



# Simulating California's High Renewable Future: Implications for Integration Requirements, Wholesale Prices and GHG Emissions

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## California is planning towards multiple power sector environmental objectives by 2020

- State law AB32 – Reduction of greenhouse gas emissions to 1990 levels by 2020
- 20% Renewable Portfolio Standard (RPS) by 2012
- 33% RPS by 2020 (Executive Order)
- Repowering or replacement of once-through cooling power plants (~38% of in-state gas and nuclear capacity)

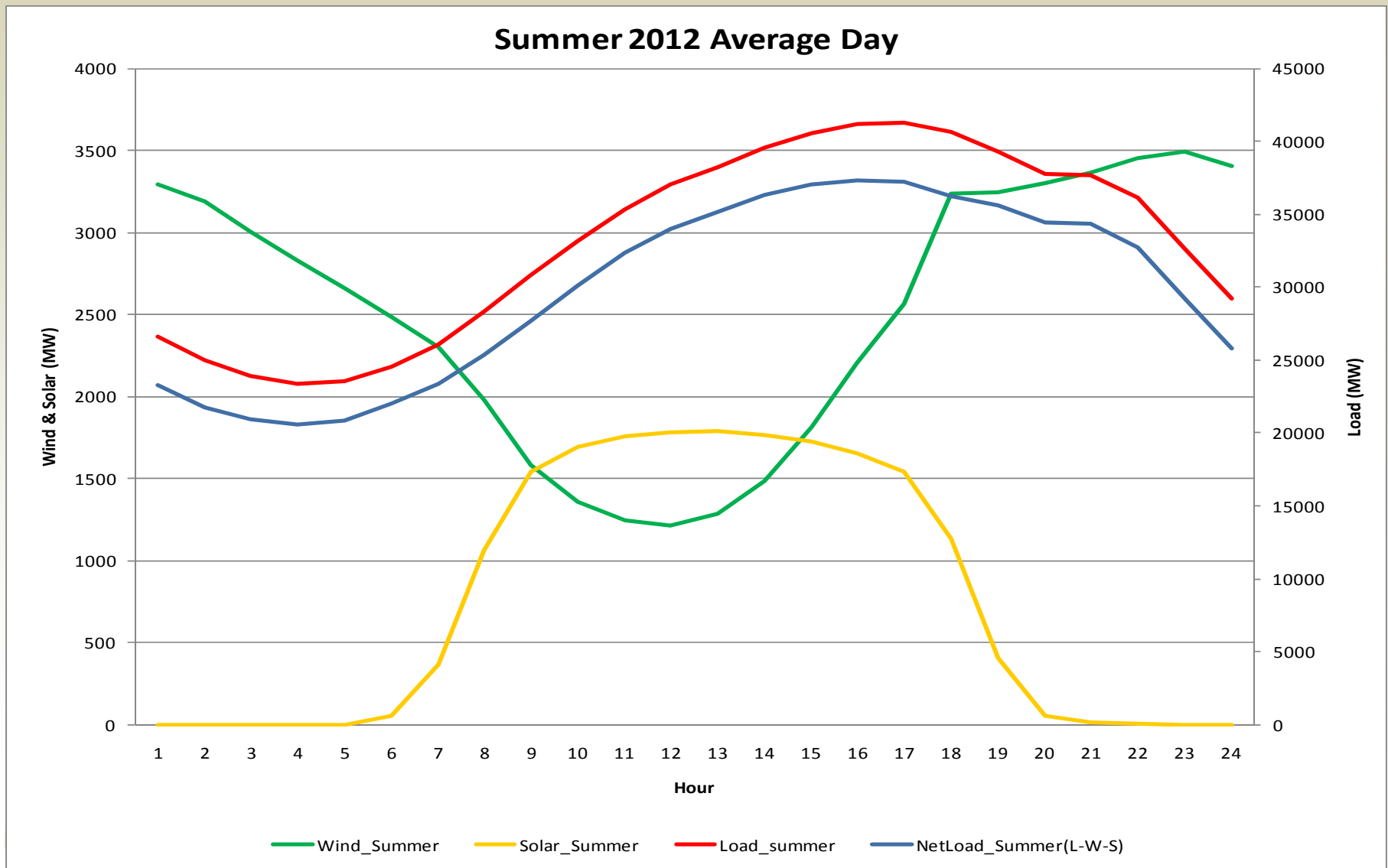
## Both resource and transmission planning are moving towards a scenario-based approach

- **ISO operational studies to integrate 20% RPS by 2012-13** (initial results in 2007; updated simulations 2009-10)
  - 20% RPS Reference Case based on existing renewable contracts
  - All Gas Benchmark Case (no additional renewables)
- **ISO-led stakeholder team to conduct operational study to integrate 33% RPS by 2020** under alternative scenarios combining renewable generation portfolios and demand-side policies (e.g., energy efficiency)
  - 33% RPS Reference Case based on existing renewable queue projects, contracts, feasibility studies
  - High Distributed Generation Case
  - High Renewable Imports Case
  - 20% RPS Reference Case
  - All Gas Benchmark Case (no additional renewables)

