California ISO
Your Link to Power

Integration of Renewable Resources (IRRP)

Integration Working Group

January 13, 2009

Meeting Agenda

Today's Objectives	10:00AM – 10:10 AM
Existing Fleet Study & Draft Results	10:10 AM – 11:45 AM
Stakeholder Discussion	11:45 AM – 12:30 PM
Lunch Break	12:30 PM – 1:00 PM
2009 Integration Studies &Discussion	1:00 PM – 1:50 PM
Next Steps	1:50 PM – 2:00 PM

Today's Objectives

- Explain scope and methodology of "existing fleet" 20% RPS study and describe some "draft" preliminary results
- Frame and plan the working group process to:
  - Obtain stakeholder input on framing the issues to be evaluated by the California ISO's future integration studies.
  - Determine what information and outputs from the integration studies do market participants and policy makers need to guide decisions on infrastructure and regulatory requirements.
  - Discuss source of the 33% resource build out scenarios.
  - Assist with assessment of potential methodologies and selection of methodology to perform integration analyses.

Integration of Renewable Resources (IRRP)

Existing Fleet Study and Draft Results

Grant Rosenblum, California ISO
Clyde Loutan, California ISO
Udi Helman, California ISO
Eric Toolson, Plexos
Tao Guo, Plexos

January 13, 2009

2012 Operational Flexibility Analyses

Presentation Outline

- Study Overview
- Specific Study Assumptions
- Draft Results (to date)

Study Overview

Study Participants

- CAISO
  - Grant Rosenblum (Project Manager)
  - Clyde Loutan
  - David Hawkins
  - Udi Helman
  - Phillip DeMello
- PLEXOS Solutions
  - Tao Guo
  - Eric Toolson

Purpose of Analysis – Phase I

- Evaluate 2012 CAISO generation resources to determine their ability to reliably integrate anticipated levels of variable renewable resources
  - Focus on the ability of CAISO fossil-fired resources to provide sufficient flexibility
  - Determine the magnitude and probability of any system operational violations
- Test (or extend) the ability of readily available analytical tools to provide credible integration evaluations
  - Scalable, repeatable
  - Understandable for stakeholders

Purpose of Analysis (cont.)

- If significant violations are found in this study phase, then next step would be to take a more detailed look at hydro and imports / exports.
- Depending on the results of this study, there may be other phases employing additional assumptions or analytical approaches.

Potential Violations Evaluated*

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

* Insufficient ramping capability results in one of the above violations.

Analytical Framework for Analysis

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- Only CAISO system modeled
  - Zonal topology initially (NP15, SP15)
  - CAISO Master File confidential generation data
    - Pmin, Pmax
    - Min. up- and down time
    - Ramp rates
    - AS Ranges
  - Hourly hydro generation (2006 and 2007) and AS contribution (2006) is fixed at the station-level based historical records
  - Hourly net interchange for NP15 and SP15 fixed based on 2006 or 2007 actuals
  - No AS provision assumed from imports
  - Hourly wind, QF, and geothermal generation is based on the 2006 historical profiles

Hydro and Import Variation Observed in 2006 & 2007 (GWh/yr) *

Parameter	2006	2007	% Dif.
CA hydro	48,876	26,958	-45%
CA net imports			
- NW	19,808	24,669	25%
- SW	44,959	67,547	50%
- total	64,767	92,216	42%

* CAISO historical (and not CA) values are used in this study. The CA values are provided above are for historical perspective only. Source is CEC "Net System Power Report", Table 2, "Gross System Power.

Analytical Model For This Phase – PLEXOS

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- Hourly (or 10-minute) simulation time steps
- Mimics MRTU with respect to co-optimization of energy and AS (i.e. simultaneous solution)
- Previously used by CAISO in the following applications:
  - Path 26 and PVD2 economic feasibility studies
  - Analytical support for development of Transmission Economic Assessment Methodology (TEAM)
  - Competitive path assessment studies
  - Provided unit commitment and AS reservations for Study 3C, etc.

Model Priorities Established By:

- Least-cost solution (energy and AS requirements, and other constraints)
- Penalty costs for violations *
    - Spin –- $160,000/MWh
    - Unserved energy -- $100,000/MWh
    - Reg-Up –- $80,000/MWh
    - Reg-Down -- $70,000/MWh
    - Non-Spin – $2/MWh
    - Overgeneration -– $1/MWh

* **F**or purposes of this study only, does not represent CAISO operating procedures.

Summary of Simulation Steps for This Study Phase

- CAISO simulation consists of 4 Steps:
  - Steps 1 and 2 mimic the Day-ahead Market (DAM) UC and Dispatch procedure
    - Step 1: 2012 deterministic day-ahead hourly simulation
    - Step 2: 2012 stochastic day-ahead hourly simulation
  - Steps 3 and 4 mimic the Real-time Market (RTM) UC and Dispatch procedure
    - Step 3: 2012 deterministic 10-minute simulation for selected 5-hour intervals
    - Step 4: 2012 stochastic 10-minute simulation for selected 5-hour intervals
  - Unit Commitment patterns from Steps 1 or 2 are passed to Steps 3 and 4
  - Purpose of simulations is to develop estimates of any violations in an increasingly detailed manner

Step 1: Deterministic Day-Ahead Hourly Simulation

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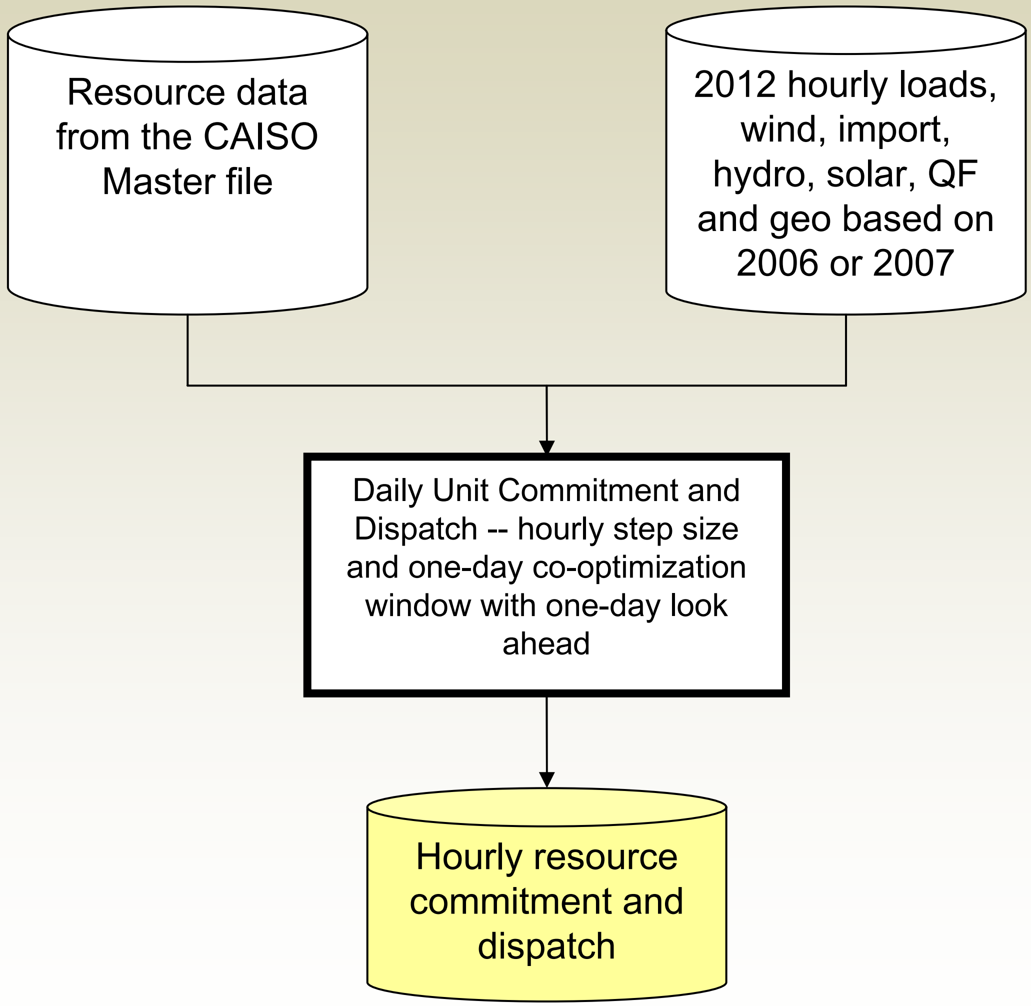
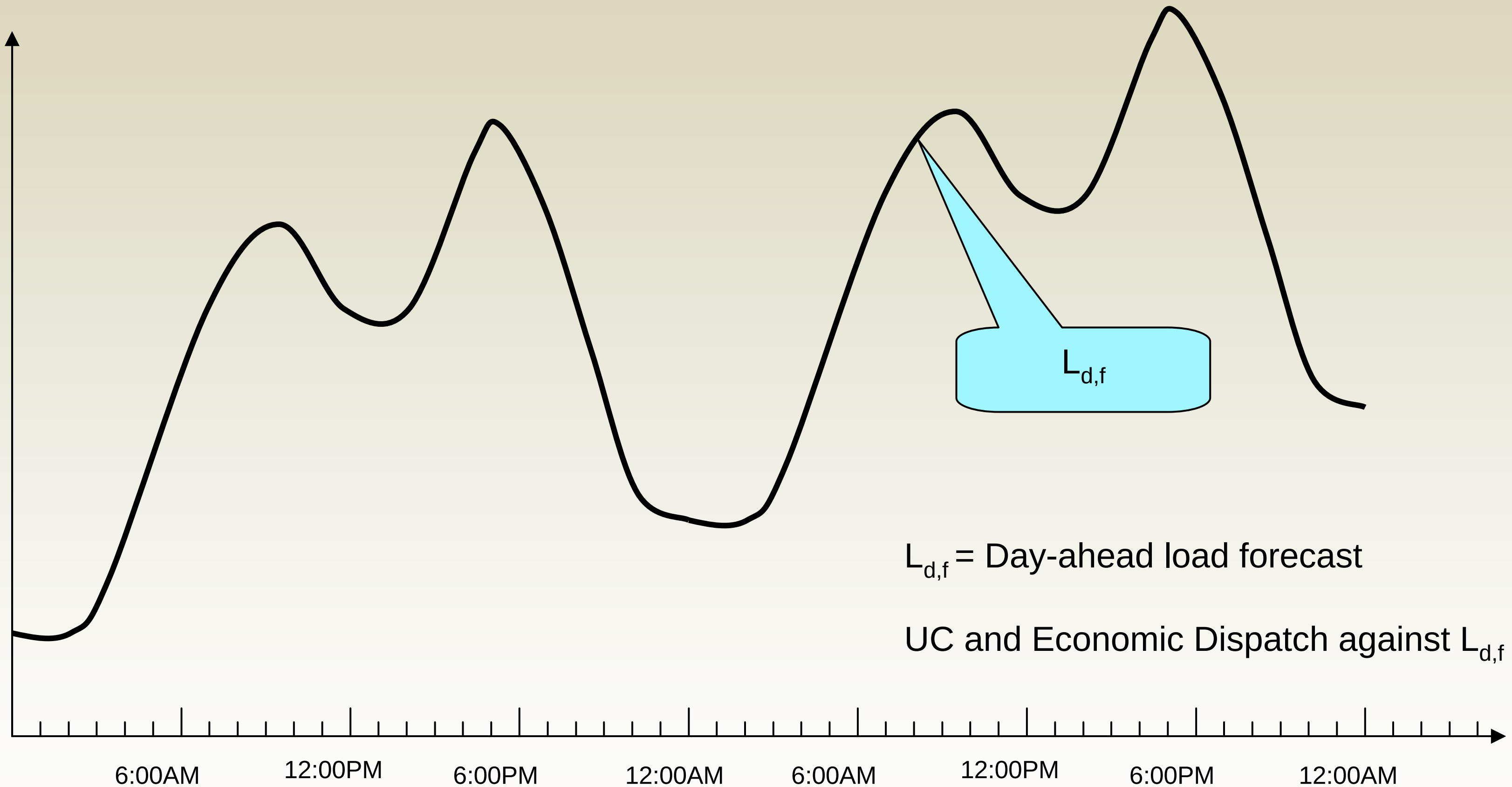
- Purpose -- Step 1 provides a high-level, deterministic assessment of potential operating violations, as well as unit commitment for real-time market simulations (Steps 3 and 4).
- Simulation interval and time window
  - Hourly interval
  - 24-hour scheduling window plus 24-hour look ahead (48-hour unit commitment window)
- Simulation Mode
  - Deterministic (one iteration)
- Inputs
  - 2012 hourly ***day-ahead load forecasts***, $L_{d,f}$, for IOU's
  - 2012 hourly ***day-ahead wind generation forecasts***, $W_{d,f}$, for 5 zones
  - 2012 hourly hydro, solar, QF, Geothermal, import and export profiles based 2006 or 2007 historical hourly generation
  - 3,263 MW of new resource additions
  - Convergent Monte Carlo for generator forced outage modeling

