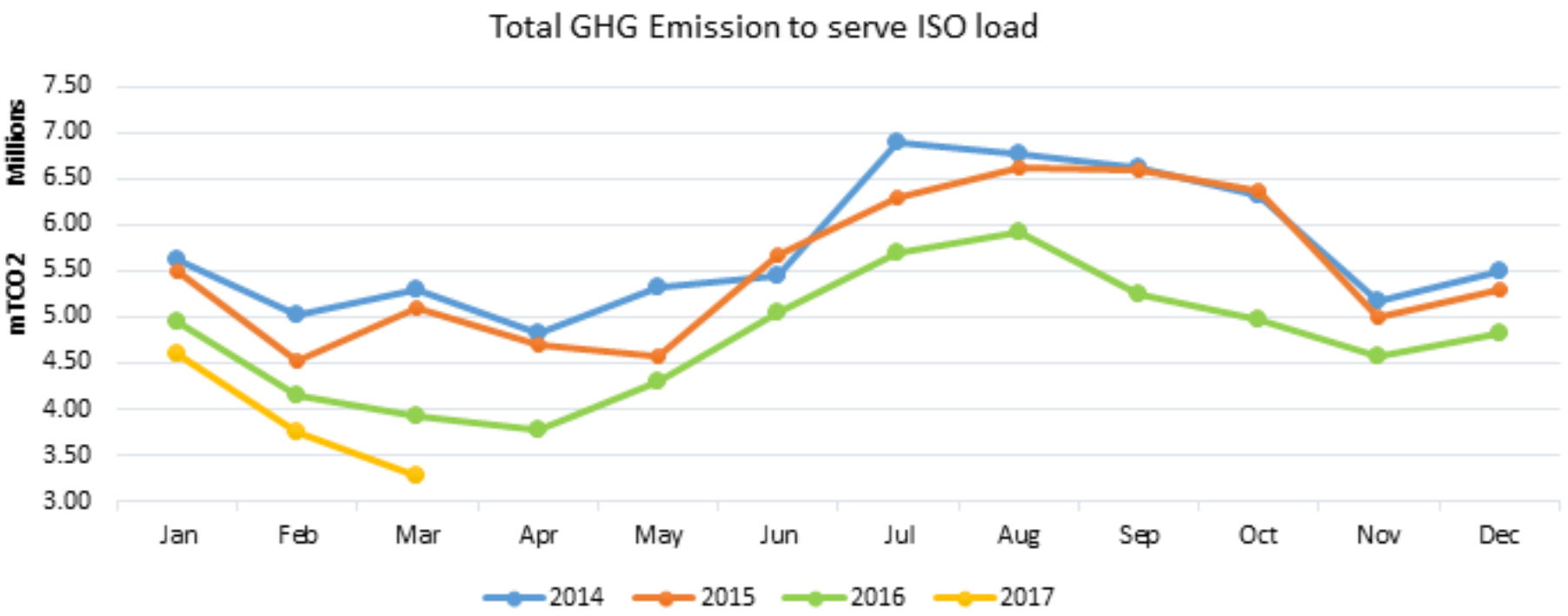
Behind the meter solar PV build-out through 2020



