# California Independent System Operator Renewable Integration Study

January 2008

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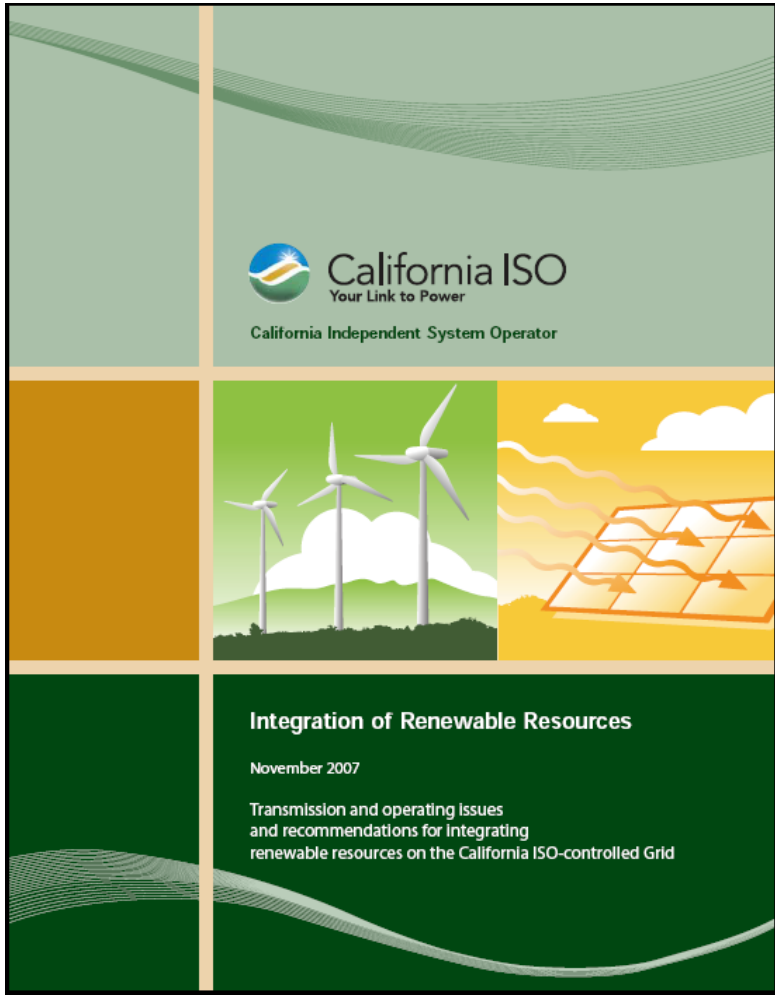
Achieving California's 20% Renewable Portfolio Standard

# Integration of Renewables Report published November 2007

## Key Report Topics

- Renewables transmission plans
  - Tehachapi transmission
  - Voltage & dynamic stability
- Forecasting wind & solar
- Operations integration
- Storage Technology
- Experience of others
  - National & International
- Conclusions & Recommendations
- Appendices
  - Detailed description of the study methodology

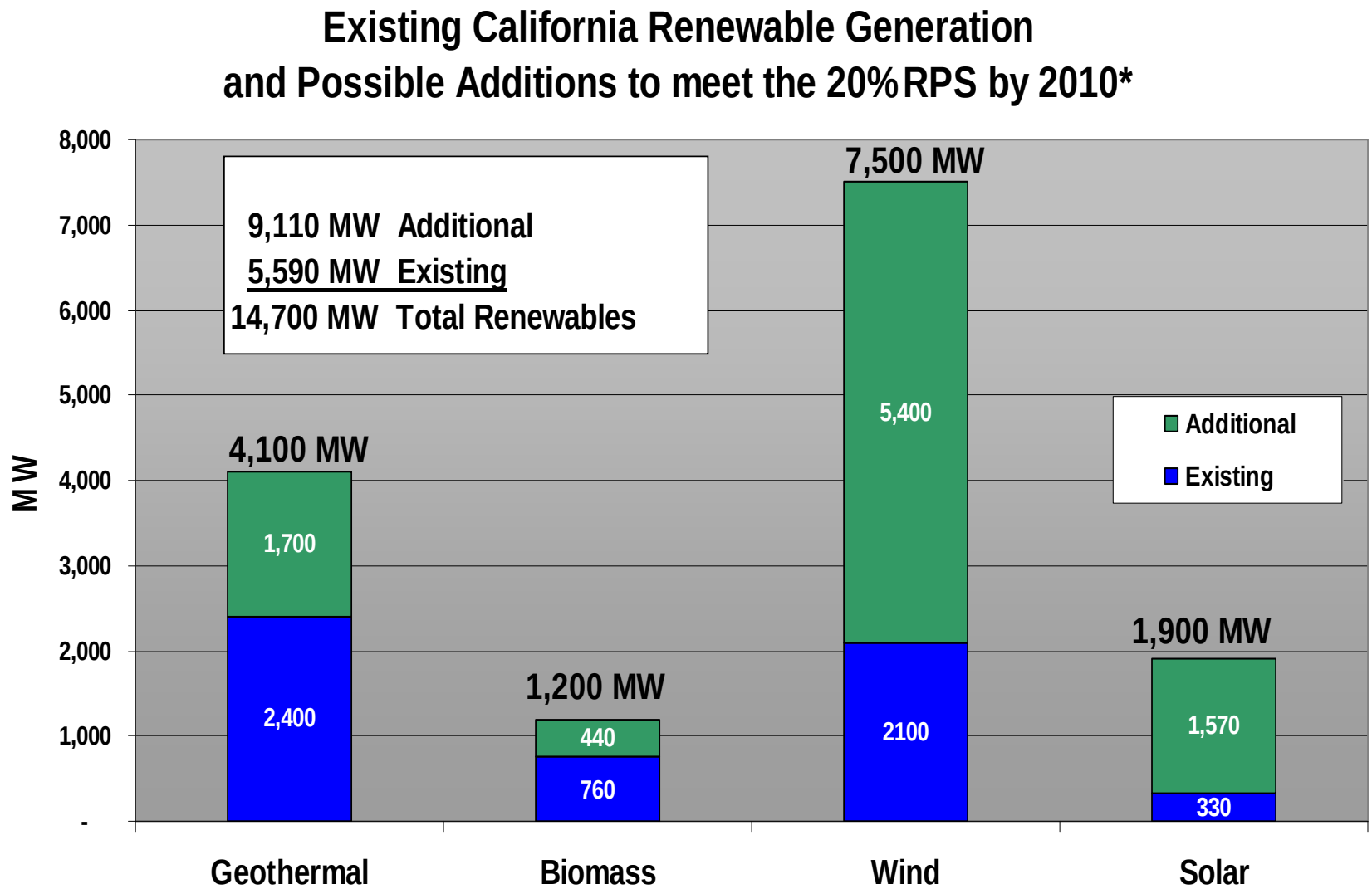



http://www.caiso.com/1ca5/1ca5a7a026270.pdf

# The study builds on the CEC's intermittency analysis for the 2007 Integrated Energy Policy Report.

- **Took the analysis to the next level of detail**
  - System stability analysis
  - More accurate modeling of operations
  - Constraints on existing operations
- **Goal – Identify operational changes to meet 20% RPS**
- **Challenges largely associated with intermittency**
- **Conclusion -- It can be done.**

# 20% Renewables Forecast by type




* Source of data on additional renewable resource is from Table 2-2 in the CEC IAP report, published July, 2007



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# The Transmission system study included both existing and new wind generator installations

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

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

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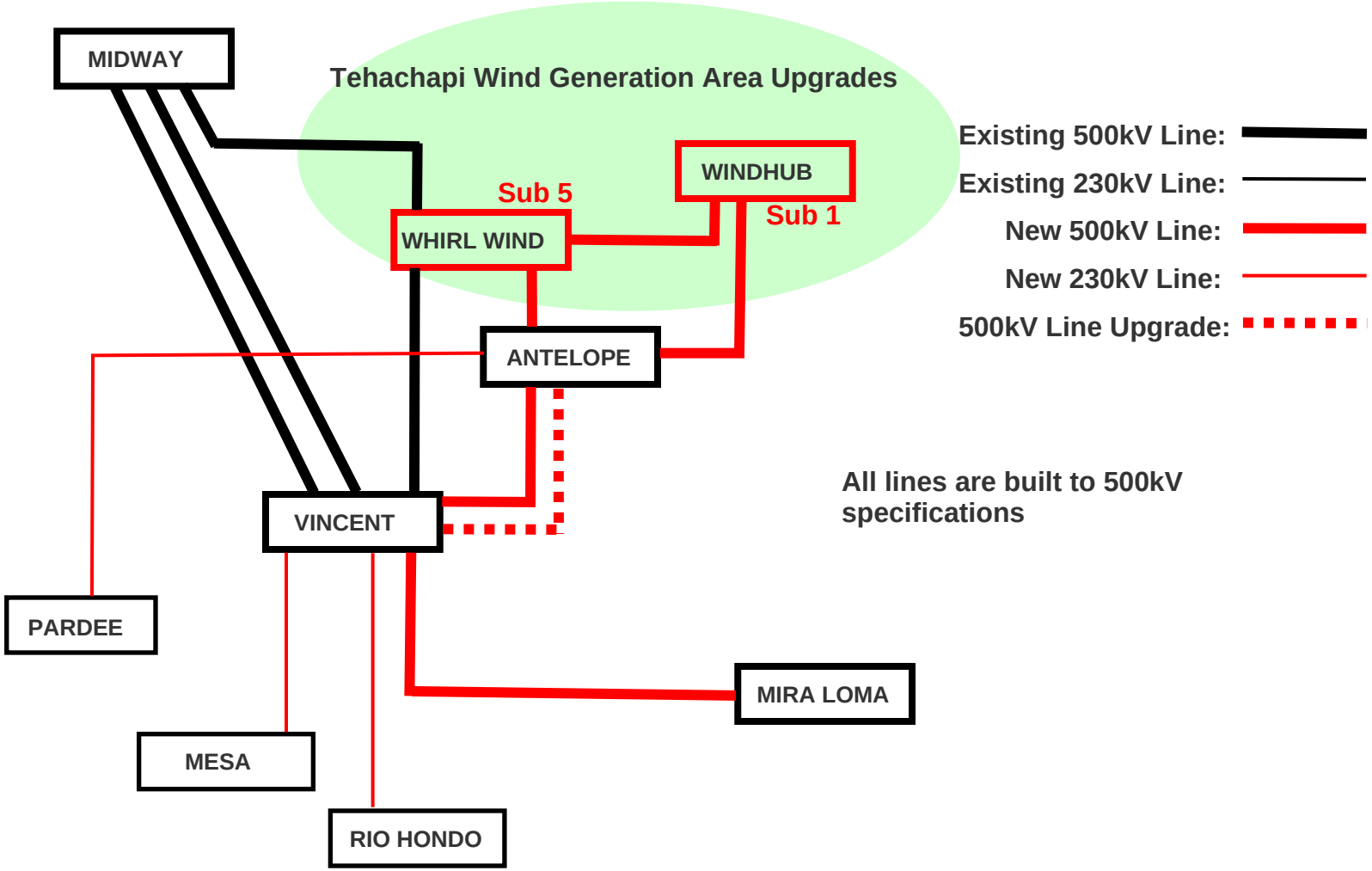
# The transmission system analysis considers variety of scenarios and contingencies.