Step 1: Deterministic Day-Ahead Hourly Simulation Logical Flow



Step 1: Deterministic Day-Ahead Hourly Simulation Timeline



$L_{d,f}$ = Day-ahead load forecast

UC and Economic Dispatch against $L_{d,f}$

24 hours UC (with 24 hours look ahead)

Step 2: Stochastic Day-Ahead Hourly Simulation

- Purpose -- Step 2 provides a stochastic assessment of potential operating violations, as well as unit commitment for real-time market simulations (Steps 3 and 4).
- Simulation interval, time window, and base inputs - same as in Step 1
- Simulation mode - 100-iterations
- Stochastic drivers
  - Convergent Monte Carlo for generator forced-outage modeling
  - 2012 hourly day-ahead load forecasts with ***day-ahead forecast deviations***, $d^{i}_{d,f}$, modeled as Brownian Motion with Mean Reversion; parameters are derived from the 2006 and 2007 historical hourly day-ahead load forecast errors by season
  - 2012 hourly day-ahead wind generation forecasts with ***day-ahead forecast deviations***, $wd^{i}_{d,f}$, modeled as Brownian Motion with Mean Reversion; parameters are derived from the 2006 and 2007 historical hourly day-ahead wind generation forecast errors

Step 2: Stochastic Day-ahead Hourly Simulation Logical Flow

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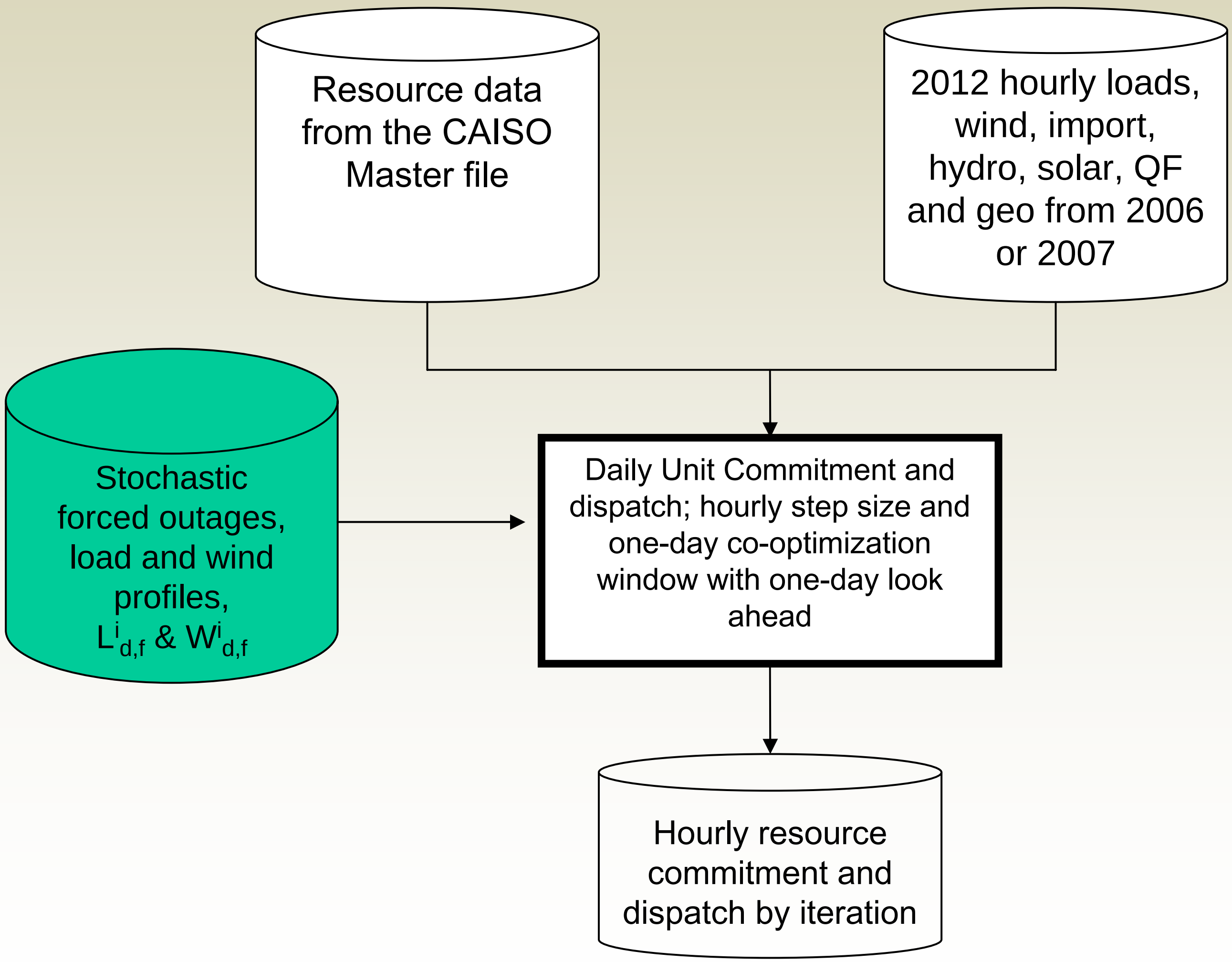

Step 2: Stochastic Day-Ahead Hourly Simulation Timeline

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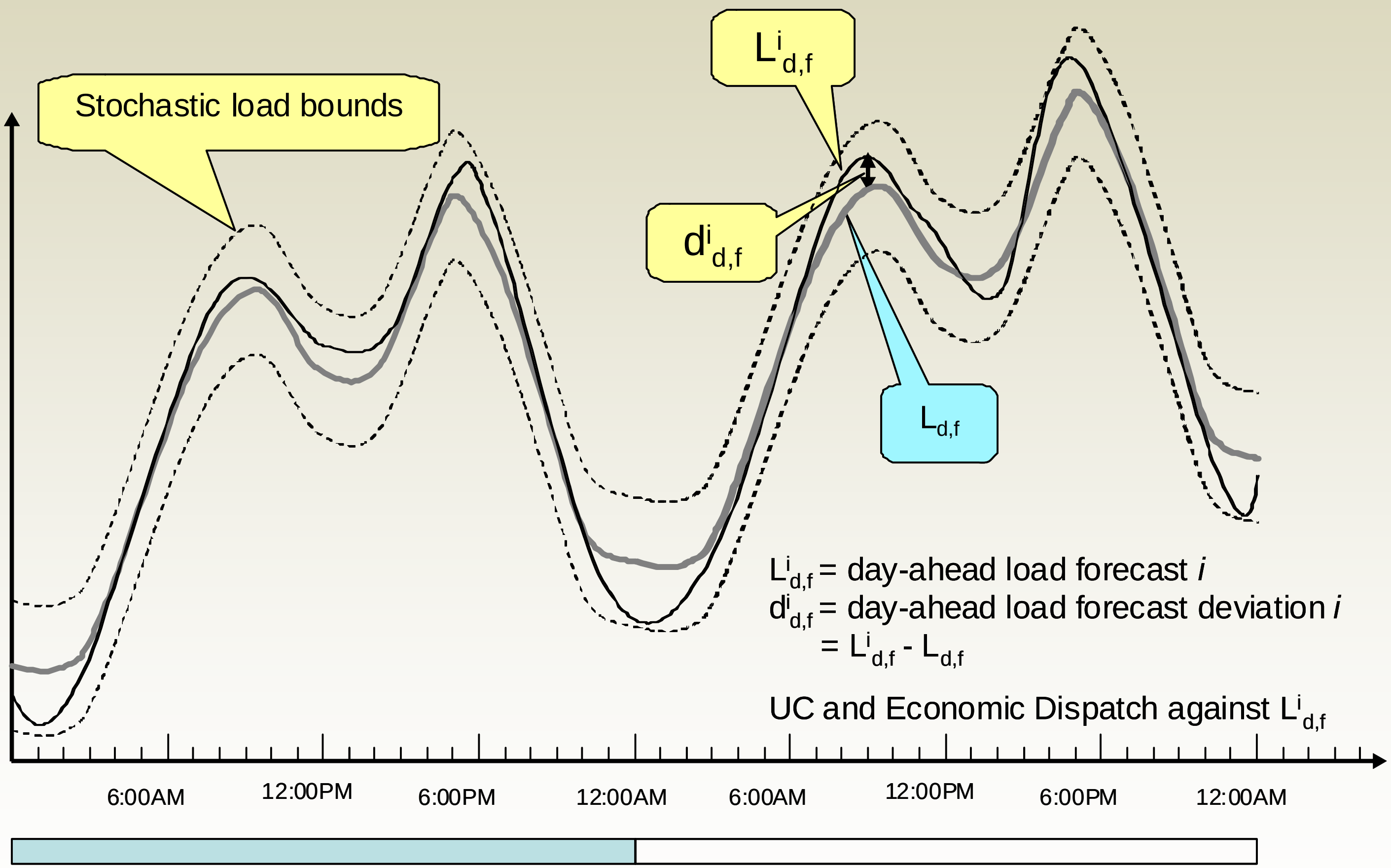

