SMUD™

October 28, 2014
Chron # ER&D 14-0040

Mr. John Mathias
Electric Generation System Specialist
Supply Analysis Office; Energy Assessments Division
California Energy Commission; MS 20
1516 Ninth St.
Sacramento, CA 95814

Dear Mr. Mathias:

In accordance with AB 2514, on March 1, 2012, the SMUD Board of Directors (Board) initiated a process under which staff would consider energy storage options through SMUD's integrated resource planning process (IRP). Based on the IRP findings, staff committed to return to the Board with either a proposed recommendation for appropriate energy storage procurement targets, or a recommendation that the Board defer establishing energy storage procurement targets until more viable and cost-effective energy storage systems become available.

Public owned utilities (POUs), such as SMUD, must adopt these procurement targets by October 1, 2014, but only if determined to be appropriate after considering viability, cost-effectiveness, and "a variety of possible policies to encourage the cost-effective deployment of energy storage systems, including refinement of existing procurement methods to properly value energy storage systems."[1] POUs must re-evaluate their determination of appropriate targets at least every three years.

Since 2008, SMUD has invested over $30 million dollars in internally and externally funded research to understand and prepare SMUD and its customers for eventual deployment and utilization of energy storage. Staff has been conducting various field demonstrations, studies, and assessments of different storage technologies, used for different applications ranging from transmission scale to distribution scale to customer scale systems. On technical issues, this body of work has assessed technology performance including such factors as efficiency, reliability, and durability. On economic issues, this body of work has assessed capital costs, installation costs, operation costs, value, and cost effectiveness. Additionally through this body of work, staff has assessed grid integration issues and strategies for interconnecting, aggregating, visualizing and controlling storage systems from grid planning and operations perspectives.

Based upon this body of research, staff finds the storage applications examined are not cost-effective at this time, with the exception of large scale pumped hydro storage. Consequently, staff recommended and the Board resolved that it is not appropriate to establish storage procurement targets for December 31, 2016 and December 31, 2020 at this time. As required by AB 2514, SMUD will revisit this determination at least once every three years and assess the cost effectiveness of energy storage.

[1] California Pub. Util. Code § 2836(b).

Attached please find a copy of the Board's resolution 14-09-02 adopted on September 4, 2014 and Attachment A to that resolution which is the staff report on its assessment of storage at this time.

If you have any questions, please let me know.

Sincerely,

Mark R. Rawson

Mark Rawson
Energy Research Technology Officer

Attachments

RESOLUTION NO. 14-09-02

WHEREAS, Assembly Bill 2514 required that, on or before March 1, 2012, the governing board of each local publicly owned electric utility, including **SMUD,** initiate a process to determine appropriate targets, if any, to procure viable and cost-effective energy storage systems to be achieved by December 31, 2016, and December 31, 2020; and

WHEREAS, by Resolution 12-03-07, adopted on March 1, 2012, this Board initiated a proceeding under which Staff would consider energy storage options through the integrated resource planning (IRP) process; and

WHEREAS, based upon the IRP findings, Staff committed to return to the Board with either a proposed recommendation for appropriate energy storage targets, or a recommendation that the Board defer establishing energy storage targets until more viable and cost-effective energy storage systems become available; and

WHEREAS, for the reasons set forth in the attached AB 2514 Storage Procurement Report, **SMUD**'s IRP team has determined that all energy storage systems except for pumped hydro storage are not cost effective at this time; and

WHEREAS, **SMUD** has been evaluating the Iowa Hill pumped hydro storage project, which will not be developed until sometime after 2020, thus **SMUD** does not consider the project a viable and cost-effective energy storage system achievable by the target dates set forth in AB 2514; and

WHEREAS, in accordance with AB 2514, the Board must re-evaluate its determination of appropriate storage targets in no more than three years; **NOW THEREFORE,**

BE IT RESOLVED BY THE BOARD OF DIRECTORS
OF THE SACRAMENTO MUNICIPAL UTILITY DISTRICT:

The Board hereby determines that the adoption of energy storage procurement targets is not appropriate at this time due to the lack of viable and cost-effective energy storage options prior to the target dates set forth in Assembly Bill 2514.

Adopted: September 4, 2014

INTRODUCED: DIRECTOR POSNER				
SECONDED: DIRECTOR BUI-THOMPSON_				
DIRECTOR	AYE	NO	ABSTAIN	ABSENT
SHIROMA	X			
CARR				X
TAYLOR	X			
BUI-THOMPSON	X			
POSNER	X			
KERTH	X			
SLATON				X

SMUD AB 2514
Storage Procurement Report

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0301-14

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1 Executive Summary

AB 2514 requires evaluation of appropriate targets, if any, for electric utilities to procure viable and cost-effective energy storage systems. Public owned utilities (POUs), such as SMUD, must adopt these procurement targets by October 1, 2014, but only if determined to be appropriate after considering viability, cost-effectiveness, and "a variety of possible policies to encourage the cost-effective deployment of energy storage systems, including refinement of existing procurement methods to properly value energy storage systems."[1] The POUs must report to the California Energy Commission regarding their progress towards compliance with these energy storage procurement targets and policies by January 1, 2017, and January 1, 2022. POUs must re-evaluate their determination of appropriate targets at least every three years.

Since 2008, SMUD has invested over $30 million dollars in internally and externally funded research to understand and prepare SMUD and its customers for eventual deployment and utilization of energy storage. Staff has been conducting various field demonstrations, studies, and assessments of different storage technologies, used for different applications ranging from transmission scale to distribution scale to customer scale systems. On technical issues, this body of work has assessed technology performance including such factors as efficiency, reliability, and durability. On economic issues, this body of work has assessed capital costs, installation costs, operation costs, value, and cost effectiveness. Additionally through this body of work, staff has assessed grid integration issues and strategies for interconnecting, aggregating, visualizing and controlling storage systems from grid planning and operations perspectives.

Based upon this body of research, staff finds the storage applications examined are not cost-effective at this time, with the exception of large scale pumped hydro storage. Consequently, staff recommends the SMUD Board of Directors should decline to establish a storage procurement target for December 31, 2016 and December 31, 2020 at this time. Pursuant to AB 2514, SMUD will revisit this determination at least once every three years and assess the cost effectiveness of energy storage.

SMUD has been seriously evaluating and developing the Iowa Hill pumped hydro storage project. Analysis to date indicates that the facility will be cost effective under certain market and cost assumptions. The project, however, will not be developed until after 2020, so SMUD is not including the project in our pre-2020 energy storage procurement targets determination. SMUD will continue to study and evaluate the project.

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[1] California Pub. Util. Code § 2836(b).

Although other energy storage applications are not currently cost-effective, storage costs have continued to decline as technology advancements have been made, as global production capacity has increased, and as the transportation industry has continued development of electric vehicles. Staff anticipates energy storage will become cost effective for some applications within the next ten years. To prepare for cost effective energy storage, staff recommend that SMUD continue investing in energy storage technology assessment, demonstrations and pilots, monitor other storage developments in California, and develop staff expertise in Customer Services to provide assistance to customers considering installation of energy storage systems.

2 Assembly Bill 2514 Requirements

Legislative Requirements of AB 2514

In February 2010, the California Assembly formally recognized the benefits of energy storage through passage of Assembly Bill AB 2514 titled "Energy Storage Systems." The bill was authored by Chair of the Assembly Rules Committee Nancy Skinner in partnership with then California Attorney General Jerry Brown. The bill passed both houses on September 9, 2010 and was signed by Governor Schwarzenegger on September 10, 2010. In passing the bill, the legislature found that increased deployment of energy storage systems can 1) help integrate increased amounts of variable, intermittent, and off-peak wind and solar energy that will be entering the California power mix on an accelerated basis; 2) avoid or defer the need for new fossil fuel peaking plants and avoid or defer distribution and transmission system upgrades, 3) reduce the use of high carbon-emitting power plants during high electricity demand periods and 4) provide the ancillary services otherwise provided by high carbon-emitting fossil-fueled plants. The legislature also found that there are significant barriers to obtaining the benefits of energy storage systems, including inadequate evaluation of the use of energy storage in electricity resource planning, lack of recognition of technological and marketplace advancements, and inadequate statutory and regulatory support.

AB 2514 required that, on or before March 1, 2012, the governing board of each local publicly owned electric utility initiate a process to determine appropriate targets, if any, for the utility to procure viable and cost-effective energy storage systems to be achieved by December 31, 2016, and December 31, 2020. In accordance with AB 2514, on March 1, 2012, the Board initiated a process under which Staff would consider energy storage options through the integrated resource planning process (IRP). Based on the IRP findings, Staff committed to return to the Board with either a proposed recommendation for appropriate energy storage targets, or a recommendation that the Board defer establishing energy storage targets until more viable and cost-effective energy storage systems become available.

The Board must adopt procurement targets by October 1, 2014, but only if it determines them to be appropriate after considering viability, cost-effectiveness, and "a variety of possible policies to encourage the cost-effective deployment of energy storage systems, including refinement of existing procurement methods to properly value energy storage systems."[2] If the Board adopts energy storage targets, SMUD must report to the California Energy Commission regarding its progress towards compliance with these energy storage procurement targets and policies by January 1, 2017, and January 1, 2022.[3] All POUs must re-evaluate their determination of appropriate targets at least every three years.

AB 2514 identifies specific requirements for any "energy storage systems" to be procured. The energy storage system must utilize commercially available technology that is capable of absorbing energy, storing it for a period of time, and dispatching the energy. It may be either centralized or distributed, and either owned by the utility, a customer or a third party. It must be cost effective and provide at least one of the following benefits:

- reduce GHG emissions;
- reduce demand for peak electrical generation;
- defer or substitute for an investment in generation, transmission, or distribution assets; or
- improve the reliable operation of the electrical transmission or distribution grid.

It also must do at least one of the following:

- Use mechanical, chemical, or thermal processes to store electricity generated for use at a later time;
- Store thermal energy for direct use for heating or cooling, avoiding the need for electricity generation at a later time;
- Use mechanical, chemical, or thermal processes to store energy from renewable resources for use at a later time; or
- Use mechanical, chemical, or thermal processes to store energy generated from mechanical processes that would otherwise be wasted for delivery at a later time.

[2] California Pub. Util. Code § 2836(b).
[3] California Pub. Util. Code § 9506(b)-(c).

Section 2836.2 of AB 2514 contains a list of items to consider when setting procurement targets:

> (a) Consider existing operational data and results of testing and trial pilot projects from existing energy storage facilities.
> (b) Consider available information from the California Independent System Operator derived from California Independent System Operator testing and evaluation procedures.
> (c) Consider the integration of energy storage technologies with other programs, including demand-side management or other means of achieving the purposes identified in Section 2837 that will result in the most efficient use of generation resources and cost-effective energy efficient grid integration and management.
> (d) Ensure that the energy storage system procurement targets and policies that are established are technologically viable and cost effective.

CPUC Decision 13-10-040 (issued 10/21/2013)

Similar to the requirements imposed on the POUs, AB 2514 required the California Public Utilities Commission (CPUC) to open a proceeding to determine appropriate storage targets, if any, on or before March 1, 2012. The legislation mandated that the CPUC make the determination by October 1, 2013.On October 21, 2013, the CPUC issued Decision D.13-10-040 requiring California's three investor-owned utilities (IOUs), PG&E, SCE, and SDG&E, to procure 1,325 MW in aggregate of electricity storage projects by 2020 across each of the transmission, distribution and customer grid domains. The specific targets by domain, IOU and year are shown in the following table.