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

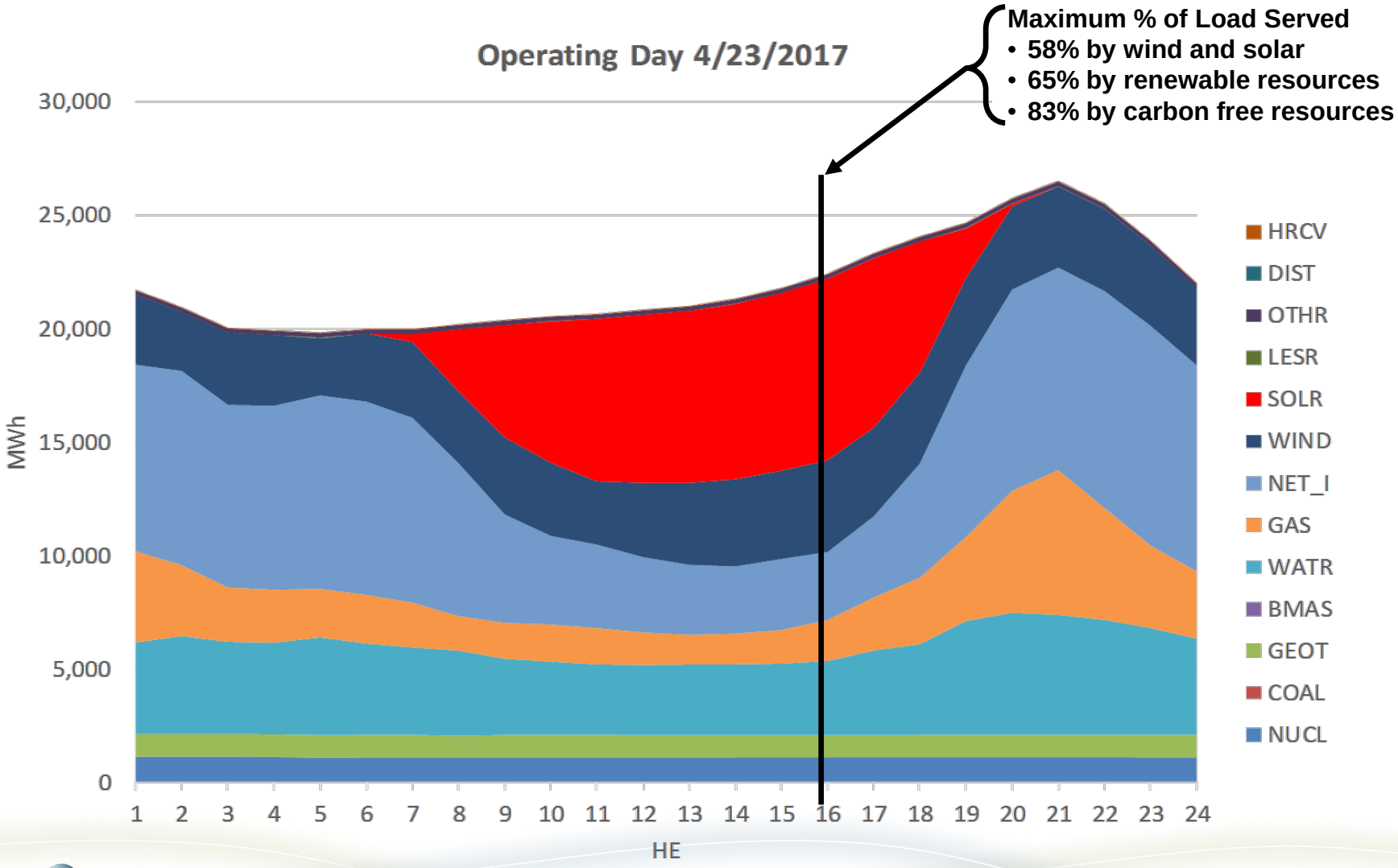


Greenhouse gas reductions are occurring as renewables increase

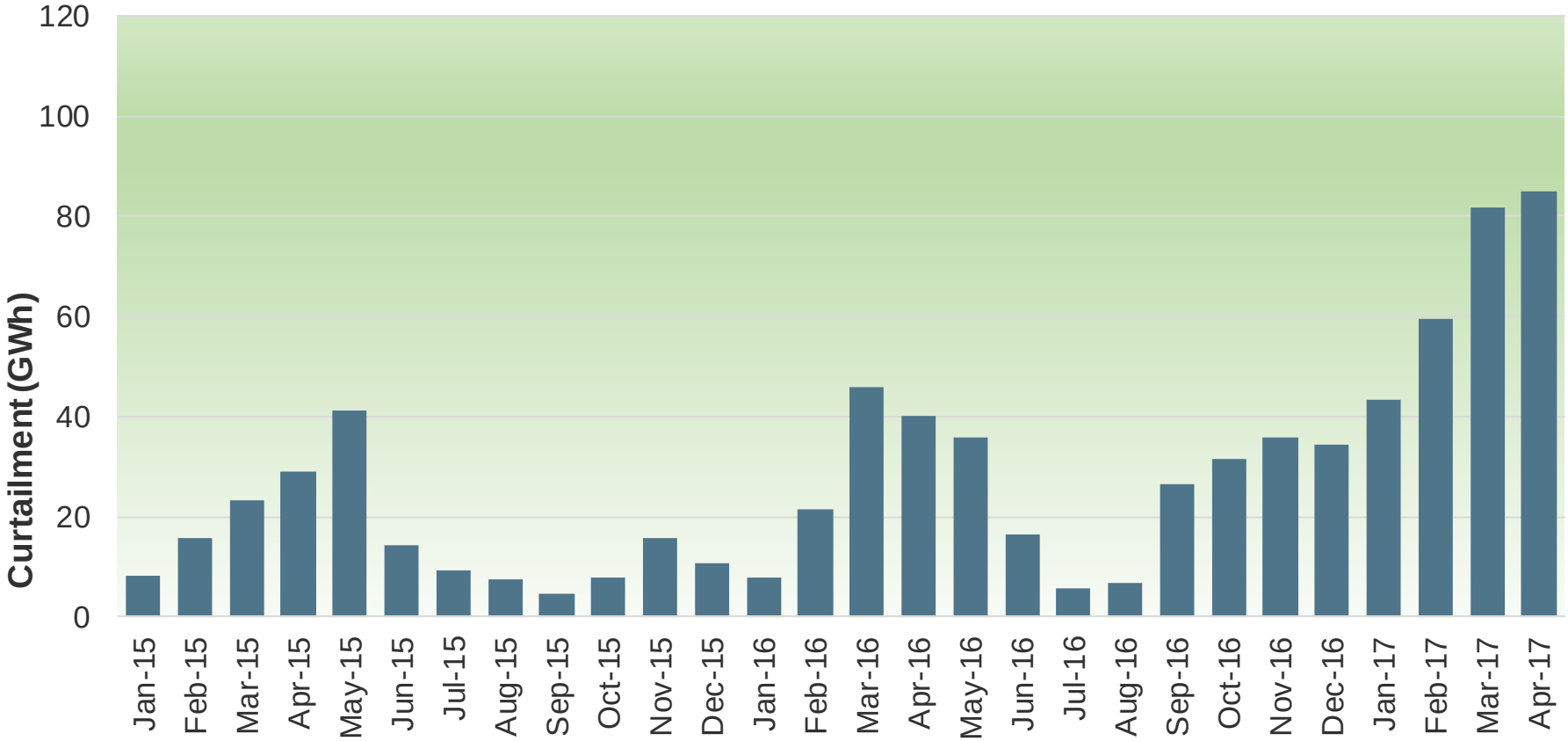


OPPORTUNITIES

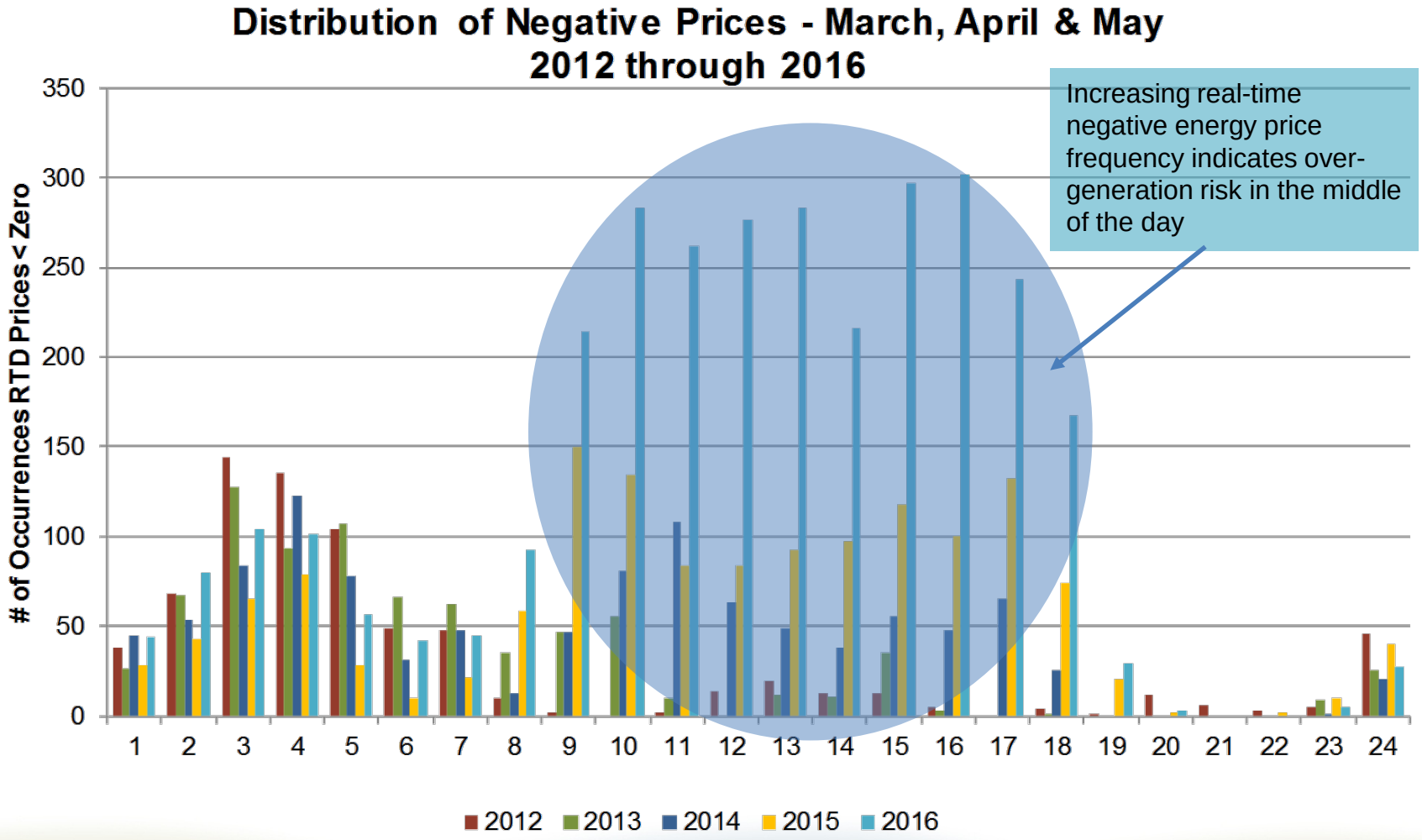
The success of integrating renewables leads to new grid opportunities



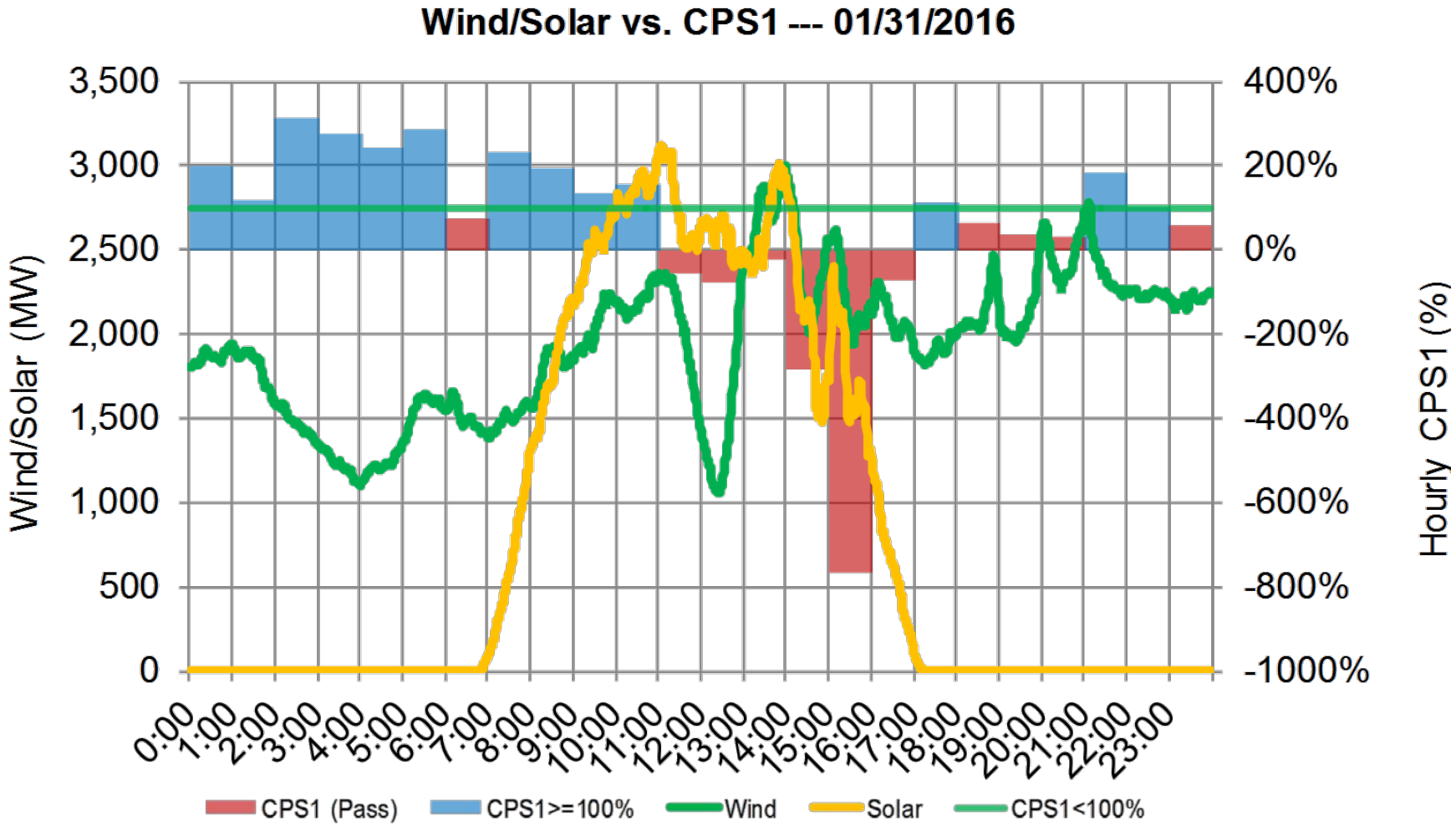
Opportunity 1: Manage oversupply and minimize curtailment



