



Energy Storage System Plan

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PUBLIC UTILITIES DEPARTMENT
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White Paper Analysis of the
Operational and Technological Options
for Energy Storage Systems

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Executive Summary

Background

Development of the Energy Storage System Plan (ES Plan) and the approved work effort was a response to mandates established by Assembly Bill 2514 (AB 2514), an energy storage bill that was signed into law on September 29, 2010. ES systems store energy from thermal, chemical or mechanical sources for use at a later time. Energy storage systems (ES systems) are identified by the bill as a component of the future electric grid that includes the continued integration of more intermittent renewables and more local generation.

AB 2514 requires all utilities statewide, which serve more than 60,000 customers, to analyze and adopt policies for the procurement of ES systems. Specifically, the bill directed the California Public Utilities Commission (CPUC) to hold proceedings for all investor-owned utilities (IOU) and required the governing boards of all POU to conduct an evaluation to determine appropriate targets, if any, for each utility to procure viable and cost-effective ES systems.¹

As a publicly owned utility (POU) with 115,000 electric customers, the City of Anaheim, Public Utilities Department (Department) is required to comply with the bill. Relative to the Department, the bill requires that on or before October 1, 2014, the City Council shall determine the need for energy storage system procurement targets, if any, to be achieved by December 31, 2016 and a second target to be achieved by December 31, 2021.²

On April 17, 2012 the City Council directed the Department to develop an ES Plan that would identify the technical feasibility of ES systems, potential benefits to the Department and based on cost/benefit analysis, recommended targets of procurement. This report is the ES Plan that was developed.

Discussion and Findings

The Department has completed the ES Plan as presented herein. The ES Plan defines ES systems, how they are used on the grid, the current technologies available and the currently defined uses for the technology. The viability of ES systems as well as their cost-effectiveness were both evaluated. The Department reviewed its existing and near future needs and developed a case study to evaluate the use of an ES system within the distribution grid. Software created for the Department of Energy (DOE) by Navigant Consulting³ was used to evaluate the cost effectiveness of an ES system in the case study.

¹ AB 2514, Skinner, Energy Storage Systems.

² Ibid.

³ Navigant Consulting, Inc., *ES Computational Tool (ESCT) Version 1.2*, Prepared for the U. S. Department of energy under DOE contract DE-FE004001 Task 430.05, August 2012.

Additionally, the Department met with investor-owned and other municipal utilities, in particular, San Diego Gas and Electric, since investor-owned utilities have prescribed ES targets mandated, to discuss project and technical attributes as well as limitations of ES systems.

As a result of the Department's analysis, the following findings were made:

ES is not cost effective for most applications at this time: Many ES technologies that are relatively new, such as battery systems, are expensive. For example, one 5 Megawatt (MW) system installed at a substation would cost approximately \$20M. This is the amount of the Department's annual routine capital program (replacement of wires, transformers, switches, etc.), and would require a 6% rate increase or issuance of additional bonds. Since ES systems do not replace existing infrastructure, this would be an added cost to Anaheim ratepayers. In the City, only thermal ES technologies have been cost effective for customers under specific circumstances.

Because the City is essentially built-out, siting ES systems will be difficult: ES technologies are space intensive and difficult to site in urban settings such as Anaheim. As an example, a 5 MW battery system would require enough space to house 5 semi-trailer sized containers, in addition to all the wiring and balance of plant to connect the batteries to a substation. Limited space is available at the Department's existing substations. Finding locations in areas that are best suited to ES systems, such as in West or Central Anaheim where there is a higher density of electric demand would be difficult and costly because of the need to purchase parcels of land.

Peak reduction is a one of the primary uses for ES systems but has already been addressed by the Department with the construction of the Canyon Power Plant: One of the key benefits of ES is that it addresses shortfalls in energy supply and allows a utility to call upon it when needed; however, the Department has Canyon Power Plant which effectively performs the same function with many other benefits of reducing California Independent System Operator (ISO) fees, providing local and regional grid support, and the ability to bid into the wholesale energy market.