24 hours UC (with 24 hours look ahead)

Step 3: Deterministic Real-Time 10-Minute Simulation Steps

- Purpose – Develop more sophisticated assessment of potential violations incorporating real-time market.
- Simulation interval and time window
  - 10-minute simulation interval
  - 1-hour time window (with 4-hour look ahead)
- Simulation Mode
  - Deterministic (one iteration)
- Inputs
  - 2012 10-minute ***hour-ahead load forecasts***, $L_{h,f}$, for IOU's
  - 2012 10-minute ***hour-ahead wind generation forecasts***, $W_{h,f}$, for 5 zones
  - 2012 10-minute hydro, solar, QF, Geothermal, import and export profiles based 2006 or 2007 historical 10-minute generation
  - Convergent Monte Carlo for generator forced outage modeling
- Initial unit commitment is derived from day-ahead UC
- Real-time changes in unit commitment are allowed (less than 5 hour ramp rate)

Step 3: Deterministic Real-time 10-minute Simulation Logical Flow

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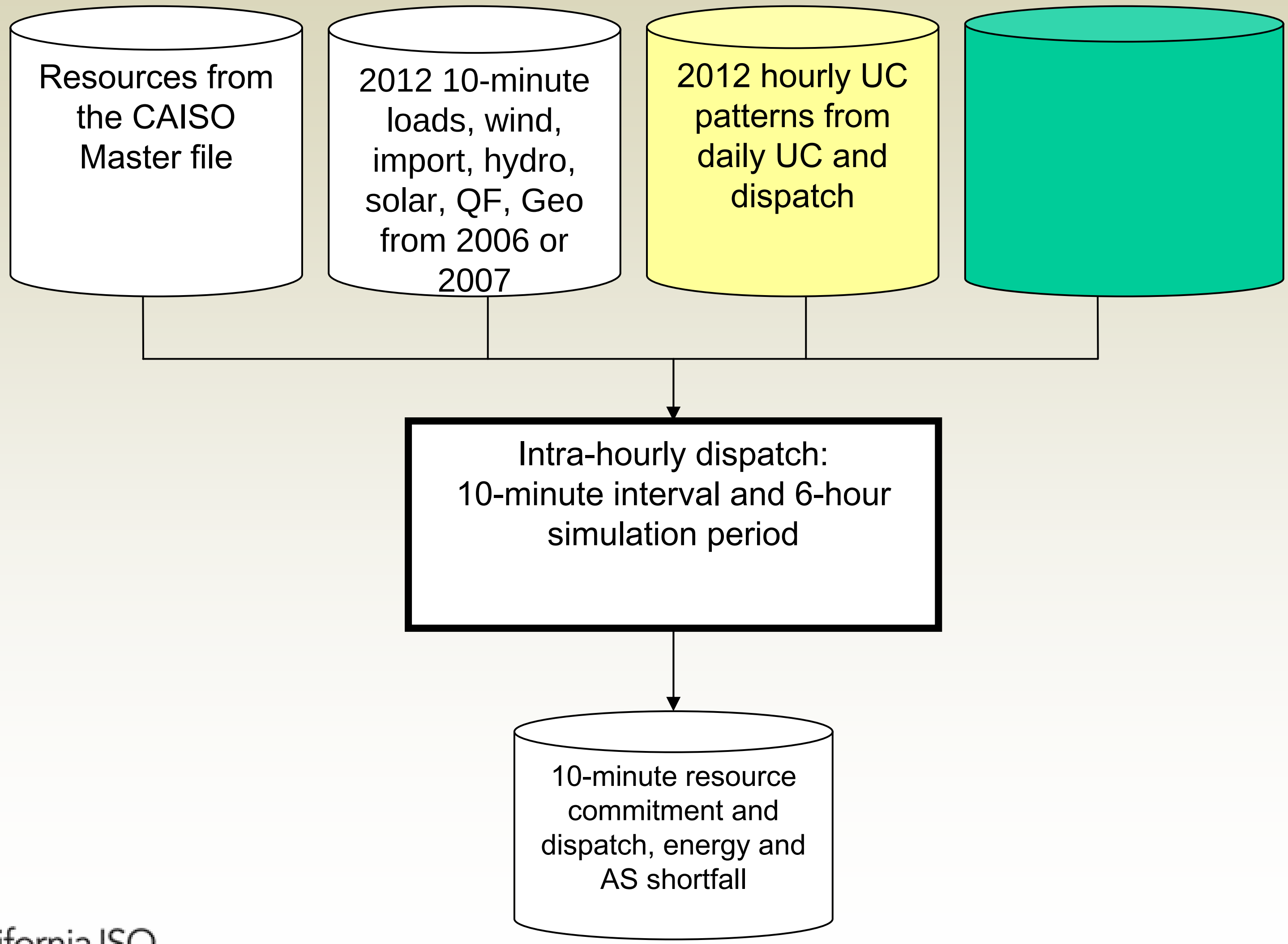
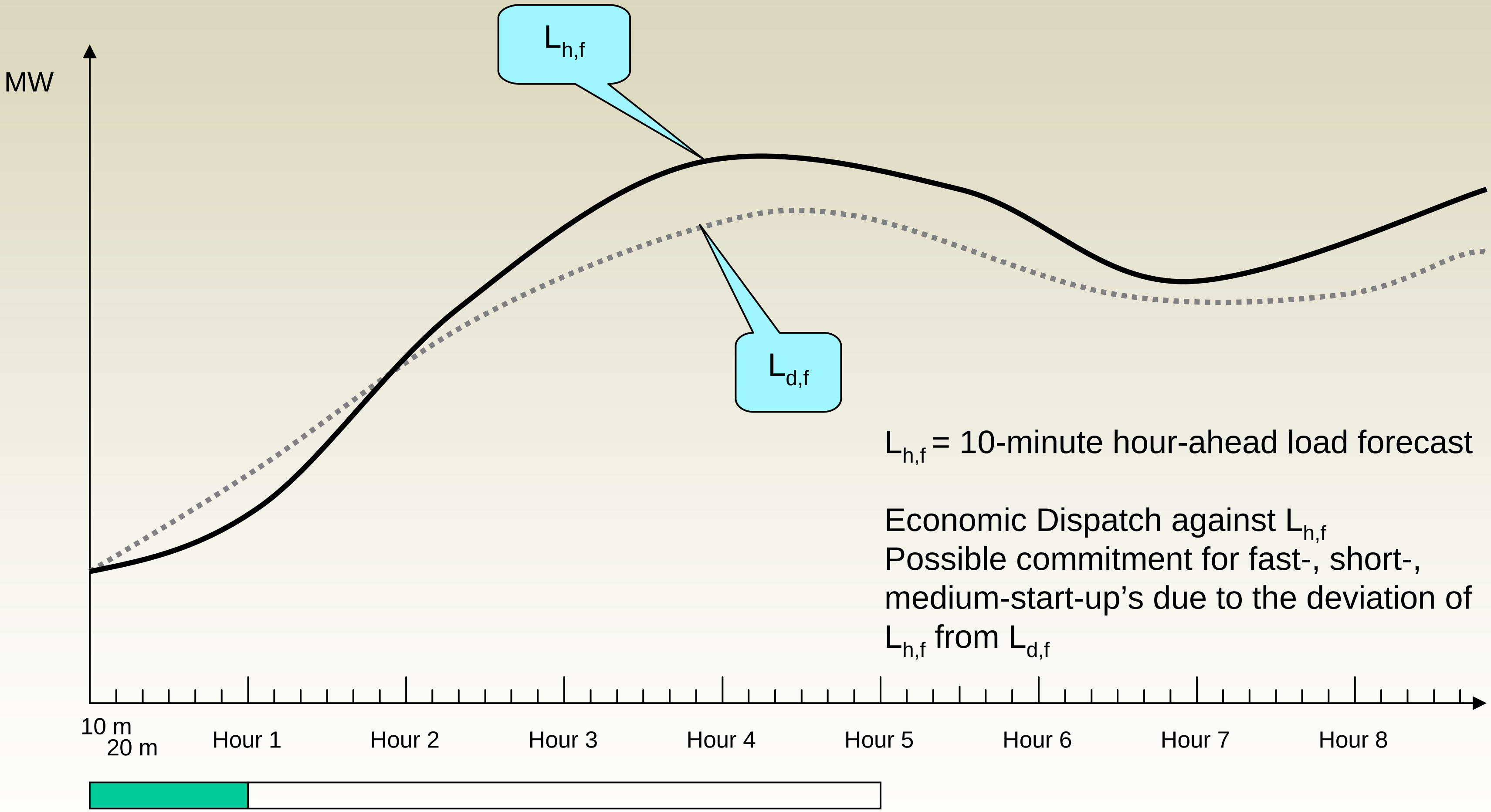


Step 3: Deterministic Real-Time 10-Minute Simulation Timeline



$L_{h,f}$ = 10-minute hour-ahead load forecast

Economic Dispatch against $L_{h,f}$
Possible commitment for fast-, short-, medium-start-up's due to the deviation of $L_{h,f}$ from $L_{d,f}$

6 10-minutes UC (with 24, 10-minutes look ahead)

Step 4: Stochastic Real-Time 10-minute Simulation Steps

- Purpose – Of four steps in this phase of the study, this is the most sophisticated assessment of potential violations.
- Simulation interval, time window, and base-case inputs - same as in

  Step 3
- Simulation Mode - 100-iterations
- Unit Commitment pattern from Day-Ahead Unit Commitment
- Real-time changes in unit commitment are allowed (less than 4 hour ramp rate)
- Stochastic drivers
  - Convergent Monte Carlo for generator forced outage modeling
  - 2012 ***10-minute actual loads*** with ***hour-ahead forecast errors***, $e^i_{h,f}$, modeled as Brownian Motion with Mean Reversion; parameters are derived from the 2006 historical ***10-minute hour-ahead load forecast errors*** by season
  - 2012 ***10-minute actual wind generations*** with ***hour-ahead forecast errors***, $we^i_{h,f}$, modeled as Brownian Motion with Mean Reversion; parameters are derived from the 2006 historical ***10-minute hour-ahead wind generation forecast errors***