Table 1. Specific Energy Storage Procurement Targets under D.13-10-040

Storage Grid Domain Point of Interconnection	2014	2016	2018	2020	Total
Southern California Edison					
Transmission	50	65	85	110	310
Distribution	30	40	50	65	185
Customer	10	15	25	35	85
Subtotal SCE	**90**	**120**	**160**	**210**	**580**
Pacific Gas and Electric					
Transmission	50	65	85	110	310
Distribution	30	40	50	65	185
Customer	10	15	25	35	85
Subtotal PG&E	**90**	**120**	**160**	**210**	**580**
San Diego Gas & Electric					
Transmission	10	15	22	33	80
Distribution	7	10	15	23	55
Customer	3	5	8	14	30
Subtotal SDG&E	**20**	**30**	**45**	**70**	**165**
Total - all 3 utilities	**200**	**270**	**365**	**490**	**1,325**

The Decision allows for procurement of all stationary energy storage technologies, except pumped hydro greater than 50 MW. This resource type was excluded because the CPUC was concerned the "sheer size of pumped storage projects would dwarf other smaller, emerging technologies; and as such would inhibit the fulfillment of market transformation goals."[4] Nevertheless, the CPUC "encouraged" the IOUs to develop large-scale pumped storage projects to meet other procurement goals, particularly because pumped storage "offer[s] similar benefits as all of the emerging storage technologies targeted by this program…"[5]

The IOUs each filed a procurement application with the CPUC by March 1, 2014. The first procurement for each IOU is scheduled to begin by December 1, 2014. Further procurement applications and solicitations will be held biennially until 2020. The Decision allows IOUs to request deferral of up to 80 percent of a procurement target to the next solicitation, based on a showing that it was unable to procure enough operationally or economically viable projects to meet the targets for a specific solicitation period. Banking of procured capacity is also allowed in situations of over-procurement during a solicitation period.

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[4] D.13-10-040, p. 34.
[5] D.13-10-040, p. 36.

The Decision also targets community choice aggregators (CCAs) and electric service providers (ESPs) to procure energy storage equal to one percent of their annual peak load by 2020 with installation no later than 2024. Beginning January 1, 2016, and every two years thereafter, CCAs and ESPs must demonstrate their compliance towards meeting this target.

For the 2014 solicitation cycle, SCE plans to procure 50 MW of transmission and 16 MW of distribution connected storage. Its total need will be filled through its recent 2013 Local Capacity Requirement RFO (bids submitted on January 30, 2014), its recent 2013 RPS RFO (bids submitted on January 31, 2014), bilateral contract opportunities, utility-owned storage, and customer programs including electric vehicle storage projects. It intends to fill its remaining need through new Energy Storage RFO.

For the 2014 solicitation cycle, PG&E's need is larger than SCE's. PG&E intends to procure approximately 78 MW of storage primarily at the transmission grid level. Transmission & Distribution procurement will focus on three basic configurations; Stand-alone Energy Storage, Hybrid/Co-Located Energy Storage and Energy Storage Providing a T&D reliability function (Transmission or Distribution Asset). PG&E expects its total need will be filled through a new Energy Storage RFO, competitive solicitations authorized in other proceedings (i.e. the Long Term Procurement Plan, Resource Adequacy, or RPS proceedings), an application for a storage project to meet a utility-identified storage opportunity. PG&E will rely on existing CPUC-approved customer programs to meet the targets for the customer segment.

SDG&E's need is the smallest, with only 16 MW of procurement planned for the 2014 solicitation cycle. Based on existing projects, SDG&E views itself in compliance with the 2014 procurement target for the transmission and customer domains and in compliance for the distribution domain if it elects to transfer between buckets and/or take advantage of deferment. Nevertheless, for two of the domains (transmission and distribution), SDG&E is still planning to conduct solicitations for the 2014 cycle in order to capture any cost-effective, viable storage that may be available.

Other POU Activities

Several POUs other than SMUD have already assessed the availability of commercially available, cost-effective storage and made determinations concerning appropriate storage procurement targets.

In June 2012, the Redding Electric Utility (REU) received City Council authorization for long-term extension of the Utility's Energy Storage Program, including permanent load shifting through the procurement and installation of several ice storage facilities ("Ice Bear") throughout the service area. This technology permanently shifts air conditioner-driven peak demand to off-peak hours thereby increasing electric system efficiency and reducing operating costs. The program has proven to be a successful and cost-effective means of improving electric system efficiency for REU, given their climate and load patterns. This type of thermal energy storage meets the requirements of AB 2514 since it is cost-effective, reduces demand for peak electrical generation and also stores thermal energy for direct use for heating or cooling at a later time in a manner that avoids the need to use electricity at that later time. In August of 2014, REU established procurement targets around this program of 3.6 MW by 2016 and 4.4 MW by 2020[6]

In February 2013, the Truckee Donner Public Utility District ("Truckee")[7] analyzed the viability and cost-effectiveness of energy storage pursuant to AB 2514. Truckee reviewed a report from the Electric Power Research Institute (EPRI) on electricity energy storage technologies, which included a framework methodology for valuation of energy storage applications. Truckee assessed its geographic location, load shape, type of customers and existing generation portfolio. Truckee found that given the immature nature of many energy storage technologies, their relatively high cost, and Truckee's relatively high monthly load factor, electricity energy storage systems were not a cost-effective viable resource for Truckee at that time.

In October 2013, the Lodi Electric Utility (LEC) analyzed the viability and cost effectiveness of energy storage pursuant to AB 2514. LEC staff reviewed the same EPRI report on electricity energy storage technologies, noting that many of the energy storage options have not been fully validated and are therefore not "grid ready". They also assessed the load shape, geographic location, type of customers served and existing generation portfolio of LEC. Like Truckee, LEC found that the economics behind energy storage are not cost-effective at this time.

In February 2014, the City of Palo Alto Utilities (Palo Alto) published a lengthy report on the cost and benefit of various energy storage systems for local applications, both from the utility and customer perspective. Palo Alto found that over the next five years, the costs of utility-owned and operated energy storage exceed the value of benefits, and are therefore not cost-effective for Palo Alto, its customers or the city. Palo Alto relied on the aforementioned EPRI report as well as other reports from state and federal agencies.

In January 2014, the Imperial Irrigation District (IID) issued a request for proposals for 20-40 megawatts of battery storage, but has not yet established a target. Respondents were to design, engineer, procure and construct a utility-scale battery energy storage project.

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[6] http://www.ci.redding.ca.us/cclerk/Agendas-2014/EUC/Staff%20Reports/Energy%20Storage%20Compliance%20Plan%2008-26-2014.pdf
[7] http://www.tdpud.org/home/showdocument?id=392

The solicitation was very broad in asking that the project accommodate, at a minimum, the following operational characteristics:

- Spin/non-spin reserves
- Automatic ramping
- Frequency regulation
- Capacity (20 MW to 40 MW)
- Support intermittent renewable integration
- Peak shift energy
- Black-start capability
- Ancillary service capacity
- Smooth intermittent resource output
- Improve short-duration performance
- Improve system reliability
- Improve power quality
- Integrate intermittent distributed generation
- Provide uninterruptible power supply

IID subsequently selected nine firms for continued discussions, including AES Energy Storage, Invenergy Storage Development, UC Synergetic (Hitachi) and ZBB Energy Corporation.

3 Overview of Current Storage Technologies

SMUD considered 10 energy storage technologies in this report including six battery chemistries, pumped storage, compressed air energy storage, flywheels and thermal energy storage. The battery chemistries considered are: lithium ion, lead acid batteries, advanced lead acid, flow batteries, sodium sulfur batteries, and sodium metal halide (sodium nickel chloride is within the genre of battery technology). Each technology offers different operating, performance, capital expense, operating expense, footprint, safety, and technology readiness levels.

Pumped Storage

Fixed speed pumped storage has traditionally been the technology of choice for shifting off peak surplus energy to on peak production, and delivering grid balancing and ancillary services, since it is the most mature and largest storage technology available. Facilities pump water from one reservoir into another at a higher elevation, typically using lower priced off-peak electricity. When energy is required, the water in the higher elevation reservoir is released and runs through hydraulic turbines that generate electricity. One key advantage of this system is that the gravitational energy stored in the upper reservoir can be stored for long periods of time with virtually no energy loss.

Pumped storage is an efficient way to augment baseload generation from conventional power plants. However, efficiency is limited by the efficiency of the pump and turbine unit used in the facilities. It also requires two proximal large reservoirs with a sufficient amount of water surface and pressure elevation between them. Suitable geologic formations are rare and tend to be found in remote off-grid locations, such as mountains, where construction is difficult or restricted.

Variable speed pumped storage has not yet been deployed in the United States, but has all the benefits of fixed speed applications and much improved support of ancillary services such as short and longer term balancing in both the pumping and generating modes of operation.

Compressed Air

Compressed Air Energy Storage (CAES) technology is particularly well-suited for energy-intensive applications such as peak-shifting or spinning reserves. CAES converts inexpensive, excess off-peak electricity into compressed air through the use of a motor and compressor. The compressed air is typically stored in sealed underground air pockets or caverns. When electricity is required, the system returns the compressed air to the surface. The air is then heated with natural gas and put through expanders to power a generator, which in turn produces electricity. While CAES utilizes natural gas, the technology uses less fuel than conventional gas turbines – in some cases two-thirds less. Above ground compressed air storage tanks and pipeline networks are also being explored by energy storage players. Modular systems that do not rely on geologic formations offer strong energy and power storage capabilities across a suite of applications, and ultimately can be sited where needed – near a load center, for instance.

Flywheel

A flywheel is a mass rotating about an axis that stores energy mechanically in the form of kinetic energy. An electrical input accelerates the rotor with a built-in motor. When power is interrupted or needs to be supplied, inertia keeps the flywheel moving, and the built-in motor functions as a generator, converting kinetic energy into electricity. Flywheels offer several important advantages. Flywheels are approximately 85% efficient, the response time is extremely rapid, and while duration is low (typically between a few seconds and a few minutes); flywheels can provide a significant power surge. For example, the world's largest flywheel has an effective capacity of 160 MW and a discharge time of around 30 seconds

Thermal Energy Storage

Thermal energy storage refers to storage systems that store heat or cooling (in the form of chilled or frozen water) to displace electrical air conditioning load during peak periods. In the case of California, ice thermal storage is particularly relevant. Most firms in this space offer large-scale systems for commercial businesses such as airports, convention centers, or large hotels. Small, modular systems have also been developed for single-building applications such as office buildings.

Chemical Energy Storage

Chemical energy storage refers to storing electrical energy in a chemical or elemental form, such as in hydrogen. For example, electrolysis can utilize excess generation to create hydrogen gas from water, releasing oxygen. Hydrogen can then be combined with other compounds to create liquid or gaseous fuels such as methane, the primary component of fossil natural gas, which can then be stored for use in conventional power plants.

Battery Energy Storage

Battery energy storage is the most diverse in terms of offerings, operating and performance characteristics, marginal cost, and technology subtypes. The 6 chemistries included in this report are: lithium ion, lead acid batteries, advanced lead acid, flow batteries, sodium sulfur batteries, and sodium metal halide.

The lithium ion (Li-ion) battery market consists of multiple sub chemistries, including lithium iron phosphate (LFP), lithium manganese oxide (LMO), lithium titanate oxide (LTO), lithium cobalt oxide (LCO), lithium nickel cobalt aluminum (NCA), and lithium nickel manganese cobalt (NMC). Each of these chemistry names refers to the primary material of the cathode, with the exception of LTO, which refers to the primary material of the anode. Overall, Li-ion batteries offer high performance, high efficiency, small footprints, and high power density. Li-ion offers the most diversity in terms of sub-chemistries and borrows heavily from consumer electronics and electric vehicles industries.

The lead acid technologies that are typically used in stationary storage include valve-regulated lead-acid (VRLA) and lead-carbon batteries (advanced lead-acid). VRLA batteries are a dry cell technology that minimizes the potential for electrolyte leakage by sealing off the electrolyte solution, either suspending it between glass mats or housing the electrolyte in gel form. The gases produced during charge and discharge of the battery are then recombined to create water which keeps the cells moisturized. VRLA batteries are typically used for reserve power.

Lead-carbon batteries refer to the addition of carbon to the negative electrodes of the battery cell, which provides several benefits. The addition of carbon, either in a split electrode or as a replacement electrode, enhances the battery’s higher charge and discharge power characteristics by increasing the surface area on which the electrochemical reaction can take place. Furthermore, these batteries can operate on a broader depth-of-discharge range, increasing the functionality of the cells. The carbon replacement also enhances lifecycle.

Flow batteries utilize a central battery stack that captures electron flow from a charged liquid electrolyte and converts that into an electric current. During the charge cycle, electricity is applied to reenergize the electrolyte into an energy storage material. The key advantage of flow batteries is that adding extra energy storage is merely a matter of adding extra tanks of electrolyte. In addition, these batteries ultimately hold the promise of an affordable means of long-term energy storage. The leading chemistries within the flow battery space today are zinc bromide redox, vanadium redox, and iron chromium.

