Research Evaluation of Wind Generation, Solar Generation, and Storage Impact on the California Grid

Paving the Way for Renewables Symposium
Project Final Results & Subsequent Investigations
October 25, 2010 Sacramento, CA

Report Prepared for:

California Energy Commission

Public Interest Energy Research Program

CEC-500-2010-010, June 2010

.

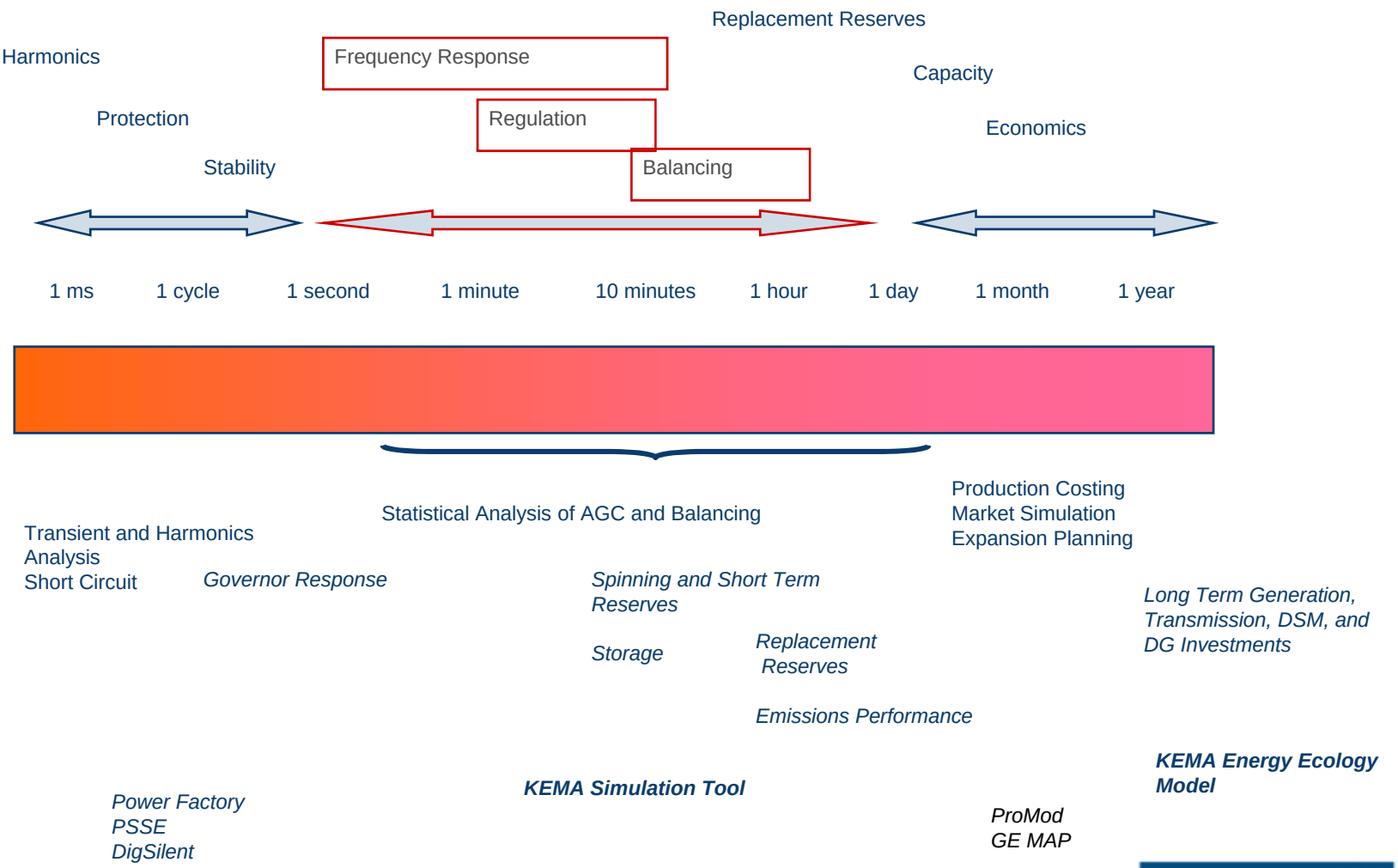
Project Overview

- Research examined the effects of high renewable penetration on intra-hour system operations of the California Independent System Operator (California ISO) control area
- Examined how grid-connected electricity storage might be used to accommodate the effects of renewables on the system
- Utilized KEMA's high-fidelity model (KERMIT) to analyze the effects of planned additions of renewable generation on electric system performance
- Research focused on required changes to current systems to balance generation and load second-by-second and minute-by-minute
- Study also assessed potential benefits of deploying grid-connected electricity storage to provide some of the required components—including regulation, spinning reserves, automatic governor control response, and balancing energy—necessary for integrating large amounts renewable generation.

