Wind and Solar Generation and Storage Impacts on the California Grid

Results of Joint KEMA and CAISO study performed in 2009

Presentation to NARUC Meeting

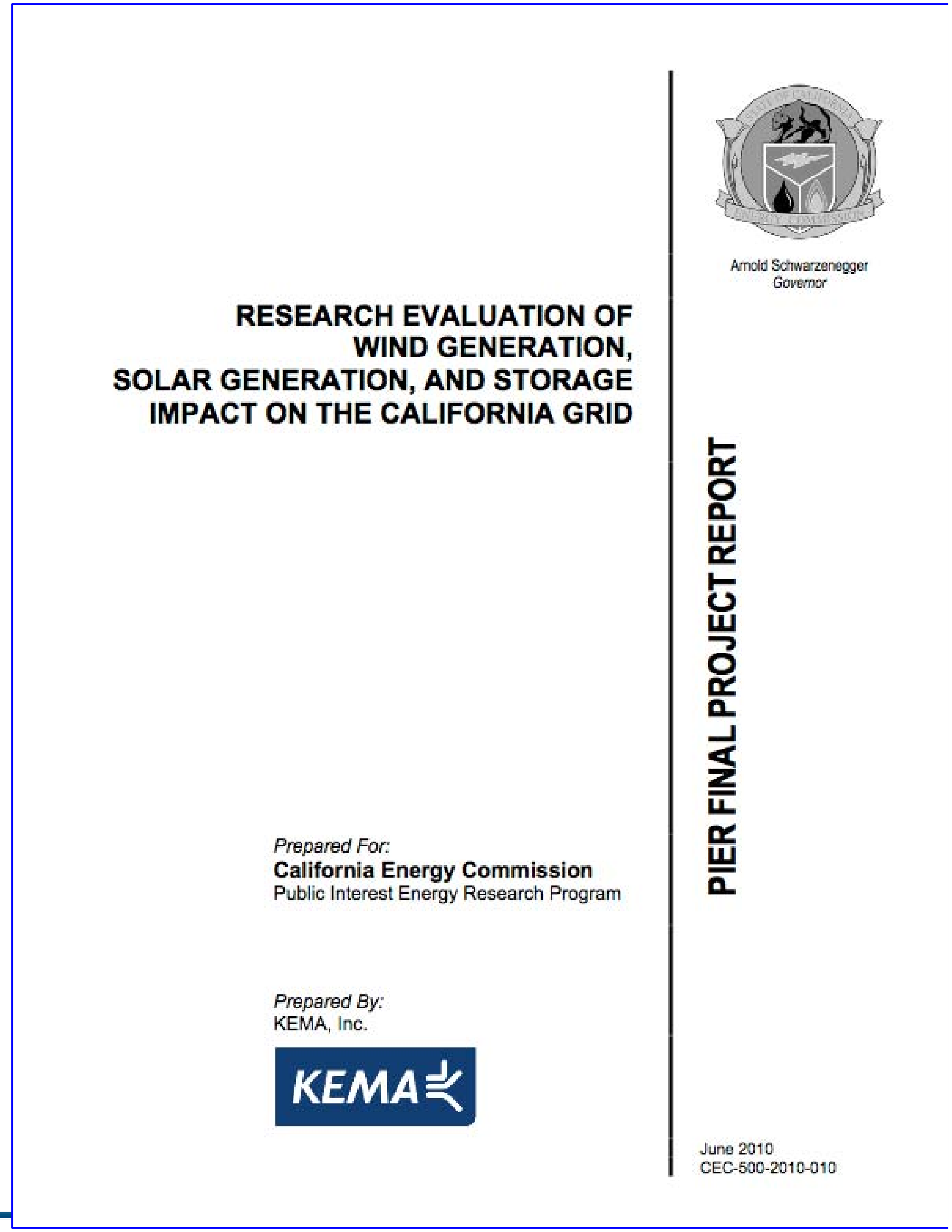
Sacramento, CA

By David Hawkins

July 18 2010,

Report published on CEC website in June, 2010

The report describes the new analytical model that KEMA developed to analyze the minute to minute variable of wind and solar renewable resources, the ability of conventional generation resources to the variability, and the role that energy storage can fulfill to assist with the integration of large amounts of renewable resources.



Arnold Schwarzenegger
Governor

RESEARCH EVALUATION OF
WIND GENERATION,
SOLAR GENERATION, AND STORAGE
IMPACT ON THE CALIFORNIA GRID

PIER FINAL PROJECT REPORT

Prepared For:
California Energy Commission
Public Interest Energy Research Program

Prepared By:
KEMA, Inc.

June 2010
CEC-500-2010-010

Project Objectives

- Evaluate Impact of 20% and 33% Renewable Portfolios on California Grid Operations
  - AGC Performance, Load Following Ability
- Determine Ancillary Services (Regulation, Governor Response) Requirements of 20% and 33% Renewable Portfolios
- Determine Requirements for Use of Large Scale Grid Connected Storage for Ancillary Services
- Evaluate Storage Equivalent of a 100MW Combustion Turbine
- Determine Policy Issues Affecting Storage Development in California

Study Highlights

- Model of California generators, loads and WECC regions
  - Second by second simulation for 24 hours of California system
  - Model of 4 second EMS dispatch of regulation
  - Model of Market dispatch of supplemental energy
  - Model of wind and solar variability – but limited solar data was available
- Number of days studied was very limited
  - Intensive data collection / validation effort involved
- Results clearly showed that:
  - Energy Ramps in less than 1 hour is going to be a major issue
  - Increased Renewables will Increase regulation needs significantly
  - Large amounts of regulation alone will not solve the problem
  - Energy Storage with 2 hours of capacity or more is an (expensive) solution
  - This simulation tool can be a major asset for renewable integration studies
  - AGC Algorithm development desirable for renewables integration

Calibrated to System Frequency Response (Unit Trip) and to System AGC Performance (CPS, ACE PSD)

