California Independent System Operator Renewable Integration Study

Clyde Loutan

California ISO
Your Link to Power

Achieving California's 20% Renewable Operation Issues

The transmission system analysis accounts for existing and new wind installations

The ISO study assumes the new generation is installed in the Solano and Tehachapi wind areas based on projects in the transmission queue and approved transmission upgrades.

The ISO study accounts for about 2,600 MW of existing wind generation.

California ISO
Your Link to Power

Operational Studies

- Objectives of Operational Studies

  To Determine:

  - Magnitude of multi-hour ramps
  - Load Following Capacity and Ramping Requirements
  - Regulation Capacity and Ramping Requirements
  - Over generation Issues and Potential Solutions

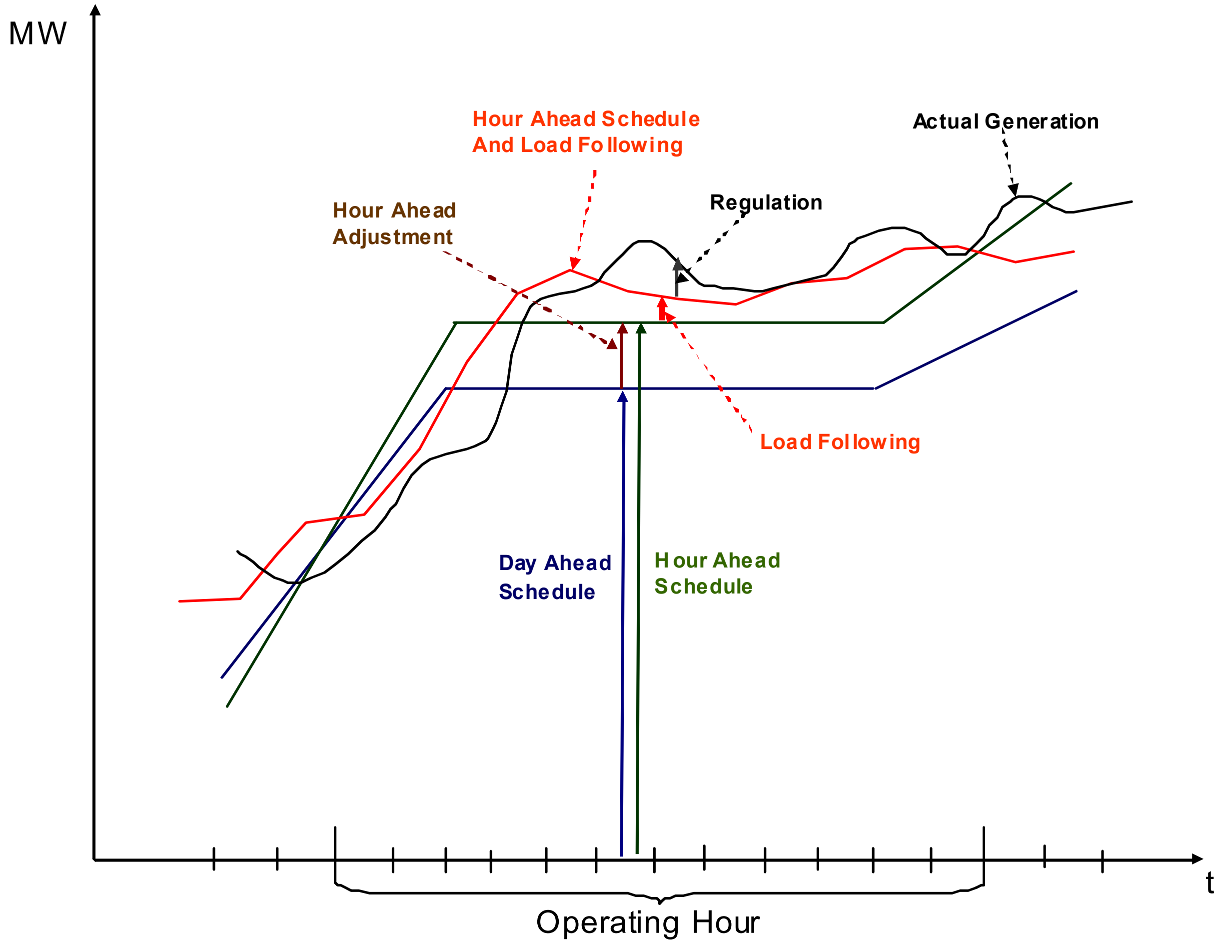
Study Methodology

- Study conducted jointly with Battelle - Northwest
  - Day Ahead and Hour Ahead Scheduling Process
  - Real-Time Dispatch
  - Regulation Process
- Determined load forecasting and wind forecasting errors
- Obtained projected hourly wind generation data from AWS Truewind Company
- Build Mathematical Model to Mimic Actual Operations

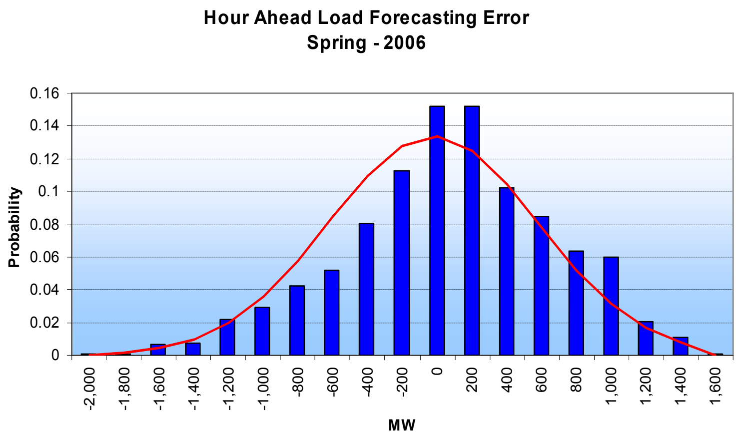
Operations/market study assumptions reflect likely operational and market conditions

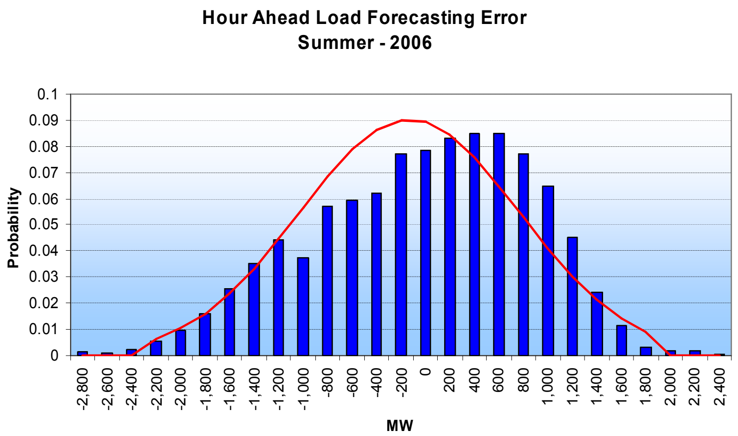
- Load growth assumed at about 1.5% per year
- Based on actual operating data
- New wind generators participate in CAISO PIRP program, with centralized Day-Ahead and Hour-Ahead forecasting service
- New market design is implemented
  - Hour-ahead load and wind generation energy forecasts provided no less than 120-minutes before beginning of next operating hour
  - Real Time five-minute load forecasts provided 7.5 minutes before beginning of five-minute dispatch interval
- Real Time telemetry from wind resources sent to CAISO on a four-second basis, similar to non-intermittent resources
- Pump storage considered a scheduled resource

