Stochastic Simulation of Unit Commitment and Dispatch Under a 20% RPS in California

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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 2012-13
- 33% RPS by 2020 (Executive Order)
- Repowering or replacement of once-through cooling power plants (~38% of in-state gas and nuclear capacity)

CAISO is utilizing several operational and market simulation tools to evaluate VER integration

1. **Probabilistic simulation tool to assess intra-hour operational requirements (CAISO model developed by PNNL/ISO)**
   - Monte Carlo simulation used to generate realistic hour-ahead and 5 minute-ahead load and wind forecast errors, then applied to hourly and sub-hourly schedules and actual demand as incremented to future years
   - Estimates potential intra-hour capacity and ramp rate requirements for load-following and Regulation Up and Regulation Down
2. **Regulation and frequency simulation tool**
   - Quantifies changes in system frequency deviation and area control error (ACE) due to wind and solar variability at 20% - 33% RPS
   - Calculates the Regulation/frequency response requirements and value of additional capabilities, such as storage
   - Tool developed by KEMA; initial report under review by CEC for publication; utilization will follow

CAISO is utilizing several operational and market simulation tools to evaluate VER integration (*cont.*)

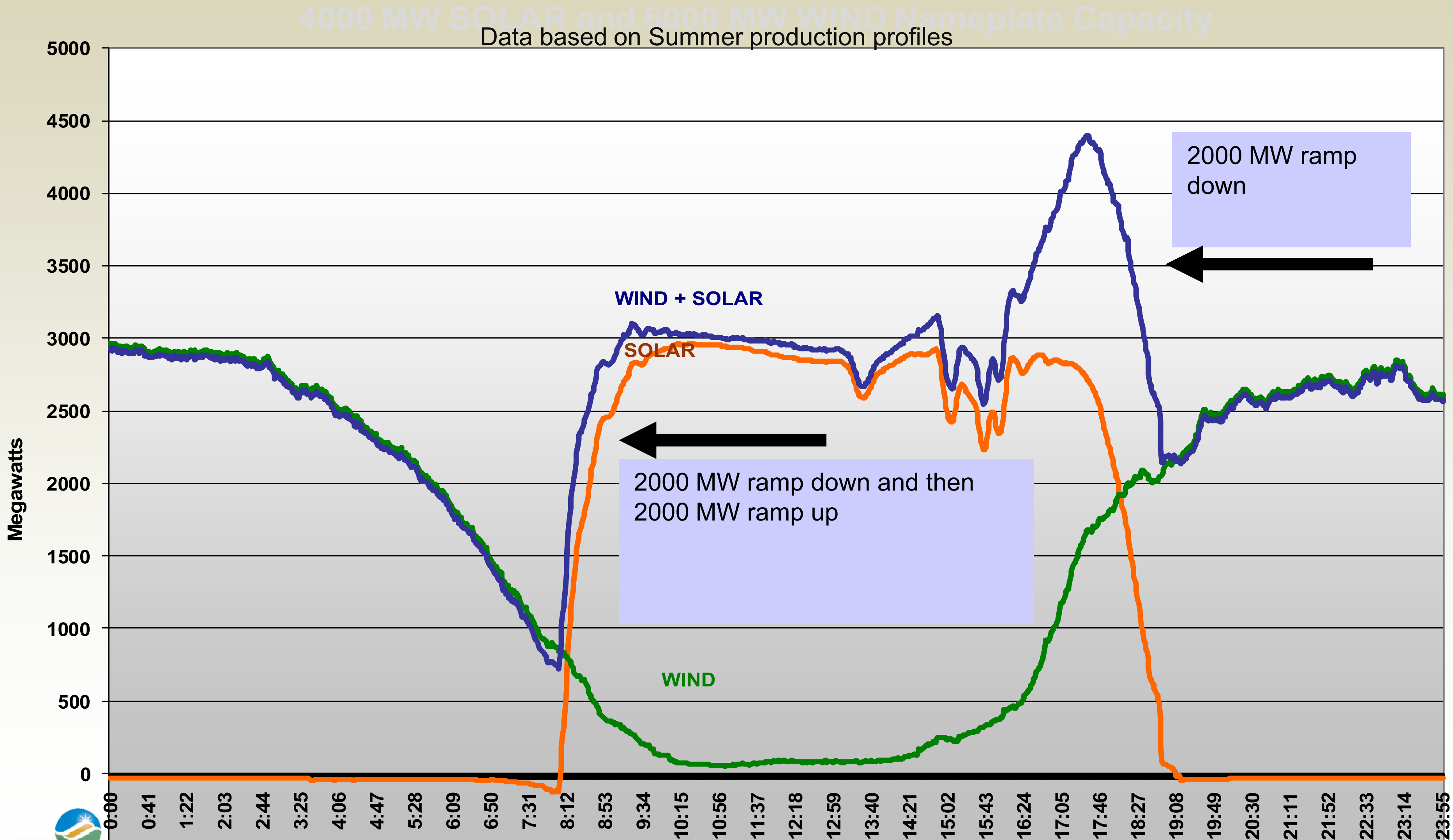
3. Production simulation of unit commitment and dispatch