Step 4: Stochastic Real-time 10-minute Simulation Logical Flow

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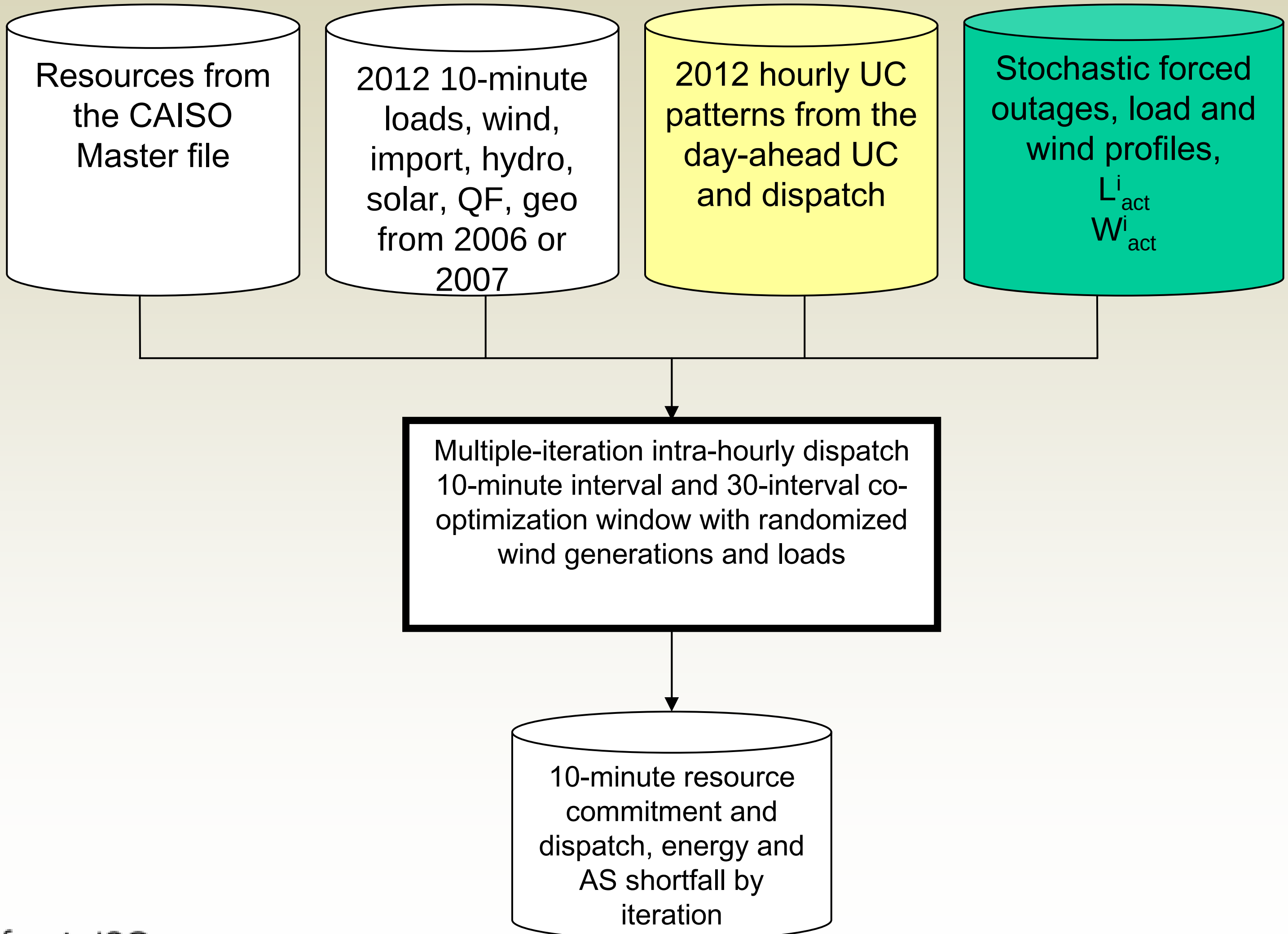
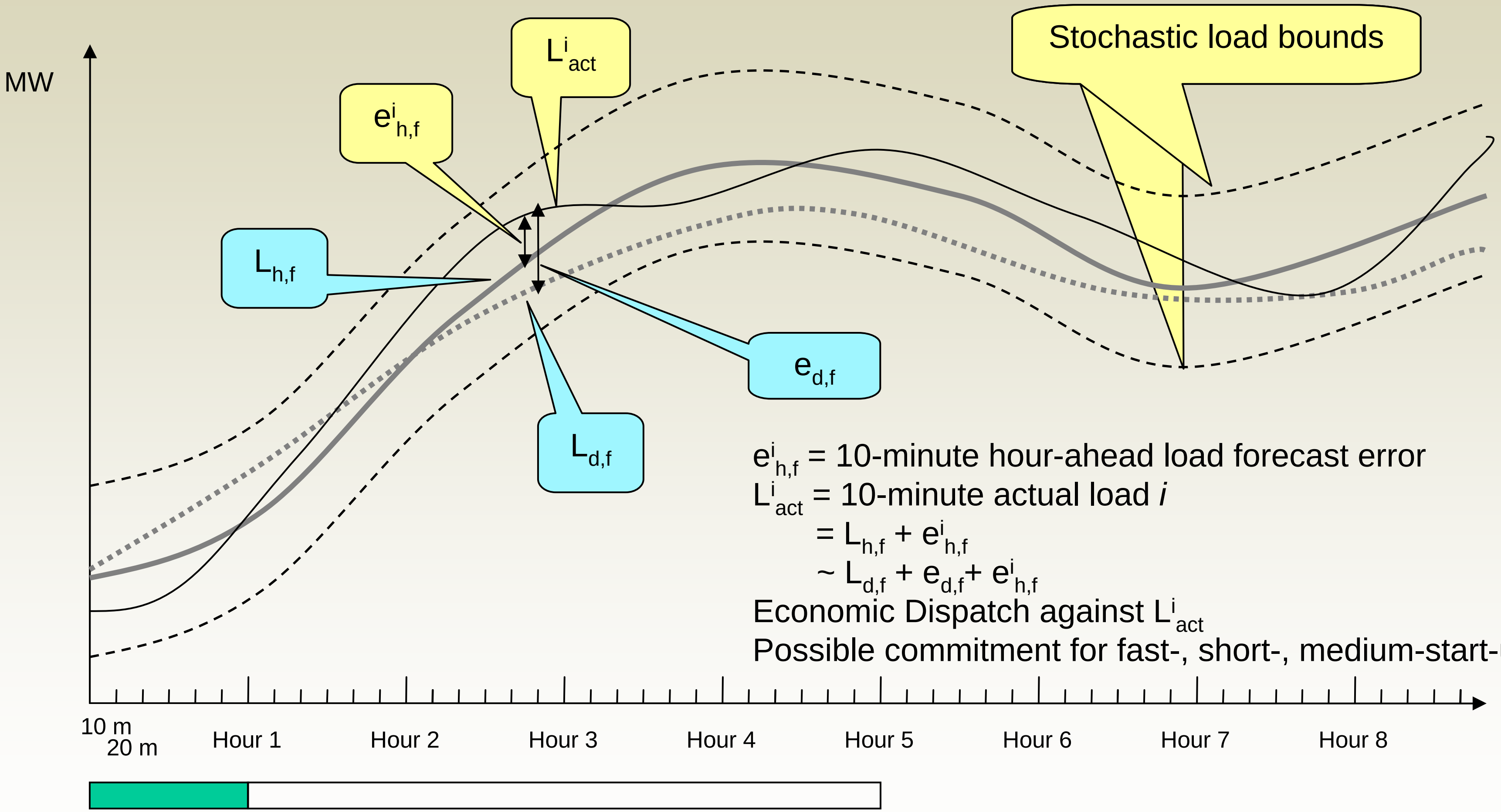