Zinc bromide redox batteries use a reversible zinc electroplating process to charge and discharge the electrolyte in the batteries. This relatively complex electrochemical reaction has caused problems in the past with battery life and membrane clogging. Most of the entrants in this space, claim that they have solved these durability problems and can now produce long-lasting batteries. Zinc bromide batteries still require pumps and fluid flow (as do all flow batteries), which can lead to operations and maintenance issues during the long life of a stationary energy storage asset.

Although it is a relatively rare and expensive element, vanadium is an excellent energy storage medium with very smooth voltage profiles and low internal resistance. Thus, a vanadium redox battery is capable of extremely long life and high efficiencies compared to other flow battery technologies. No manufacturer, however, has yet successfully figured out how to reduce the costs of these flow batteries to the point where they can compete with other chemistries such as Li-ion or advanced lead-acid.

Another emerging flow battery technology is iron chromium. In addition to offering long-term energy storage at reasonable price points in the coming years, iron chromium also has the capability to operate at a range of output voltages. As a result, operators can calibrate power flow somewhat.

Sodium sulfur (NaS) technology is a liquid state battery with sulfur at the positive electrode and sodium at the negative electrode. This technology maintains high roundtrip efficiency, high energy density, and long lifecycles, but the drawbacks include significant technical risks due to high operating temperatures. These technical risks mean NaS batteries are ideally suited for immobile, utility-scale applications and have been deployed primarily in Japan to support grid-scale applications.

Sodium metal halides high-temperature chemistry was originally invented in the 1970’s. Sodium metal halide batteries have the advantage of relatively low-cost materials, primarily sodium, zinc, and some nickel. This battery chemistry is still more expensive than Li-ion chemistries such as NCA and LFP. Additionally, sodium metal hydride batteries operate at very high operating temperatures (between 250°C and 350°C), which creates safety and efficiency risks that add to the cost of engineering the systems.

Uses for Energy Storage

Table 2 lists the energy storage technologies covered in this report – excluding traditional lead acid – and indicates the typical applications for each technology across nine line-side applications.

Table 2. Energy Storage Technologies and Best-Suited Utility Applications (ex customer-sited applications)

	PHS	CAES	Flywheel	Li-ion	Flow	Advanced Lead-Acid	NaS	Thermal Energy Storage	Sodium Metal Halide
Frequency Regulation	X	X	X	X	X	X	X		
Voltage Support			X	X		X	X		
Fast Reserve	X	X	X	X	X	X	X		X
Load Following	X	X	X	X	X	X	X		
Peak-shifting	X	X		X	X	X	X	X	X
Wind Integration	X	X		X	X	X	X		X
Solar Integration	X	X		X	X	X	X		X
T&D Upgrade Deferral	T only	T only		X	X	X	X		X
Community Storage				X	X	X			

(Source: Navigant Research)

Summary of Energy Storage Deployments

According to Navigant Research, 126,073.6 MW (599 systems) of energy storage are currently deployed globally. Another 34,860 MW (comprising 165 systems) are in the pipeline, which refers to projects that have been announced, projects that are funded, or projects currently under construction. Of the nearly 35,000 MW of energy storage in the pipeline, 89% is pumped hydro (traditional or small-scale variants), leaving 3,801 MW of advanced energy storage in the pipeline.

Since 2000, 30,465 MW of energy storage have been deployed globally. Asia-Pacific leads the market with 20,317 MW installed, followed by Europe with 8,448 MW deployed, the Middle East with 1034 MW deployed and North America with 622 MW deployed. Within Asia Pacific, the leading countries are China, India, South Korea, and Japan. In Europe, Ukraine, Germany, Spain, Norway, and Switzerland lead the market. The Middle East's market share is mainly comprised of a large pumped storage plant in

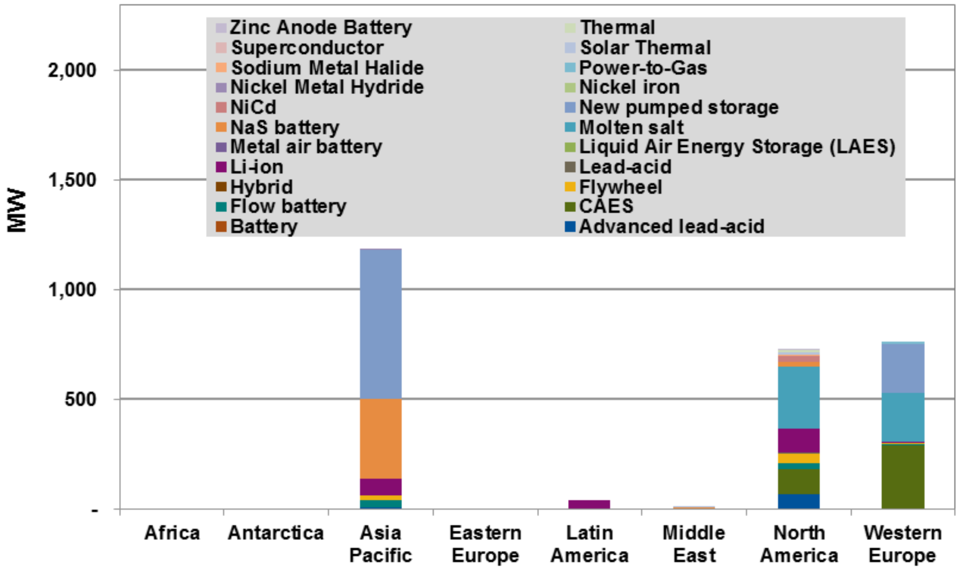
Iran. The majority of these installations are pumped storage, which accounts for the high volume of storage installed over the past 15 years.

Since 2000 in North America, 622 MW of energy storage have been installed, 619 MW in the United States. Of these 619 MW, 572 MW have been advanced energy storage technologies such as advanced batteries, flywheels, or compressed air, for example. 2013 and 2011 were the standout years for energy storage in the United States. In 2011 103 MW were installed in the U.S. and in 2013 that number more than tripled with 341 MW installed.

Globally, as of the third quarter of 2014 (Figure 1), there are 23 energy storage technologies installed. Excluding pumped storage, these technologies account for 2730 MW of projects. North America leads the market with 19 technologies installed on the grid system. In sharp contrast, only 10 storage technologies are deployed in Europe and 8 technologies are installed in Asia Pacific. Overall, however, Asia Pacific leads the market with 1181 MW of energy storage installed (excluding pumped storage), compared to 762.7 MW in Europe or 726.4 MW in North America.

Globally, 35 projects have been cancelled, decommissioned, or are otherwise inactive. This figure amounts to 4,127 MW of projects that were in the pipeline at one time – nearly all of these projects were active in the past 10 years or less. The majority of cancelled or inactive projects are in North America. Twenty projects, or approximately 3010 MW of energy storage falls into this category. This is a product of two different trends. First, the 2009 American Recovery and Reinvestment Act (ARRA) jumpstarted a number of early-stage demonstration projects, some of which were never installed. Second, successful demonstrations have been built, commissioned, produced data, and subsequently decommissioned.

Thermal storage is not included in these statistics above as many firms have been selling systems for decades, and selling into the private sector. As a result, complete market data does not exist. However, thermal energy storage systems have been deployed by several utilities and customers across California. Some municipal utilities (e.g. the city of Redding) have established incentive programs for thermal energy storage. In addition, the statewide Permanent Load Shifting program also encourages thermal storage by offering a one-time upfront incentive, based on the number of kilowatts shifted, to offset the capital expense in a thermal energy storage system. Customers are required to shift energy use during the summer peak hours as defined by each utility. The standard Permanent Load Shifting incentive across the IOUs is $875/kW.



(Source: Navigant Research)

Figure 1. Megawatts Deployed Energy Storage Projects by Region and Technology, Excluding Pumped Storage 3Q14

4 SMUD Storage Research Learning and Valuation

Overview of Storage Demonstrations and Activities at SMUD

SMUD has been actively engaging in energy storage demonstration and testing activities over the past few years. These efforts, which are depicted in Figure 2 and summarized in Table 3, have been driven by the prospect for greenhouse gas regulations and the need to effectively integrate intermittent renewable energy sources to meet renewable portfolio standards. Additionally, storage has the potential to provide a valuable variety of services and benefits including backup power, peak load reduction, mitigation of electrical vehicle (EV) charging loads, management of time-of-use (TOU) rates, and deferment of distribution investments. In recent years, SMUD has examined a range of energy storage technologies including Li-ion batteries, molten salt batteries, pumped hydro, and compressed air. Moreover, SMUD has evaluated these technologies at residential, commercial, and utility sites, performing assessment of the technical, operational, and financial aspects of deploying energy storage.

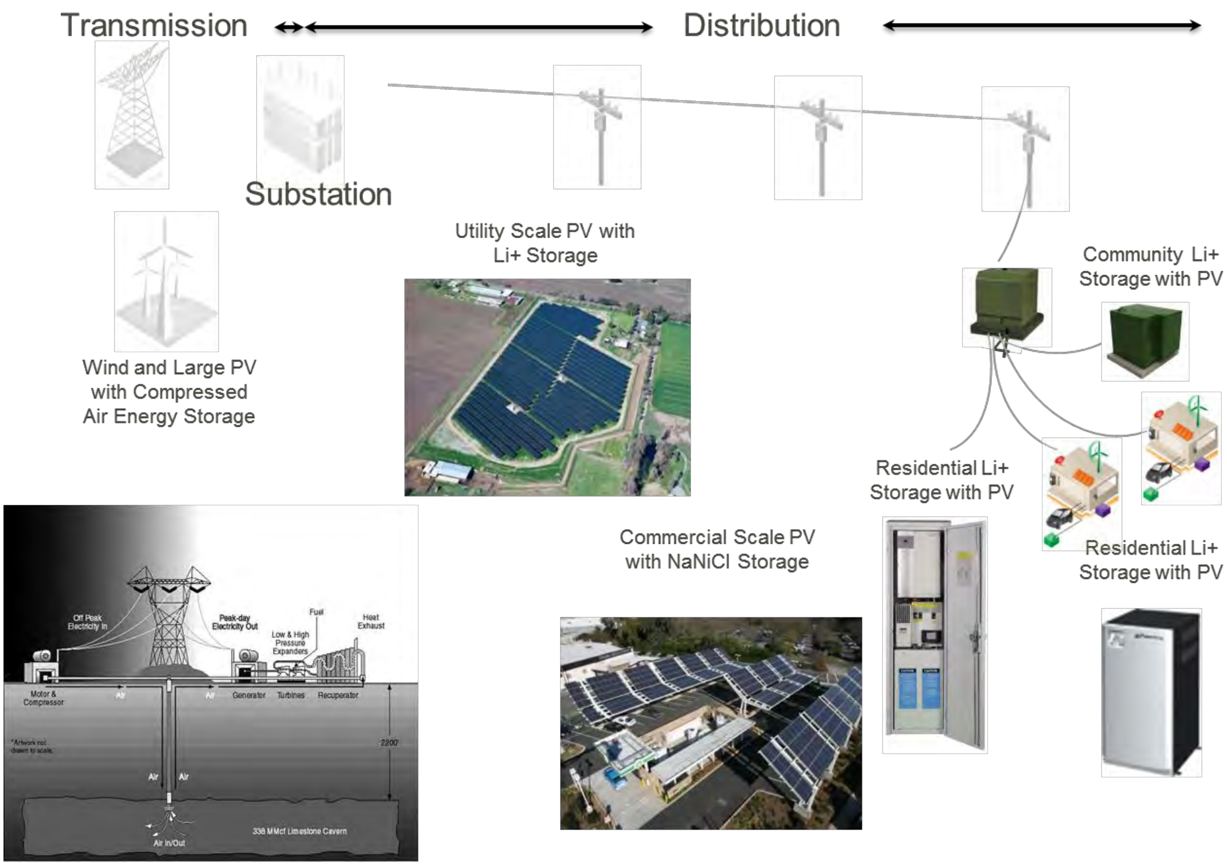


Figure 2. SMUD Current Energy Storage R&D Portfolio

Table 3. Summary of SMUD Energy Storage Demonstrations

Projects	Objectives	Time frame	Technologies	Applications
PV and Storage Demonstration at Anatolia	Assess customer and edge of grid sited storage to address intermittent PV, peak load reduction and customer energy cost reduction	2010-2013	Lithium Ion	Renewables Smoothing, Renewables Shifting, Peak Load Reduction, Customer TOU Energy Cost Reduction
Residential Energy Smart Community Demonstration Pilot	Assess customer net zero energy homes with PV, storage and demand response	2012-2015	Lithium Ion	Renewables Smoothing, Renewables Shifting, Peak Load Reduction, Customer TOU Energy Cost Reduction, Demand Response, Uninterruptible

