ELECTRIC POWER
RESEARCH INSTITUTE

April 6, 2009

California Energy Commission
Dockets Office, MS-4
Re: Docket No. **09-IEP-1G**
1516 Ninth Street
Sacramento, CA 95814-5512

Subject: Comments to Docket number 09-IEP-1G and indicate "2009 IEPR - Energy Storage Technologies".

Dear Sir / Madam:

My name is Dan Rastler and I am the Energy Storage Program Manager at the Electric Power Research Institute (EPRI). EPRI manages a broad R&D portfolio on behalf of the global electric power industry to address RD&D in critical issues of importance to the electric power sector. EPRI seeks to accelerate deployment and adoption of the most promising solutions to solve industry issues. EPRI's current energy storage program addresses RD&D in both Bulk Energy Storage and Distributed Energy Storage systems. The key drivers for electric energy storage solutions identified by our utility industry advisors include:

- Energy Storage as an enabler of wind penetration and integration
- Energy Storage for Ancillary services and avoiding cycling of thermal fossil units
- Energy Storage for distribution grid support; capital deferral and reliability
- Energy Storage solutions to manage end-use peak loads and enable load shifting
- Energy Storage to enable improved integration and value of photovoltaic energy systems.
- Energy Storage as key asset in the smart grid

With this background, I am pleased to have the opportunity to provided written and oral comments to the subject Docket and during the **Workshop on Energy Storage Technologies and Policies Needed to Support California's Renewable Portfolio Standard (RPS) Goals of 2020.**

Below are my comments to each of the questions of interest to the Energy Commission.

1. What barriers and/or obstacles have prevented large, utility scale electricity energy storage systems from being installed in California and the nation?

Investments in large-scale energy storage systems are based on need. The California power system already includes a very large amount of hydro-electric power, with significant short-term flexibility to work around short-term deviations from schedules of intermittent generation. There is high uncertainty surrounding future need for storage beyond what is provided at

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present. In that regard an integrated state analysis should be considered which includes supply side investments; wind penetration; T&D investments and operational issues and challenges with high wind and Solar PV penetration – to better estimate the scale and magnitude of energy storage systems required to meet the states 2020 RPS goals.

Historically, the primary barriers to the adoption of large scale energy storage systems in California and the nation have been: lack of cost effective and robust energy storage systems; deregulation; lack of a key business case; and the availability of low cost natural gas system which serve as a proxy for the storage function. De-regulation has also been a barrier as independent power producers or other third parties have not been able to make a business case for energy storage – primarily due to low returns on investment. Electric utilities have not been willing to take early adoption and demonstration risks to become more confident in the performance and viability of energy storage systems, and there has not been a clear regulatory driver or incentive for utilities to adopt /deploy such systems.

There is no energy technology that is superior in all functional categories – and a portfolio of storage options will be needed to address grid challenges. Successful deployment of energy storage will depend on: technology readiness; improved cost economics and understanding of benefits – to date limited cost effective solutions exist; need for more real world experience of large scale storage systems; and market rules and policy recognition of storage is needed for increased adoption.

Today there are confluences of new drivers for energy storage which include:

- 20%-30% renewable portfolio standards -creating more penetration of variable and intermittent wind and solar generation
- increased deployment of large and distributed scale PV generation
- increased variable renewable generation will create an issue in managing the operation of the grid (transmission system)
- need for management of grid peak loads and for improved utilization of T&D infrastructure and the higher cost of managing grid peak loads in a carbon constrained world
- Energy efficiency, and load control as option for meeting new demands for power and the role energy storage can play in enabling the use of demand measures in a smart grid.

The confluence of these drivers is creating a new and urgent opportunity for energy storage systems within the electricity enterprise. Utilities and third parties also have not been comfortable with the technology risks and life-cycle costs of energy storage systems. These risks, coupled with very little risk tolerance in de-regulated markets, have been a barrier to the early adoption, demonstration and deployment of entry market energy storage systems.

