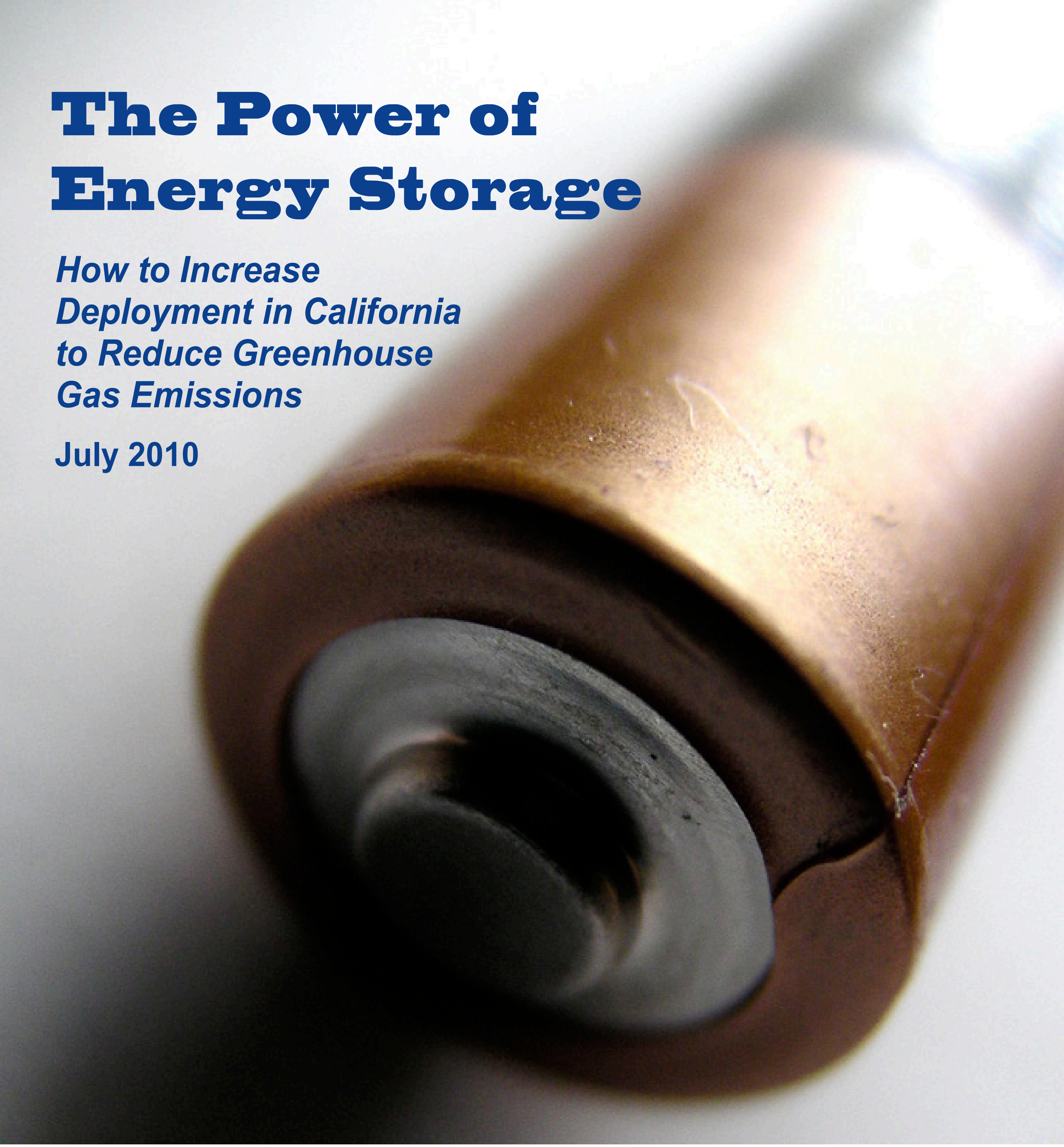
The Power of Energy Storage

How to Increase Deployment in California to Reduce Greenhouse Gas Emissions

July 2010



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About this Report

This policy paper is the sixth in a series of reports on how climate change will create opportunities for specific sectors of the business community and how policy-makers can facilitate those opportunities. Each paper results from one-day workshop discussions that include representatives from key business, academic, and policy sectors of the targeted industries. The workshops and resulting policy papers are sponsored by Bank of America and produced by a partnership of the UC Berkeley School of Law's Center for Law, Energy & the Environment and UCLA School of Law's Environmental Law Center & Emmett Center on Climate Change and the Environment.

Authorship

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Executive Summary: Expanding Energy Storage in California

Sunshine and wind, even in California, are intermittent resources, while the state's energy needs run twenty-fours hours of every day. As California seeks to expand solar and wind power, storage of that energy for use at any time, day or night, becomes critical. Energy storage performs key functions: it can even out the supply of electricity, ensure the stability and quality of electricity, and also help decrease reliance on power plants called "peakers" – often the dirtiest and most expensive – that exist solely to meet peak energy demand during the hottest hours of the hottest days. Because energy storage can "time-shift" the use of electricity, it can dispatch energy when electricity is needed rather than when it was originally generated, thus enhancing the efficiency of the grid and the value of renewable energy. Finally, energy storage can eliminate some of the need for new transmission lines and power plants and provide more grid security by making blackouts less disruptive.

Energy storage is a concept far broader than the familiar battery. Examples include pumping water uphill overnight, when demand is low and electricity is cheap, and then releasing it downhill to generate valuable daytime electricity; pressurizing underground caverns with air and then releasing the pressure later to generate electricity when it is needed; multiple battery technologies; flywheels that provide rapid dispatch of rotational energy; and freezing water at night to cool offices during the day, among other technologies. Energy storage can be local and distributed in neighborhoods, centralized in large systems on the grid, or attached directly to the generation source.

As California moves towards the goal of generating 33 percent of the state's power from renewable sources by 2020, it will need significantly greater deployment of energy storage technologies to address the challenges posed by integration of large amounts of renewables into the grid. At a recent workshop at the UC Berkeley School of Law, energy storage manufacturers, grid operators, renewable energy developers, investors, regulators, and other experts gathered to identify the most critical barriers to greater deployment of energy storage and the policies needed to overcome them. The key challenges include:

- A regulatory structure and utility processes that disfavor energy storage
- High cost of energy storage technologies due to the small scale of production
- Lack of awareness of the benefits of energy storage among policy-makers and the public

Based on the workshop discussion, this paper identifies the actions that policy-makers, energy storage advocates, and agency officials could take to stimulate significant deployment of energy storage technologies. Policy-makers could:

- Allow utilities to include investments in energy storage in their electricity ratebase;
- Launch proceedings and studies at California's key energy agencies to quantify the full value of energy storage and explore policies needed to stimulate its deployment;
- Extend tax credits and loan guarantees to energy storage projects; and
- Make investments in energy storage a high priority and compile and publicize data on its effectiveness.

Glossary of Terms

Ancillary Services: Services that support electricity transmission and reliable operations of the grid, such as load regulation, spinning reserve, non-spinning reserve, replacement reserve, and voltage support.

California Air Resources Board: State agency charged with implementing AB 32, the state global warming law.

California Energy Commission (CEC): The state's primary energy policy and planning agency.

California Independent Systems Operator (CAISO): Nonprofit corporation that operates the transmission system between power plants and utilities

California Public Utilities Commission (CPUC): State agency that regulates investor-owned electric companies.

United States Department of Energy (DOE): Federal agency responsible for regulating energy and promoting scientific and technological innovations.

Federal Energy Regulatory Commission (FERC): Federal agency with jurisdiction over transmission siting, interstate electricity sales, and wholesale electric rates, among other areas.

Investor-Owned Utility (IOU): A privately-owned electric company that is regulated by the CPUC.

Load-Serving Entity (LSE): Power plant that provides baseload energy.

Loading Order: California's official prioritization list for energy procurement.

Megawatt (MW): Roughly equivalent to the energy required to power 750 homes.

Public Interest Energy Research (PIER): Research program of the California Energy Commission.

Public Utility: A publically-owned electric company that is subject to forms of public control and regulation ranging from local community-based groups to state-wide government monopolies.

Rate Base: The value of property upon which a utility is permitted to earn a specified rate of return as established by a regulatory authority.

Renewable Portfolio Standards (RPS): Legal requirements that renewable energy sources constitute a specific percentage of retail electrical power for the state.

Three Key Barriers to Expanding Energy Storage in California & Possible Solutions

1) **Regulations and Utility Processes that Disfavor Energy Storage**
Utility and California Independent System Operator (CAISO, the nonprofit entity that operates most of the state's electricity transmission system between power plants and utilities) electricity purchasing processes contain no formal mechanism for calculating and recovering the full value of the resource savings and the more effective use of existing grid assets that energy storage offers, thereby distorting the perceived costs and benefits of energy storage as compared to energy generation.

2) **Costs**
Some energy storage systems have difficulty competing with other technologies, such as fossil fuel-based power plants, due to their stage of commercialization, the expense of materials, the lack of large-scale manufacturing, and the uncertainty surrounding the calculation of their benefits and their cost-recoverability under the current regulatory structure.

3) **Lack of Awareness of Energy Storage Benefits**
Many policy-makers, grid operators, and the general public are unaware of what energy storage is, the specific technologies that comprise energy storage, the recent technological advancements, data about its effectiveness, and what benefits energy storage can provide.

Short- and Long-Term Solutions

SOLUTION #1: Allow Energy Storage Owners to Capture the Full Value of Storage and Encourage Utilities and Policy-Makers to Invest in Energy Storage.

Federal Energy Regulatory Commission should establish rules for energy storage to help states develop a separate asset class for energy storage that will provide utilities with more certainty that the capital costs of energy storage can be recovered in the ratebase

Federal Energy Regulatory Commission and the California Independent System Operator should consider creating cost and performance requirements for long-term, must-take contracts with utilities that include performance standards under which a utility or the California Independent System Operator would have to enter into a long-term agreement with the energy storage provider.

California Independent System Operator should consider "unbundling" the procurement of ancillary services (that contribute to the overall power quality and reliability) to allow energy storage owners to bid to provide discrete ancillary services that energy storage offers.

California Energy Commission's Public Interest Energy Research (PIER) program should sponsor an analysis of performance and cost features of energy storage to offer more solid data to help utilities decide when to invest in energy storage, to assess the value of storage in conjunction with other models to achieve the 33 percent renewables target, to document and study the barriers to capturing the multiple value streams offered by energy storage, and to develop metrics for investments that mitigate system risk and improve reliability.