- Dynamic optimization model that simulates system least-cost commitment and dispatch of resources to meet energy and ancillary services in an hourly or sub-hourly time-step.
- Can be coupled to intra-hour operational simulation type (1) by incorporating Regulation capacity requirements (and possibly load-following capacity requirements) developed in those simulations
- Can use stochastic process to simulate day-ahead and hour-ahead forecast errors for VERs

4. "MarketSim" market simulations

- Used for detailed simulations utilizing actual day-ahead to real-time market data and full network model
- Will run renewable resource portfolios through sample days
- Initially used to benchmark 20% RPS production simulations; later will examine "stress days"

Example of ramping challenges at ~20% RPS



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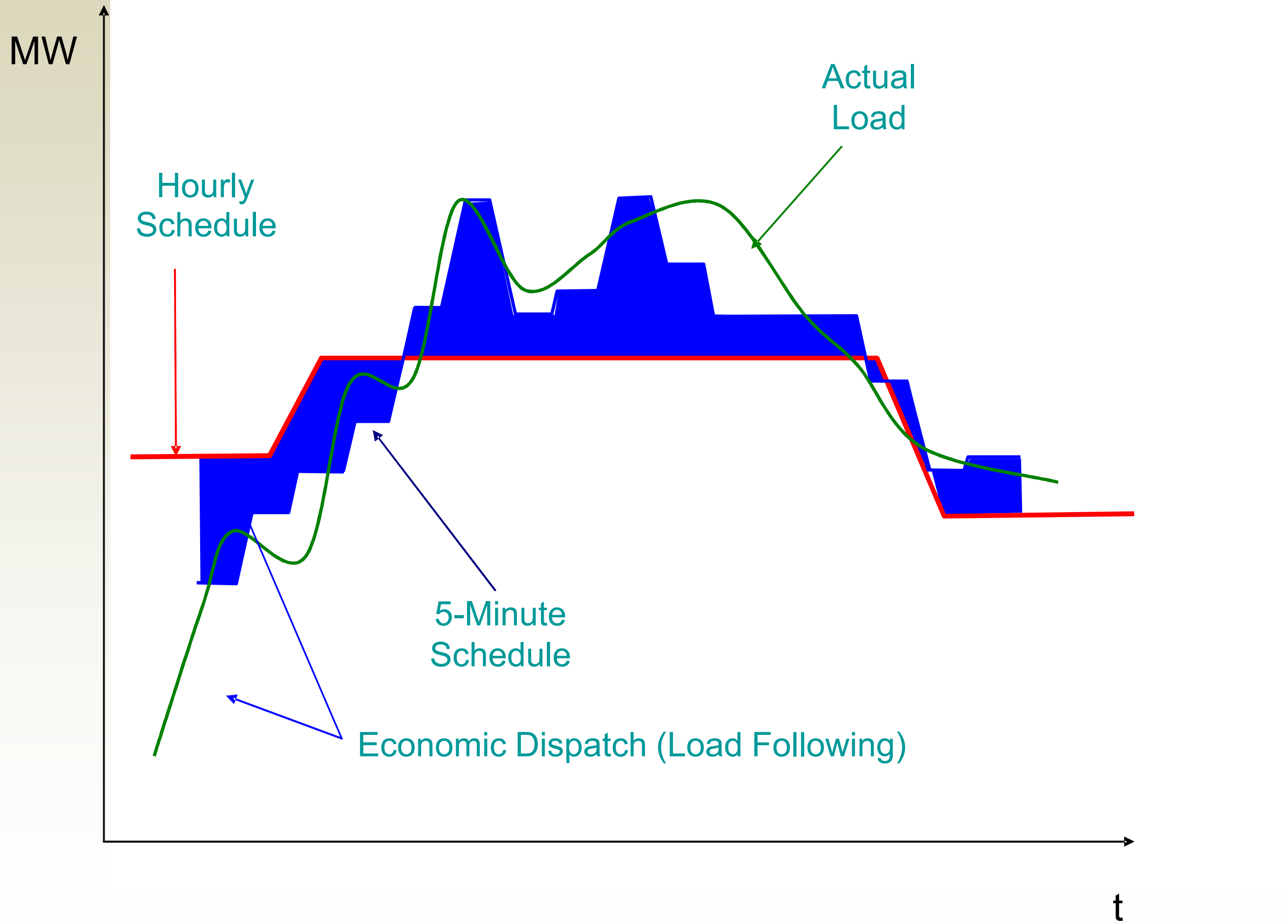
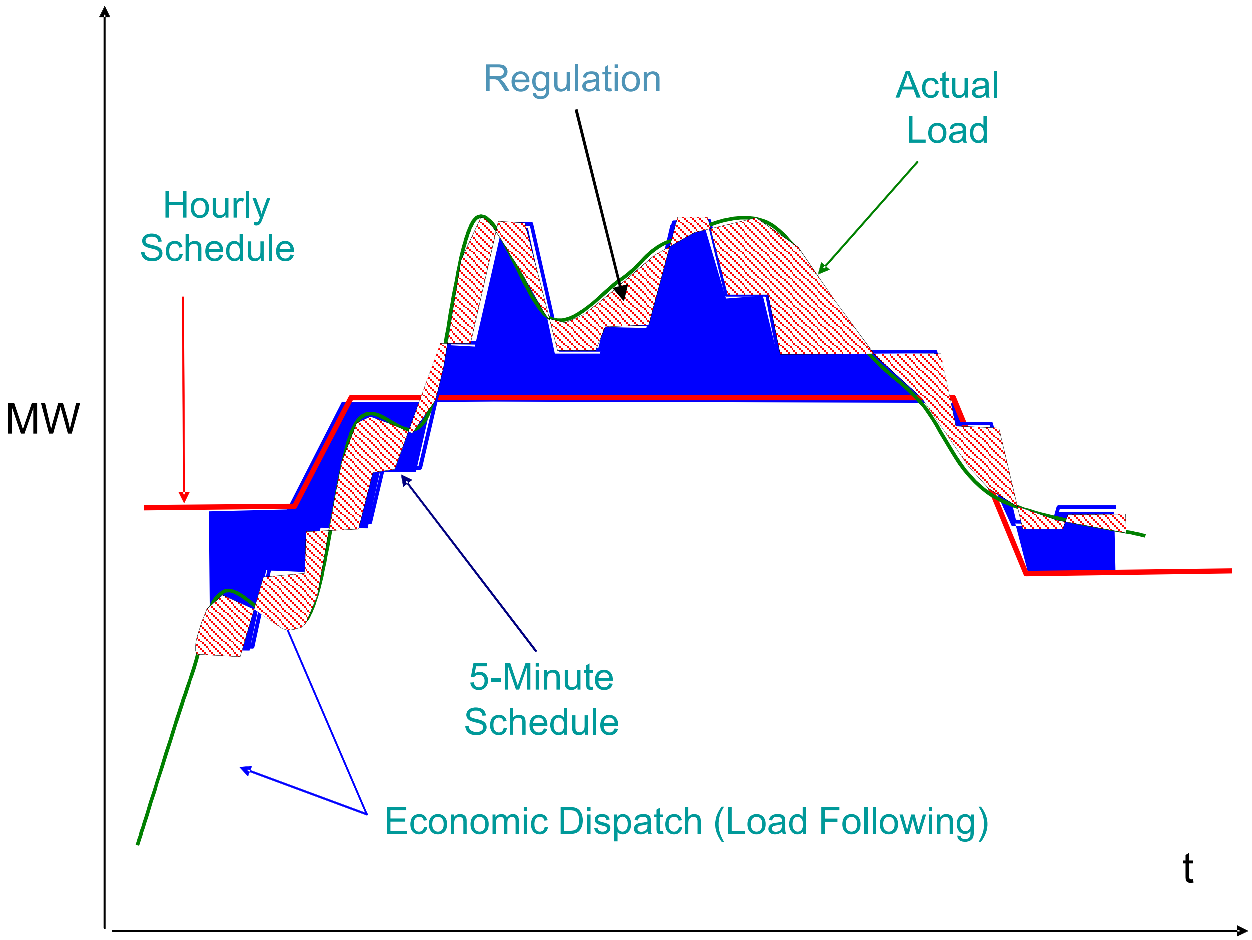
Five Minute Economic Dispatch (Load Following) Requirement shown as blue shaded area