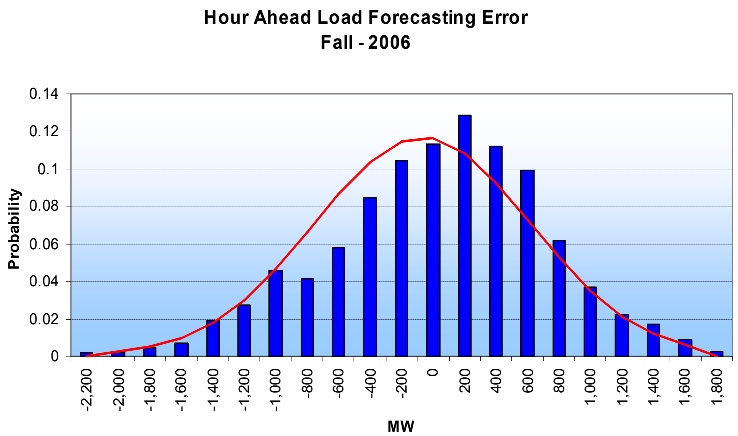
CAISO Scheduling Process

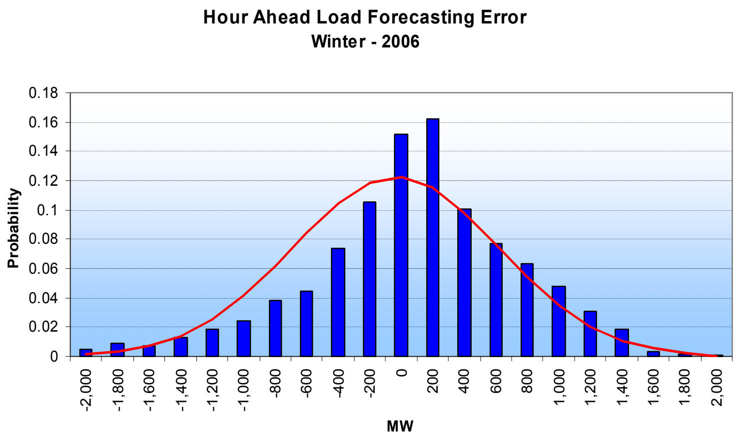


Hour Ahead Load Forecasting Errors

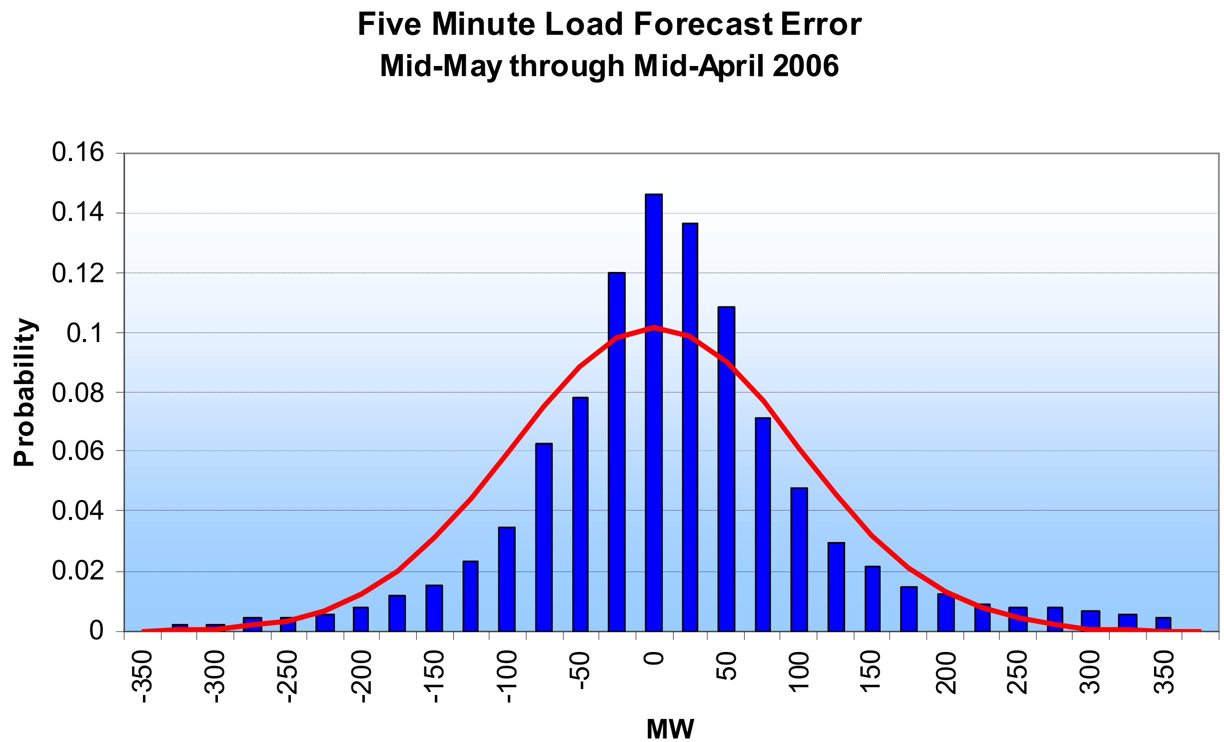






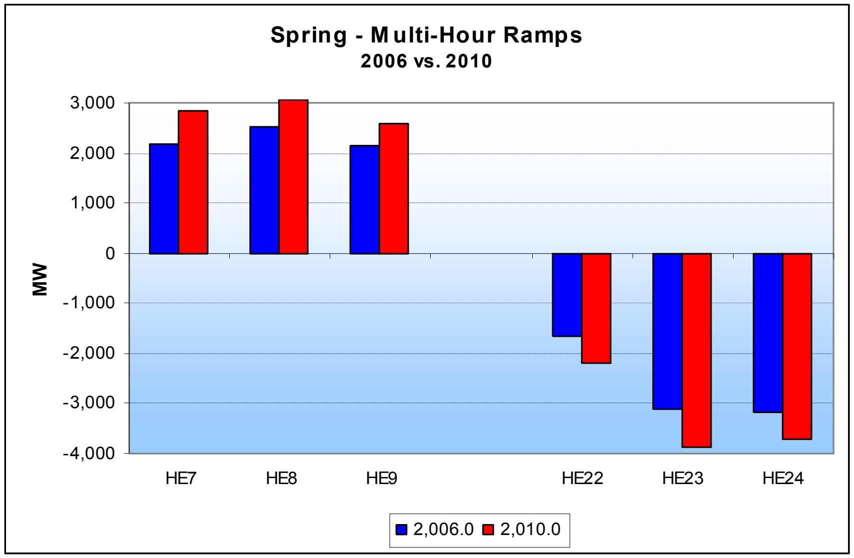


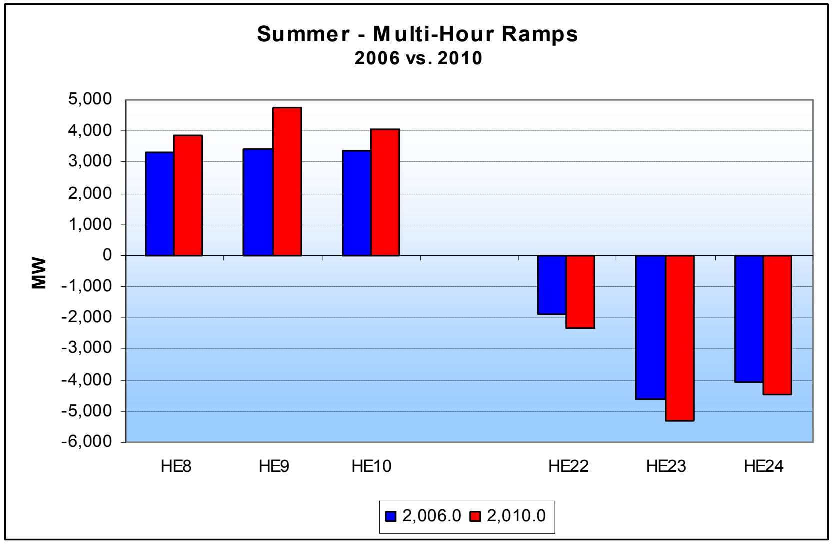
Five Minute Load Forecast Error

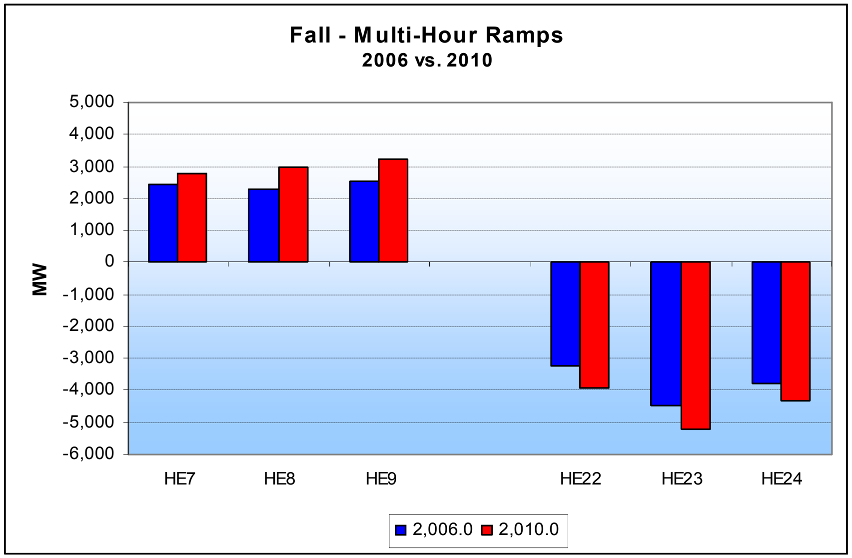


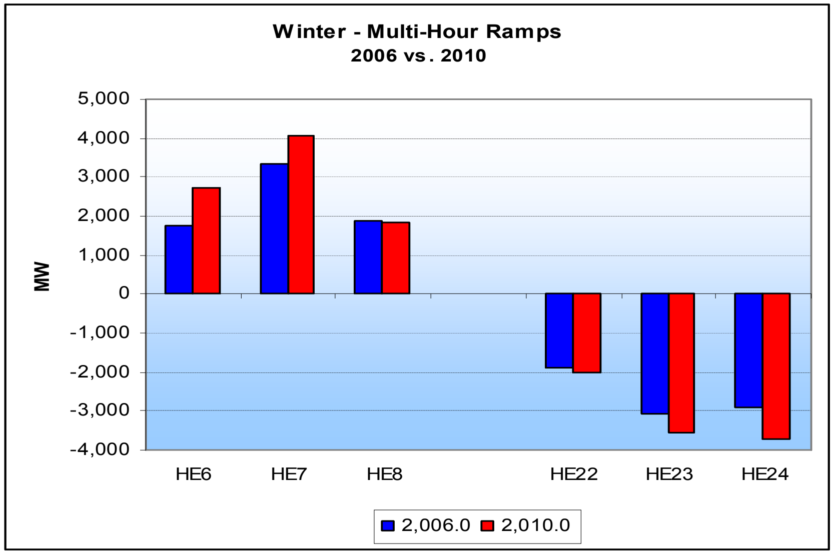
Average (MW)	Min (MW)	Max (MW)	Standard Deviation (MW)	Autocorrelation
1.15	-349	349	98	0.61

Ramping impacts vary by season









Studies document additional ramping requirements

Maximum Change in Ramping Requirements
With Implementation of RPS

Seasons	***2006 Morning Ramps MW***	***Expected 2010 Morning Ramps MW***	***Change due to Intermittency (MW)***	***2006 Evening Ramps MW***	***Expected 2010 Evening Ramps MW***	***Change due to Intermittency (MW)***
Spring	6,860	8,494	955	7,962	9,788	984
Summer	10,090	12,664	1,529	10,589	12,135	427
Fall	7,229	8,995	1,023	11,511	13,483	740
Winter	6,979	8,631	926	7,856	9,293	603

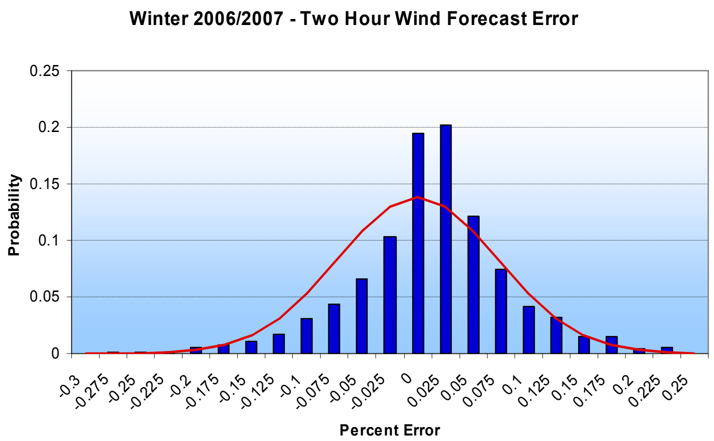
Actual Hour Ahead Load forecasted distribution errors

