Renewable Integration Study Next Steps

Mark Rothleder

Director, Department Analysis and Development

Working Group Meeting

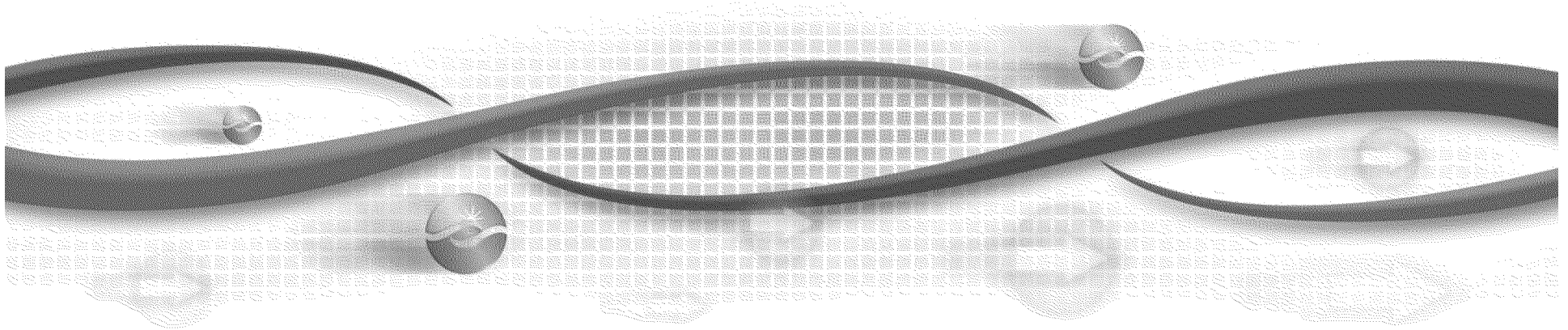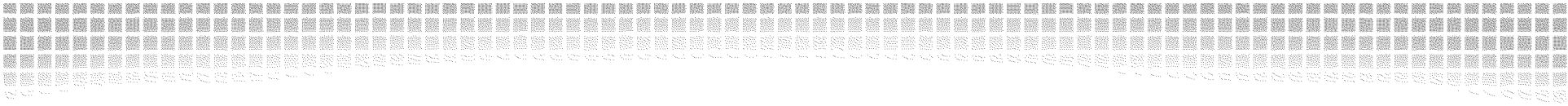October 7, 2011

PURPOSE AND PROCESS

Mark Rothleder

California ISO
Shaping a Renewed Future

Purpose and Process

- Identify operational requirements and bound potential needs to be prepared for the changes it the fleet

- Evaluate alternatives to meeting the identified operational requirements and needs

- Incorporate results from LCR/OTC studies into 33% study work

- Advisory team will review, guide and prioritize work

- Objective is to complete sensitivity analysis work by December 2011 and perform final study work in Q1 2012

California ISO
Shaping a Renewed Future

Next Steps Schedule

Next Step	Target Schedule
Working group kick-off	October 7, 2011
Requests for additional study work	October 14, 2011
Triage and prioritize requests	October 19, 2011
Perform priority analysis and review results	October - December, 2011
Complete LCR/OTC analysis	December, 2011
Scope final study work	January 2012
Perform final study work	January 2012-March 2012
Final results	March 2012

California ISO
Shaping a Renewed Future

REVIEW OF METHODOLOGY AND RESULTS

Mark Rothleder

California ISO
Shaping a Renewed Future

Slide 5

Electricity is produced, delivered, and consumed at the speed of light while balance must be maintained.

California ISO
Shaping a Renewed Future
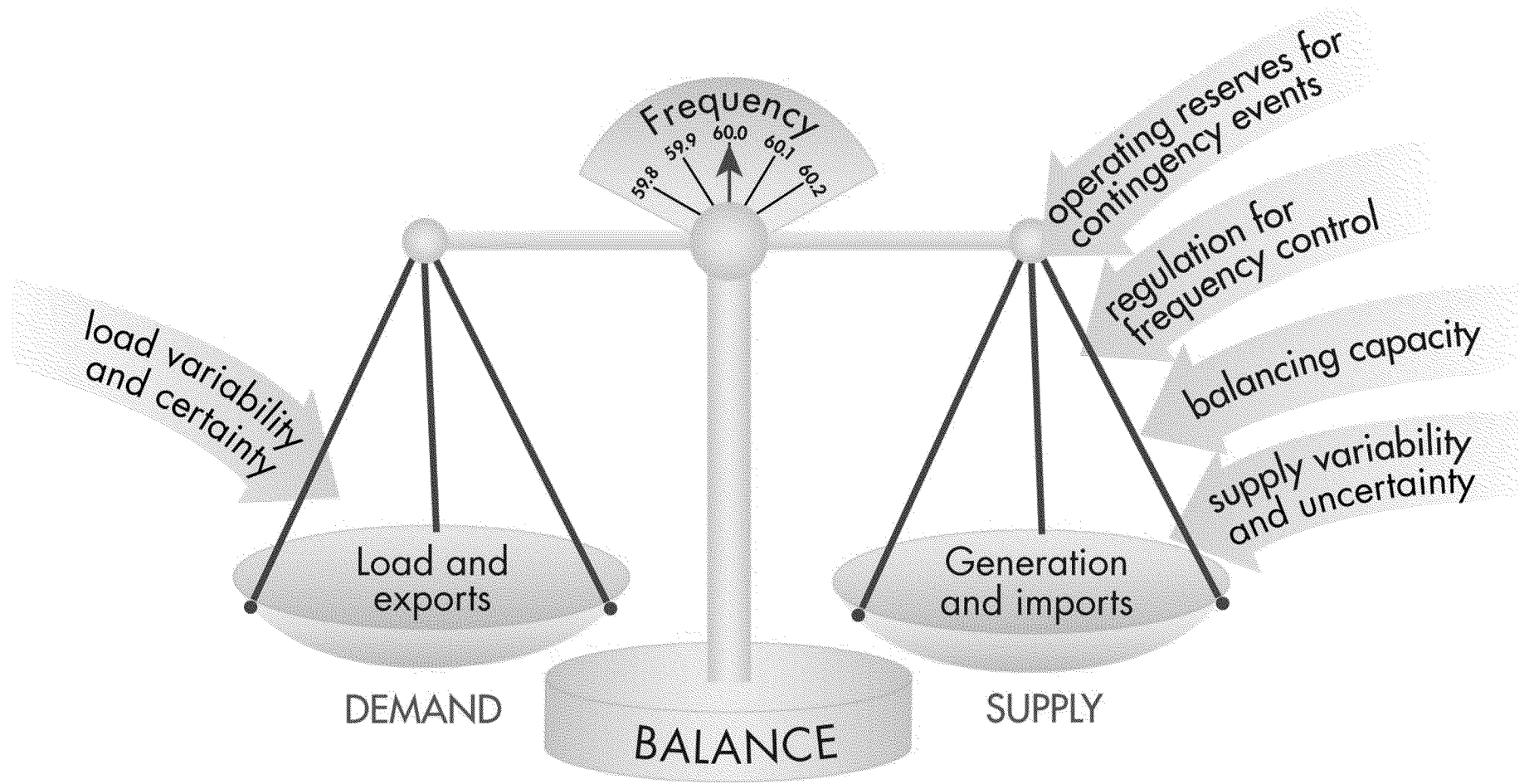
Supply variability and uncertainty will increase while the flexible capability of the fleet is decreases

Capacity changes

Legend:
- Solar capacity (variable resources)
- Wind capacity (variable resources)
- OTC retired capacity (flexible resources)

Net qualifying capacity change

Legend:
- Solar NQC (MW) (variable resources)
- Wind NQC (MW) (variable resources)
- OTC retired NQC (MW) (flexible resources)

Energy changes

Legend:
- Solar (Gwh) (variable resources)
- Wind (Gwh) (variable resources)
- OTC retired (Gwh) (flexible resources)

- Operational requirements for flexible capacity will approximately double due to increase of variable resources

- Approximately 15% of the fleet's flexible capability will retire by 2020

California ISO
Shaping a Renewed Future

Renewable integration study process quantifies operational requirements and evaluates fleets ability to meet operating requirements.

Develop Profiles

Statistical Analysis/ model

Production Simulation

Renewable Portfolios

Variable Resource

Wind / Solar and Load

Profiles

Flexibility Requirements

(Regulation, Balancing)

Shortages

Infrastructure Needs

Costs, Emissions Import/Export Capacity Factor

California ISO
Shaping a Renewed Future
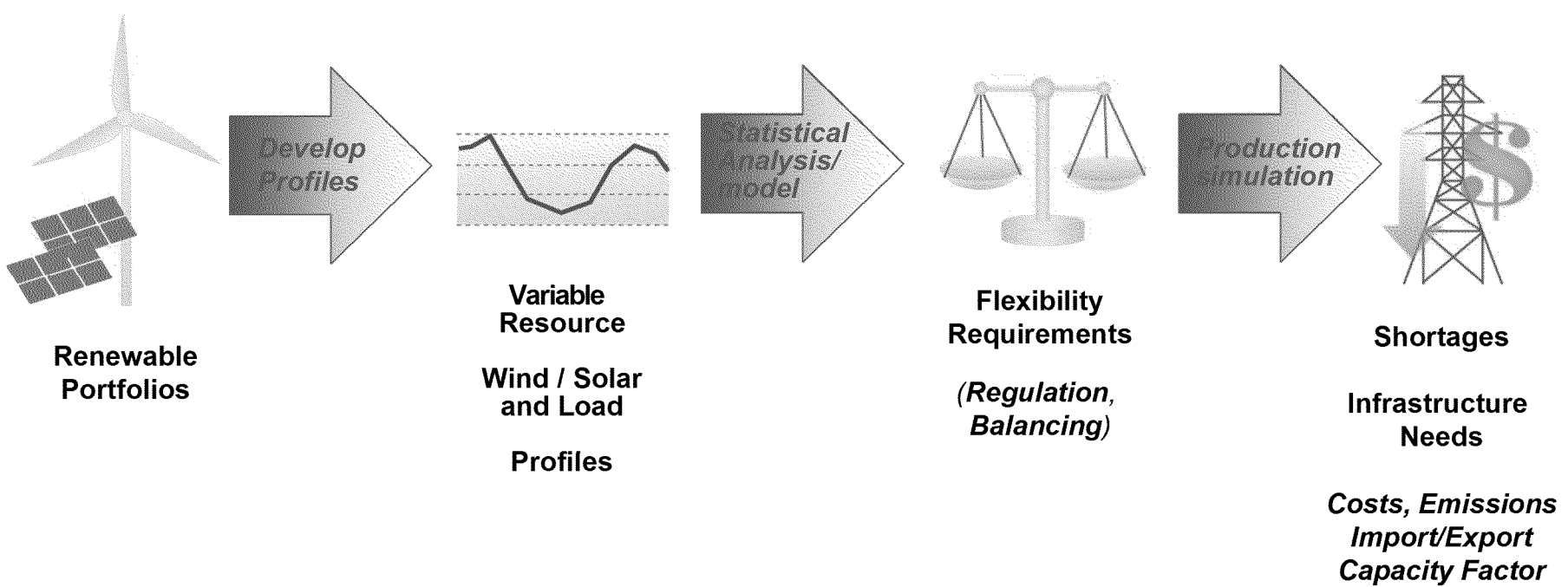
# 33% scenarios in 2020 cover range renewable and load conditions.

| Case	Case Title	Description
1	33% Trajectory	Based on contracted activity
2	Environmental Constrained	High distributed solar
3	Cost Constrained	Low cost (wind, out of state)
4	Time Constrained	Fast development (out-of-state)
5	20% Trajectory	For comparison
6	33% Trajectory High Load	Higher load growth and/or energy program under-performance
7	33% Trajectory Low Load	Lower load growth and/or energy program over-performance

Potential need for 4,600MW of upward flexible resources observed in the high-load scenario.

Upward balancing flexibility shortage/needs

- Local capacity needs
- Residual generic capacity needed
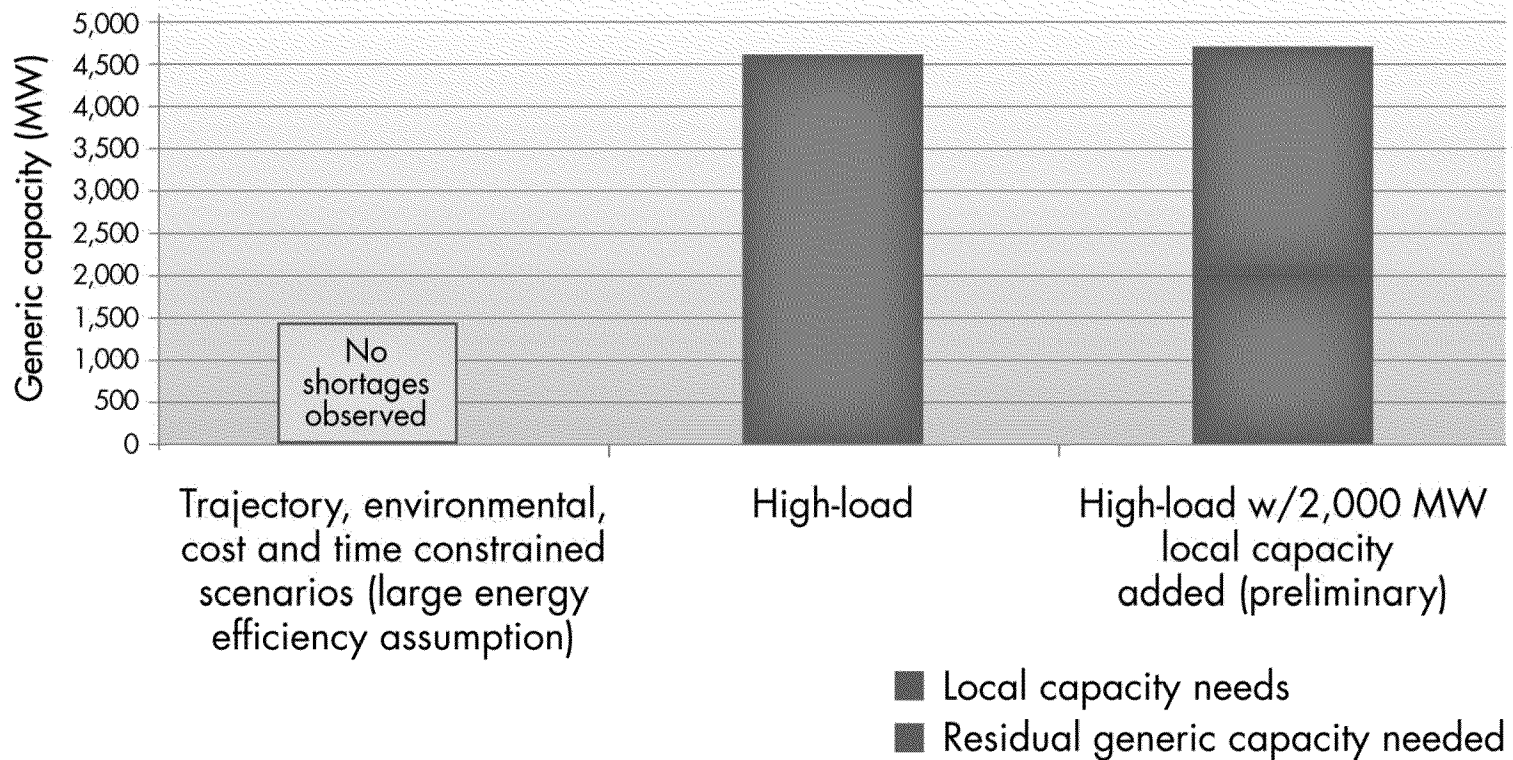
Out of approximately 3,500 MW downward balancing requirements, observed some hours of potential shortages.