Regulation Requirement shown as red shaded area



From operational simulation model (1): Expected increase in Regulation and load-following capacity (MW) requirements

	Spring			*Summer*			*Fall*			*Winter*		
	2006	**2012**	**2020**	**2006**	**2012**	**2020**	**2006**	**2012**	**2020**	**2006**	**2012**	**2020**
Maximum Regulation Up Requirement (MW)	277	502	1,135	278	455	1,144	275	428	1,308	274	474	1,286
Maximum Regulation Down Requirement (MW)	-382	-569	-1,097	-434	-763	-1,034	-440	-515	-1,264	-353	-442	-1,076
Maximum Load Following Up Requirement (MW)	2,292	3,207	4,423	3,140	3,737	4,841	2,680	3,326	4,565	2,624	3,063	4,880
Maximum Load Following Down Requirement (MW)	-2,246	-3,275	-5,283	-3,365	-3,962	-5,235	-2,509	-3,247	-5,579	-2,424	-3,094	-5,176

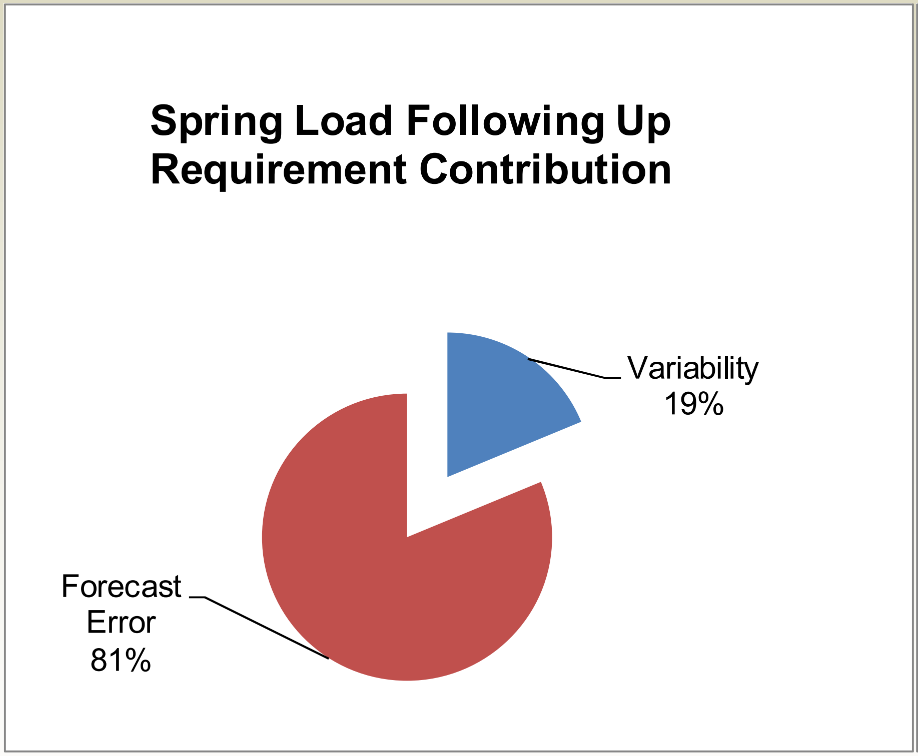
2012 Case = 20% RPS with additional 1,800 MW solar and 4,100 MW wind
2020 Case = 33% RPS with additional 9,700 MW solar and 8,350 MW wind

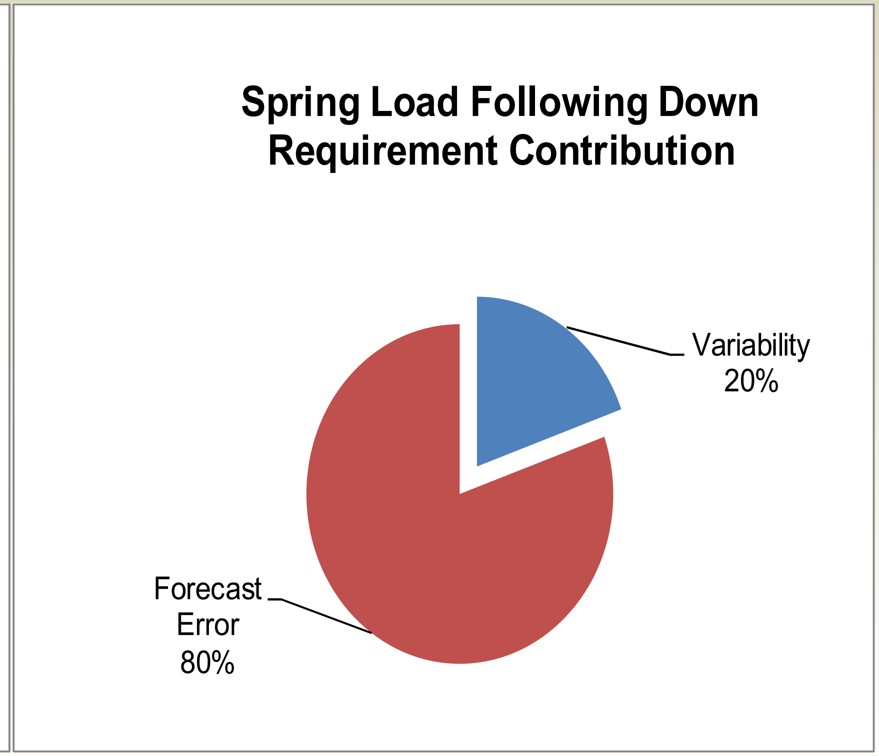
From operational simulation model (1): Expected increase in Regulation and load-following ramp rate (MW/min) requirements

	Spring			Summer			Fall			Winter		
	2006	2012	2020	2006	2012	2020	2006	2012	2020	2006	2012	2020
Maximum Regulation Ramp Up Rate (MW/Min)	67	122	447	75	118	528	70	114	472	73	107	344
Maximum Regulation Ramp Down Rate (MW/Min)	-66	-90	-310	-76	-97	-300	-72	-90	-301	-79	-90	-303
Maximum Load Following Ramp Up Rate (MW/Min)	150	168	325	166	194	313	147	181	324	143	165	296
Maximum Load Following Ramp Down Rate (MW/Min)	-138	-162	-451	-145	-169	-434	-134	-167	-438	-158	-198	-427

2012 Case = 20% RPS with additional 1,800 MW solar and 4,100 MW wind
2020 Case = 33% RPS with additional 9,700 MW solar and 8,350 MW wind

Forecast error is the bigger driver of the change in the load following requirement (shown for 20% RPS)





Draft results from operational simulations of type (1)