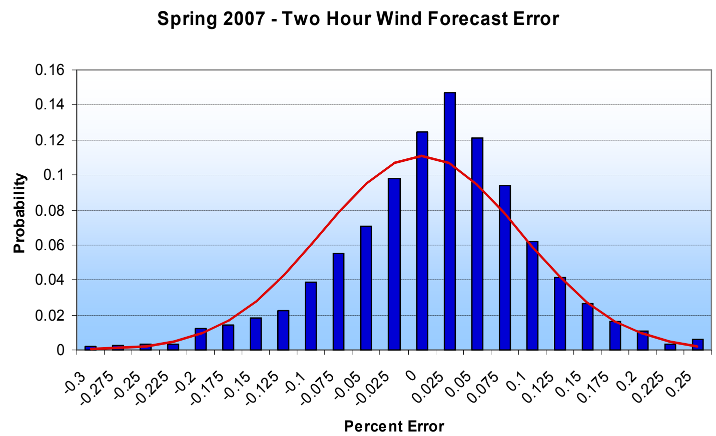
The Hour Ahead Forecast error is simply the difference between the Hour Ahead forecast and the average hourly actual demand (including pump loads) for a particular operating hour

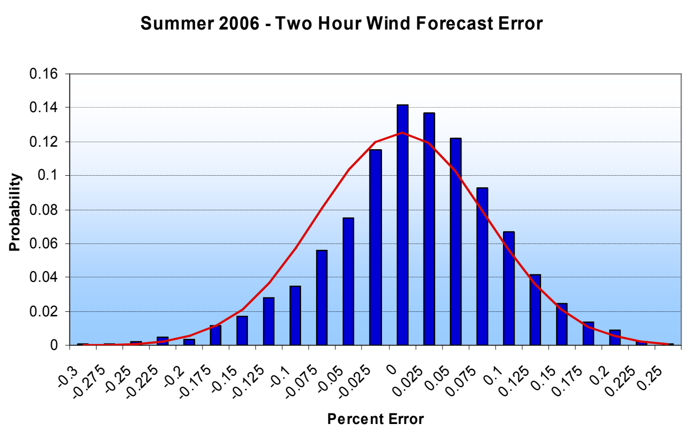
Season	Average (MW)	Min (MW)	Max (MW)	Standard Deviation (MW)	Autocorrelation
Winter	-35.2	-3,849	1,519	652	0.69
Spring	-24.1	-2,101	1,931	601	0.73
Summer	-130.4	-3,771	2,446	900	0.89
Fall	-69.2	-2,628	2,081	687	0.83

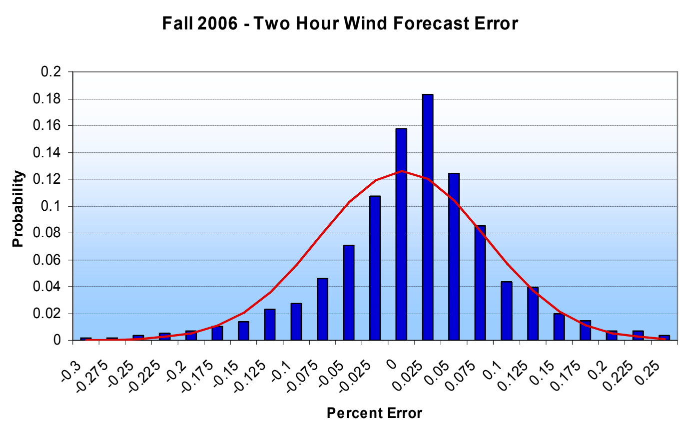
Forecasting error is higher at higher loads. In 2006, average temperatures 100 degrees F on many occasions. The forecasting error was greater than 800 MW for approximately 23% of the time.

Hour Ahead Wind Forecasting Error

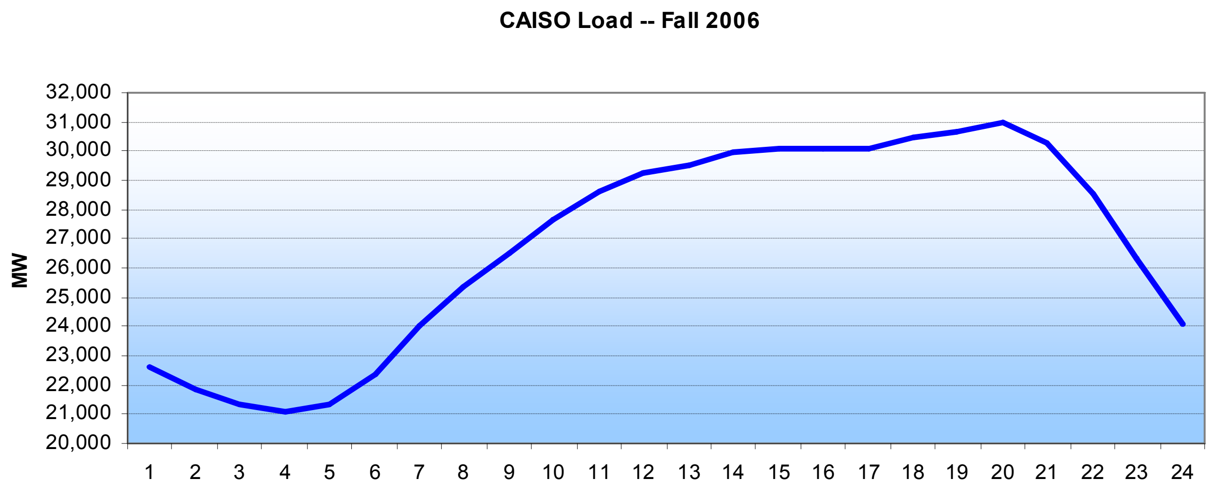


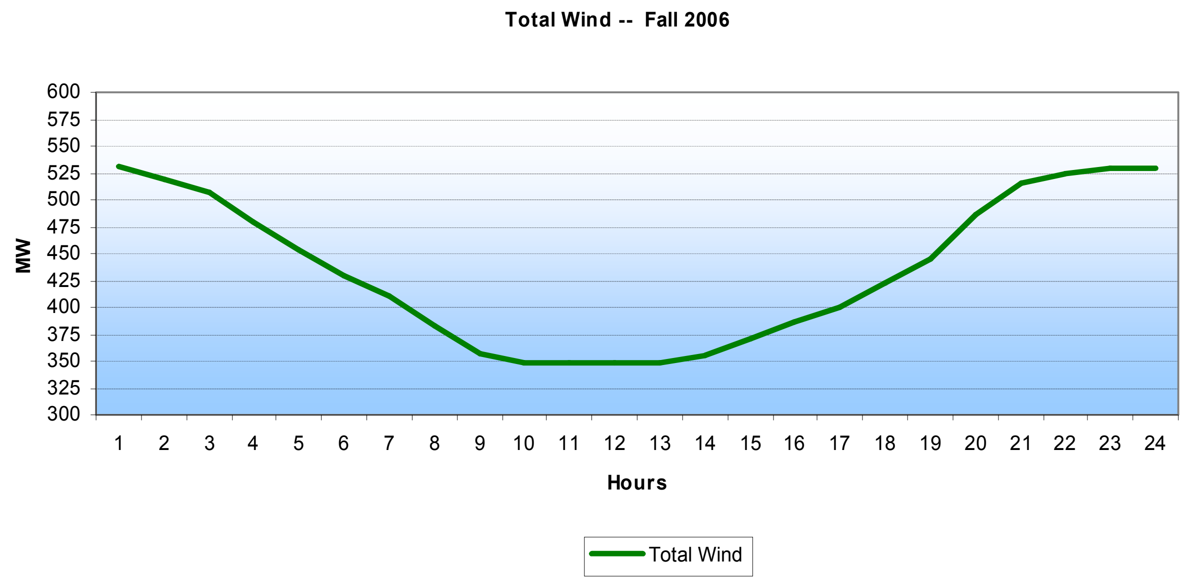






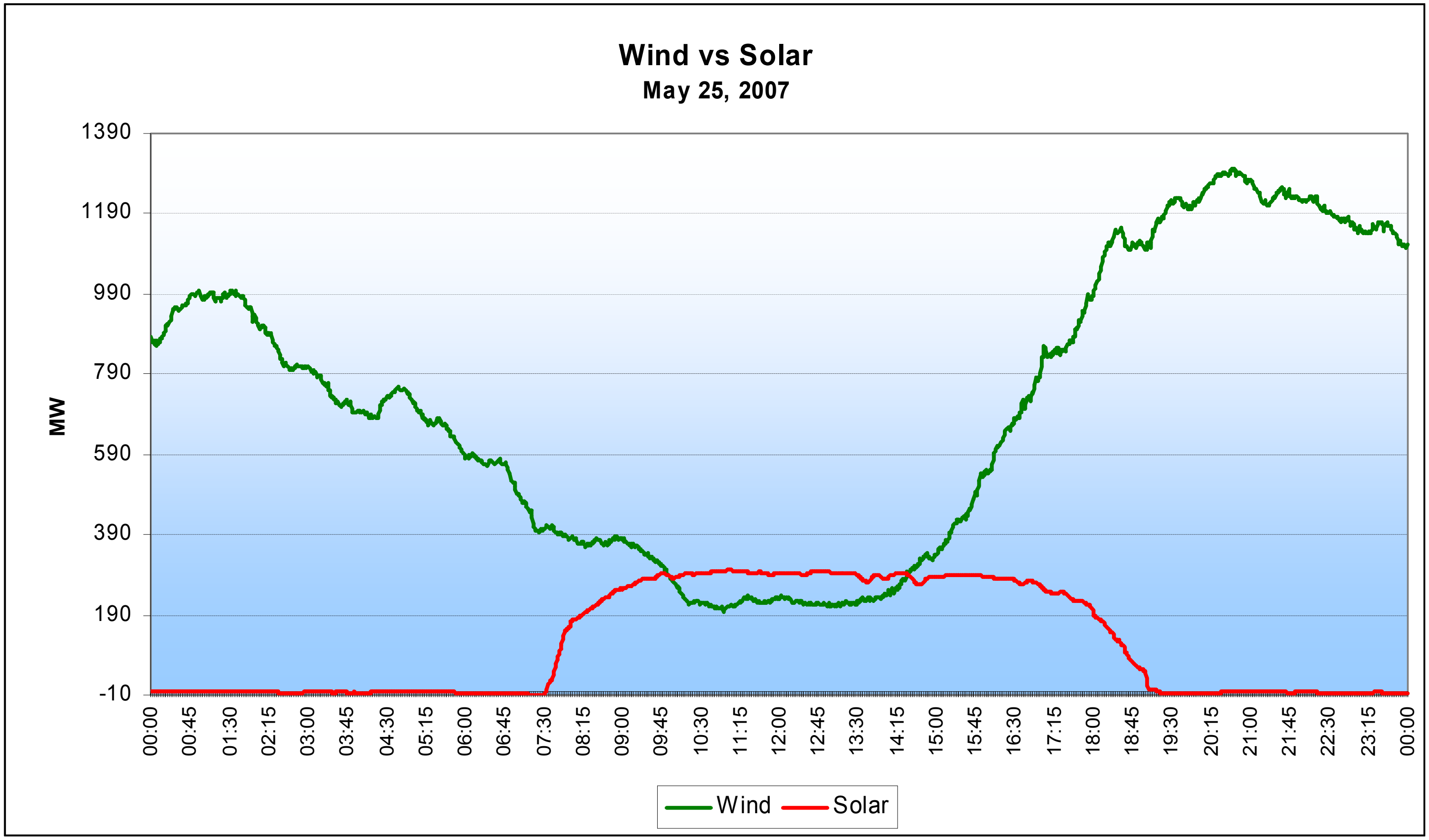
Wind generation tends are inversely correlated to daily load curve, creating ramping impacts