In the past few years a number of new energy storage systems have emerged which may have more attractive life cycle costs and attractive performance features than earlier systems. For example, 2[nd] generation compressed air energy storage systems (CAES) have been identified which are estimated to be lower in cost and less complex than earlier systems deployed over 20 years ago. Many utilities and third parties are now examining CASE systems as a bulk energy storage option. There are also sodium sulfur batteries, certain flow batteries, and advanced lead-acid battery systems that look potentially more competitive than older lead-acid battery systems. These systems are projected to be lower in costs than historical alternatives. Such systems may therefore be more competitive than options historically available to utilities.

Sodium sulfur batteries and Zn / Bromine battery systems are finding applications for utility substation grid support in the MW – plus range for 4-7 hrs of energy storage. The primary application for these systems is substation grid support to support urban load pockets. Utilities and developers are starting to examine these systems for wind and solar integration applications. Exhibit 1 provides a snapshot of the projected costs of energy storage systems both bulk and distributed and those positioned for power quality. The projected costs in Exhibit 1 are lower than "current costs" and are based on a reasonable volume and business. It should be noted that these estimates are highly subject to change, because of strong dependence on specific applications for example:

- Cost of systems in $/kW may have breakpoints based on power conditioning system ratings
- Cost of systems in *both $/kW and $/kWh* will change radically between 2 hour systems and 8 hour systems
- A system situated at a distant location with extreme environments may have significantly higher BOP costs than a system located in an easily accessible area with more temperate climate
- Costs do not include owner and permitting costs and other site specific related costs

In 2009, EPRI will publish a publicly available report updating the capital cost and estimated life cycle costs of current and emerging systems.

2. How does energy storage affect the ramping and regulation of renewable energy sources?

When properly coordinated with renewable energy sources, energy storage has the effect of limiting the ramping of these sources and also can smooth their production over short periods of time through Regulation services. The exact workings of these coordinated operations are a subject of current research and development.

Each of the bulk and distributed energy storage systems have features which include fast response rate cycling rates, which should enable them to respond to variable renewable generation requirements as long as proper controls are designed into these systems.

Just how energy storage systems can provide Regulation services to accommodate renewable energy in the ISO area is a subject that has to be specifically modeled and evaluated. Limited studies have been done in that regard.

3. What value does a large scale electric energy storage system provide the integration of large amounts of renewable resources as compared to other backup or intermittency support alternatives?

The values of large scale energy storage can be segmented into these areas:

- Arbitrage – buy low-cost power and sell when the price is higher
- Ancillary Services: Ramping; frequency regulation; and spin reserve; this can also include avoiding the cycling of thermal power plants and the associated benefits and lower GHG emissions from avoiding thermal systems to cycle and ramp.
- Improving the delivery of renewable energy to the system: improved wind and solar capacity factor
- Improving the T&D asset utilization or potentially deferral or avoidance of transmission lines to support wind integration
- Improved grid asset load factor and asset utilization of distribution system infrastructure
- Improved reliability to the system and to end-users.
- Improved power system stability through the use of power electronic inverters
- Improved provision of reactive power when located in areas of critical need

Other resources namely combustion turbines and fossil thermal units can also provide some of these benefits to the system for wind integration. An integrated cost and benefit analysis (using tools which use hourly data) over a multi-year planning period is needed to fully assess the value of storage and its dispatch competitiveness in an RTO or ISO market compared with the dispatch and deployment of fossil and other generation assets.

Distributed energy storage systems can also provide distribution capital deferral benefits, peak shaving, and reliability benefits at the local level to the system and to end-use customers. A recent EPRI study estimated the societal value of distributed energy storage could range from $350 to $500 per kWh depending on the local and site-specific assumptions. Exhibit 2 illustrates the value of distributed energy storage at commercial buildings in the PG&E service territory. Our research has also led to the following findings:

- The business case for distributed energy storage for end-use customers is much more difficult than for electric utilities. Storage systems will have to be well under $100 per kWh installed for an end-user to realize a less-than-5-year payback under the current spread between time of use rates in the high and low periods.
- As TOU rate spreads increase, the allowable cost for storage will be higher.
- Given today's TOU rates, electric utilities can monetize the value of distributed storage much better than end-users and the allowable storage costs can be much higher: $350 to $600 per kWh depending on local conditions. The technical and functional requirements for utility dispatched energy storage systems are also more relaxed than in the end-user

business model. Nevertheless win-win incentives and business models should also be evaluated and encouraged which allow end-users to adopt and deploy energy storage while allowing grid operators to also manage and dispatch such systems – especially during critical peak times.