# ISO renewable integration studies have utilized two main tools

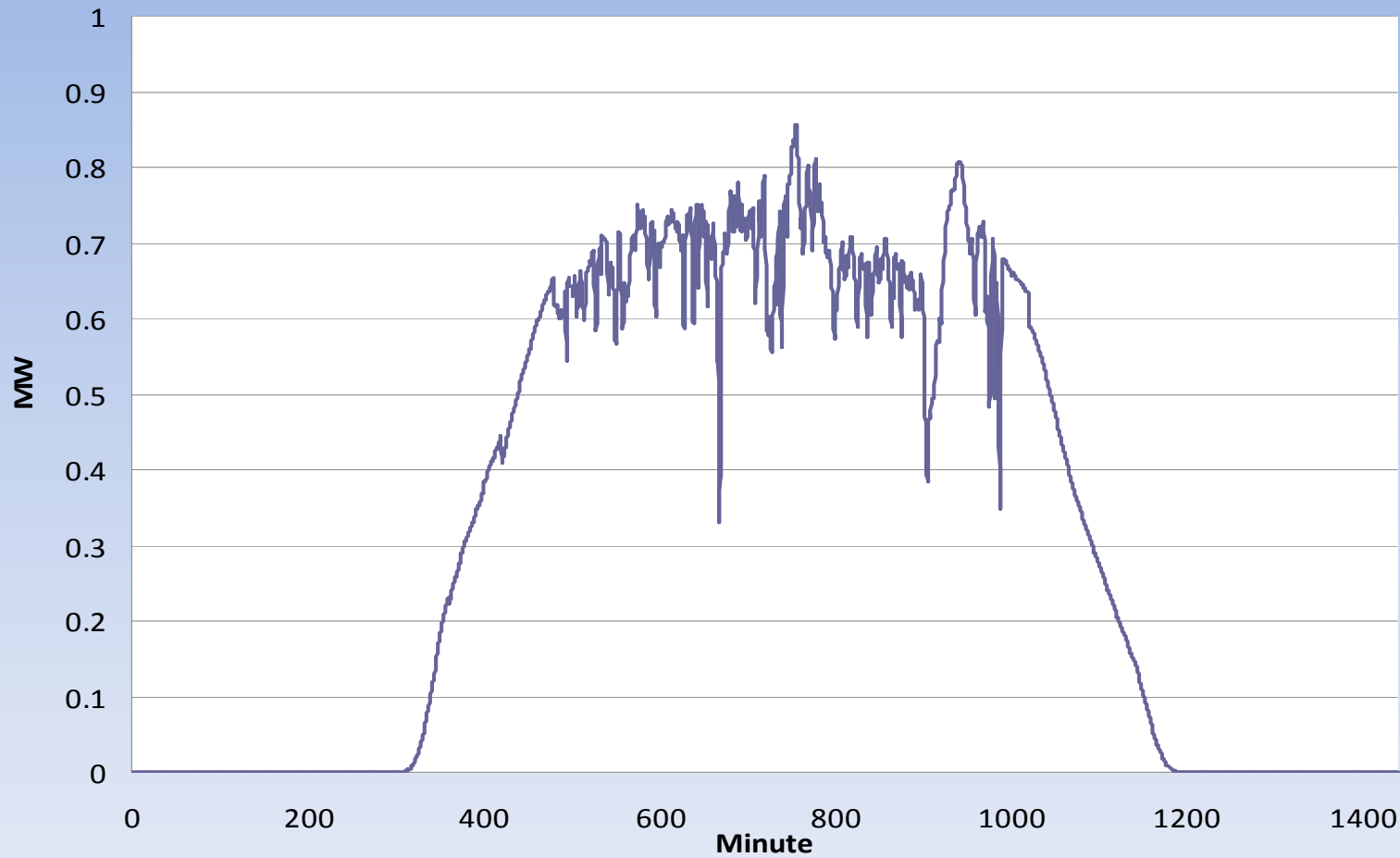
- *Step 1* – Probabilistic Simulation to Assess Intra-Hour Operational Requirements
  - Estimates added intra-hour variability under each studied renewable portfolio
  - Calculates the following by hour and season: Regulation Up and Regulation Down capacity, load-following capacity requirements, and generic ramp rate requirements
- *Step 2* – Production Simulations
  - Dynamic optimization models that simulate the power system using least-cost commitment and dispatch of resources to meet load in an hourly or subhourly time-step
  - Calculates the following by hour and season: wholesale prices and integration costs, GHG emissions, changes in dispatchable generator operations leading to ramp and ancillary service capacity violations