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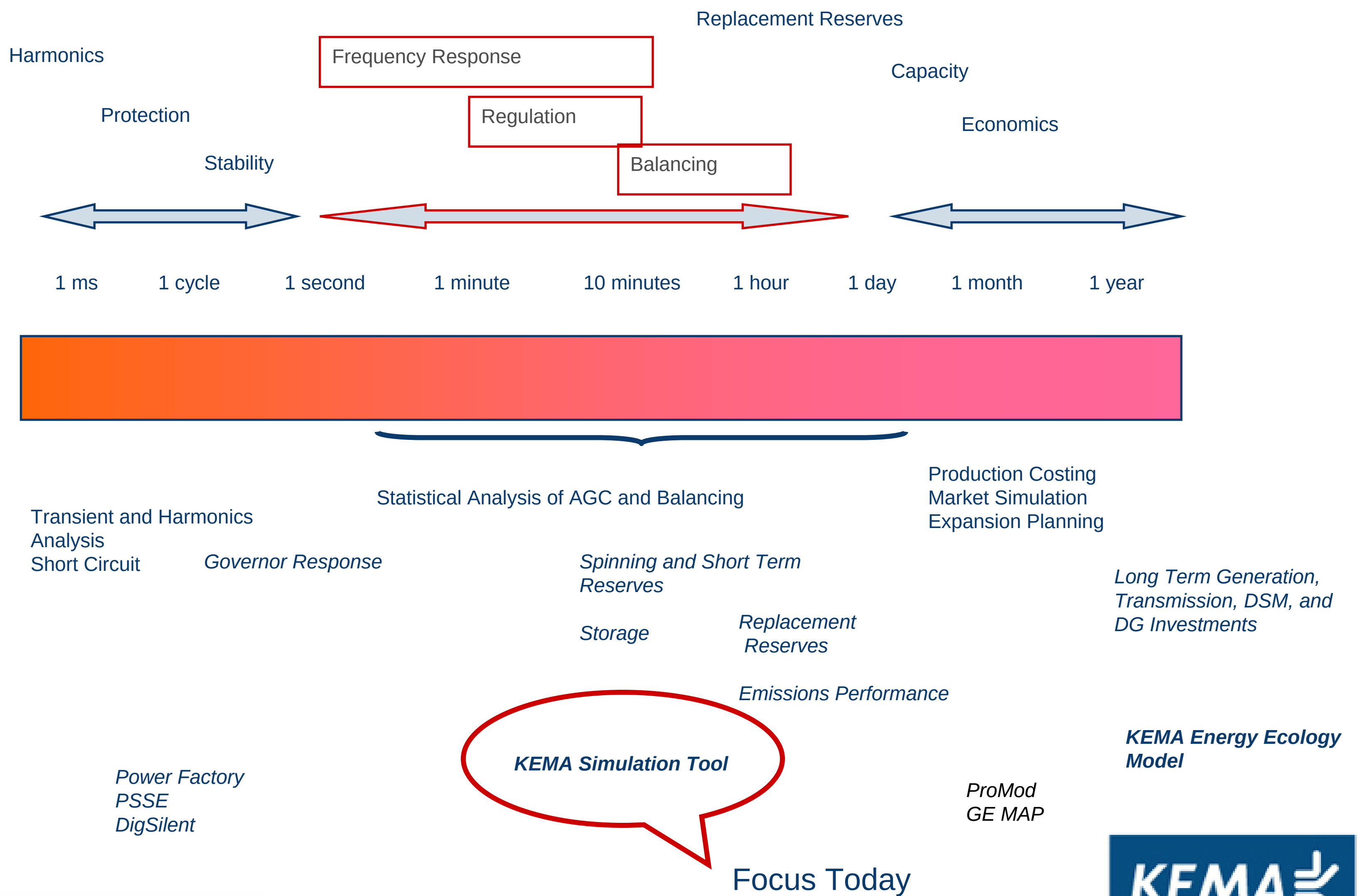
Time Domain, Problems, and Methods



Study Strengths & Weaknesses

- Detailed High Fidelity System Dynamic Model
- Calibration to "Real" World
- 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

- 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

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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

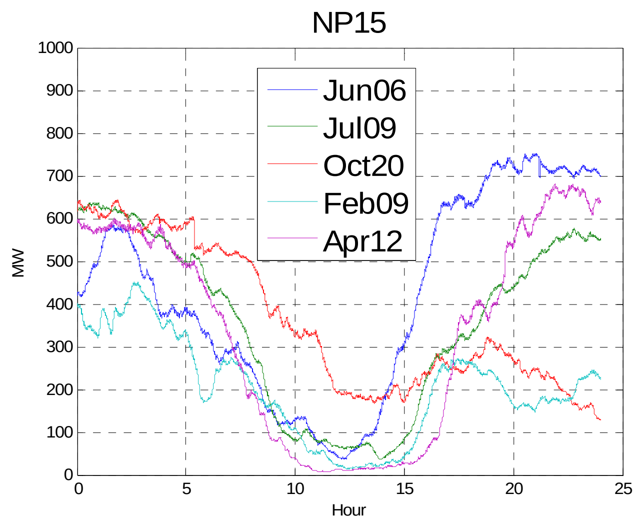
Year	**2009**	**2012**	**2020 low**	**2020 high**
PV	400	830	3234	3234
CST	400	996	7297	10000
Wind	3000	5917	10972	13000

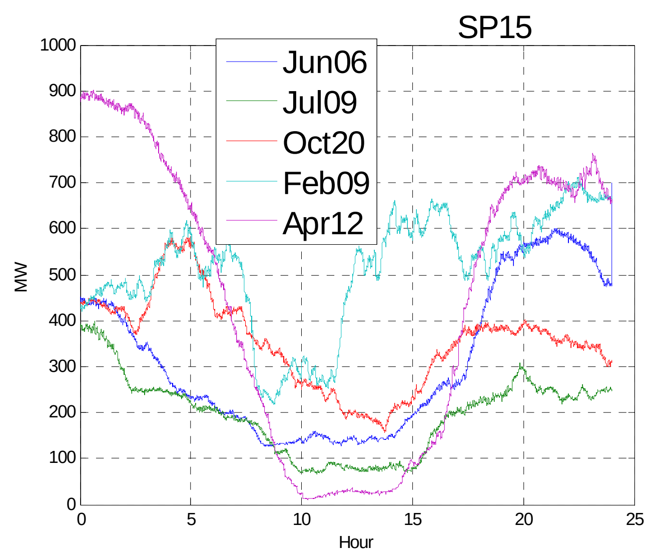
Wind power

- Available from CAISO as time series.
  - Time series of the past (see side graphs), were scaled up according to capacity table
- Appropriate weightings were used to reflect location of future windfarms including wind in BPA Control Area that has to be balanced by CA ISO