Use of ES systems to improve reliability is not currently needed by the Department: The Department already has a prominent track record of high system reliability, and has been recognized as a Reliable Public Power Provider (RP3) by the American Public Power Association since 2006. The installation of ES would have a marginal impact. As an example, ES installed at a substation would help if a broader supply issue occurred; however, those incidents are uncommon, and the more routine outages that occur due to vehicles hitting utility poles or tree branches getting caught in utility lines would not be mitigated by an ES at a substation. Customers who wish to increase their reliability already have business justifications for the higher costs and are free to invest in backup systems, generators, or Uninterruptible Power Supplies (UPS) without a utility procurement target.

Many ES technologies are still maturing: For example, battery systems have been available for many years at locations such as data centers. As additional utility applications

are identified, research and innovation will continue to improve the technology and the associated costs will decrease over time. And, the corresponding safety concerns such as batteries catching on fire will need to be addressed by manufacturers. The Department will continue to support customers who wish to install systems to reduce their peak demand, and already offers time-based rates to encourage this behavior in lieu of prescribed targets of ES procurement.

Conclusions

From the findings above, the Department concludes the following:

1. Adoption of procurement targets for either the December 31, 2016 or the December 31, 2021 time periods is premature at this point based on the findings related to costs and viability;
2. Since technology improvements will continue to be made given mandates for investor-owned utilities to invest in ES systems, the Department will closely monitor other utility projects; and,
3. The Department will continue to offer customer choice programs such as time-based rates that encourage shifting energy consumption to off-peak hours.

Section 1: Introduction

On April 17, 2012 the City Council approved the Public Utilities Department's (Department) Energy Storage System Evaluation Plan (ES Plan). Development of the ES Plan and the approved work effort was in response to mandates established by Assembly Bill 2514 (AB 2514), an energy storage bill that was signed into law on September 29, 2010. AB 2514 requires all utilities statewide, which serve more than 60,000 customers, to analyze and adopt policies for the procurement of ES. As a publicly owned utility (POU) with 115,000 electric customers, the City of Anaheim, Public Utilities Department is required to comply with the bill.

As described in the bill, Energy Storage (ES) is considered by the State to be a necessary component for the future delivery and provision of electricity in the state. The bill defines ES and associated systems as commercially available technology that is capable of storing generated energy for use or dispatch at a future time. In its simplest terms, ES essentially functions as a rechargeable battery. ES also offers a variety of other services such as voltage support, distribution upgrade deferral, regulation of electricity and more, that can benefit the electricity system. In particular, the bill notes that ES offers a variety of solutions to the integration of renewable generation into the existing grid, and facilitates the use of these alternatives to traditional fossil fuel-based technologies.

As such, ES is viewed as a means for the State to reduce greenhouse gas (GHG) emissions that contribute to climate change primarily through its support of the addition of more intermittent renewable energy. In enacting the bill, the Governor and Legislature intended for the electricity industry, including utilities, state agencies, and the California Independent System Operator (CAISO) to better evaluate how ES can be used within the State, and to ensure that the regulations governing electricity markets better accommodate ES and its multiple benefits.

The ES Plan was developed in response to the requirements of the bill. It provides the findings from the Department's research on applications and viability of ES on the Department's electric system. The conclusion of this analysis is to determine the technical feasibility of the various ES systems and whether they are applicable and cost-effective. That result will serve to identify whether the Department should pursue establishing targeted levels of investment for those systems.

Recommendations for policies fulfilling the bill's mandates are made in the concluding chapter of this report, accompanying staff report and resolution. Specifically, this report will discuss the regulatory requirements under AB 2514, the types and uses of ES systems in general and how they apply to the City of Anaheim. Application of ES in the City is further analyzed through a cost-benefit analysis of a specific use case study for an ES system in the City. Finally, recommendations to support the future integration of ES into the City's infrastructure are presented.