# Projected Wind and Solar Average Production Profiles under 20 % RPS – Summer 2012



# PV plant output variability, May 16, 2009

1 Minute Production With Variability Added for May 16



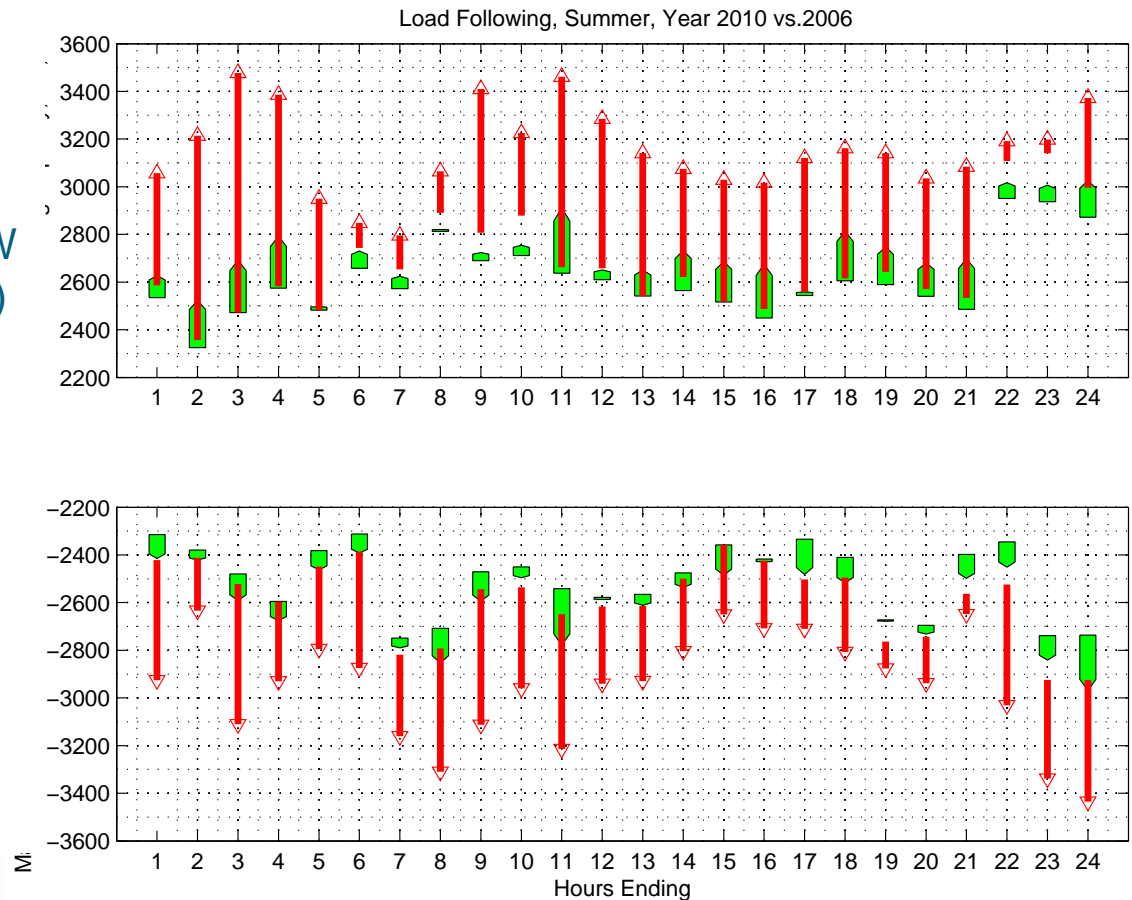
# 20% RPS Reference Case Simulation – Load Following Capacity Requirements

The maximum upward capacity requirement of 3,500 MW occurs during HE3 and HE11

The maximum increase of 800 MW occurs during HE3 (3,500 – 2,700)

The maximum downward capacity requirement of 3,450 MW occurs during HE24

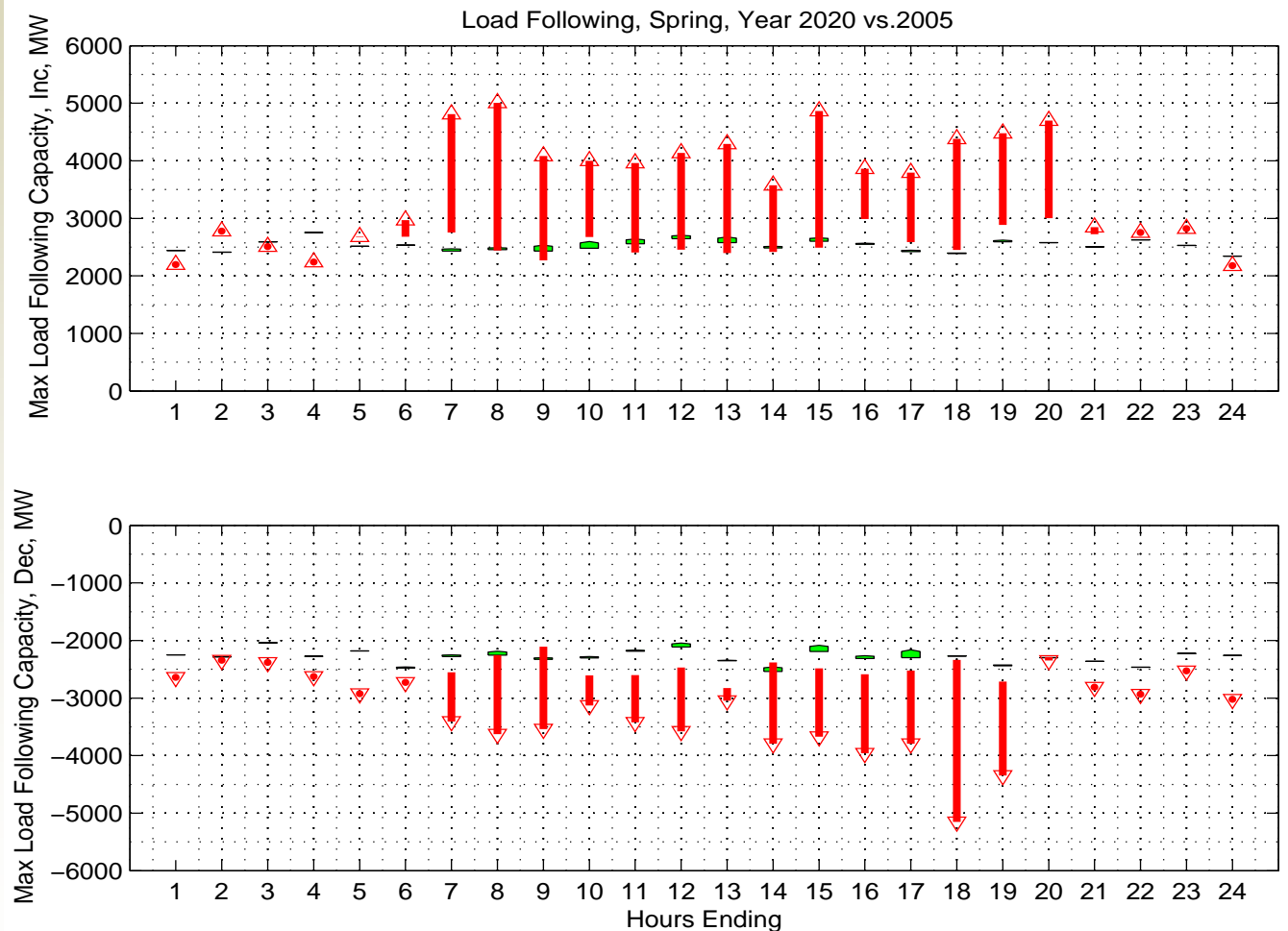
The maximum downward capacity increase of 500 MW (3,050 -2,450) occurred in HE22