- Energy storage has more value the closer it can be placed to the end-user load.

4. Where should large, utility scale electric energy storage systems be deployed to have the greatest beneficial impact on meeting the RPS goals of 2020?

This is a difficult question which needs more analysis and research. For bulk storage options, it requires an integrated supply-side and transmission investment /deployment analysis (which includes LPM considerations) throughout the entire State under varying renewable (wind) penetration and location scenarios.
EPRI is undertaking such a detailed analysis in ERCOT in 2009 using the planning tool UPLAN to learn more about the costs and value and GHG impacts of bulk energy storage in ERCOT and to help answer the question "can bulk energy storage enable more wind penetration on the system"?

Earlier EPRI work suggests that bulk storage systems do not need to be co-located at a wind farm unless there is a unique transmission deferral or grid support opportunity. More importantly is the integrated analysis of energy storage with transmission investments and related T&D planning and operation considerations under wind penetration scenarios. Exhibit # 3 illustrates an example analysis of the value of energy storage with transmission deferral opportunities.

Research and analysis is also needed to understand the costs and benefits of deployment of large amounts of distributed energy storage to help meet variable renewable resource integration. The question is, "Can cost-effective distributed energy storage systems in the distribution area support large amounts of variable renewable penetration?"

5. What is the cost of ownership of electrical storage systems, what benefits will be accrued, and how will they be distributed?

The costs of an electric storage system include:

- capital carrying charges: for example for a $ 750/kW CAES plant installed using a 15% fixed charge rate, the carrying charge would be $ 90/ kW-yr
- cost of electricity during charging a CAES plant: cost of off peak power during charging: $10-$40/ MWh
- fuel costs for CAES: cost of natural gas – varies but could be $ 4-8/ MMBTU
- other operating and maintenance costs – which will depend on the energy storage technology.

For a compressed air energy storage system the operating costs and methodology are illustrated in Exhibit # 4. Note that these estimates do not include NOx emissions reduction costs, such as SCR O&M, if this is needed.

The benefits of energy storage can include the following depending where it is located on the system:

- capacity value: 40-150 $ / kW-yr
- energy arbitrage value: 5-30 $/ MWh
- Ancillary services values (multiple)
  - Regulation: $10-$30/ MWh
- Transmission Support, deferral , or improved load factor (depending on which is applicable)
  - Long term reservation: $ 30-$60 / kW-yr
  - Avoid New Transmission Construction $ 50-120 / kW-yr:
- End-user reliability
- Outage mitigation

The benefits of distributed energy storage are illustrated in Exhibit # 3. In addition, if these systems could also capture the frequency regulation services value while located within the distribution system, the benefits would be very significant. EPRI has been using a methodology that estimates the life-cycle cost of energy storage and a life-cycle value analysis to compare cost and benefits.

With bulk energy storage systems the benefits accrue to the ISO, to society, and to the owner/operator.

With distributed storage systems the benefits would accrue to the wires utility, which owns and dispatches the systems; and to demand response storage initiatives with end-use customers – customers, utilities and society all benefit. Given the historical challenges of third parties to capture and monetize the distributed benefits of "distributed generation" like combined heat and power, policy makers and stakeholders could consider simple win-win business models that enable the societal benefits of energy storage systems to be monetized and recovered for the investors in the energy storage systems.

Business models that enable options for all participants (end-users; third parties; and utilities) to own, deploy or use energy storage should be considered and evaluated. When all participants have equal opportunity to the market, society benefits from having more options for the provision of valuable services. Situations, as in Texas, where the wire company can not own energy storage should be carefully evaluated in terms of creating a barrier to adoption.

6. What are the challenges and solutions to having the costs associated with energy storage systems be recouped from those who benefit from the technology when the benefits are expected to be provided to multiple beneficiaries?

