California Independent System Operator Renewable Integration Study

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California ISO
Your Link to Power

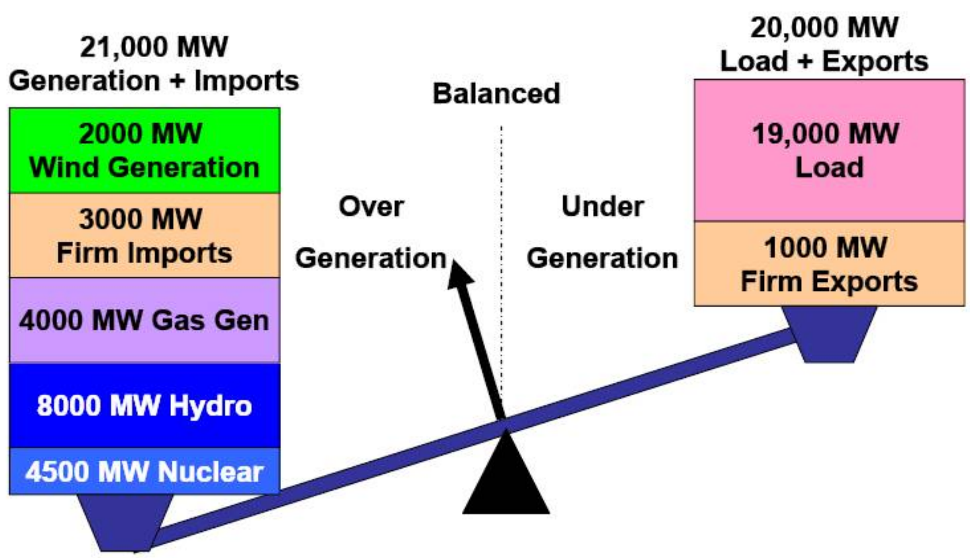
Achieving California's 20% Renewable Portfolio Standard

Over Generation Conditions

Typical conditions that lead to over generation

- 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



In Area Generation + Imports ≠ Load + Exports

Minimum Generation Levels during light load conditions

Generation/Load	Production Level Spring 2006 (MW)
Nuclear	**4,528**
Minimum "Must Take" such as QFs	**2.400**
Minimum Geysers	**650**
Minimum Thermal	**1,000**
Minimum Hydro	**3,700**
Minimum Interchange	**2,880**
Total Generation plus Interchange	***15,158***
Minimum Load	**18,070**
Difference	***2,912***

If wind generation exceeds 2,912 MW, then there is no room for the excess generation

Minimum thermal generation could be 2,000 to 3,000 MW.

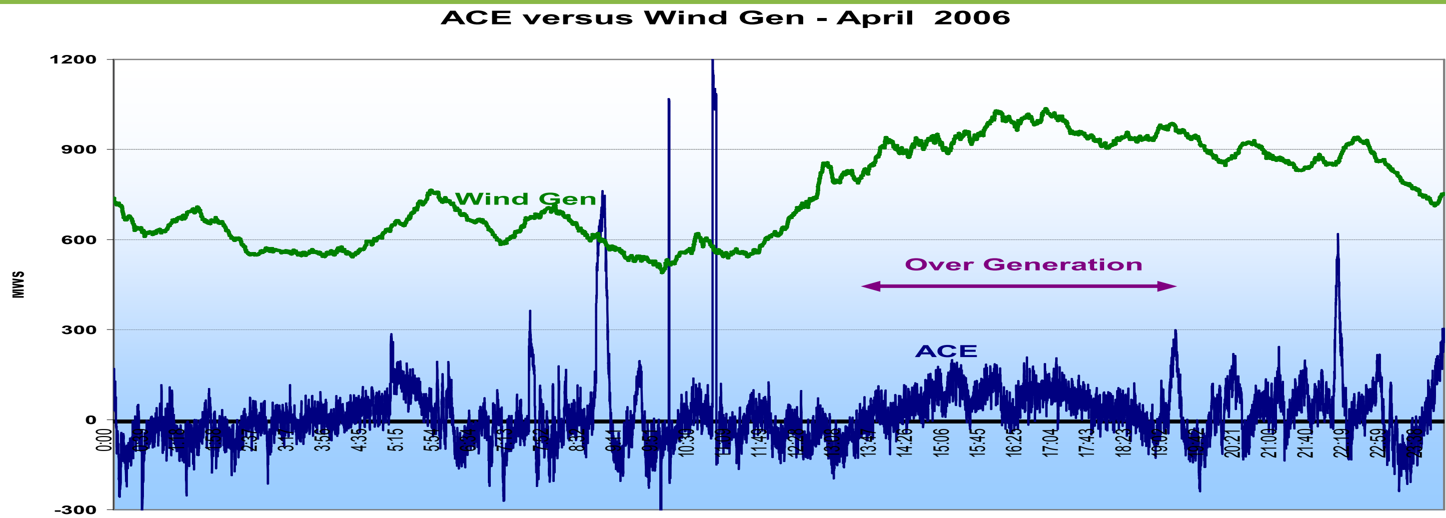
Need for lower P_{min} values and more units that have fast start