				Power Supply
Mitsubishi Energy Storage Demonstration	Assess feeder sited battery storage to mitigate PV intermittency issues from a 3 MW PV plant	2012-2015	Lithium Ion	Renewables Smoothing, Voltage Support
PV, Electric Vehicle Fast Charging and Storage Demonstration	Assess ability of storage to firm PV and offset high power EV charging impacts to distribution system	2012-2015	Sodium Nickel Chloride	Renewables Smoothing, Renewables Shifting, EV Charging Load Reduction, Peak Load Reduction
Commercial Customer Energy Storage Demonstration	Assess ability of storage to reduce commercial customer demand and energy costs	2011-2015	Lithium Ion	Customer TOU Demand Charge and Energy Cost Management
Compressed Air Energy Storage Project	Assess feasibility of bulk storage using depleted natural gas fields and aquifers to support renewable energy integration	2010-2014	Compressed Air Energy Storage	Renewable Smoothing, Renewable Shifting, Energy Arbitrage
Distributed Energy Storage Pilot	Assess feasibility of storage to firm an all solar residential community and integrate with a microgrid application	2010-2012	Zinc Bromine Flow Battery	Renewable Smoothing, Renewable Firming, Peak Load Reduction, Uninterruptible Power Supply
DC Linked PV and Energy Storage Pilot	Assess feasibility of linking storage on the DC bus with PV for dispatchable and firmed PV production	2010-2012	Lithium Ion	Renewable Smoothing, Renewable Firming, Peak Load Reduction

On the residential end, SMUD led a $5.9M DOE-funded project at the Anatolia housing division, a SolarSmart Homes^{SM} community with over 1.1 MW of installed PV systems in Rancho Cordova.[8] The project – shown in Figure 3 - included 15 residential energy storage (RES) units (10 kW, 7.7 kWh Li-ion batteries) and 3 community energy storage (CES) units (30 kW, 30 kWh Li-ion batteries). These units were able to effectively control voltage, mitigate PV ramping, and shift load. SMUD quantified the benefits for both customer-sited (RES) and transformer-sited (CES) systems, which ranged from $88/kW–$215/kW and $67/kW–$176/kW, respectively. There were a number of tradeoffs that SMUD was able to identify between RES and CES in terms of both

[8] Sacramento Municipal Utility District PV and Smart Grid Pilot at Anatolia. Sacramento Municipal Utility District, Sacramento, CA. 2013.

functionality and system management. In another project, SMUD is also investigating residential Li-ion storage in combination with PV, smart thermostats and plug controls, and home area networks to demonstrate demand response, UPS functionality, PV integration, load shifting, and data analytics.

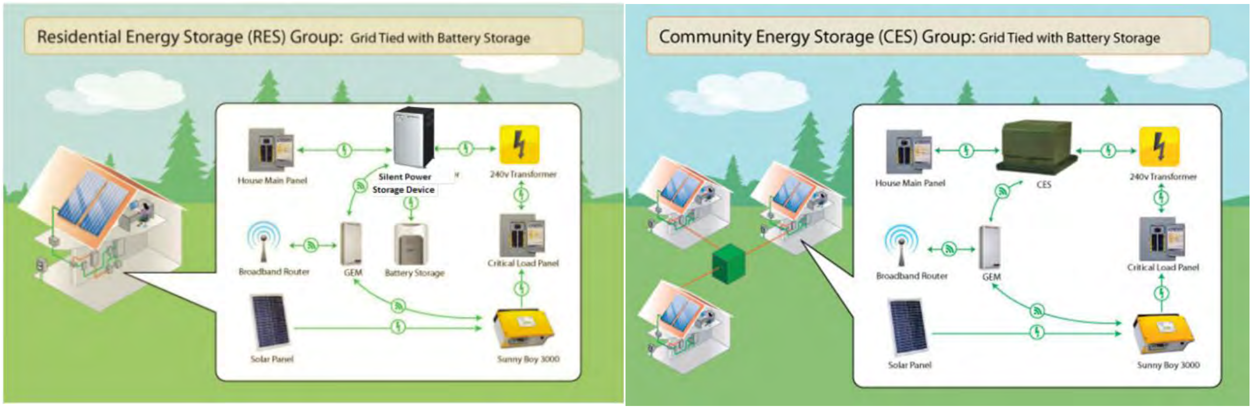


Figure 3. Anatolia Demonstration Project: Residential and Community Storage

In a pilot consisting of small commercial and light industrial customers, SMUD deployed Stem energy monitors in Phase I to collect data prior to deploying a 36 kW Li-ion energy storage system for peak demand charge reduction in Phase II.

At its headquarters parking facility, SMUD is demonstrating a solar EV charge port coupled with an energy storage system. A 50 kW / 130 kWh FIAMM sodium nickel chloride battery system has been integrated with an 80 kW PV array and 20 EV chargers, including a 50 kW DC Fast Charger. SMUD is evaluating the ability of storage to smooth PV, control PV and EV ramp rates, regulate voltage, and facilitate peak load reduction and time shifting.

For utility scale storage, SMUD has been evaluating the use of batteries, pumped hydro, and compressed air. A 500 kW / 125 kWh Li-ion battery system has been installed to augment a 3 MW PV plant. SMUD will evaluate the system's ability to mitigate PV variability, control ramp rates, and regulate voltage. At a much larger scale, SMUD is considering a 400 MW, $800M pumped hydro facility at Iowa Hill.[9] SMUD has performed extensive feasibility studies to understand the value that such a project would provide, with estimates ranging from $80-294/kW-yr depending on various factors including the extent and type of renewable generation on the grid, as well as the use of single speed versus variable speed drives within the pumped hydro storage plant.

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[9] Modeling and Evaluation of Iowa Hill Pumped-Hydro Storage Plant: Value in SMUD and in larger region. Sacramento Municipal Utility District, Sacramento, CA. 2014.

SMUD has also considered compressed air energy storage (CAES) by evaluating over 25 potential sites in and around the SMUD service territory. However, each site was found to have some significant risk associated with it, whether geological, technological, legal, or logistical. The most promising site has complex land rights issues, and the timeframe there would be 10 years or more to develop such a site for a compressed air energy storage plant. Furthermore, the value provided would be similar to Iowa Hill, but the cost on a $/kW or $/kWh basis would likely be greater than the pumped hydro storage project. Consequently, SMUD has tentatively put its CAES evaluation on hold.

Finally, SMUD was awarded $10 million in funding from the Department of Energy to implement concentrating solar power (CSP) technology with thermal storage that can provide steam augmentation to the Cosumnes Power Plant. The objective of this project is to design, develop and demonstrate through commercial operation an advanced hybrid CSP technology (with thermal storage) that will be integrated at an existing natural gas-fueled combined cycle power plant. SMUD is currently conducting the feasibility studies under Phase 1 of the project. This is a multi-year project initiated at the end of 2013.

Lessons Learned

From this range of demonstration projects, SMUD has gained valuable insight into storage technology, deployment, and management. Notably, many of SMUD's observations are consistent with those reported by other utilities regarding their energy storage demonstration projects.[10] While some of the lessons can be readily applied in future deployments, others will require technological modifications by vendors. For the most part, these challenges will be surmounted as the market matures, but nonetheless present difficulties in the short-term.

One of the most significant challenges facing energy storage is the integration of storage equipment with other infrastructure, including distributed generation, grid assets, communications equipment, and data acquisition and control systems. Utilities currently must coordinate with multiple vendors, many of which are unfamiliar with the other components of the system, particularly energy storage.

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[10] US Energy Storage Project Case Studies – 2013: Selected Results, Findings, and Lessons Learned. EPRI, Palo Alto, CA: 2013. 3002001256.;
U.S. Energy Storage Project Case Studies: Results, Findings, and Lessons Learned in 2012. EPRI, Palo Alto, CA: 2012. 1024281.;
Distributed Energy Storage Systems: Field Deployments and Lessons Learned. EPRI, Palo Alto, CA: 2013. 1024283.

As SMUD learned during its solar EV charge port project, there are multiple layers of communication (see Figure 4) that can be difficult to coordinate, especially when some are proprietary. Duke Energy used an integrated battery and power conversion system to simplify integration, but noted that this limited system customization. While SMUD can minimize some of these issues by working with experienced systems integrators and educating workers, vendors can have a more significant impact by providing modular units with standardized communications protocols. Fortunately, there is currently movement toward using DNP3 as a standard mode of communication for energy storage.

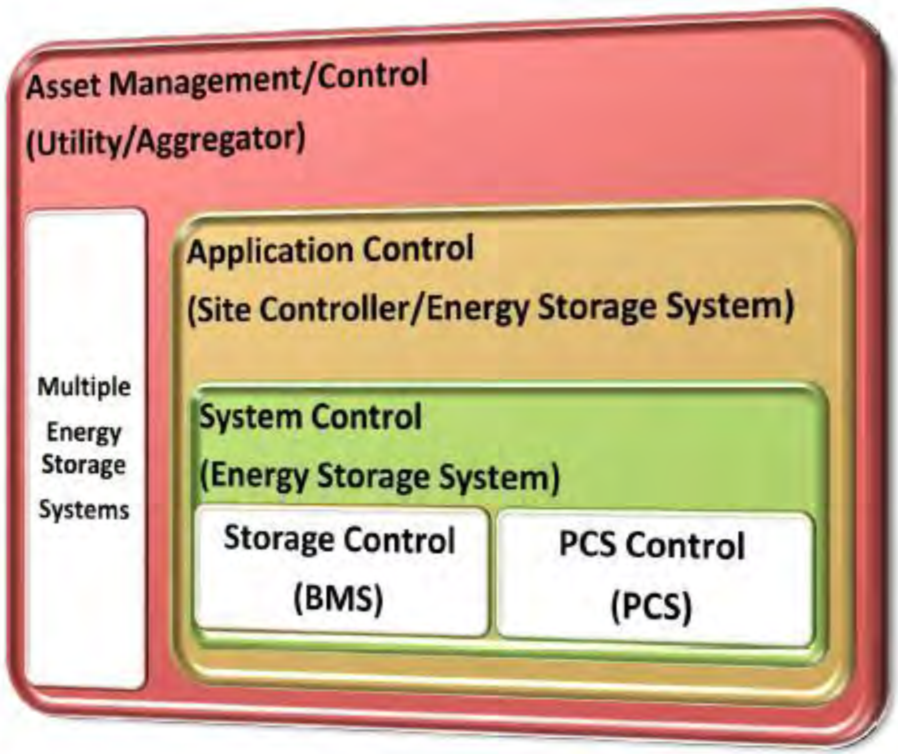


Figure 4. Layers of Communication in Energy Storage Systems.[10]

Reliability, a primary concern for utilities, needs to be proven for widespread adoption of energy storage systems. Several vendors are at the pilot stage and have deployed few systems. In the Anatolia project, the RES vendor had a manufacturing defect that caused SMUD to shut down all the RES units. SMUD encountered multiple failures with various components including cooling fans, capacitors, SD cards, and modems. In Alameda County's SmartGrid demonstration, the battery DC breakers repeatedly tripped from overcharging. Multiple others have also reported issues with charging and discharging behavior, as well as failed breakers and inverters.

As a new technology, distributed energy storage systems have not been fully optimized for certain applications. At Anatolia, the smoothing application did not work as effectively on RES units as on CES units. Furthermore, SMUD's storage scheduling software was set up for individual unit programming, whereas fleet-level programming is more useful for utility-owned distributed energy resources. Additionally, SMUD received complaints that the RES units were too noisy when operating in smoothing mode caused by the high rate of switching occurring in the inverter. Multiple utilities, including SMUD, have found that some battery systems lack desirable safety mechanisms, such as remotely operated bypasses in case of a fault. Fortunately, vendors are becoming more familiar with utility needs, and many of these issues should fade as the market matures.