California Energy Commission and the California Public Utilities Commission should add energy storage to the energy loading order to ensure that agency leaders and utilities analyze and prioritize energy storage technologies as an alternative or adjunct to building new transmission lines and power plants and as a complement to renewable energy facilities.

California Public Utilities Commission should consider requiring utilities to procure energy storage equivalent to a percentage of their overall energy storage capacity, as currently contemplated in AB 2514, pending in the California State Senate as of July 2010, which would require the California Public Utilities Commission to open a rulemaking proceeding on mandating utilities to procure energy storage.

California Public Utilities Commission should institute a rulemaking to develop a cost-effectiveness methodology to determine rates for energy storage that will allow utilities and independent energy storage owners and service providers to include the costs of capital investment in energy storage projects in their ratebase.

California Public Utilities Commission, based on data on energy storage performance, should establish a resource adequacy value for energy storage to enable power providers to meet their requirements under the resource adequacy program with appropriate storage systems.

SOLUTION #2: Make Energy Storage More Competitive for Financing

Federal leaders should offer tax credits and other incentives for energy storage projects, including an investment tax credit and accelerated depreciation for energy storage technologies.

Federal leaders should offer loan guarantees for energy storage developers by having the United States Department of Energy extend its Loan Guarantee Program to energy storage technologies.

Federal Leaders and the California Air Resources Board should set an appropriate price on carbon that reflects the environmental costs of energy to make renewable energy and energy storage more competitive in comparison to fossil fuel-based energy.

California Public Utilities Commission should develop standardized contracts that account for avoided and capacity costs.

SOLUTION #3: Compile and Disseminate Data on Energy Storage Technologies to Key Decision-Makers

The California Energy Commission should conduct a "2020 vision study" for energy storage to elevate awareness of the key barriers and policy needs to accomplish the goal of integrating more energy storage and renewable energy.

The California Energy Commission should elevate energy storage to its own category on the Commission webpage to disseminate information on energy storage resources and data to stakeholders and the public.

The California Independent System Operator should restart its dormant energy storage stakeholder process to help make energy storage projects a priority at the CAISO and coordinate further policy-making by other agencies.

Energy storage advocates, the United States Department of Energy, and the California Energy Commission should compile and publicize data on current projects, such as by identifying existing commercial energy storage projects around the country, tracking the cost of energy storage, compiling performance data and lessons learned, and then disseminating the information to decision-makers.

Energy storage advocates should provide leadership to elevate storage issues with key decision-makers at the Federal Energy Regulatory Commission, California Public Utilities Commission, California Energy Commission, Governor's office, and Legislature, which could involve participation in California Energy Commission policy reports on energy storage, holding additional workshops with experts and decision-makers, developing a "center of excellence" for energy storage, and creating a national organization to promote energy storage or modifying the existing Electricity Storage Association.

California Needs Deployment of Energy Storage Technologies to Reduce its Greenhouse Gas Emissions & Promote Renewable Energy

What is Energy Storage?

After significant discussion, participants at the workshop largely agreed (with some dissent and qualification) that energy storage technology encompasses "a physical system with the ability to capture energy for dispatch or for displacement of electricity use at a later time." One participant analogized energy storage to a grocery store owner who may purchase food in advance, keep it refrigerated or stocked on the shelves, and have it available at a later time to sell to consumers.

Energy storage includes a panoply of major technologies. At one end of the spectrum is "bulk" or "centralized" energy storage technologies, which contain hundreds of megawatts of capacity and can provide many hours of energy storage each day. At the other end of the spectrum are smaller "distributed" energy storage systems that can be located on-site with electricity consumers and along key distribution and transmission points.

Pumped Hydro

Pumped hydro storage typically involves pumping water from a low-lying reservoir during periods of low demand for electricity, typically at night, to a higher-elevation reservoir or lake. When electricity demand is greater (and therefore electricity is more expensive), operators release water back to the lower reservoir through turbines that generate electricity (similar to hydropower from dams). The technology can also work with other water storage methods, such as with contained seawater as the lower reservoir, underground caverns, and even floating sea walls that create a sealed interior to pump water in and out.[1] Many Southern Californians are familiar with the pumped hydro facilities involving Castaic Lake water pumped to the higher elevation Pyramid Lake near Interstate 5 south of the Tehachapi Mountains.

Large-scale pumped hydro energy storage can generate thousands of megawatts ("MW," where one MW is roughly equivalent to the energy required to power 750 homes) over time periods ranging from four to six hours.[2] As a result, it is frequently used for "load leveling" to provide more bulk energy during times of peak demand. However, pumped hydro is a net consumer of electricity because the energy generated, although less expensive, provides between 70 to 85 percent of the energy required to pump the water.[3]

Pumped hydro energy storage represents the largest installed capacity of storing energy in the United States today, although additional natural sites to create more facilities are limited due to lack of suitable places and community opposition. The first large-scale pumped hydro facility (31 MW) opened in the United States in 1929, and 38 facilities are now in operation. These facilities generate up to 22,000 megawatts

(MW) of electricity.[4] They also provide key "ancillary services" to the grid, which are services that support electricity transmission and reliable operations of the grid. In particular, pumped hydro energy storage offers greater supply of clean reserve generation. By 2000, roughly three percent of the total power delivered by the nation's grid came from pumped hydro energy storage facilities.[5]

Compressed Air

Compressed air energy storage (CAES) utilizes electricity to inject high-pressure air into underground geologic cavities or aboveground containers. During periods of high energy demand, the air is released and used to help power natural gas-fired turbines. The pressurized air helps the turbines generate electricity with less natural gas than conventional natural gas plants. Compressed air storage therefore constitutes a hybrid energy generation and storage technology. Like pumped hydro, compressed air energy storage can be used for load leveling because it can generate up to several hundred MWs and can be discharged over periods ranging from four to twenty-four hours at a time.[6]

The technology has received heightened attention from developers and investors because of its large size and anticipated lower capital and operating costs. A 115 MW demonstration project came on-line in the early 1990s, although experts are still evaluating the long-term costs.[7] The two facilities in operation today are a 290 MW facility in Huntorf, Germany and a 110 MW facility in McIntosh, Alabama.[8] The Pacific Gas & Electric Company (PG&E) recently received approval to determine the feasibility of a large 300 megawatt facility in California.[9]

Rechargeable Batteries

Batteries represent the most commonly-recognized type of energy storage and are seeing the most growth and investment. Batteries use a reversible chemical reaction to store energy. Several different types of large-scale rechargeable batteries exist, including sodium sulfur (NaS), lithium ion, lead acid, and flow batteries.

The lead-acid battery is the most prevalent device, in part due to the growth of data centers that support the Internet and communications centers and the technology's long-standing use in the transportation sector. These facilities utilize batteries to avoid disruptions in power supply from outages. Total consumption in the United States of lead-acid batteries for commercial, industrial, and automotive use is $2.9 billion per year and increasing annually at 8 percent.[10] Utilities have been using sodium sulfur (NAS) batteries in over 200 large-scale projects around the world, with roughly 300 megawatts operating in Japan and 13 megawatts operating in the United States, for a total of approximately 2000 megawatt hours of energy.[11]

Lithium-ion battery use has been increasing in the last two decades. The United States transportation sector has driven the market by employing these batteries for high-power transportation projects. As a result, sales have increased domestically to $1 billion in 2007, with some analysts projecting future growth rates of 50 to 60 percent per year. However, because of the limited use of batteries by utilities in the United States, there is a dearth of information about their costs and benefits for utility-scale applications.[12] This situation will likely change soon as numerous utilities have received stimulus funding for grid-scale battery projects.

Photo courtesy of A123 Systems

Thermal Energy Storage

Thermal energy storage technology involves two separate types: solar thermal power plants and end-use. Thermal energy storage for solar thermal power plants involves heating synthetic oil or molten salt using solar energy. Once the substance heats, it can support electricity generation during cloudy periods and up to ten hours past sunset. Solar thermal power plant builders have demonstrated one project at the AndaSol One facility in Spain. Applications for additional plants are pending in Nevada and California.

End-use thermal energy storage reduces the electricity consumption of a building's heating or air conditioning systems during periods of peak energy demand by using hot or cold storage in underground aquifers, ice tanks, or other storage materials.[13] Makers of end-use thermal energy storage have built projects in the United States, United Kingdom, Germany, and Scandinavia. As an indicator of the technology's potential, about eight percent of residential water heaters in the United Kingdom use thermal energy storage by heating material at night that can heat water during the day and therefore reduce peak electricity consumption.[14] In California, the Southern California Public Power Authority (SCPPA) signed an agreement with Ice Energy in January 2010 to install 53 MW of Ice Energy technology, which creates ice at night that can be used to provide air conditioning during the peak demand hours of the day. The project, implemented by SCPPA member utilities throughout Southern California, may shift as much as 64 gigawatt hours (GWh) of on-peak electrical consumption to off-peak periods every year.[15]

Hydrogen

Hydrogen storage uses electricity to split water molecules into hydrogen and oxygen (called "electrolysis"). When electricity is in high demand, the hydrogen can help generate electricity through a hydrogen-powered combustion engine or a fuel cell. This technology, according to the Pew Center on Global Climate Change, will likely require additional advances to become commercially cost-effective.[16]

Flywheels

A flywheel stores energy by using electricity to accelerate a rotating disc. To harness the energy from the disc, an operator slows the disc, which transfers energy to a generator. Although not yet widely deployed, some experts favor the technology due to its ability to regulate the frequency of electricity and other fast-response applications, high cycle life, and ability to charge and discharge anywhere from a few seconds to 15 minutes.[17]

Ultracapacitors

Ultracapacitors consist of two oppositely-charged metal plates that are separated by an insulator. These devices store energy by increasing the electric charge accumulation on each of their plates and then dispatching the energy when the metal plates release the electric charges. They may be best suited for improving power quality because they can provide short bursts of energy in under a second and store energy for up to a few minutes.[18]

Superconducting Magnetic Energy Storage

Superconducting magnetic energy (SME) storage consists of a coil with many windings of superconducting wire that stores and releases energy as the electric current that flows through the wire increases or decreases. Operators must refrigerate the device to extremely low temperatures to maintain its superconducting properties, resulting in some energy and maintenance costs. Like ultracapacitors, SMEs are typically used to improve power quality because they provide short bursts of energy.[19]