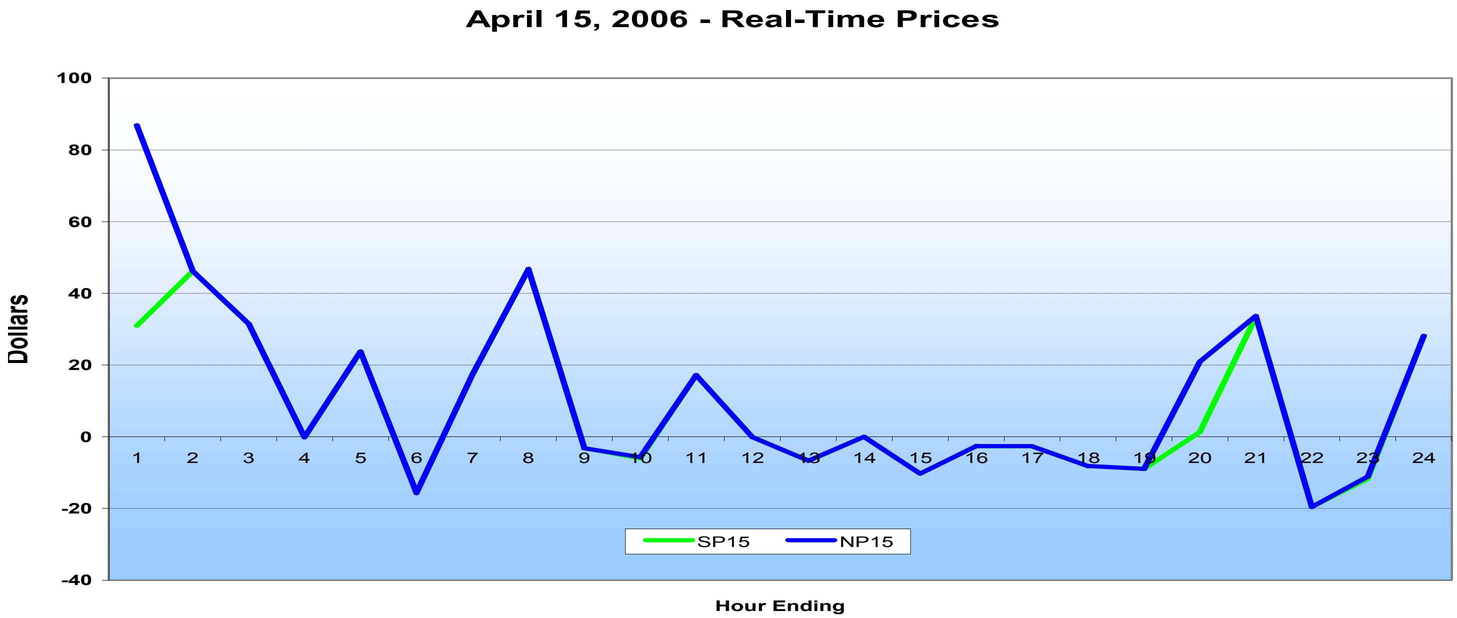
Accurate forecasting of day-ahead wind generation production will be essential to minimize over-generation schedules

Key Issue is what gets cut?