Communications were also a significant challenge in the Anatolia project. The customer broadband used for RES communication had unstable internet connectivity, and the connection with the cellular modem used for CES units was lost regularly until the cellular provider expanded coverage in the area. Also, in one instance, there was interference between a RES unit and customer broadband equipment. Consequently, research is being conducted to assess the viability of using SMUD's advanced metering infrastructure for communications in the future. Reliance on third party provided telecommunications has initially proven to be problematic in SMUD's Mitsubishi Energy Storage Demonstration as well, resulting in problems with control and monitoring systems including fire protection monitoring. Working extensively with the telecommunications company and the vendor fortunately resolved these issues however.

Another significant lesson is that storage projects take longer than anticipated. With a lack of in-house expertise on new technology, SMUD has routinely found technical efforts to be more complex and time-consuming than expected. At Anatolia, SMUD had never worked with high resolution monitoring equipment on underground feeders and had issues with monitor phasing and SCADA integration. This need for troubleshooting can be further complicated when working with residential systems, as it may require schedule coordination, and some customers complained about the frequency and duration of visits. Other delays included UL and IEEE certification of RES units and the component failures described above.

As is sometimes the case with research and development, technologies occasionally are found to be inadequate or not ready to be scaled from bench scale to field demonstration scale. This proved to be the case with SMUD's zinc bromine flow battery demonstration project with Premium Power. During the course of this project, difficulties in meeting the design and operational requirements arose and the use cases to be demonstrated were thus forced to be modified or removed by Premium Power. The original power rating of 500 kW and energy rating of 3,000 kWh expected from the system was downgraded to 160 kW and 640 kWh respectively. Additionally, the roundtrip efficiency goal of 66% was not attainable, with the system only reaching 40%

roundtrip efficiency. As a result of these shortcomings, SMUD cancelled this research project, deeming this vendor's technology not technically viable for field trial.

Another lesson learned from SMUD's energy storage technology demonstration work is that not all vendors and suppliers are financially stable. SMUD was awarded DOE funding to conduct demonstration of substation sited energy storage with Satcon and A123. The project would have demonstrated a 500 kW / 500 kWh system located at SMUD headquarters. However, before equipment could be installed, Satcon and A123 went bankrupt (for unrelated reasons). As a result, SMUD cancelled the project. This suggests energy storage vendors and the market as a whole is still developing.

Finally, a key challenge with energy storage is projecting and deriving value from energy storage assets due to lack of familiarity with the system. For example, SMUD encountered challenges setting up TOU rates with coupled PV-battery systems – no Anatolia customers wanted to remain on the established TOU rates. While SMUD has projected the value of energy storage for different applications, there is a large range due in part to technological and regulatory uncertainty. A broad challenge facing all utilities considering storage is that storage must be used for multiple different applications simultaneously to derive significant value. However, the degree to which one storage asset may be used simultaneously for multiple applications is currently unclear. In fact, SolarTAC reported[10] that it was only able to determine optimal functionality after system testing. Other considerations required for valuation are also unclear. For example, in its solar EV charge port project, SMUD found that simply measuring the efficiency of the system is challenging. Actual efficiencies, as well as lifetimes and other battery characteristics, can vary depending on how the battery is used for different applications. More reliable information can inform better decisions on storage investments, including technology selection, sizing, placement, and operating strategy.

Planned Work

SMUD is continuing its existing storage pilot projects to continue preparing for eventual storage deployments on both the customer and utility sides of the meter. In addition to its existing demonstrations, SMUD is participating in the Energy Storage Integration Council (ESIC) being facilitated by EPRI. This collaborative between storage vendors, system integrators and electric utilities is striving to accelerate the development of safe, reliable, cost-effective energy storage through the development of common industry approaches. The goal of the ESIC is to define common approaches for development of functional requirements, test protocols, technical specifications, safety, communications and best practices for installation, operation, and decommissioning of energy storage systems.

Additionally, SMUD's Customer Services Department is working to incorporate storage interconnection into SMUD's existing interconnection processes that has successfully supported customer distributed generation interconnection requests. This department is also investigating potential new customer programs or services they can offer customers who may be considering energy storage; acting as a "trusted advisor" for these customers to get unbiased information about the efficacy of possible energy storage solutions being considered.

Value Analysis Results

SMUD has conducted several studies analyzing the value of energy storage. This section briefly summarizes each study and its results, but Table 4 summarizes the values found.

Table 4. Summary of Value Analysis Results

Study	Technology	Value
EPRI/E3 Energy Storage Value Analysis	Multiple	NPV of $150 to $950/kWh
Anatolia Demonstration Value Analysis	Li-ion batteries	NPV of $4 to $15/kW-yr
Iowa Hill Value Analysis	Pumped Hydro Storage	$80 to $294/kW-yr
CAES Value Analysis	CAES	$80 to $180/kW-yr

To understand the value of energy storage, SMUD engaged EPRI and E3[11] in 2011. EPRI and E3 looked at the value of energy storage in a variety of locations and applications. The locations were: at residential homes, in a neighborhood on the SMUD side of the meter, and at substations. The applications studied were:

- Transportable Distribution Deferral
- Distributed Energy Storage Systems
- PV Load Shifting
- Commercial Energy Management
- Aggregated Energy Management with Grid Support

[11] Benefits Analysis of Energy Storage: Case Study with the Sacramento Utility Management District. EPRI, Palo Alto, CA: 2011. 1023591.

The study assessed a wide range of benefits: price arbitrage for SMUD, regulation revenues, system capacity benefits, deferred distribution investments, reduced customer demand charges, reduced customer TOU rate charges, increased power reliability and improved power quality. Figure 5 shows the results and they range from a present value of $150 to $950/kWh of energy storage capacity.

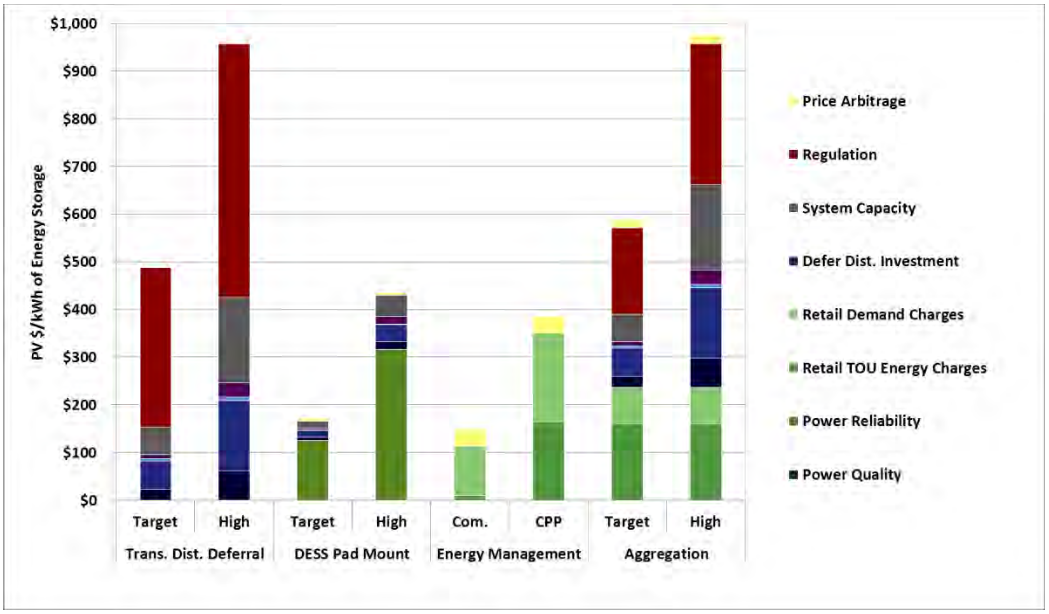


Figure 5. EPRI/E3 Value Analysis Results

As part of SMUD's demonstration of customer and transformer sited energy storage (discussed above), Navigant Consulting conducted a value analysis of the configurations tested[12]: SMUD owned, transformer sited; SMUD owned, customer sited; and customer owned, customer sited. The value analysis was based upon Navigant's benefit calculation methodology shown in Figure 6. It focused on the applications tested during the demonstration: electric energy time shift, voltage support, distribution upgrade deferral, time of use energy cost management, and electric power reliability. The range of values for each configuration is shown in Figure 7 and ranges from a net present value of $60 to $210/kW of energy storage capacity.

[12] Sacramento Municipal Utility District PV and Smart Grid Pilot at Anatolia, December 30, 2013

Applications	Economic										Reliability		Environmental		
	Market Revenue			Asset Utilization					Efficiency	Cost	Interruptions		Air		Water
	Arbitrage Revenue	Capacity Revenue	Ancillary Service Revenue	Optimized Generator Operation	Reduced Congestion Cost	Deferred Generation Capacity Investments	Deferred Transmission Capacity Investments	Deferred Distribution Capacity Investments	Reduced Electricity Losses	Reduced Electricity Cost	Reduced Outages	Improved Power Quality	Reduced CO_2 Emissions	Reduced SO_X, NO_X, and Particulate Emissions	Reduced Water Use
Load Leveling															
Renewable Energy Shifting	X			X	X	X	X	X	X	X			X	X	X
Wholesale Market Arbitrage & Cost Optimization	X			X	X	X	X	X	X	X			X	X	X
Retail Market				X	X	X	X	X	X	X			X	X	X
Asset Management				X	X	X	X	X	X				X	X	
Grid Operational Support															
Operating Reserves			X	X		X							X	X	X
Load Following				X		X							X	X	X
Frequency Regulation			X	X		X							X	X	X
Renewable Energy Capacity Firming		X													
Black Start			X			X									
Grid Stabilization															
Renewable Energy Ramping				X		X							X	X	X
Renewable Energy Smoothing				X									X	X	X
Backup Power											X				
Voltage and VAR Control												X			

Figure 6. Navigant's Energy Storage Benefit Framework

Figure 7. Value Analysis of SMUD Anatolia Energy Storage Demonstration

To complement the development of SMUD's Iowa Hill PHS project, SMUD partnered with Energy Exemplar and EPRI and won a US DOE FOA grant to model the value of the Iowa Hill project. The analysis[13] found values ranging from $80 to $294/kW-yr,

[13] Modeling and Evaluation of Iowa Hill Pumped-Hydro Storage Plant: Value in SMUD and in Larger Region

depending on the penetration of renewables and other market assumptions. Using this as a benchmark, SMUD's resource planning group[14] assessed the value of a 135 MW CAES plant and found similar values in 2030.

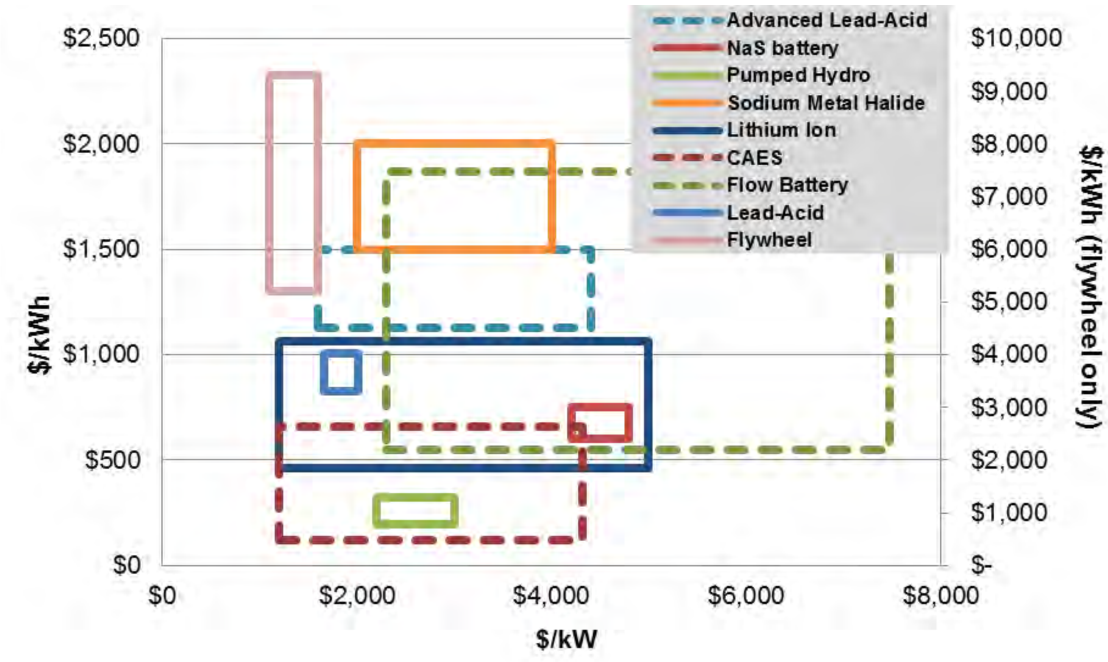
5 Current and Projected Energy Storage Costs

Current Energy Storage Costs

Current energy storage installed costs vary significantly, not only between technologies but also from project to project within a specific technology, or even vendor. Factors such as grid connection fees, system installation, land acquisition, and other site-specific costs will affect the cost of energy storage from project to project all things being equal.