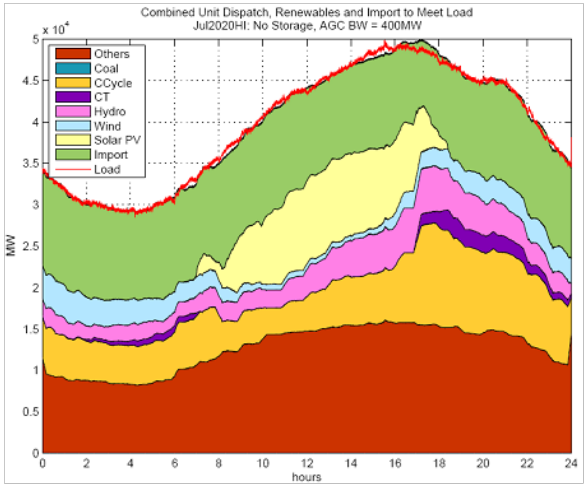
Context

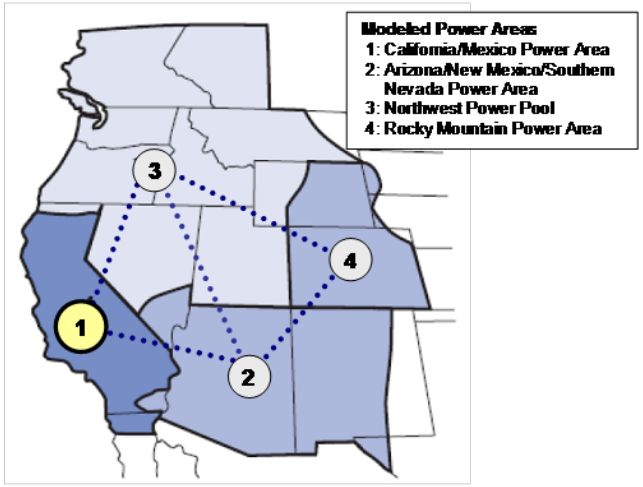
- Automatic generation control operates the generators that supply regulation services (up and down) every 4 seconds to keep system frequency and net interchange error as scheduled. The *real-time dispatch* buys and sells energy from generators participating in the real-time or balancing market every five minutes to adjust generator schedules to track a system's load changes.
- Regulation in MW is the amount of second-by-second *bandwidth* or controllability used in balancing generation and load. Spinning reserve is the excess amount of on-line generation capacity over the amount required to supply load and available to respond to sudden load changes or loss of a generator.
- Governor response is the near-instantaneous adjustment of each generator's output in response to system frequency changes, caused by the generator speed-governing device.

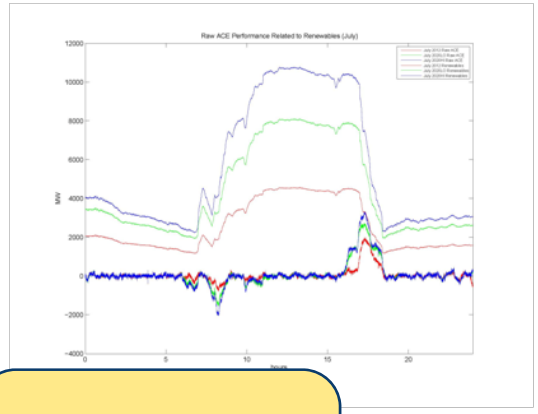
Time Domain, Problems, and Methods



KEMA Simulation Tool







Generator Trip

Load Rejection

Wind Power Forecast versus Actual

Volatility in Renewable Resources

Standard Inputs:
Load
Plant Schedules
Generation Portfolio
Grid Parameters
Market/Balancing

Scenarios:
Increasing Wind
Adding Reserves
Storage Parameters
Test AGC Parameters
Trip Events