Energy Storage is Critical to Limiting California's Greenhouse Gas Emissions

California's fight against climate change, which requires increased deployment of renewable energy technologies, has heightened demand for energy storage. In the absence of federal government action on climate change, California has mandated reductions in the greenhouse gas emissions that cause climate change. The California Global Warming Solutions Act of 2006 (AB 32) requires the state to roll back its greenhouse gas emissions to 1990 levels by 2020, which is equivalent to a 30 percent cutback from the business-as-usual scenario projected for that year.[20] And California Governor Arnold Schwarzenegger's Executive Order S-3-05 calls for an eighty percent reduction from 1990 levels by 2050.[21]

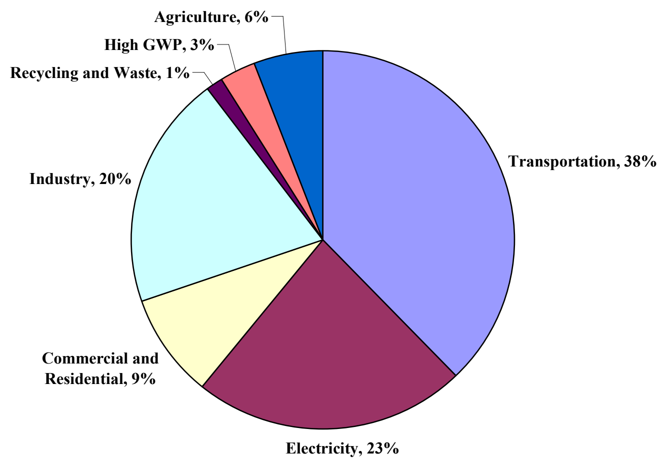


Figure 1. California's Greenhouse Gas Emissions (2002-2004 Average)

Source: California Air Resources Board

To meet these targets, much of the greenhouse gas reduction will have to come from the way the state generates and consumes electricity. Electricity generation represents the second largest source of greenhouse gas emissions in California, contributing 23 percent of statewide emissions (see Figure 1).[22] State leaders have therefore attempted to reduce demand for energy and switch from fossil-fuel based energy generation to carbon-free renewable sources.

California has made investment in renewable energy generation a priority. The state created a "renewable portfolio standard" (RPS) that requires retail electricity sellers, with the exception of public power utilities, to procure 20 percent of their electricity from eligible renewable energy resources by 2010.[23] The Governor issued Executive Order S-14-08 to increase the percentage to 33 percent by 2020.[24] The California Air Resources Board (CARB), charged with implementing AB 32, stated in its AB 32 scoping plan that achieving this 33 percent goal by 2020 "is a key part of CARB's strategy for meeting the AB 32 targets."[25]

Increased deployment of renewable energy, however, poses a challenge to grid operators and utilities. Sources like solar and wind are intermittent, as the sun does not always shine and the wind does not always blow. In addition, renewable production, particularly from wind energy, may not always occur when demand is highest. The California Independent System Operator (CAISO), the nonprofit corporation that operates the transmission system between power plants and utilities, reports, "Wind generation energy production is extremely variable, and in California, it often produces its highest energy output when the demand for power is at a low point."[26] For example, the report notes that wind activity in the Tehachapi Mountains in Southern California, an area slated for a significant expansion of production, includes a summertime pattern of maximum wind at night, followed by a decrease in the morning and an increase in the evening.[27]

California's renewable energy goals therefore complicate the already difficult task of providing consumers with electricity to meet their varying demand. This process involves electric power system operators forecasting electricity demand and then scheduling and operating numerous power plants to meet fluctuations in demand. Utilities therefore build and operate a variety of power plants, starting with "baseload" plants that serve the large constant demand for electricity. These often include nuclear and coal-fired power plants, which typically run at full output. When demand starts to increase on a day-to-day basis, utilities use load-following "cycling" plants, usually fueled with natural gas. And when demand peaks (typically in the middle of the afternoon due largely to

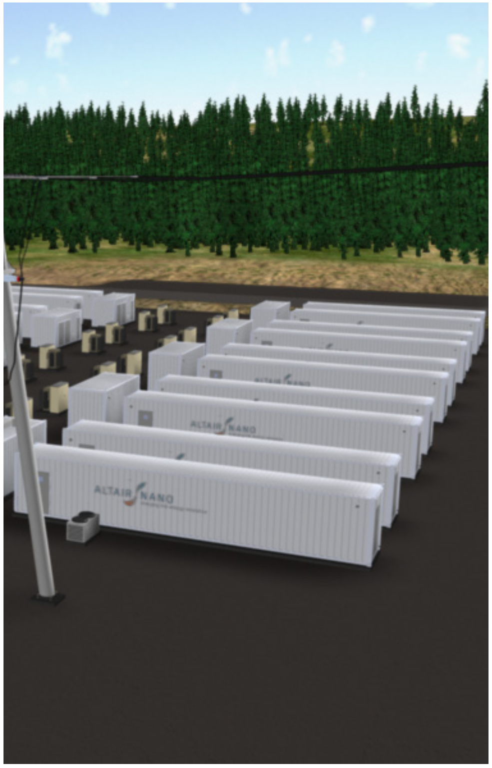


Photo courtesy of Altair Nano

"Now the conversation about renewable energy projects with the PUC is that they say you must have a natural gas or storage component for your project."

-- Rachel McMahon
Solar Millenium

air conditioning use, with the highest annual peak occurring in the afternoon of the hottest day of the year), utilities use "peaking" units. These facilities tend to run one percent of the year or less – a few hundred hours per year – and are often fueled by natural gas in California.[28]

Utilities must also keep additional power plants in reserve in case of an unforeseen rise in demand, the sudden outage of a power plant or transmission line, or other unexpected events. These facilities are referred to as "operating reserves," and they can also provide utilities with other key ancillary services that can protect the grid from random fluctuations in the normal load, load-forecasting errors, and other contingencies.[29]

Greater deployment of intermittent renewable energy technologies from wind and solar power will require grid operators to upgrade and adapt the existing system to integrate more renewable energy and balance the fluctuation in supply. A United States Department of Energy (DOE) report indicated that supplying 20 percent of the nation's electricity with wind energy (300 gigawatts) would require approximately 50 gigawatts of new peaking plant gas turbines just to compensate for the variability of wind power.[30] The CAISO projects that the expansion of wind energy production in the state to meet the 20 percent RPS will require an increase in what is known as "load-following energy" of 870 to 1050 megawatts per day. The load-following energy is necessary to compensate for the decrease in wind production during the daytime. An additional 700 to 1,500 megawatts per day will then be required to "ramp down" load-following energy production as the wind increases in the evening. The average production hike over the year will be 100 megawatts per day, with some days requiring up to a 30 percent increase, depending on the wind output.[31]

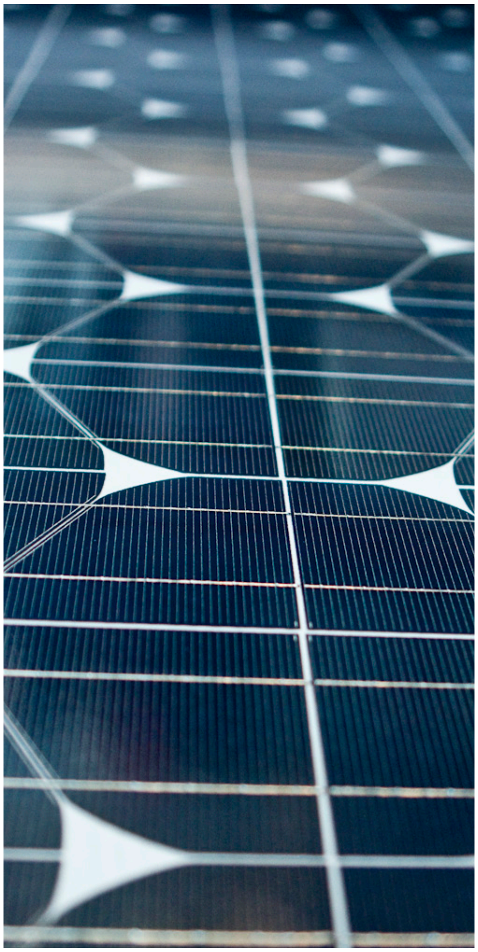
This need for additional production to "firm" or "shape" the electricity load will intensify significantly as the state moves towards its 33 percent renewable energy target in 2020. The California Energy Commission estimates that almost half of the renewable energy in 2020 will have to come from intermittent sources like wind and solar.[32] By 2020, the CAISO predicts that without energy storage the state will need an additional 4,800 megawatts of load-following energy to meet the 33 percent RPS.[33]

Energy Storage is Critical to Integrating More Renewable Energy into the Grid

Policy-makers and grid operators have identified energy storage as a key means of integrating renewable energy into the grid to help avoid using fossil-fuel based energy production to supplement the intermittent supply. Energy storage assists in leveling the output and quality of renewable energy, reduces the expense and need for new transmission lines, and replaces supplemental energy from fossil fuel-based generators.

To be sure, energy storage does not represent the only means of integrating renewable energy, as grid operators can partially address this challenge with demand response strategies that discourage consumption when electricity is scarce, advanced wind forecasting techniques,[34] and improved grid operating practices.[35] However, policy-makers view energy storage as indispensable to the integration effort, particularly as the state meets its 33 percent RPS target in 2020. The California Energy Commission (CEC) identified storage as "a key strategy for accommodating the intermittent nature of some renewables"[36] and recommended further study to determine the best placement and size of new energy storage facilities to maximize system value.[37] Concerned about the possible need for more conventional generation to supplement renewables, the

CEC recommended that the state "consider other means of providing regulation besides conventional generation, such as flywheels or variable speed pumped hydro" energy storage.[38]



CAISO, the state's operator of most of the state's transmission system, also recommends that the state "encourage the development of new energy storage technology that facilitates the storage of off-peak wind generation energy for delivery during on-peak periods."[39] CAISO leaders note that the large amount of new wind generation needed to meet the 20 percent renewable portfolio standard will likely result in periods of electricity over-generation that will require the curtailment of production.[40] As a result, CAISO officials advocate "continuing exploration of other storage technologies and off-peak loads that can be combined with the wind generation production."[41] And in a report to the California Energy Commission, CAISO researchers found that "on an incremental basis, [energy] storage can be up to two to three times as effective as adding a [natural gas] combustion turbine to the system for [energy] regulation purposes."[42]