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



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

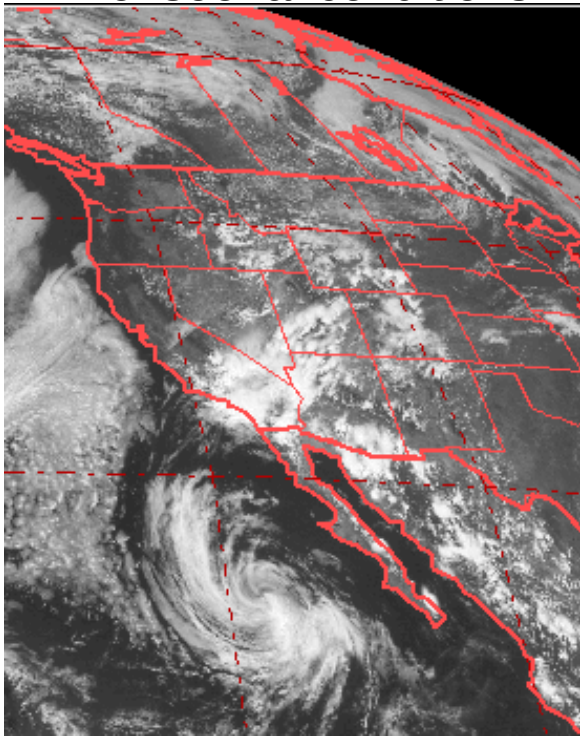


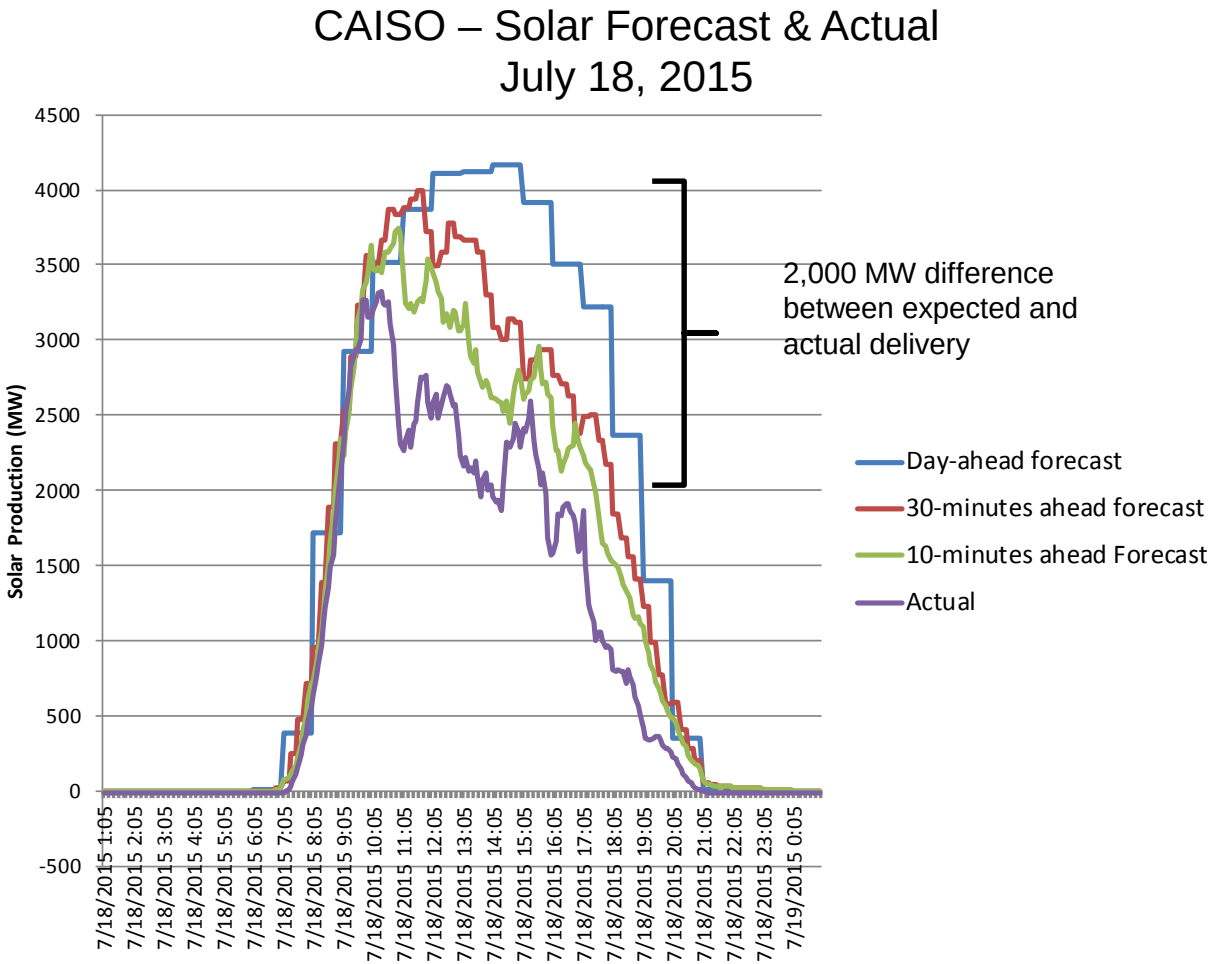
CPS1 is NERC Control Performance Standard which is evaluated on a rolling 12-month average. Over the past few years, the rolling average has been declining as a result of some poor daily performances.

Thus, the CAISO need to take measures to enhance daily performance on days with higher variability.

Opportunity 4: Enhance forecasting to manage supply uncertainty

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

SOLUTIONS

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.

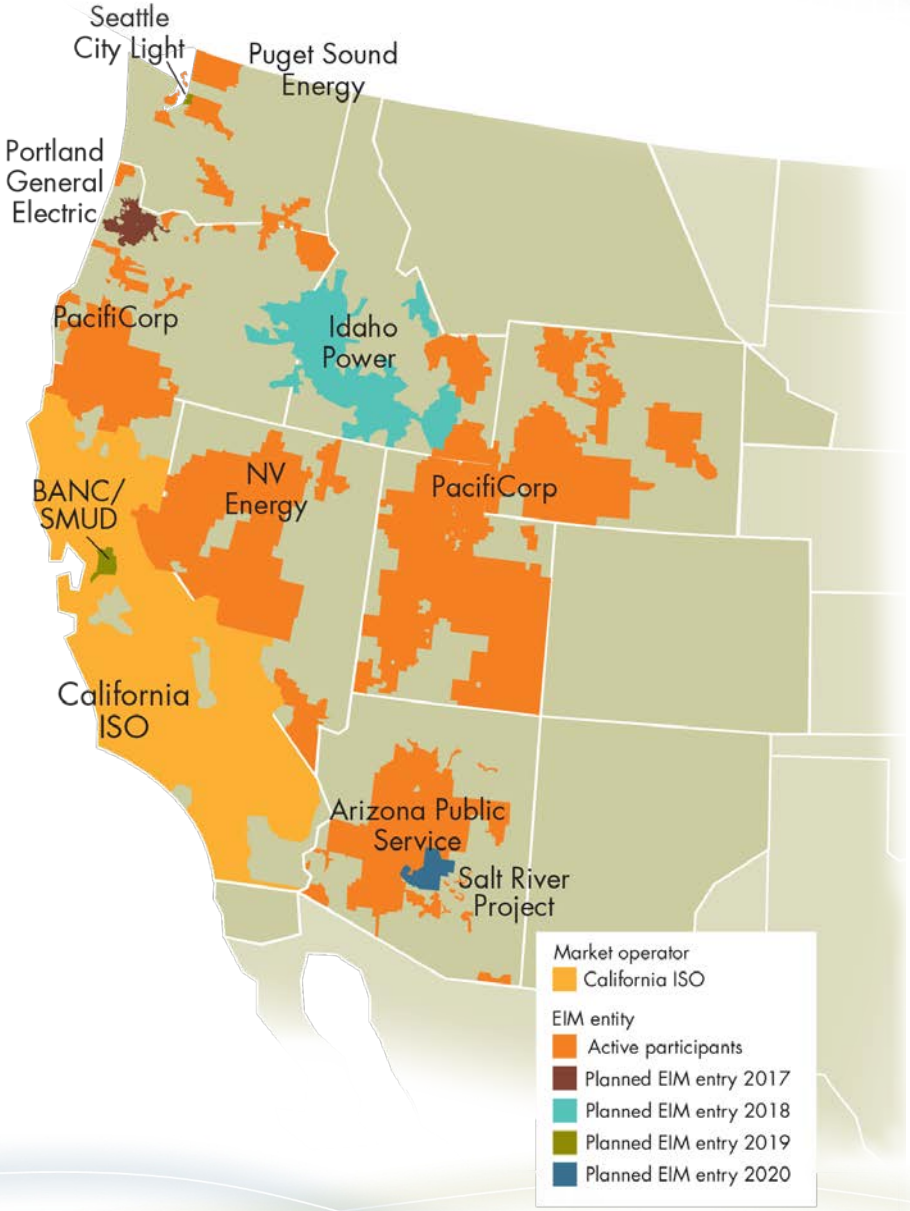
Electric vehicles – incorporate electric vehicle charging systems that are responsive to changing grid conditions.

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

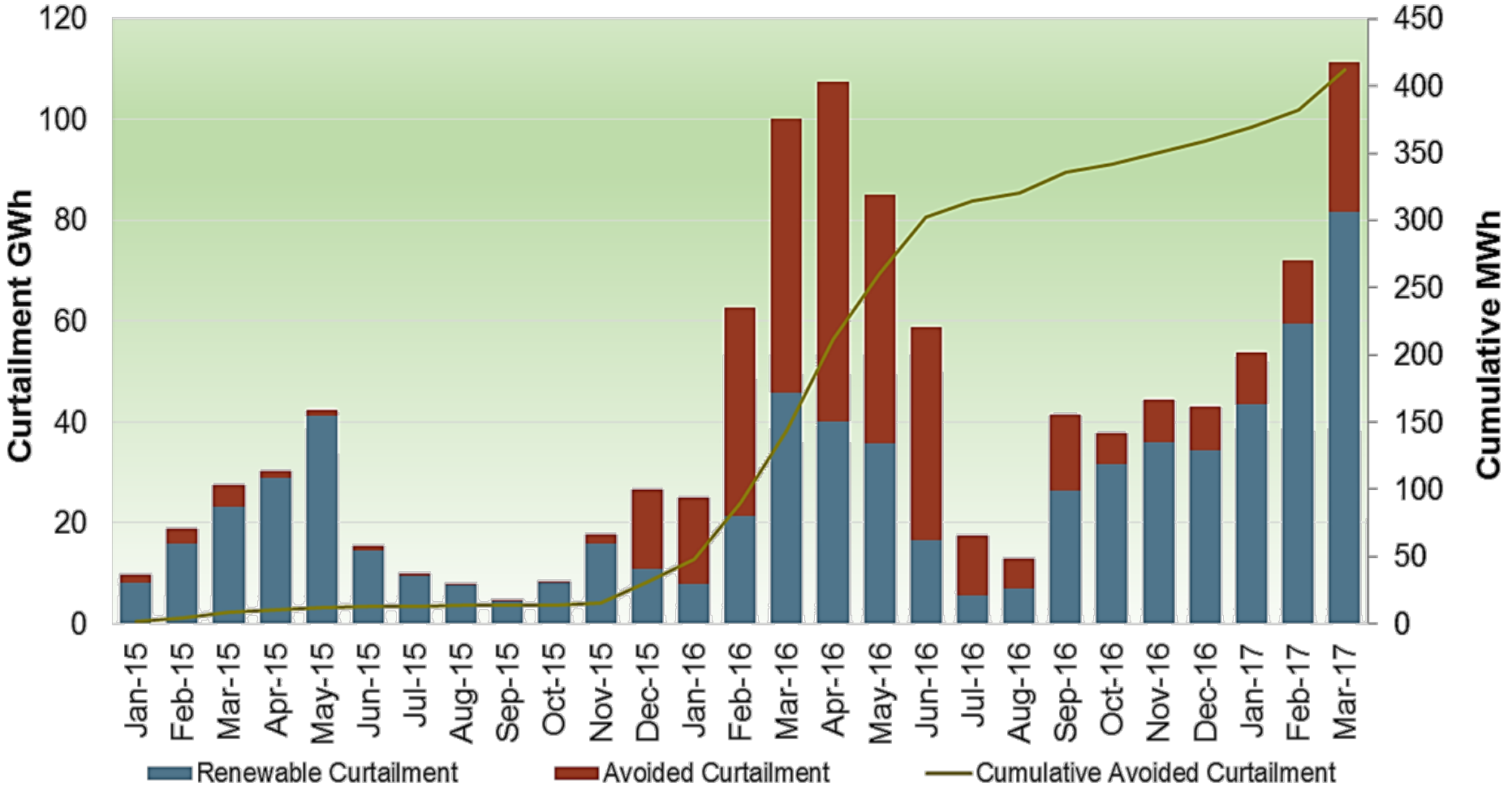
Flexible resources – invest in modern, fast-responding resources that can follow sudden increases and decreases in demand.