Plant Capacity in Megawatts

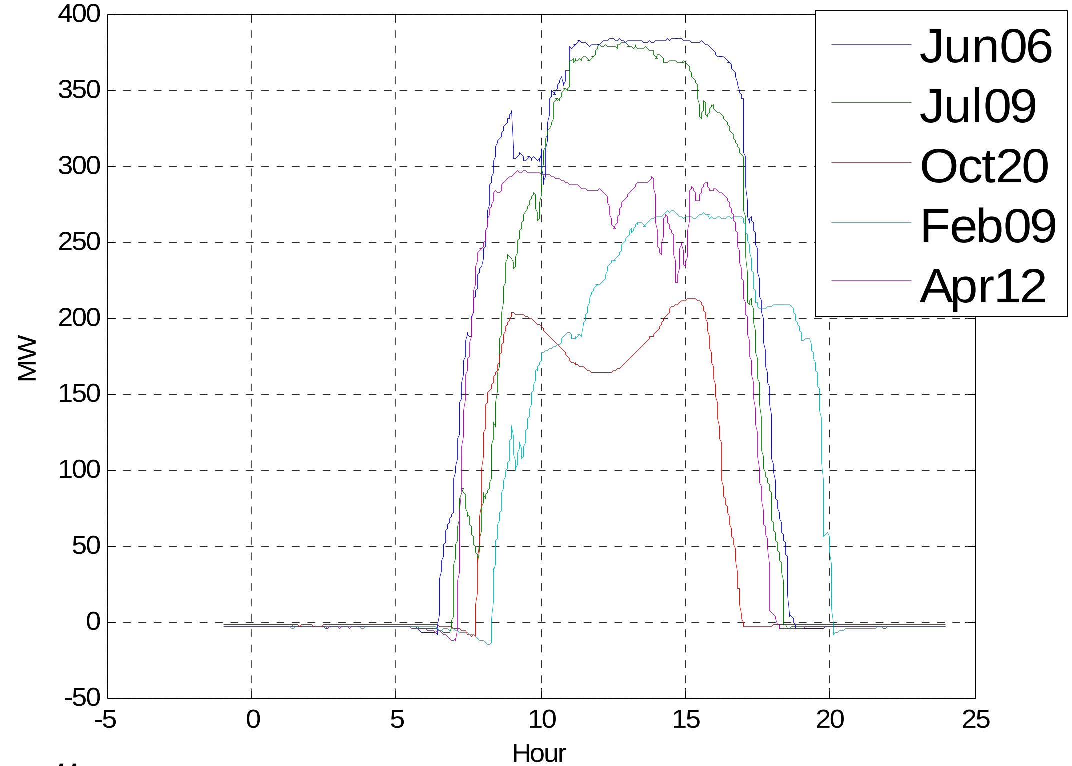
Year	2009	2012	2020 low	2020 high
Wind	3000	5917	10972	13000





Concentrated Solar Thermal

- Available from CAISO as time series
- Afternoon production extended two hours to reflect gas firing
- Scaled up to reflect capacity table
  - Belief is that geographic diversity will be minimal



Plant Capacity in Megawatts

Year	2009	2012	2020 low	2020 high
CST	400	996	7297	10000

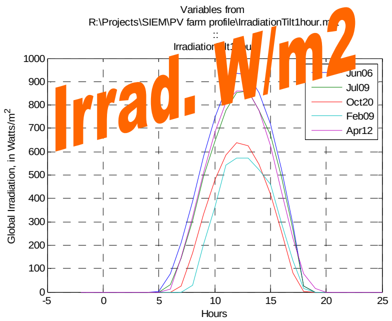
Photovoltaic

- Lacking measurements, we will use simulated time series.
- KERMIT has PV model:
  - Direct inputs are time series for Temperature (degC) and Solar intensity (W/m^2).
    - From NOAA site, we can get these data for selected days for a particular locations in the US.
  - Indirect inputs are related to panel characteristics (electrical and tilt), the surroundings (clouds, abedo)
- The next slide shows simulated time series for a 100MW fictitious PV farm in N. California.
- Such time series will be scaled up for 2012 and 2020, based on the capacity table below.