- Spill some wind ?
- Spill some water?
- Spill some of both?

Over Generation typically drives real-time prices negative





Conclusions & Recommendations about Over Generation

- Over generation occurs with the existing amount of wind generation but it is relatively rare occurrence.
- The lack of good Day Ahead wind generation forecast contributes to the problem.
- The addition of large amounts of wind generation facilities will exacerbate the problem.
- MRTU Integrated Forward Market should help to mitigate the problem
  - Generation schedules match the load forecast.
  - Accurate Day Ahead wind generation forecasts will be a key component for the Day Ahead RUC process.
- Wind generation operators should be prepared to curtail some wind generation production to mitigate serious over generation conditions in the future. The amount of renewable energy lost will be small.
- The CAISO must work with the wind generator operators to ensure procedures, protocols, and communication facilities are in place so dispatch commands can be communicated to the plant operators.
- Additional storage capability on the system would help to mitigate both over generation and large ramp conditions.

Comparison of CEC IAP study and ISO Renewables Integration Report

Issue	**CEC IAP Report**	**CAISO Report**
Report covers both 20% RPS target and 33% target	Yes report covers the transmission and renewable resources required to meet the 2010 20% RPS target and the 2020 33% RPS target.	No the CAISO report focuses only on the requirements to meet the 20% RPS target. The 2020 33% RPS requirements will be done as a future project.
Report covers all types of renewable resources.	The IAP report does a forecast of the amount of all types of renewables that could potentially developed in the State and then concentrates on the issues with intermittent resources such as wind and solar.	The CAISO report covers the amount of energy being delivered from the various types of renewable resources but then concentrates on the transmission plan for the planned build out of wind generation in Tehachapi and the operations issues associated with intermittent resources.

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Transmission Study	The project conducted power flow and production cost simulations to establish a 2006 baseline, and to develop renewable resource portfolios and infrastructure for 2010 and 2020. Load flows were prepared using PowerWorld software. Production costs were modeled using General Electric's Multi-Area Production Simulation (GE-MAPS™) modeling software to evaluate grid operation with increasing levels of wind and solar generation in the generation mix.	The project built on the IAP modeling work and engaged GE to do joint detailed studies of the Tehachapi Transmission Plan. The CAISO and GE team did detailed Load Flow, Transient Stability and Post Transient analysis of the planned build out of wind and solar generation in the Tehachapi area for the 20% RPS target scenario. The

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Issue	CEC IAP Report	CAISO Report
Transmission Conclusions 20% RPS target by 2010	Significant transmission investments are necessary to meet the 2010 and 2020 RPS targets. For the 2010 Tehachapi case, 74 new or upgraded transmission line segments are needed at a first order estimated cost of $1.2 billion plus $161 million for transformer upgrades and unknown costs for land use and right-of-way costs	A detailed study of the approved $1.8 billion Tehachapi transmission plan meets all planning standards for voltage control, line loading, and dynamic system response. The results are dependent on the type of wind generation installed in Tehachapi so all future turbine installations must be type 3 or Type 4 units which have power factor controls and meet WECC LVRT standard.

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Issue	CEC IAP Report	CAISO Report
Transmission Conclusions 33% RPS target by 2020	The 2020 case would require 128 new or upgraded transmission line segments, with just over half (66) needed to serve increasing load requirements. For just the 500kV and 230kV additions, a first order estimated cost would be $5.7 billion. In addition, 40 new or improved transformers would be needed at an estimated cost of $655 million (excluding detailed land use and right-of-way costs).	The first step in developing a transmission plan for 33% renewable resources is to determine where the resources will be located and what type of resources will be built. The CAISO currently has 20,000 MW of solar and 20,000 MW of wind generation facilities in our interconnection queue. CAISO will work with the developers, utilities and state agencies to determine the most likely renewable locations that will be developed and then develop a transmission plan that connects these resources to the load centers in the State.