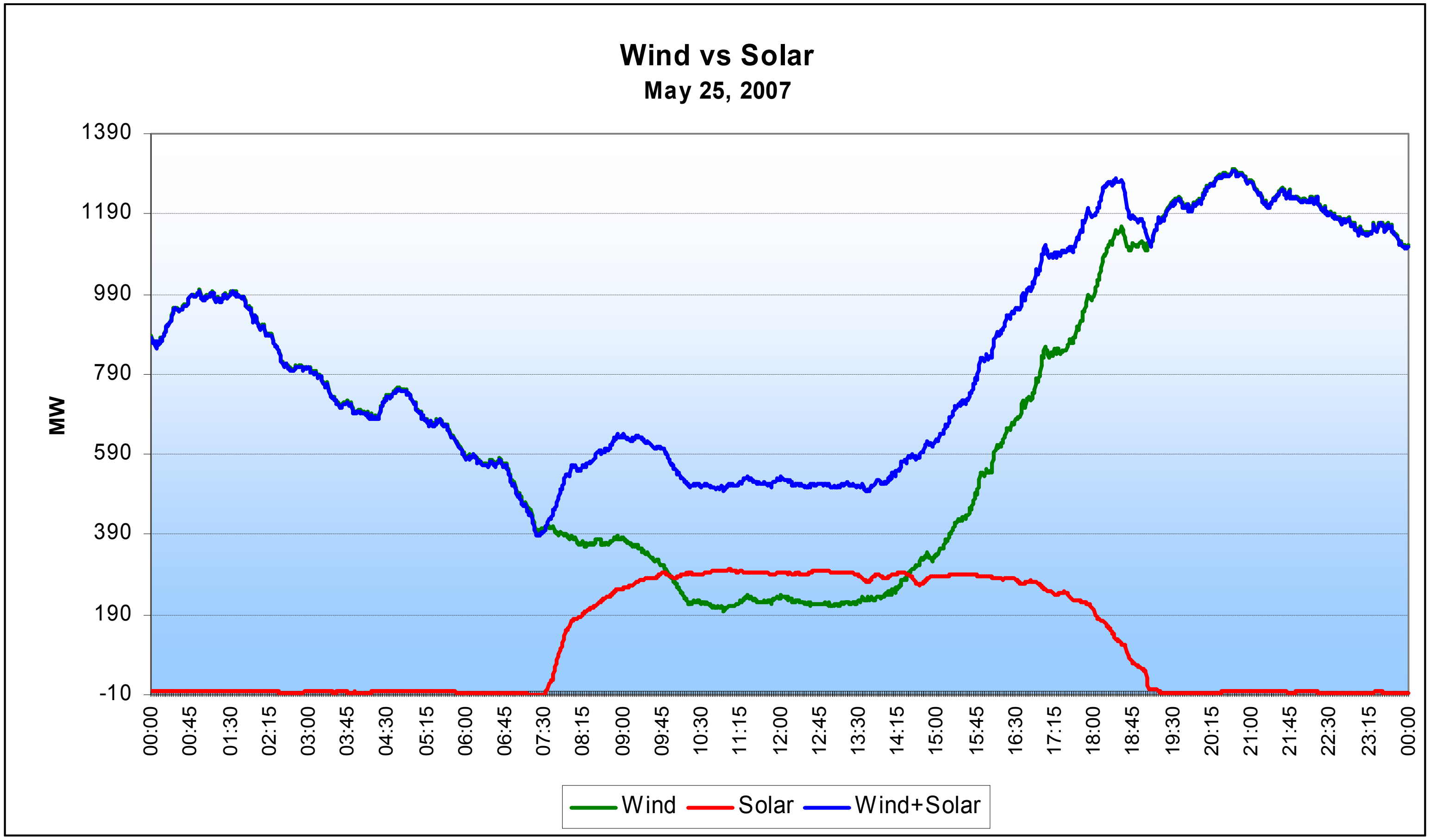


California ISO
Your Link to Power

Typical Daily Wind vs. Solar Generation Pattern

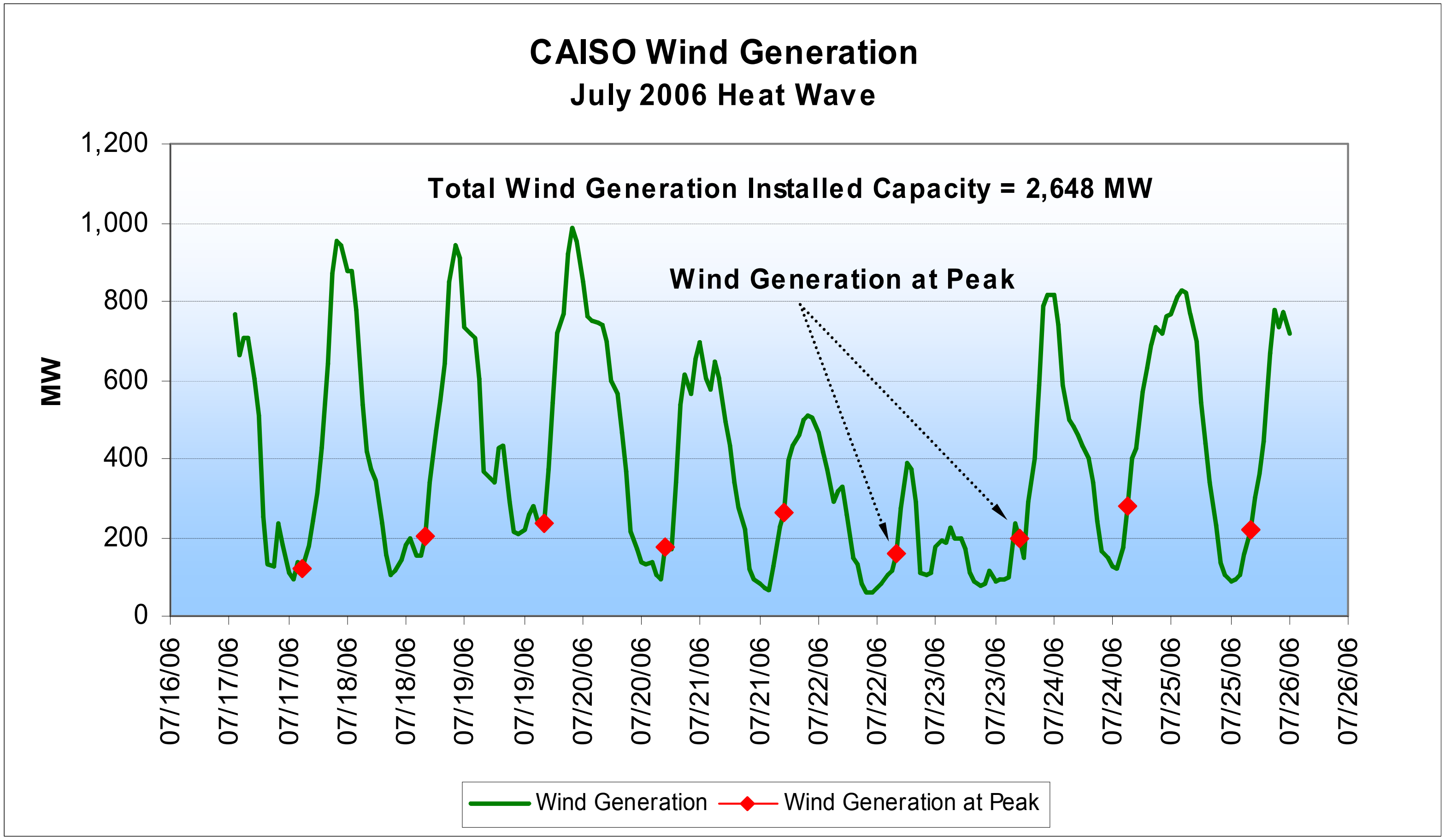


Typical Daily Wind vs. Solar Generation Pattern



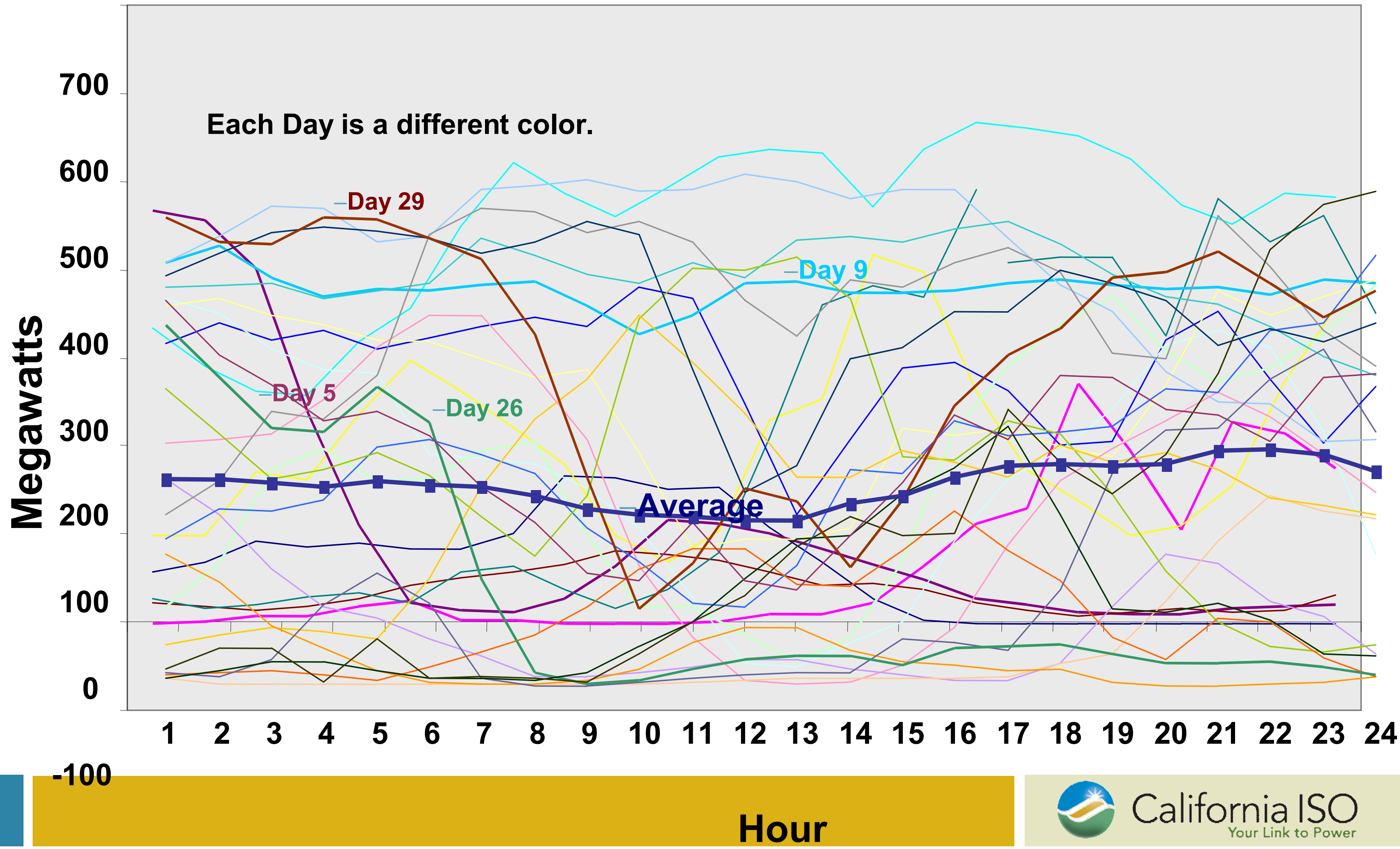