Western Energy Imbalance benefits: $173 million

- Entities now in the implementation phase
  - ~ Portland General – Fall 2017
  - ~ Idaho Power – Spring 2018
  - ~ BANC/SMUD & Seattle City Light – Spring 2019
  - ~ Salt River Project – Spring 2020
- Entities exploring future entry
  - ~ CENACE, Baja California, Mexico
  - ~ Los Angeles Department of Water & Power (LADWP)
  - ~ Northwestern Energy

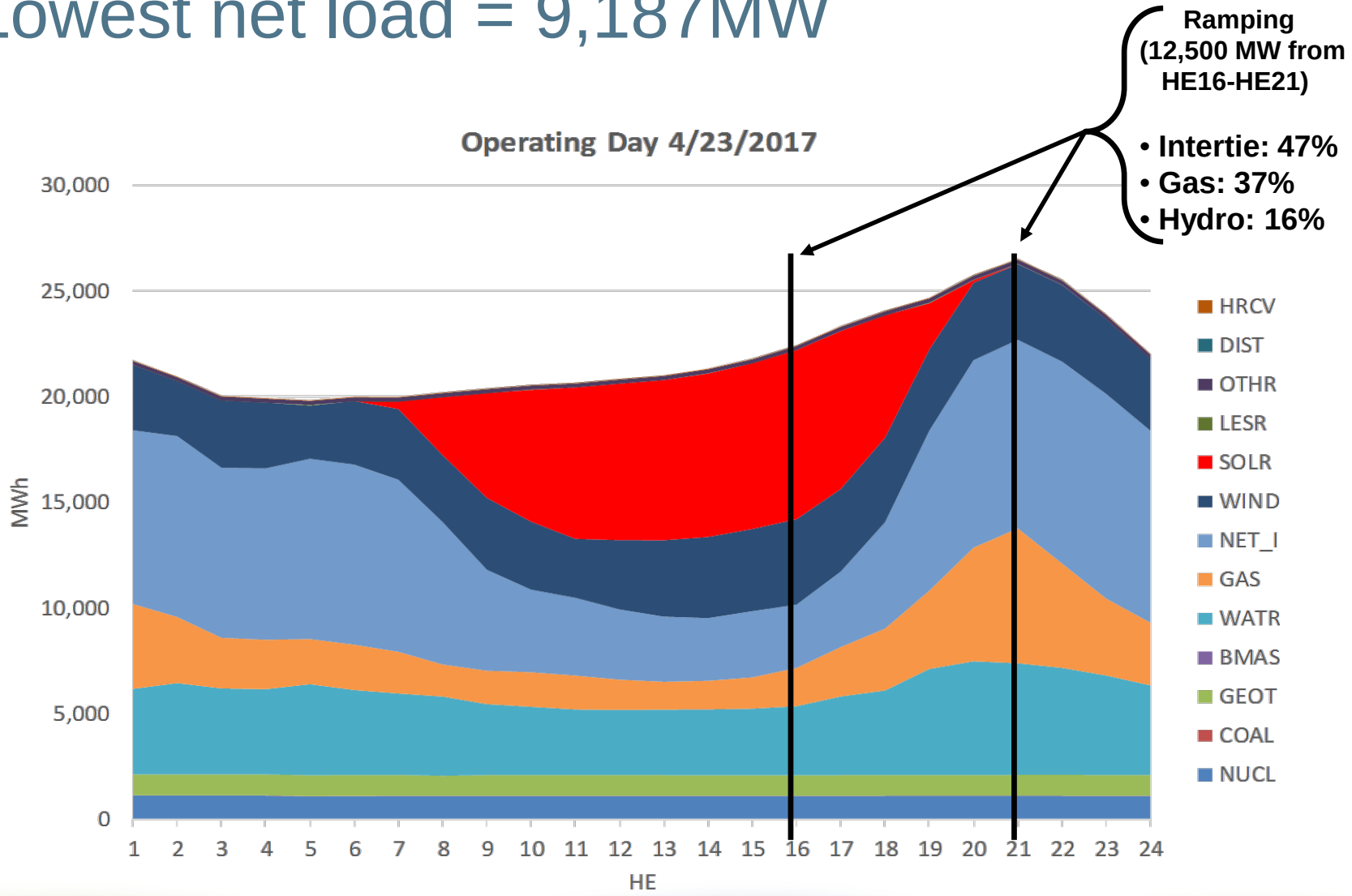


Energy imbalance market helps avoid curtailment

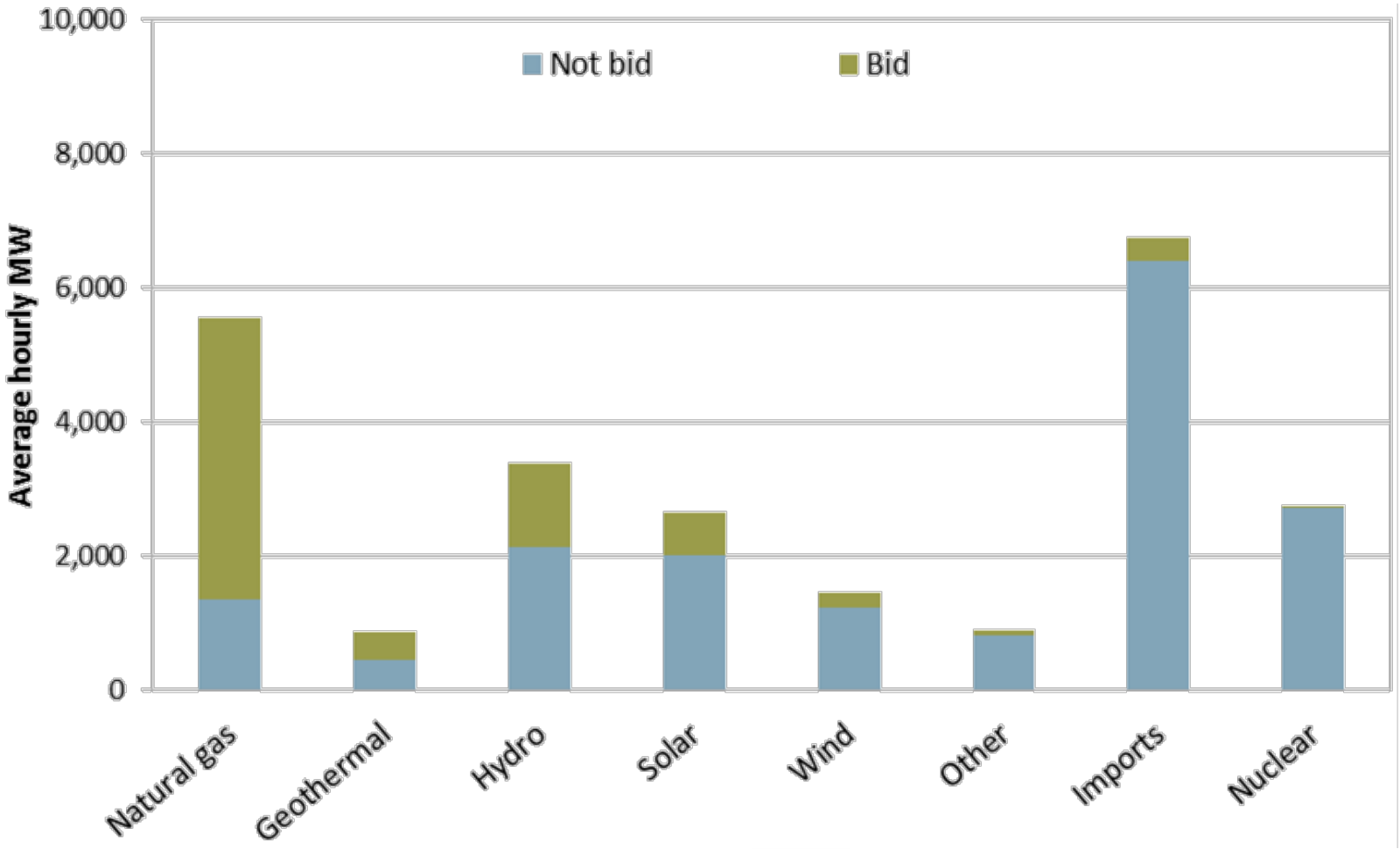


Year-to-date estimated metric tons of CO2 displaced = 176,241