- **Load grows at about 1.5% per year**
- **Transmission for the Tehachapi Area – 4500 MWs of new wind gen**
- **Transmission upgrades to move renewable energy to customer load centers and to storage facilities (Helms, etc.)**
- **Study examines six scenarios**
  - Two base cases for 20% renewables (2010 and 2012)
    - Summer peak load conditions, heavy N-S flow on Path 15
    - Spring light load, heavy S-N flow on Path 15
  - Three wind output levels
    - Full wind: all Tehachapi operating at rated MW
    - Low wind: all Tehachapi operating at 25% rated MW
    - No wind: all Tehachapi wind off line
- **Simulated 23 contingencies for six scenarios to evaluate:**
  - Transient stability performance
  - Post transient performance
  - Other sensitivities, such as types of wind gen

# Studies assume Tehachapi and Solano upgrades built on schedule



# New wind technologies will meet reliability requirements (LVRT)

| | Configuration | Tehachapi Installed and Planned Capacity | Meets WECC LVRT standards? |
|---|---|---|---|
| Type 1 | Conventional induction generator | 722 MW (existing) | No |
| Type 2 | Wound rotor induction generator with variable rotor resistance | 0 MW | No |
| Type 3 | Doubly-fed induction generator | 2700 MW (forecasted) | Yes |
| Type 4 | Full converter interface | 840 MW (forecasted) | Yes |

# Transmission Study Results

The Tehachapi Transmission Plan is sound and there are no serious transient stability or voltage control problems

- Key conclusions
  - Power factor control is critical - New wind generators must meet WECC criteria for ±0.95 power factor control
  - Low Voltage Ride Through Standard – all new units must meet WECC LVRT Standard.
  - New wind generators should be Type 3 or Type 4 units
  - Existing Type 1 Wind Generators in Tehachapi area do not meet LVRT standards and will probably be lost in event of voltage collapse

# Overall, transmission system impacts are manageable

- 20% RPS target can be met, without adverse transmission system impacts
- Focus should be on operational issues.

# Analysis of operating issues

- Based on actual operating data (2600 MW of existing wind gen.)
- New wind generators participate in CAISO PIRP program, with centralized Day-Ahead and Hour-Ahead forecasting service
- New market design (MRTU) 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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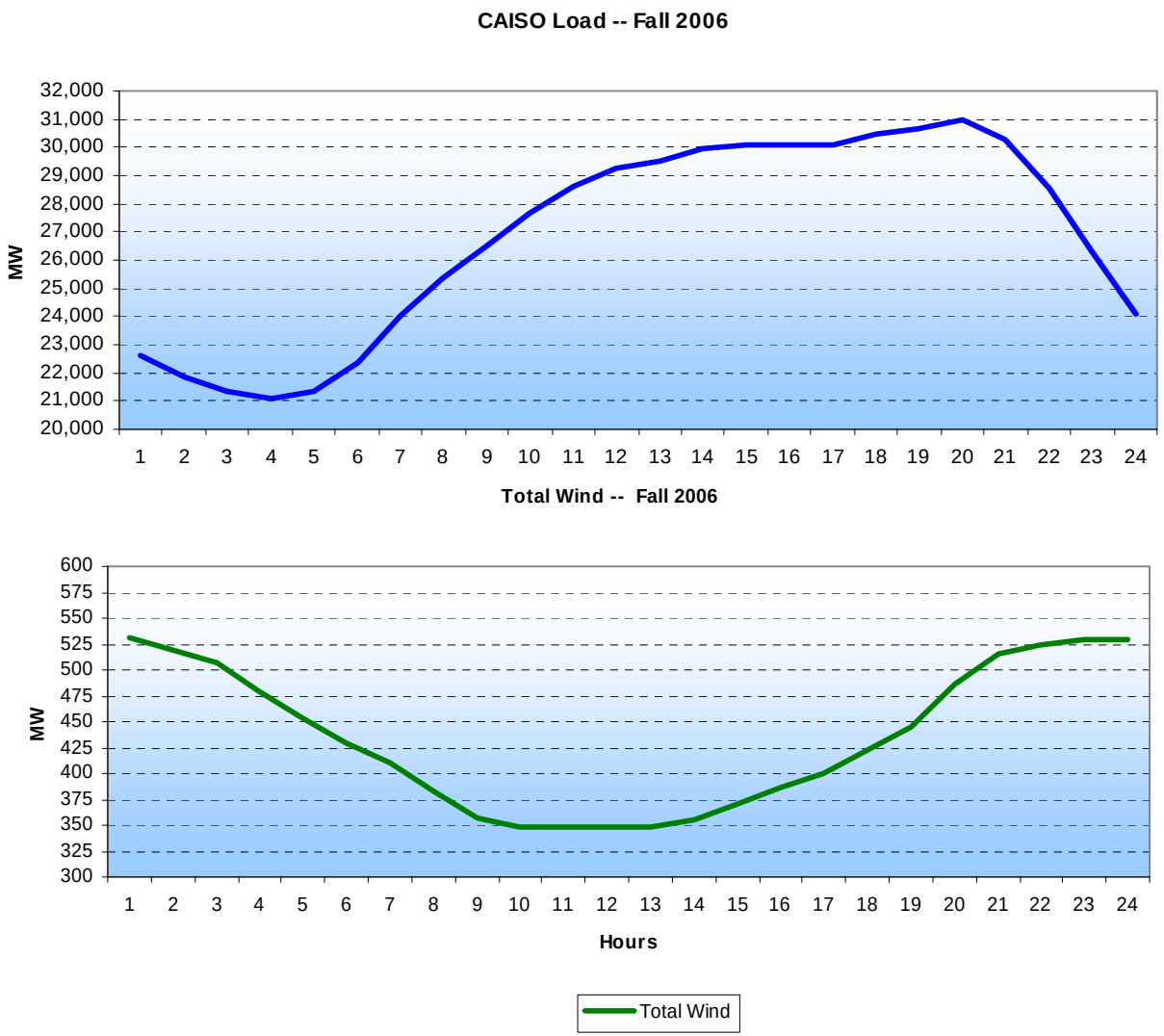
# Wind generation tends to be inversely correlated to daily load curve, creating ramping impacts.



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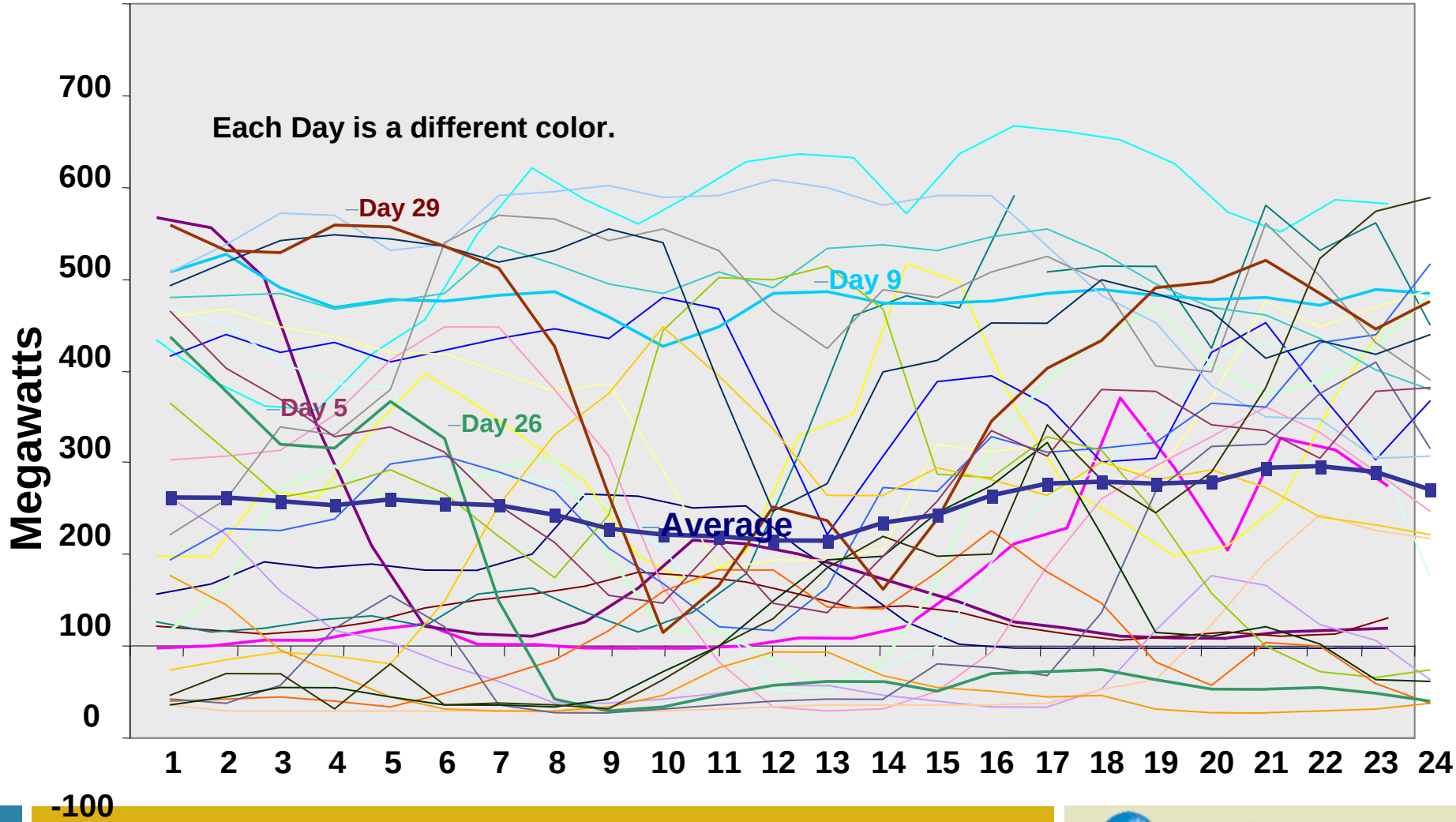
# Tehachapi Wind Generation in April – 2005