Step 4: Stochastic Real-Time 10-Minute Simulation Timeline



$e^{i}_{h,f}$ = 10-minute hour-ahead load forecast error

L^{i}_{act} = 10-minute actual load *i*

$= L_{h,f} + e^{i}_{h,f}$

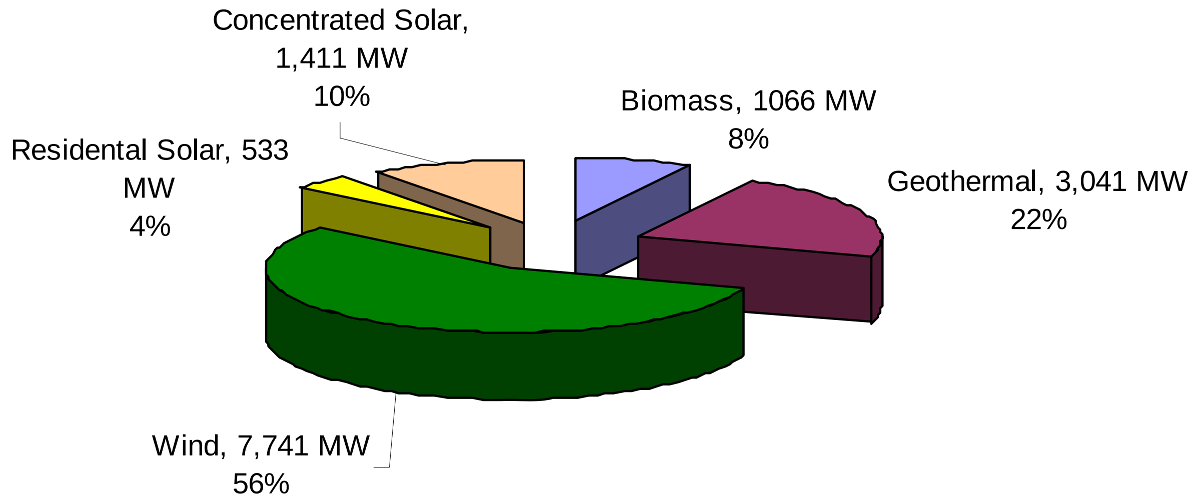
$\sim L_{d,f} + e_{d,f} + e^{i}_{h,f}$

Economic Dispatch against L^{i}_{act}

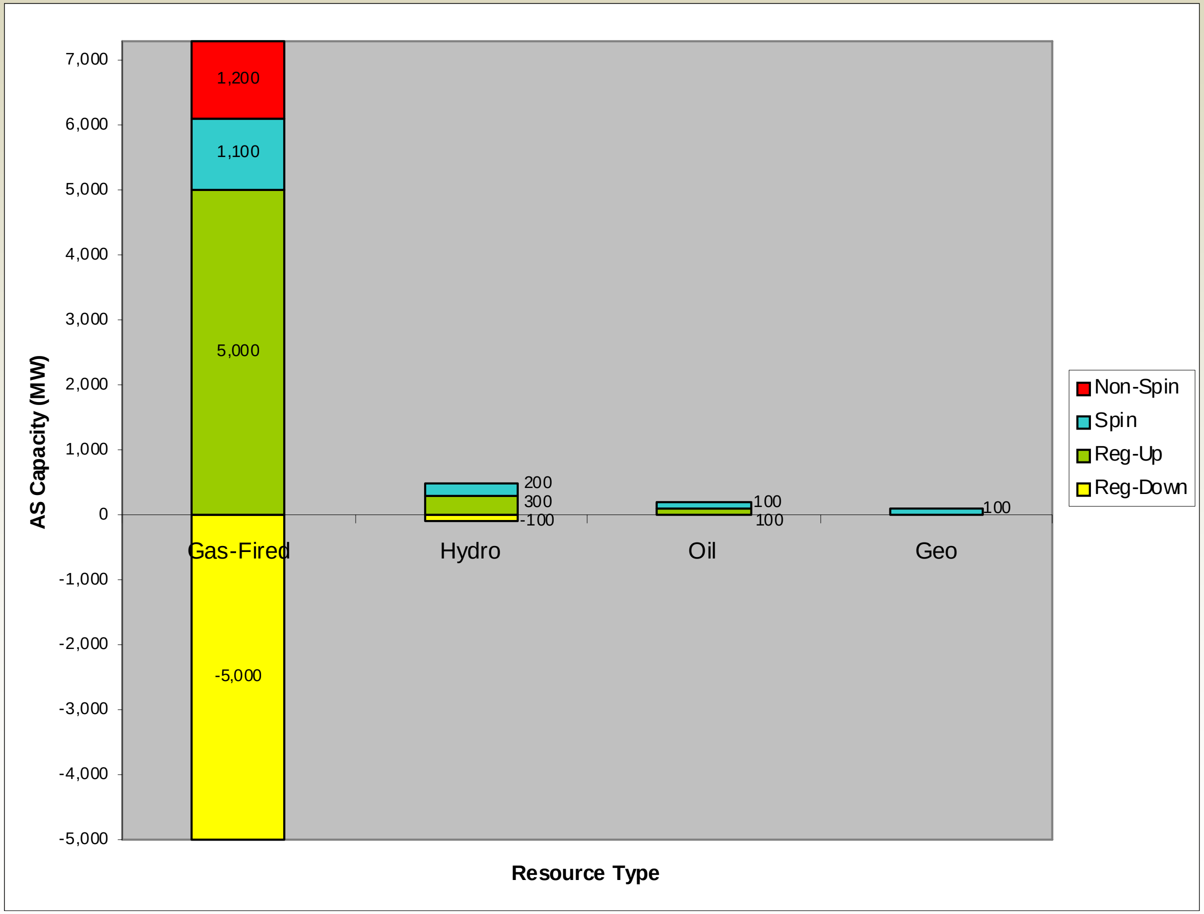
Possible commitment for fast-, short-, medium-start-up's

6 10-minutes UC with 24 10-minutes look ahead

20% Renewable Resources
MW



2012 Resources Available for Ancillary Services (AS)*



* Hydro AS is based on 2006 peak hour capability

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2009-2011 Additional Resource Capacity (MW)

	New Resources	Max. Cap. (MW)	Location	Commission Date
1	EIF_Panoche_2_PL1X2	400	Fresno, NP15	August 2009
2	GateWay_2_PL1X4	530	Contra Costa, NP15	May 2009
3	Humboldt_1_PL1X2	163	Humboldt, NP15	April 2010
4	Inland_Emp_2_PL1X4	800	Riverside, SP15	Unit 1: November 2008 Unit 2: July 2009
5	Otay_Mesa_2_PL1X2	590	San Diego, SP15	October, 2009
6	Starwood_1_PL1X2	120	Fresno, NP15	May 2009
	Total	3263		

2012 Ancillary Service Requirements

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Parameter	Units	Requirement
Reg-Down	MW	350-750 *
Reg-Up	MW	350-530 *
Spin	MW	0.5*(3%*L + 3%*G)
Non-Spin	MW	0.5*(3%*L + 3%*G)

* Regulation requirements vary by TOD and season

Step 1 Draft Results

Step 1 Overview

- 8760-hour market simulation
- No stochastics, expected conditions
- 48-hour period for commitment
  - End of previous day establishes initial commitment
  - Commitment and dispatch for next 24 hours is optimized
  - Second 24 hours used to better determine commitment of resources with slow ramp rates or long min. up or down time
- Simulation solution results show:
  - no unserved energy,
  - no overgeneration
  - no AS deficiencies

Step 2 Draft Results

Assumptions and Findings

- Simulation mode
  - 100-iterations,
  - 24-hour Unit Commitment and Dispatch with 24-hour look ahead
- Loads
  - 2012 CAISO demand forecasts are derived from 2006 actual demands recorded in the Energy Management System (EMS)
- Stochastic Drivers
  - Generator forced outages
  - CAISO demand forecast errors in three IOU’s
  - CAISO wind generation forecast errors in 5 zones
- Draft results are:
  - No unserved energy
  - Some overgeneration in April and May
  - Some regulation-up, spin and non-spin deficiencies in July
  - In future simulations, spinning requirement penalty price will be increased above the un-served energy penalty price so that NERC reliability standards will be enforced

Monthly Average Unserved Energy in GWh (2006-based Stochastic Simulation)

	Average Unserved Energy of 100 iterations			
Month	CAISO-PGAE	CAISO-SCE	CAISO-SDGE	Grand Total
1/1/2012	0	0	0	0
2/1/2012	0	0	0	0
3/1/2012	0	0	0	0
4/1/2012	0	0	0	0
5/1/2012	0	0	0	0
6/1/2012	0	0	0	0
7/1/2012	0	0	0	0
8/1/2012	0	0	0	0
9/1/2012	0	0	0	0
10/1/2012	0	0	0	0
11/1/2012	0	0	0	0
12/1/2012	0	0	0	0
Total	0	0	0	0

Monthly Average Reserve Shortfall in GWh (2006-based Stochastic Simulation)

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	Average Reserve Shortfall from 100 iterations			
Month	CAISO Non-Spin	CAISO Reg-dn	CAISO Reg-up	CAISO Spin
1/1/2012	0	0	0	0
2/1/2012	0	0	0	0
3/1/2012	0	0	0	0
4/1/2012	0	0	0	0
5/1/2012	0	0	0	0
6/1/2012	0	0	0	0
7/1/2012	1.619	0.000	0.002	0.053
8/1/2012	0	0	0	0
9/1/2012	0.008	0	0	0
10/1/2012	0	0	0	0
11/1/2012	0	0	0	0
12/1/2012	0	0	0	0
Total	1.627	0.000	0.002	0.054

Monthly Average Overgeneration in GWh (2006-based Stochastic Simulation)

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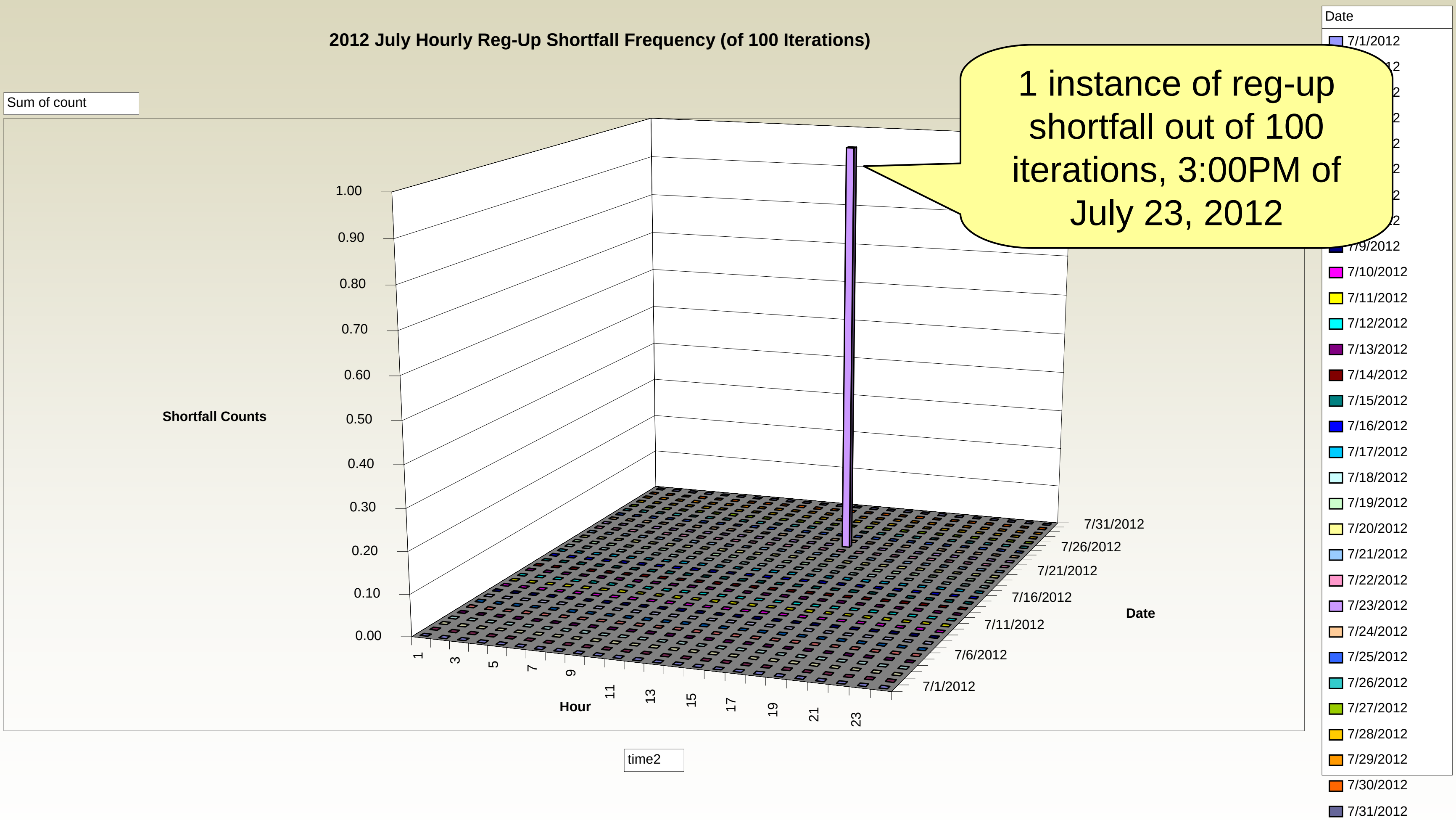
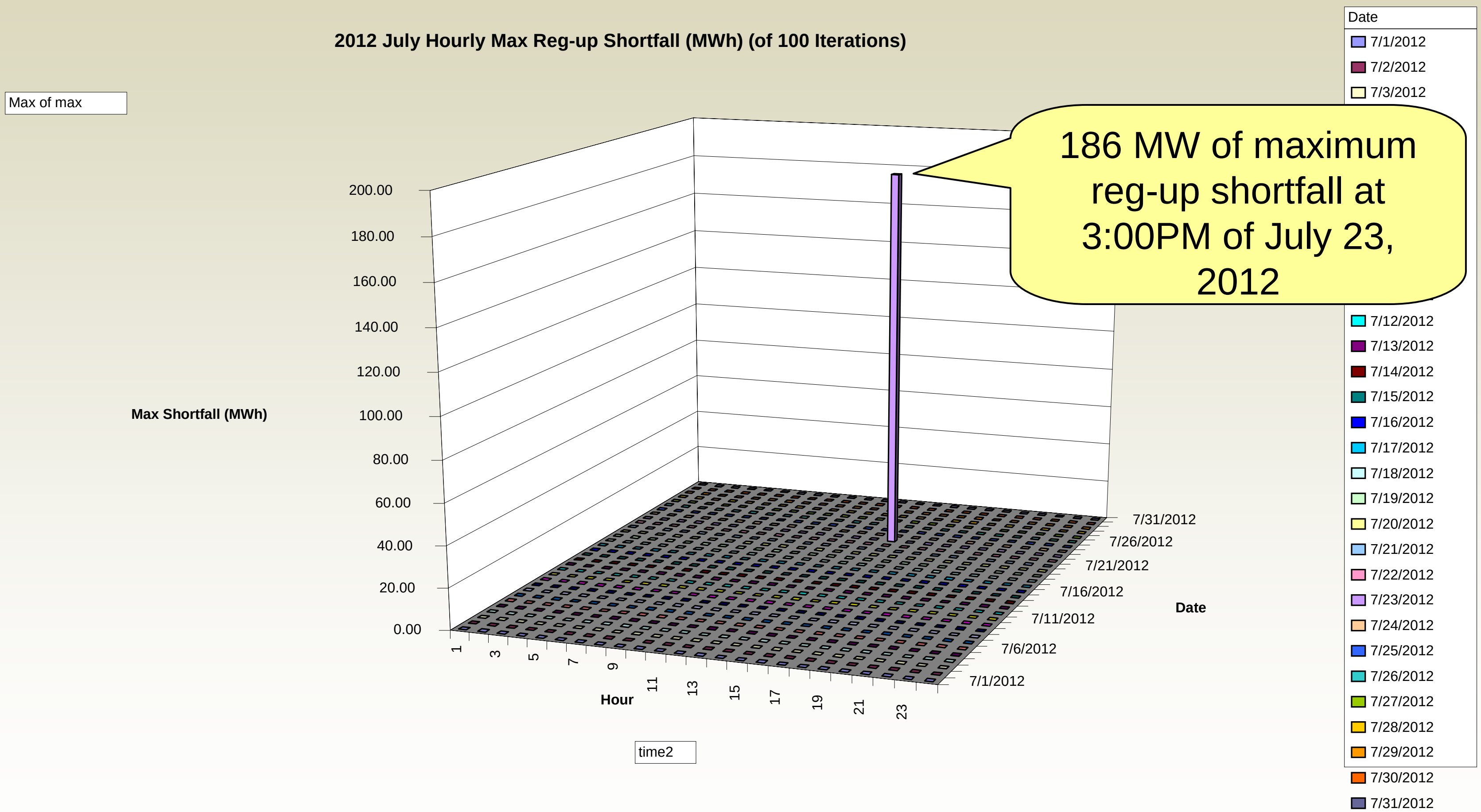
	Average Dump Energy of 100 iterations			
Month	CAISO PGAE	CAISO SCE	CAISO SDGE	Grand Total
1/1/2012	0	0	0	0
2/1/2012	0	0	0	0
3/1/2012	0	0	0	0
4/1/2012	0.347	0.048	0.011	0.407
5/1/2012	0.090	0.141	0.037	0.267
6/1/2012	0	0	0	0
7/1/2012	0	0	0	0
8/1/2012	0	0	0	0
9/1/2012	0	0	0	0
10/1/2012	0	0	0	0
11/1/2012	0	0	0	0
12/1/2012	0	0	0	0
Total	0.437	0.188	0.048	0.674