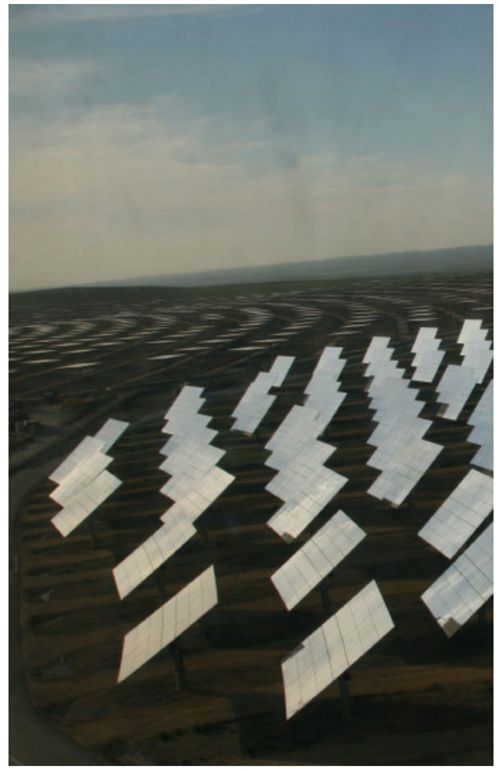
Energy storage may also provide a key opportunity to reduce greenhouse gas emissions by obviating the need to build conventional natural gas generators to supplement increased renewable energy deployment. The Economic and Technology Advancement Advisory Committee (ETAAC), which advises CARB on AB 32 implementation, noted that energy storage for integrating wind power into the grid "displaces fossil fuel generation that would otherwise be needed to provide ancillary services (e.g., regulation up and down, ramping, spinning reserve) as well as meet capacity needs. Energy storage systems can provide those services more efficiently and without the CO2 emissions associated with fossil fuel generation."[43] Research consultants reported to the CEC that the use of energy storage to meet the 33 percent RPS "avoids greenhouse gas emissions increases associated with committing combustion turbines strictly for regulation, balancing, and ramping duty."[44] Finally, the ETAAC report to CARB stated that the "potential for a transformative effect from electricity storage is truly 'game-changing'" and recommended a "high priority pursuit" of energy storage technologies.[45]

Energy Storage Will Increase the Value of Renewable Energy

By capturing energy produced during periods of low demand for later dispatch, energy storage can enhance the value of renewable energy facilities, thus making them more attractive for investors. By adding flexibility to dispatch, these renewable sources can offer day-ahead guaranteed contracts to utilities, increasing their profitability and likely encouraging greater investment. In addition, energy storage technologies can provide greater frequency control and improved power quality for renewables, which may otherwise fluctuate with the intensity of the sun or wind.[46]

A study by the National Renewable Energy Laboratory, based on 2004 energy storage cost figures and including only pumped hydro, compressed air, and sodium-sulfur battery energy storage technologies, found that in a scenario involving 20 percent wind energy supply by 2030, "storage can lower electricity prices, a good proxy for the cost of the overall system." The report showed that for both the business-as-usual and the 20 percent wind scenarios, the value of storage relative to wind increased in proportion to the amount of supplied wind energy.[47] In addition, a study at Princeton University demonstrated that the addition of compressed air energy storage would allow wind farms to meet base load power demand with 85 to 90 percent of their capacity.[48]

Energy storage may also be able to reduce the transmission capacity needed for renewables by up to two-thirds.[49] Many large-scale renewable energy facilities for solar and wind farms are located in remote areas that require new transmission lines to access them. In California, these lines are notoriously difficult to site and expensive to build. However, energy storage could reduce the cost of these lines by decreasing the capacity of transmission needed to transmit the electricity. Without storage, the transmission lines to these remote sites would be built to accommodate the maximum amount of wind or solar energy produced, or else the facilities would have to dump any excess energy that the line cannot accommodate. According to the Electricity Advisory Committee, for some wind projects, it is currently more cost-effective either to build transmission capacity for less than the full energy maximum of the project or dump surplus energy during the hours when output exceeds transmission capacity.[50] Energy storage, however, allows the renewable energy provider to capture surplus energy and dispatch it when the facility has unused capacity in the transmission system, thus allowing a smaller transmission infrastructure to carry the same, or even more, total renewable energy from remote locations.[51]



Energy Storage Will Reduce Reliance on Fossil Fuel-Based Power to Meet Peak Energy Demand

The United States electric grid represents the largest interconnected machine on Earth. It contains over nine thousand generating units with one million MWs of generating capacity and 300,000 miles of transmission lines. However, almost half of this infrastructure has been built to meet the time of peak energy demand, which typically occurs during the hottest few hours of the hottest days of the year. Because nobody wants a power outage and many people run their air conditioners at the same time as each other, electricity suppliers have built the grid to meet this maximum possible demand.[52] Since 1982, growth in peak demand, from air conditioners, new buildings, computers, and numerous appliances associated with modern life (see Figure 2), has exceeded transmission capacity annually by 25 percent. Power outages, meanwhile, have cost businesses over $100 billion per year nationally.[53]

As daytime peak demand increases, two problems arise: first, utilities must run fossil fuel-based generation to serve the peak, which is both costly and undermines California's twin goals of reducing air pollution and greenhouse gas emissions. Second, a growing percentage of California's transmission and distribution infrastructure costs are devoted solely to meeting the marginal peak demand of electricity customers.[54]

"We know the ISO is dumping excess energy at night. So if you had storage facilities to contract with, we could get it back."

-- Joseph Desmond
Former Chair,
California Energy Commission

Capturing renewable energy generated during periods of low demand for later dispatch will help flatten the generation profile of electricity and may obviate the need for much of the grid infrastructure dedicated only to meeting peak demand. It will also help reduce greenhouse gas and other harmful air pollutants generated by natural gas "peaker" plants because there are fewer transmission and distribution losses at night when congestion on the grid is reduced.

Finally, energy storage can reduce greenhouse gas emissions by improving the efficiency of the grid through the provision of key ancillary services. A report prepared for the DOE noted that making the grid even five percent more efficient would be the equivalent of removing 53 million cars and their attendant greenhouse gas emissions from the road.[55]

Energy Storage can Save Consumers Money and Protect the Electricity Supply

Energy storage enhances opportunities for distributed generation, which involves small- to medium-scale generation close to demand, and also can provide security to the grid by hastening recovery from blackouts. Customers with on-site solar panels or other forms of renewable energy generation can

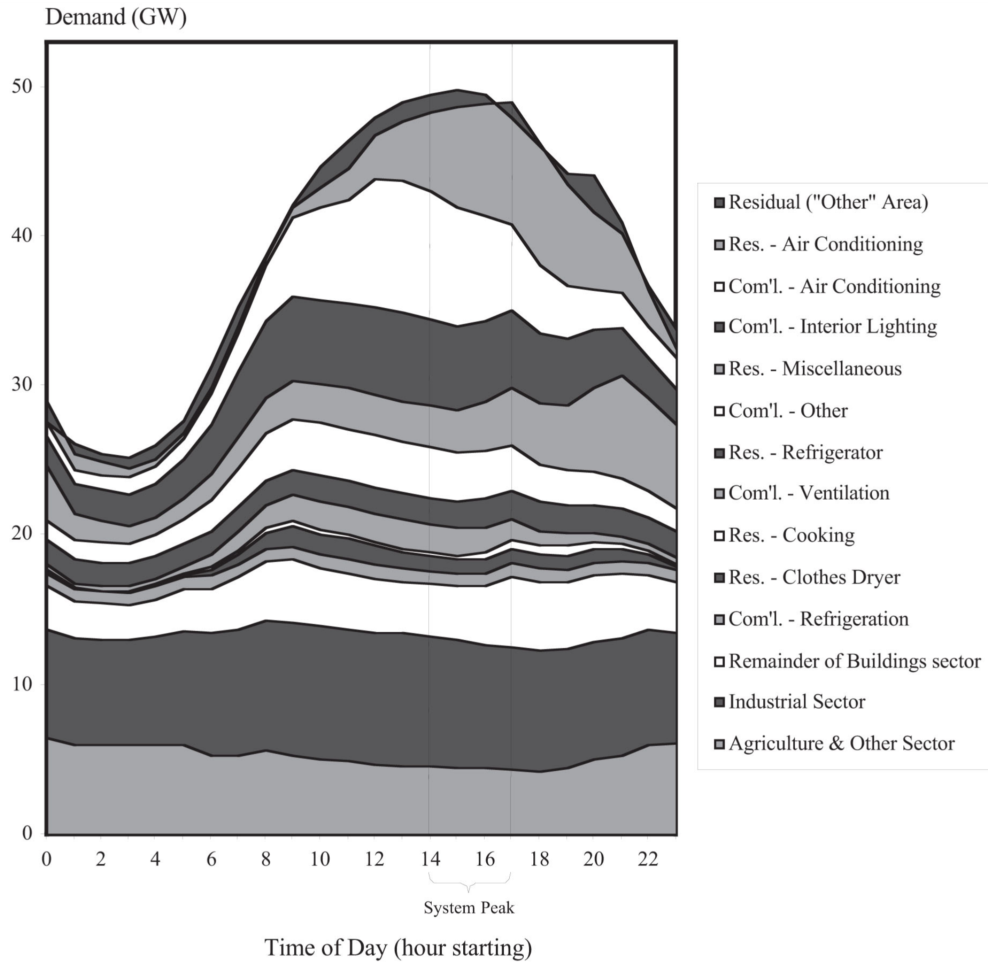


Figure 2. Example of California Peak Energy Demand Profile and Sources

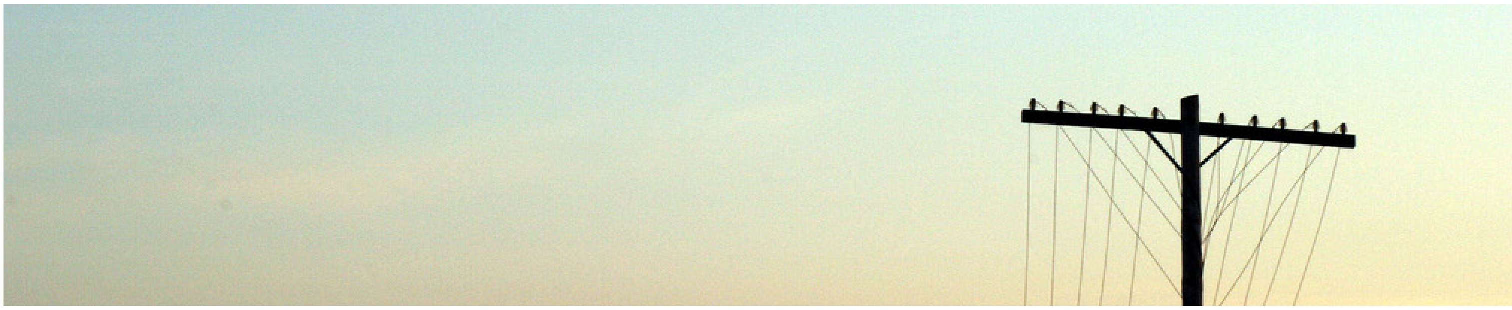
Source: *Electricity Use in California: Past Trends and Present Usage Patterns*, May 2002, Lawrence Berkeley National Laboratory, University of California, Berkeley

utilize storage technologies to reduce their demand for non-renewable off-site energy. They can capture excess energy generated by their renewable energy technologies for use at a later time when the generators are not producing, thus potentially allowing some consumers to live off the grid entirely without disruption of their electricity consumption.