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Issue	CEC IAP Report	CAISO Report
Minimum load operation and potential over generation conditions	**• A combination of in-state generating resources and power exchange agreements or capability should be pursued to allow operation to a minimum net load of between 18,000 to 20,000 MW.** **• Pursuing generating resources with greater minimum turndown and diurnal start/stop capabilities, ensuring greater participation by loads, and optimizing use of pumped storage hydro will also aid with integrating variable renewable energy generation.** **• In-state generating resources should also be targeted for providing scheduling flexibility hourly.** **• Maintaining or improving hydro flexibility and accessing generating resources with faster start and stop capabilities will aid with hourly scheduling flexibility.**	The CAISO report agrees with the IAP report and recommendations. The report does a more in-depth analysis of potential over generation problems during light load conditions with maximum hydro generation that occurs during spring runoff. The conclusions are similar to the IAP report in that we will need • More fast start fossil fueled units that can be shut down during periods of maximum wind generation production, • More hours of 3 pump operation at Helms Pump Storage Plant, and the need to evaluate new storage technologies • Potential need to implement pro-rata cuts in wind generation production to mitigate serious over generation problems for a limited number of hours per year.

Comparison of CEC IAP study and ISO Renewables Integration Report

Issue	CEC IAP Report	CAISO Report
Regulation and Load Following	The IAP report concludes that there will be an increase of 10 MW/minute of load following and 70 MW/minute of down load-following during light load periods. The increase in regulation is relatively modest at 20 MW	The CAISO study developed a new method and model for calculating the amount of regulation and load following that will be required. The average amount of regulation increase is approximately 100 MW annually. There is a major seasonality factor for calculating the amount of regulation required. Regulation up may increase by 250 MW for some hours and regulation down may increase by 500 MW for some hours.
Ramp Rates	The IAP report included a finding that ramp rates will increase to as high as 12,000 MW over a three hour period during the morning load pick up.	The CAISO study found similar ramp rates as the IAP study.

Comparison of CEC IAP study and ISO Renewables Integration Report

Issue	CEC IAP Report	CAISO Report
Storage Technology	Not included in IAP report	Summary of current technologies included in the report
Wind Generation forecasting	Extensive discussion of the wind generation forecasting methodologies	Not included in the study
International experience	Extensive amount of material on the international experiences with wind generation	Brief discussion of the significant issues on wind generation that we could use for wind integration in California

National & International Experiences

- National
  - Collaboration with BPA on Wind Integration studies
  - Monitoring the NY, Minnesota, XCEL Energy, and ERCOT studies
  - NREL Study for Southwestern Area wind integration
- International
  - Extensive material in CEC IAP report on Europe and Asia
  - ISO participated in Canadian workshop on wind integration
  - Review of Spain, Germany, Demark and Ireland experiences with integration of large amounts of wind generation
  - Meeting with representatives from Australia and New Zeeland

Storage Technology

Pumped hydro, which generates electricity by reversing water flow between reservoirs, is the most widespread energy storage system on power networks. With an efficiency rate of more than 70%, pumped storage accounts for over 90GW worldwide, according to the Electricity Storage Association (ESA).

Flywheel systems, which utilize a massive rotating cylinder, boast effective load following characteristics and a wide-range of short and long-term capabilities. Beacon Power has refined low-cost commercial flywheel designs for operation that could last up to several hours and experts estimate that forty 25kW (25kWh) wheels can efficiently store 1MW for one hour.

Compressed Air Storage, takes advantage of the many abandoned gas and oil wells in the state as a cavern to store compressed air and recover it for use in a turbine.