Requirements of Assembly Bill 2514: Energy Storage Systems

AB 2514 seeks to ensure that the State's electricity system, including the grid and electricity market itself, are structured to support ES such that multiple benefits can be realized if the ES systems can provide them. To achieve the goal of integrating ES into the existing electric grid, AB 2514 laid out a process and timeline for the evaluation and implementation of ES and the associated policies, as well as defining energy storage for purposes of the bill's implementation. Specifically, the bill directed the California Public Utilities Commission (CPUC) to hold proceedings for all investor-owned utilities (IOU) and required the governing boards of all POUs to conduct an evaluation to determine appropriate targets, if any, for each utility to procure viable and cost-effective ES systems.⁴

Applicable Energy Storage Systems

AB 2514 defines characteristics and purposes that must be met by an ES system for it to be considered a valid ES use under the bill. As mentioned above, the bill requires that all procurement of ES systems by the utilities be both cost-effective and viable. It was not the intent of the bill to require utilities to procure ES systems at any cost, or to implement ES systems that are not yet proven or tested. In fact, the bill defines ES systems as those that are commercially available.

In addition to being viable and cost-effective, the ES systems must perform at least one of the following functions⁵:

- Use mechanical, chemical, or thermal processes to store energy that was generated at one time for use at a later time.
- Store 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.
- Use mechanical, chemical, or thermal processes to store energy generated from renewable resources for use at a later time.
- Use mechanical, chemical, or thermal processes to store energy generated from mechanical processes that would otherwise be wasted for delivery at a later time.

It further requires that the ES system accomplish one or more of the following purposes⁶:

- Reduce emissions of greenhouse gases (GHG),
- 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.

⁴ Section 2836.6 of AB 2514, Skinner, Energy Storage Systems.

⁵ Section 2835(a)(4) of AB 2514.

⁶ Section 2835(3) of AB 2514.

Overarching these specific requirements is the intent of the bill outlined in the findings and declarations. ES systems are expected to:⁷

- Integrate intermittent generation from eligible renewable energy resources into the reliable operation of the electric system.
- Allow intermittent generation from eligible renewable energy resources to operate at or near full capacity.
- Reduce the need for new fossil-fuel powered peaking generation facilities by using stored electricity to meet peak demand.
- Reduce purchases of electricity generation sources with higher emissions of greenhouse gases.
- Eliminate or reduce transmission and distribution losses, including increased losses during periods of congestion on the grid.
- Reduce the demand for electricity during peak periods and achieve permanent load-shifting by using thermal storage to meet air-conditioning needs.
- Avoid or delay investments in distribution system upgrades.
- Use energy storage systems to provide the ancillary services otherwise provided by fossil-fueled generating facilities.

Timing Requirements

AB 2514 included deadlines to ensure that utilities undertake the efforts envisioned by the bill, and that the processes and results are made available to the public in a manner as transparent as possible. The following deadlines are applicable to the Department⁸:

1. In April, 2012, the City Council initiated a process to determine appropriate target, if any, for the Department to procure viable and cost-effective energy storage. As part of the process, the Department was allowed to consider 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. On or before October 1, 2014, the City Council shall establish energy storage system procurement targets, if any, to be achieved by December 31, 2016 and a second target to be achieved by December 31, 2021.
3. Once every three years, the City Council shall reevaluate the determinations made by the previous processes.
4. The Department shall report to the California Energy Commission (CEC) regarding any energy storage system procurement targets and policies adopted by the Council during the initial and subsequent evaluations.
5. In the case of recommendation by the City Council to adopt ES System Procurement Targets or ES system procurement policies, then by January 1, 2017, the Department shall submit a report to the CEC demonstrating that it has complied with the ES System procurement targets, if any, and policies adopted by the City

⁷ Paraphrased from Section 1 of AB 2514.

⁸ Paraphrased from AB 2514.

Council. This report, with confidential information redacted, shall be made available to the public by being published by the CEC and/or the Department on their respective websites.