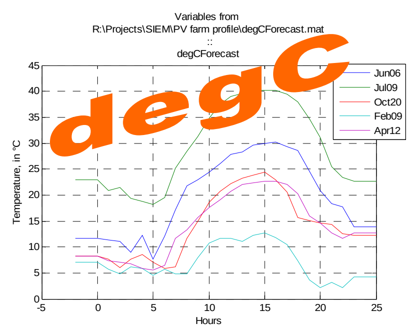
Plant Capacity in Megawatts

Year	**2009**	**2012**	**2020 low**	**2020 high**
PV	400	830	3234	3234

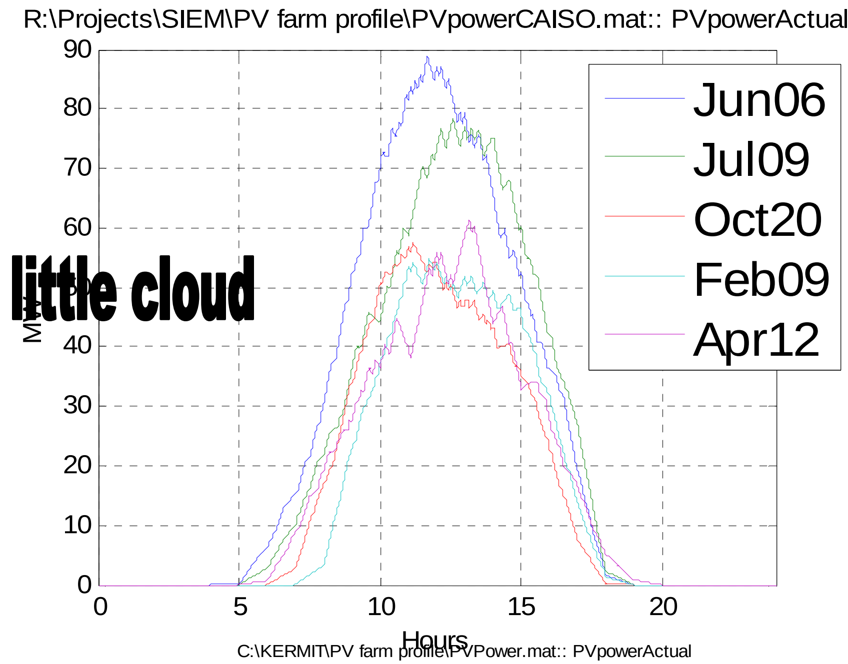
Solar Panel model – 100MW size

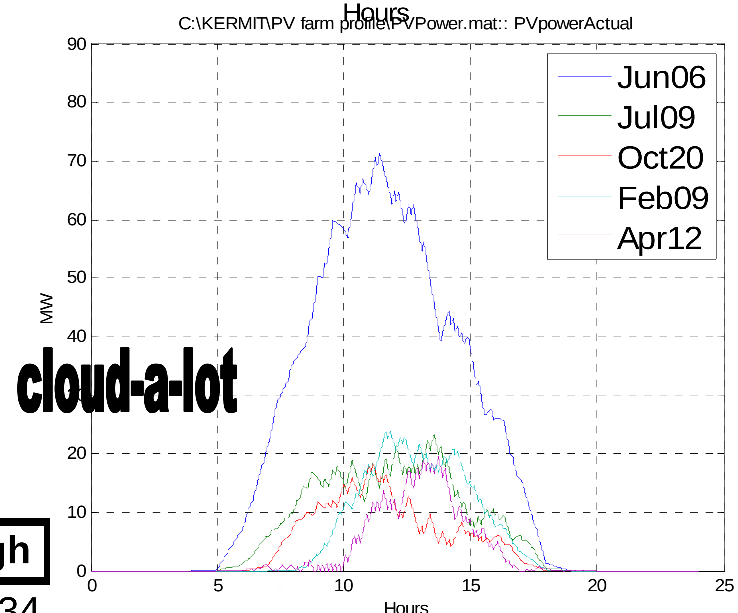


Raw data (Solar Irradiation, temp) come from ftp://ftp.ncdc.noaa.gov. Choose a site near Sacramento



PV panel model, incl. Cloud effect, tilt angle, abedo, etc.





Plant Capacity in Megawatts

Year	2009	2012	2020 low	2020 high
PV	400	830	3234	3234

Adjusting Conventional Generation Schedules for the 2012 and 2020 Cases

- Some conventional plants must be decommitted in hourly schedules
  - Each MW from renewables would mean 1MW less from conventional plants
  - Plan A: use results from CAISO/Nexant production costs study. (not available in study time frame)
  - Plan B: “Poor Man’s Decommit”
    - Of the 250 plants modeled, we have ranked them by age and by type.
    - Plants are decommitted based on the priority list. (“Least efficient” units would go first.)
  - Some plants will be retired anyway. (per preliminary list of scheduled retirements)
  - Different cases / scenarios “re-commit” Combustion Turbines (or any other class of unit selectively) to provide ramping / regulation at specified level
  - New schedules “sanity checked” against scheduled imports, renewables, and load to ensure balance

Comment: Scheduling / De-commitment process is NOT for best economics but to study system dynamics; precise economics not a requirement for this study