# 33% RPS Reference Case Simulation – Load Following Capacity Requirements

Maximum upward  
increase from  
2500 MW to 5100  
MW in HE 8.

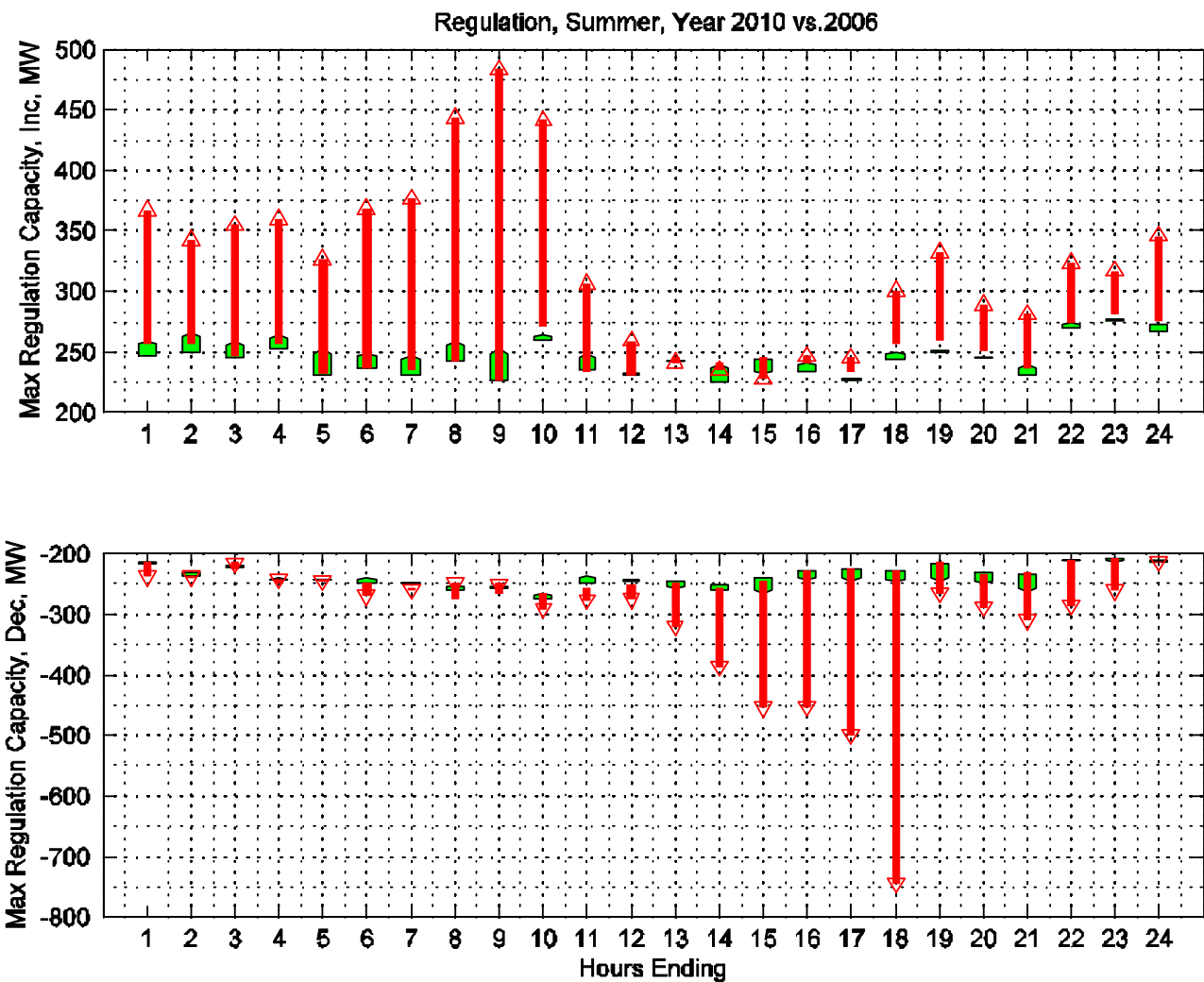
Maximum  
downward  
decrease from  
2100 MW to 5200  
MW in HE 18.