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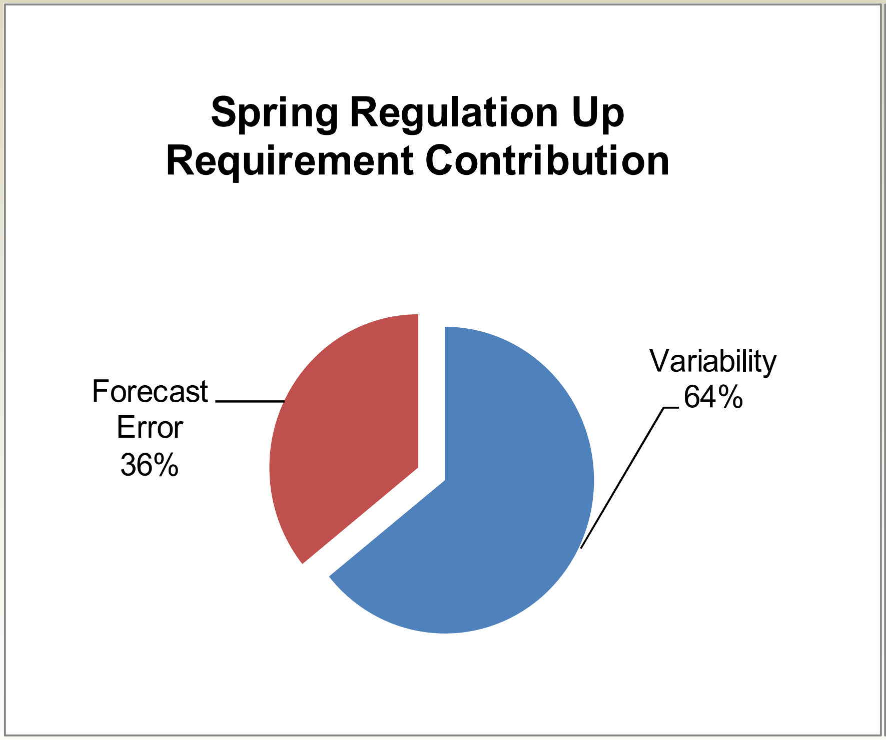
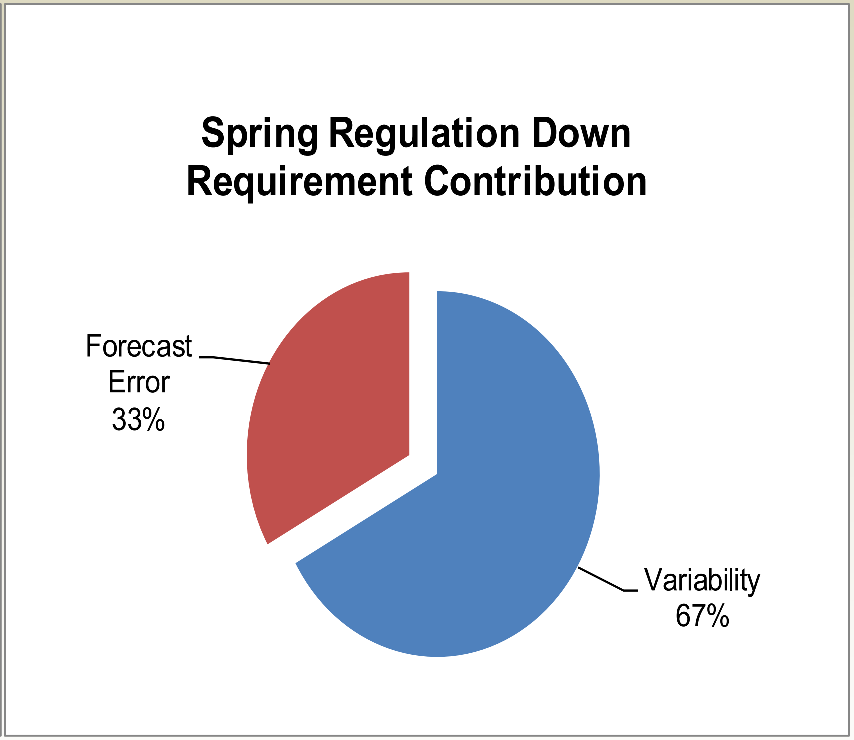
Variability is the bigger driver of the change in the Regulation requirement (shown for 20% RPS)





Draft results from operational simulations of type (1)