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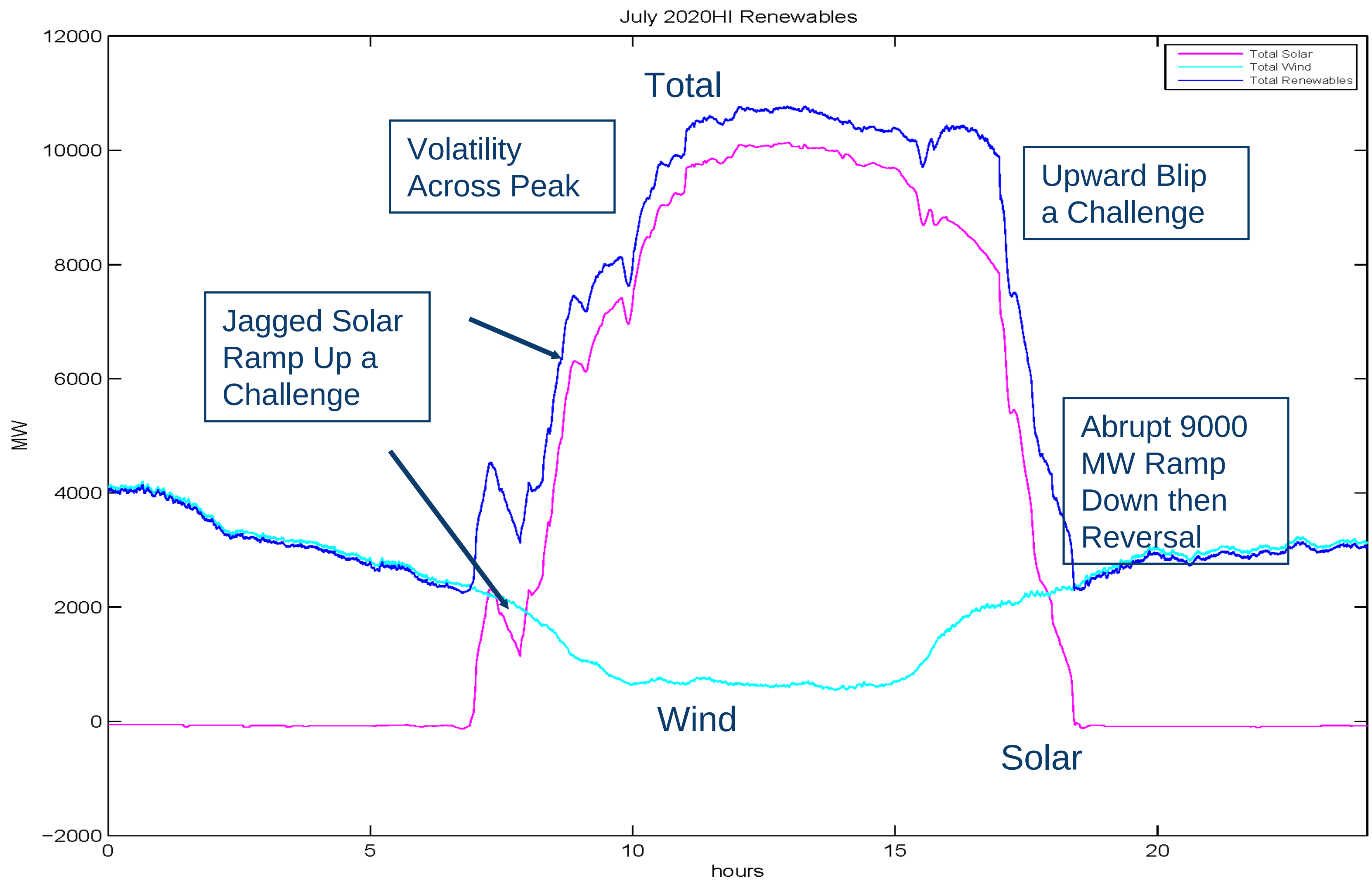