What can we learn from the April 23, 2017: Lowest net load = 9,187MW

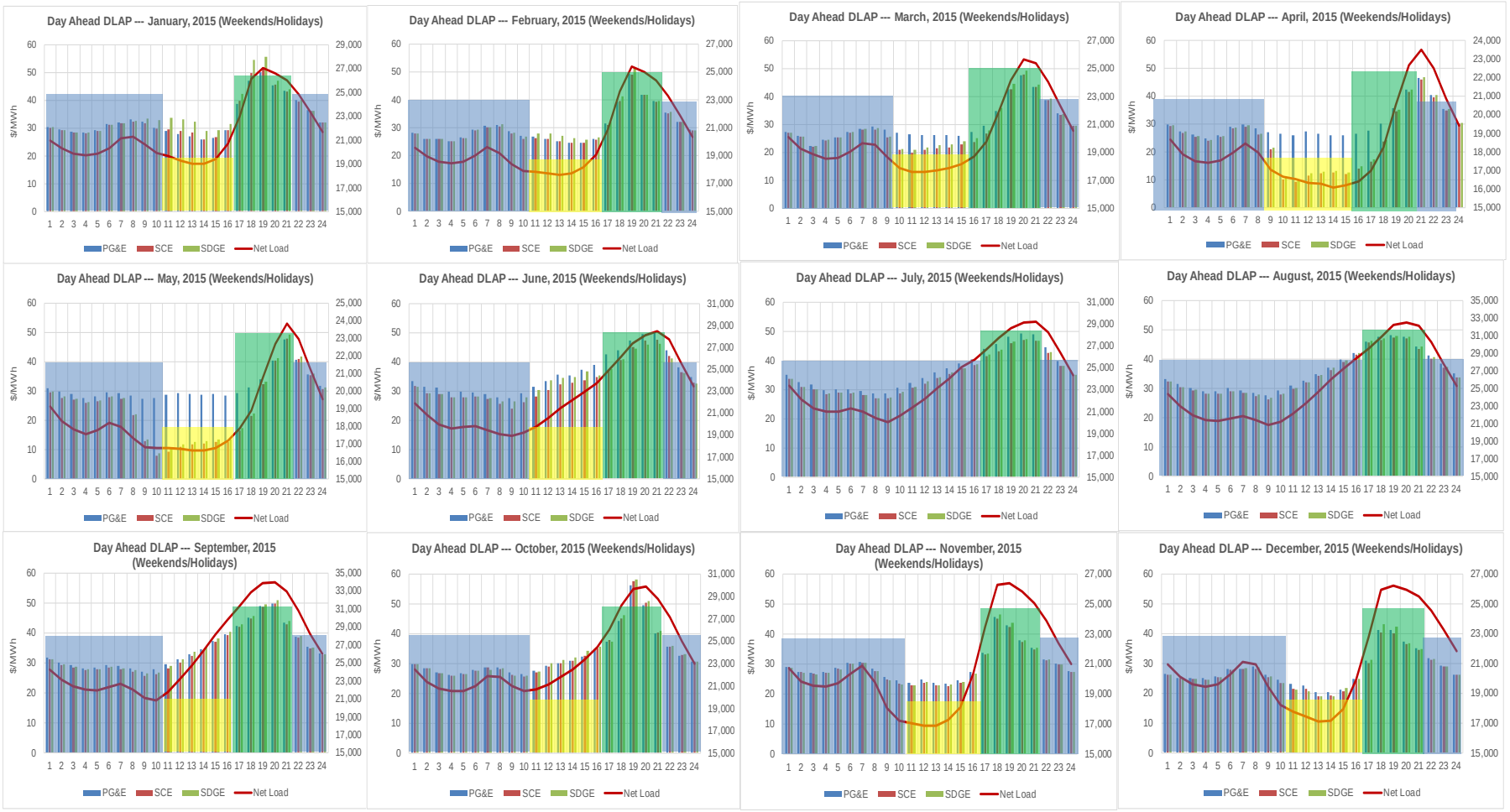


Opportunity for renewables and imports to provide more real-time flexibility via bids



Source: DMM 2016 Annual Report

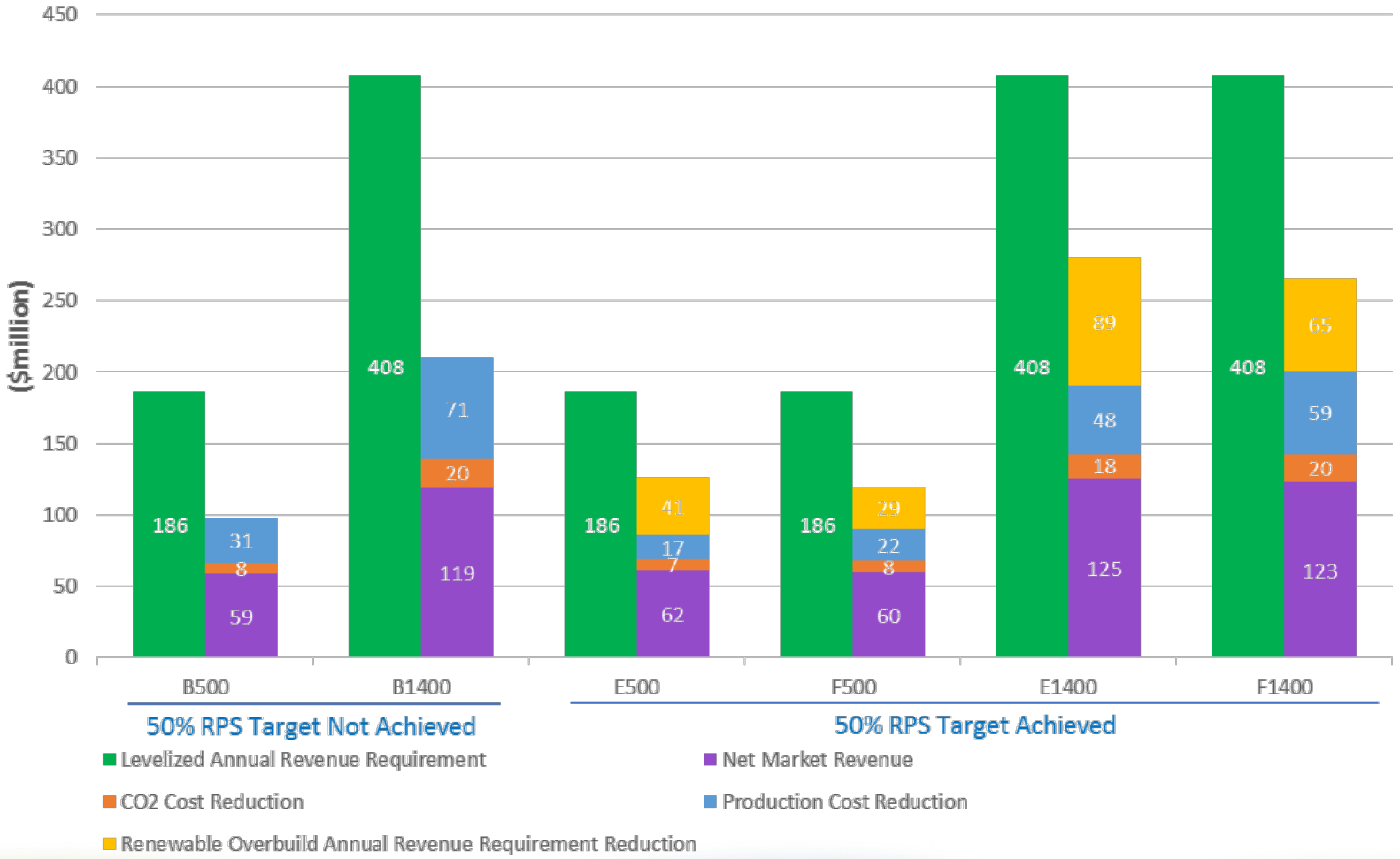
Time-of-Use Rates can align retail signals with system conditions



Off-Peak
Peak
Net Load
Super Off-Peak
Super Peak

Energy storage could provide multiple benefits

Comparison of levelized annual revenue requirement and benefit streams
(Based on preliminary update to 2016-2017 TPP Special Study on Bulk Storage in 2026)