KERMIT
24h Simulation

Generation
- **Conventional**
- **Renewable**

Frequency Response

Inter-connection

Real Time Market

Outputs:
ACE
Power Plant MW Outputs
Area Interchange
Frequency Deviation

Data Summary

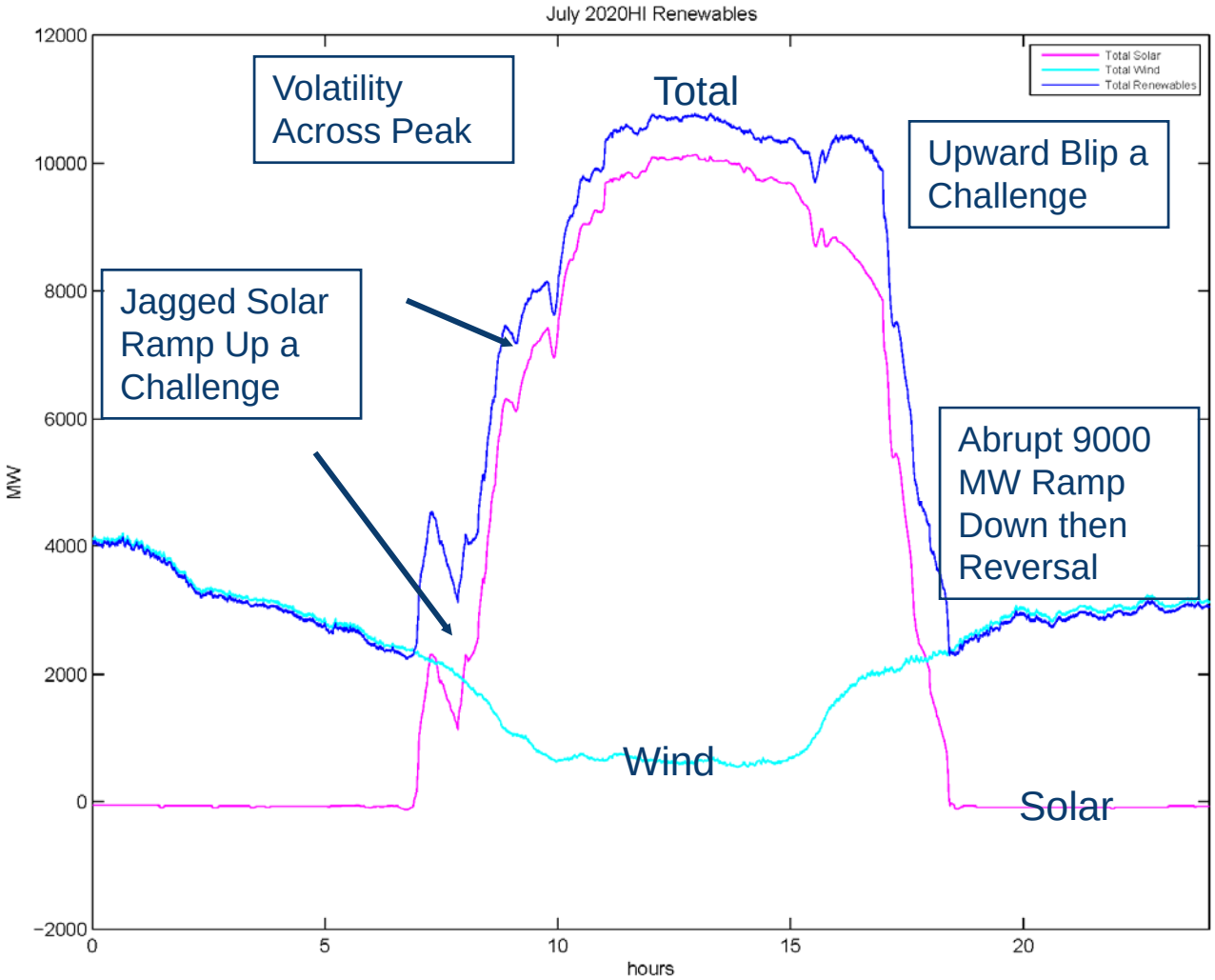
- We have time-series data for the following days, which are used during calibration process:
  - 06/05/2008
  - 07/09/2008
  - 10/20/2008
  - 02/09/2009
  - 04/12/2009

- For simulation of future years: Existing time series were scaled up to reflect the projected capacities in 2012 and 2020.