This is a very important issue. As more variable renewable generation comes on to the system, there will be increasing need for balancing and ancillary services. However the maximum amount needed is not expected to be too large. Wind generators have heretofore not been interested in owning storage. Solutions are needed that enable the owners / operators of storage systems to monetize the system and societal benefits such systems provide. However, given the current cost of storage and the value of the system benefits; there may not be adequate financial returns to warrant storage investments. Some considerations:

Policy is a driver for renewable generation, and wind generation needs the production tax credit to be competitive today. When carbon has a price, future wind is anticipated to be much more competitive. Perhaps policies need to be considered for energy storage, which can enable the support of wind penetration, of operations of the transmission system, and of societal benefit.

7. What actions are being taken by the electric energy storage industry to bring down the overall costs of large, utility scale electric energy storage systems?

The industry is developing plans for future demonstration projects to help bring down overall costs and to ensure the reliable operation of new, large-scale energy storage technologies. Utilities have deployed limited number of distributed energy storage systems for grid support. Second generation compressed air energy storage systems are being evaluated and are planned to be demonstrated within the next 2-3 years. Early demonstration, standardization, and multiple orders to lower non-recurring engineering costs should help reduce the capital and installation costs. Advanced, non-fuel CAES systems are still under research, and capital costs are being investigated.

Large flow batteries, and advanced lead-acid batteries are in the early stages of field demonstrations and could benefit from incentives to increase deployment. Additional support to increase the frequency and number of demonstrations in distributed storage-market applications can help reduce and lower costs for these systems. Utilities are starting to deploy smart grid pilots – many of which include energy storage.

While energy storage companies are doing what they can to come up with innovative low-cost products, the single biggest thing that can help bring down the cost is development of manufacturing infrastructure and the ability to achieve volume discounts on materials, which will together help build large number of cells at low unit costs.

8. What incentive programs or other economic stimulus alternatives can be proposed that will encourage the deployment and fielding of more large, utility scale electric energy storage systems in California?

- Consider incentives for utilities to deploy energy storage systems for grid support, smart grid pilots, and demonstrations to help kick-start a robust energy storage deployment in California.

- Encourage win-win programs with utilities and end-use customers, where the storage system can be dispatched and controlled during peak load periods.
- Consider policies which enable utilities to rate-base energy storage solutions and therefore get recovery for storage investments.

9. What research is needed on energy storage in order for the California Grid to be capable of supporting the RPS goal of 33 percent renewables by 2020?

EPRI research shows that the following RD&D activities are needed to advance the deployment and integration of energy to storage systems in California:

1. Conduct integrated state-wide supply and transmission investment analysis for bulk and distributed energy storage, under varying renewable penetration scenarios. New and existing tools and models capable of integrated supply and transmission planning and hourly dispatch are recommended to be used. For instance, CA specific statewide analysis would be useful in understanding regarding energy storage to support renewable portfolio standards: how much energy storage is needed; what are the best locations; what are the state-wide benefits throughout the value chain; to what extent can aggregated distributed energy storage make a contribution to help meet the RPS integration issues.
2. Support the assessment and demonstration of 2nd-generation compressed air energy storage systems: both below ground and above ground storage systems.
3. Support R&D on non-fuel CAES cycles and advanced development through a demonstration project.
4. Support multiple technology demonstrations / applications, on the utility side of the meter and the customer side of the meter, of distributed energy storage systems including: NaS, flow battery, advanced lead-acid battery, and emerging Zn /air and lithium-ion energy storage systems.
5. Support utility energy storage system deployment in renewable smart-grid pilots.
6. Support customer-side-of-the-meter energy storage demonstrations and utility smart grid integration.
7. Evaluate market rules for energy storage; for example relieving the following restrictions could have a huge impact on the value of distributed energy storage and thus increase penetration:
    a. Minimum bid duration of 1 hour.
    b. Minimum bid size of 1 MW.
    c. Prohibition of asymmetrical bidding (except in CAISO).
8. Support and leverage basic science R&D at universities and at small and large companies to advance innovation and lower the capital and life cycle costs of energy storage systems.
9. All storage systems deployed need to be inter-operable with the grid and the emerging smart grid. This will enable storage assets to be managed and dispatched whether they

are on the utility side of the meter or customer side of the meter. All future storage systems should be equipped and designed with standardized smart grid protocols for inter-operability.