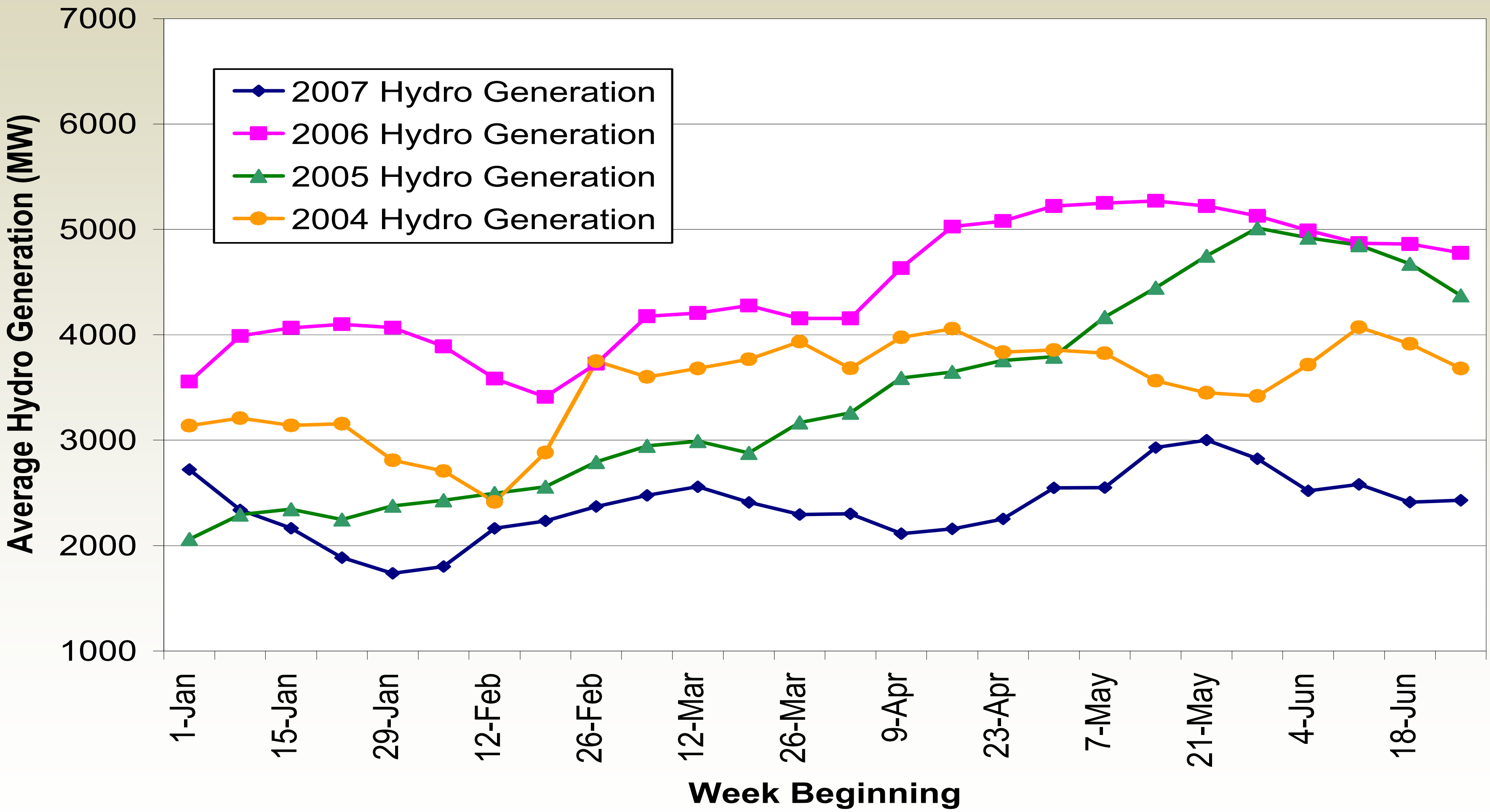
Production simulation of 20% RPS: Objectives

- Evaluate capability of CAISO resources to reliably integrate anticipated levels of VERs
  - Focus initially on the ability of CAISO fossil-fired resources to provide sufficient operational flexibility (starts/stops, ramp, ancillary services)
  - Incorporate any additional ancillary service requirements from operational simulations (initially just Regulation Up and Regulation Down)