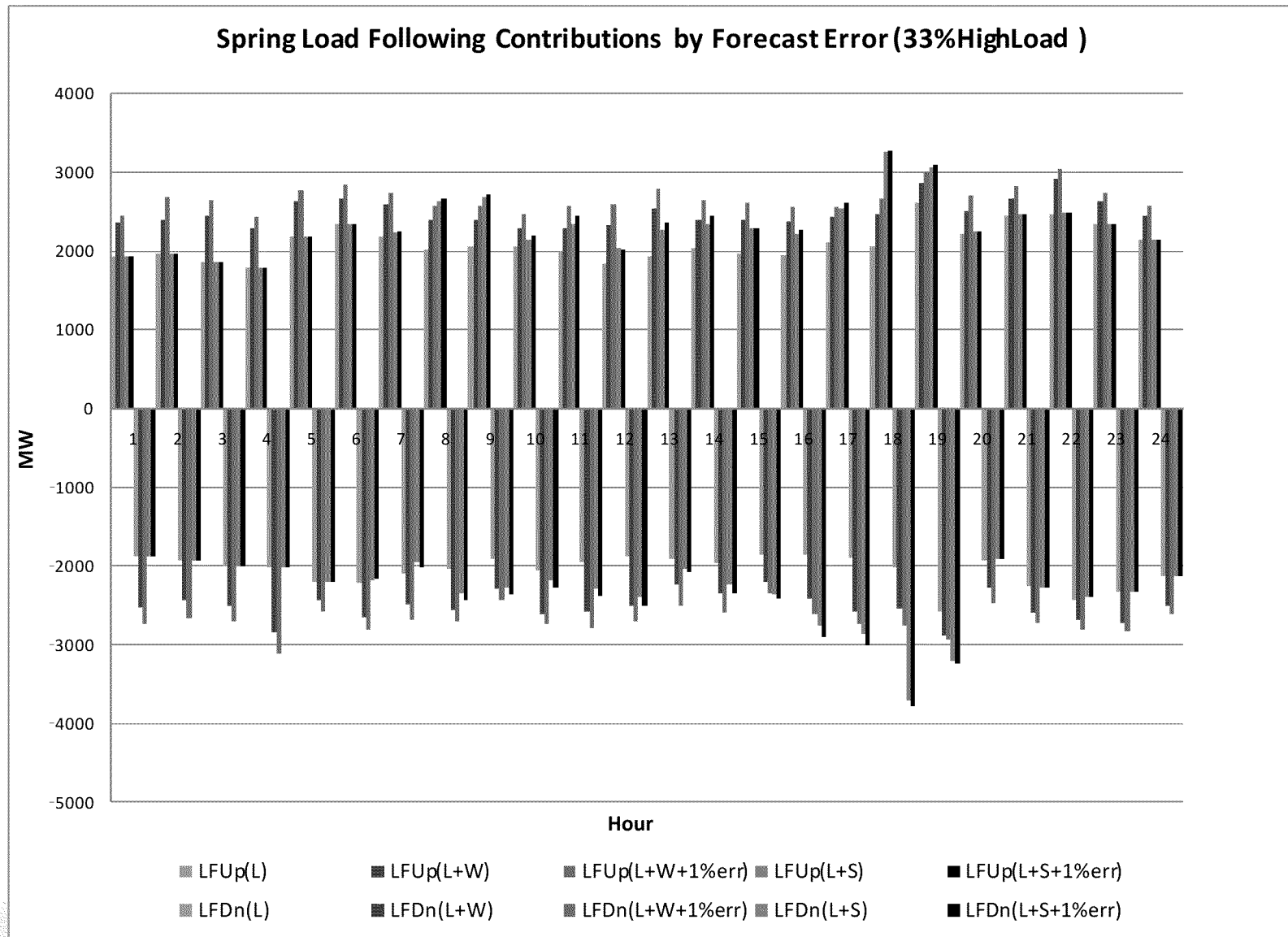**Downward balancing shortage**
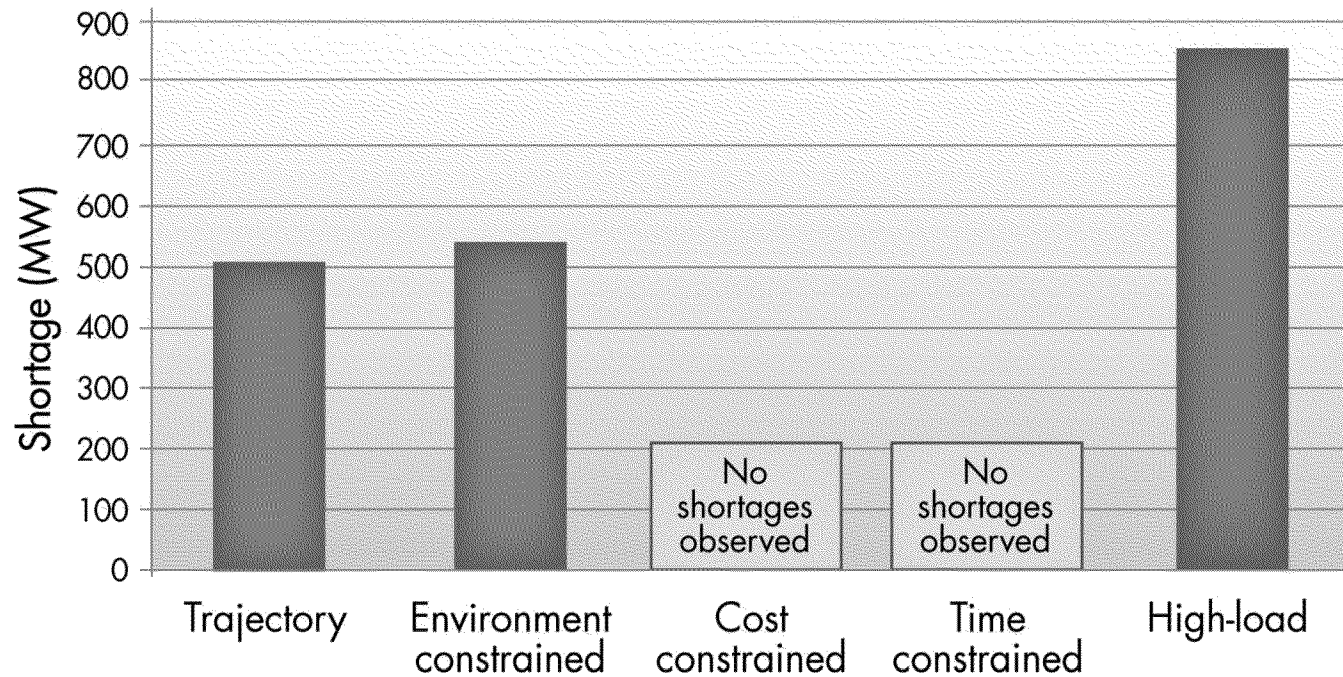
Note: Downward balancing may be more effectively and efficiently managed using curtailment or storage rather than less economic dispatch of flexible resources to higher level to maintain downward flexibility
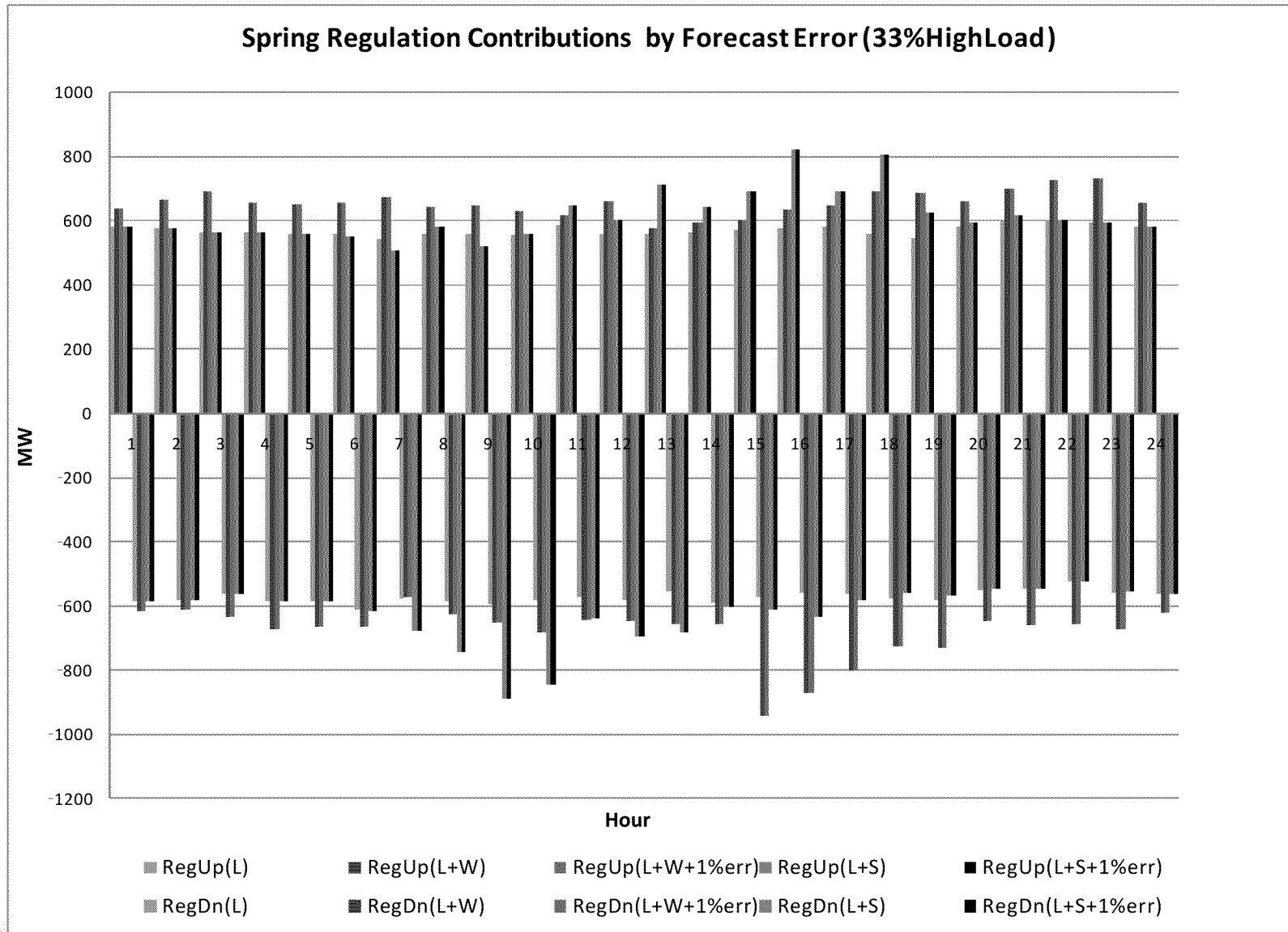
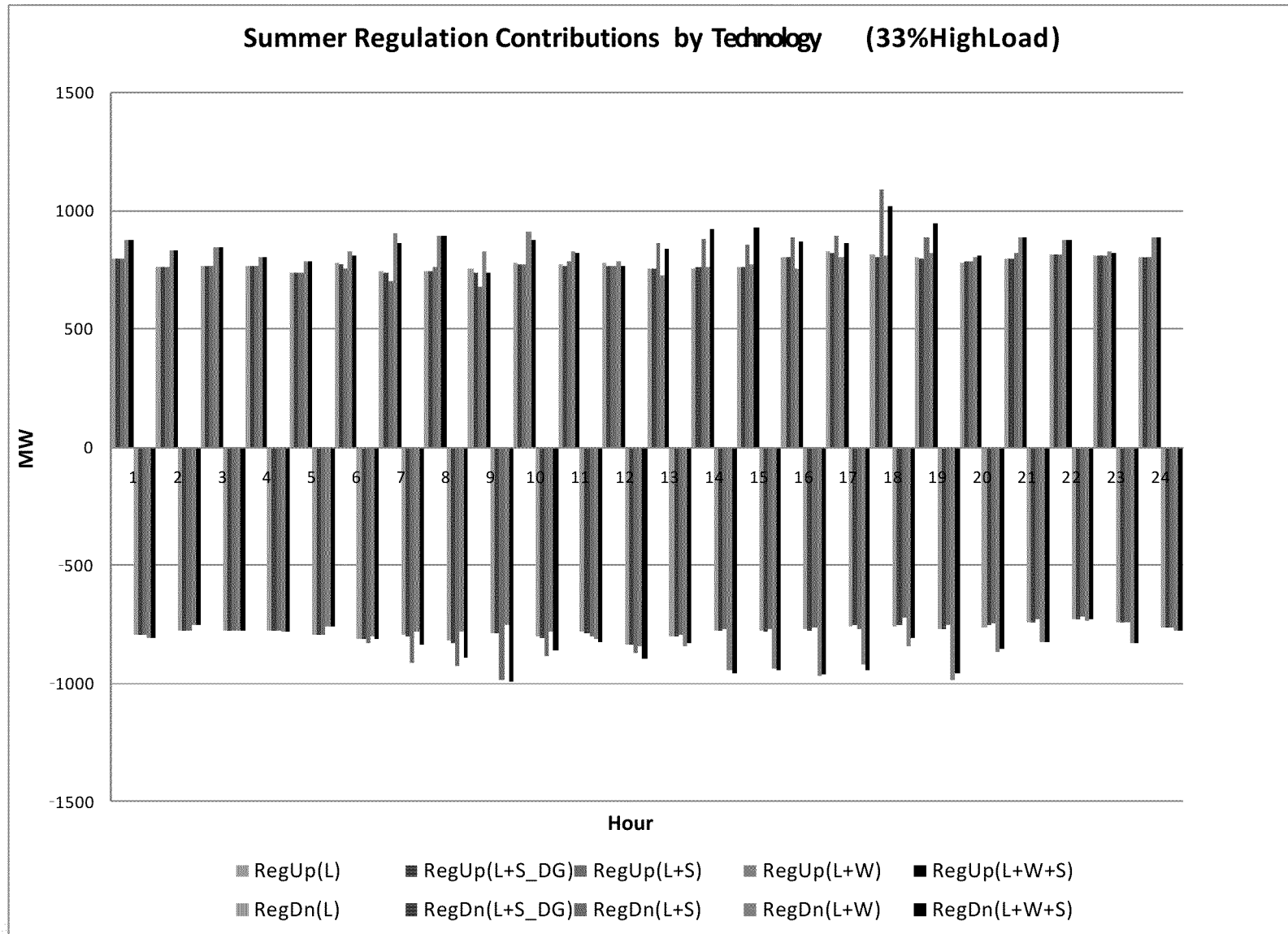# ADDITIONAL ANALYSIS OF RESULTS