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



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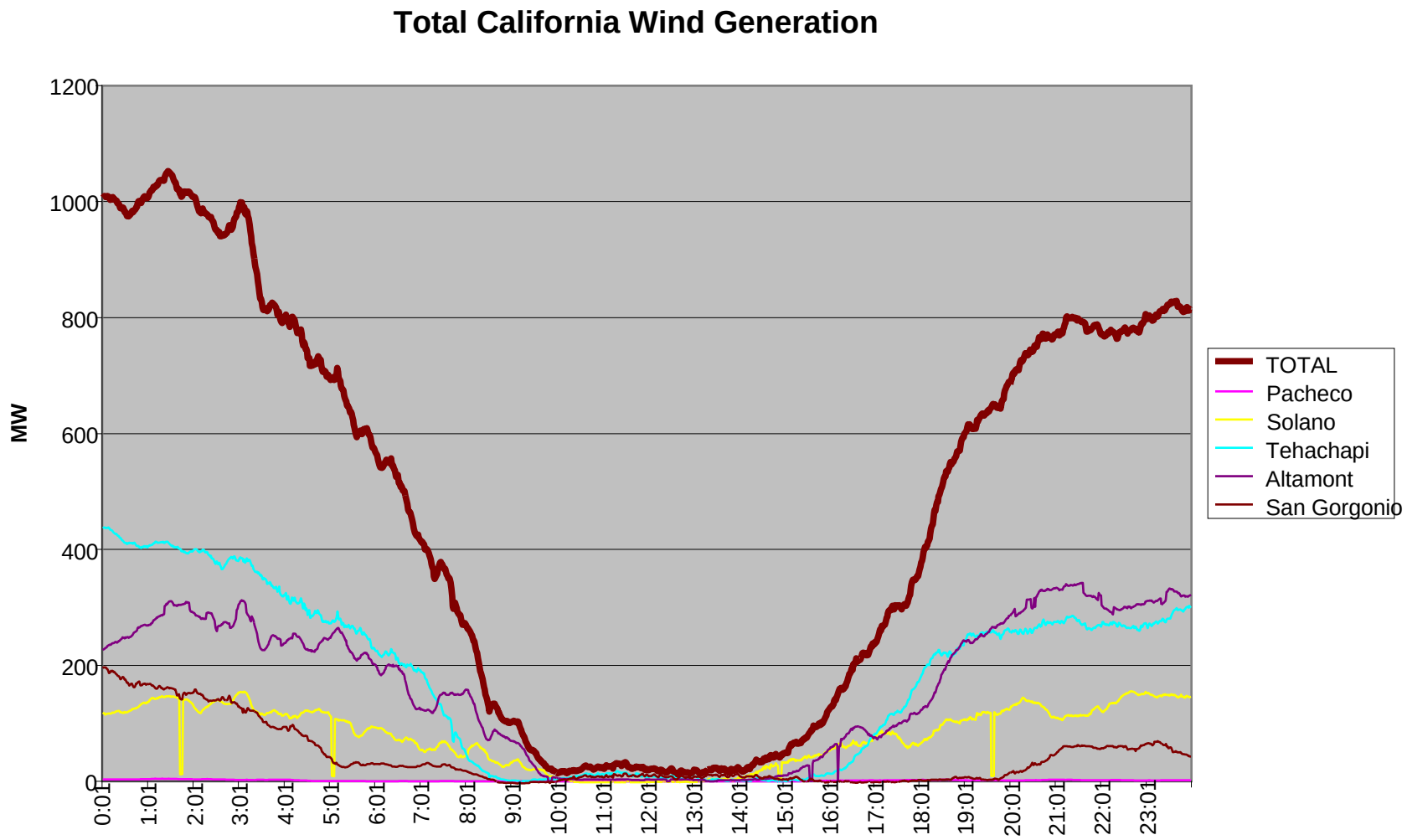
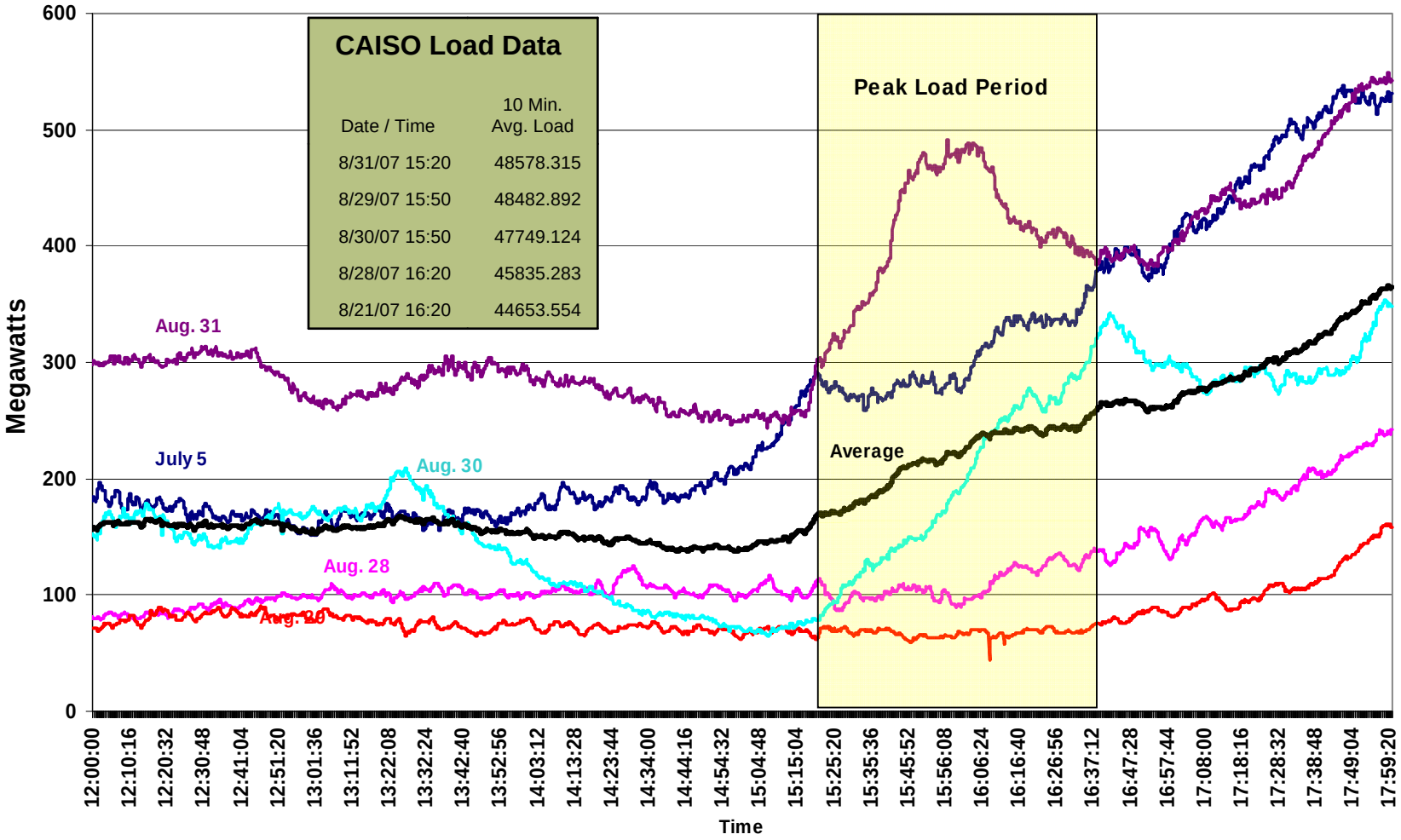
# Wind generation output changes quickly – diversity?



# Wind Generation Summer 2007 – 5 Hottest Days



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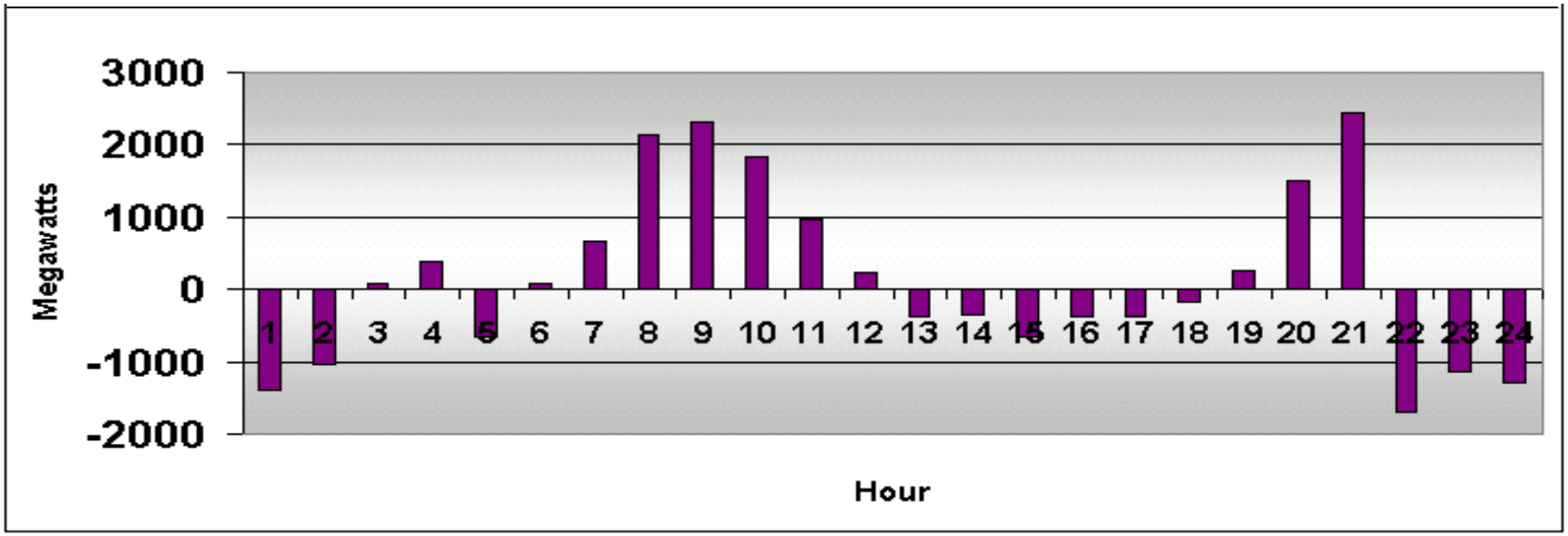
# Ramping issues

• In California, the wind generation energy production tends to be inversely correlated with the daily load curve. The wind energy production peaks during the night and falls off during the morning load pick up. The net result will be morning ramps of 2000 to 4000 MW per hour for 3 hours – a total of 6000 to 12,000 MW over 3 hours.