Plant Capacity in Megawatts

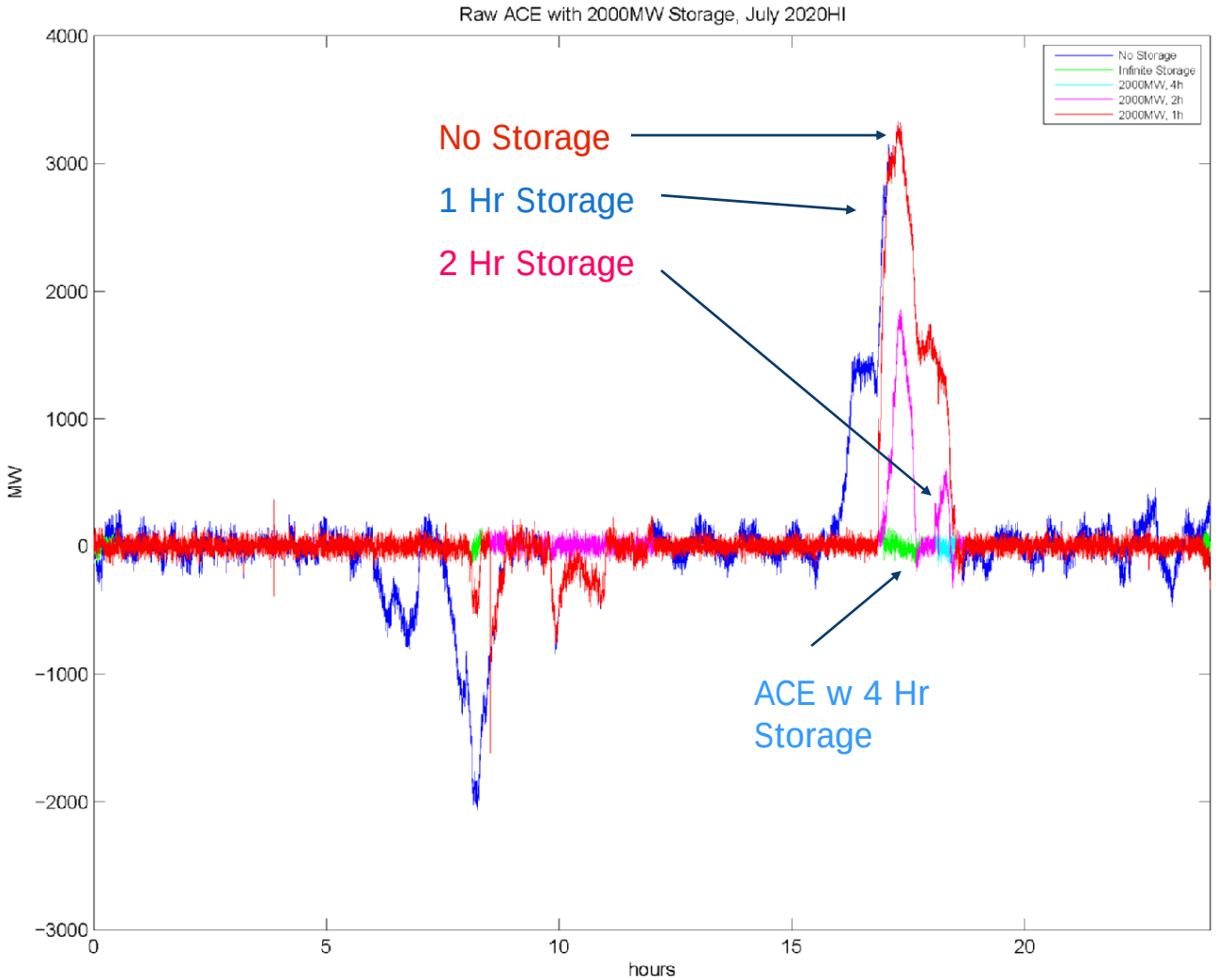
Year	2009	2012	2020 low	2020 high
PV	400	830	3234	3234
CST	400	996	7297	10000
Wind	3000	5917	10972	13000

July Renewables – 2020 High Penetration



Evaluating Performance - 2000 MW Storage, July 2020HI Scenario

System Area Control Error (ACE)