6. By January 1, 2022, the Department shall submit a report to the CEC demonstrating that it complied with the ES System procurement targets or ES system procurement policies adopted by the City Council. The report, with confidential information redacted, shall be made available to the public by the CEC and/or the Department on their respective websites.

Methodology

In order to address the requirements of AB 2514, Department staff undertook an extensive literature and technology review, and completed a cost/benefit analysis of an ES application utilizing software that was developed for the Department of Energy (DOE) that was most applicable to the Department's infrastructure. The Department also met with other utilities to discuss their ES programs, including San Diego Gas & Electric, as well as other municipalities who are part of the Southern California Public Power Association (SCPPA) committee to review ES technologies.

Department staff undertook a thorough review of the relevant literature about energy storage. It is important to note, the many of the studies that provided the most beneficial information were released in late 2012 and 2013 in conjunction with the CPUC's proceedings on energy storage targets for the IOUs. During the course of the analysis, staff also attended the Energy Storage North America Conference in September 2013 and the Electric Energy Storage Conference in January 2014 to hear from regulators and policy makers, as well as other utilities' experiences in the implementation of energy storage. As such, much of the analysis that the Department completed was done in the last half of 2013 and early 2014, when the most current information on ES systems was available to be evaluated by staff.

Section 2: What is Energy Storage?

Definition of Energy Storage

Energy storage is simply the storage of energy generated at a given point in time for use at a future time. One of the more traditional purposes for this is based on economics; utilities would generate less expensive energy to be stored for discharging at a time when the alternative cost for generating power was more expensive. In a sense, a time shifting of costs that minimizes the total cost of serving retail customers.

Electrical systems have traditionally balanced the production of electricity with its consumption instantaneously. Electricity was generated and delivered only when it was demanded and only in the quantity demanded. ES allows for the generation of electricity and demand for electricity to be disassociated. With ES systems, the electric grid now has the ability to store energy from less expensive resources that can be discharged where most productive or most cost-effective to meet higher demand requirements during peak hours. And, as more intermittent renewables generation is developed which generates only when its energy source (the sun or wind) is available, ES systems allow the energy to be stored as it is generated and discharge it when it is actually needed. Further, ES systems can also be utilized for grid or distribution level reliability purposes, which may or may not be when the electricity is demanded. It is important to note that the any proliferation of ES will not diminish the need for the electric grid; rather, it will enhance and support the integration of renewables into the grid.

Utilities, including the Department, recognize a significant number of potential uses for ES that could facilitate a variety of changes to the electric grid. However, ES systems have historically been cost-prohibitive solutions, have experienced reliability problems, or are highly dependent on geographic location. This is changing as advances in technology expand the types of ES systems that are available and the range of functions they can perform. An important characteristic of ES is that it is not a single technology that performs a single function. Any technology that provides for a time shift of generation and demand, regardless of duration, frequency of use, or amount of energy involved can be considered to be ES. Thus, there are a variety of technologies that perform a variety of functions that provide a different set of services to the electric grid.

In preparing this analysis of ES, it was important to identify both the technologies and the types of applications where ES technologies could be useful in Anaheim. The concepts behind ES have been around for many years. As demand for electricity has increased, specific ES technologies and their uses have been studied by various entities, such as the Department of Energy (DOE) and other utilities, including Southern California Edison (SCE), Pacific Gas and Electric (PG&E), San Diego Gas and Electric (SDG&E), and Sacramento Municipal Utility District (SMUD). Traditional uses of ES systems were thru pumped storage hydro-electric generation, where water was stored during off-peak hours with energy from low-cost resources and dispatched during high demand periods where cost of energy is much higher.

Newer ES technologies, such as large-scale batteries are available but are limited by high costs and limited reliability of technology, as well as a defined actual need that could drive development of the technology. In other words, with the exception of storing water for hydro-electric generation, the electric grid has been functioning without energy storage using existing technologies that have cost less than an ES solution.