**Forecasted Hourly Ramps due to Additional Wind Generation**



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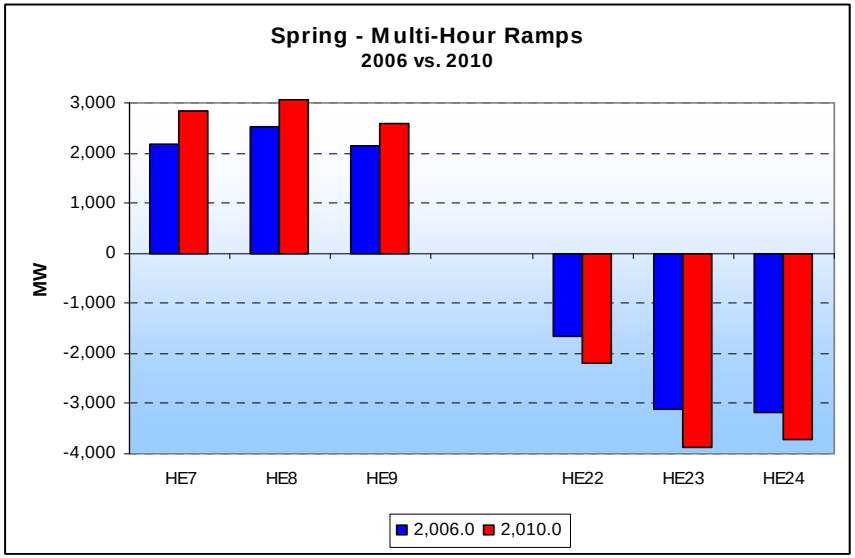
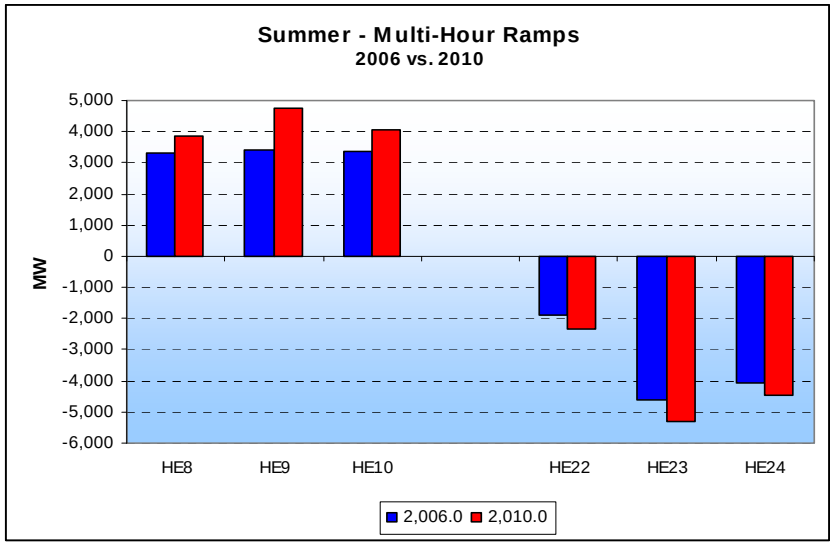
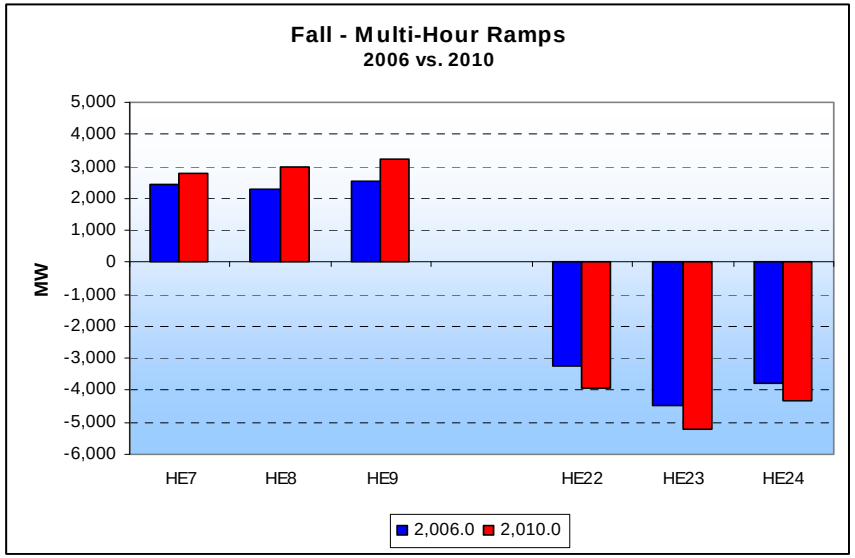
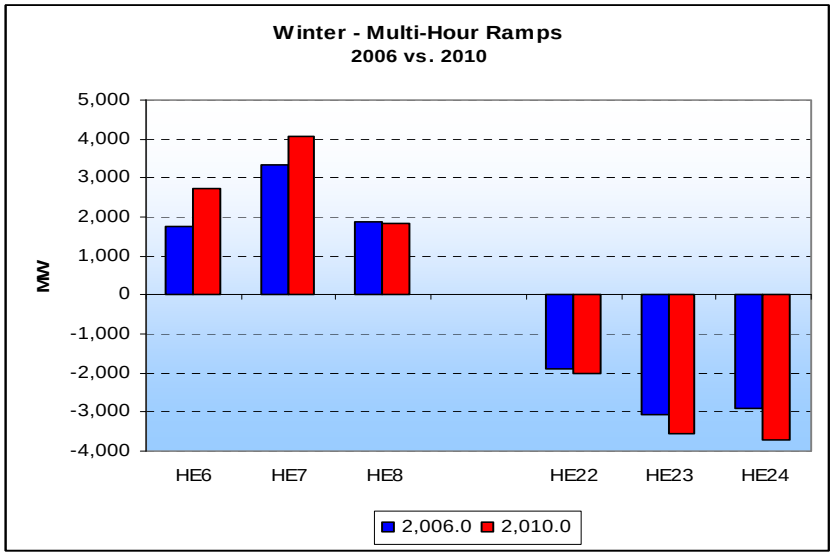
# Ramping impacts vary by season.



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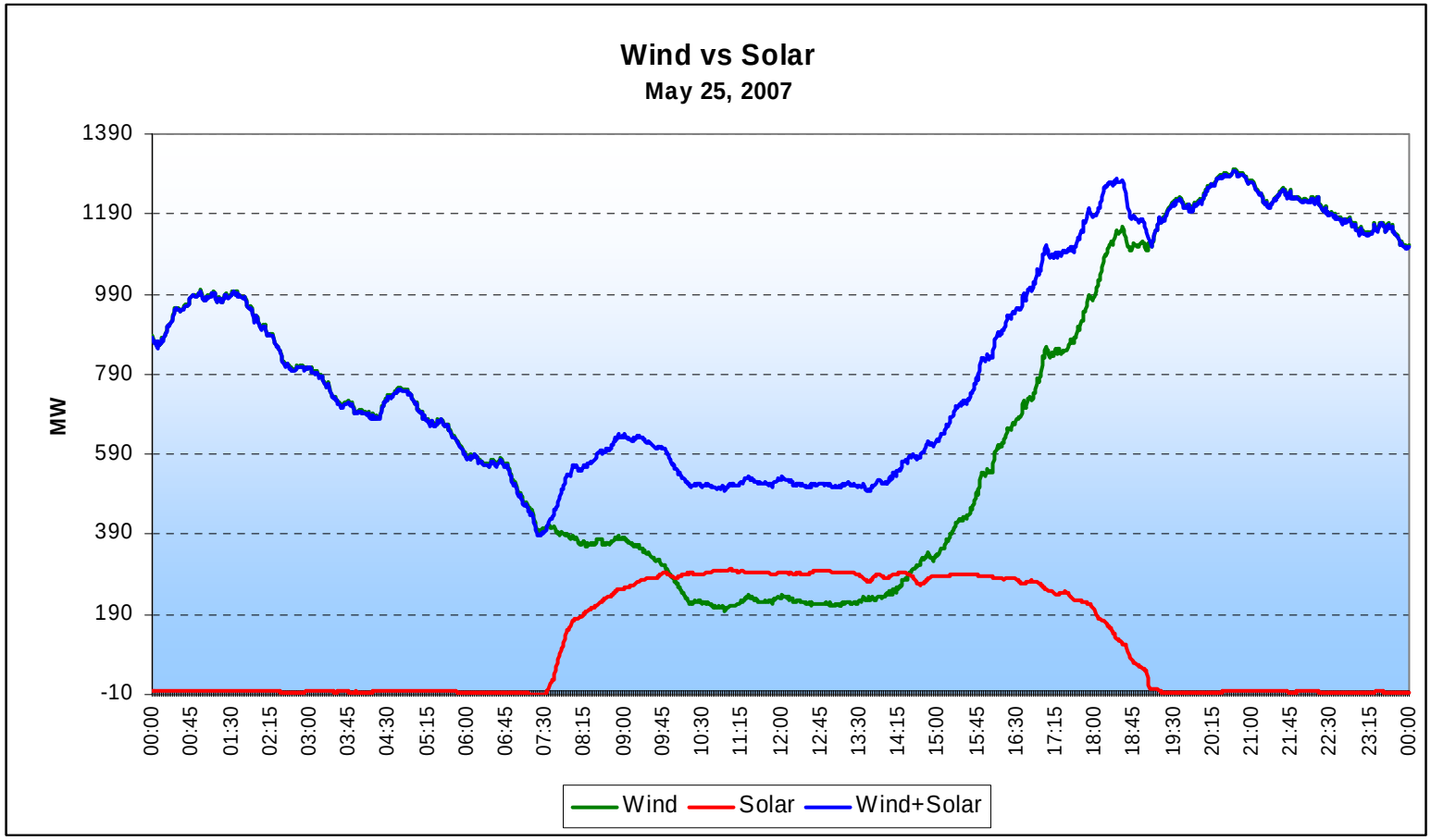
# Typical Daily Wind vs. Solar Generation Pattern



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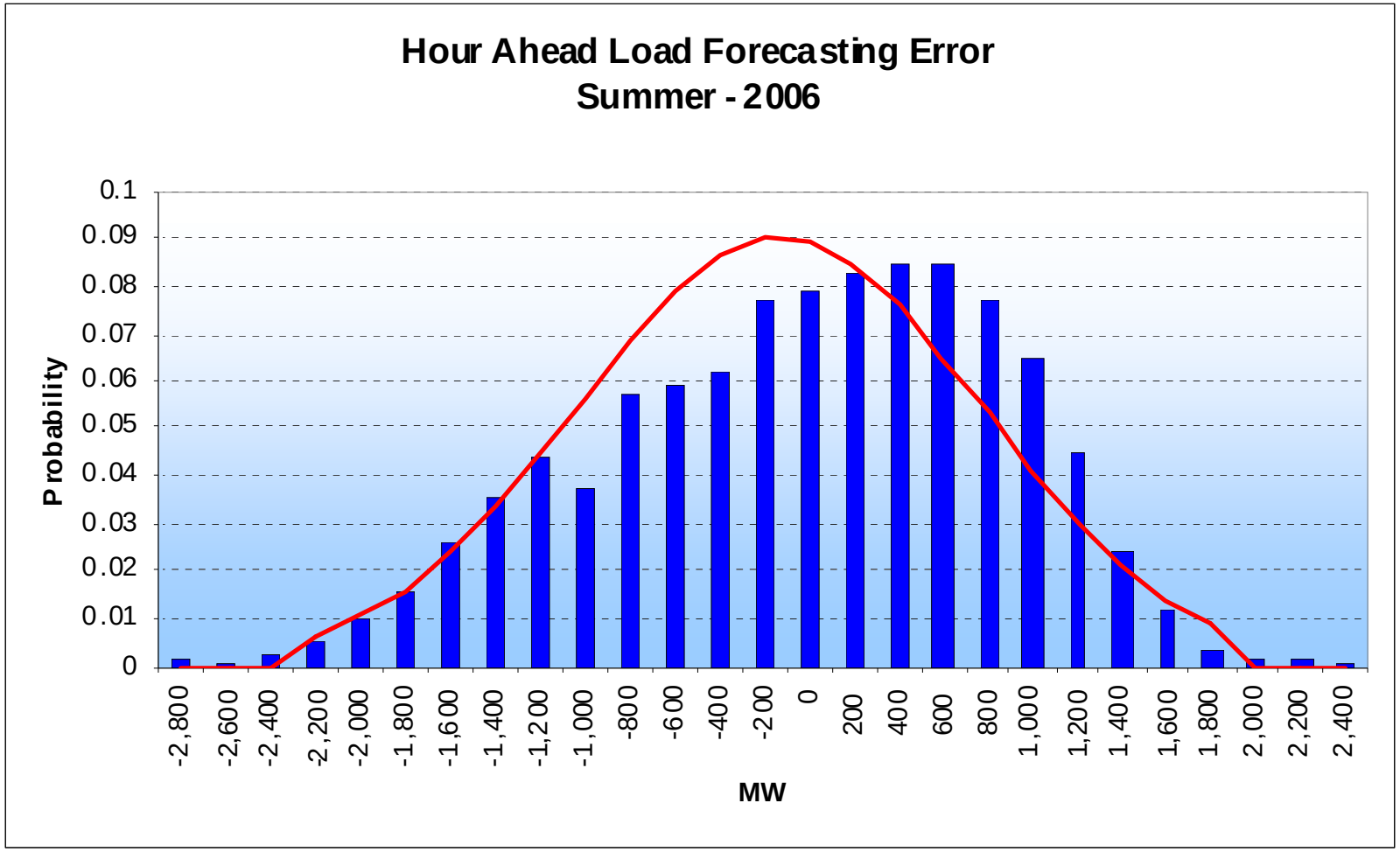
# Actual Load forecasted distribution errors (blue bars) to the theoretical error normal distribution (red line) for the summer months




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.