  - Evaluate the impact of day-ahead and hour-ahead forecast errors on unit commitment and dispatch using stochastic process
  - Determine the magnitude and frequency of any system operational violations (within model capabilities)
- Test (or extend) the ability of readily available commercial software (PLEXOS) to provide credible VER integration evaluations
  - Scalable, repeatable, benchmarked

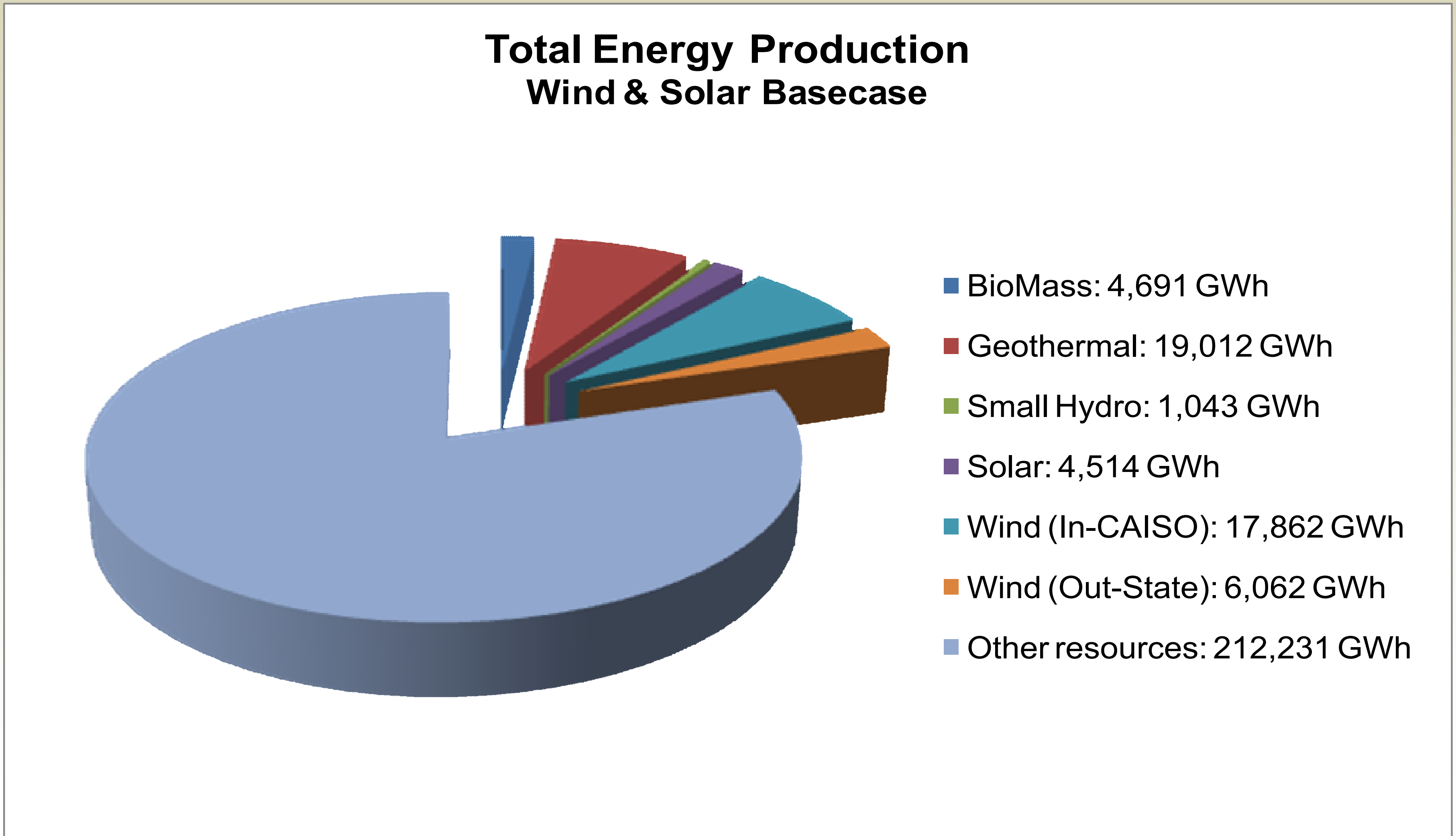
Production simulation of 20% RPS: Key assumptions for initial simulations