Most newer ES systems that have been introduced into the market place have been heavily subsidized by government grants for research and development. Without these grants, the cost to deploy these early systems would have been extremely cost prohibitive. While rapid changes in ES technology are beginning to address some of the cost and reliability issues faced in the past, implementation of ES solutions is being driven by changes in the electric grid and regulatory requirements, such as AB 2514, as well as advances in ES technology itself. In particular, the recent expansion and integration of variable generation from renewable resources, particularly wind and solar, and from the increase in distributed generation resources such as rooftop solar photovoltaic systems. In general, these changes are creating system needs that may be more effectively addressed by ES versus conventional generation resources, such as coal or gas fired power plants or existing technology for grid infrastructure.

For the Department, ES could play a role in providing system support in areas where there may be high penetration of distributed generation (e.g. roof-top photovoltaic systems); however, because the Department has invested in a peaking power plant, much of the benefit derived from peak shaving services that could be provided by ES is limited from a financial perspective. ES could also possibly defer capacity upgrades on infrastructure by reducing the peak demand on a circuit, but this is contingent upon many factors such as wire size, number of customers on the circuit, age of equipment, and if there are plans for undergrounding.

Energy Storage Technologies: Past, Present, and Future

One of the complexities when considering an ES system is that it is not represented by a single technology. ES can be accomplished in many different ways as is represented by the expansive list of available technologies described in the literature – some of which are more developed than others. As referenced by the CPUC⁹, energy storage can be accomplished through chemical, thermal, kinetic, or mechanical means. Different ES systems are more suited to specific uses than others. It is, therefore, important to understand the different technologies in order to identify the type of storage device that would be appropriate for the use and specific application.

This section will not provide detail on the physical aspects of each technology or technical detail about how they function; this information is well documented in the literature and on the internet.¹⁰ Rather, this section will provide an overview of the various types of ES

⁹ CPUC Proceeding for Docket R.10-12-007.

¹⁰ See Sandia National Laboratories and CPUC Proceeding documentation.

technologies available, their levels of development and availability, and the applicability of the technology for the various uses.

Technology Overview

ES is essentially provided by five technology types: pumped hydro, compressed air storage, flywheels, batteries, and thermal storage. Other technologies are being developed but are still being researched and tested. Batteries are the most commonly thought of ES technology and also have the widest range of technological options. They use chemical processes to store energy. Energy may also be stored kinetically, as is the case with flywheel, compressed air, and pumped hydro technologies. Thermal technologies can store energy either in ice or use solar heat.

An important finding in the study of ES systems is that many ES technologies are not yet mature or fully vetted for utility-scale application. While some technologies, such as pumped hydro have been used for decades, other technologies are just now being developed. This can be the case within a technology type as well. Some battery and compressed air technologies are well developed while others are still in their conceptual stage or are just moving into preliminary testing phases.

Other technologies are mature, but have significant limitations. Mature technologies include pumped hydro and compressed air systems used for bulk energy storage and primarily to perform energy time shifting. However, both of these mature technologies have siting constraints requiring specific geologic or other natural features in order to operate. Pumped hydro requires sufficient raw land, often hundreds of acres, to create two reservoirs at different elevations and compressed air systems require naturally occurring geologic features to hold compressed air.

Further, the costs associated with ES systems are often higher than traditional or conventional infrastructure technologies when compared with a new generation resource that could provide electricity and regulation services. A conventional combined cycle gas power plant will have an installed cost of about \$1,000/kW and a levelized cost of about \$100 to \$110/MWh.¹¹ Some ES systems have costs that are more comparable to a new generation resources, but all except some thermal storage options, exceed the cost of a new generation resource. If ES costs decline in the coming years as anticipated, it will become more competitive against conventional technologies. For thermal storage, the Department already supports and has installed systems both in customer and City facilities. Sizing of these systems is dependent on the facility size and needs of the customer and is thus difficult to establish targets for.