# 20% RPS Reference Case Simulation – Regulation Capacity Requirements

The maximum increase of 230 MW occurs during HE9 (480 MW–250 MW)

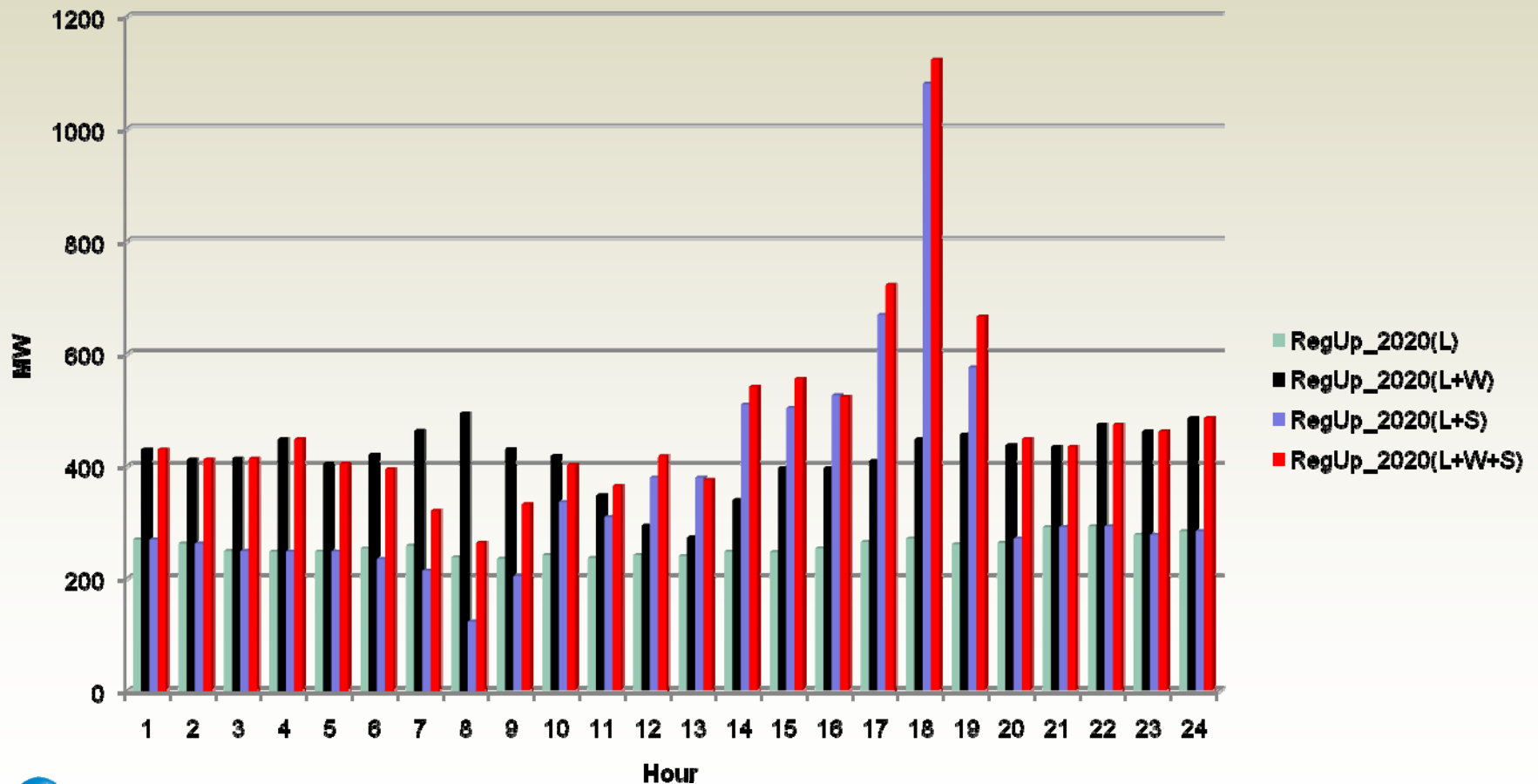
The maximum downward increase of 500 MW (750 MW -250 MW) occurred in HE18