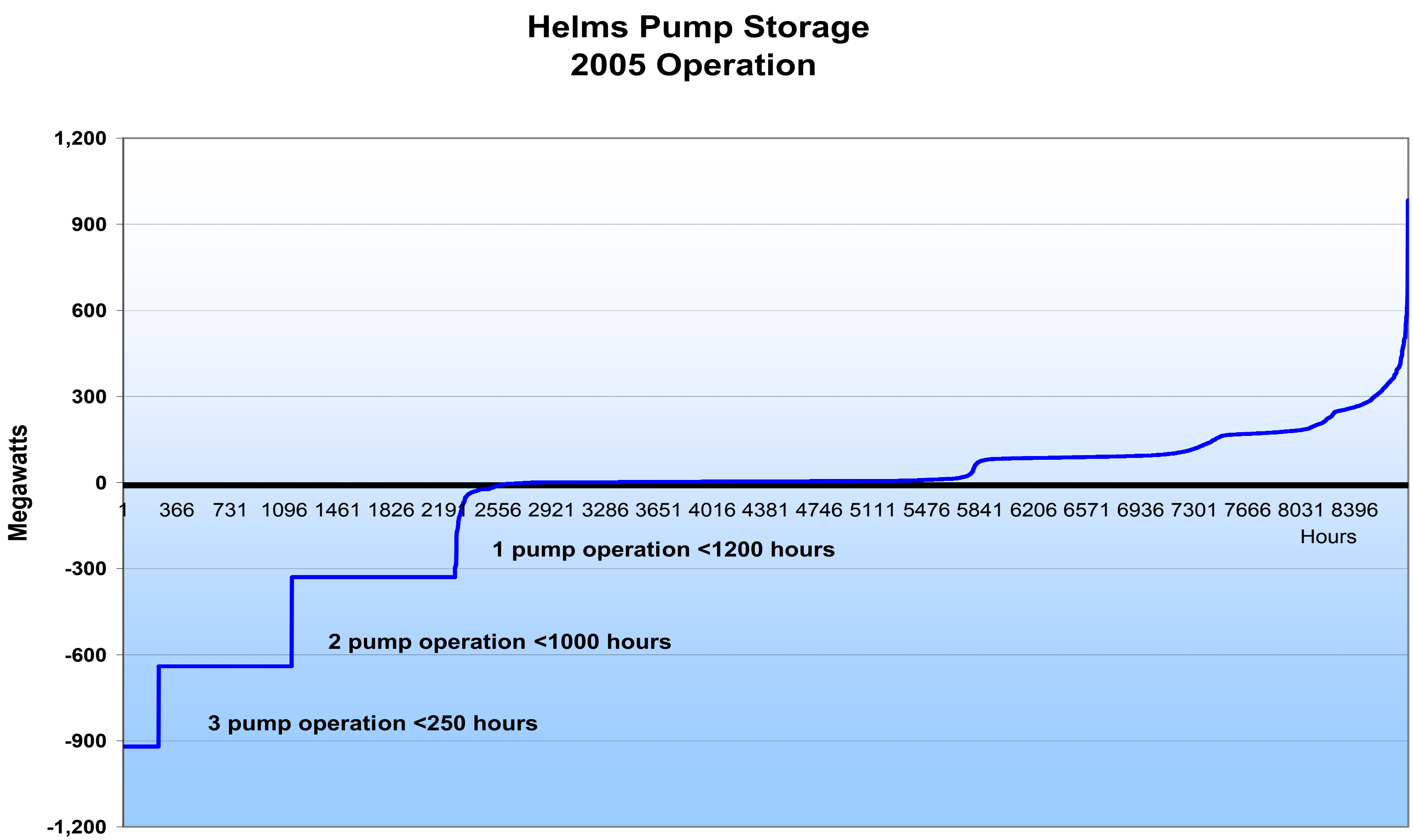
Super capacitors, or electrochemical capacitors, possess swift charge and discharge capabilities. More powerful than batteries, they can be cycled tens of thousands of times. Those with energy densities under 20kWh/m3 have been successfully developed, and work is underway to expand the effectiveness of larger units.

Flow batteries have low energy density, but they offer high capacity and independent power and energy ratings. Technologies in use include polysulfide bromide (PSB), vanadium redox (VRB), and zinc bromide (ZnBr).

Vehicle-to-grid. The idea of using the batteries of plug-in hybrid vehicles as an energy storage resource -- a concept called Vehicle to Grid (V2G) -- is still in its infancy, but may have potential as a quick-response, high-value service to balance fluctuations in load.