10. Large investments in R&D and factory capacity are under way to lower the cost of lithium-ion batteries; RD&D should be undertaken to seek opportunities to leverage PHEV-type battery systems in high-value stationary energy storage application.
11. Other emerging storage chemistries should be monitored and evaluated: Fe/Cr, Zn/Cl, and Zn/Air battery systems are in early-stage development, and they could open up cost-effective bulk and distributed storage applications.
12. Consider networking the California universities, venture capital, research institutions, and national labs into a robust energy storage R&D initiative.
13. Consider supporting a Center of Excellence in California, where storage systems can be vetted, tested, and applied in both lab and real-world environments.
14. Support R&D for high-risk and high-pay-off concepts involving energy storage.

Sincerely,

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Exhibit 1: Snap Shot of the Costs of Energy Storage Systems

A Snapshot of current Energy Storage System Costs

Energy Storage Technologies Capital Cost Estimates (EPRI Estimate, February 2010)

Storage Type (See footnotes)	$/kW	$/kWh	Hours	Total Capital, $/kW
Compressed Air Energy Storage Large (100-300 MW Underground storage)	590-730	1-2	10	600-750
Small (10-20 MW Above ground storage)	700-800	200-250	3	1300-1550
Pumped Hydro Conventional (1000 MW)	1300	80	10	2100
Battery (10 MW)				
Lead Acid, commercial	420-660	330-480	4	1740-2580
Sodium Sulfur (projected)	450-550	350-400	4	1850-2150
Flow Battery (projected)	425-1300	280-450	4	1545-3100
Lithium Ion (small cell)	700-1250	450-650	4	2500-3850
Lithium Ion (large cell, projected)	350-500	400-600	4	1950-2900
Flywheel (10 MW)	3360-3920	1340-1570	0.25	3695-4313
Superconducting Magnetic Storage commercial	200-250	650,000-860,000	1 sec	380-489
Supercapacitors (Projected)	250-350	20000-30000	10 sec	300-450

1. In this table, Total Capital Cost = $/kW + (Number of Hours x $/kWh)
2. All figures are rough order-of-magnitude estimates and are subject to changes as better information becomes available
3. Total capital costs include power conditioning system and all equipment necessary to supply power to the grid. Not included are battery replacement costs, site permitting, interest during construction and substation costs.
4. These costs are for the hours shown ±25%
5. Cost may vary depending on the price of commodity materials and location of project

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These estimates are highly subject to change, because of strong dependence on specific applications

- Example: Cost of systems in $/kW may have breakpoints based on power conditioning system ratings
- Example: Cost of systems in *both $/kW and $/kWh* will change radically between 2 hour systems and 8 hour systems
- Example: A system situated at a distant location with extreme environments may have significantly higher BOP costs than a system located in an easily accessible area with more temperate climate

Exhibit 2: Value of Distributed Energy Storage in the Commercial Sector in the San Francisco Bay Area