# 33% RPS Reference Case Simulation – Regulation Capacity Requirements

**DRAFT – RESULTS MAY BE REVISED**

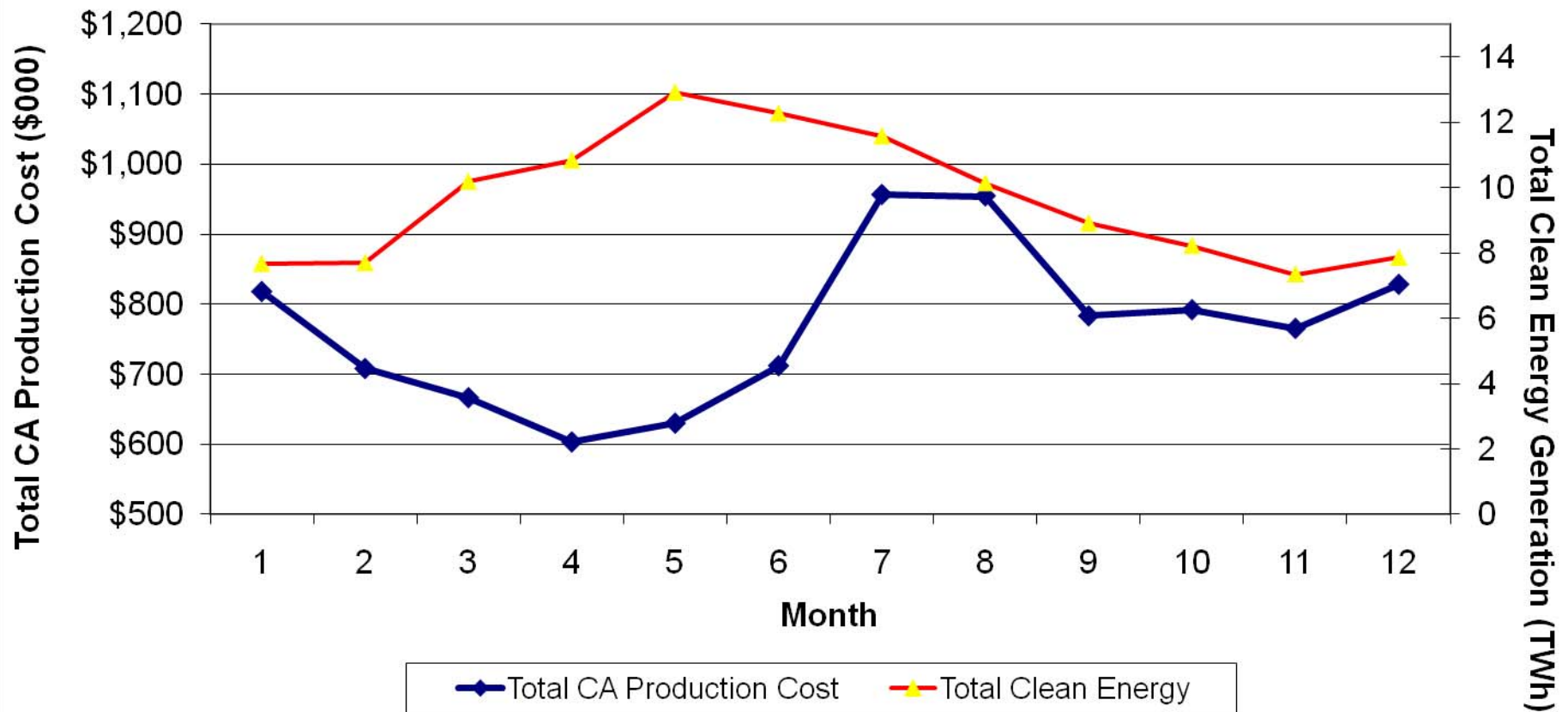
## Summer Regulation Up



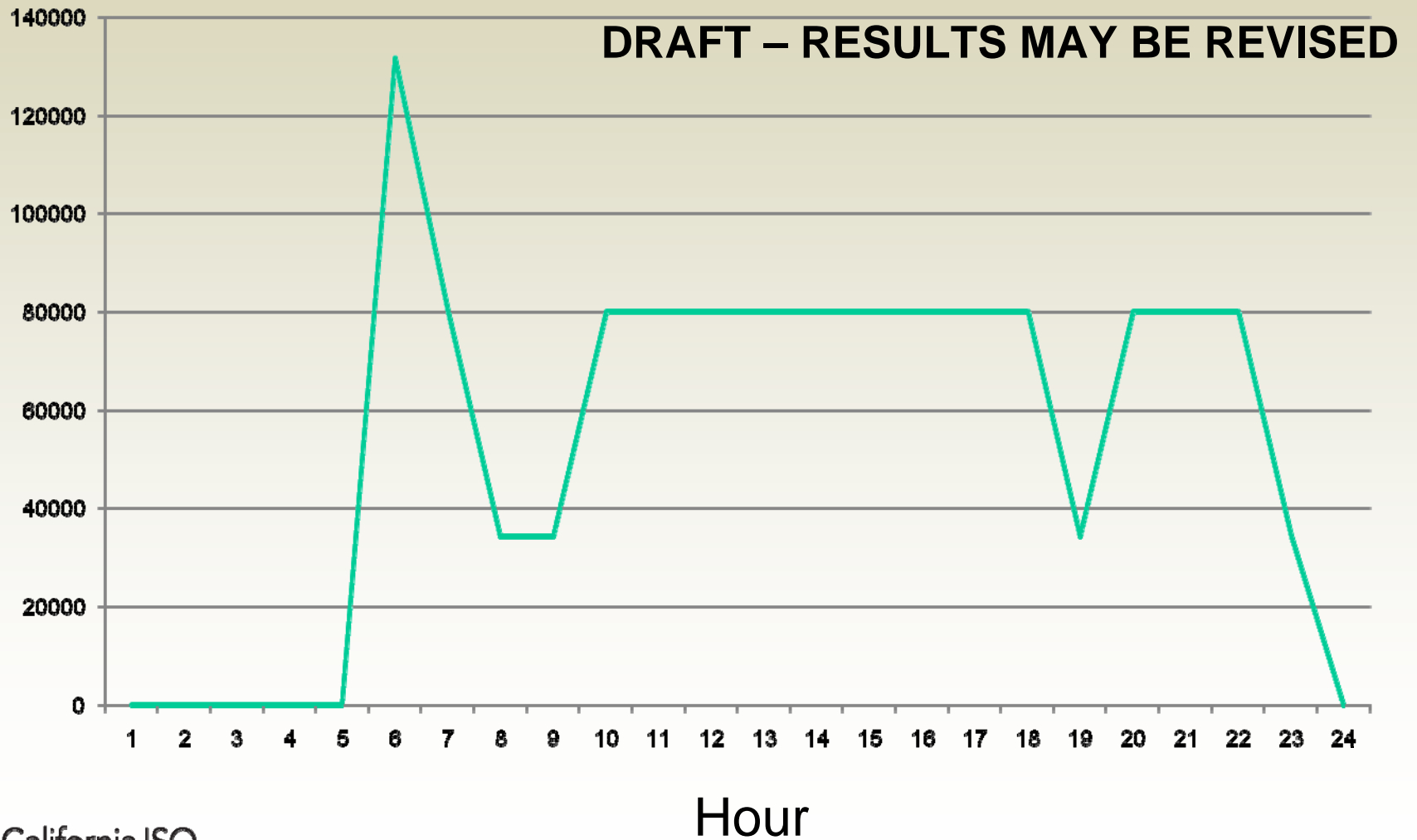
# 33% RPS Reference Case Production Simulation -- Clean energy (Renewables + Hydro) overall impact on production costs (not including all integration costs)