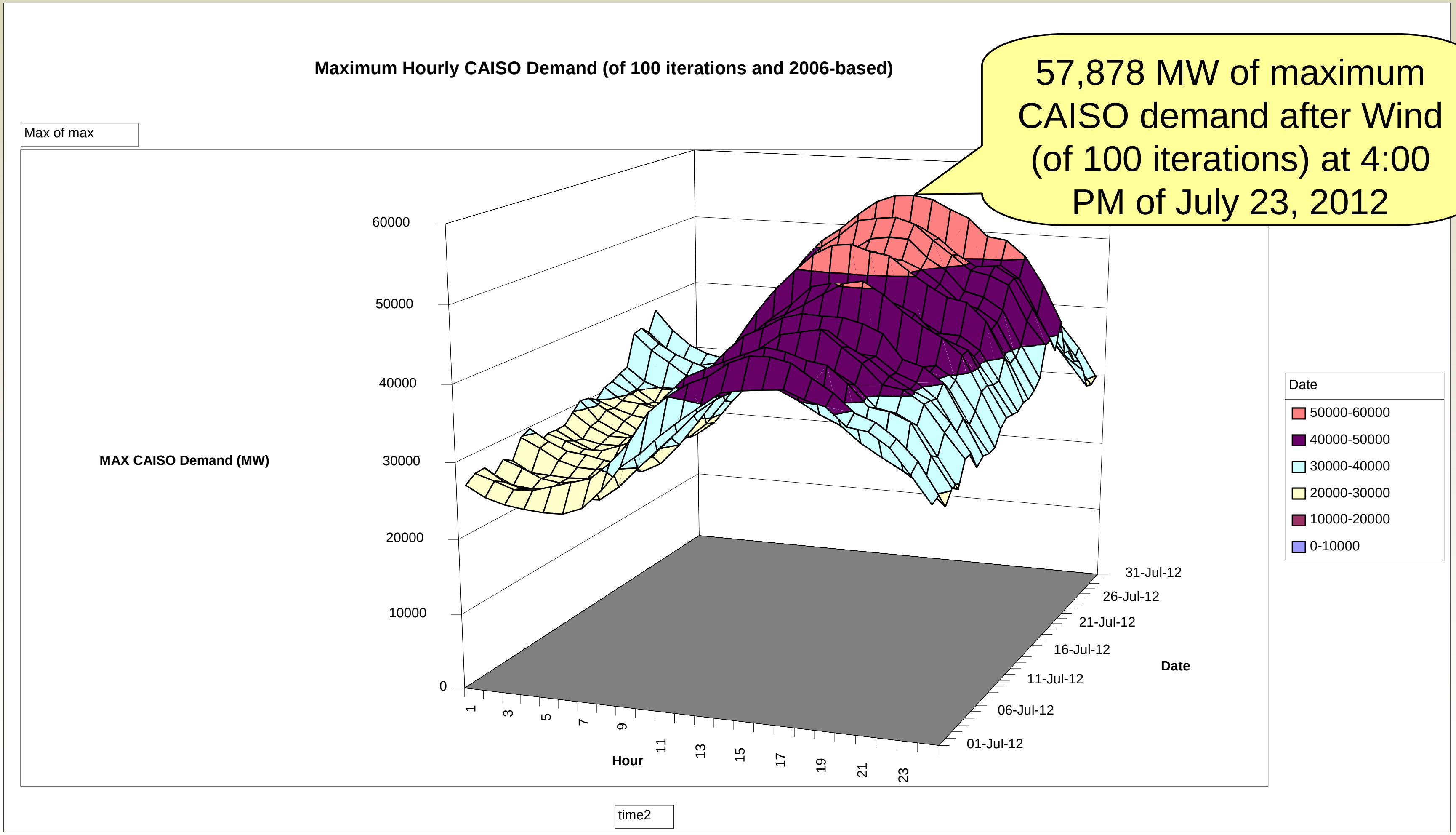
Hourly Regulation-Up Shortfall Frequency in July (of 100 iterations and 2006-based)



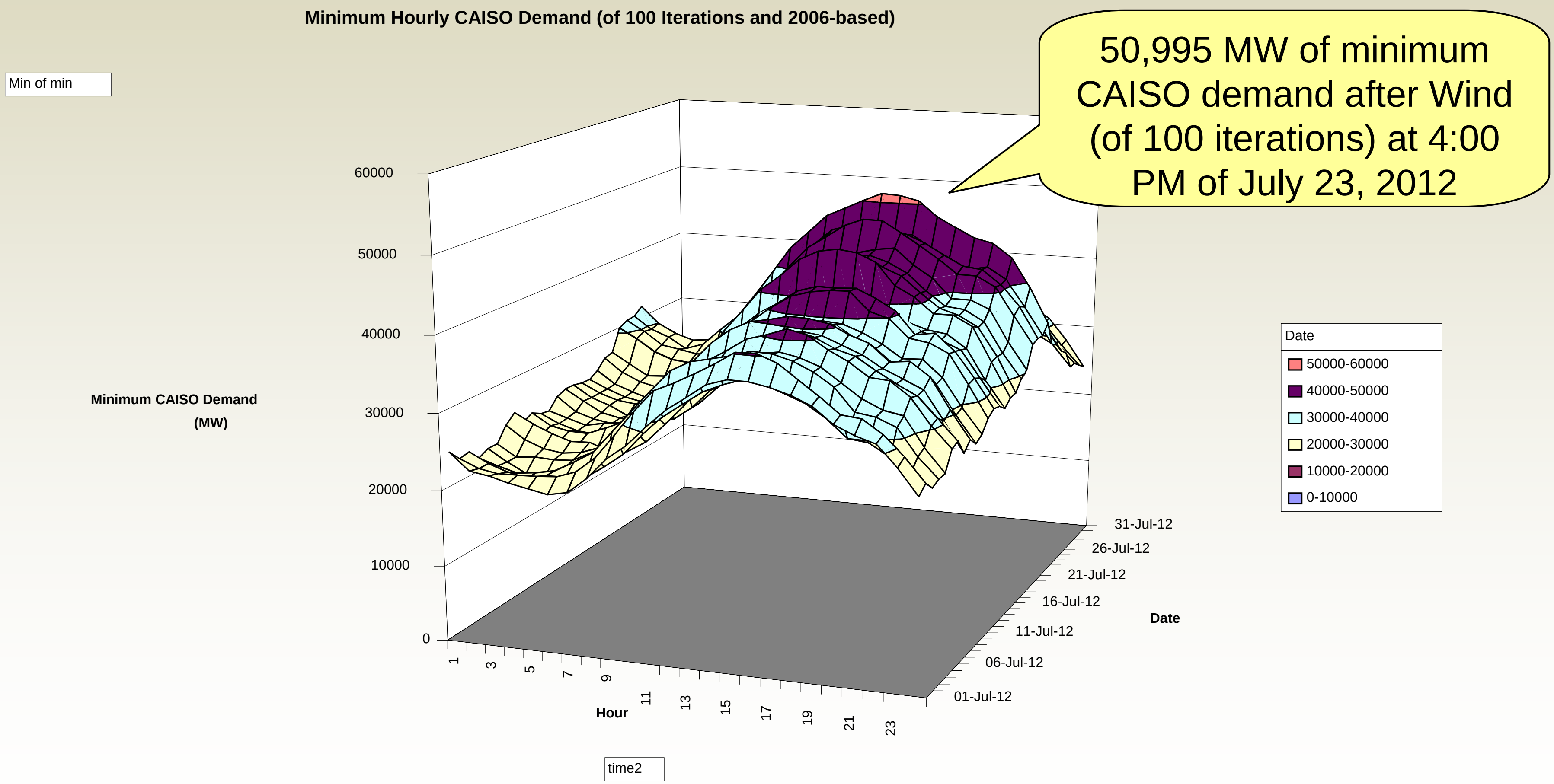
Hourly Maximum Regulation-up Shortfall in July (of 100 iterations and 2006-based)