While details of all of the various ES technologies is provided in this section, Table 1 on the following pages provides a summary of the technologies that are described in this section, their maturity and availability, costs, and applicability to the Department.

¹¹ California Energy Commission, *Energy Almanac, Cost of Generation Data*, website, www.energy.almanac.ca.gov/electricity/levelized_costs.html, May 13, 2014.

Table 1: Development Status (Maturity), Availability, and Costs of Various Energy Storage Technologies

ES Technology	Development Status	Availability	Minimum Installed Costs and Levelized Cost of Energy	Contingencies and Applicability for the Department
Pumped Hydro	Mature	Commercially Available Numerous projects have been developed	Installed Cost: \$5,500 / kW Cost of Energy: \$180 / MWh	<ul style="list-style-type: none"> • Uncertainties in siting, permitting, environmental impact and construction • While a larger pumped hydro system could not be located within Anaheim, it is possible that smaller systems could be located in the City once the technologies are more fully developed
Compressed Air Storage – 1 st Generation	Mature	Commercial offer possible Two projects have been developed	Installed Cost: \$4,480 / kW Cost of Energy: \$120 / MWh	<ul style="list-style-type: none"> • Plant costs will vary depending upon underground site geology • Siting constraints render this technology unfeasible for establishing procurement targets but it could be considered by the Department if there is a need for large scale ES storage
Compressed Air Storage – 2 nd Generation	Demonstration	System to be verified by demonstration units No units have been developed for commercial operation	Installed Cost: \$4,480 / kW Cost of Energy: \$120 / MWh	<ul style="list-style-type: none"> • Key components and controls need to be verified for second-generation systems. Plant costs will vary depending upon underground site geology. • The Department may consider this technology in the future once it matures and is demonstrated viable and cost effective at a utility scale.
Flywheel	Mature for UPS Applications	Commercial Numerous uses in power quality applications	Installed Cost: \$4,250 / kW Cost of Energy: \$380 / MWh	<ul style="list-style-type: none"> • Uncertain long-term life and performance for the flywheel subsystem • This technology could be considered by customers for their applications; however, it remains more costly than other alternative technologies