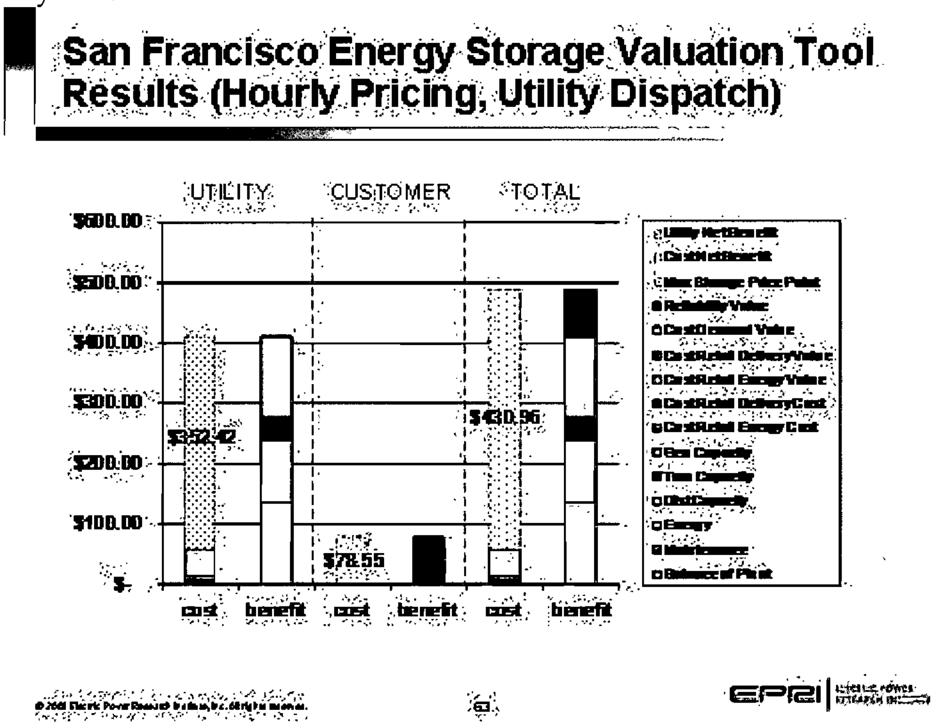

Exhibit 3: Case Study of Energy Storage an Application with Transmission Line Deferral

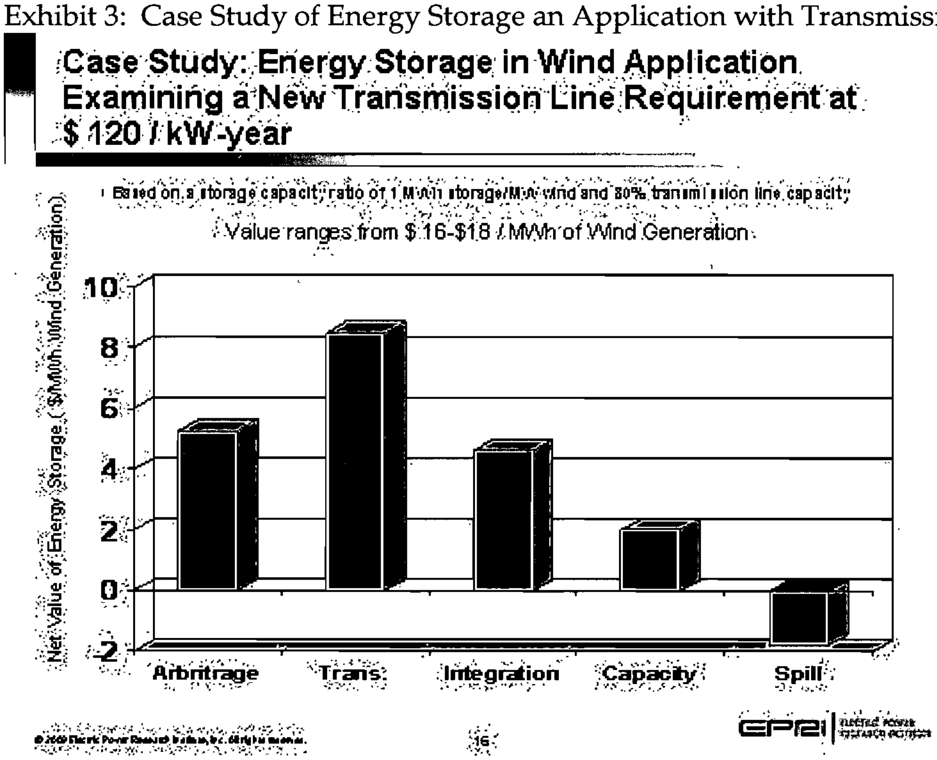

Exhibit 4: Illustration of CAES Operating Costs (Does not include costs for emission-reduction technology such as SCR.)

Operating Costs for CAES Plant

Operational Costs For CAES Plants:

$/kWh = Incremental, Off-Peak Cost for Charging Electricity
x Energy Ratio + Generation Heat Rate (Btu/kWh)
x Fuel Cost ($/Million Btu)
+ Variable Operational & Maintenance Costs

For Example, If :

CAES Heat Rate = 3810 Btu/kWh

Energy Ratio = 0.70

Off-peak electricity cost = $10/MWh

Fuel Cost = $8/MMBtu

Variable O&M = $5/MWh

Then:

CAES Operational Cost = $42.5/MWh

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