In addition, energy storage systems can provide emergency support in the event of a power blackout. Repowering the grid can take many hours, at which point perishable food in refrigerators begins to spoil. Exacerbating the situation, California's move to more remote, renewable-based energy production increases the danger to the grid by creating longer transmission lines that are difficult to protect and repair. With energy storage systems along the grid, however, the rebooting of the grid can happen more quickly and can help microgrids bridge the electricity gap to avoid blackouts altogether. Energy storage can therefore prevent businesses and consumers from losing money and resources from these incidents.

"The grid is becoming more complex, but with storage during a major blackout event, we can recover the system three times faster than in the past."

-- Workshop Participant



Barrier #1: Regulations & Utility Processes that Disfavor Energy Storage

Utility and CAISO purchasing processes are highly regulated and contain no formal mechanism for calculating the value of the resource savings offered by energy storage. Investor-owned utilities must seek approval from the California Public Utilities Commission (CPUC) for all changes to their rate structure, while publicly-owned utilities answer to their respective local governing boards for rate approval. In California, the investor-owned utilities also own most of the transmission lines operated by the CAISO. The Federal Energy Regulatory Commission (FERC) approves the ultimate transmission charges passed to ratepayers.

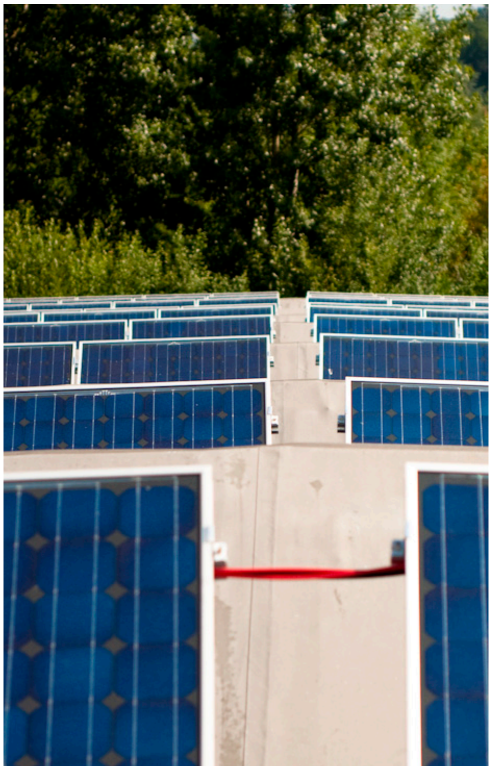
As workshop participants described, the current rate structuring process, however, contains no explicit mechanism to recover the value provided by energy storage. Energy storage facilities provide ancillary services to the grid that help it run more efficiently and can avert the need for new transmission lines and power plants. These benefits may translate to cost savings for utilities and ratepayers. However, utilities and policy-makers lack methodologies to quantify these savings and lack incentives to make investments in energy storage. As a result, the current regulatory structure discourages them from considering energy storage as an alternative to building new transmission lines and power plants that may be more costly than comparable energy storage facilities. As a CPUC white paper on energy storage described, "Regulators are uncertain how [energy storage systems] should fit into the electric system, in part because [they provide] multiple services such as generation, transmission and distribution. Furthermore, regulators do not yet know how [energy storage system] costs and benefits should be allocated among these three main elements of the electric system."[56]

Many participants at the workshop also cited the difficulty of getting utilities to change their business models and become proactive in the effort to invest in more energy storage. Utilities may not want to deviate from a model that they know works for them and that would take resources to change.

Energy regulators have also failed to define and prioritize energy storage. The lack of a federal statutory or regulatory definition for energy storage may hinder state and federal agencies' ability to develop regulations and incentives to benefit energy storage. State regulators have also not included energy storage in the loading order, which guides state energy decisions.

SOLUTION: Develop Means to Fully Calculate and Capture the Value of Energy Storage and Encourage Utilities and Developers to Invest in Storage Facilities

Federal and state regulators should develop the means for energy storage facility owners to analyze and recover the full value of the storage services provided. The process should start with regulatory proceedings that adopt methodologies to determine this value and the possible means to recapture it. Such policy changes could include adding energy storage to the transmission ratebase, defining storage in a federal statute to facilitate federal incentives and regulations, mandating utilities to procure energy storage, and having the CEC and CPUC institute rulemaking proceedings to promote the use of energy storage.



FERC should establish rules for energy storage Electricity regulators such as the CPUC allow utilities to recover their costs from the ratebase according to specific asset classes, which covers costs ranging from a new transmission line to a flashlight. According to workshop participants, the lack of a separate asset class for energy storage facilities makes utilities less likely to invest in these systems because the utilities lack certainty that the investment can be recovered. To help states develop a separate asset class for energy storage that will allow utilities, transmission operators, and independent energy storage owners and service providers to include the capital costs of energy storage in the ratebases, FERC should develop a method for analyzing how much value an energy storage project will bring to the grid and to ratepayers. Transmission line owners under FERC jurisdiction could then receive credits for the benefits of energy storage. FERC appears to be taking action on this issue with its June 11, 2010 request for comments regarding rates, accounting, and financial procedures for energy storage technologies.[57]

FERC and the CAISO should consider creating cost and performance requirements for long-term, must-take contracts with utilities The federal government and CAISO could develop performance standards under which a utility would have to enter into an appropriate medium- or long-term agreement with the energy storage provider for the various services offered by the energy storage facility. These standards should be designed to protect the utilities from losses and give them the right to void the contract if the energy storage component fails to meet reliability requirements.

CAISO should consider "unbundling" the procurement of ancillary services Ancillary services provide key support for the stability and power quality of electricity. Currently, the CAISO purchases these services for the grid. Unbundling the process to allow outside parties to bid to provide specific ancillary services would help energy storage technologies compete to provide these specific services at lower costs. As part of the unbundling, the CAISO should enable long-term procurement contracts of ten to fifteen years that would provide certainty for investors. The CAISO appears to be taking steps in this direction, through its stakeholder process, by evaluating "non-generator" participation in the CAISO's ancillary services markets.[58]

CEC's Public Interest Energy Research (PIER) program should sponsor the analysis of performance and cost features of energy storage Utilities and the CAISO may be reluctant to approve new energy storage projects because they lack data on the likely cost savings of these projects. Agency leaders at the CEC, as well as its PIER program, should consider performing studies to develop more solid data to help utilities decide when to invest in energy storage. The data could include a methodology for evaluating the cost effectiveness of energy storage and capturing the multiple value streams offered by storage. It should also include the value of storage in helping to achieve the 33 percent RPS target at lowest cost and in mitigating system risk and improving reliability of the grid. CEC-developed metrics could then be considered by the CPUC in a rulemaking proceeding.

CEC and CPUC should add energy storage to the energy loading order
The CEC, CPUC, and the now-defunct California Consumer Power and Conservation Financing Authority established the energy resource loading order to guide energy decisions, starting with decreasing electricity demand by increasing energy efficiency and demand response, and meeting new

Photo courtesy of Ice Energy

generation needs first with renewable and distributed generation resources, and second with clean fossil-fueled generation. Adding energy storage to this list of priorities would help ensure that agency leaders and utilities analyze storage technologies as an alternative to building new transmission lines and power plants and as a complement to renewable energy facilities. The agencies will require input from stakeholders about where in the loading order energy storage should fall. In July 2010, CPUC staff recommended that the agency consider pursuing this option.[59]

CPUC should consider requiring utilities to procure storage systems equivalent to a percentage of their overall energy capacity AB 2514, which passed the Assembly in June 2010 and is currently in debate in the California State Senate, would require the CPUC to determine appropriate energy storage procurement targets for utilities.[60]

CPUC should institute a rulemaking to develop a cost-effectiveness methodology to determine rates for energy storage An "Order Instituting Rulemaking" (OIR) on developing a cost-effectiveness methodology to determine the appropriate rates for energy storage would help rate-making authorities and energy storage investors calculate the value of storage and provide certainty for investment.

CPUC should establish a resource adequacy rating for energy storage The Resource Adequacy (RA) program at the CPUC requires all load-serving entities (LSE) that provide base load power to demonstrate that they have sufficient resources and reserves to meet the aggregate load on a monthly basis. The goal of the program is to ensure the safe and reliable operation of the grid at all times. CPUC staff lead annual RA proceedings to refine the RA program. In these proceedings, the CPUC should examine data on energy storage performance and use it as a basis for establishing credit and valuation for energy storage under this program. LSEs could then invest in energy storage with the knowledge that the energy storage projects would help them meet a certain amount of their RA obligations. CPUC staff have also recommended that the agency consider this option.[61]

Barrier #2: Costs

While costs of energy storage technology are declining, many are still relatively expensive due to their newness, expense of materials, and lack of large-scale manufacturing. Less expensive technologies, like pumped hydro, face permitting or siting challenges that add to their expense. The relatively high costs of some technologies make it more difficult for them to attract financing or to compete with other technologies, such as natural gas-fired power plants, that can serve similar functions but do not offer the same greenhouse gas reduction benefits.

SOLUTION: Develop Tax Incentives, Federal Support for Funding, Energy Pricing Mechanisms, and Streamlined Regulatory Approvals to Make Energy Storage More Attractive to Investors

Federal leaders should offer tax credits and other incentives for storage projects Congress should consider an investment tax credit for energy storage. The credit would spur more investors to finance these projects and could potentially offset the high upfront costs of deploying and developing cutting edge technologies. Similar federal tax credits for renewable energy technologies helped stimulate that market.

In addition, the Internal Revenue Code could provide tax benefits in the form of accelerated depreciation for storage technologies, as is offered to renewable energy producers. Congress could expand the Modified Accelerated Cost Recovery System (MACRS), which allows investors to deduct annually the capitalized cost of depreciable property, to cover energy storage investments.