Cost ranges in terms of both power and energy are plotted in Figure 8 for comparison. Flywheel energy ranges ($/kWh) are plotted on the secondary y-axis. Practically speaking, flywheels are only used in power-intensive applications such as frequency regulation and most commercial flywheel systems are 15-minute systems. This puts flywheels at a disadvantage when comparing flywheel technology on an energy basis. The most mature technologies, pumped hydro, lead acid batteries, and NaS batteries have the smallest ranges in terms of both energy and power cost. Overall, these technologies have not experienced significant innovation in the past ten years.

[14] Internal resource planning documents



(Source: Navigant Research)

Figure 8. Installed Power and Energy Storage Cost Ranges, 3Q14

CAES, advanced lead-acid, sodium metal halide and lithium ion have a significant amount of variation in both power and energy cost. In the case of CAES, this is a function of geologic restrictions for traditional CAES technology, a combination of geologic and some technology innovation in case of iso-thermal underground CAES, and for modular-CAES systems, this variance reflects mainly technology innovation.

In the case of advanced lead-acid and sodium metal halide, the variance in cost is partly site-specific and partly driven by innovation within this battery chemistry and volume manufacturing constraints.

Lithium ion is unique in the sense that the figures presented here represent a blending of the most expensive and least expensive subchemistries within lithium ion, both in terms of energy and power. Therefore, the large range of costs is a function of the diversity of subchemistries, some of which are developed for high-power applications, and others developed for high-energy applications.

Flow batteries have the widest range of costs, and this is primarily a function of the varied sub-chemistries and manufacturing models that are being tested within this battery type. Vendors building facilities with large electrolyte storage tanks may have higher $/kW figures than vendors opting to build identical modules. However, this strategy will result in a much lower $/kWh. Sub-chemistries that rely on expensive, albeit efficient and high-performance inputs such as vanadium, will have higher upfront costs than zinc or iron-based subchemistries.

Not shown in the figure above are thermal energy storage costs. These are highly site specific depending on building's layout, existing HVAC equipment and the amount of thermal storage required. In 2012, SMUD commissioned[15] a technical potential study for large thermal energy storage systems in its service territory, focusing on adding chilled water to existing HVAC systems. The thermal energy storage would be used to shift cooling loads to off peak hours. Detailed onsite surveys were done to estimate: the potential cooling capacity that could be shifted, installation costs, and customer willingness to adopt. The study found costs ranging from ~$50 to $70/ton-hour for chilled water systems and ~$210 to $230/ton-hour for ice storage systems.

Installed costs however are not the only metric by which to compare different storage technologies because their application and life-cycle characteristics can be quite different, even within the same technology type. As noted above for example, comparing installed costs of flywheels used for frequency regulation (i.e., a power application) to batteries used for energy arbitrage (i.e., an energy application) can be misleading. In this instance, to have comparable life-cycles, batteries would require replacement and this would need to be considered as a variable O&M expense in any life-cycle analysis. Unfortunately, for many emerging storage technologies there is not yet sufficient data on useful life and annual O&M cost by application to understand life-cycle costs adequately.

Unfortunately, no recent and comprehensive analysis can be found in literature that compares storage technologies on life-cycle bases for different applications. A 2013 Sandia National Laboratory report[16] has information on life-cycle costs, but it is primarily based upon vendor provided and has not been verified with independent real world performance data.

A study by EPRI[17] in 2010 assessed different energy storage technologies on a levelized cost basis. This was done by dividing the total construction, finance, operating and maintenance, and replacement costs of an energy storage system by its useful output. The costs were then levelized using the cost of capital or discount rate to calculate flat cost of energy on a $/kWh basis and capacity on a $/kW-yr basis over the life of the systems. In this manner, EPRI was able to compare the costs of technologies with different useful lives, efficiencies and capacity factors in a more equitable manner. Unfortunately, the study only assessed two combined applications for use of the storage systems – renewable integration/time shifting, and transmission and distribution grid support. Figure 9 below from the EPRI report shows the results of their analysis in $/kWh using low and high costs and efficiencies specific to each technology.

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[15] *Thermal Energy Storage Systems, Market Penetration Study, February 14, 2012*
[16] *DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA, July 2013 SAND2013-3131*
[17] *Electric Energy Storage Technology Options: A White Paper Primer on Applications, Costs and Benefits. EPRI, Palo Alto, CA, 2010. 1020676*

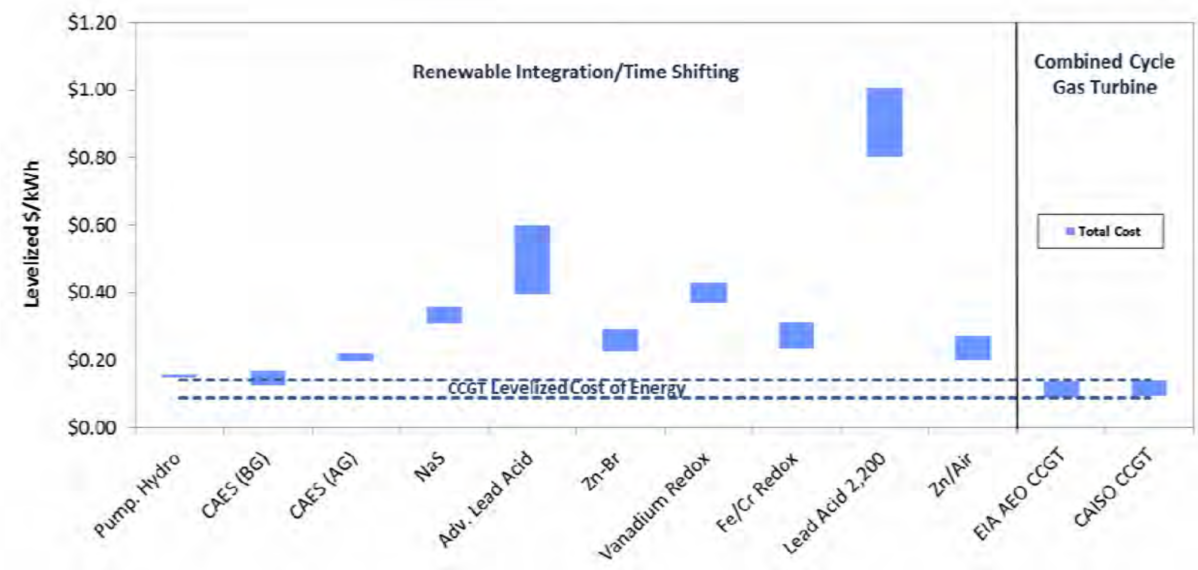

Figure 9. Levelized Cost of Delivered Energy for Energy Storage Technologies Compared to CCGT

Though dated, the results show that of the technologies analyzed PHS and CAES are the most cost competitive with using a combined cycle gas turbine to integrate renewables and align the renewable energy production with a utility's peak load when the energy is most valuable.

Projected Energy Storage Costs

Market research firm Navigant Research has published that the majority of the cost reductions in each technology will come from developments in the systems integration piece of the supply chain and not in reduced costs from the technologies themselves. Systems integration is woefully underdeveloped in the storage industry. Currently, many technology developers devote significant resources to integrate technologies into energy storage projects.

Navigant Research expects that more systems developers will move into the energy storage system market in the next 18 months. Eventually, this will put downward pressure on integration costs. In a related area of development, advanced controls and software for advanced battery energy storage are being developed and deployed by a number of firms in North America, Europe and Asia Pacific. One of the major benefits of these technologies from a cost perspective includes: longer lifetime, reduced degradation, and being able to use a smaller battery to deliver the same services as a larger battery without the sophisticated controls. All energy storage technologies will benefit from innovations in financing mechanisms for storage projects.

Lithium ion is expected to make significant strides in cost reduction, primarily thanks to economies of scale within manufacturing and also materials innovation.

Traditional lead acid, though starting from a relatively low price point is not expected to make significant strides in cost reductions – primarily due to the maturity of the technology. Lithium ion and CAES are projected to have the most significant cost reductions over the next 5 years. This is a function of manufacturing capacity, innovations in manufacturing processes, and innovation in key materials. The Compound Average Growth Rate (CAGR) for the power costs for these technologies is between -6.8% and -6.5%.

Nearly every other storage technology has a projected cost CAGR between -2.8% and -4.4%, although each technology will have distinct challenges to overcome. Some technologies, such as sodium metal halide or flywheels, have few vendors. As a result, the relative successes and failures in achieving cost reductions for a single vendor affect the overall cost projections disproportionately and the cost curves are much more sensitive to each vendor. Technologies such as flow batteries have plenty of diversity in technology type and manufacturing strategies, but the overall number of vendors is still limited compared to other technologies such as lithium ion.

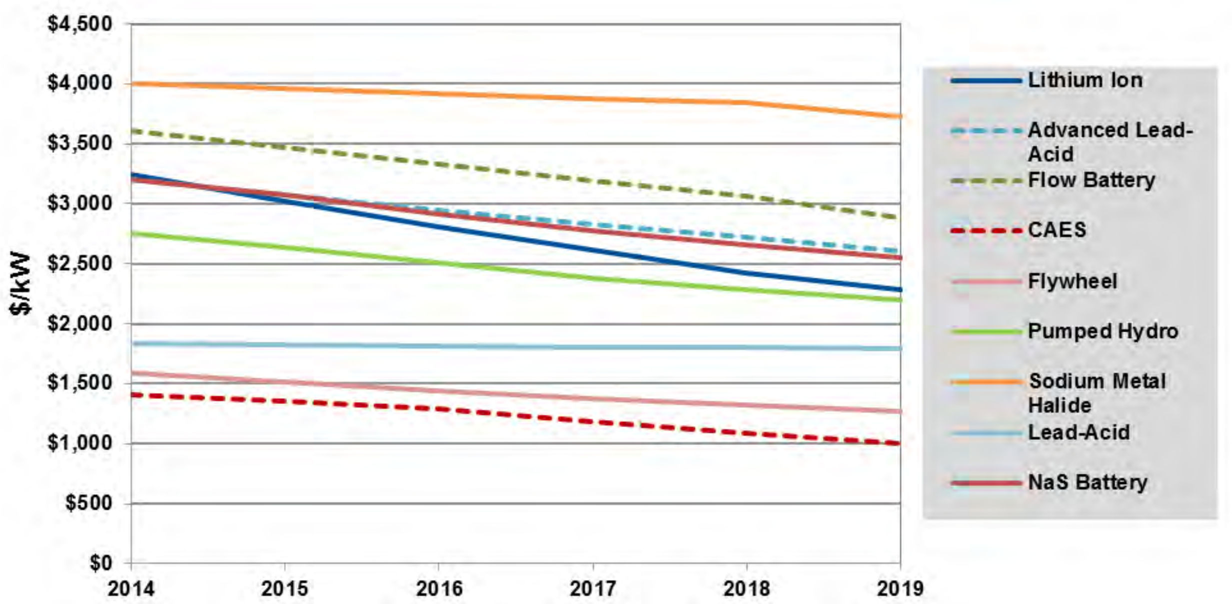

Figure 10. Energy Storage Capacity Costs, World Markets: 2014-2019

(Source: Navigant Research)

6 Analysis of Viable and Cost Effective Energy Storage Systems

Staff analyzed the technical and economic viability of energy storage systems, beginning with the direction for assessment provided by AB 2514 in Section 2836.2. Using this guidance, staff looked at current technical viability based upon SMUD's demonstrations and lessons learned reported on other demonstrations. In addition to the guidance provided by section 2836.2, staff considered the ability of other technologies and programs to achieve the same goals.