- Only CAISO system modeled
  - Zonal topology initially (NP15, SP15)
  - Dynamic co-optimization of energy and ancillary services
  - CAISO Master File confidential generation data (Pmin, Pmax; Min. up- and down time; Ramp rates; ancillary service Ranges)
  - Hourly hydro generation (2006 and 2007) and ancillary services contribution (2006) is fixed at the station-level based historical records
  - Hourly net interchange for NP15 and SP15 fixed based on 2006 or 2007 actual
  - No ancillary services provision assumed from imports
  - Hourly wind, QF, and geothermal generation is based on the 2006 historical profiles
  - 2012 generation resource additions included

Production simulation of 20% RPS:
High Hydro (2006) vs. Low Hydro (2007) Years for Overgeneration Sensitivity



Production simulation of 20% RPS: Annual energy production shares (GWh) by fuel type



Production simulation of 20% RPS: Potential Operational Violations Evaluated*

1. Regulation-Up
2. Regulation-Down
3. Spin
4. Non-Spin
5. Unserved Energy
6. Over-generation

* *Either insufficient ramping capability or insufficient available capacity results in one of the above violations.*

Two types of production simulations

1. Annual simulations (8760 hours) – with and without day-ahead and hour-ahead forecast errors
   - Objective is to get sense of frequency and magnitude of violations as well as generation production metrics (e.g., # starts/stops, cycling)
2. Selected days evaluated through sequential day-ahead to hour-ahead to real-time unit commitment and dispatch process; real-time dispatch is conducted on 10-minute or 5-minute time-step
   - Stochastic process used to generate day-ahead and hour-ahead wind and load “forecasts” for 2012
   - Objective is to evaluate the impact of forecast error and variability on unit commitment and dispatch, particularly load-following

Stochastic aspects of market sequence modeling

- Day-ahead and hour-ahead load and wind forecasts modeled with stochastic process
  - Brownian motion with mean reversion
  - parameters derived from the 2006 and 2007 historical hourly day-ahead and hour-ahead load forecast errors by season
- 100 iterations of day-ahead and hour-ahead commitments passed through to the real-time dispatch as follows:
  - After day-ahead commitment solution, all committed units with 5 hour or greater start-up times are required to operate at ≥ minimum operating levels; others remain flexible
  - After hour-ahead commitment, all remaining committed units are required to operate at ≥ minimum operating level
  - Quick start units can be committed in the real-time dispatch

Draft results shown here are of incremental wind resources only to meet 20% RPS

- The first phase of analysis evaluated additional wind resources to meet the 20% RPS (consistent with ISO's 2007 renewable integration study)
- Some draft results are discussed in next slides
- Next phase is evaluating wind + expanded solar to meet 20% RPS; results will be available end of June/July 2010