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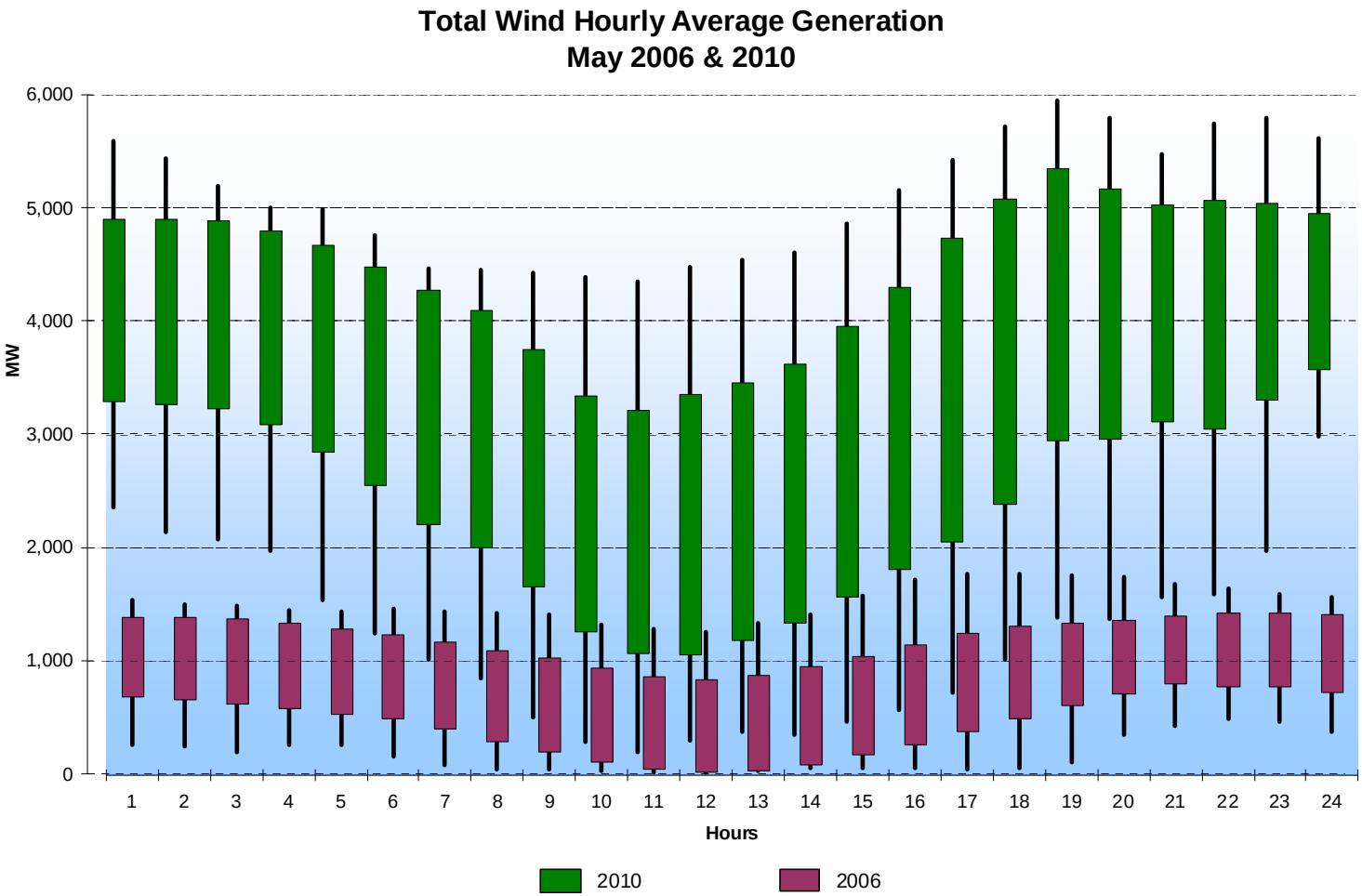
# Actual Wind Generation 2006 vs. Expected Wind Generation 2010




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



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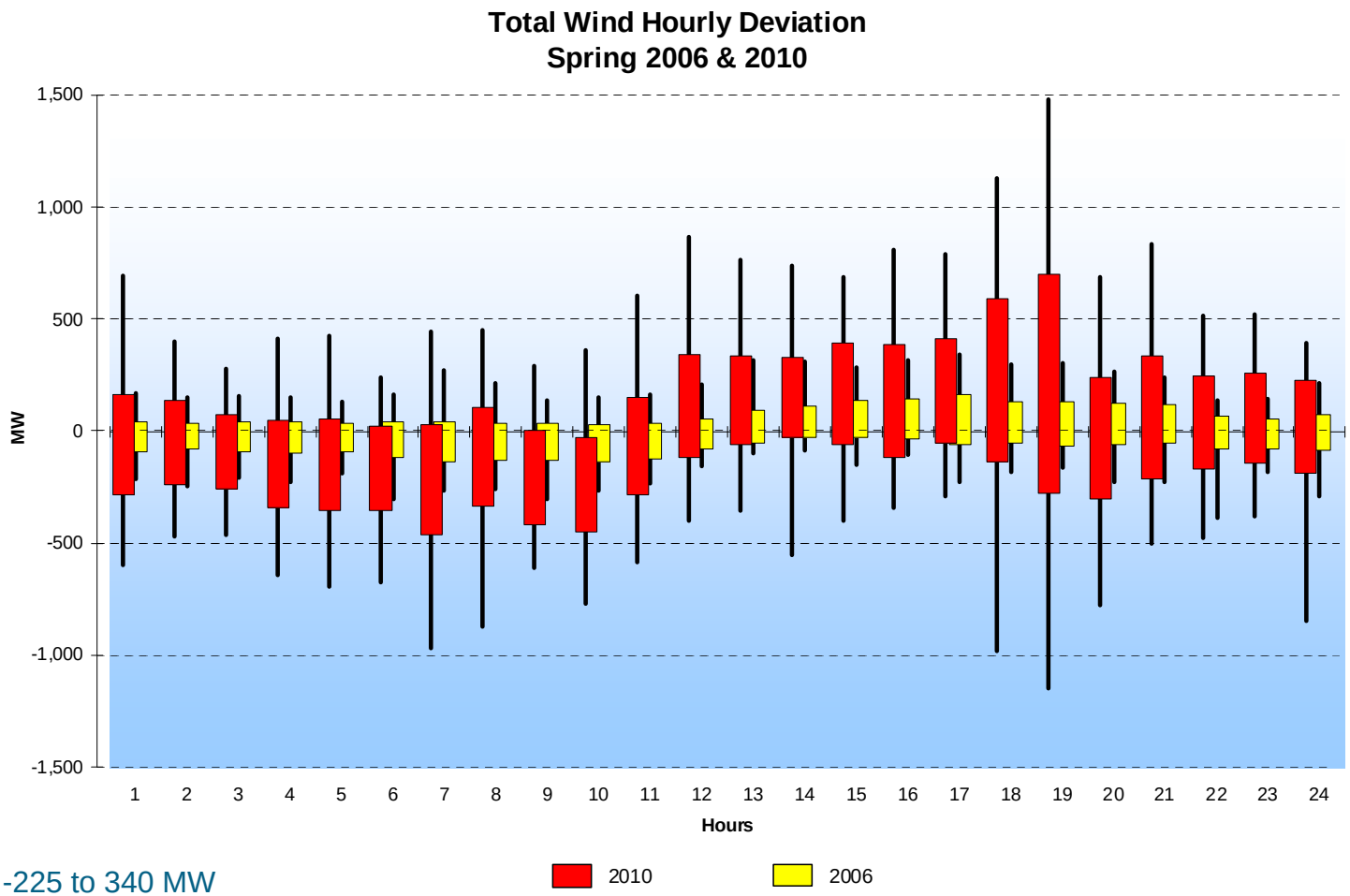
# Comparison of Hourly Deviations of Wind Generation observed in 2006 and Expected Deviations in 2010




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



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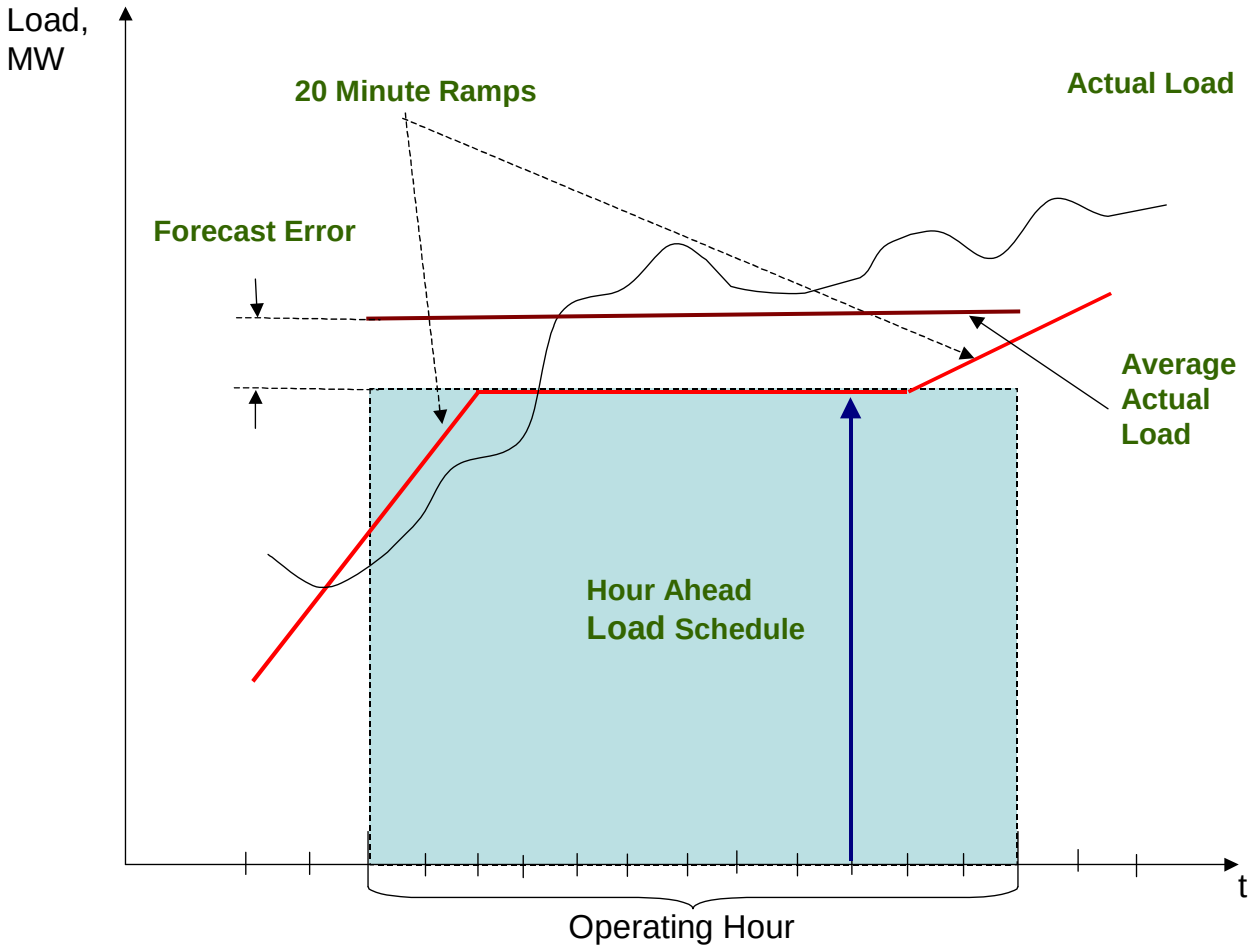
# Studies document additional ramping requirements.