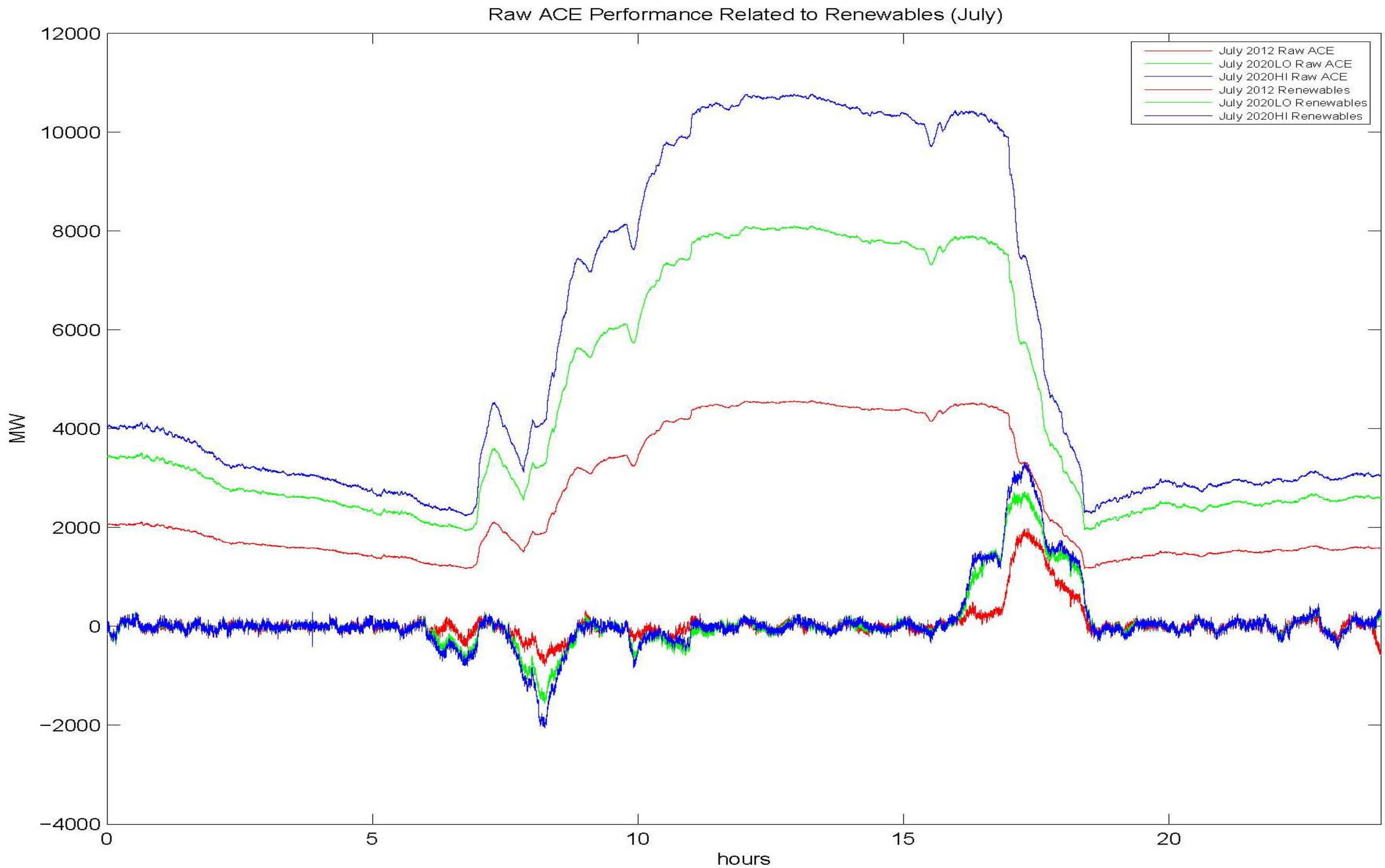
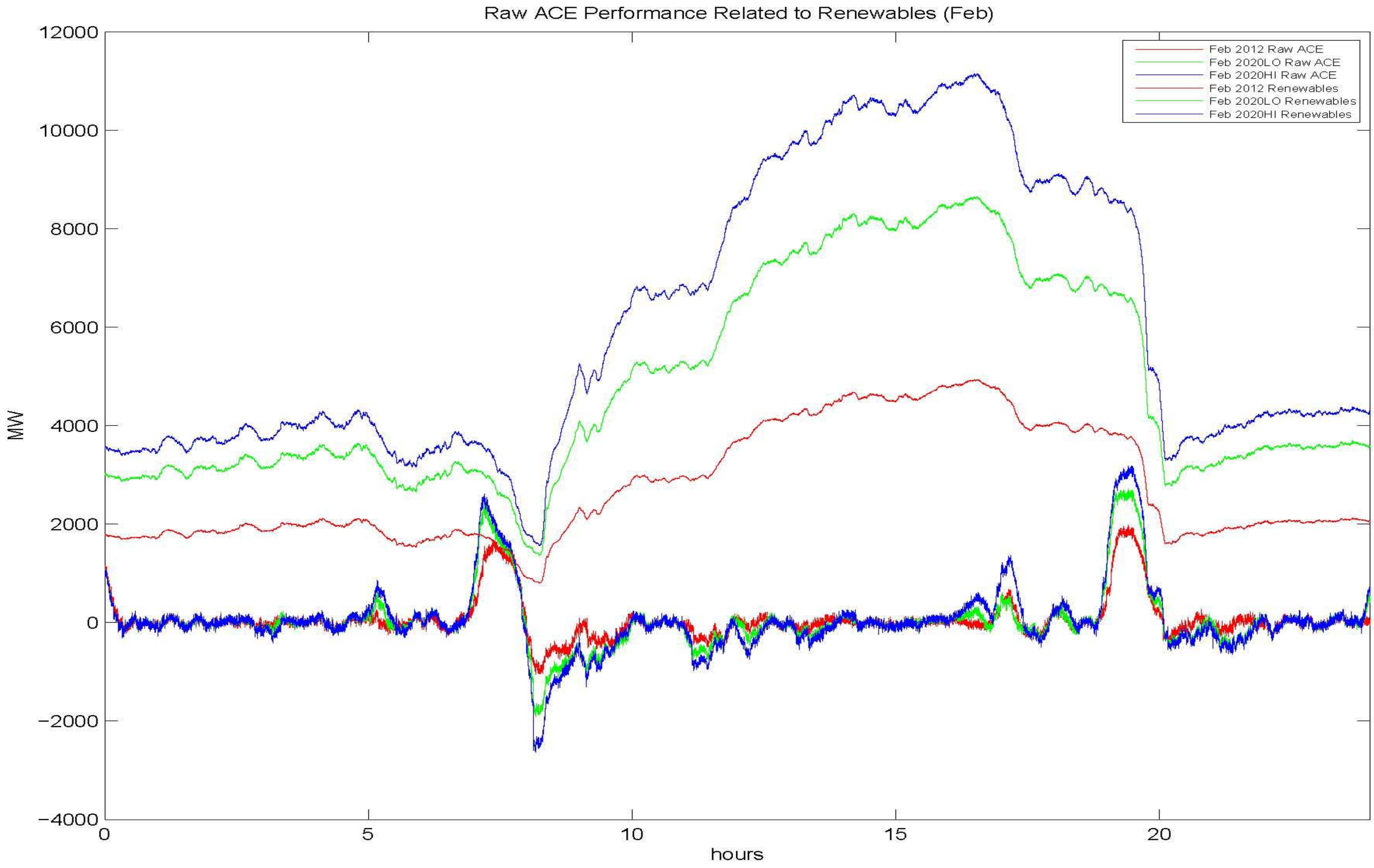
July 2020 High Solar Renewables