Storage Technology – Pump Storage

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



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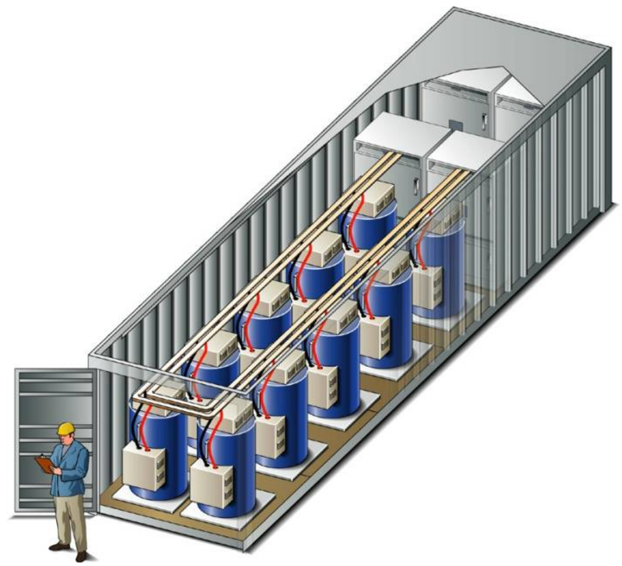
Storage Technology – High Speed Flywheels

- 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
- Test system was 100 KVA to demonstrate proof of concept and validation of technical and economic performance
- Next step is a 20 MVA or 40 MVA facility



A “Megawatt in a Box”

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

Storage Blockers

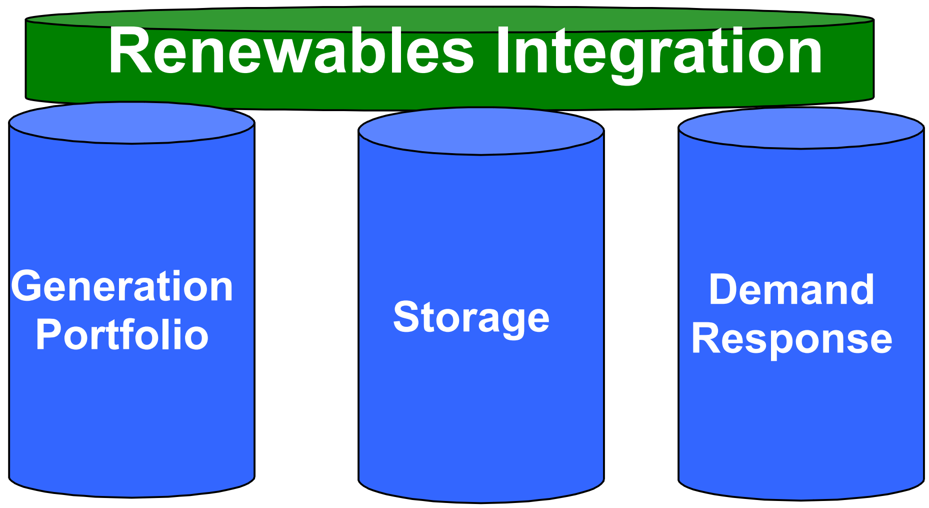
#1 A good economic model for making storage payoff. Is the differential between off-peak prices and on-peak prices large enough or sustained to make a compelling business case?

#2 What value added services can storage provide to improve the economic model? Fast ramp rates? High Speed Regulation? FRR-Frequency Responsive Reserves?

The storage industry has been working work with governments, regulators, utilities, and operators to address and attempt to overcome the challenges to the proliferation of electricity storage. Some of these include:

- A lack of government subsidies and incentives to encourage investment
- Regulatory constraints and limitations
- The uncertainty of selling electricity storage systems at a price that will allow both developers and customers to profit
- Political will (it will take time to influence decision-makers. Will the window of opportunity stay open long enough for that to happen?

Going Forward: a comprehensive view



Quick Start Units

Fast Ramping

Wider Operating Range

Regulation capability

Shift Energy from off-peak to on-peak

Mitigate Over Generation

Voltage Support

Regulation capability

Price sensitive load

Responsive to ISO dispatches

Frequency Responsive

Responsive to Wind Generation Production