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 |

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



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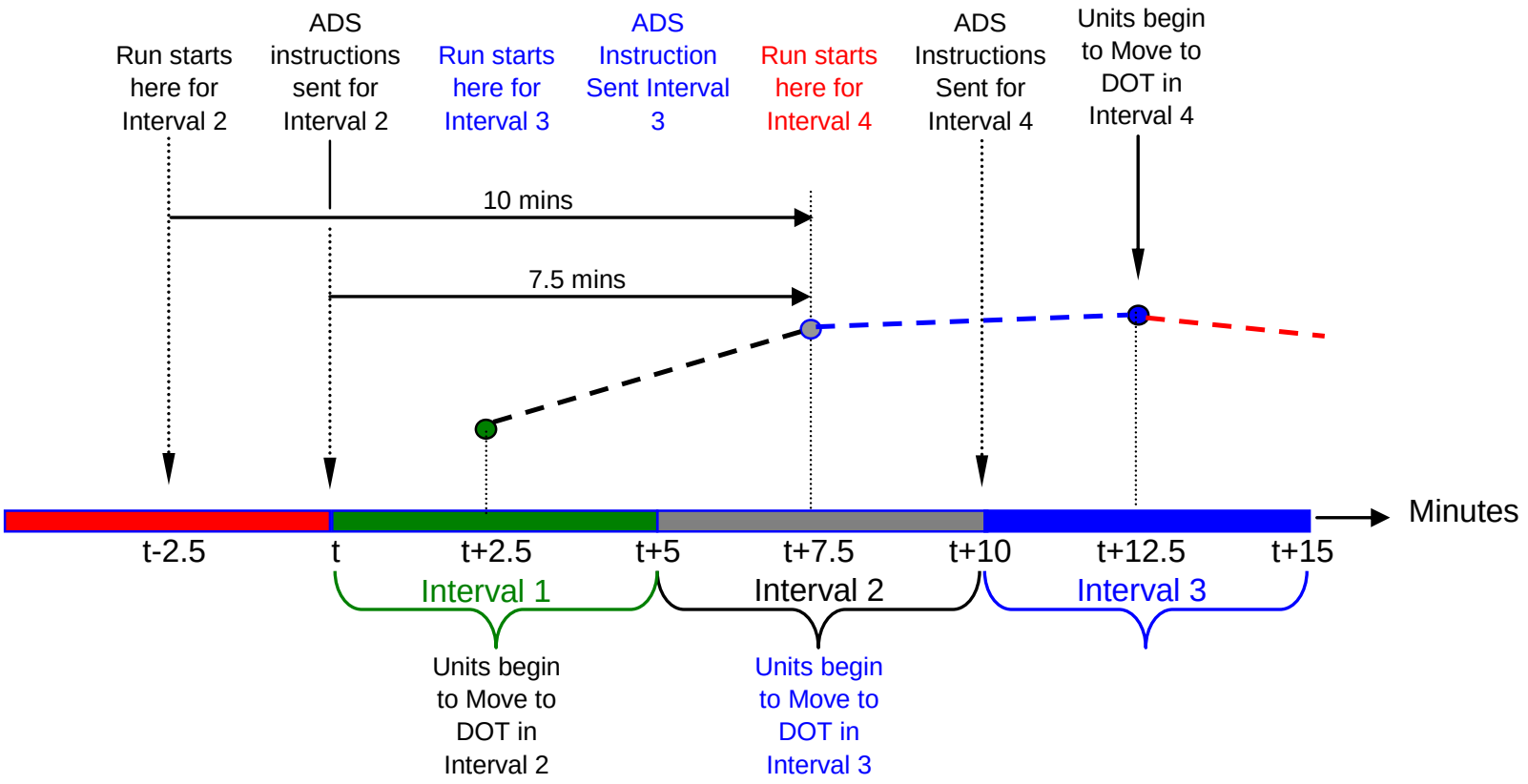
# MRTU timelines benefit renewable integration.

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.



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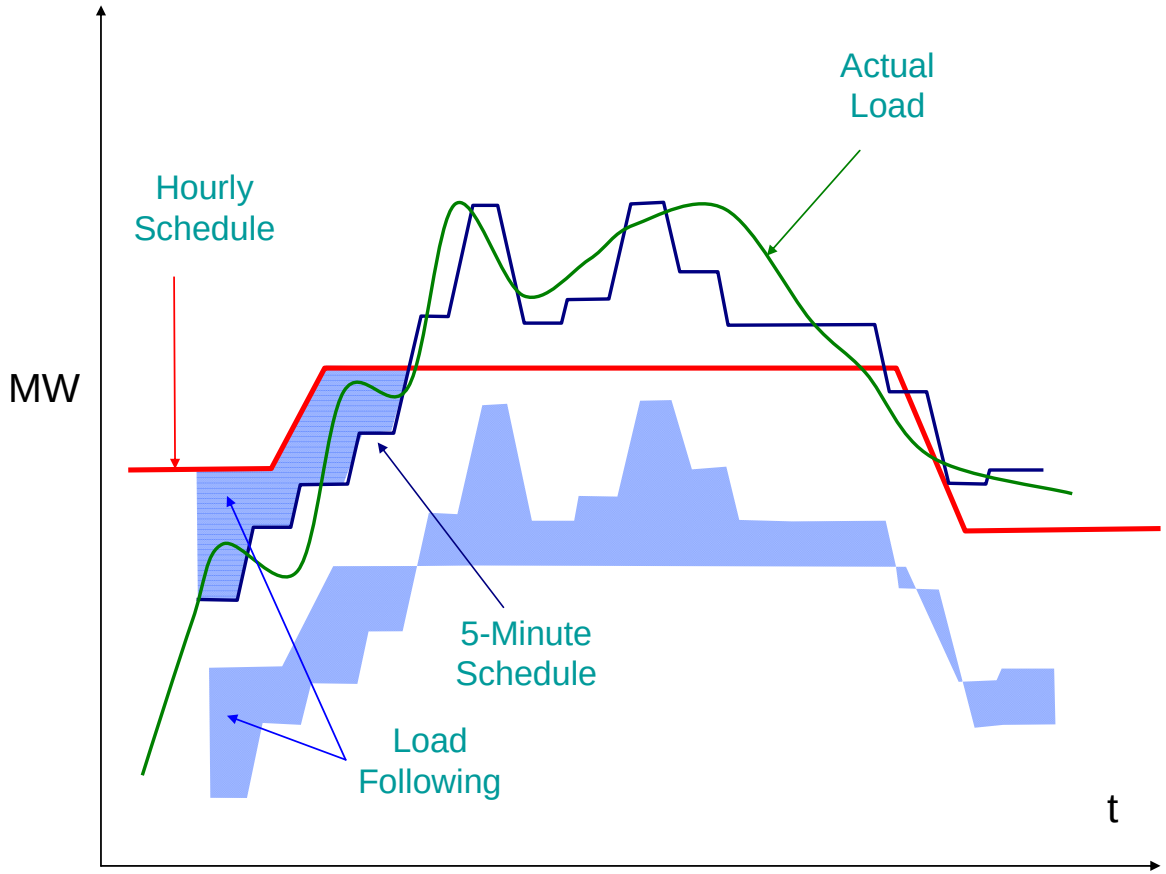
# *Load Following Requirement shown as blue shaded area*



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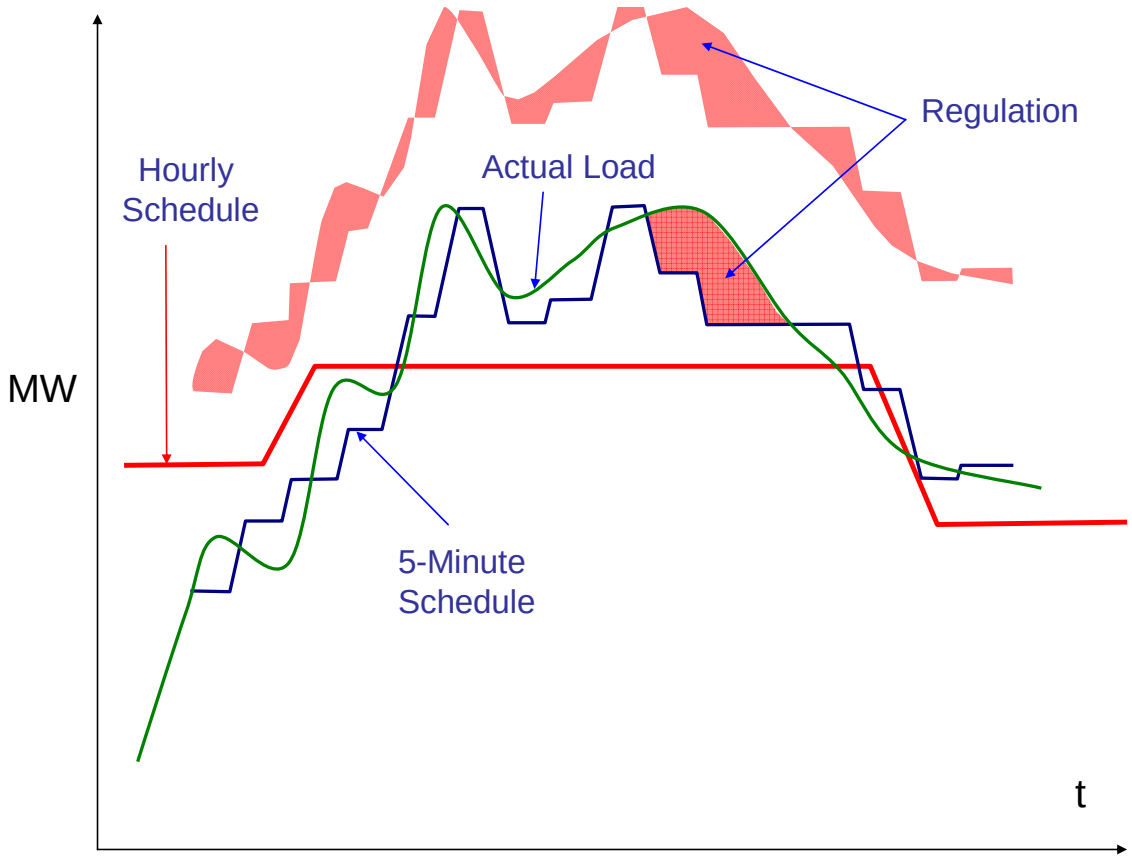
# The studies conclude that intra-hour load following impacts are manageable.

- 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 ramping requirements will increase and require more generation to be available for both upward (700-800 MW) and downward (600-1,000 MW) dispatch.