4 Hr works

1 Hr does not work

Major Conclusions

- System Requirements for “Normal” (non-ramping) periods
  - > 800 MW regulation in 2012
  - Approximately 1,600 MW in 2020
  - Storage more effective in smaller incremental amounts
- In the 2020 33% High Renewable Capacity Case the System may Require 3000 – 4000 MW of Regulation & Reserves
  - Even so, performance will not be acceptable by today’s standards
  - Requires further investigation of renewable scheduling for certainty
  - System appears to have adequate ramping capability in CT & Hydro but wind / solar scheduling vs. conventional generation is a major difficulty
  - Performance will be sensitive to 15 – 30 minute errors in renewable forecasting
- 3000 MW / 6000MW of Storage will Suffice (except possibly for the April day studied)
  - Preserves current levels of performance with respect to ACE, Frequency, CPS1
- Storage Requires an Aggregate Ramping Capability of 0 – 100% in 5 minutes in the 33% scenario
  - May indicate limited effectiveness of pumped hydro and CAES

Major Conclusions (2)

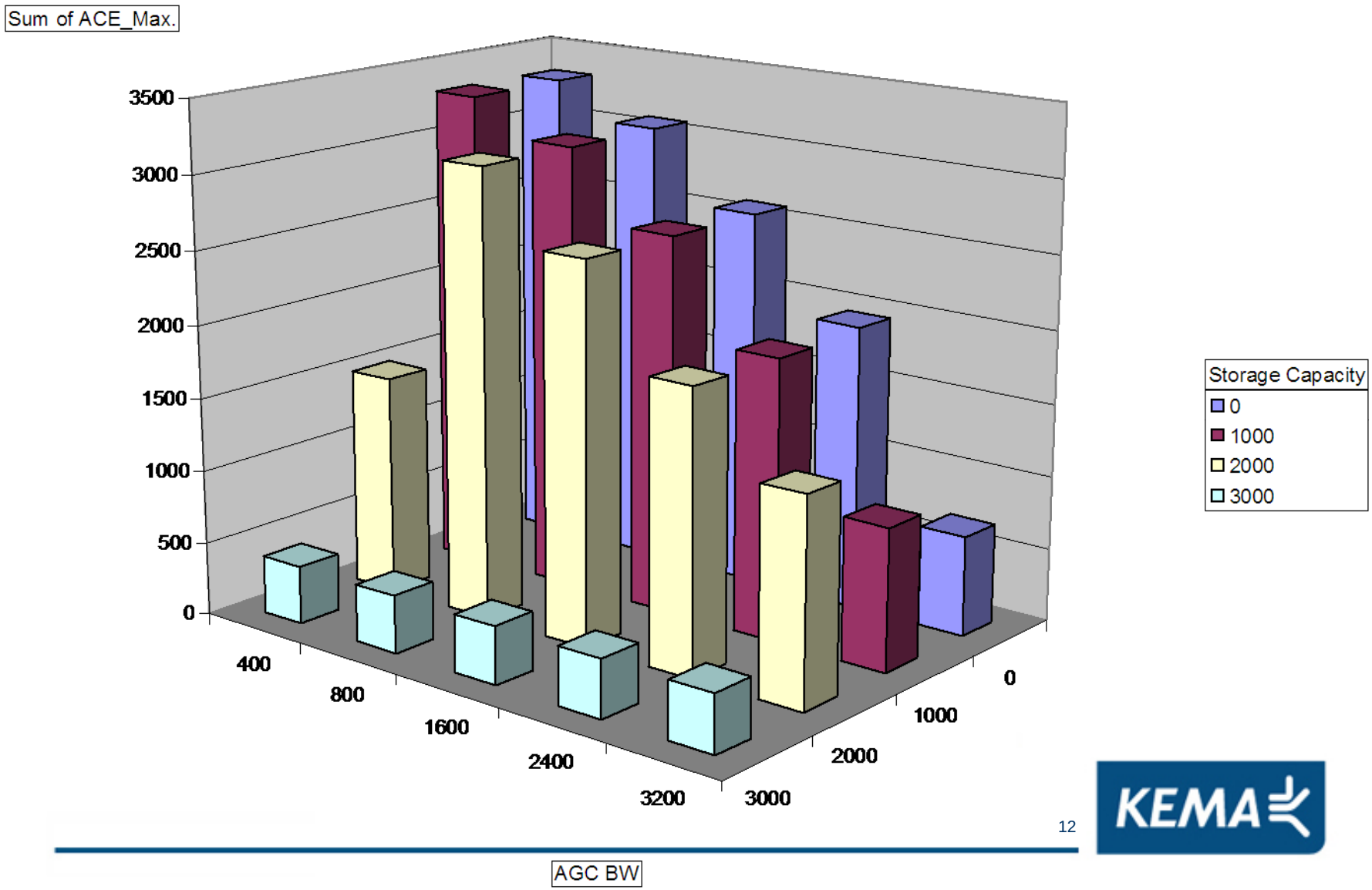
- Storage equivalent to 110 MW Combustion Turbine appears to range between 30 – 50 MW of storage
  - Varies with other system conditions especially how much regulation is present
- Use of Combustion Turbines for increased regulation (forced commitment) increases overall system emissions by approximately 3% vs. using storage