## Production Cost Comparison

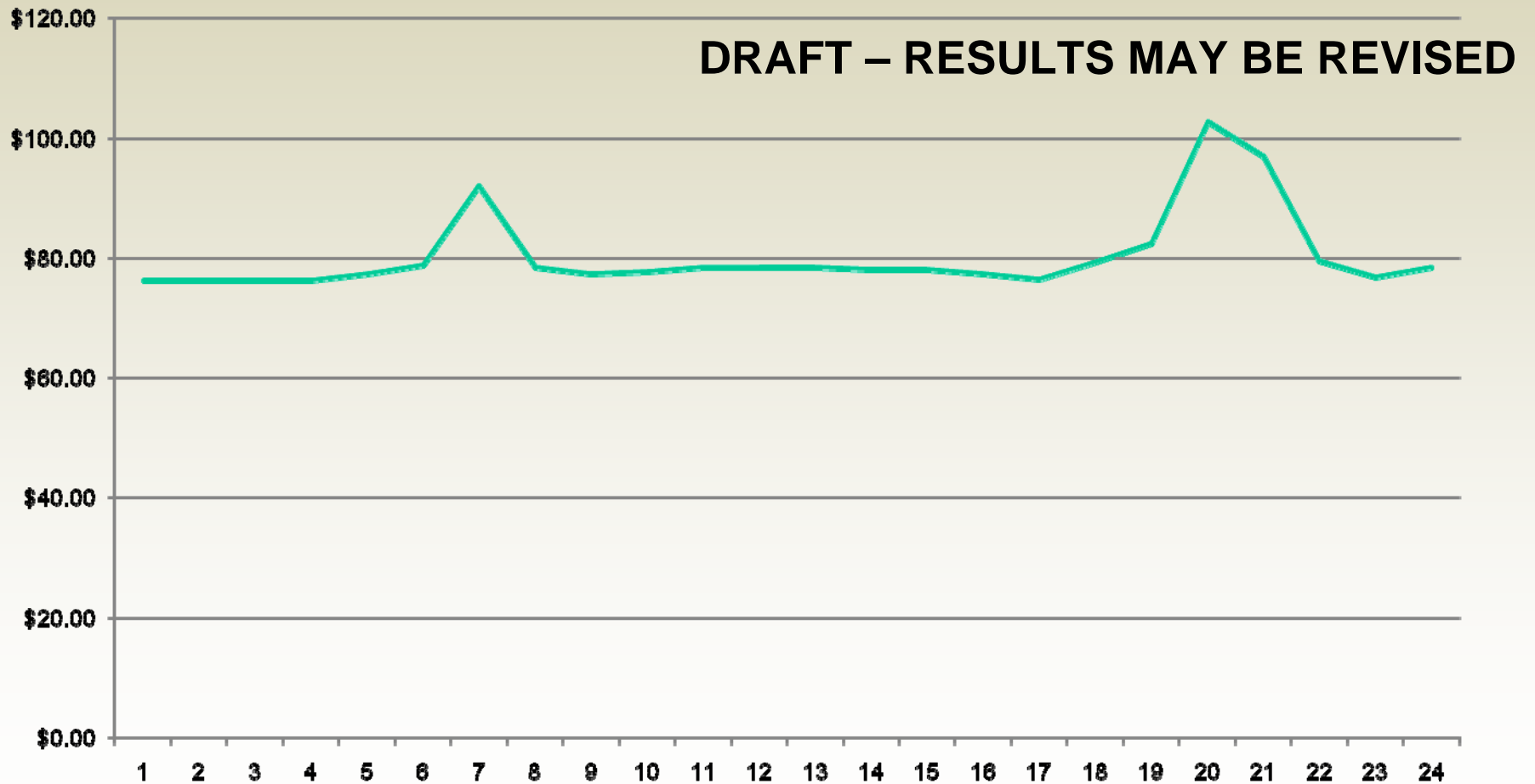
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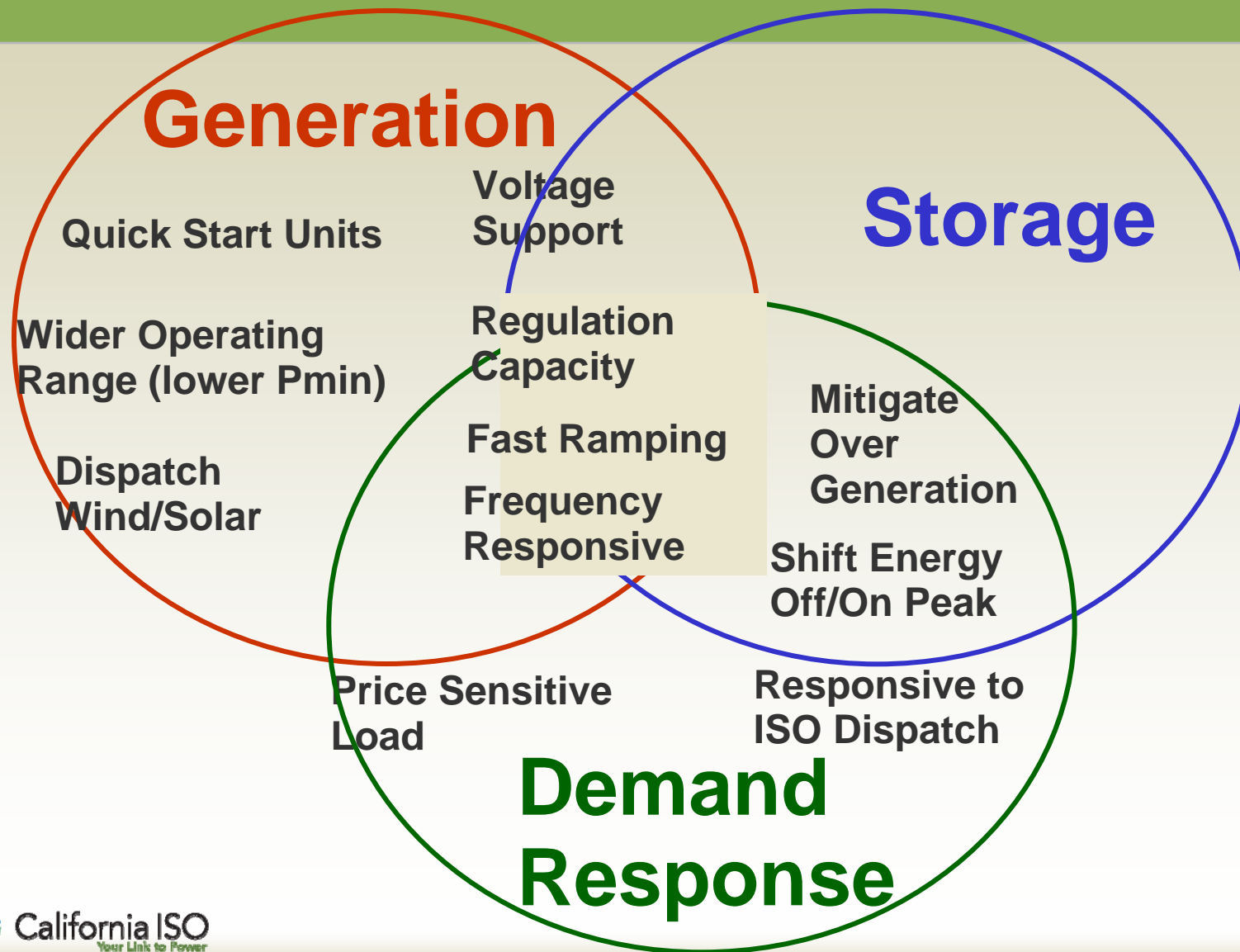
# 33% RPS Reference Case Production Simulation -- Hourly carbon emissions profile of a large steam turbine following renewable production (March 2020 simulation)



# 33% RPS Reference Case Production Simulation – Wholesale Energy Prices may start to follow variants on this pattern (April 15, 2020)



# Resource Characteristics for Renewable Integration



## Stay Tuned for Results...

- [www.caiso.com](http://www.caiso.com)
- Integration of Renewable Resources Program
  - <http://www.caiso.com/1c51/1c51c7946a480.html>
- Renewable Transmission Planning
  - <http://www.caiso.com/242a/242abe1517440.html>
  - <http://www.caiso.com/20a1/20a1dbe417300.html>