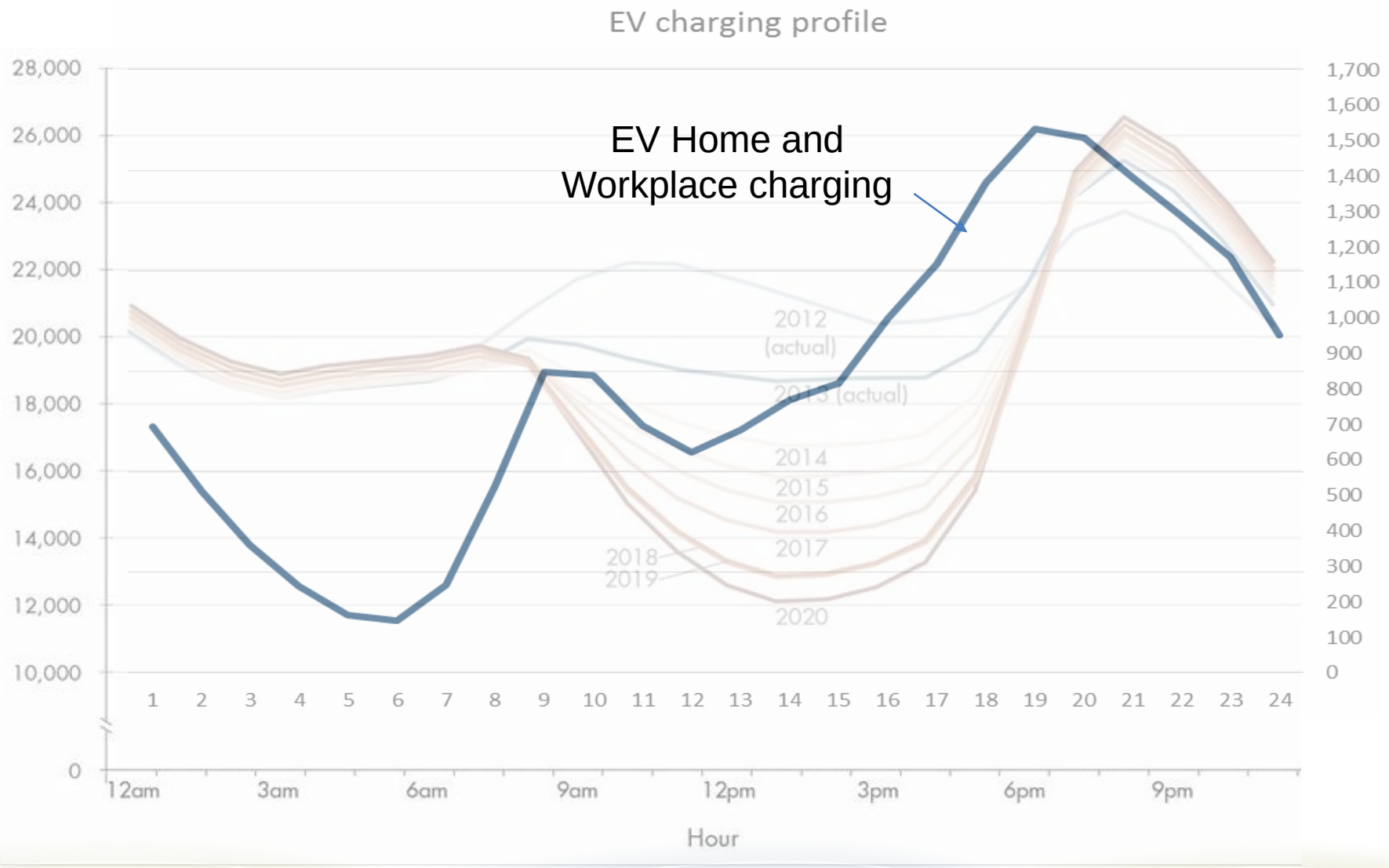


Net Market Revenue is revenue from energy, reserves and load following minus cost of energy and operation.
System benefits includes reduction of CO2 emission cost, WECC production cost and renewable overbuild cost

Distributed energy resources (DERs) can contribute to meeting operational challenges

- Energy Storage can help mitigate over-generation
- Load shifting can help mitigate conventional resource needs
- DERs may also benefit the system by reducing peak demand and thereby avoiding the need for transmission upgrades
- Controlled load dropping can provide spinning reserve and frequency response
- Demand Response can reduce the need for conventional resources
- Distributed Generation can off-set transmission upgrades
- Electric Vehicles can provide regulation service or balancing needs
- Micro grids allows participation in ancillary services markets

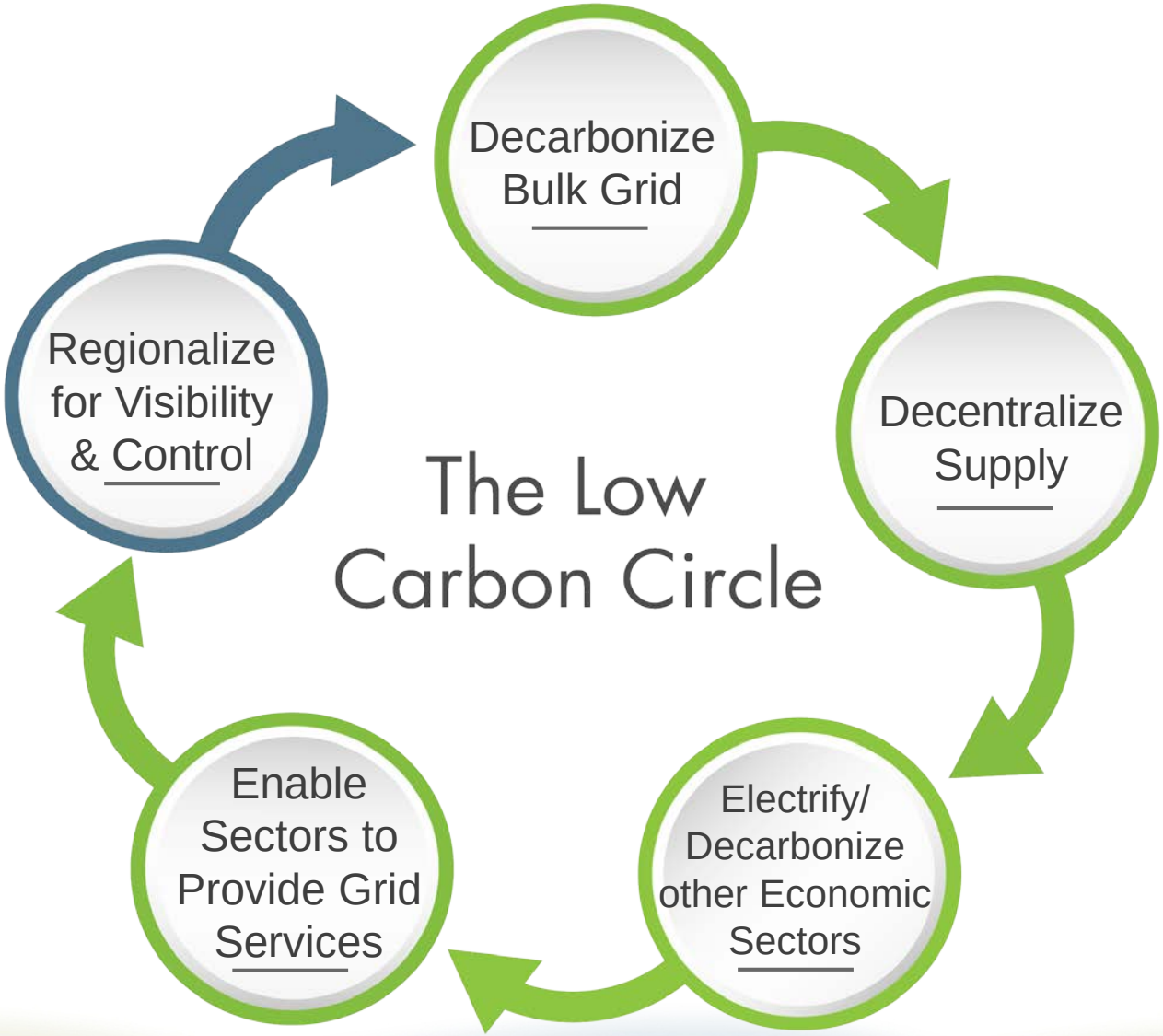
EV charging helps “Duck” depending on alignment



The Long Game: Unlocking the “Dividend” from California’s investment in renewables

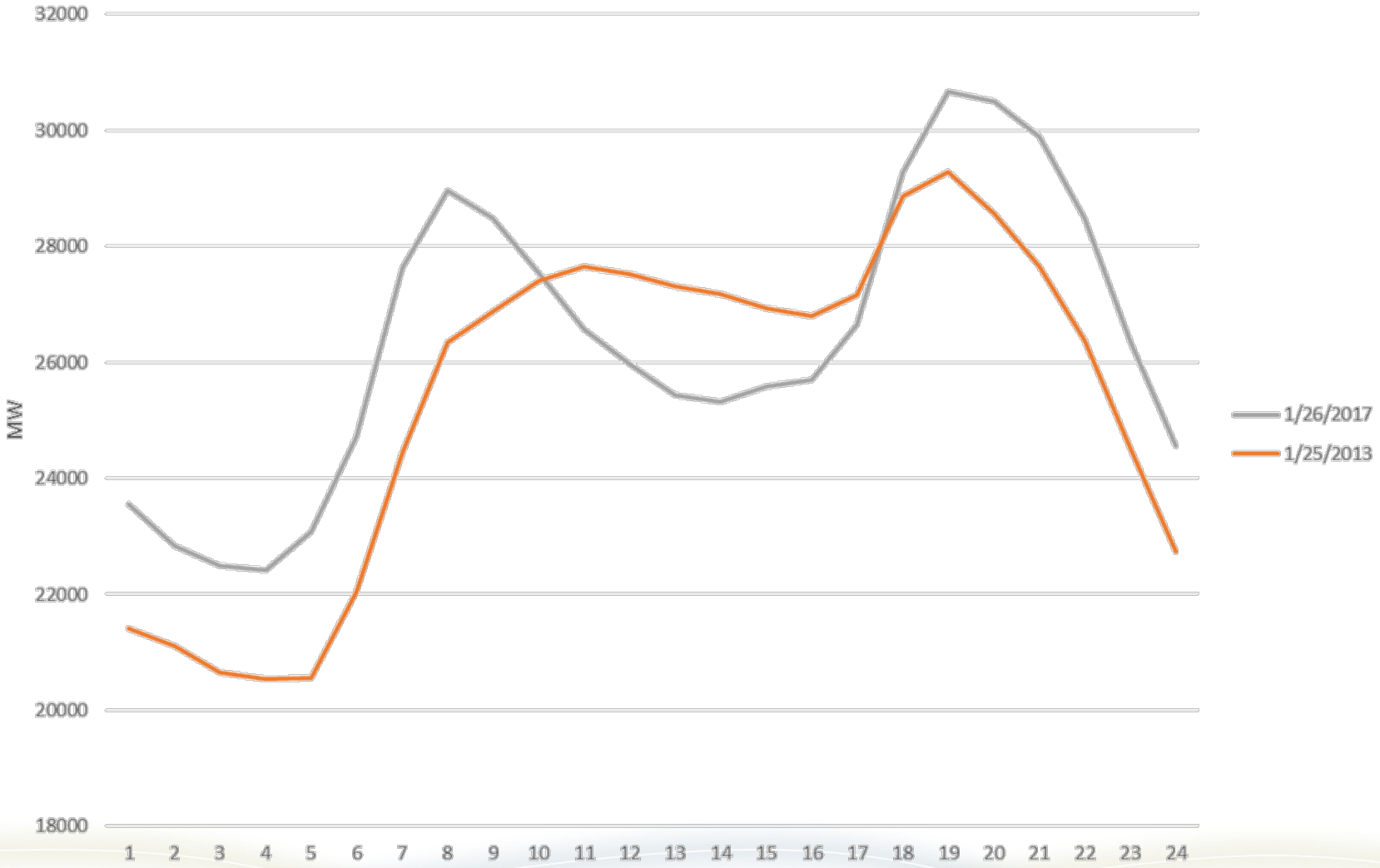
- California has invested $billions in renewables
- A new “dividend:” Clean, plentiful energy that can electrify a low-carbon economy
- New consumption opportunities for consumers:
  - Electric vehicle charging
  - Industrial processes
  - Cooking and heating
  - Bulk and local energy storage
- Then…incent these sectors to provide grid balancing services