- Demand Response – broad, regional studies[18][19] have shown the potential for demand response to help integrate renewable energy. SMUD has begun a feasibility study of this.
- Smart Thermostats – SMUD conducted[20] a pilot study to determine the effectiveness of Smart Thermostats in reducing residential peak loads.
- Time of Use Rates – SMUD conducted[21] a pilot study of different combinations of rate structures and home energy use displays and found that they were effective in reducing overall energy usage and peak loads.

Finally, staff looked at economic viability based upon staff's value analysis discussed in section 4 and staff's cost assessment discussed in section 5.

Technology Viability

There are various characteristics of a technology that help to define its technological viability. These characteristics include:

- Operating Scale
- Funding Source
- Overall Maturity

A technology can only be considered viable if it has demonstrated performance by operating as intended in a real world application. Therefore, the scale at which a technology is operated to demonstrate performance (e.g., lab, prototype, pilot, or full-scale) contributes to technical viability. A lab-scale test can provide proof of concept and a pilot scale test can incorporate other components to demonstrate a system.

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[18] http://www.calmac.org/publications/7-18-12_Final_White_Paper_on_Use_of_DR_for_Renewable_Energy_Integration.pdf

[19] http://www.brattle.com/system/publications/pdfs/000/004/952/original/The_Potential_for_Demand_Response_to_Integrate_Variable_Energy_Resources_with_the_Grid_Faruqui_Nov_1_2013.pdf?1383338631

[20] http://www.herterenergy.com/pdfs/Publications/2014_Herter_SMUD_ResSummerSolutions2011-2012.pdf

[21] *The effects of combining dynamic pricing, AC load control, and real-time energy feedback: SMUD'S 2011 Residential Summer Solutions Study, June 18, 2013*

However, it's not until one conducts a pilot-scale demonstration that one can understand the performance that a technology and overall system might provide when deployed at full-scale. It is understood and expected that design changes will occur between each step to optimize the performance until you have a commercial product.

Pilot and full-scale demonstrations could be publically funded or privately funded, or a combination of both. While the funding source is not an absolute measurement of technical maturity and viability, it is often an indicator of the technology readiness and overall acceptance in the industry. If a system is completely privately funded, it is more likely to be technically viable and mature because the financing community considers it a reasonable risk.

A technology's maturity is defined by its phase along the commercialization path (e.g., research and development, demonstration, pre-commercial, and commercial) which takes into consideration the scale at which it is operated, funding source, level of deployment, and manufacturing capacity. A technology that is demonstrated at the pilot or full-scale level may still be considered "pre-commercial" because that system is the first of its type and future systems would incorporate design improvements and cost saving measures. It is important to remember that a technology that is "commercially available" and is available for purchase is not necessarily mature or technically viable. Some companies consider their products commercially available but may still be in the demonstration phase and their manufacturing process is still producing prototypes.

For the purposes of developing procurement targets, SMUD considers an energy storage technology technically viable for a specific application if it has demonstrated performance in that application. For example, flywheels are considered to have demonstrated performance for high power, short duration applications such as frequency regulation. Technologies that have been successfully operating (whether developed through private funds or in conjunction with public demonstration or loan programs) qualify as viable. While some systems have been decommissioned at the end of the demonstration period, they are considered technically viable as long as the results validated positive performance.

Moreover, when evaluating technical viability, it's important to consider not only the energy storage technology but also the balance of system, communication and control software, and integration with existing software platforms. A summary of the technical viability of energy storage systems with respect to all these aspects is provided below.

Energy Storage Technology

Energy storage devices, especially conventional lead acid batteries are well established in commercial and industrial applications such as data center backup power, uninterruptible power supplies, and telecommunication towers. However, staff is not considering those end user applications as part of "grid scale" applications for which SMUD might set procurement targets. With respect to electric grid applications, there are several energy storage technologies that are technically viable today because they have been deployed commercially or have been demonstrated and offer validated performance results.

Pumped hydro storage (PHS) and compressed air energy storage (CAES) have a long history of full-scale implementation. In the 1890s, the initial PHS system prototypes were built in Italy and Switzerland. By the 1920s and early 1930s, the first pumped hydro system was built in America, and reversible pump-turbines with motor-generators became available. Since then, PHS has matured and become a widespread energy storage technology with a worldwide installed capacity of about 123GW.[22] There are currently two existing CAES facilities in the world: a 290 MW facility in Huntorf, Germany built in 1978; and a 110 MW facility in McIntosh, Alabama built in 1991. Both PHS and CAES can have very large system sizes with high power and energy, making them ideal for utility applications such as load management and operating reserves. The disadvantage is that both PHS and CAES have geographical limitations. PHS requires a reservoir, and underground CAES requires certain geological formations for storing compressed air. If those conditions are available, then PHS and CAES are viable options for bulk grid applications.

Sodium sulfur batteries, flywheels, lithium ion batteries, advanced lead acid batteries, vanadium redox flow batteries, and zinc bromide flow batteries have been deployed in commercial applications over the last five years, if not longer. For example, the following companies have deployed their technologies in commercial, grid connected applications:

- NGK sodium sulfur batteries
- Beacon Power flywheel systems
- AES Energy Storage and Sempra lithium ion systems (i.e., Lithium Manganese Spinel and lithium iron phosphate)
- Duke, First Wind, Public Service Company of New Mexico, and East Penn advanced lead acid batteries
- Prudent Energy vanadium redox flow batteries
- ZBB and RedFlow zinc bromide batteries

Other technologies are currently being demonstrated and validated and are expected to be technically viable within the next few years. For example, various other lithium ion chemistries, nickel metal halide batteries, other flow batteries, and above ground CAES are very promising. Lastly, there are some advanced battery technologies that are still in the research and demonstration phase but are anticipated to offer promising advantages in 5-10 years.

[22] Navigant Research *Energy Storage Tracker 3Q13.* 2013.

Balance of System

The components that make up the balance of system typically include: power conversion, HVAC, and battery management systems (BMS) or control system. Power conversion and HVAC systems are well established technologies. The BMS or storage control system is typically designed and provided by each technology provider.

According to the Energy Storage Association's recent report entitled, "Survey of Modeling Capabilities and Needs for the Stationary Energy Storage Industry"[23], most energy storage system vendors offer software to allow an owner to control their system and view the system status. Some of these are device independent. Some can control one unit or an entire fleet, but vary in communication path (e.g., broadband, utility DMS, and cellular network). While these control systems are likely to perform adequately after initial system commissioning, they tend to be vendor specific and are not standardized across various technologies or vendors.

On the other hand, there are some companies offering publicly available tools to meet the specific needs of the energy storage industry with tools that are not technology specific. Examples include products from GELI, 1EnergySystems, and GreenSmith that are focused on controlling system operation and optimizing system performance. These tools are not tied to a specific equipment type or original equipment manufacturer, and were created to meet a market need.

This is an area that could use additional testing and demonstration to optimize performance.

Communication Software

One of the most significant challenges facing energy storage is the integration of storage equipment with other infrastructure, including distributed generation, grid assets, communications equipment, and data acquisition systems. Furthermore, there are multiple layers of communication that can be difficult to coordinate, especially when some are proprietary. While SMUD can minimize some of these issues by working with experienced systems integrators and educating workers, vendors can have a more significant impact by providing modular units with standardized communications protocols. Fortunately, there is currently movement toward using DNP3 as a standard mode of communication for energy storage.

[23] Energy Storage Association, *Survey of Modeling Capabilities and Needs for the Stationary Energy Storage Industry*, prepared by Navigant Consulting, Inc. May 2014.

The recent Energy Storage Association report also noted the need to push for engineering standards regarding energy storage system hardware, protocols, and controls. Continued effort from industry stakeholders will be needed to highlight and resolve this issue.

Cost Effectiveness

Per the guidance provided by Section 2836.2 of AB 2514, staff assessed the cost effectiveness of energy storage for a variety of standalone uses – summarized in Table 5 – and bundled uses. Staff first reviewed standalone uses, their applicability to SMUD and cost effectiveness. Staff then reviewed bundled uses and their cost effectiveness.

Table 5. Summary of Applications and Cost Effectiveness

Application	Currently Applicable to SMUD?	Currently Cost Effective?
Renewable Energy Shifting	Yes	No
Wholesale Market Arbitrage & Cost Optimization	Yes	No
Retail Market	Yes	No
Asset Management	Yes	No
Load Following	Yes	No
Operating Reserves	Yes	No
Frequency Regulation	Yes	No
Renewable Energy Capacity Firming	Yes	No
Black Start	Yes	No
Renewable Energy Ramping	No	-
Renewable Energy Smoothing	Yes	No
Backup Power	Yes	No
Power Quality	Yes	No

Stand Alone Uses

Renewable Energy Shifting – SMUD could use energy storage to store excess renewable energy and discharge during times of high need. However, SMUD currently does not have an issue with excess renewable energy and would get little value from this application.

Wholesale Market Arbitrage and Cost Optimization – This application uses energy storage to charge during times of low energy cost and discharge during times of high energy cost. SMUD has analyzed this application in detail, but does not project a large enough, persistent (e.g. occurring over many hours a year) difference between on-peak and off-peak prices to make this cost effective.

Retail Market – A SMUD customer could own an energy storage system and use it to manage time of use rates and/or demand charges. However, given SMUD's current rate structures, staff's analysis shows that this is not cost effective for SMUD or the customer.

Asset Management – Asset Management is the use of energy storage to defer investments in generation, distribution or transmission upgrades. This is applicable to SMUD; however SMUD is currently long on capacity. In addition, as part of its value analysis (see footnote 11), SMUD conducted a comprehensive review of current distribution assets to see if energy storage could defer any investments. SMUD found that its distribution system is robust and could use energy storage for deferral in a very small number of locations and the dollar value of deferral was small relative to the cost of energy storage.

Load Following – SMUD could use energy storage for load following, however SMUD currently uses its hydro resources for load following and they are very cost effective.

Operating Reserves – Energy storage could be used to provide operating reserves but SMUD currently has enough reserves for the foreseeable future from its thermal and hydro assets.

Frequency Regulation – Similar to Load Following, SMUD could use energy storage for frequency regulation, but SMUD uses its hydro resources for this and they are cost effective.

Renewable Energy Capacity Firming – SMUD could use energy storage to increase the effective capacity of its renewable resources. However, SMUD currently purchases firming services from the CAISO (using thermal resources) at a competitive price.

Black Start – Energy storage could provide Black Start capabilities for SMUD, but SMUD currently has that capability in existing power plants and does not need more capability.

Renewable Energy Ramping – SMUD does not have wind in its Balancing Authority (BA) that would require ramping support. SMUD does have PV in its BA, but at current penetrations and through post-2020[24], staff's current analysis indicates that SMUD can handle PV ramping with current assets.

Renewable Energy Smoothing – For SMUD's large solar Feed In Tariff projects, energy storage could provide smoothing to mitigate the impacts (e.g. voltage violations, excessive equipment cycling, etc.) of large fluctuations in PV output. SMUD is currently demonstrating the technical viability of this but it has not proven cost effective as a standalone application.

[24] SMUD is currently studying this issue and interim results indicate current assets can handle ramping post 2020

Backup Power – Energy storage owned by SMUD or its customers could provide backup power during outages. However, SMUD has top tier SAIDI, SAIFI and CAIDI scores, so system uptime is very high and the need for backup power is low in SMUD's service territory. In addition, when outages do occur, staff research(see footnote 11) indicates that the value of having backup power is low for most customer segments. One exception is the industrial segment, but most industrial customers likely already have backup power systems in place.

Power Quality – Using energy storage to manage power quality on a feeder is applicable, but staff has not found it to be cost effective relative to traditional power quality control equipment (e.g. load tap changers, voltage regulators, etc.). Industrial customers and data centers have high power quality requirements that energy storage could help meet, but they likely already have equipment in place to manage power quality and would not need to add energy storage for this purpose.