July Day – ACE across renewable scenarios

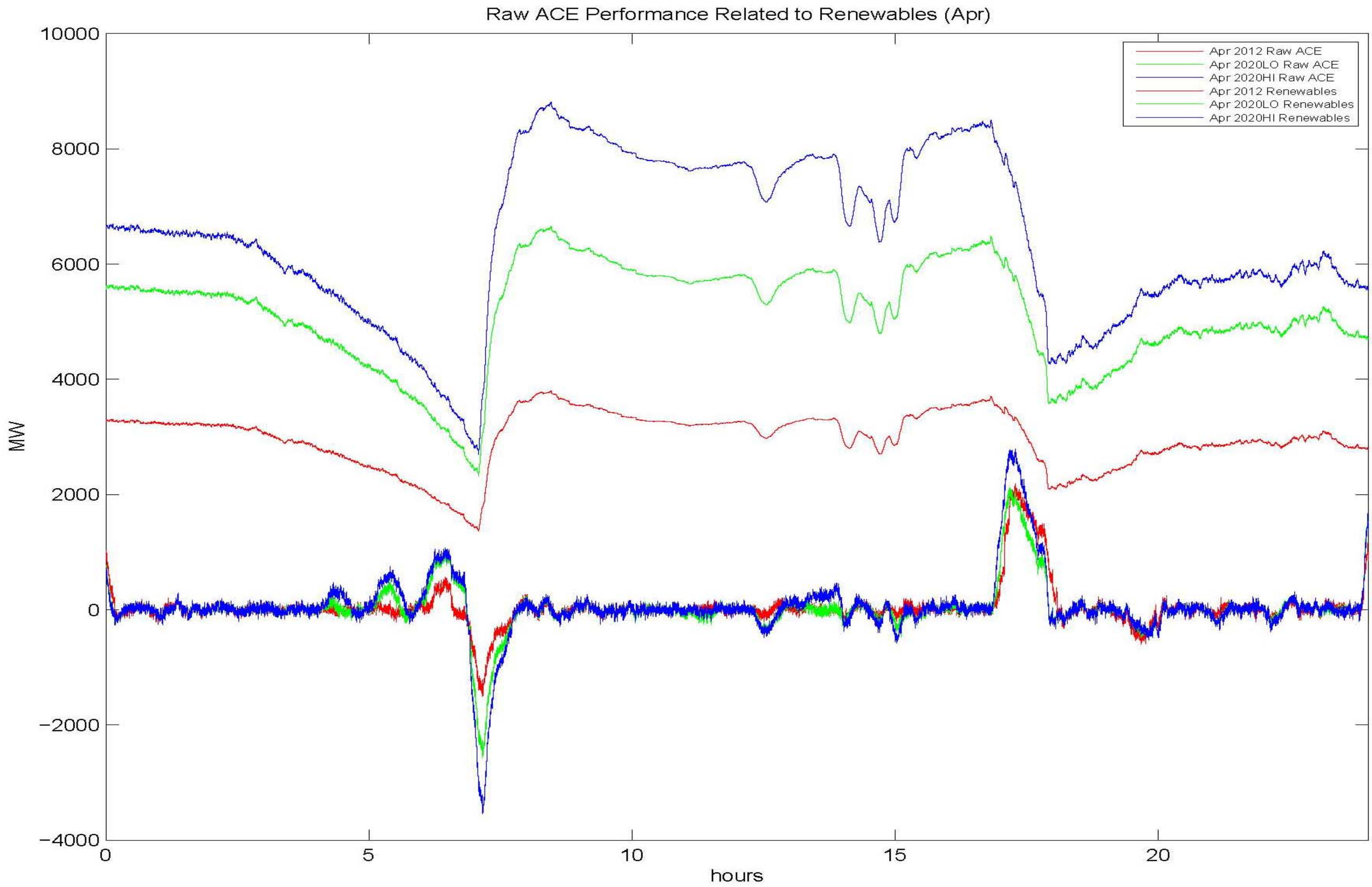


Feb Day – ACE

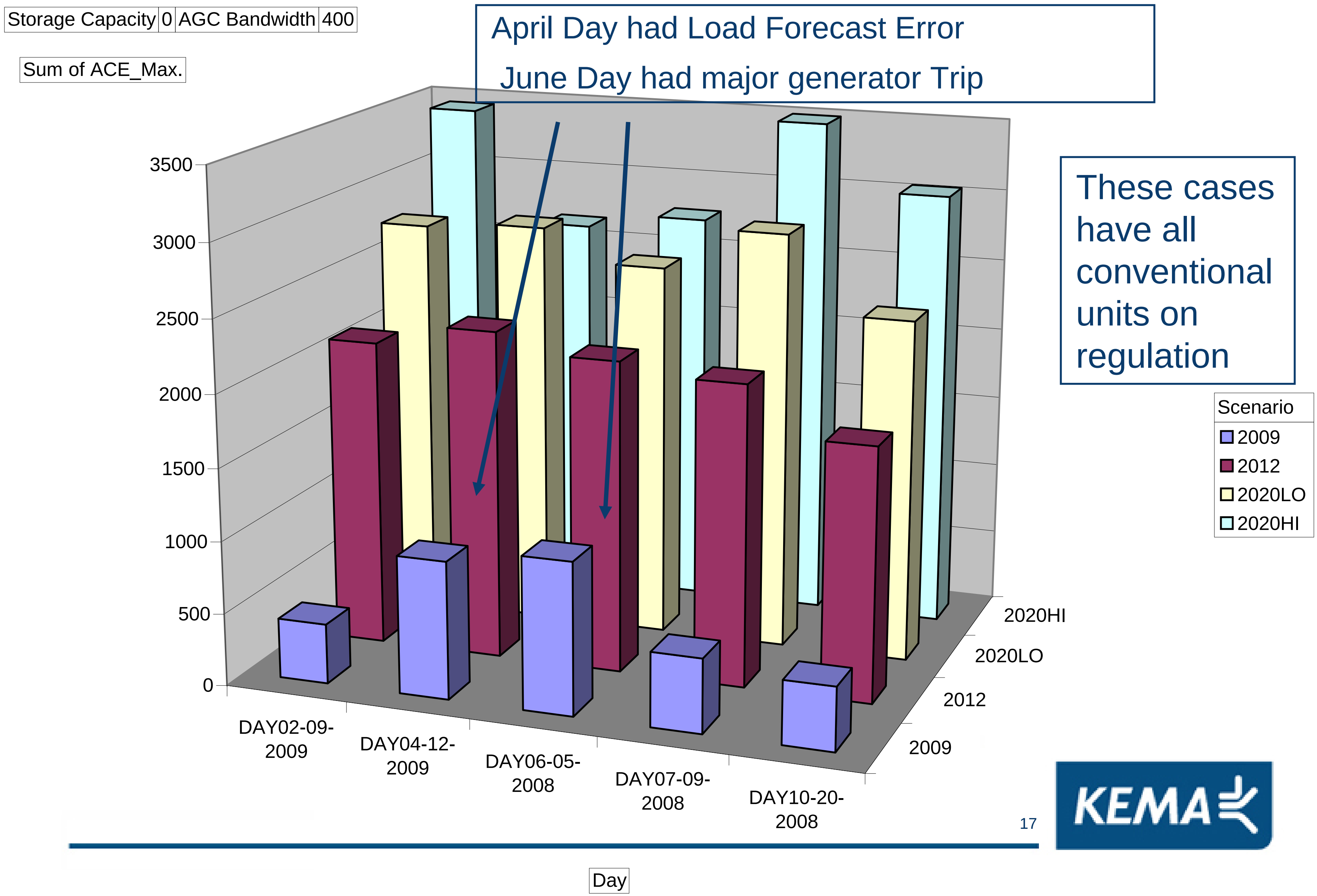


Raw ACE Performance Related to Renewables (Feb)
Feb 2012 Raw ACE
Feb 2020LO Raw ACE
Feb 2020HI Raw ACE
Feb 2012 Renewables
Feb 2020LO Renewables
Feb 2020HI Renewables
12000
10000
8000
6000
4000
2000
0
−2000
−4000
MW
0
5
10
15
20
hours