Bringing it all together…

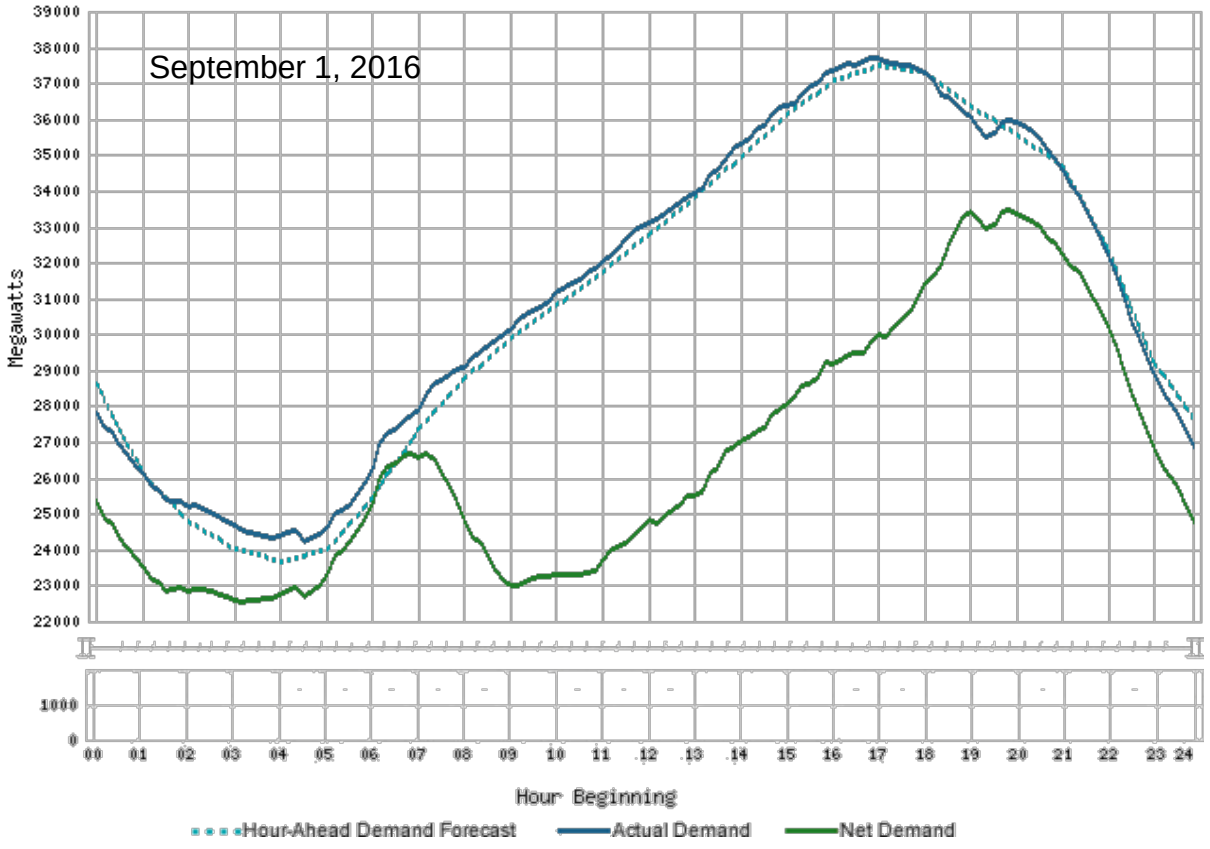


APPENDIX

Distributed generation by itself is having significant impact on the actual load curve



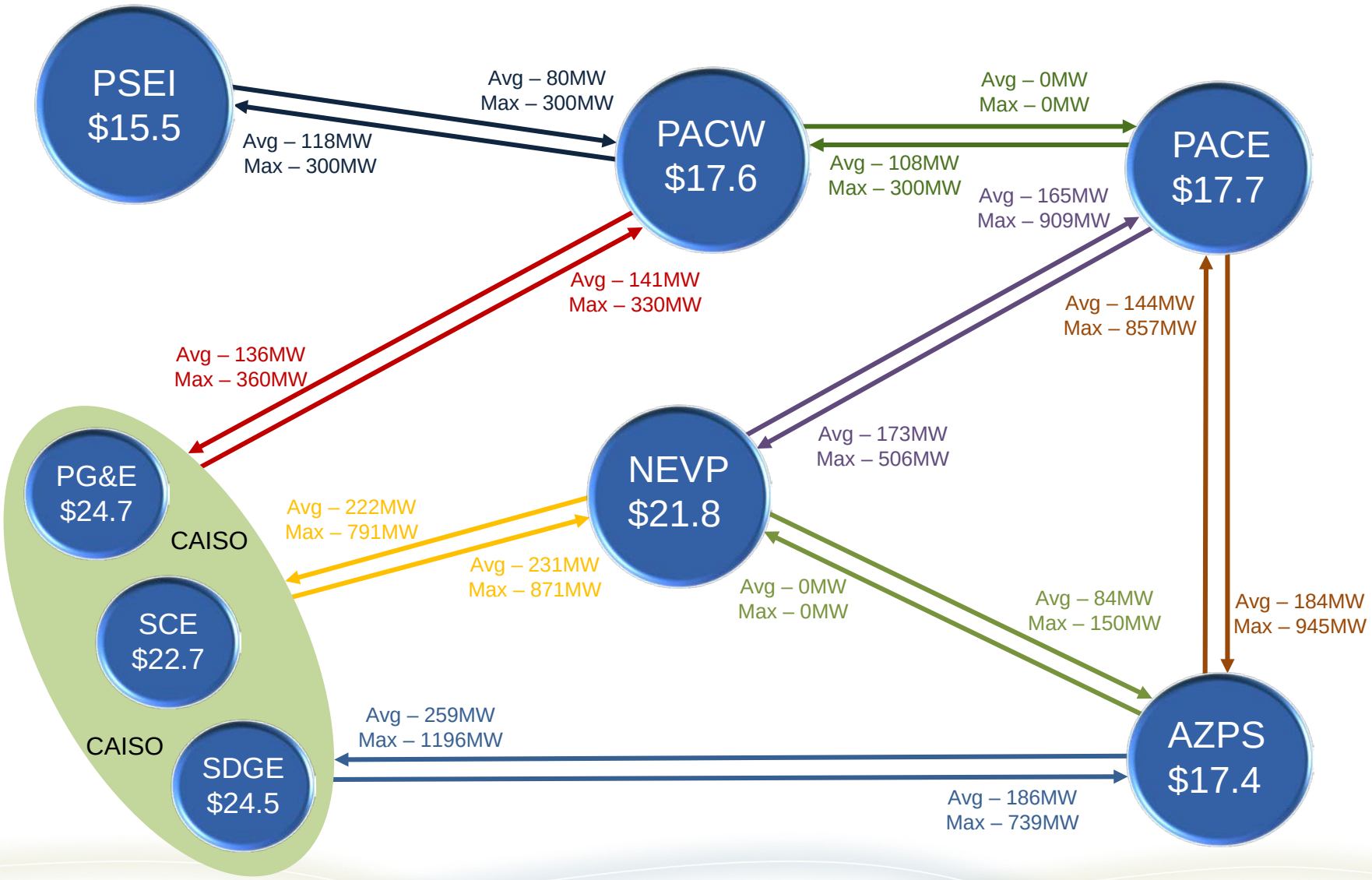
Solar and wind production is shifting the use pattern of conventional resources on peak demand days