Mark Rothleder

California ISO
Shaping a Renewed Future

Slide 12

Spring Load Following Contributions by Forecast Error (33%HighLoad)

Legend:
- LFUp(L)
- LFUp(L+W)
- LFUp(L+W+1%err)
- LFUp(L+S)
- LFUp(L+S+1%err)
- LFDn(L)
- LFDn(L+W)
- LFDn(L+W+1%err)
- LFDn(L+S)
- LFDn(L+S+1%err)

California ISO
Shaping a Renewed Future

Slide 13

Spring Regulation Contributions by Forecast Error (33% High Load)

Summer Regulation Contributions by Technology   (33%HighLoad)

Summer Load Following Contributions by Technology (33%HighLoad)

Spring Regulation Contributions by Technology (33%HighLoad)

California ISO
Shaping a Renewed Future

Slide 17

SB_GT&S_0234605

Spring Load Following Contributions by Technology (33% HighLoad)
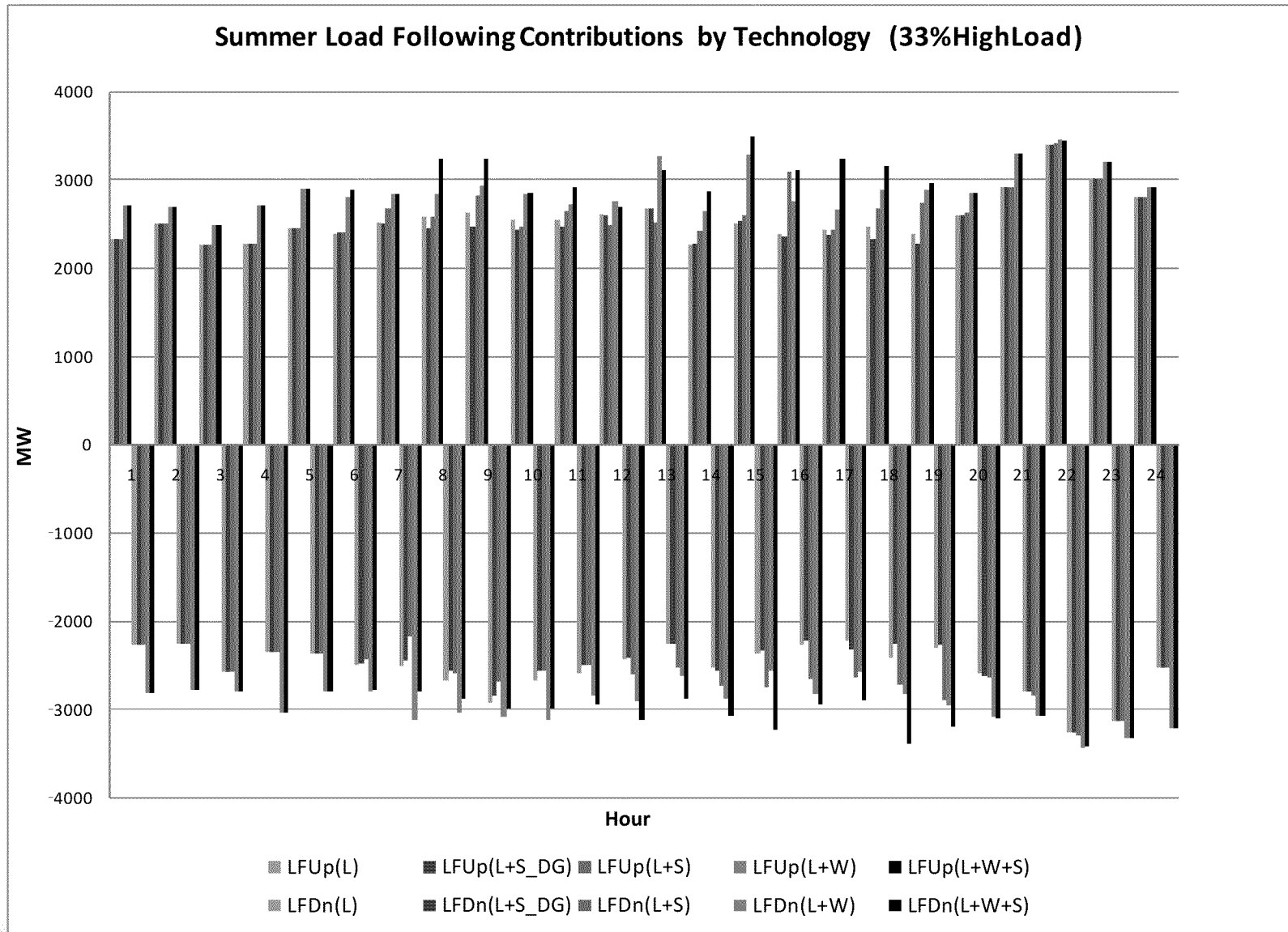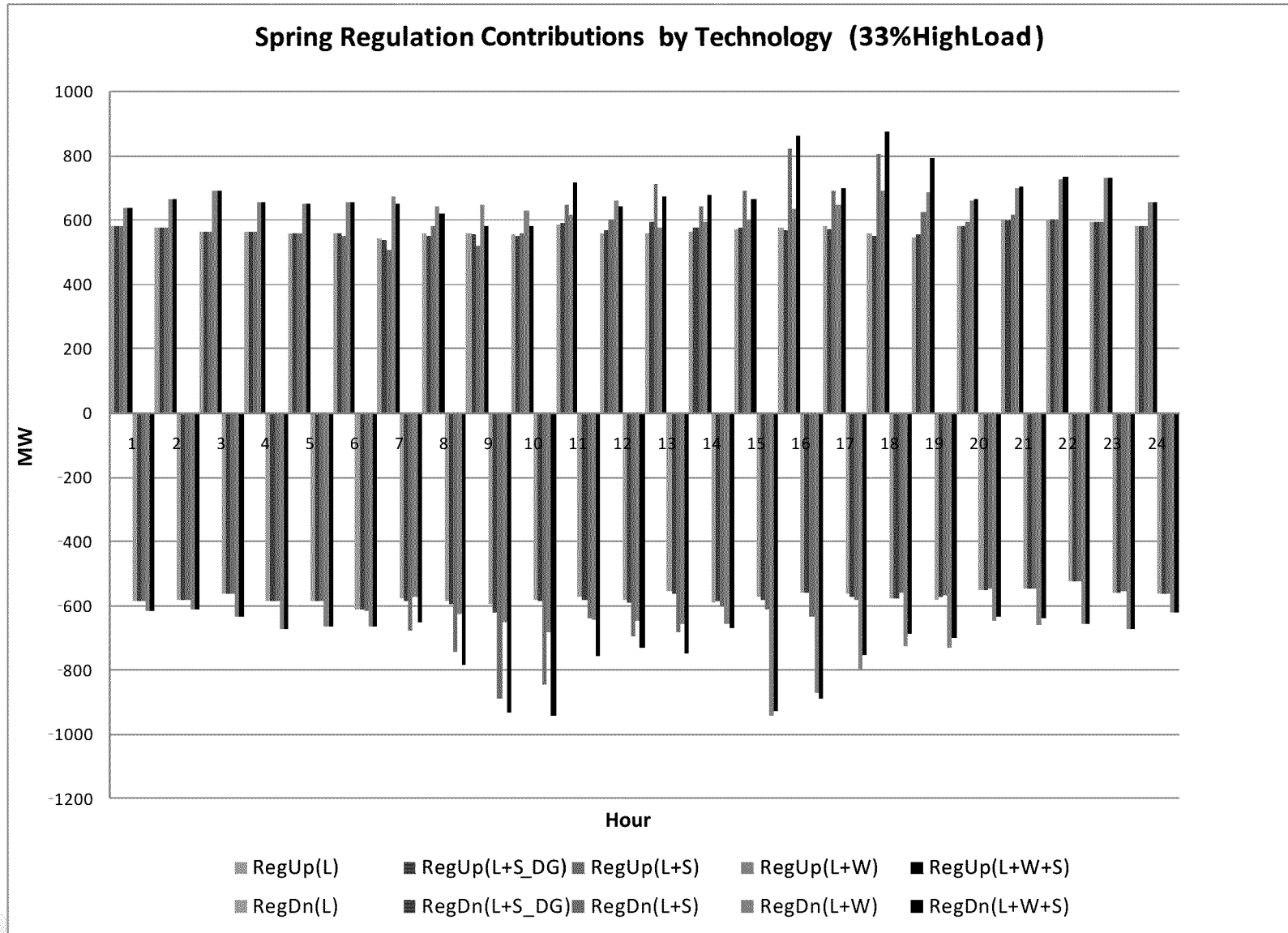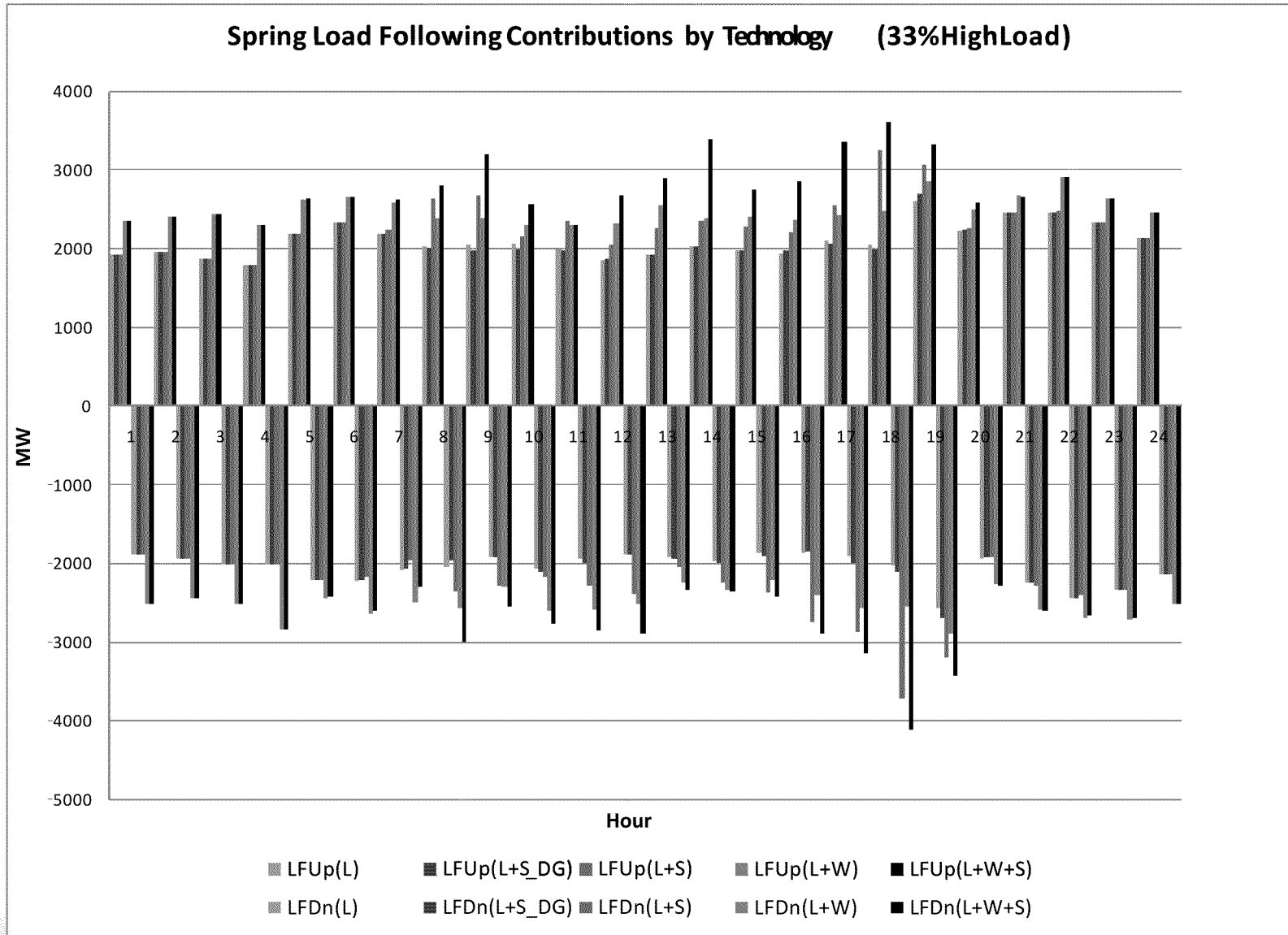
Actual Real-Time Upward Energy Dispatch:
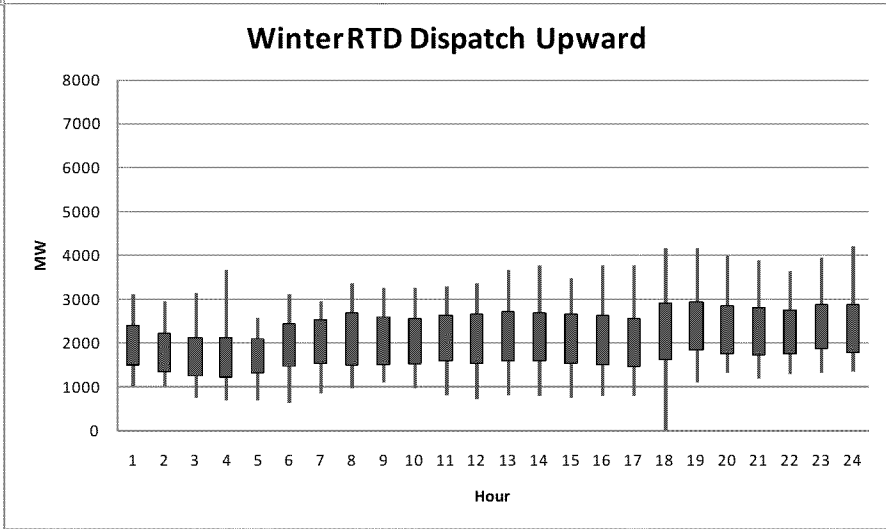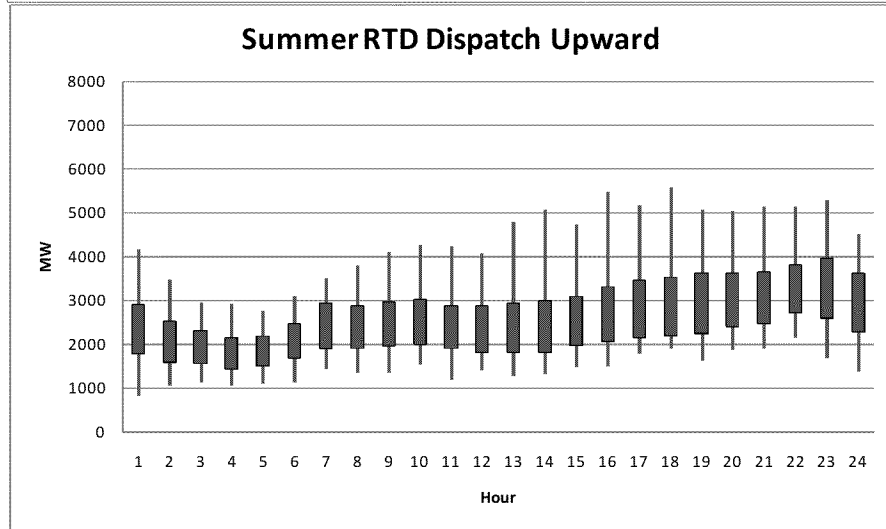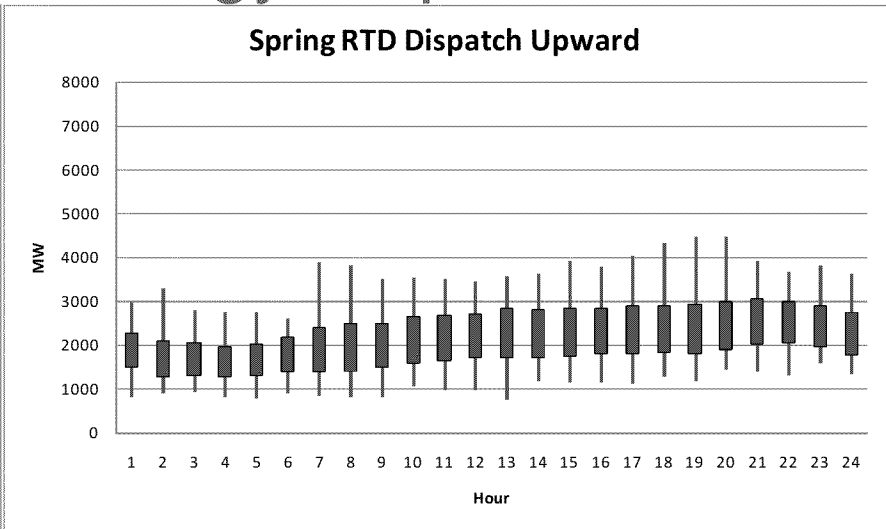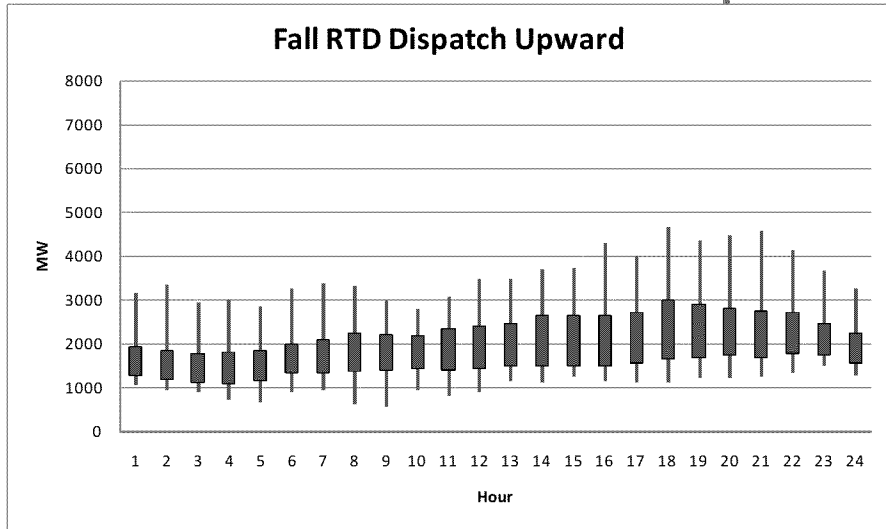
Actual Real-Time Downward Energy Dispatch:
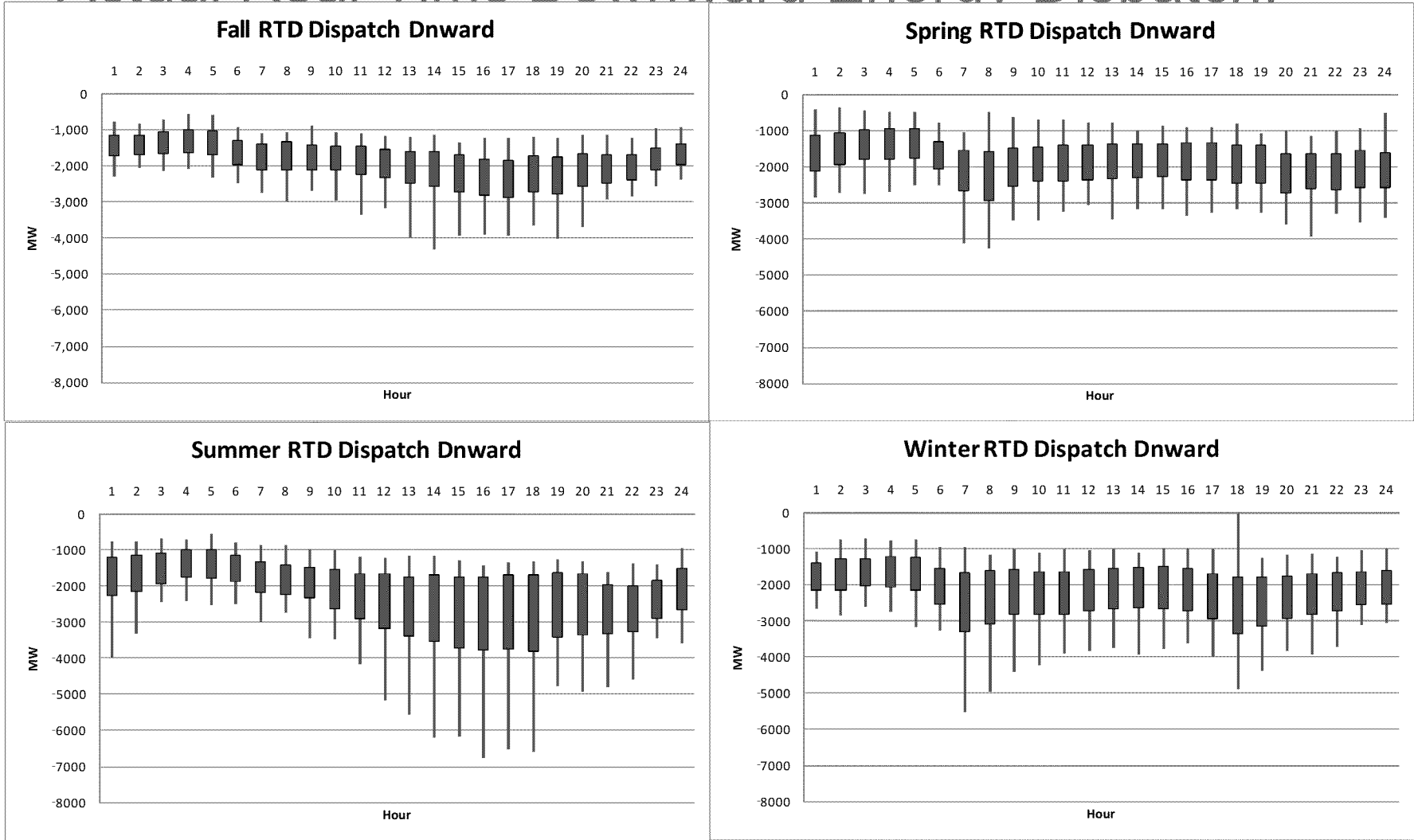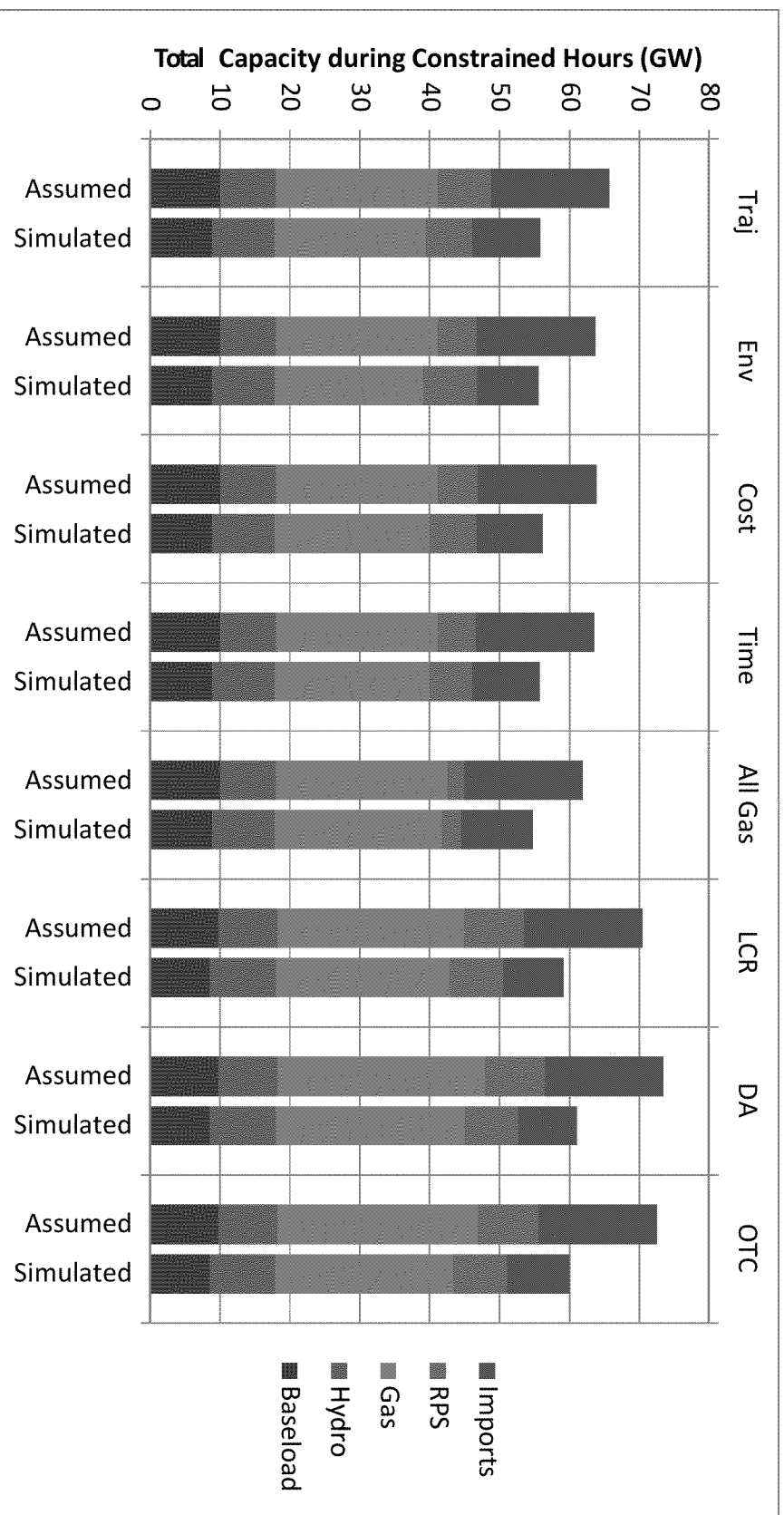
Fall RTD Dispatch Dnward