Federal leaders should offer loan guarantees for energy storage developers DOE should extend its Loan Guarantee Program to energy storage technologies. The program offers federal support for clean energy projects using innovative technologies to spur investment. Title XVII of the Energy Policy Act of 2005 authorizes the Secretary of Energy to make these loan guarantees to projects that demonstrate the potential to "sustain economic growth, yield environmental benefits, and produce a more stable and secure energy supply."[62]

The Federal Government and CARB should set an appropriate price on carbon Federal climate legislation, such as the Waxman-Markey bill that passed the United States House of Representatives in 2009, and AB 32 should put a price on carbon that reflects the true cost of fossil fuel generation and thus will make carbon-free renewable energy more competitive in comparison to fossil fuel-based energy. This action will stimulate more investment in energy storage and renewable energy, which can then provide potentially cheaper alternatives and more certainty for investors.

"The pricing of energy storage doesn't include the full value that storage provides. It's a big policy issue."

-- Roger Levy

4MW, 24MWh Sodium Sulfur (NAS) Battery at AEP Presidio, Texas

Interior Installation for Extreme Climate Conditions
Photograph Courtesy of Electric Transmission Texas

CPUC should develop standardized contracts for energy storage

A pro forma, CPUC-approved rate for energy storage facilities as part of a standard offer contract, where terms and requirements are uniform for all parties without the need for negotiation each time, would reduce transaction costs for energy storage and provide more certainty for investors. The contract should make use of financial models that account for avoided and capacity costs and could require the energy storage provider to purchase replacement power if the energy storage technology fails. FERC-approved tariffs and natural gas contracts could be used as a model for these pro forma agreements, assuming FERC does not treat energy storage as wholesale generation. Another example includes the CPUC's 2009 decision to require investor-owned utilities to study ways, including standard offer contracts, of encouraging permanent load-shifting and deliver a report on their findings to the to the CPUC by December 1, 2010.[63]

Photo courtesy of Altair Nano

Barrier #3: Lack of Awareness of Energy Storage Benefits

Although energy storage has existed as an explicit policy goal since at least the 1970s in California, many policy-makers and the general public are unaware of what energy storage is, the specific technologies that comprise energy storage, and what benefits storage can provide. In addition, because many of these technologies have never been deployed at a large scale, policy-makers and utilities lack conclusive data about both their costs and energy savings capability.

SOLUTION: Expand Data on Energy Storage Technologies, Perform Studies, and Promote the Findings to Key Decision-Makers

Industry leaders and energy storage advocates can help policy-makers learn about energy storage by holding workshops, commissioning reports, and using other means of reaching the public. Policy-makers and industry leaders should also compile and share performance data on existing energy storage technologies to help grid operators, utilities, regulators, and investors make more informed decisions about energy storage.

The CEC should conduct a "2020 vision study" for energy storage with a supporting model The CEC can use an analysis of how energy storage could be integrated into the grid by 2020 to elevate awareness of the key barriers and policy needs to accomplish this goal. A CEC-led convening of stakeholders to provide input on this vision could present policy-makers with the key solutions and raise the profile of this issue.

"There is a great lack of knowledge about energy storage among legislators and regulators. Half the time, they give you a curious stare and ask, 'What is storage?'"

-- David Nemtzow

The CEC should elevate storage to its own category on the CEC webpage
A dedicated web page would help disseminate information on storage resources and data to stakeholders and the public. Among other information, the site could include analytical tools for helping to calculate energy storage's costs and cost-effectiveness in a particular application, as well as information on the various energy storage technologies and their attributes.

CAISO should restart its in-house energy storage stakeholder group
A revitalized Energy Storage Stakeholder Group could help make energy storage projects a priority at the CAISO and coordinate further energy storage research. CAISO should assign a project manager to oversee this effort, using CEC PIER funding or other available resources.

Energy storage experts and the CEC should compile and publicize data on current projects Energy storage experts could identify a sampling of existing commercial storage projects around the country, compile performance data and lessons learned, and disseminate the information to decision-makers. The California Energy Storage Alliance (CESA) should post the results on its website (after ensuring that the data are not proprietary or securing appropriate access to the data). The CEC should dedicate funds, such as from Advanced Research

Projects Agency-Energy (ARPA-E), a federal agency created to promote and fund research and development of advanced energy technologies, to compile some of this information and to finance further demonstration projects.

Energy storage experts and advocates should also use existing tools to demonstrate the value of energy storage to the CAISO. The experts and advocates can use existing grid modeling technologies to test different scenarios with multiple assumptions in order to compile the data. The modeling should examine load flow and distribution models, among other factors, to inform decision-makers about storage values. Advocates should also identify potential sources of funding (such as from ARPA-E, universities, or the venture capital community) to conduct some of this research and release white papers with this data.

Energy storage advocates should provide leadership to elevate energy storage issues among key decision-makers at FERC, CPUC, CEC, Governor's office, and Legislature Energy storage advocates will need these key leaders to understand the value of energy storage and to adopt the necessary policies. They may need multiple initiatives to accomplish this goal, which could involve participation in CEC policy reports on energy storage, additional workshops with experts and decision-makers, or developing a "Center of Excellence" for energy storage. Such a center could be a virtual collaborative with universities to produce research and market information on energy storage, explore policy solutions, engage DOE and other policy-makers, establish standards for storage contracts and investment, and make this information available and accessible to the public. Advocates will probably want to create a national organization to promote energy storage, perhaps by building on CESA in California or utilizing or altering the existing Electricity Storage Association. This national organization could start by publishing an accessible and interesting report that describes energy storage in a practical way for policy-makers and average citizens and provides policy proposals to advance cost-effective storage.[63]

Photo courtesy of Jakub Mosur

Conclusion: The Future of Renewables and Storage

As California moves toward the 33 percent renewables target by 2020, energy storage will be increasingly vital to ensuring that the transition is efficient and does not increase fossil fuel-based generation to supplement the renewables. Energy storage can also reduce greenhouse gas emissions and other air pollutants by decreasing the need for dirtier power sources to service peak energy demand and by helping the grid to operate more efficiently. Finally, energy storage may ultimately save ratepayers money, protect them against blackouts, and provide them with greater opportunities to live independently from the grid. But given the highly-regulated nature of energy provision in California and beyond, policy-makers, regulators, and advocates will need to work together to open the "rules of the game" to unleash innovation in the energy storage sector.

Participant Bios

Victor Babbitt
RES Americas

Victor Babbitt is presently managing the energy storage efforts for RES Americas, a major renewable energy developer that has developed and/or constructed over 10% of all the wind energy capacity in the USA. Previously Victor founded and built Battery Power System, Inc. of Seattle, the premier company supplying energy storage systems to the utility and telecom industries in the Western USA. Victor has also served as a program manager in Microsoft Advanced Technologies, and developed electronic voting systems used today in federal, state and local elections in over 20 states. Victor holds 4 issued patents, and several patents pending.

Edward G. Cazalet, PhD
MegaWatt Storage Farms, Inc.

Dr. Cazalet has over forty years of electric power experience as an executive, board member, consultant, and entrepreneur. In 2007 Dr Cazalet co-founded MegaWatt Storage Farms. MegaWatt deploys and manages grid-scale electricity storage farms for multiple applications, including integration of intermittent wind and solar generation. Dr. Cazalet is also CEO of The Cazalet Group, a consulting firm focused on electric industry strategic planning and market design. He is also a leader in the development of standards for dynamic pricing and automated smart grid transactions. Dr Cazalet was appointed by California Governor Schwarzenegger in 2004 to a three-year term as a member the Board of Governors of the California Independent System Operator (CAISO). Dr. Cazalet founded APX in 1996 and served for many years as CEO. Dr. Cazalet founded Decision Focus, Inc. (DFI) in 1976 and led DFI to become a leading firm in energy and electric power market modeling and decision analysis consulting to corporations and government agencies. Dr. Cazalet holds a PhD from Stanford University focused on economics, decision analysis and power system planning and degrees in engineering from the University of Washington.

Matthew Deal
California Public Utilities Commission

Matthew joined the PUC in 2006 as an analyst in the California Public Utility Commission's Energy Division procurement section. In 2007, Matthew joined President Peevey's advisory team. While in President Peevey's office he focused on numerous issues including Wholesale Market Structure and Design, Resource Adequacy, Long-Term Procurement, Energy Efficiency, Demand Response, Renewable Portfolio Standards, Transmission, Greenhouse Gas Reductions, Retail Market Design, and RFP evaluation, among others. In January 2010, Matthew became Director of the Commission's Policy & Planning Division (PPD). PPD consists of a group of analysts charged with identifying the upcoming/emerging issues facing all of the industries the Commission regulates. Prior to joining the PUC, Matthew worked at the Illinois Commerce Commission (ICC), and later the Federal Energy Regulatory Commission (FERC). Matthew holds a Master's Degree in Economics from the Institute for Regulatory Policy Studies at Illinois State University in Bloomington-Normal Illinois.

Joe Desmond
Chairman, California Energy Commission (former)

Joseph Desmond served as Chairman of the California Energy Commission and was appointed Under Secretary for Energy Affairs in the California Resources Agency. As Chairman, Mr. Desmond represented the Governor on the Western Interstate Energy Board (WIEB). Mr. Desmond, of Pleasanton, served as Deputy Secretary for Energy at the Resources Agency in 2004. Prior to that, he was President and Chief Executive Officer of Infotility, Inc., an energy consulting and software development firm for four years. From 1997 to 2000, Mr. Desmond was President and Chief Executive Officer of Electronic Lighting, Inc., a manufacturer of controllable lighting systems, and from 1991 to 1997 he was with Parke Industries, where he served as vice president. Mr. Desmond was marketing and demand planning administrator for Taunton Municipal Lighting Plant, a publicly owned utility, from 1987 to 1991. He also served as co-chair of the Silicon Valley Manufacturing Group's Energy Committee from 2001 to 2004 and as a board member of the National Association of Energy Service Companies.

Harold Gotschall
Technology Insights

Harold is a founding Principal in the consulting firm, Technology Insights, with over thirty years of experience in advanced power systems development. Since the mid '90s, he has supported clients on technical and economic assessments of emerging energy storage technologies for U.S. markets, as well as with the deployment of early projects. In addition, Harold was the lead author on the EPRI-DOE Handbook of Energy Storage for Transmission and Distribution Applications, and related supplements. He has supported NGK's introduction of NAS Battery product lines to the North American market for several years.