Maximum Hourly CAISO Demand After Wind Generation in July (of 100 iterations & 2006-based)



Minimum Hourly CAISO Demand After Wind Generation in July (of 100 iterations & 2006-based)



Monthly Average Reserve Shortfall (2006-based Stochastic Simulation Without New Builds)

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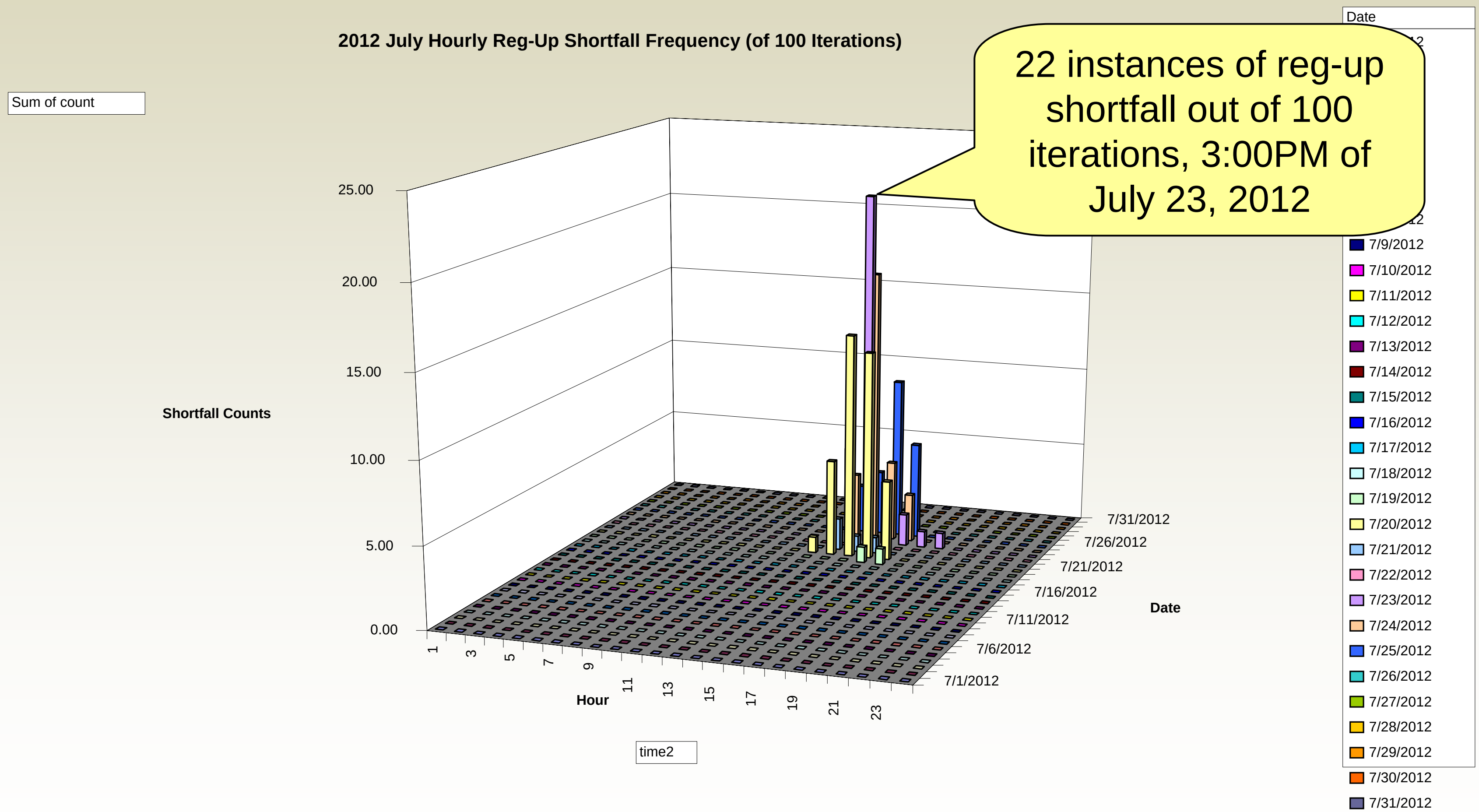
	Average Reserve Shortfall of 100 iterations			
Month	CAISO-NonSpin	CAISO-Regdn	CAISO-Regup	CAISO-Spin
1/1/2012	0.00	0.00	0.00	0.00
2/1/2012	0.00	0.00	0.00	0.00
3/1/2012	0.00	0.00	0.00	0.00
4/1/2012	0.00	0.00	0.00	0.00
5/1/2012	0.00	0.00	0.00	0.00
6/1/2012	0.05	0.00	0.00	0.00
7/1/2012	16.52	0.00	0.26	2.66
8/1/2012	0.00	0.00	0.00	0.00
9/1/2012	0.01	0.00	0.00	0.00
10/1/2012	0.00	0.00	0.00	0.00
11/1/2012	0.00	0.00	0.00	0.00
12/1/2012	0.00	0.00	0.00	0.00
Total	16.58	0.00	0.26	2.66

Hourly Regulation-Up Shortfall Frequency in July (of 100 iterations and 2006-based w/o New Builds)



Hourly Maximum Regulation-Up Shortfall in July (of 100 iterations and 2006-based w/o New Builds)

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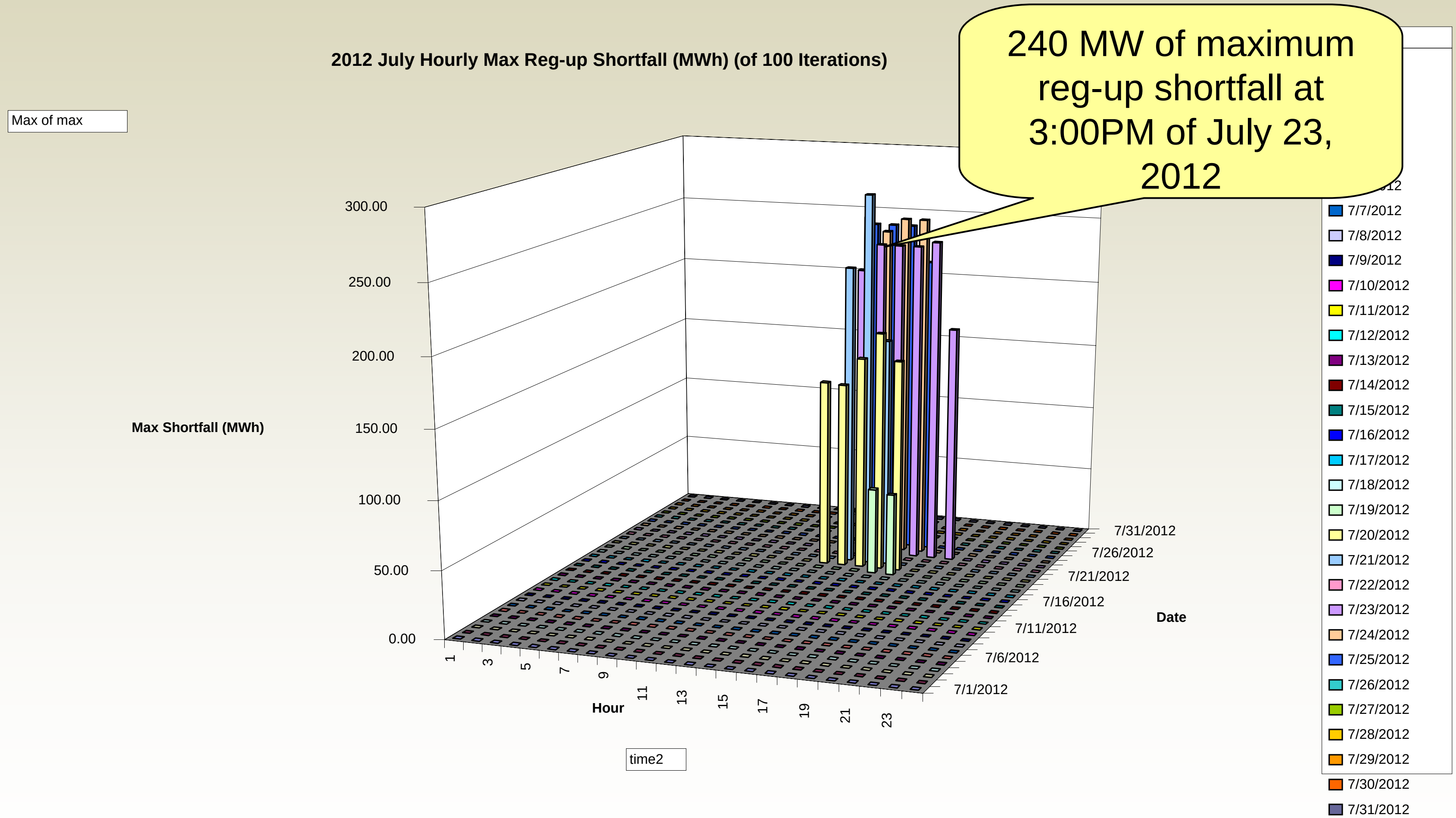


Summary of Draft Findings to Date

- There appear to be no violations using a traditional production-costing approach and modeling the day-ahead market with hourly time steps (Step 1).
- If we consider load, wind, and forced outages to be uncertain variables, we see some violations in Reg-Up, Spin, Non-Spin in the summer, and some Overgeneration in the spring (Step 2).
- No unserved energy or Reg-Down violations.
- At this point in the study, these violations may not be significant, since many (if not all) of the AS violations would be eliminated if we allowed more flexible hydro modeling, or assumed some AS procurement available from imports.

Draft Findings (cont.)

- These results suggest that there will be some probability of Overgeneration in the spring due to a combination of high hydro possibly coupled with low loads and / or high must-take generation availability.
- If no new generation is added to the system, or if 3200 MW of existing generation is forced to retire (i.e., OTC), the violations are substantially increased.
  - However, it is not known at this time what the violation level would be given more flexible hydro and import assumptions.

Next Steps . . .

- Receive and review input from stakeholders
- Review hydro and import assumptions regarding AS capability
- Update violation penalty factors so that load is shed before spin is violated
- Update simulations in Steps 1 and 2 and provide results to stakeholders
- Set up Steps 3 and 4, perform the simulations, summarize the results, and check for validity (intra-hour simulations)
- Provide draft results for Steps 3 and 4 to stakeholders and solicit their input

How you can participate ?