# *Regulation Requirement shown as the red shaded area*



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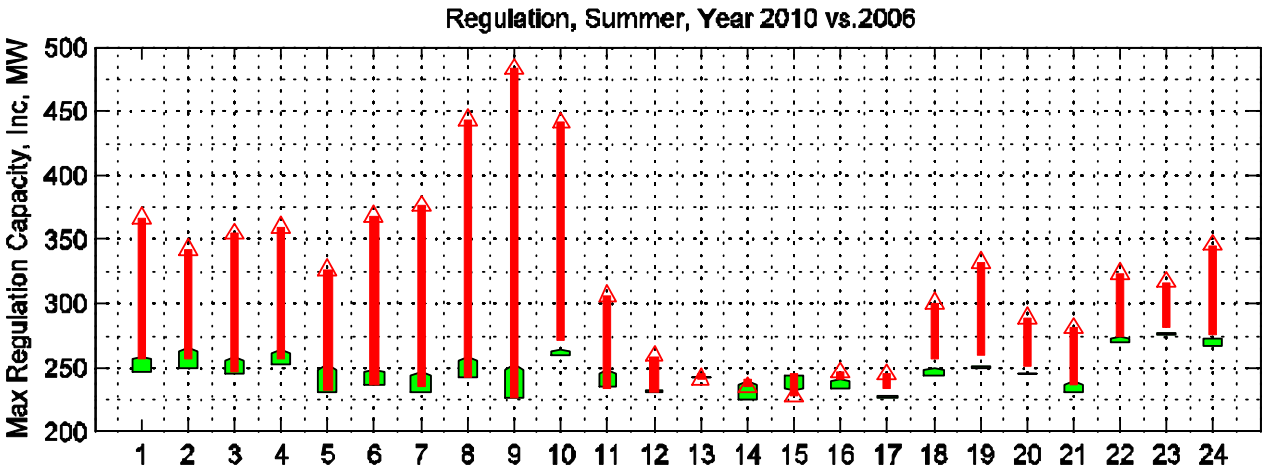
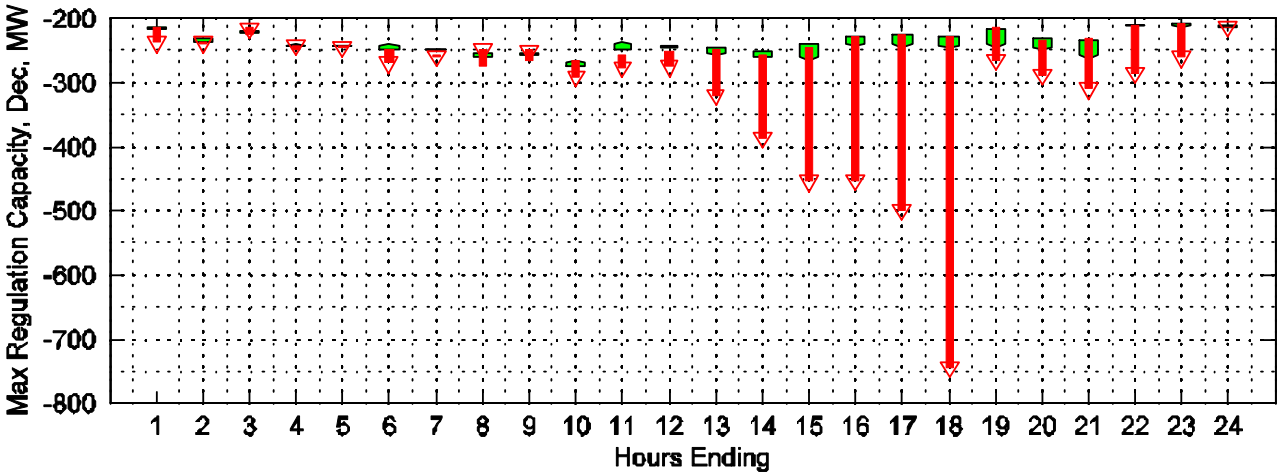
# The CAISO regulation capacity requirements would increase noticeably during certain hour ranges

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



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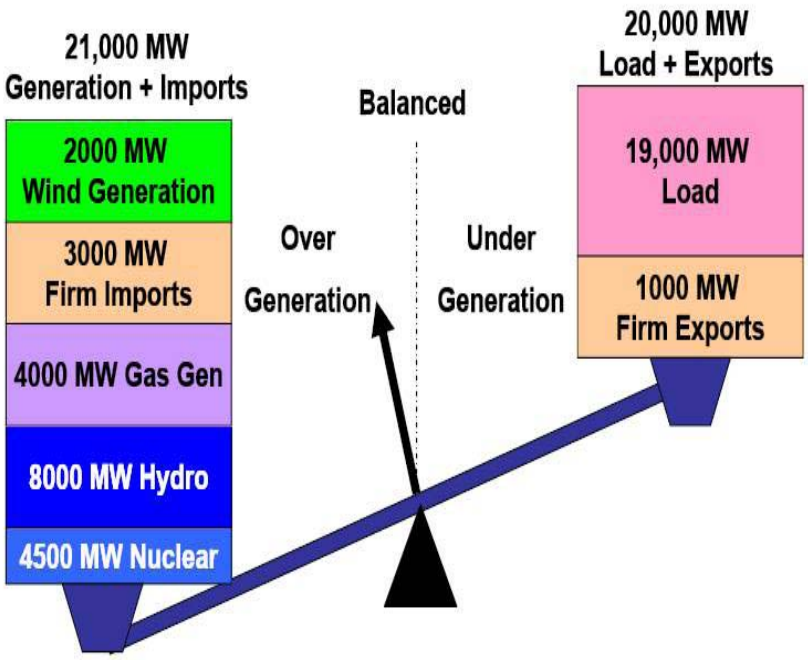
## The studies conclude that additional regulation requirements are significant but remain manageable.

- 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.
- 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.

# Typical Oversupply Conditions - CAISO

- Light load conditions – loads around 22,000 MW or less,
- All the nuclear plants on-line and at maximum production,
- Hydro generation at high production levels due to rapid snow melt in the mountains,
- Long start thermal units on line and operating at their Pmin levels because they are required for future operating hours,
- Other generation in a “Must Take” status or required for local reliability reasons, and
- Wind generation at high production levels.




Imbalance between Generation and Load

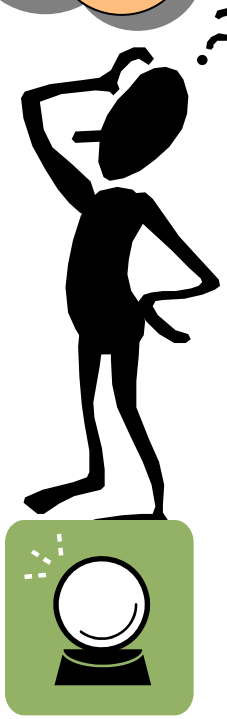
# Operators Need Info - What is Changing?

What is the load forecast change? What is the ramp rate?

How good is the load forecast today?

What are the Interconnection schedules?

Is the merit order changing?



What generators are still ramping from the last dispatch? How much energy is still to come?

How good is the wind power forecast today?

What is the wind power forecast? What is the ramp rate?

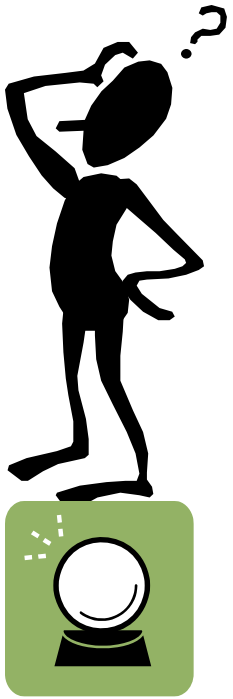
# Operators Need to Tools to make supply-demand balancing decisions

What is the ramp rate capability in the merit order over the next 10, 20, 30 minutes?

What are the Regulating Reserve units doing?

How much capacity to dispatch to get the required ramp rate?

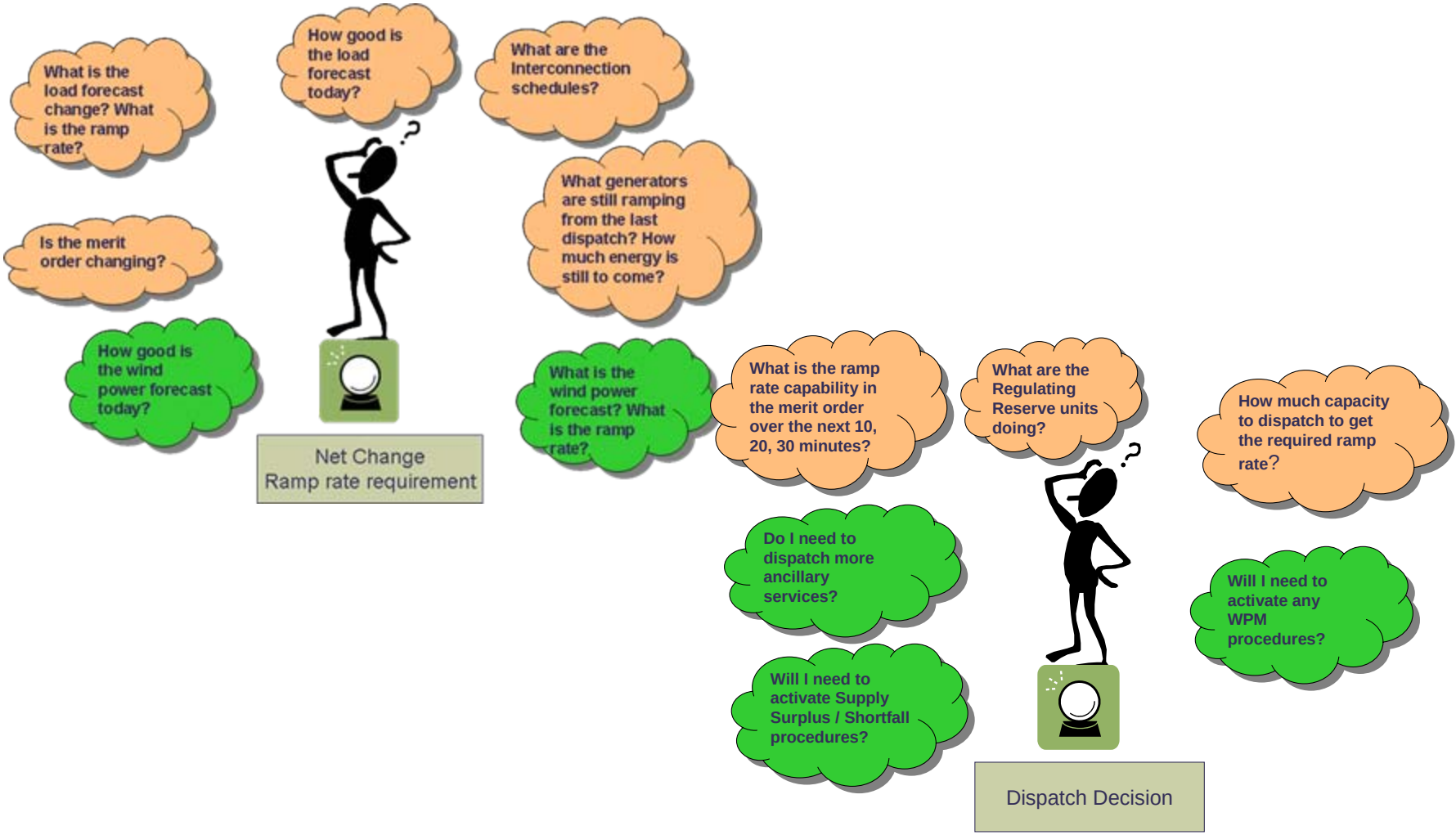
Do I need to dispatch more ancillary services?



Will I need to activate any WPM procedures?

Will I need to activate Supply Surplus / Shortfall procedures?