Spring RTD Dispatch Dnward

Summer RTD Dispatch Dnward

Winter RTD Dispatch Dnward

California ISO
Shaping a Renewed Future

Total Capacity during Constrained Hours (GW)

Assumed: deemed (or assumed) NQC value of resource

Simulated: average resource performance during 50 constrained hours of PLEXOS simulation

California ISO
Shaping a Renewed Future

21

Total Capacity during Constrained Hours (MW)

Assumed: deemed (or assumed) NQC value of resource

Simulated: average resource performance during 50 constrained hours of PLEXOS simulation

California ISO
Shaping a Renewable Future

High solar cases cause constraint to occur during hours with less load

Gas resources provide more energy in All-Gas Case

Legend:
- Reserves
- RU
- LFU
- Flex Maint
- Baseload Maint
- Imports
- Flex Gen
- RPS Gen
- Baseload Gen

Values:
- Traj: 55,511
- Env: 54,197
- Cost: 56,546
- Time: 56,065
- All Gas: 55,423

Y-axis: MW (70,000 / 60,000 / 50,000 / 40,000 / 30,000 / 20,000 / 10,000 / -)

California ISO
Shaping a Renewed Future

23

ISO Load/Resource Balance --- July 22, 2020

Legend:
- Awarded LF_Up
- Awarded A/S
- Demand Response
- Wind
- Solar
- GT
- Imports
- Hydro
- Biomass/Biogas
- Pump Storage
- CHP
- CCGT
- Nuclear
- Load + A/S Req.
- Load+A/S+LF_Up Req.

California ISO
Shaping a Renewed Future
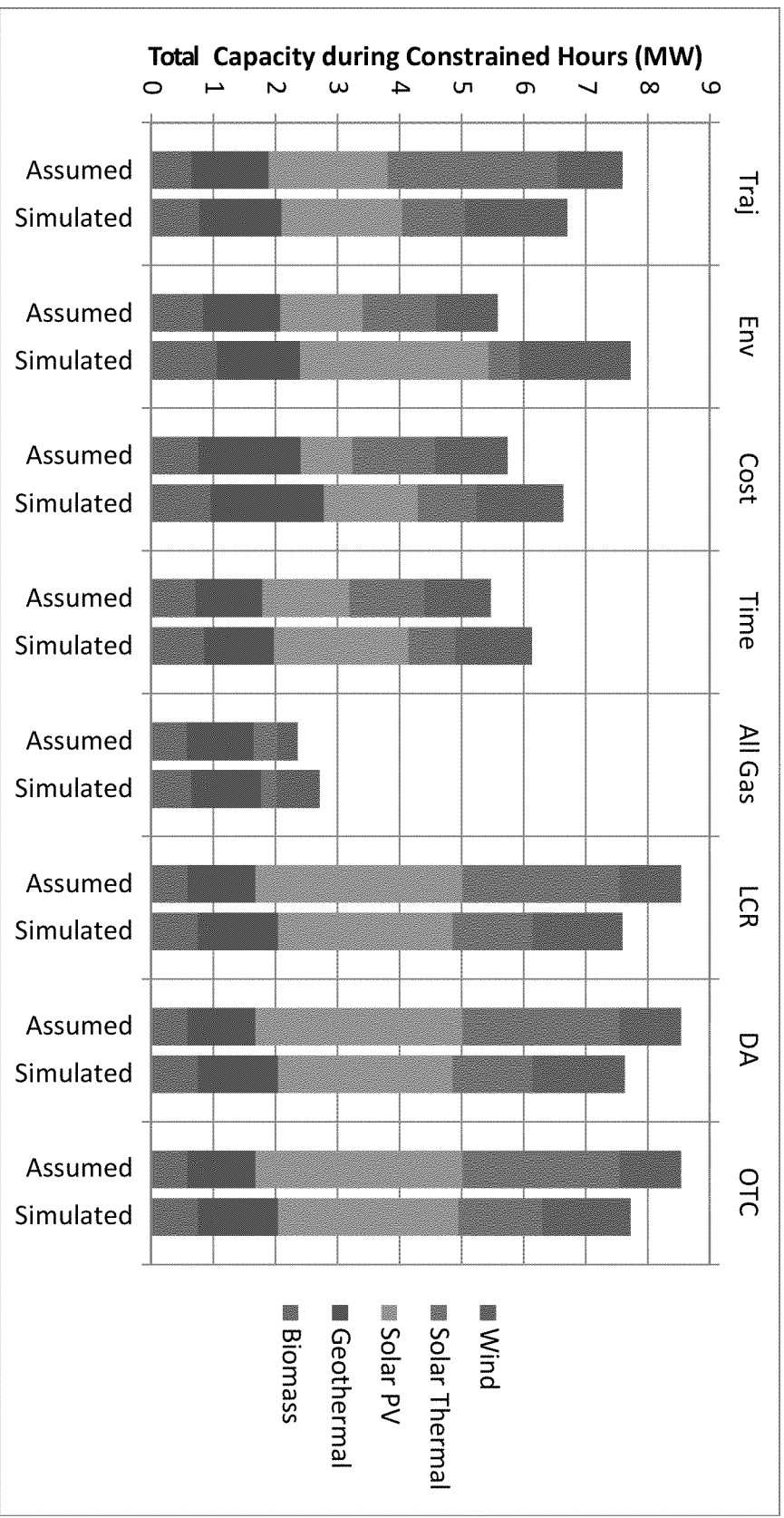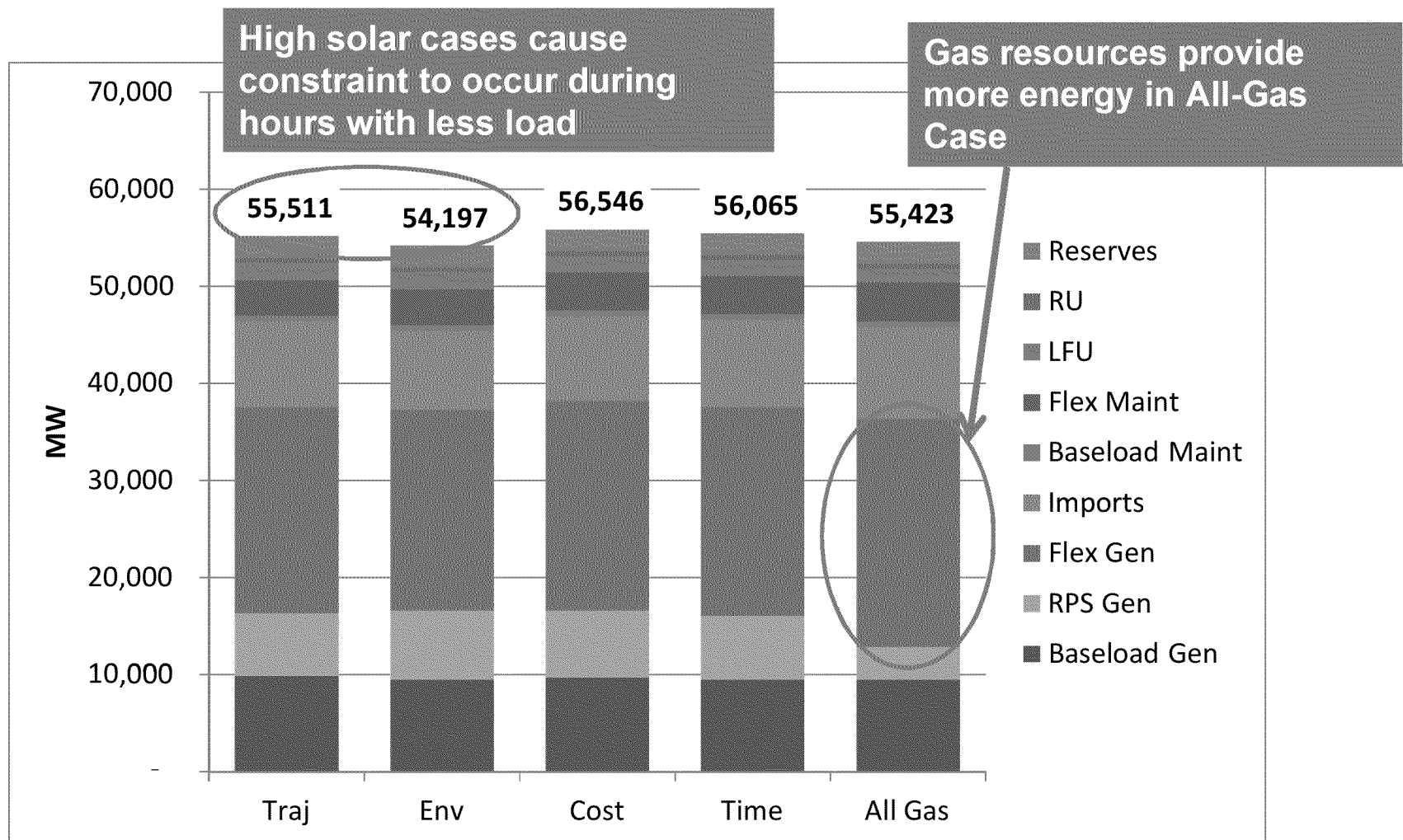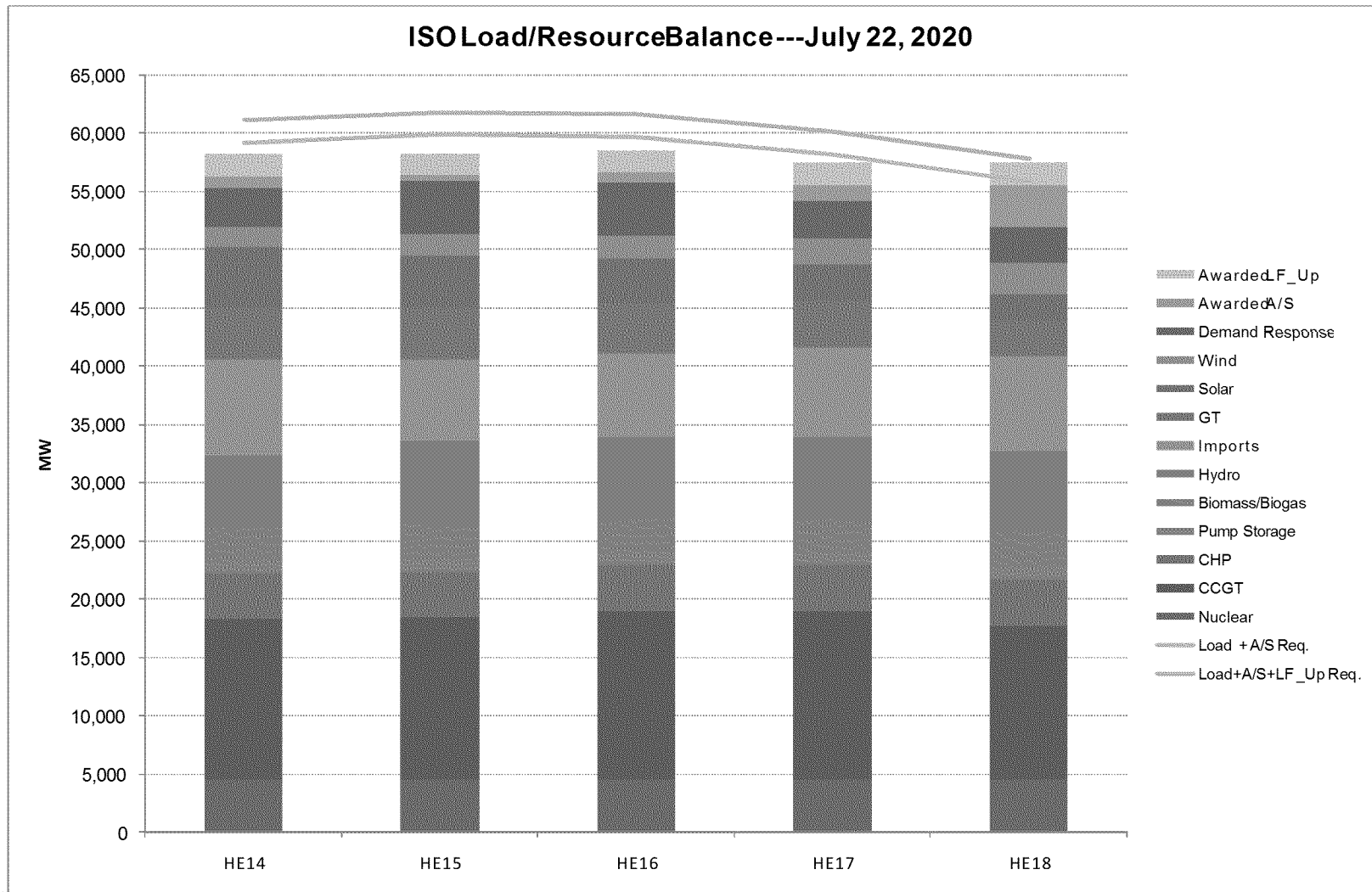
Hydro patterns – 2006 High-Hydro Year