- Stakeholder input is welcome and encouraged
- Please submit comments or questions to the jblatchford@caiso.com by January 20, 2009
  - We apologize for the short turn around, but this is necessary to prevent delay in moving to Steps 3 and 4

Lunch Break

- Back at 1:00 PM

California ISO
Your Link to Power

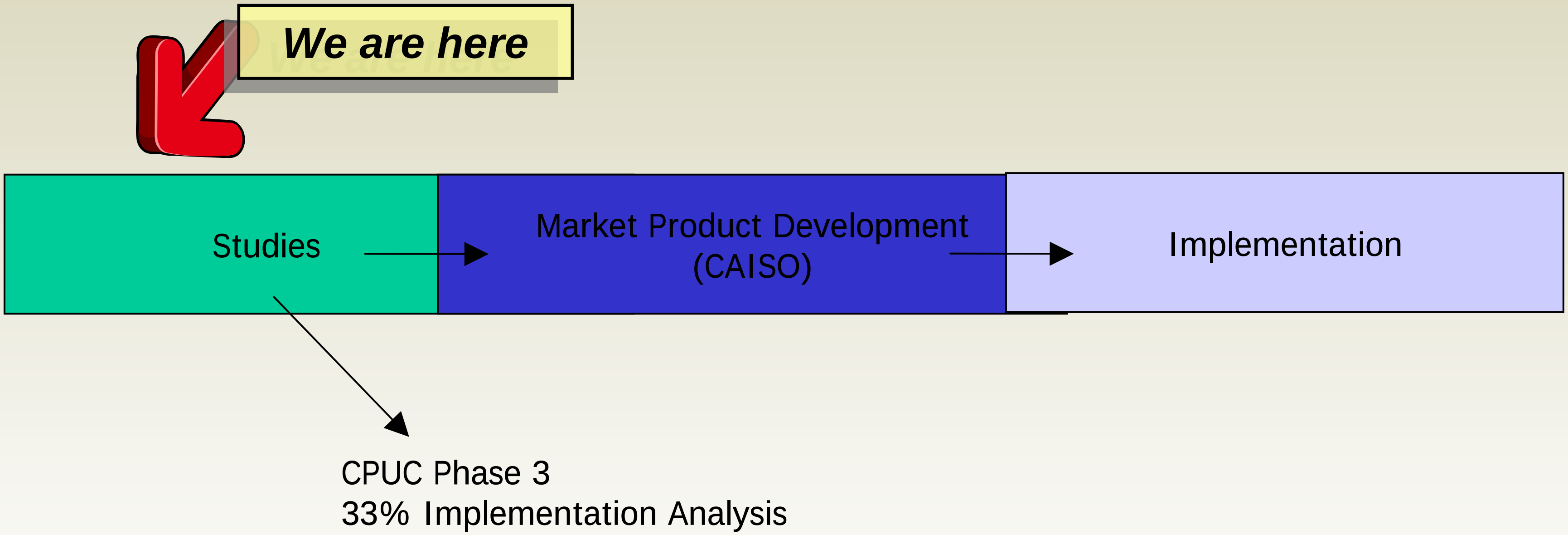
Integration of Renewable Resources (IRRP)

2009 Integration Studies & Discussion

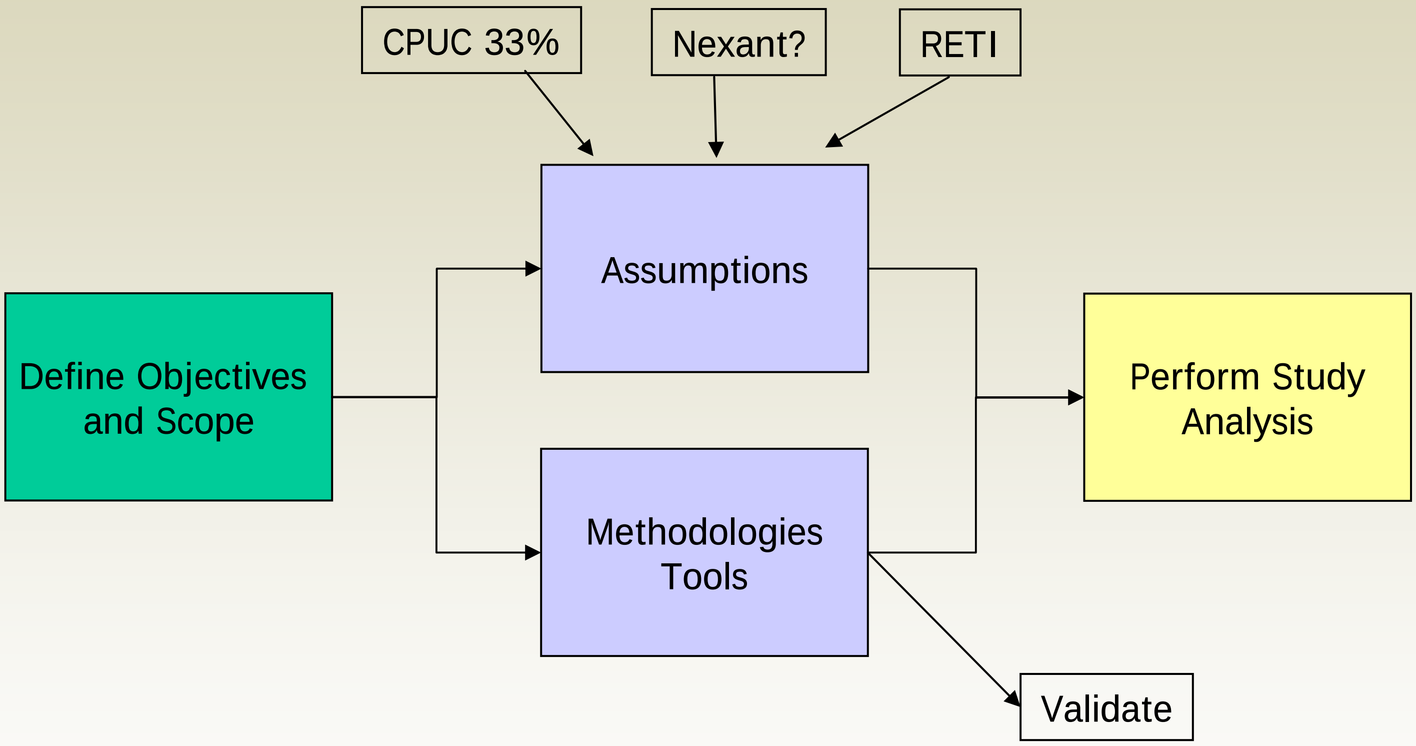
Grant Rosenblum
Udi Helman
Clyde Loutan

January 13, 2009

High Level – Study Implementation Process



Study Process



2009 Integration Study Efforts – “Onwards to 33%”

- Follow-up on request to have more stakeholder input on integration analyses
- Start at the beginning – Define Objectives and Scope
  - What information will assist market participants, investors, and policy makers?
  - What information will assist in assessing the adequacy of current market products and structure?
  - Does the scope include cost impacts or simply operational impacts from which costs can be derived?, etc.
  - Should the focus be on GHG reduction, simply achieving RPS goals, or both?

Suggested 2009 Operational Studies to Support Renewables Integration

- Ramping and Ancillary Services Evaluation
- Fleet Characteristics Analyses
- Overgeneration
- Additional Studies
  - Fast Regulation
  - Wide Area Energy Storage and Management System
  - Evaluation of Inter-hour Scheduling at Inter-ties
  - Impact on Gas Transmission and Storage

Ramping and Ancillary Services Evaluation

- Proposed objectives – Determine on a seasonal basis:
  - Multi-hour ramp capacity needs and ramp rate requirements
  - Intra-hour load following capacity needs, ramp rate and ramp duration requirement
  - Regulation, ramp capacity, ramp rate and ramp duration requirements
  - Meet the needs of CPUC LTTP
- Study methodology should:
  - Mimic MRTU operating timelines and practices
  - Determine requirements independent of existing resources
  - Determine requirements independent of new conventional resources
  - Evaluate low probability events
  - Utilize load and wind stochastic characteristics

Fleet Characteristics

- Proposed objectives:
  - Identify the flexibility, controllability and speed of delivery attributes of new conventional resources – cycling, min. load, quick start and ramping capabilities, frequency response reserves, etc.
  - Identify options to improve overall coordination of existing and new resources
  - Evaluate and recommend changes to unit commitment and dispatch strategies to mitigate negative impact of variable generation
  - Meet the needs of LTPP

- Study methodology should:
  - Mimic MRTU operating timelines and practices
  - Accurately reflect Day-Ahead unit commitment and dispatch
  - Apply variable generation forecasts and forecast errors
  - Utilize load and wind stochastic characteristics

Overgeneration Studies

- Proposed objectives:
  - Quantify the frequency, duration, and magnitude of Overgeneration – potential curtailment by season and MWh
  - Identify mitigation measures
  - Evaluate high hydro, low hydro, once through cooling scenarios and ability of system to meet FRR requirement

- Methodology should:
  - Mimic MRTU timelines and practices
  - Accurately reflect Day-Ahead unit commitment and dispatch
  - Apply variable generation forecasts and forecast errors
  - Utilize load and wind stochastic characteristics
  - Incorporate expected changes in conventional fleet due to retirements, once-through cooling, etc.

Additional Studies

Fast Regulation

- Proposed Objectives:
  - Develop a methodology to assess the benefits of fast regulation
  - Quantify potential reduction in traditional regulation capacity
  - Build a framework for incorporating more fast responsive resources into the CAISO controlled Grid

- Methodology:
  - Under development

Additional Studies

Wide Area Energy Storage and Management System

- Proposed Objectives:
  - Develop operational principles, algorithms, market integration rules, functional design and technical specification for an energy storage device that mitigates the intermittency and fast ramps that occur at higher penetration of renewable generation,
  - Provide essential numerical results needed for the subsequent design of the system architecture and specification,
  - Provide a cost-benefit analysis and develop a business model for an investment-based practical deployment of such a system
- Methodology
  - Under Development

Additional Studies

Evaluation of Inter-hour Scheduling at Inter-ties

- Proposed Objectives:
  - Evaluate value of changing current hourly scheduling timeline to reduce overall Regulation requirements between balancing authorities,
  - Optimize available transmission capacity

- Methodology
  - Under Development

Stakeholder Feedback

- Input on objectives and scope.
- What gaps do you see?
- What else were you hoping would be covered?
- Did we miss other work that needs to be tied in somehow?
- What do you think the outputs of the studies should be?

Next Steps

- Future Working Groups
  - Collaborative Discussion on Scope and Objectives: February 2009
  - Analysis of Methodologies: March 2009

- Feedback due by January 20th:
  - Feedback to jblatchford@caiso.com