Mike Gravely
California Energy Commission

Mike Gravely is the Manager of the Energy Systems Research Office at the California Energy Commission. His office manages over $250 million in active energy related research and development projects. The office supports research for California in a variety of technical areas that include: Smart Grid, Renewable Grid Integration, Transmission, Distribution, Demand Response, Energy Storage, Distributed Energy Resources, Carbon Capture and Sequestration (CCS), and Energy Smart Sustainable

Communities. His office is completing several research activities focused on understanding and defining what California needs in a future Smart Grid. Mike has over 30 years of engineering and integration experience in the energy, aerospace and communications fields. Prior to the Energy Commission, Mike served in executive positions in the Federal Government and private industry including managing research, testing and fielding of distributed generation and energy storage systems for the Department of Defense, addressing the challenges of a start up energy storage company and overseeing a staffing and training company that specialized in serving the utility industry. Mike Gravely has a BSEE from the Virginia Military Institute and an MSEE from California State University at Sacramento.

Maurice E.P. Gunderson

CMEA Capital

Maurice Gunderson, Senior Partner, joined CMEA Capital in 2006 to focus on investments in new and innovative energy sources and technologies. Maurice is a specialist in thermodynamics and energy technologies. Throughout Maurice's career, he has been instrumental in the development of cryogenic equipment, engines and energy conversion systems, turbo-machinery, and control systems for process plants and pipelines. Previously, Maurice co-founded Nth Power, a venture capital firm specializing in investments emerging from the global restructuring of the energy industry. Prior to founding Nth Power, Maurice spent more than 20 years developing energy products and launched five successful companies. Maurice also has served on the board of directors of over twenty energy technology companies. He currently serves on the boards of Amerigon, Inc. (Nasdaq:ARGN), and CMEA Capital portfolio companies Superprotonic, Inc., CFX Battery, Inc., and NuScale Power, Inc., and is an expert team member at Scion-Sprays, Ltd. in the UK. Maurice has an MBA from Stanford University as well as an MS in Thermodynamics and a BA in Mechanical Engineering from Oregon State University. He is also a member of ASME, SAE, ASHRAE, AIAA and AEE, and a patent holder, Registered Professional Engineer, and pilot.

Dave Hawkins

California ISO

David Hawkins is the Lead Renewables Power Engineer in the Operations Division at the California ISO. He is a Principal Investigator for the integration of renewable resources and a member of the Smart Grid Team at the CAISO. The ISO has a major project to assess the operational impact on intermittent resources such as wind and solar generation for 20% and 33 % renewable resources. The objective is to identify potential grid operations, market operations and transmission issues and to develop strategies to mitigate these issues. He is also responsible for assessment of new technologies such as energy storage technology and their potential application for solving operating issues. Dave has over 40 years of experience in the power industry with 15 years with Consolidated Edison Co of New York in the Engineering and R&D

areas, 14 years with PG&E in Computer Operations, Engineering Computer Applications and Distribution Systems. He has been with the California ISO for 12 years in Grid Operations and coordinator of the organizations R&D programs. He is a graduate from the University of Michigan in Electric Engineering and Life Member of IEEE.

Martin Kurtovich

Chevron Energy Solutions

Marty Kurtovich, P.E., is Senior Business Development Manager for Chevron Energy Solutions, based in San Francisco. He has over 20 years of experience in technology transfer, business development, acquisitions/alliances, and utilities and infrastructure planning and development. His past positions has included six years as a Special Assistant for the Department of Energy during the 1990s, working on major White House and Secretary of Energy initiatives to improve the deployment of energy efficiency and distributed energy resources in key U.S. markets. He then went on to work for Pacific Gas & Electric, working on power generation and hydro asset planning, development and licensing projects. At Chevron Energy Solutions, Marty is responsible for developing new markets and products that capture opportunities presented with new technologies and grid modernization initiatives in California and the West. Marty holds a BS in Environmental Engineering from Berkeley and MS from Johns Hopkins University.

Kelly Krpata

Joint Venture

Kelly Krpata joined Joint Venture in 2009 and serves as Director of the Applied Materials Climate Prosperity Initiative. Kelly has more than nine years of experience in the private sector, where he held various positions in the finance, clean technology and media industries. Prior to Joint Venture, he operated his own firm, Krpata Capital Partners, which provided capital advisory services to companies in the clean technology sector, including the Electric Power Research Institute. Kelly formerly founded his own licensed apparel company and worked at Bear, Stearns & Co. in the Leveraged Finance Group. He also worked in media relations for the “Today” show and began his career as an NBC Page in New York. An endurance trail runner, Krpata survived a Grizzly bear mauling in Glacier National Park in 2000 and ran with the bulls in Pamplona, Spain in 2001. He holds an MBA from the University of Michigan’s Ross School of Business and a BA from Boston College.

Roger Levy
Levy Associates

Roger Levy is the President of Levy Associates, a consulting firm started in 1980. He has been actively involved with the utility industry since the mid 1970's, completing over 200 projects in system development, planning, implementation, evaluation, and research. He was the principal consultant for the California Energy Commission advanced metering, pricing, and related demand response initiatives. He is a consultant to the Lawrence Berkeley National Laboratory, for the Demand Response Research Center and the lead consultant on a Smart Grid Technical Advisory project, which is providing technical support to state regulatory commissions nationally. Roger has also been involved with sustainable community development projects, transportation planning, environmental impact evaluations, technology development, and implementation in industry and with utilities. Mr. Levy received a BS degree in Management Science from the University of Rochester and a MBA from the University of Southern California. His work experience includes positions with Xerox Corporation, RCA, Arthur Young & Company and Price Waterhouse. Roger is a member of IEEE and serves on the Technical Advisory Committee for the Demand Response Enabling Technology Development project under the U.C. Office of the President.

Don Liddell
Douglass & Liddell

Don is a principal of Douglass & Liddell, specializing exclusively in energy business transactions and regulatory proceedings involving a broad array of energy-related products and services. Don has over 30 years of experience in the private and government sectors of the industry. He cofounded and serves as general counsel for the California Energy Storage Alliance. Prior to joining with Dan Douglass to form Douglass & Liddell, Don was Assistant General Counsel for Sempra Energy. He also served on the Board of Directors of the Independent Energy Producers Association from 1990 to 1997, including a term as Chairman. As an Adjunct Professor, he helped create and taught a course in Energy Law and Policy at the University of San Diego's School of Law. Prior to joining Sempra's predecessor companies in 1982, he was counsel to the United States Department of Energy's San Francisco office. He received an LL.M from the London School of Economics, a J.D. from the University of California Hastings College of the Law, and his B.A. with honors from San Diego State University.

Peter Light
Bloom Energy

Peter Light is responsible for Product Management at Bloom Energy. He was instrumental in the customer selection, feature definition, marketing, and launch of the company's first commercial fuel cell-based Energy Server. Today he focuses on bringing future products to market. Peter has a strong background in distributed generation policy, and is an expert in the emerging markets of RECs, renewable biogas, and tradable environmental benefits. Peter previously worked at Energy & Environmental Economics (E3), Verdant Power, and the Rocky Mountain Institute. Peter holds a bachelor's degree in Mechanical Engineering from Brown University.

Janice Lin

StrateGen Consulting, LLC & California Energy Storage Alliance

Janice Lin is the founder and Managing Partner of StrateGen Consulting, LLC, a strategic consultancy that helps businesses create sustainable value through clean energy solutions. She has advised a diverse range of clients including renewable energy equipment manufacturers and service providers, large corporations diversifying into clean energy, and real estate developers building sustainable communities. Janice has been active in advanced energy storage (AES), having led a successful effort to obtain incentive co-funding for AES through the CA Self Generation Incentive Program. In early 2009 Janice co-founded the California Energy Storage Alliance (CESA), an inter-industry advocacy group focused on expanding the role of AES technology to promote the growth of renewable energy and a more stable and secure electric system in California. Janice has held several senior management positions with PowerLight Corporation (now SunPower Systems), including Vice President of Product Strategy and Vice President of Business Development. Janice holds an MBA from the Stanford Graduate School of Business, a BS from the Wharton School, University of Pennsylvania, and a BA in International Relations from the University of Pennsylvania's College of Arts and Sciences.

Rachel McMahon

Solar Millenium

Rachel McMahon is Director of Government Affairs for Solar Millennium, LLC, and is responsible for regulatory and legislative outreach and advocacy at the local, state and federal levels. Ms. McMahon has advocated and shaped legislation and policy related to alternative energy and the impacts of energy on the environment since 1999. Before coming to Solar Millennium in February 2009, she was Director of Regulatory Affairs for the Center for Energy Efficiency and Renewable Technologies (CEERT), and led the organization's advocacy on renewable energy and climate change policy, including implementation of California's AB 32, the Western Climate Initiative, and the state's 33% RPS. She has also researched, managed and edited two published books on renewable energy and the hydrogen economy, and developed green building guidance for affordable housing developers and schools in post-Katrina New Orleans.

David Nemtzow
Ice Energy, Inc.

David Nemtzow leads Ice Energy's legislative, policy, and regulatory efforts at the federal, state, and local levels. David previously had a utility and regulatory consultant practice, with clients that included electric utilities, clean energy companies, national associations, and others, as well as Ice Energy. David was Chair of the Demand Response and Energy Efficiency conference; co-authored the California Energy Efficiency Strategic Plan (2008); lead author of "The Green Effect: How demand response programs contribute to energy efficiency and environmental quality" (Public Utilities Fortnightly, 2007); and was the only witness invited by the U.S. House Appropriations Committee to testify regarding efficiency at a major hearing on the 10-year outlook for energy. David served (2004-2006) as Director-General of the Department of Energy, Utilities and Sustainability for New South Wales, Australia's most populous state. David served (1994-2003) as President of the Alliance to Save Energy, a Washington, DC-based association of industry, government, utility, consumer and environmental executives that promotes investment in energy efficiency and demand management. He previously served as senior U.S. Congressional staff where he drafted legislation that created competitive markets for electricity transmission and drafted successful legislation on tradable air emission permits, energy efficiency and state energy planning programs. Earlier he was a floor hand on a natural gas drill rig, research assistant for the California Public Utilities Commission, and engineering assistant for a nuclear power plant engineering firm. He holds a Master's from Harvard University (Public Policy, 1988) and a Bachelor's from Brown University (Environmental Policy, 1979).