California ISO
Your Link to Power

Wind vs. Actual Load on a Typical Hot Day in 2006

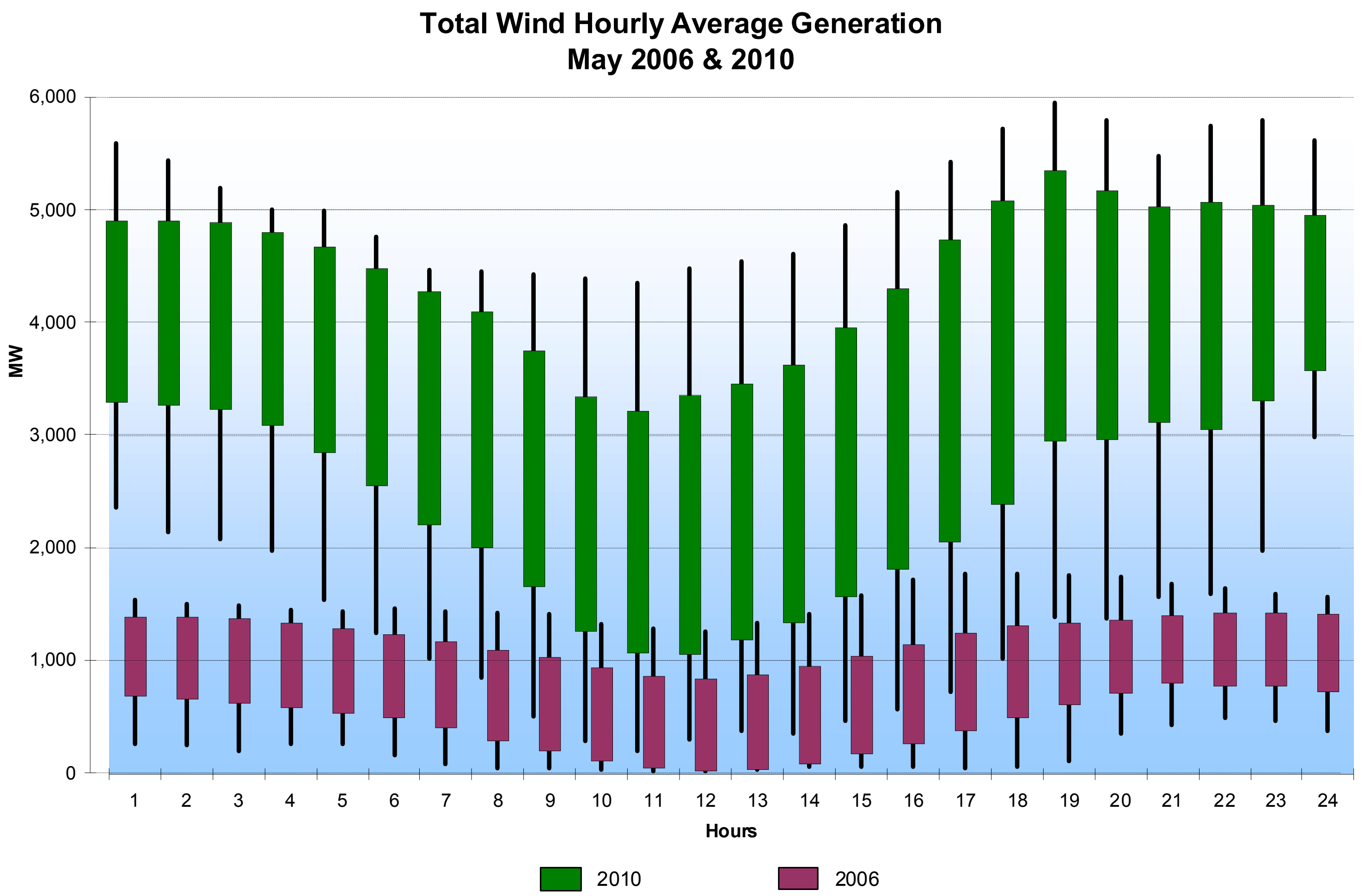


Tehachapi Wind Generation in April – 2005

Could you predict the energy production for this wind park either day-ahead or 5 hours in advance?