In summary, SMUD reviewed all the possible standalone applications of energy storage and did not find any cost effective.

Bundled Uses

As part of a value analysis (see footnote 11)SMUD looked at bundles of applications – described below – and the resulting value of those bundles.

Transportable Distribution Deferral

The transportable distribution deferral application represents a battery located at the utility substation. It would be owned and operated by the utility. A 1 MW system with either 2 hours or 4 hours of storage was modeled for this application. The application would most likely take the form of a large battery on a re-locatable trailer. In the modeling of this bundling, 500 hours are reserved for operations to provide distribution system benefits. During the remainder of the year, the storage system is able to earn revenue through energy and ancillary services markets.

Distributed Energy Storage Systems

The distributed energy storage system (DESS) (also known as community energy storage or CES) application represents a system of networked batteries that would be located along the distribution system either pad mounted or at the final line transformer. The batteries would be owned and operated by the utility. Staff looked at an aggregated capacity of 1 MW with 2 hours of storage. Staff assumed 50% of the capacity is reserved for customer reliability while 50% is available to provide grid support services. Of the grid support services, 500 hours are used for distribution deferral and the rest is used for energy and ancillary service market revenue.

Commercial Energy Management

The Commercial Energy Management bundle is a commercial customer using battery energy storage to manage demand charges and energy charges. Staff assumed that the system is able to optimize charge and discharge to minimize utility bills. Staff used current SMUD rate structures for this analysis.

Aggregated Energy Management with Grid Support

The aggregated energy management application represents a system in which multiple customer-owned batteries are aggregated and operated by an energy services company. The batteries would be located at the customer side of the meter, but by aggregating the batteries, it was assumed that the energy services company would be able to negotiate with and provide benefits to the utility or wholesale energy market. Staff modeled the aggregated system as a 1 MW system with 2 hours of storage. Because the benefit values modeled are presented in a $/kW-h basis, the results of this application would be applicable for the individual commercially owned batteries minus the transaction costs of aggregation. The batteries are operated to provide energy management services and grid services.

Bulk Energy Storage

SMUD has conducted feasibility studies of using potential CAES or PHS projects in its service territory to provide a variety of benefits including renewable energy integration and ancillary services. The modeling used economic dispatch algorithms to optimize between different applications on an hour by hour basis.

Results

Figure 11 summarizes ranges of values calculated for the battery related bundles and compares them to current costs. Figure 11 shows Transportable Distribution Deferral and Aggregated Energy Management with Grid Support could be cost effective. However, Transportable Distribution Deferral relies on a) distribution deferral benefits to be cost effective and SMUD has very few locations where distribution upgrades are required in the near term and b) SMUD currently has low regulation costs, so the regulation revenues would be low. Thus Transportable Distribution Deferral is not cost effective right now. As to Aggregated Energy Management with Grid Support, a viable business model for this bundle does not yet exist[25]. Thus, staff cannot consider this when setting procurement targets because it is not yet viable.

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[25] However, SMUD has several projects to look at new business models for aggregating customer side storage to provide grid benefits. For example, SMUD is partnering with E3 and others under a recent California Solar Initiative research grant to explore such business models.

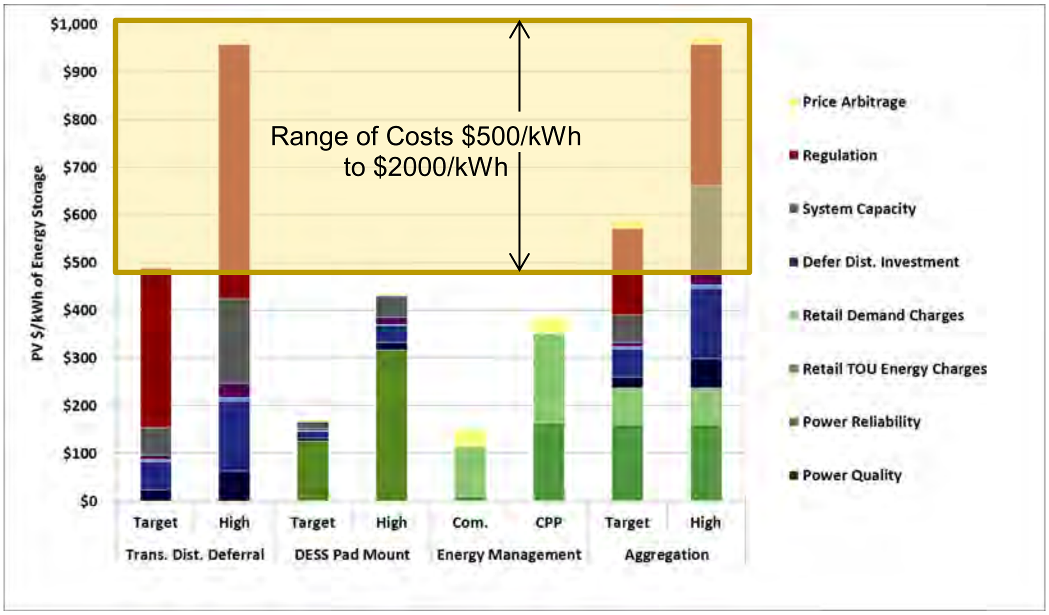

Figure 11. Comparison of Costs and Benefits of Bundled Battery Applications

As an alternate to battery energy storage for Commercial Energy Management, staff analyzed the use of thermal energy storage systems. Using costs from SMUD thermal energy storage technical potential study (see footnote 15)[15], staff analyzed the cost effectiveness for customers using SMUD's current rate structures. Staff modeled systems that defer cooling load during super peak hours from 2 PM to 8 PM from June through September. SMUD found payback periods ranging from 5 to 7 years. In staff's experience, most customers are not willing to adopt measures unless they have a 2 to 3 year payback period and during the study, one customer surveyed specifically cited the need for a 1 to 2 year payback period. At this time, staff assumes thermal energy storage to not be cost effective, but will continue to track its progress and reassess if costs decline.

For the bulk storage systems, Figure 12 shows the results for PHS (see footnote 9)[9]. Recall that staff found CAES unfeasible at this time (as discussed in section 4) so staff does not show the CAES results in the figure. Figure 12 shows that the lifetime benefits outweigh the lifetime costs. However, the Iowa Hill project will not be developed until after 2020, so SMUD cannot set pre-2020 energy storage procurement targets based upon PHS projects.

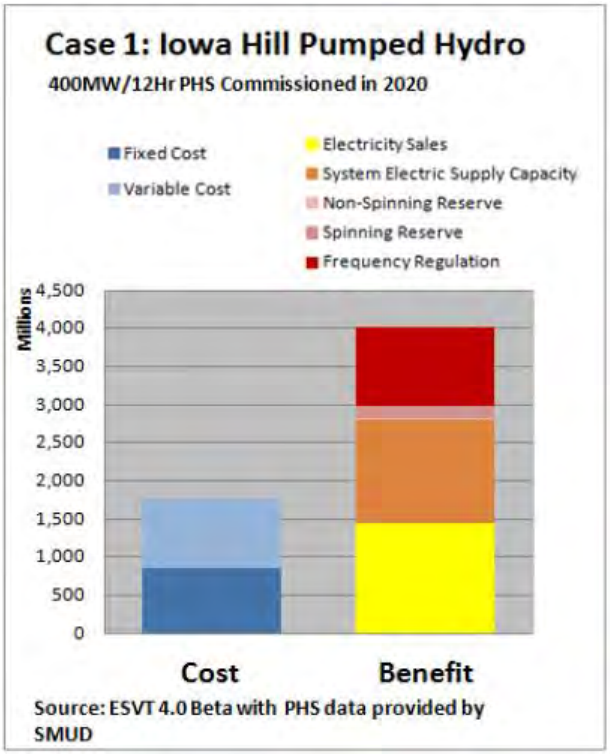

Figure 12. Comparison of Costs and Benefits of PHS

Note that the California Public Utilities Commission commissioned a study[26] of the cost effectiveness of energy storage and found that some applications are cost effective. However, the results are not applicable to SMUD at this time because:

1. Several of the applications are not applicable to SMUD, such as using energy storage for ancillary services and peaker substitution.
2. The report relied on expected 2020 energy storage costs for its analysis. Staff is currently considering 2016 procurement targets and using 2020 costs is not appropriate for 2016.

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[26] Cost-Effectiveness of Energy Storage in California (Expanded), Electric Power Research Institute, Technical Update, December 2013.

7 Recommendations

Based upon SMUD's research and analysis to date, staff makes the following five recommendations.

1. Do Not Establish An Energy Storage Procurement Target for SMUD

Since 2008, SMUD has invested over $30 million dollars in internally and externally funded research to understand and prepare SMUD and its customers for eventual deployment and utilization of energy storage. Staff has been conducting various field demonstrations, studies, and assessments of different storage technologies, used for different applications ranging from transmission scale to distribution scale to customer scale systems. On technical issues, this body of work has assessed technology performance including such factors as efficiency, reliability, and durability. On economic issues, this body of work has assessed capital costs, installation costs, operation costs, value, and cost effectiveness. Additionally through this body of work, staff has assessed grid integration issues and strategies for interconnecting, aggregating, visualizing and controlling storage systems from grid planning and operations perspectives.

In addition to SMUD's storage research, SMUD is investing significant resources into renewable energy integration research to find cost effective solutions that minimize grid integration costs to SMUD customers. This includes research such as advanced inverter technology that allows curtailing PV production, using demand response (e.g. smart thermostats and EV charging), better solar and wind forecasting technologies to assist grid planning and operations, etc.

Based upon this body of research, staff finds storage at this time is not cost effective with the exception of large pumped hydro storage. Consequently, staff recommends the SMUD Board of Directors should decline to establish an energy storage procurement target for December 31, 2016 and December 31, 2020 at this time. Pursuant to AB 2514, this determination must be revisited at least once every three years.

2. Continue Investing In Energy Storage Technology Assessment, Demonstrations and Pilots

Although energy storage is not currently cost-effective, storage costs have continued to decline as technology advancements have been made, as global production capacity has increased, and as the transportation industry has continued development of electric vehicles. Staff anticipates energy storage will become cost effective for some applications within the next ten years.

To prepare SMUD and its customers, staff recommends that SMUD continue investing in research to develop, demonstrate and pilot promising storage technologies. Research should continue in order to assess technology performance and application, costs, values, business models, grid integration, and utility and customer experiences using energy storage systems. Building upon its existing, robust research portfolio, staff will expand its efforts to conduct enhanced demonstrations of varied energy storage systems in both utility and customer applications to educate end-users, and technology vendors and manufacturers about technology performance and economics. Additionally, staff will develop and pilot new customer programs and business models for energy storage systems.

Staff will continue to assess viability of storage to assist with making its transmission and distribution system smarter, more nimble, and accommodating of renewable energy sources such as wind and solar while maintaining system reliability.

3. Develop staff expertise in Customer Services to provide assistance to customers considering installation of energy storage systems

The Customer Services Department is working to incorporate storage interconnection into SMUD's existing interconnection processes that has successfully supported customer distributed generation interconnection requests. This department is also investigating potential new customer programs or services they can offer customers who may be considering energy storage; acting as a "trusted advisor" for these customers to get unbiased information about the efficacy of possible energy storage solutions being considered.

4. Continue exploring the potential development of the Iowa Hill pumped hydro project.

SMUD has included the potential development of the 400 MW pumped hydro Iowa Hill project in the recent relicensing application for the Upper American River Project – SMUD's "stairway of power" hydro power plant system on the American River. FERC recently granted SMUD's license to continue operating our hydro facilities and add the Iowa Hill project if it proves viable. Staff is currently conducting engineering studies to better assess the geologic viability of the project. As these studies progress, staff expects to provide the Board with a recommendation on whether to construct the project.

5. Monitor ongoing developments with energy storage procurement by the IOUs in California.

Staff is watching with interest the energy storage procurement activities of the investor owned utilities in California, as ordered by the CPUC. Staff will continue to monitor and analyze those procurement actions, in order to be fully aware of how they may transform the storage market in California, leading to faster cost-effectiveness for storage applications.