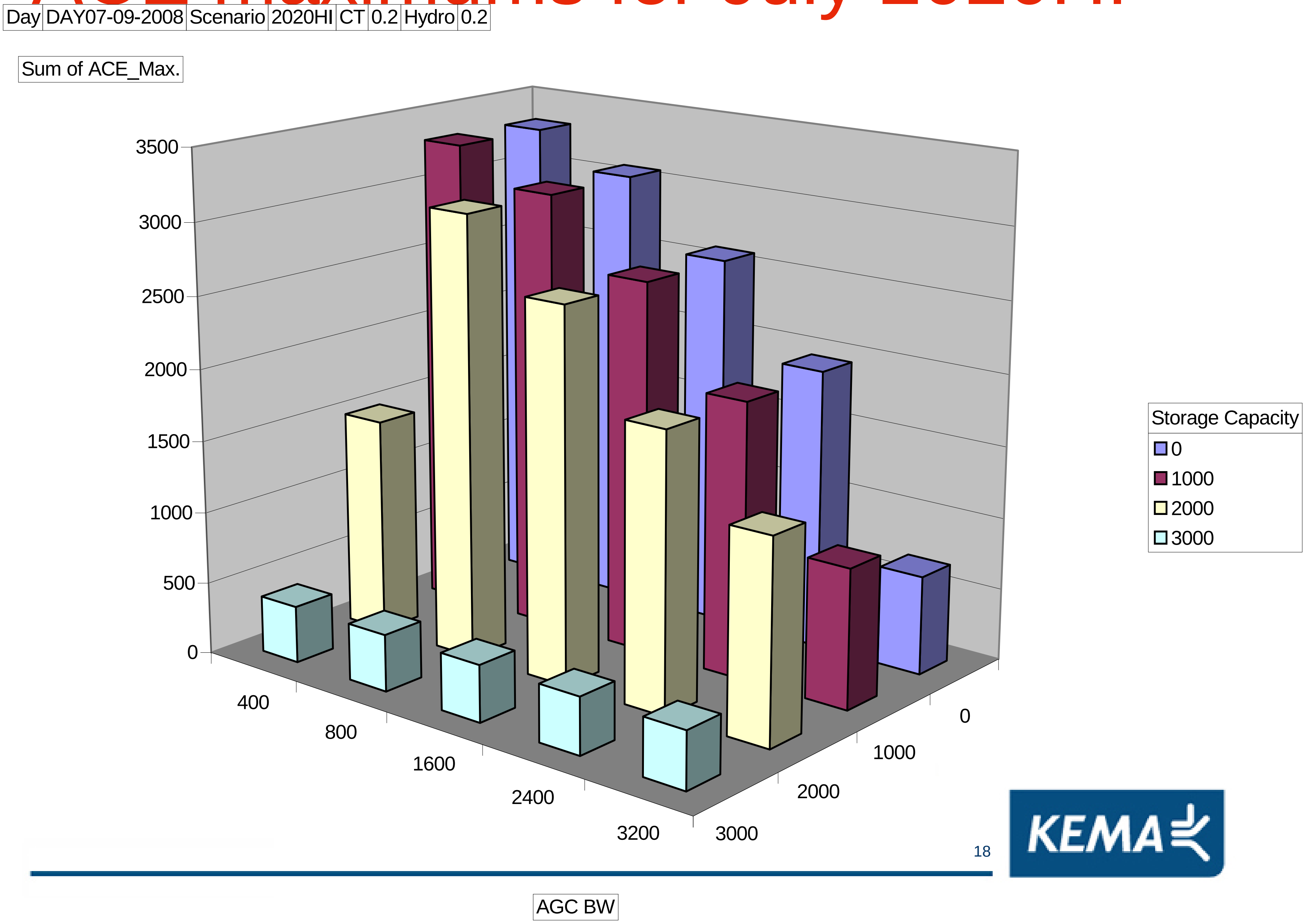
April Day – ACE



ACE maximums for Base Cases



ACE maximums for July 2020HI



Adding Storage for Normal Operations

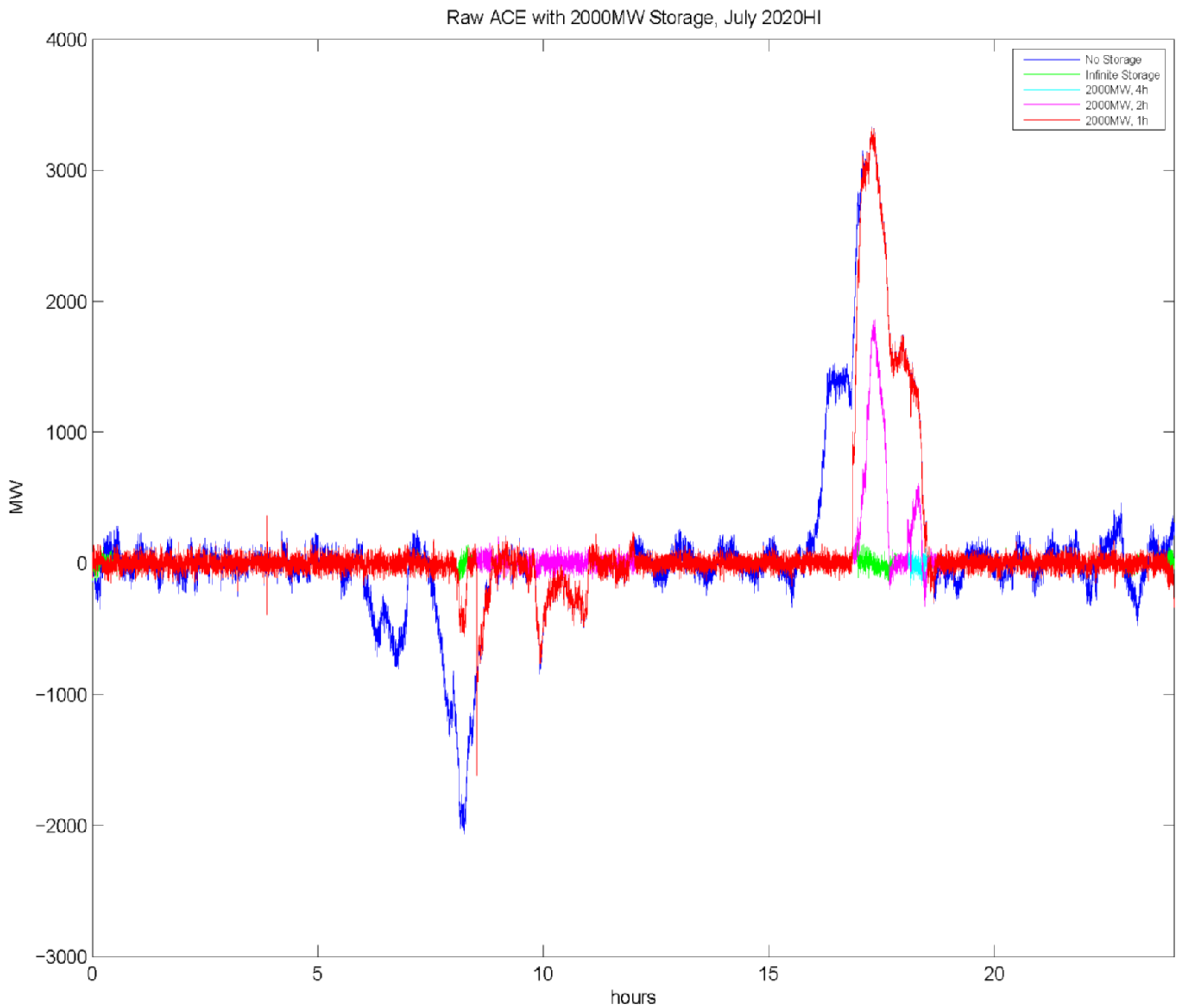
		Performance Across Regulation Levels With No Storage			Storage Added to 400 MW Regulation			
Year	Regulation	worst max ACE	worst dF	worst CPS1	Storage Added	worst max ACE	worst dF	worst CPS1
2012	400	477	0.047	184	200	311	0.0438	195
2012	800	325	0.0425	195				
2012	1600	316	0.0424	196				
2020 LO	400	690	0.063	173	400	493	0.0609	190
2020 LO	800	480	0.061	190				
2020 LO	1600	480	0.061	194				
2020LO	2400	480	0.061	194				
2020 HI	400	950	0.062	141	1200	344	0.059	196
2020 HI	800	662	0.061	172				
2020 HI	1600	480	0.061	191				
2020 HI	2400	382	0.061	191				
2020 HI	3200	382	0.061	191				

200 MW Storage > 400 MW Regulation

400 MW Storage = 400 MW Regulation

1200 MW Storage > 2400 MW Regulation

Evaluating Storage



2000 MW of storage with 4 hours of energy solves the problem.

2000 MW with 2 hours of energy helps

2000 MW of storage with only 1 Hr of energy does not control the ACE problem.

Major Conclusions

- 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 a major difficulty
  - Performance will be sensitive to 15 – 30 minute errors in renewable forecasting
- 3000 MW / 6000MWH of Storage will Suffice (except possibly for the April day Studied)
  - Preserves current levels of performance wrt 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
- System Requires > 800 MW Regulation in 2012 and Approx. 1600 MW in 2020 for "Normal" (non-ramping) Periods
  - Storage more effective in smaller incremental amounts

Major Conclusions (2)

- Storage Equivalent to 110 MW CT Appears to Range Between 30 – 50 MW of Storage
  - Varies with other system conditions especially how much regulation is present
- Use of CT's for Increased Regulation (forced commitment) Increases Overall System Emissions Approximately 3% vs Using Storage
- Changing Real Time Dispatch Periodicity to 30 Sec (vs 5 Minutes) Has Modest Benefits – Not Significant

Next Phase Proposed

- Study More Days
  - Begun under CEC CSI Auspices
- Use CA ISO Production Cost simulations to establish future hourly schedules
- Simulate MRTU as appropriate
- Investigate Forecast Errors and Significance
- Develop dynamic models of Concentrating Solar Thermal
  - Investigate thermal storage and ramping controls

Conclusions

- Frequency Responsive Load (or Storage /Autonomous DR) is of benefit
  - Will be of greatest benefit in an island situation
- Using fast resources in response to ACE is better than response to frequency (assuming similar time constants and control/ communications) especially in terms of controlling tie flows resulting from generation/load imbalance
- Best choice of control will depend upon the situation and the problem being addressed
  - Autonomous frequency response has the virtue of requiring no control / communications