System performance with storage and increased regulation during non-ramping hours

Scenario	Added Amount (MW)		Worst Maximum Area Control Error (MW)		Worst Frequency Deviation (Hz)		Worst Control Performance Standard 1 (percent)	
	Regulation	Storage	Regulation	Storage	Regulation	Storage	Regulation	Storage
20% RPS*	400	200	477	311	0.0470	0.0438	184	195
33% RPS* Low	800	400	480	493	0.0610	0.0609	190	190
33% RPS* High	1,600	1,200	480	344	0.0610	0.0590	191	196

ACE maximums for July 2020HI

Day	DAY07-09-2008	Scenario	2020HI	CT	0.2	Hydro	0.2



Policy Recommendations

- Use fast storage for regulation, balancing, and ramping either as a system resource to address aggregate system variability or as a resource used by renewable resource operators to address individual resource variability and ramping characteristics
- Procurement of increased regulation, balancing, and reserves by the California ISO
- Consider possible imposition of requirements on renewable resources to accommodate their effects on grid operation, such as ramp rate limits on renewable resources, more accurate short-term forecasting, sub-hourly scheduling, and other possibilities
- Pursue changes to the market system to encourage fast ramping by conventional generation resources
- Use demand response as a ramping/load following resource, not just a resource for hourly energy in the day-ahead market or for emergencies

Study Strengths & Weaknesses

Strengths:

- Detailed High Fidelity System Dynamic Model
- Calibration to CA ISO Data
- Ability to investigate the interaction of renewables, scheduling, dispatch, regulation, droop
- Development of algorithms for renewables and storage integration
- Runs 24 Hrs in approx 15 minutes
- Extensive post processing analysis capabilities

Weaknesses:

- Only a few representative days studied
- Real Time Dispatch / Balancing was old BEEP rather than MRTU
  - Some look-ahead embedded
- Conventional Unit response capabilities “optimistic”
  - Follow dispatch at rate limit promptly; regulation through full range
- “Perfect” Renewables Forecasts
- Concentrating Thermal Solar data based on two existing plants

Goal – Understand Renewables' Impact on Grid Operations

- Understand variability and volatility of Renewables – esp CST and PV
- Understand characteristics and potential of ADR
- How to forecast better – day ahead, hour ahead, intra hour
- How to factor renewable variability/volatility in dispatch and how to use storage and ADR
- What resource capabilities (storage, ADR) are needed to manage renewables
- How to distribute volatility management across time frames and products
- Understand Requirements of AGC to manage Renewables and Use ADR and Storage
- Develop and test AGC Algorithms
- What monitoring, command, and control over new resources is required?
- Understand requirements of AGC to manage Renewables and use ADR and storage
- Develop and test AGC algorithms
- What monitoring, command, and control over new resources is required?

What are Priorities for Future Work?

Develop dynamic models of CST and CSP / utility scale PV

Develop statistical description of variability with temporal and spatial correlations

Develop consensus forecast

Develop models of distributed PV and ADR for use in load disaggregation

Incorporate Renewable Variability, Storage characterizations, and ADR characteristics in Day Ahead Scheduling and Real Time Dispatch

Develop realistic scenarios of conventional unit performance for simulation

Integrate ADR, updated renewables and storage models

Install KERMIT at CA ISO and deliver training

Develop AGC Algorithms and Test

Identify “scenarios” for future portfolio and use in 2012 and 2020 studies

Integrate production cost / market simulations as inputs to KERMIT

Use KERMIT to iterate with production and market simulations around ancillaries requirements

Study impacts of forecasting accuracies