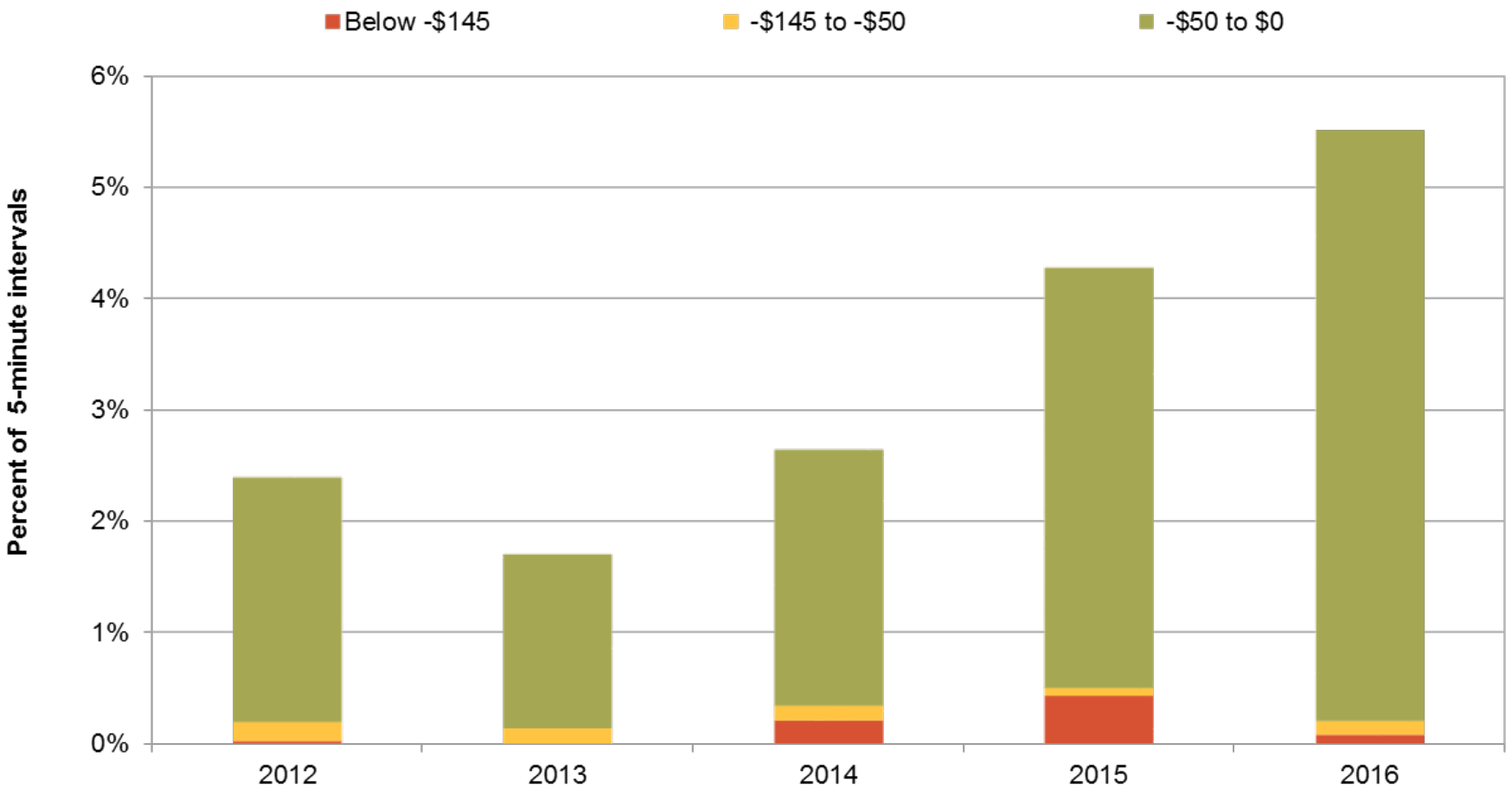
Net Demand

The net demand curve depicts the variability in demand and wind and solar supply that the ISO must meet to maintain grid reliability. Net demand is calculated by taking the actual demand and subtracting the electricity produced by wind and solar resources that are directly connected to the ISO grid.

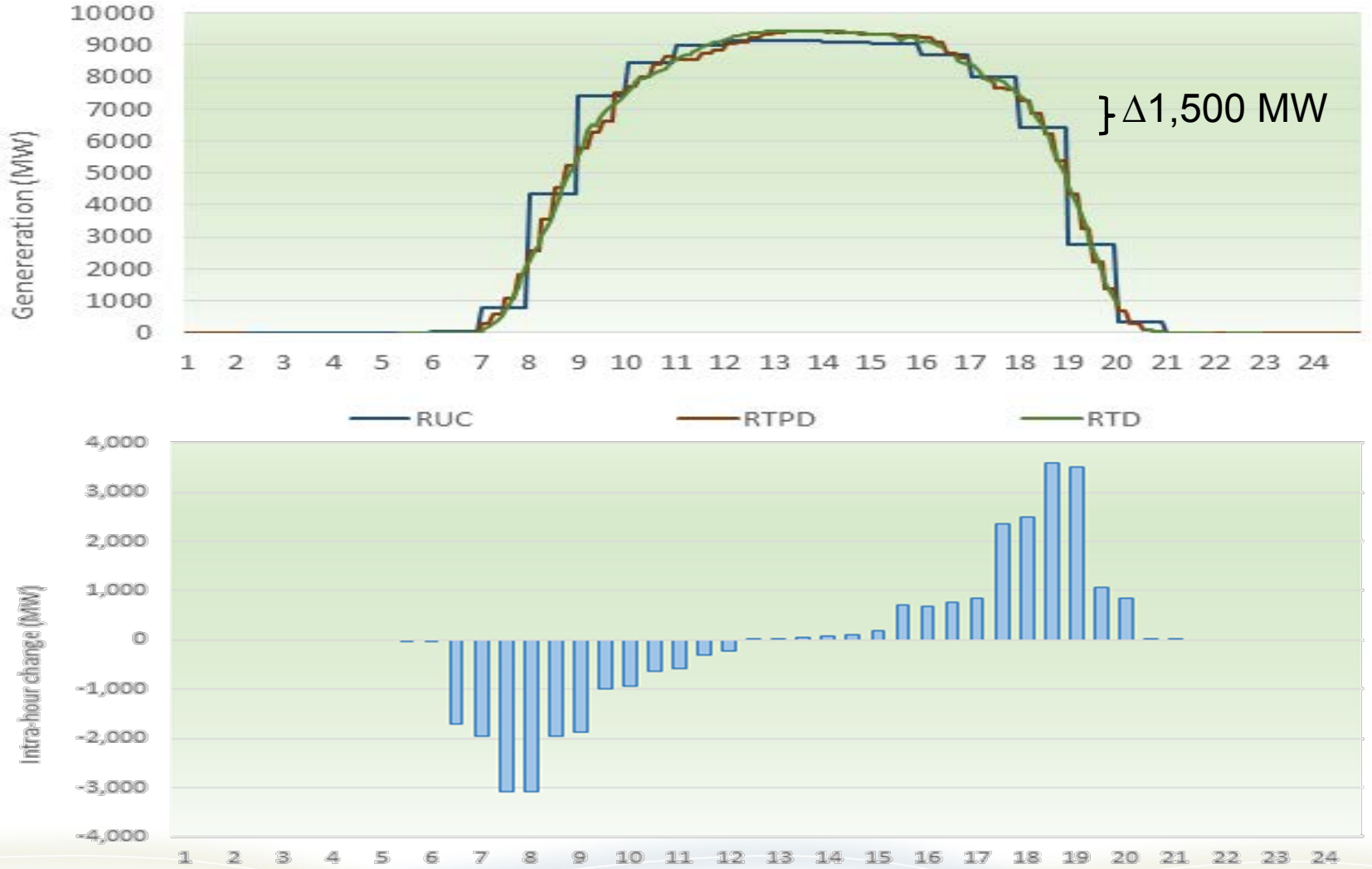
Energy transfers in 1st quarter, 2017



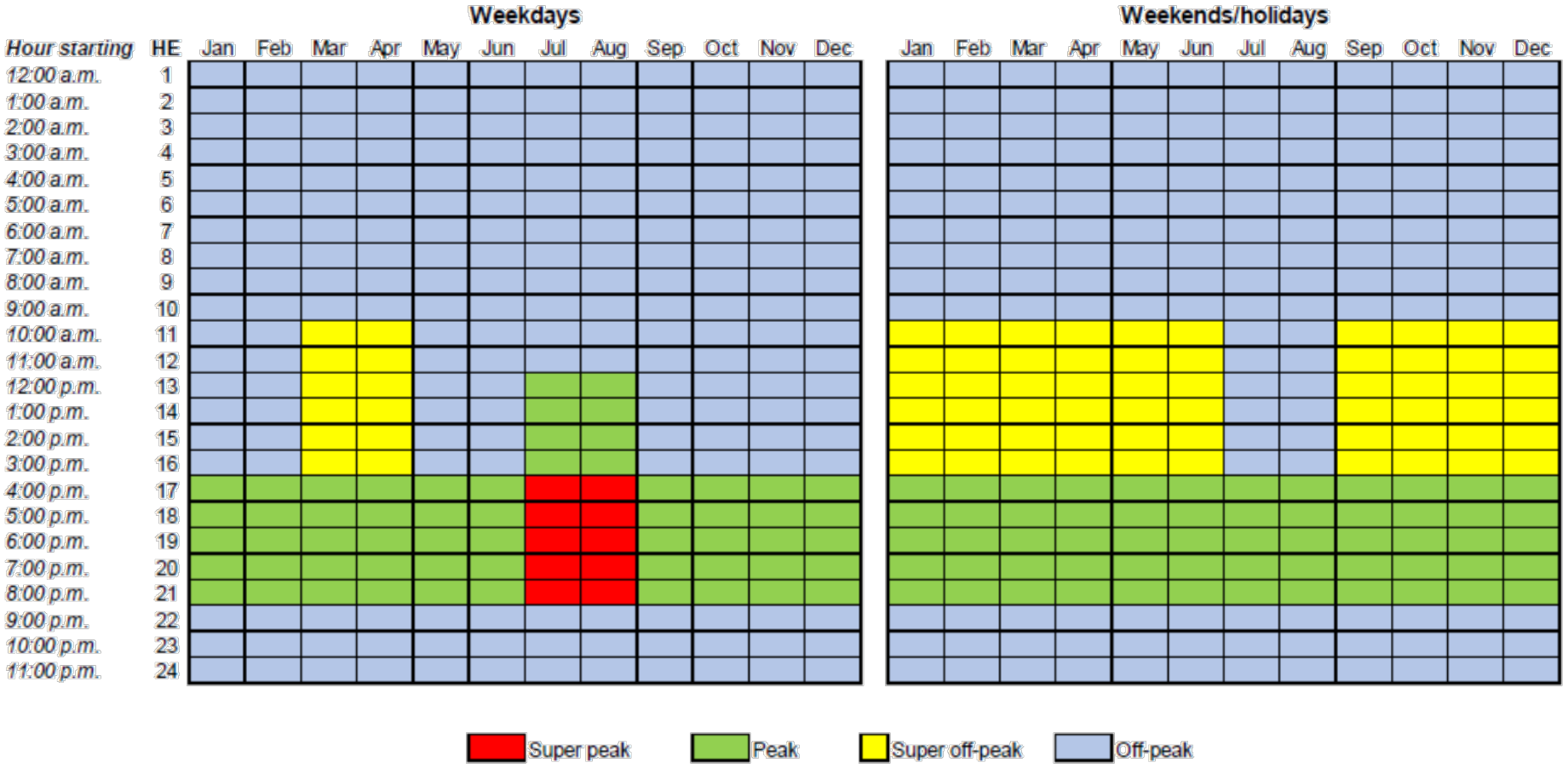
Increase frequency market clearing at negative



Example of how solar ramp affects real-time imbalance



Time-of-Use Rates can align retail signals with system conditions



Periods were simplified to provide a CAISO system-wide uniform approach and limit variation in peak and off-peak periods.

EV charging is not well aligned to help the “Duck”