# Repeat When Necessary



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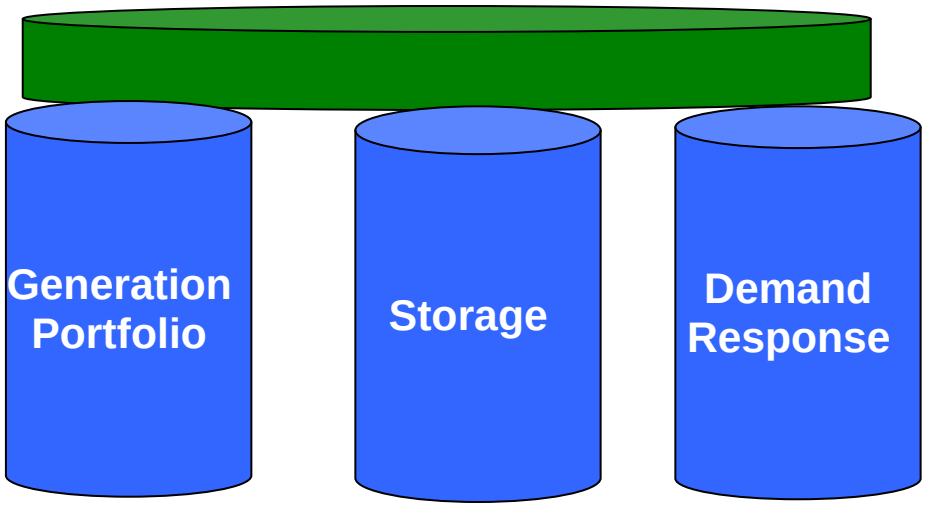
# Three requirements for Integration of Renewables




**Generation Portfolio**

- Quick Start Units
- Fast Ramping
- Wider Operating Range
- Regulation capability

**Storage**

- Shift Energy from off-peak to on-peak
- Mitigate Over Generation
- Voltage Support
- Regulation capability

**Demand Response**

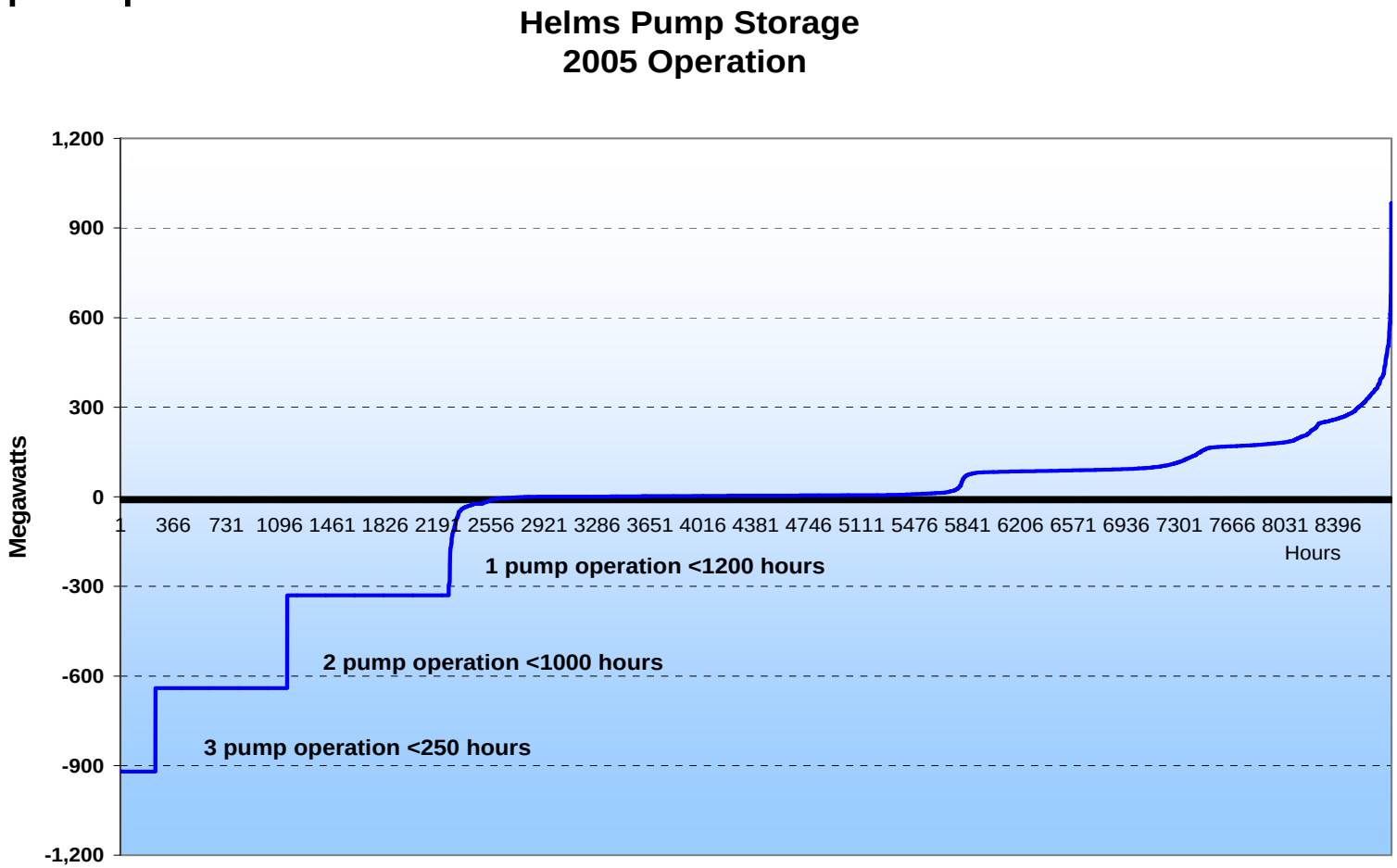
- Price sensitive load
- Responsive to ISO dispatches
- Frequency Responsive
- Responsive to Wind Generation Production

# Storage Technology

- Pump Storage
  - Operation of 3rd pump at Helms will be a significant help with the integration of large amounts of wind generation. This requires a upgrade of transmission facilities to Fresno area
- Hydrogen Storage
  - The CAISO, CPUC and CEC staff need to be involved in evaluation of new storage technology such as hydrogen storage – recommend visit to DOE sponsored hydrogen storage project in Colorado
- Compressed Air Storage
- Flow Based Battery Storage – Santa Rita Jail Project
- High Speed Flywheel Storage
- Develop strategy for financing and implementing storage systems
  - Storage Workshop in 2008

# Storage Technology – Pump Storage

- Helms Pump Storage Plant rarely operates all three 300 MW pumps.



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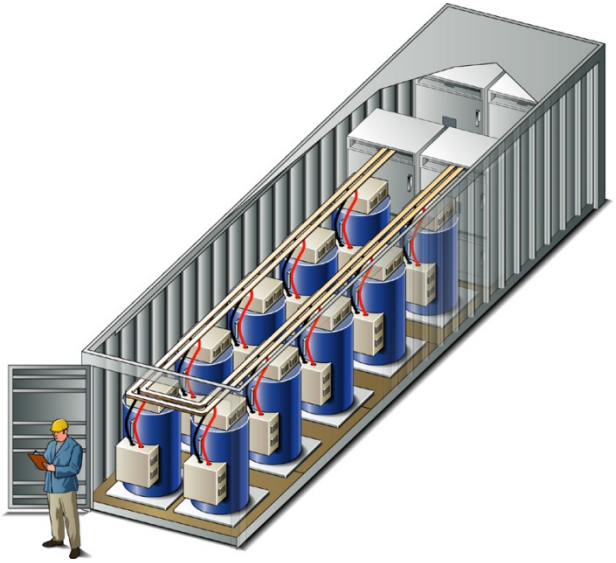
# Storage Technology – High Speed Flywheels

- Flywheel Energy storage project for AGC Regulation Service and frequency control. Test system installed in Sept. 2005 at the Research Center in San Ramon. Research project successfully completed 2007
- Need a performance based contract with a market participant
- Can we justify a 20 MVA or 40 MVA facility for AGC?



A "Megawatt in a Box"

- Beacon Power technology
- (10) 25-kWh flywheels
- 1 MW for 15 minutes
- Quick deployment
- Price about 1 million $$

# Demand Response Programs

- 4 Types required
  1. Price Sensitive load that is willing to reduce demand for the right price. Demand that is bid into Day-Ahead markets to reduce peak load
  2. Interruptible Load – Loads that are willing to be interrupted or curtailed under emergency conditions – Stage 2 Emergencies – and will immediately take action in response to a dispatch notice.
  3. Frequency sensitive load – Load that is willing to turn off or reduce consumption due to a drop is system frequency. Example is Plug-In Hybrid Vehicles that will automatically stop charging their batteries when the frequency is low.
  4. Load that is willing to change based on availability of excess wind generation production

## We need to work with stakeholders and the State to develop an effective action plan to successfully integrate expected new renewable generation.

- Enhance ISO wind integration program
  - Apply PIRP interconnection rules to all wind generation
  - Improve wind forecast -- Incorporate into scheduling processes and integrate with unit commitment and dispatch applications
- Change existing processes:
  - Improve utilization of existing hydro-electric generation
  - Increase reliance on existing fossil generation
  - Integrate improved wind forecasting into system dispatch
- Adjust resource procurement policies
  - Align procurement programs to address need for fast start units, increased ramping, and larger operating ranges
  - Provide for pro-rata wind curtailment for few hours of over-generation
- Coordinate with other state policy objectives – GHG and Once-Through Cooling
- Increase storage options
- Increase demand response options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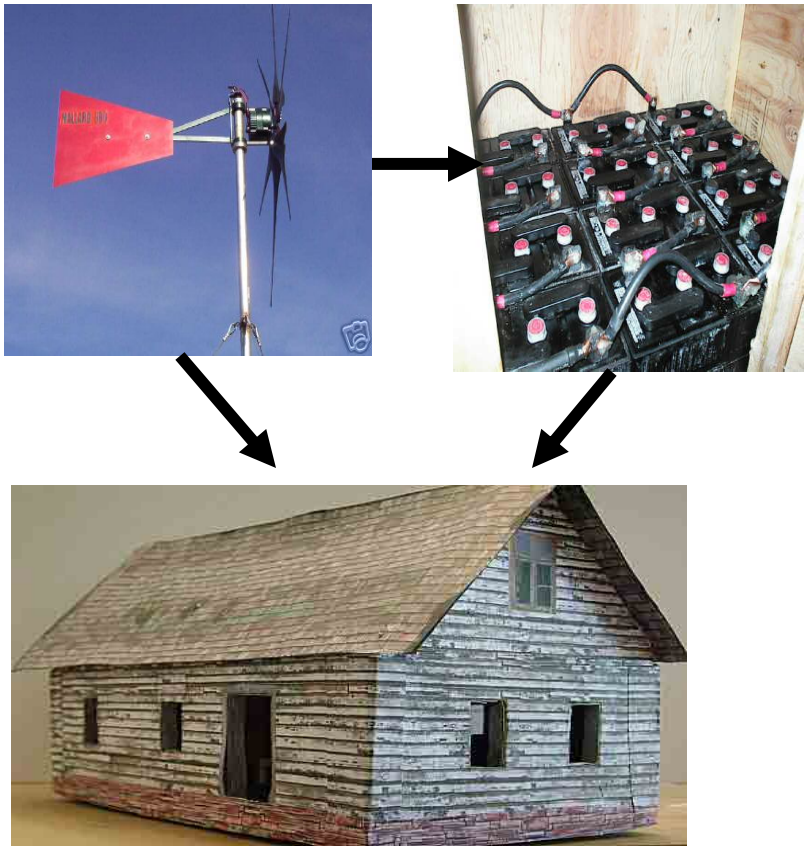
# We can reliably integrate 20% renewable generation.

- Intermittency and timing of wind generation creates need for integration services.
  - Increased need for morning and evening ramp resources by 20-30%
  - Increased need for regulation capacity and a much deeper supplemental energy stack due to potential wind forecast errors
  - Over-generation during certain hours – possible to mitigate by minimal curtailment.
- Needed integration services can be provided by:
  - Hydro, IF there is enough water
  - New thermal, IF it has the right characteristics
  - Existing thermal, IF it is kept operating at certain levels
- Other mitigation measures are also necessary:
  - Curtailment mechanisms
  - Improved technology
  - Better forecasting tools
- Maintaining existing generation is essential (although replacement or re-powering can work).

# Summary

- Must understand the reliability and planning implications of Policy Initiatives, Legislation and Renewable Portfolio Standards
- Need sophisticated wind forecasting tools
- Need conventional generation – wind needs a dance partner
- Need wind power management
- Operators need to know what to do and have the resources, tools and operating procedures
- Need Major Transmission Upgrades
- WPF must meet technical requirements (SCADA, voice, LVRT, reactive power)
- Storage and Demand technologies/options can assist

# Final Thoughts

- **We are learning as we go**
  - Need to share acquired knowledge
- **We need to educate**
  - The public, policy makers and many new players to the industry
- **We must simplify the messages**
  - Our dads/grandfathers remember windmills and back-up on the farm
- **We <u>must</u> maintain reliability**