CAISO Average Hydro Production - 2006

Legend: 0-2,000 | 2,000-4,000 | 4,000-6,000 | 6,000-8,000

California ISO
Shaping a Renewed Future

25

CAISO Average Hydro Production – 2007

26
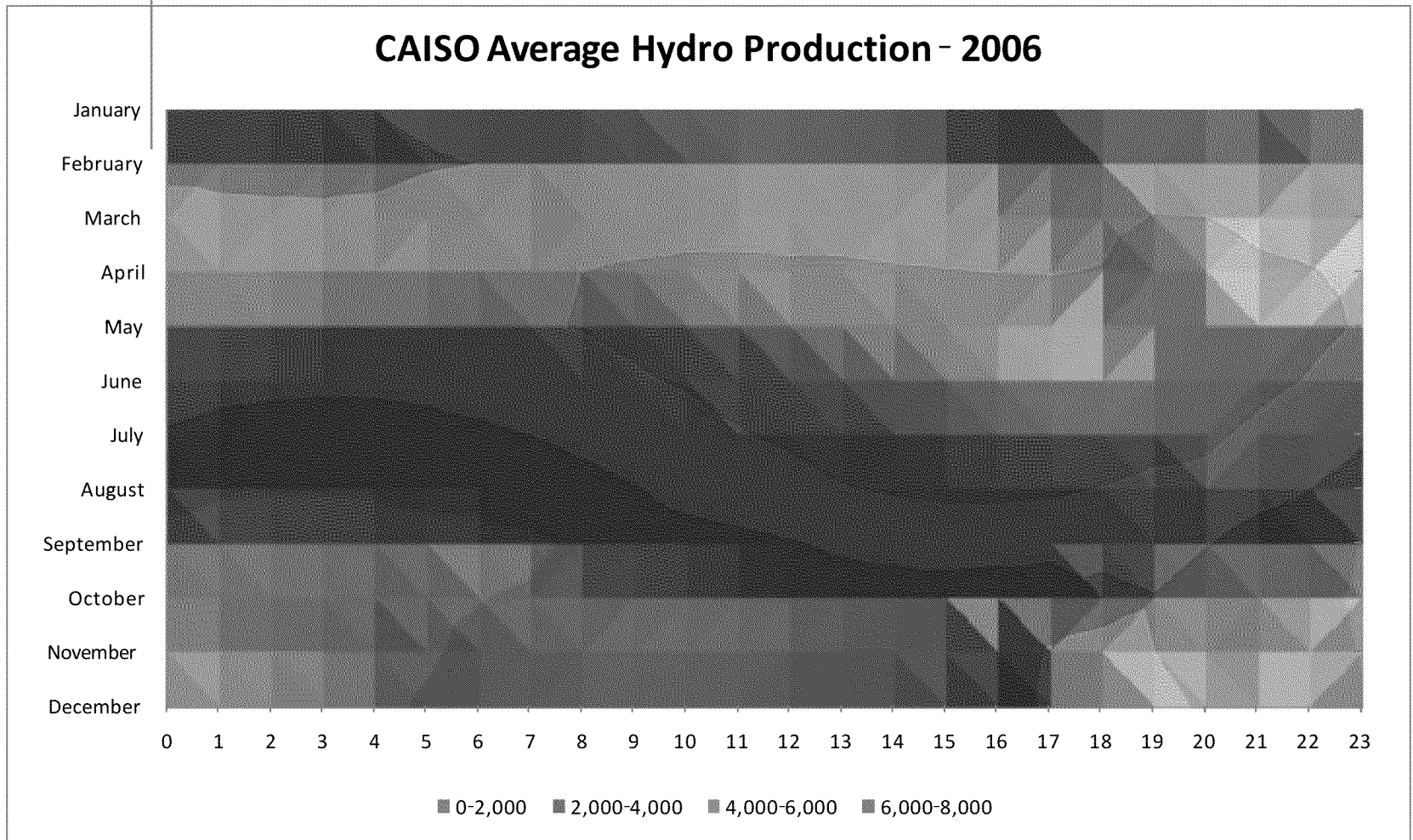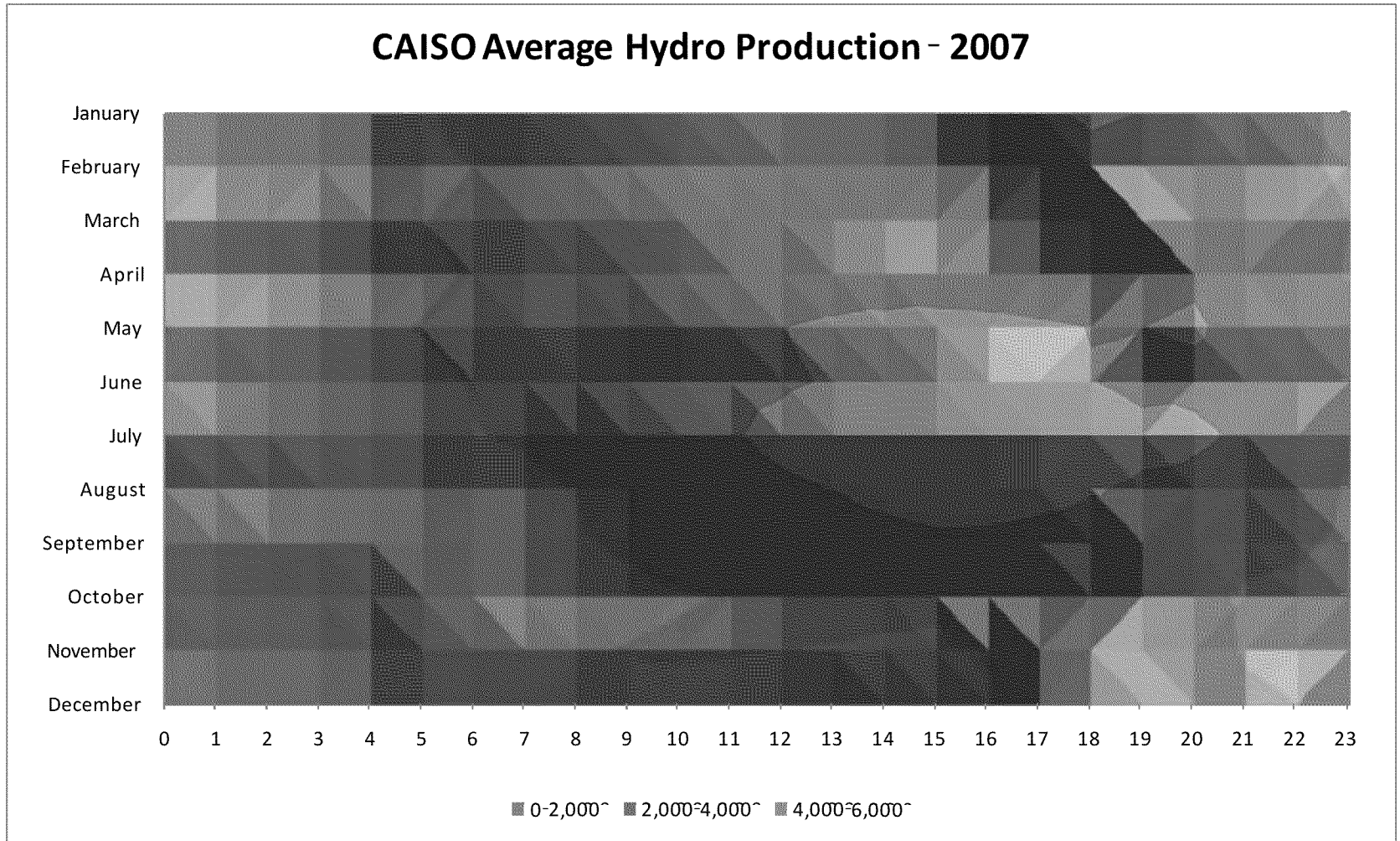
Summary of previous requested work

- Incorporate results of LCR/OTC study work expected to complete in December 2011

- Identify timing and needs in intervening year analysis

- Consider resources that been approved since the scenarios were developed

- Perform probabilistic analysis to study risk and range of operational needs
    - Loss of Load Probability (LOLP)

- Perform additional analysis of planning reserve margin
    - Consider the "All Gas" case

California ISO
Shaping a Renewed Future

Summary of previous requested work

- Perform operational requirements (regulation / load following) sensitivities
    - Assess impacts of different forecast errors
    - Decompose impacts of load, solar (technologies) and wind on requirements
    - Affects of controlled intertie ramp and quantity of import assumptions
    - Analyzes results to identify ramping speed and duration
    - Consider impact of market structure and timelines on forecast errors and requirements

- Perform production simulation sensitivities
    - Different load assumptions
    - Different maintenance profiles
    - Helms analysis that considers transmission constraints
    - Perform 5-minute simulation to validate load following shortages ~ energy shortage
    - Consider impact of market structure and timelines
    - Study different hydro patterns

- Perform phase 2 work that consider alternatives to meeting flexibility needs
    - Increase ramping flexibility of existing fleet sensitivity
    - Storage alternatives (may be able to leverage EPRI study work)
    - More flexible renewable technologies (may be able to leverage NREL study work))
    - Demand Response

California ISO
Shaping a Renewed Future

FRAMEWORK FOR PROBABILISTIC ANALYSIS

Shucheng Liu

California ISO
Shaping a Renewed Future

Slide 29

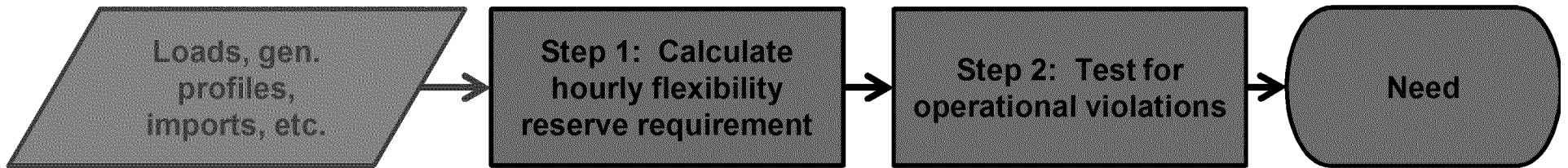# A stochastic model is developed to assess the probability of upward ramping capacity shortage.

- A deterministic production simulation case adopts only one of the many possible combinations of input assumptions

- A stochastic model' can evaluate various input combinations and determine the probability of ramping capacity shortage

- The stochastic model complements the deterministic production simulation

E3 Proposed Approach

Current Methodology

Loads, gen. profiles, imports, etc. → **Step 1: Calculate hourly flexibility reserve requirement** → **Step 2: Test for operational violations** → **Need**

Potential Incorporation of Probabilistic Analysis

Loads, gen. profiles, imports, etc. → **Step 1: Calculate hourly flexibility reserve requirement** → **Step 2: Test for flexibility within base portfolio** → **Need**

Step 1.5: Perform probabilistic analysis based on range of conditions

California ISO
Shaping a Renewed Future

31
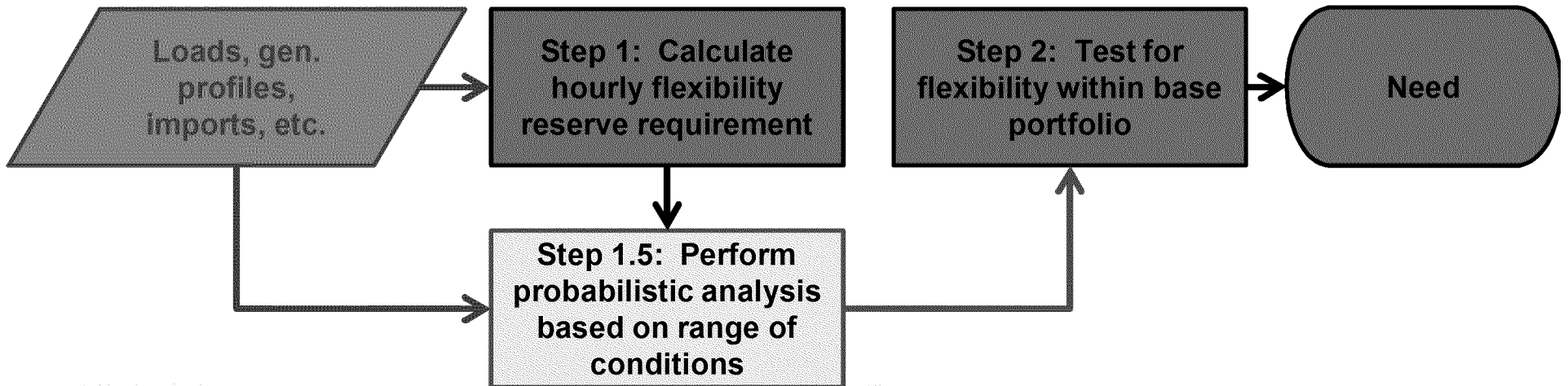
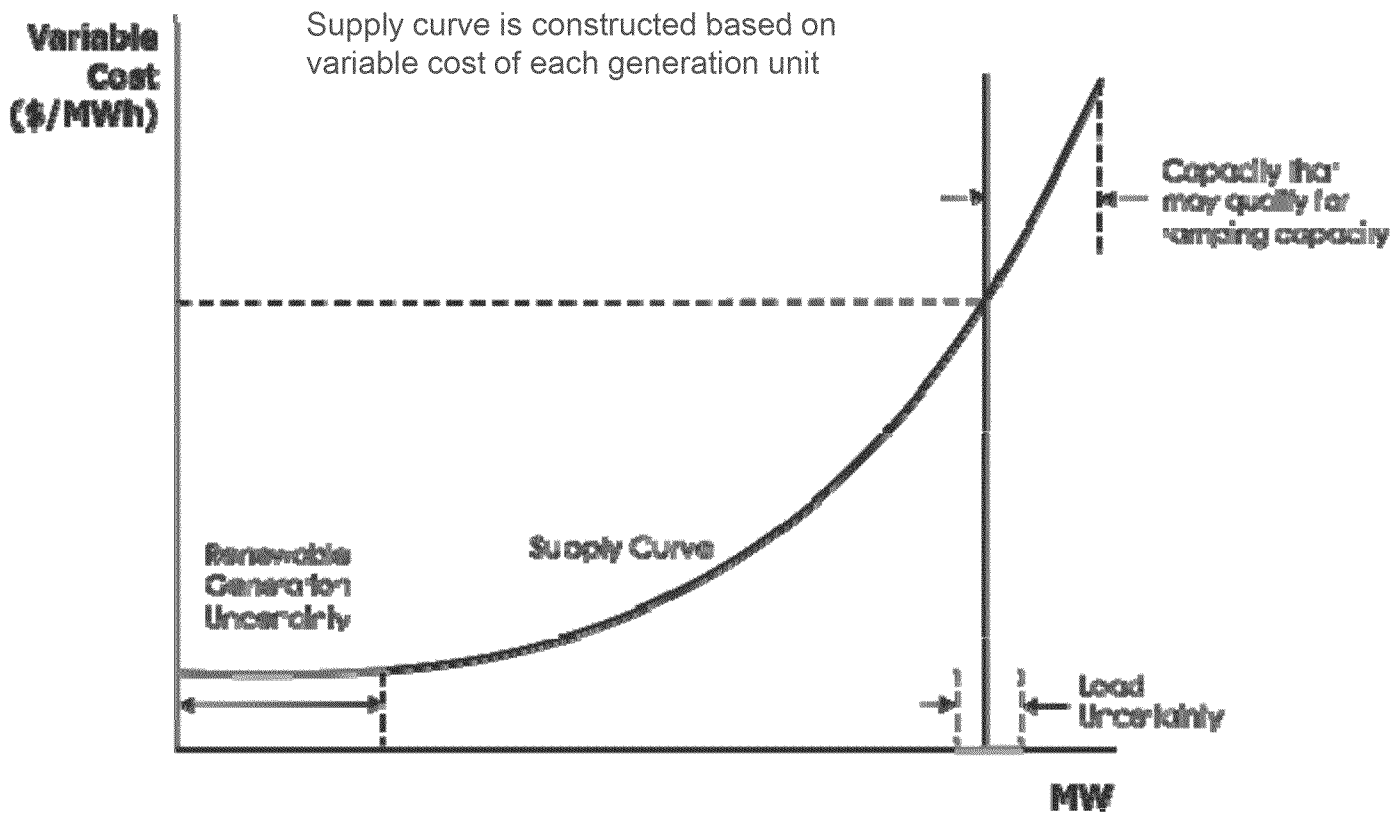# The stochastic model considers uncertainties in some of the key model inputs, including:

- California load forecast
- Requirements for regulation-up service and load following-up
- Generation by wind, solar, and hydro resources
- California import capability
- Availability of each generation unit

It is not a chronologic unit commitment simulation model.

- No unit commitment decision
- No chronologic constraint (such as min run time and min down time, etc.)
- Sequential capacity usage as initial design
  - Dispatching capacity economically to meet load first
  - Qualifying remaining capacity for ramping capacity to meet upward ancillary service and load following requirements
- Co-optimization between energy and ramping capacity implemented

Available ramping capacity depends on the balance of supply and load.

Supply curve is constructed based on variable cost of each generation unit

Variable Cost ($/MWh)

Capacity that may qualify for ramping capacity

Renewable Generation Uncertainty

Supply Curve

Load Uncertainty

MW

California ISO
Shaping a Renewed Future

Variation in load due to uncertainty affects availability of ramping capacity.
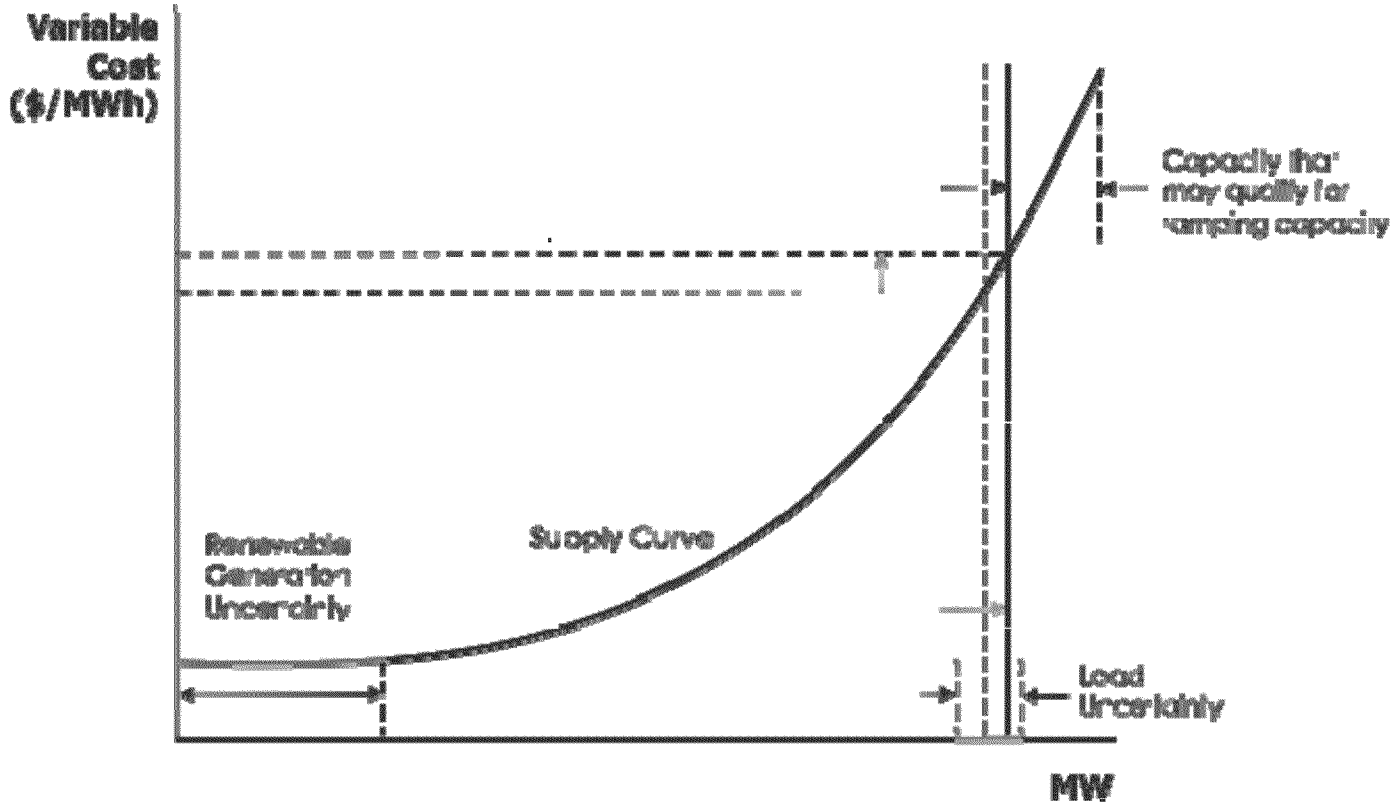
Variation in supply due to uncertainty in renewable generation also affects availability of ramping capacity.
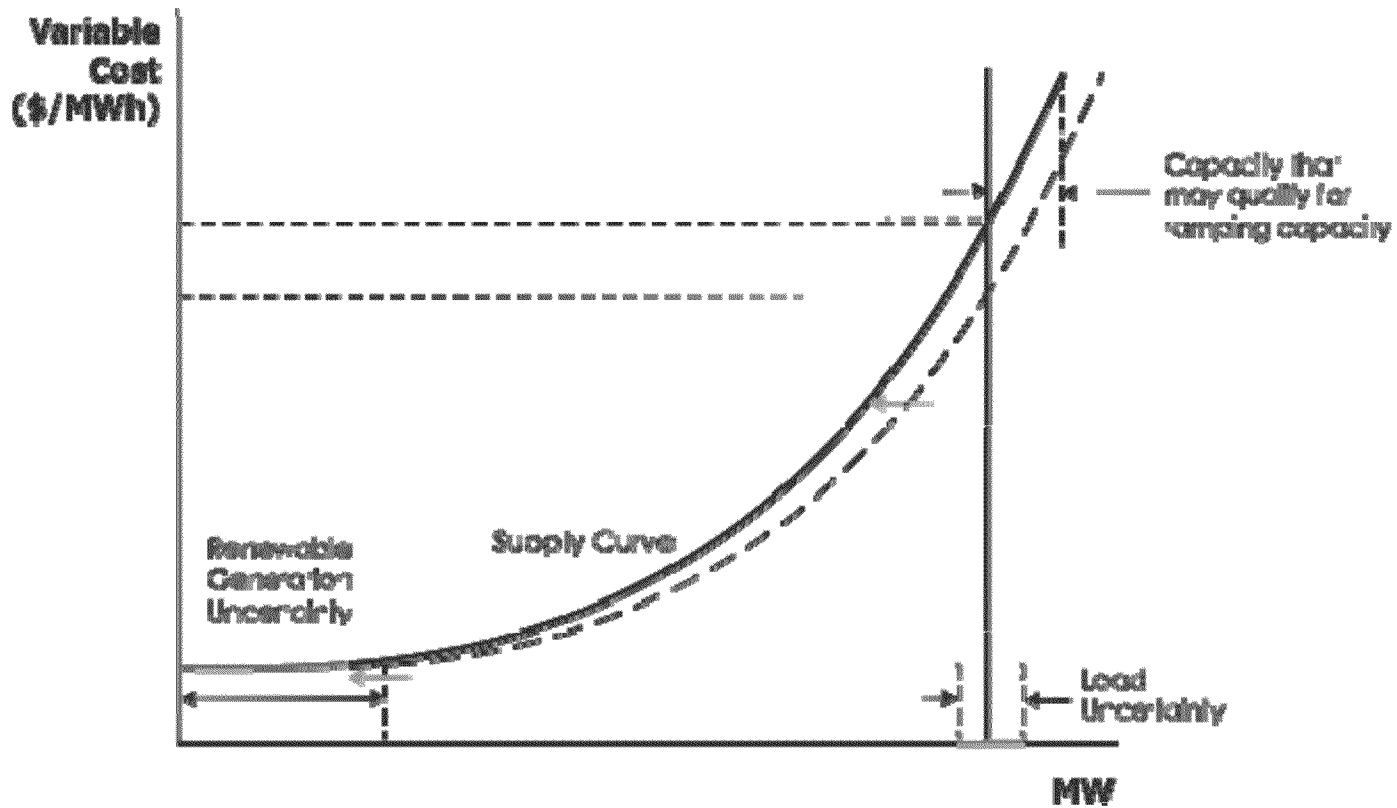
Variations in both load and supply may occur at the same time.
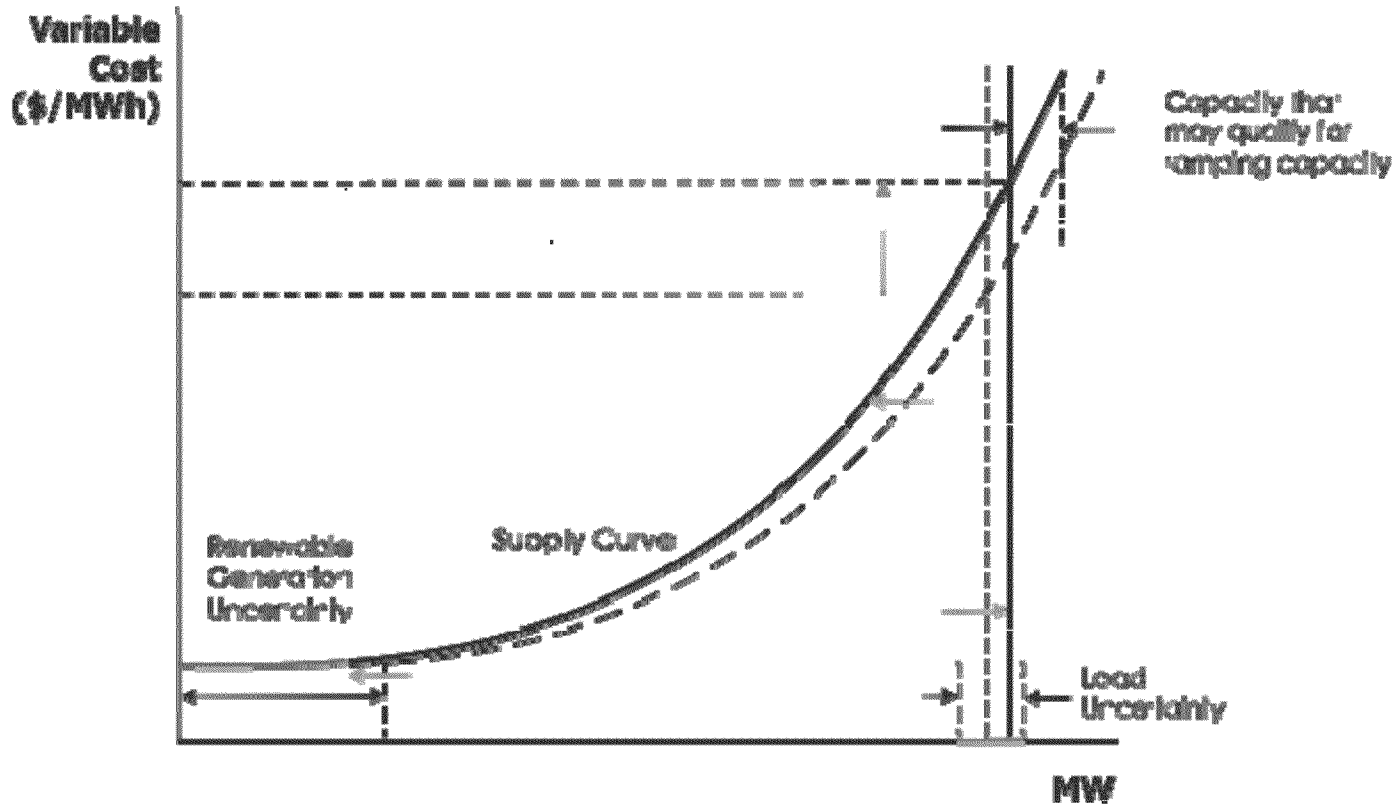
Available ramping capacity of each generation unit is qualified based on the following factors:

- Maximum and minimum capacity
- Dispatch level
- Ramp rate
- Ramp time (10 or 20 minutes)
- Commitment status (for demand response resources that can provide off-line non-spinning only)
- Unit availability (due to forced and maintenance outages)

Available ramping capacity is used to meet ancillary service and load following requirements.
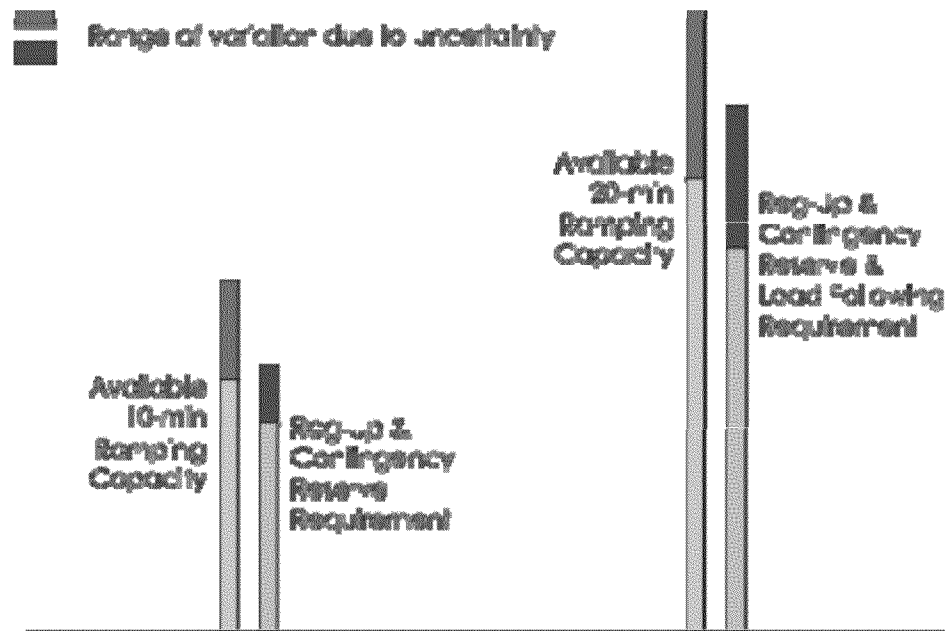
Shortage may occur due to the variations in available ramping capacity and requirement.
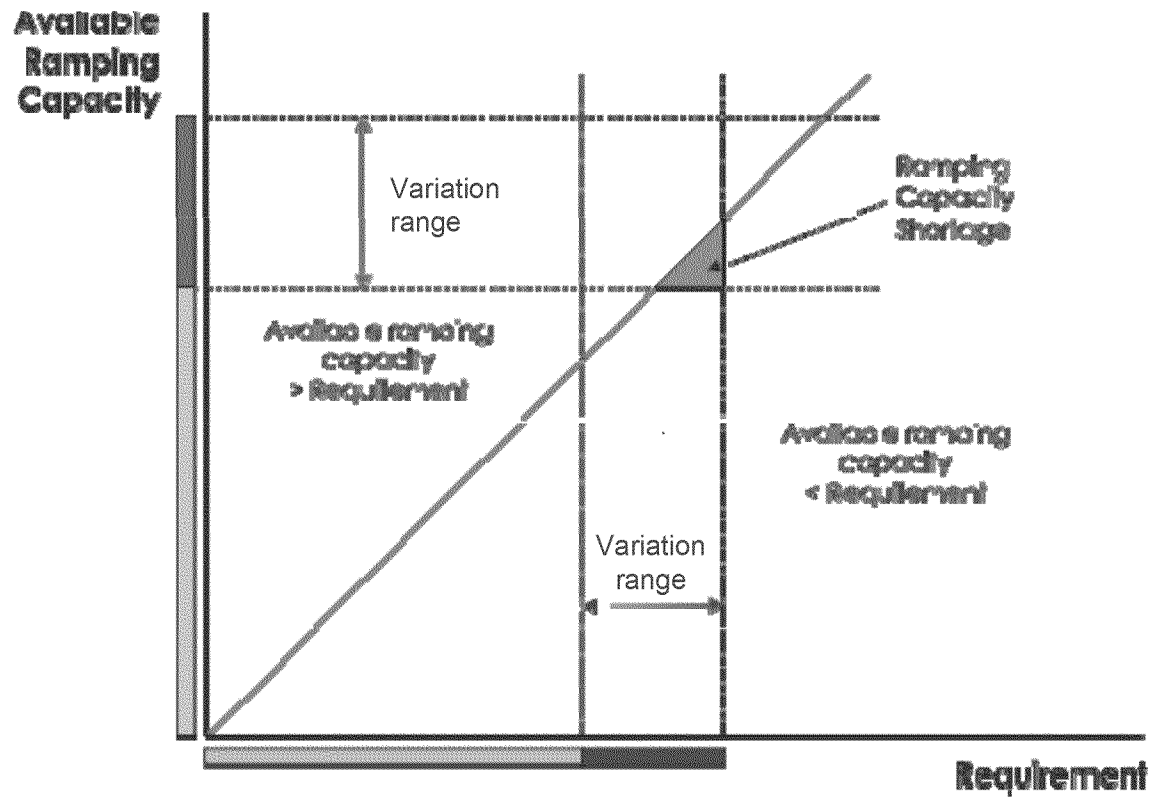
The model is developed based on input and output data of the Plexos production simulation model.

- From input data
  - Hourly California load forecast
  - Hourly regulation and load following-up requirement
  - Hourly wind, solar, and hydro generation
  - California import limit and hourly import and export
  - Generator characteristics (capacity, ramp rate, forced and maintenance outage rates, etc.)

- From output data
  - Variable generation cost of each generation unit ($/MWh)
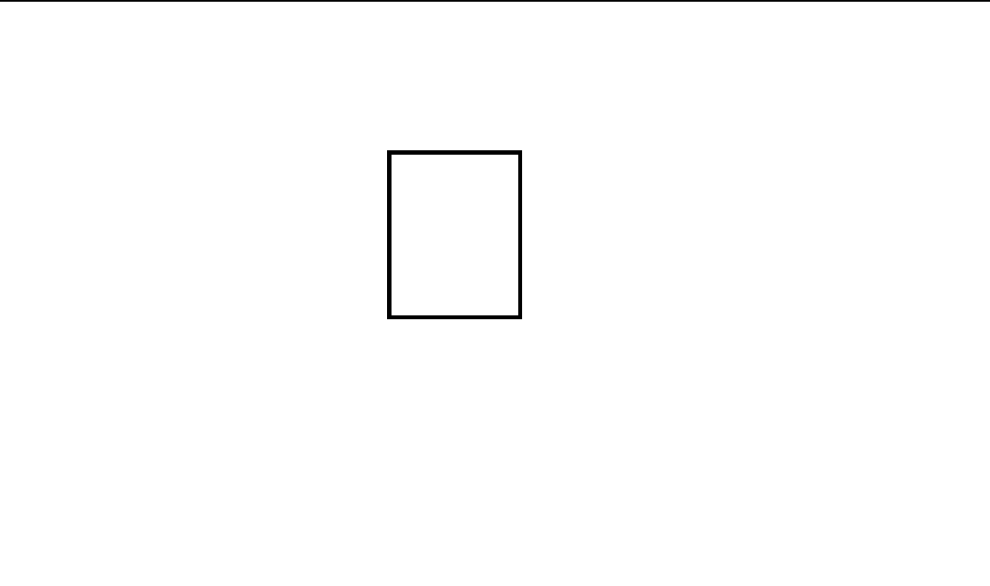
These are examples of the input probability distribution functions fitted based on hourly sample data.

Fit Comparison for Total CA Load
RiskBetaGeneral(1.5122,1.5704,36266,70059)

38935		66257
5.0%	90.0%	5.0%
3.8%	90.8%	5.4%

Input
Minimum	36429.6600
Maximum	69948.4100
Mean	52846.2858
Std Dev	8409.0017
Values	630

BetaGeneral
Minimum	36266.0000
Maximum	70059.0000
Mean	52843.4913
Std Dev	8360.8594

Fit Comparison for Total LFU
RiskGamma(54.190,39.996,RiskShift(98.588))

1801		2767
5.0%	90.0%	5.0%
4.8%	90.0%	5.2%

Input
Minimum	1350.4400
Maximum	3492.3600
Mean	2265.9731
Std Dev	295.3382
Values	630

Gamma
Minimum	98.5880
Maximum	+ ∞
Mean	2265.9712
Std Dev	294.4260

Fit Comparison for Wind Gen
RiskInvGauss(2611.5,10804.9,RiskShift(-489.50))

	5.0%	90.0%	5.0%
	6.0%	89.8%	4.2%

647   4774

Input
Minimum	197.6900
Maximum	6509.0300
Mean	2121.9544
Std Dev	1245.0564
Values	630

InvGauss
Minimum	-489.5000
Maximum	+ ∞
Mean	2122.0000
Std Dev	1283.8807

Fit Comparison for Solar Gen
RiskBetaGeneral(6.3810,1.1541,-2999.5,9688.9)

	5.0%	90.0%	5.0%
	3.6%	88.8%	7.6%

4236   9454

Input
Minimum	2491.6537
Maximum	9688.6904
Mean	7751.9740
Std Dev	1620.0039
Values	630

BetaGeneral
Minimum	-2999.5000
Maximum	9688.9000
Mean	7745.5041
Std Dev	1564.1544

California ISO
Shaping a Renewed Future

Correlations among the stochastic variables are enforced.

	Load	Import	Wind	Solar	Hydro	RegU	LFU
Load							
Import							
Wind							
Solar							
Hydro							
RegU							
LFU							

Generation unit forced and maintenance outages are stochastically determined.
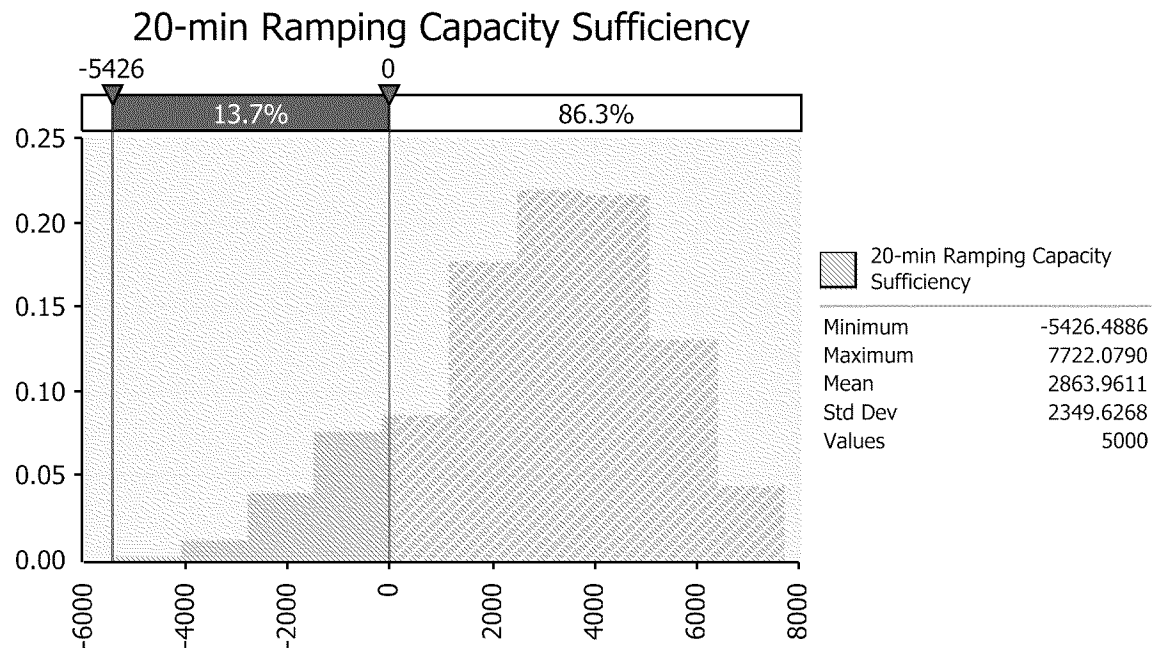
- Forced and maintenance outages are determined independently for each generation unit

- Each of the outages is determined based on the unit's outage rate and a draw using a uniform distribution function

- The unit is unavailable when one or both outages occur

California ISO
Shaping a Renewed Future

Monte Carlo simulation of the model produces probabilistic results.

- Monte Carlo simulation is conducted using this stochastic model

- The simulation results are presented in a probability distribution format

This is an example of the Monte Carlo simulation result - probability distribution of 20-min ramping capacity sufficiency.

20-min Ramping Capacity Sufficiency

20-min Ramping Capacity Sufficiency	
Minimum	-5426.4886
Maximum	7722.0790
Mean	2863.9611
Std Dev	2349.6268
Values	5000

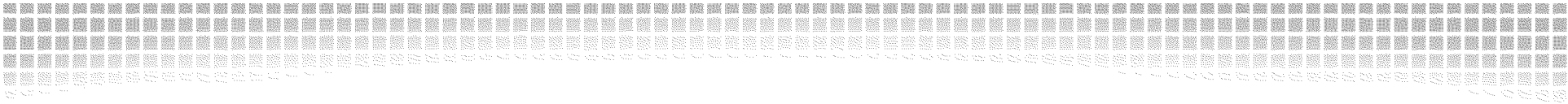# The model can also be used in other ways for different purposes.

- Constructing the supply curve based on different criteria (without co-optimization), such as
  - by ramp rates from high to low – least ramping capacity is left to meet upward AS and LF requirements
  - by ramp rates from low to high – most ramping capacity is left to meet upward AS and LF requirements
- Evaluating the effects of adding additional resources into the system

Commercial software is used to run Monte Carlo simulations of the model

- Model is developed in Excel

- Commercial software is used to run model simulations with co-optimization

  Frontline Risk Solver Platform for Excel

  http://solver.com/platform/risk-solver-platform.htm

Question?