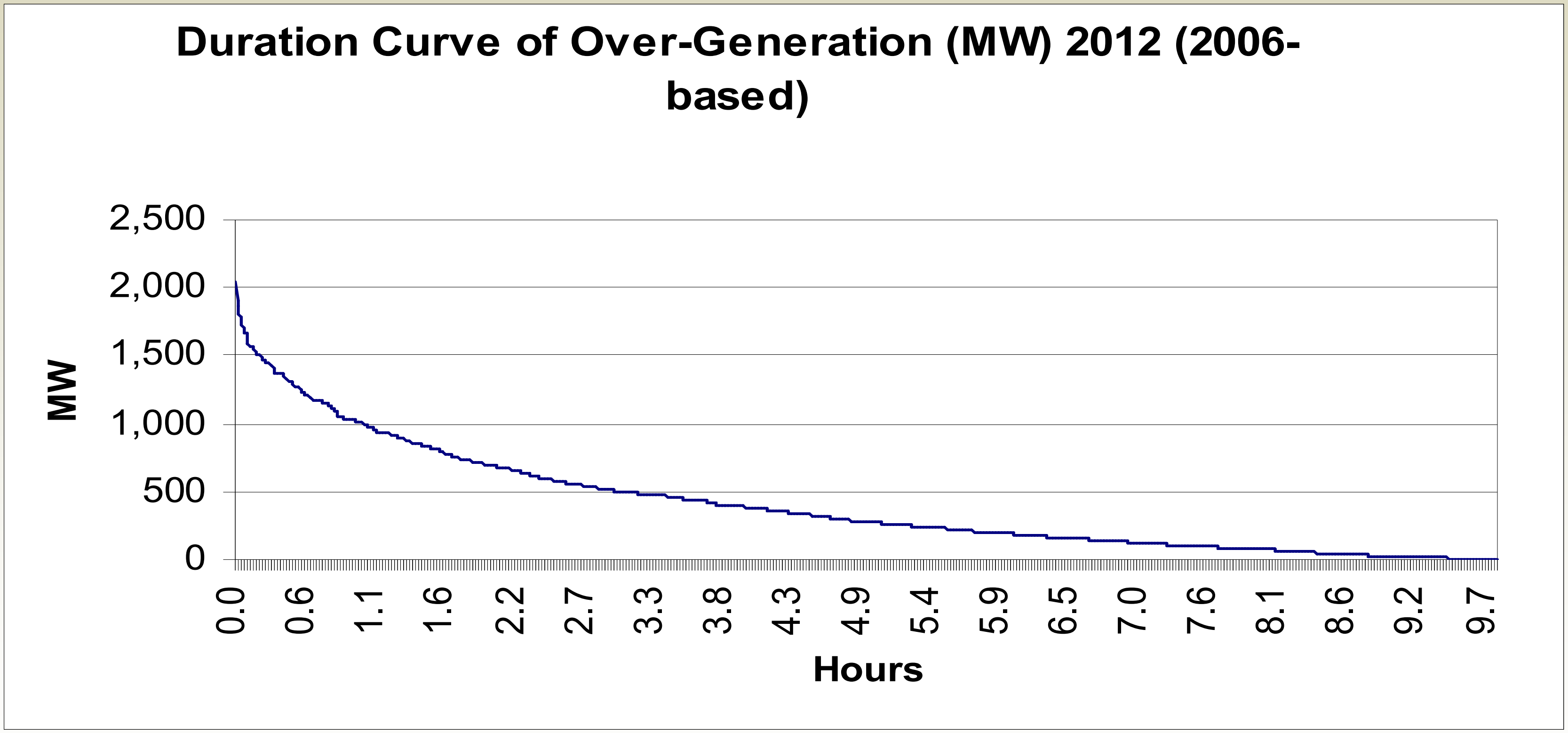
Summary of total number of violation occurrences in the sequential day-ahead/hour-ahead/real-time simulations

Violation Occurrences from 100-iteration Simulations										
		Overgeneration			Reg-up shortfall			Unserved Energy		
Date		DA	HA	RT	DA	HA	RT	DA	HA	RT
February 27, 2012	2006-based									
April 17, 2012	2006-based	99	49	105						
May 7, 2012	2006-based	108	82	8						
June 24, 2012	2006-based			1						
July 23-24, 2012	2006-based				6	2		5		
September 3, 2012	2006-based									
February 27, 2012	2007-based									
July 3, 2012	2007-based									
August 30, 2012	2007-based				5	2		3	2	

NOTE: DA = Day-ahead (hourly); HA = Hour-Ahead (hourly); RT = Real-time (10 minutes in this simulation)

Day-ahead simulation of *annual* over-generation duration curve (high hydro 2006-based simulation)

DRAFT RESULTS



Expected annual hours of violation based on average of 100 iterations

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Interim results for 20% RPS simulations (remaining work to be completed in June/July 2010)

- Detailed MarketSim simulations have validated the need for at least twice as much Regulation procurement in some hours under a 20% RPS
- Production simulations with additional Regulation and consideration of forecast errors have not shown significant increase in operational violations under a 20% RPS
  - But costs of additional stresses on generators have not been quantified

Interim results for 20% RPS simulations (remaining work to be completed in June/July 2010)

- Day-ahead to real-time production simulations appear to meet load following need; do not yet demonstrate need for load-following reserve
  - However, simulations of a 33% RPS underway in parallel do require a load following reserve; hence, need may arise between 20% and 33% RPS
- Production simulations have not shown significant additional duration of overgeneration issues, which is a counter-intuitive result based on historical experience; needs further investigation

References

- California ISO, Integration of Renewable Resources, November 2007 (available at www.caiso.com)
- Makarov et al., Operational Impacts of Wind Generation on California Power Systems, *IEEE Transactions on Power Systems*, 24, 2, May 2009
- California ISO, Integration of Renewable Resources Program: http://www.caiso.com/1c51/1c51c7946a480.html