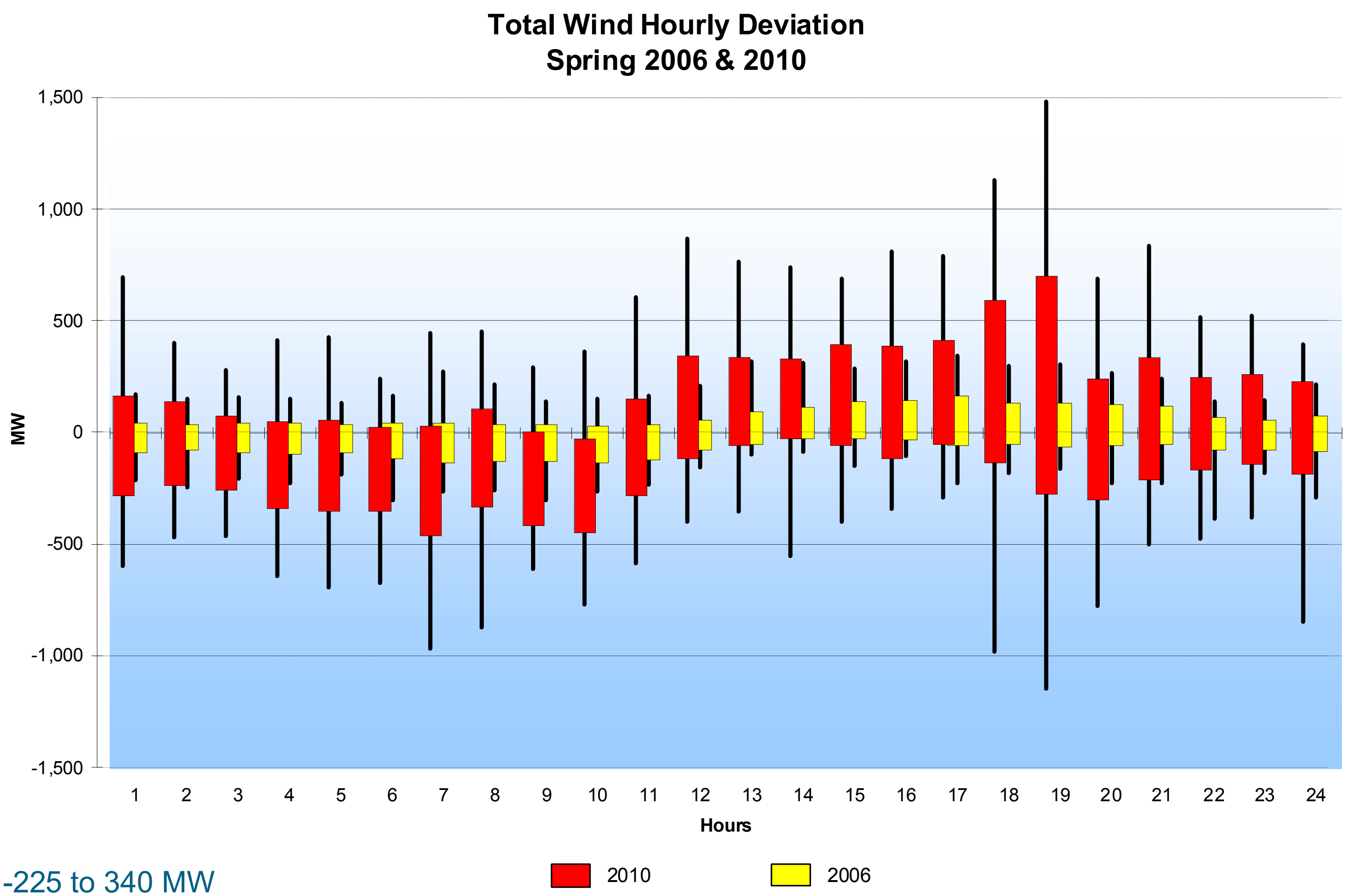


Actual Wind Generation 2006 vs. Expected Wind Generation 2010



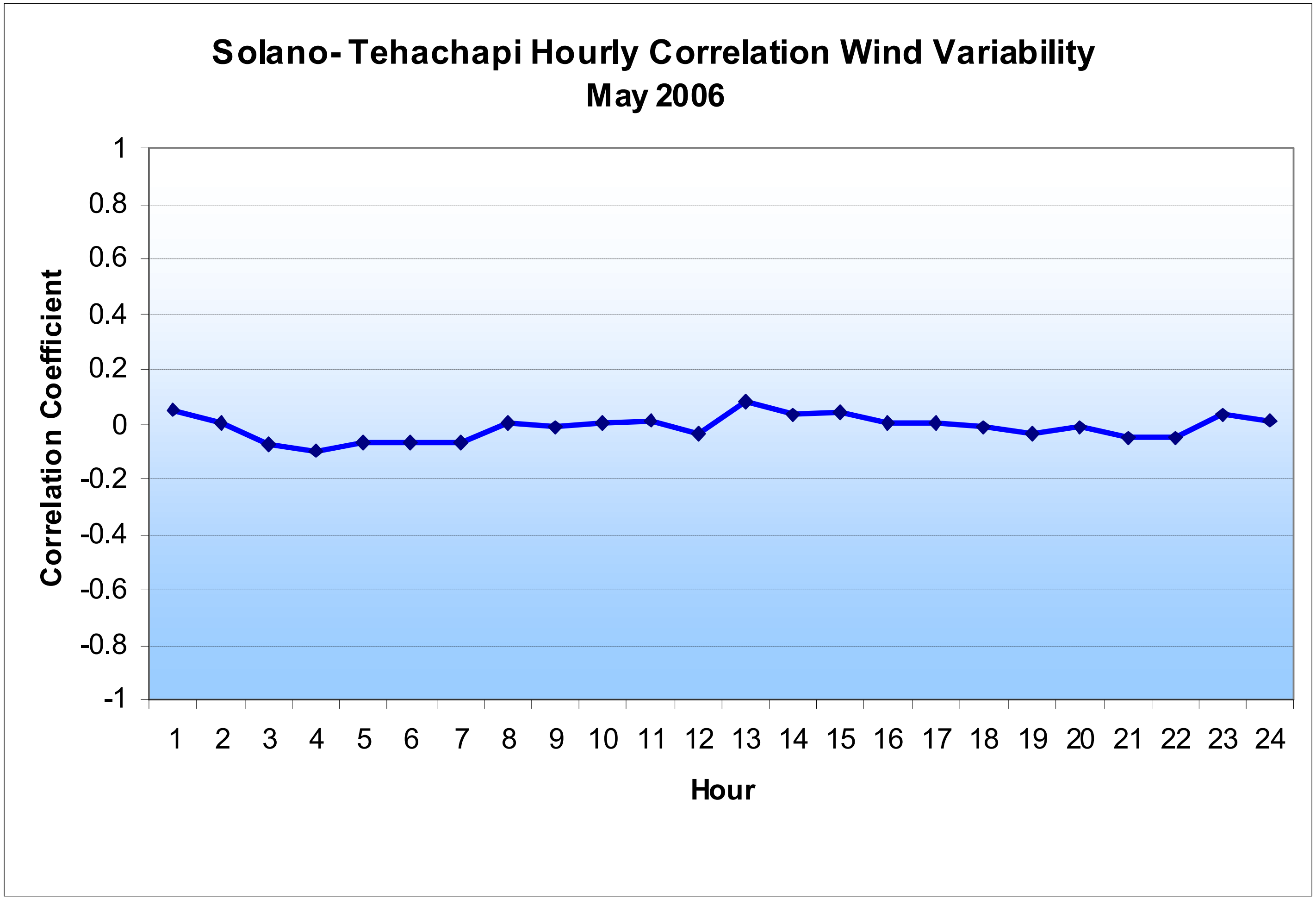
2006 - HE19: 50 to 1800 MW
2010 - HE19: 1,400 to 6,000 MW

Comparison of Hourly Deviations of Wind Generation observed in 2006 and Expected Deviations in 2010