Dr. Ali Nourai
KEMA

Dr. Nourai is the Chairman of the Electricity Storage Association (ESA) dedicated to promoting development and commercial application of energy storage technologies as solutions to power and energy problems. Dr. Nourai is an Executive Consultant with KEMA. He joined Kema in 2010 after a 30-year utility career with American Electric Power (AEP) where he launched AEP's successful sodium sulfur (NaS) battery program and introduced the concept of the Community Energy Storage (CES).

Frank Ramirez
Ice Energy, Inc.

Frank Ramirez is the co-founder and Chief Executive Officer of Ice Energy. A former principal of Alex Brown & Sons, Mr. Ramirez previously served as a managing director of Bear, Stearns and Co., and a staff attorney with the SEC in Washington, D.C. Formerly, he founded and managed a Calpine Energy funded start-up that developed innovative inside-the-fence energy solutions for mission critical facilities, and founded and directed Structured Capital Management, a northern California boutique investment bank specializing in complex asset securitizations. A native of Colorado, he holds a B.A. in economics and an M.B.A from Stanford University, and a J.D. from Boalt Hall, University of California, Berkeley.

Charlie Vartanian
A123 Systems

Charlie Vartanian is Director of Grid Integration at A123 Systems (www.a123systems.com). A123 is a manufacturer of advanced Lithium-ion batteries and systems. Charlie focuses on grid application development and market access advocacy to expand the use of advanced storage technologies for grid benefit. Previously, he was Distributed Energy Resource Development Manager at Southern California Edison where he supported and participated in joint research studies with external entities working on advanced grid concepts. Other prior engagements include SCE Transmission Planning, SCE Field Engineering, California Energy Commission Staff, Enron Energy Services, and the U.S. Navy. Charlie received his MSEE from USC, and his BSEE from Cal Poly Pomona. Charlie is a licensed Professional Engineer in California, and is a member of IEEE.

Laura Wisland
Union of Concerned Scientists

As an energy analyst at the Union of Concerned Scientists (UCS), Laura Wisland focuses on developing state policies that will effectively increase the amount of renewable energy used in California. She provides technical and policy analysis to legislative and regulatory agencies to successfully guide implementation of the state's renewables electricity standard and designs effective electricity sector climate change policies in accordance with the state's landmark global warming bill. Prior to coming to UCS, Ms. Wisland was the director of the California Hydropower Reform Coalition where she helped design several state and federal policies to reduce the environmental impacts of California's existing network of hydropower dams. She also worked for the energy division of the California Public Utilities Commission on implementation of the Renewable Portfolio Standard and for Pacific Gas and Electric Company, where she helped develop new demand response programs for the California ancillary services market. Ms. Wisland has a master's degree from UC Berkeley's Goldman School of Public Policy, and a bachelor's degree from the University of North Carolina at Chapel Hill honors program in public policy.

Endnotes

1 Ecogeek.org, *The Energy Island*. Available at: http://www.ecogeek.org/content/view/1017/

2 Pew Center on Global Climate Change, *Energy Storage*. Available at: http://www.pewclimate.org/technology/factsheet/EnergyStorage

3 Electricity Storage Association, *Technologies: Pumped Hydro*. Available at: http://electricitystorage.org/tech/technologies_technologies_pumpedhydro.htm

4 Pew Center on Global Climate Change.

5 Electricity Advisory Committee, *Bottling Electricity*, December 2008, p. 1.

6 Pew Center on Global Climate Change.

7 Electricity Advisory Committee, p. 1.

8 Pew Center on Global Climate Change.

9 For the California Public Utilities Commission press release, visit: http://docs.cpuc.ca.gov/PUBLISHED/NEWS_RELEASE/112654.htm

10 Electricity Advisory Committee, p. 2.

11 Interview with Harold Gotschall by author and Pew Center on Global Climate Change, Energy Storage. Available at: http://www.pewclimate.org/technology/factsheet/EnergyStorage

12 Electricity Advisory Committee, p. 2.

13 Pew Center on Global Climate Change.

14 Pew Center on Global Climate Change.

15 Ice Energy Press Release, *SCPPA to Undertake Largest Utility-Scale Distributed Energy Storage*, January 27, 2010. Available at: http://www.ice-energy.com/NEWSEVENTS/PRESSRELEASES/DATA/tabid/357/articleType/ArticleView/articleId/4/SCPPA-to-Undertake-Largest-Utility-Scale-Distributed-Energy-Storage.aspx

16 Pew Center on Global Climate Change.

17 Pew Center on Global Climate Change.

18 Pew Center on Global Climate Change.

19 Pew Center on Global Climate Change.

20 California Air Resources Board, *Climate Change Scoping Plan*, December 2008, p. ES-1.

21 Governor Arnold Schwarzenegger, *Executive Order S-3-05*, June 1, 2005. Available at: http://gov.ca.gov/executive-order/1861/

22 California Air Resources Board, p. 12.

23 Bill Powers, *San Diego Smart Energy 2020*, October 2007, p. 8. Available at: www.etechinternational.org

24 California Energy Commission, *California Feed-In Tariff Design and Policy Options*, November 2008, p. v.

25 California Air Resources Board, p. 16.

26 Clyde Loutan and David Hawkins (Principal Investigators), *Integration of Renewable Resources: Transmission and Operating Issues and Recommendations for Integrating Renewable Resources on the California ISO-Controlled Grid*, California Independent System Operator Corporation, November 2007, p. 2.

27 Clyde Loutan and David Hawkins, p. 2.

28 Paul Denholm, Erik Ela, Brendan Kirby, and Michael Milligan, *The Role of Energy Storage with Renewable Electricity Generation,* National Renewable Energy Laboratory, January 2010, p. 2-3. Available at: http://www.nrel.gov/wind/systemsintegration/pdfs/2010/ela_energy_storage.pdf

29 Paul Denholm, et al., pp. 2-3.

30 Electricity Advisory Committee, p. 5.

31 David Hawkins, *CAISO's Plan for Integration of Renewable Resources*, Presentation at NARUC Meeting, July 20, 2008, p. 14.

32 MRW & Associates, LLC, *Framework for Evaluating Greenhouse Gas Implications of Natural Gas-Fired Power Plants in California*, Report Prepared for the California Energy Commission, December 2009, p. 3.

33 Kema, Inc., *Research Evaluation of Wind Generation, Solar Generation, and Storage Impact on the California Grid*, Prepared For the California Energy Commission, Public Interest Energy Research Program, June 2010, p. 3.

34 Michael Milligan, Kevin Porter, Edgar DeMeo, Paul Denholm, Hannele Holttinen, Brendan Kirby, Nicholas Miller, Andrew Mills, Mark O'Malley, Matthew Schuerger, and Lennart Soder, *Wind Power Myths Debunked*, IEEE power & energy magazine, Nov-Dec 09, p. 95. Available at: http://www.ieee-pes.org/images/pdf/open-access-milligan.pdf

35 Paul Denholm, et al., p. 1.

36 California Energy Commission, *2009 Integrated Energy Policy Report,* Final Commission Report, December 2009, CEC -100-2009-003-CMF, p. 233. Available at: http://www.energy.ca.gov/2009publications/CEC-100-2009-003/CEC-100-2009-003-CMF.PDF

37 California Energy Commission, *2009 Integrated Energy Policy Report*, p. 232.

38 Intermittency Analysis Project Team, *Intermittency Analysis Project: Final Report*, prepared for the California Energy Commission, July 2007, pp. 5-6. Available at: http://www.energy.ca.gov/2007publications/CEC-500-2007-081/CEC-500-2007-081.PDF

39 Clyde Loutan and David Hawkins, p. 8.

40 Clyde Loutan and David Hawkins, pp. 8, 51-87.

41 Clyde Loutan and David Hawkins, p. 87.

42 Kema, Inc., p. 4.

43 Economic and Technology Advancement Advisory Committee, *Technologies and Policies to Consider for Reducing Greenhouse Gas Emissions in California,* February 11, 2008, p. 5-15. Available at: http://www.etaac.org/jsp/genericdoc.jsp

44 Kema, Inc., p. 6.

45 Economic and Technology Advancement Advisory Committee, p. 5-3.

46 Roger Peters, P.Eng. with Lynda O'Malley, *Storing Renewable Power*, The Pembina Institute, June 2008, p. 3.

47 Patrick Sullivan, Walter Short, and Nate Blair, *Modeling the Benefits of Storage Technologies to Wind Power*, National Renewable Energy Laboratory, pp. 5 & 15. Presented at the American Wind Energy Association (AWEA) WindPower 2008 Conference Houston, Texas June 1–4, 2008. Available at: http://www.nrel.gov/wind/systemsintegration/pdfs/2008/short_storage.pdf

48 See Roger Peters, P.Eng. with Lynda O'Malley, p. 3.

49 See Roger Peters, P.Eng. with Lynda O'Malley, p. 3.

50 Electricity Advisory Committee, p. 10.

51 Roger Peters, P.Eng. with Lynda O'Malley, p. 3.

52 Litos Strategic Communication, *The Smart Grid: An Introduction*, prepared for the Department of Energy, p. 5.

53 Litos Strategic Communication, p. 5.

54 California Energy Storage Alliance, *The Imperative of Energy Storage for Meeting California's Clean Energy Needs*, Executive Summary DRAFT, January 27, 2010, p. 4.

55 Litos Strategic Communication, p. 7.

56 California Public Utilities Commission, *Electric Energy Storage: An Assessment of Potential Barriers and Opportunities*, July 9, 2010, p. 2. Available at: www.cpuc.ca.gov/PUC/energy/reports.htm

57 Federal Energy Regulatory Commission, *Request for Comments Regarding Rates, Accounting and Financial Reporting for New Electric Storage Technology*, June 11, 2010. Available at: http://www.ferc.gov/media/headlines/2010/2010-2/06-14-10-notice.pdf

58 California Independent System Operator, *Non-Generator Resources in Ancillary Services Market*. Available at: http://www.caiso.com/2415/24157662689a0.html

59 California Public Utilities Commission, p. 9.

60 To view the most recent version of the bill, please visit: http://www.leginfo.ca.gov/pub/09-10/bill/asm/ab_2501-2550/ab_2514_bill_20100621_history.html

61 California Public Utilities Commission, p. 8.

62 For more information on U.S. Department of Energy loan guarantees, visit: http://www.lgprogram.energy.gov/

63 California Public Utilities Commission, D.09-08-027, issued August 20, 2009. Available at: http://162.15.7.24/PUBLISHED/FINAL_DECISION/106008.htm

64 One potential model for such a report is *The Smart Grid: An Introduction*, prepared for the US Department of Energy by Litos Strategic Communications and cited above in this paper.

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