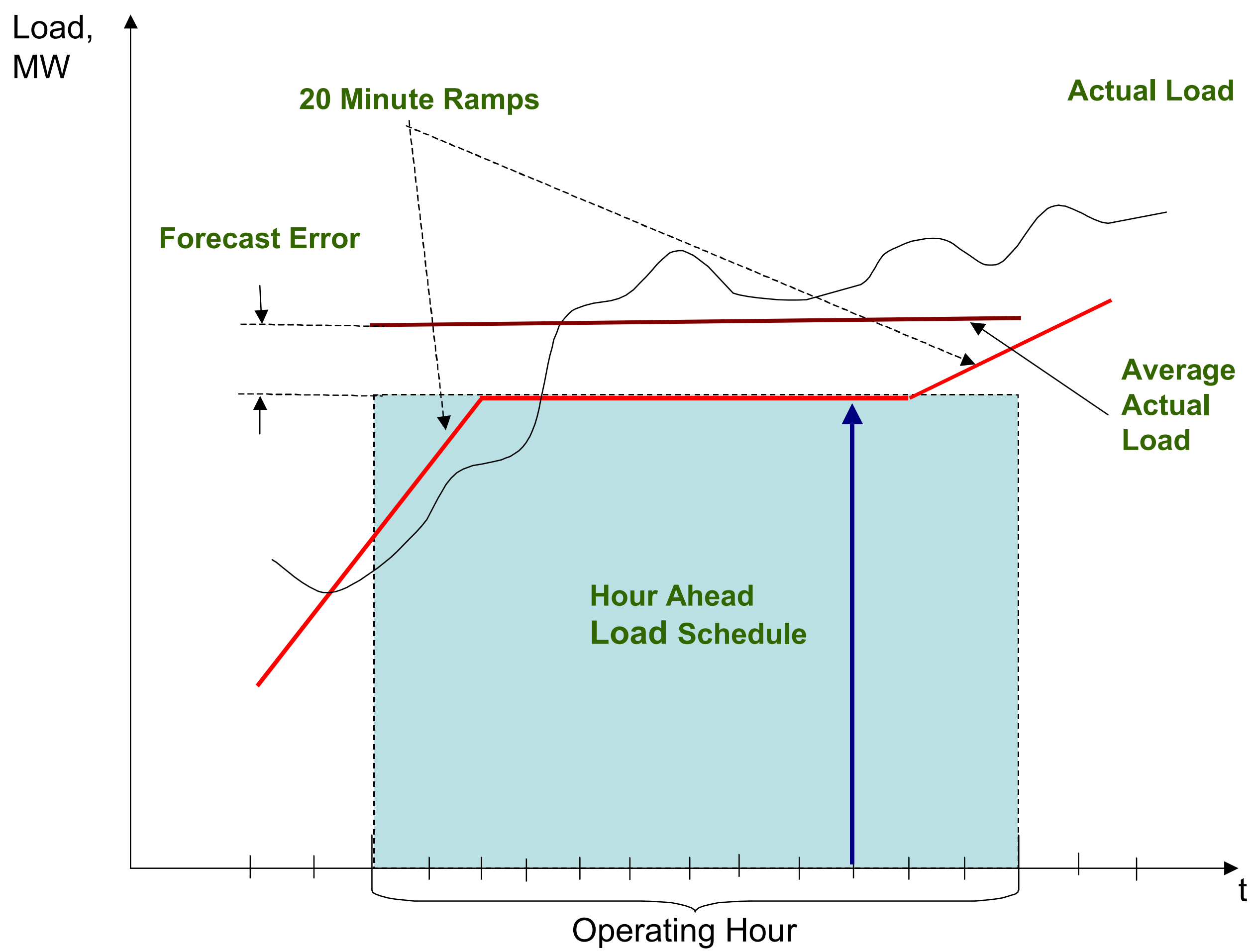


2006 – HE19: -225 to 340 MW
2010 – HE19: -1,150 to 1,480 MW

Correlation Between Wind Parks

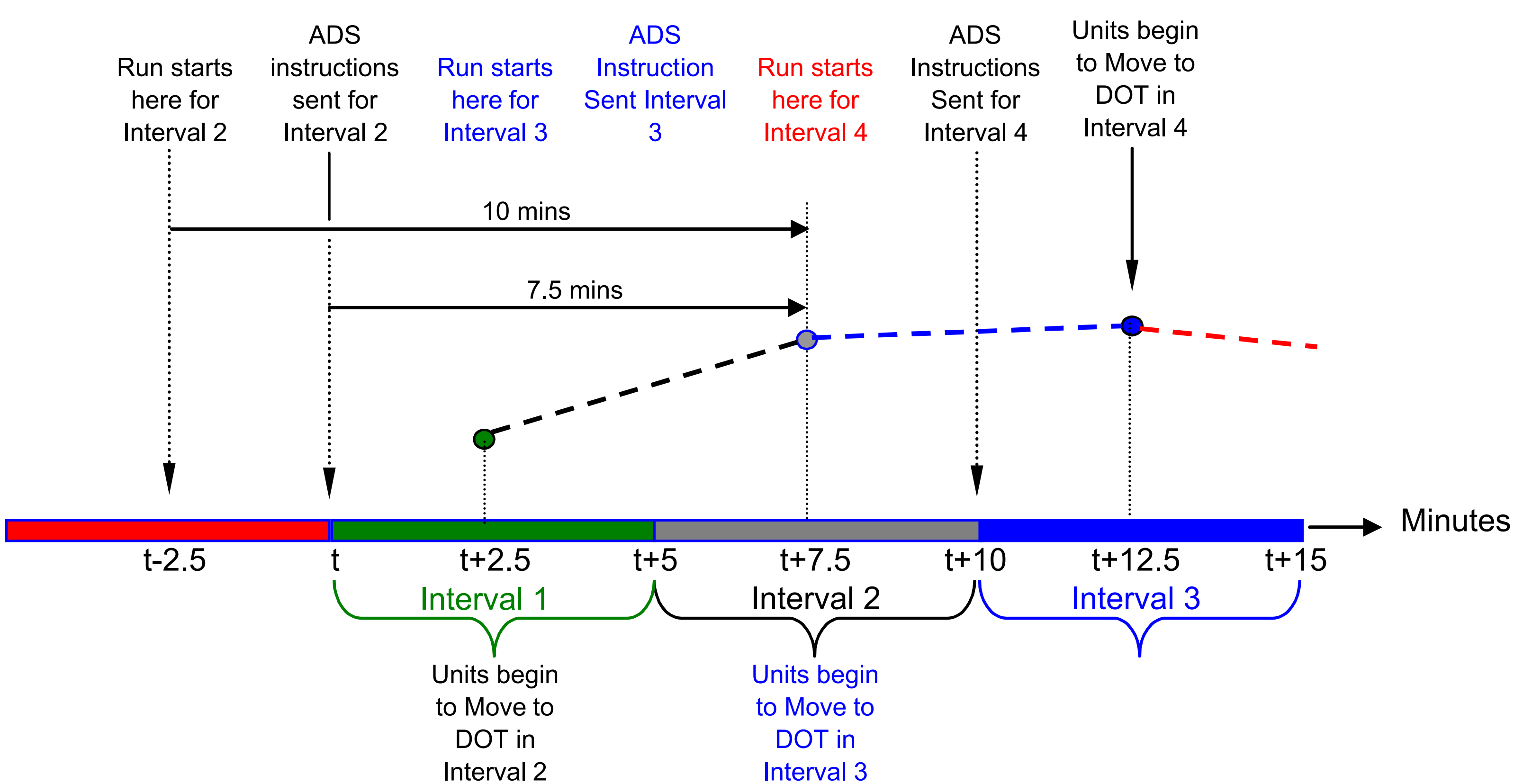


One-hour block energy schedule includes 20-minute ramps between the hours



MRTU timelines benefit renewable integration.

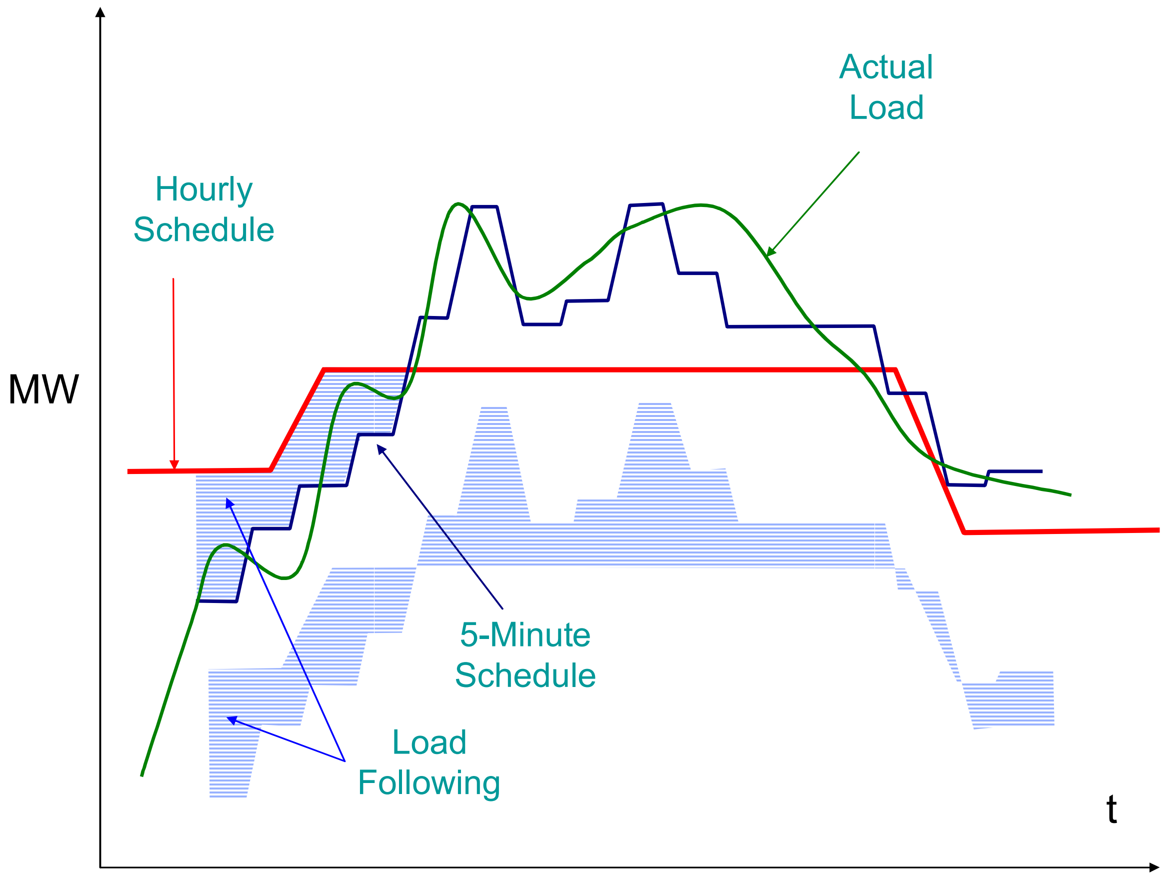
The Real Time Economic Dispatch software runs every five-minutes starting at approximately 7.5 minutes prior to the start of the next Dispatch Interval and produces Dispatch Instruction for Energy for the next Dispatch Interval and advisory Dispatch Instructions for as many as 13 future Dispatch Intervals.



What is Load Following?

- Load following necessary to maintain stable operations
- The CAISO's Real Time Market balances Load and Generation on a forward looking basis
- Some generators are dispatched upwards to meet their next hour schedules other generators may have to be moved downwards to maintain a generation load balance
- Real Time Economic Dispatch software runs every 5-minutes and dispatches generation based on economics and ramping capability

Load Following Requirement shown as blue shaded area



Conclusion – Load Following Requirement

- Load following ramping requirements will increase and require more generation to be available for both upward (700-800 MW) and downward (500-900 MW) dispatch

Season	Max Load Following Inc, MW	Max Load Following Dec, MW	Max Hourly Increase (Inc), MW	Max Hourly Increase (Dec), MW
Spring	+2,850	-2,950	+800	-500
Summer	+3,500	-3,450	+800	-600
Fall	+3,100	-3,250	+750	-900
Winter	+2,900	-3,000	+700	-750

Season	Max Load Following Ramp Up, MW/min	Max Load Following Ramp Down, MW/min
Spring	+35	-30
Summer	+40	-40
Fall	+40	-30
Winter	+30	-40

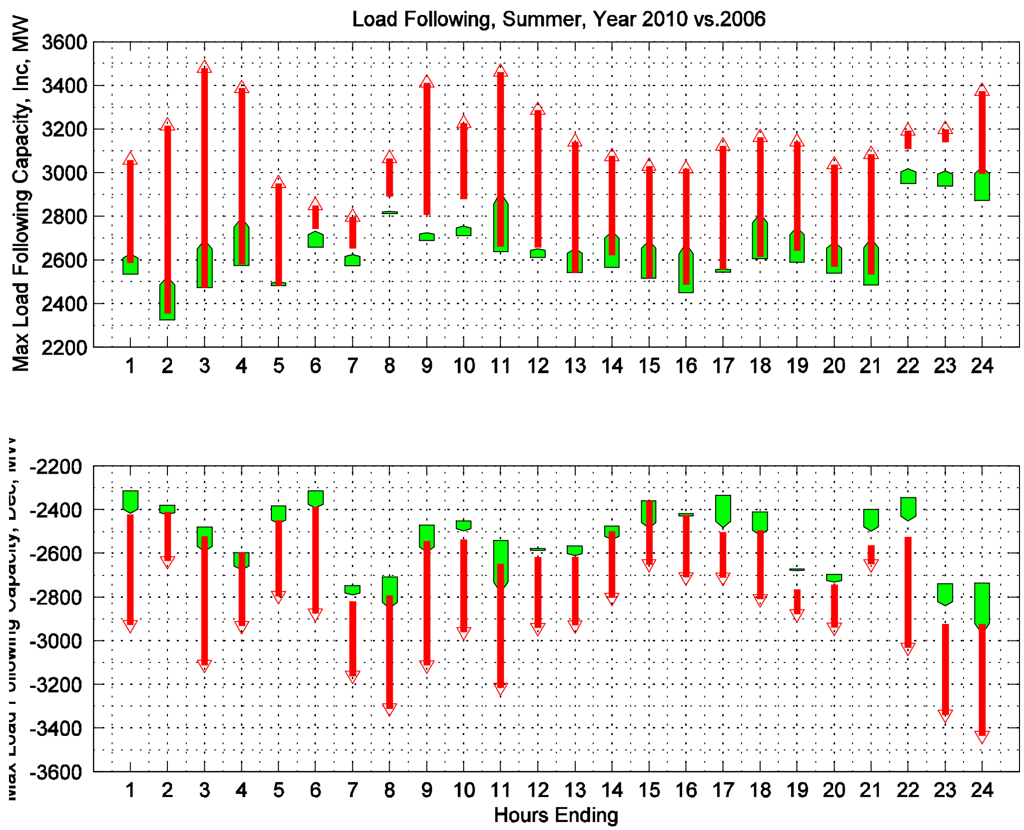
Summary of Regulation Capacity Requirements

The maximum upward capacity requirement of 3,500 MW occurs during HE3 and HE11

The maximum increase of 800 MW occurs during HE3 (3,500 – 2,700)

The maximum downward capacity requirement of 3,450 MW occurs during HE24

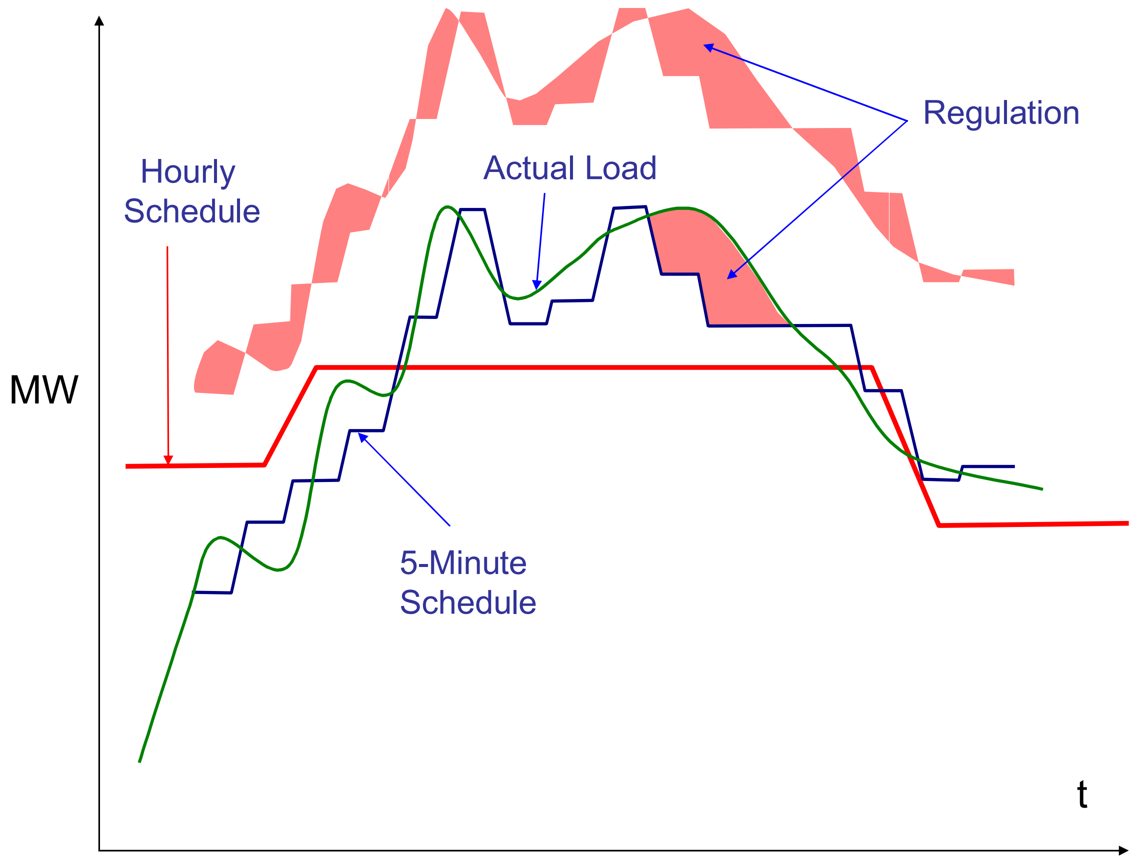
The maximum downward capacity increase of 500 MW (3,050 -2,450) occurred in HE22



What is Regulation?

- Regulation is required for the CAISO to maintain scheduled frequency and maintain interchange schedules on the ties
- Regulation is not dispatched based on its Energy Bid Curve Price
- Regulating resources are dispatched through Automatic Generation Control every four-seconds to meet moment-to-moment fluctuations in the system

Regulation Requirement shown as the red shaded area



Conclusion – Regulation Requirement

- Today, the CAISO can effectively operate the system by procuring ± 350 MW of regulation on an hourly basis
- By 2010 regulation capacity requirements will increase by 170-250 MW for “up regulation” and 100-500 MW for “down regulation” depending on the season and time of day

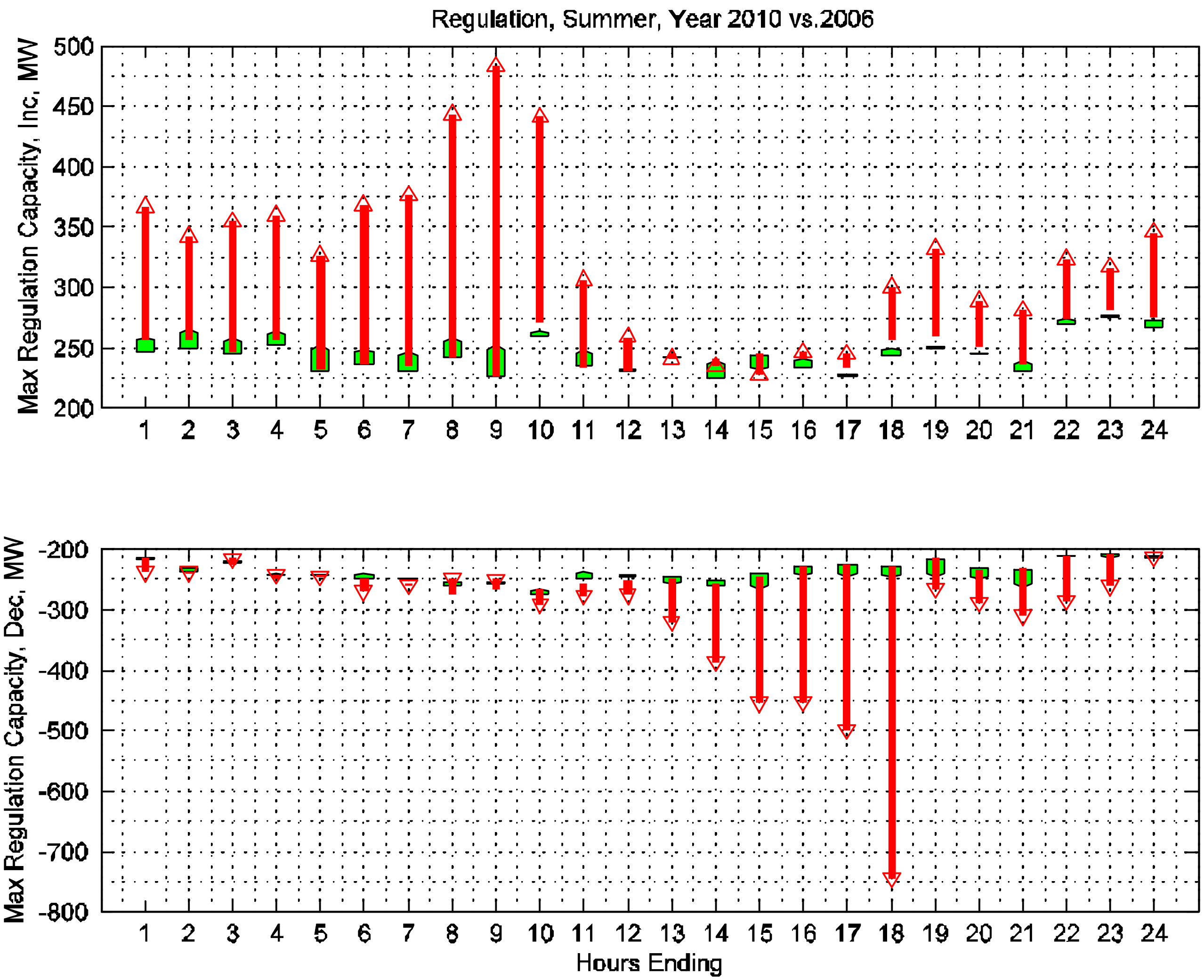
Season	Max Regulation Up, MW	Max Regulation Down, MW	Max Hourly Increase (Up), MW	Max Hourly Increase (Down), MW
Spring	+510	-550	+240 (HE18)	-300 (HE18)
Summer	+480	-750	+230 (HE09)	-500 (HE18)
Fall	+400	-525	+170 (HE06, HE18)	-275 (HE18)
Winter	+475	-370	+250 (HE18)	-100 (HE10)

Seasons	***Max Increase Regulation Ramp Up, MW/min***	***Max Increase Regulation Ramp Down, MW/min***
Spring	+20	-25
Summer	+10	-18
Fall	+25	-20
Winter	+15	-15

The CAISO regulation capacity requirements would increase noticeably during certain hour ranges

The maximum increase of 230 MW occurs during HE9 (480 MW – 250 MW)

The maximum downward increase of 500 MW (750 MW -250 MW) occurred in HE18



Sensitivity of Load Following Capacity due to 5% Hour Ahead Wind Forecasting Error

Season	INC 7%-9%	INC 5%	Reduction MW	Reduction %	DEC 7%-9%	DEC 5%	Reduction MW	Reduction %
Spring	2,850	2,450	400	14%	-3,000	-2,550	-450	-15%
Summer	3, 470	3,320	150	4.3%	-3,430	-3,280	-150	-4.4%
Fall	3,080	2,550	530	17.2%	-3,200	-2,600	-600	-18.8%
Winter	2,850	2,660	190	6.7%	-3,050	-2,700	-350	-11.5%

Recommendations

- Implement a state-of-the-art (DA, HA, RT) wind forecasting service for all wind generator energy production within the CAISO operational jurisdiction
- Incorporate the Day and Hour Ahead wind generation forecasts (block energy schedules) into the CAISO's and SC's scheduling processes
- Integrate the Real Time wind generation forecast (average wind generation for 5-minute dispatch intervals) with the Real Time unit commitment and MRTU dispatching applications
- Develop a new ramp forecasting tool to help system operators anticipate large energy ramps, both up and down, on the system
- Change the ISO generator interconnection standards to require compliance of all intermittent resources with the interconnection rules established for the PIPR

Recommendations (cont.)

- Implement a procedure where the CAISO Dispatcher can send dispatch notices to wind generation operators and require them to implement pro-rata cuts in their energy production.
- Analyze the impact of solar power intermittency with load and wind generation intermittency
- Evaluate the benefits of participating in a wider-area arrangement like ACE sharing or Wide Area Energy Management system
- Study the impact that additional cycling (additional start ups) and associated wearing-and-tearing issues and associated additional costs and environmental impacts on conventional generation
- Recommend changes in Resource Adequacy standard to require more generation with faster and more durable ramping capabilities that will be required to meet future ramp requirements
- Recommend changes in Resource Adequacy standard to require additional quick start units that will be required to accommodate Hour Ahead forecasting errors and intra-hour wind variations.
- Encourage the development of new energy storage technology that facilitates the storage of off peak wind generation energy for delivery during on-peak periods

Conclusion -- the impact of 20% RPS is manageable

- New market design mitigates current challenges
  - Important to integrate improved wind forecasting with dispatch procedures.
- Operational implications significant but manageable