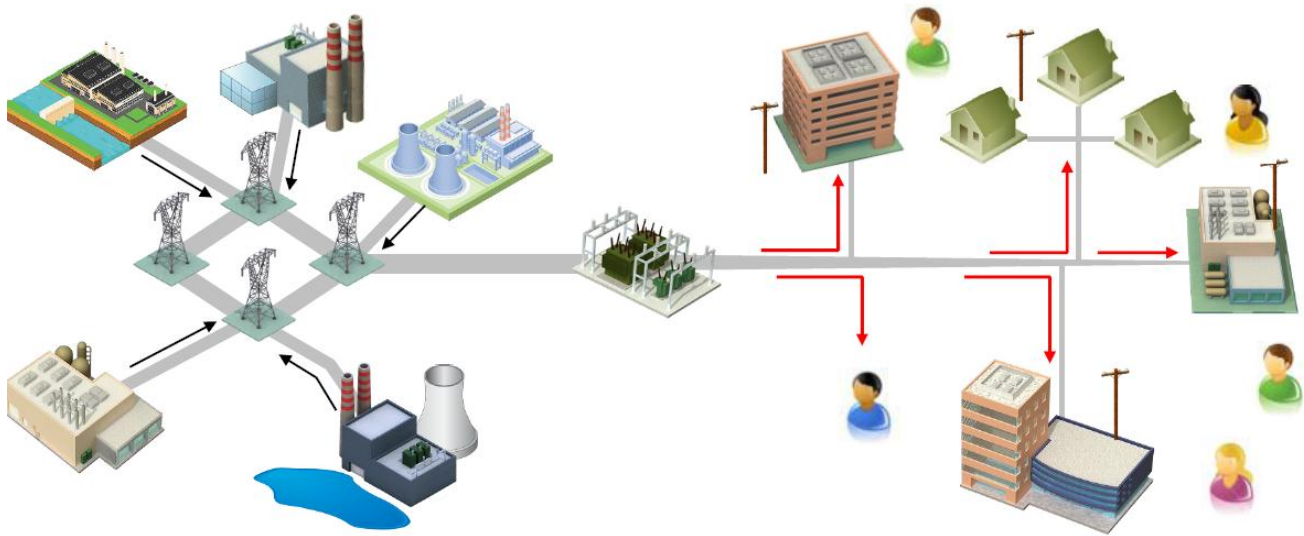
ES Technology	Development Status	Availability	Minimum Installed Costs and Levelized Cost of Energy	Contingencies and Applicability for the Department
Flywheel	Demonstration for frequency regulations	Pilots in ISO A/S Market applications Numerous uses in power quality applications	Installed Cost: \$4,250 / kW Cost of Energy: \$380 / MWh	<ul style="list-style-type: none"> • Uncertain long-term life and performance for the flywheel subsystem • Once the technology matures and is proven for grid level deployment, the Department could consider this technology
Lead-Acid Battery	Demonstration	Limited field demonstrations though some advanced systems can be classified as commercial Several wind and photovoltaic applications expected by 2013	Installed Cost: \$2,500 Cost of Energy: \$220	<ul style="list-style-type: none"> • Limited testing and field experience. Cycle life and depth of discharge for application needs careful evaluation; limited operation and maintenance cost data. • The Department may consider this technology once it matures and is demonstrated viable and cost effective at a utility scale.
Lithium-Ion Family of Batteries	Demonstration	Systems verified in several field demonstration in a variety of use cases Numerous small demonstrations in the 5-kW to 25kW sizes are underway. MW-scale short-energy-duration systems are being operated in frequency regulation applications. MW class for grid support and PV smoothing are being introduced. 2-MW/4-MWh system installed in one end-use customer peak shaving application.	Installed Cost: \$1,950 Cost of Energy: \$170	<ul style="list-style-type: none"> • Battery management system, system integration, and cooling need to be addressed. Performance in cold climate zones needs to be verified. Limited experience in grid-support applications, including systems with utility grid interface. Uncertain cycle life for frequency regulation applications. • The Department may consider this technology in the future once it matures and is demonstrated viable and cost effective at a utility scale.

ES Technology	Development Status	Availability	Minimum Installed Costs and Levelized Cost of Energy	Contingencies and Applicability for the Department
Sodium-Sulfur Battery	Mature	Significant recent commercial experience Proven performance with 306 MW installed	Installed Cost: \$5,775 / kW Cost of Energy: \$292 / MWh	<ul style="list-style-type: none"> • Costs dependent on site conditions. • The Department may consider this technology but overall costs, siting, and safety concerns need to be incorporated into any future evaluation
Zinc-Air Battery	Laboratory	Small cells and stacks in a lab setting with some bench scale system tests No utility-scale demonstrations	Installed Cost: \$3,200 Cost of Energy: \$165	<ul style="list-style-type: none"> • Uncertain efficiency, cycle-life, and scale up capabilities. Limited definition of product designs. • The Department may consider this technology in the future once it matures and is demonstrated viable and cost effective at a utility scale
Sodium-Nickel-Chloride Battery	Demonstration	Limited field demonstrations Several photovoltaic & distributed storage installations by 2012	Installed Cost: \$4,000 / kW Cost of Energy: \$610 / MWh	<ul style="list-style-type: none"> • Limited testing and field experience. Limited data on life-cycle costs. Limited operation and maintenance cost data. • The Department may consider this technology in the future once it matures and is demonstrated viable and cost effective at a utility scale.
Vanadium Redox Flow Battery	Pre-Commercial	Systems verified in limited field demonstrations Units operating in renewable integration, end-user energy management, and telecom applications	Installed Cost: \$6,000 / kW Cost of Energy: \$550 / MWh	<ul style="list-style-type: none"> • Contingency will vary by size of the application. Vendors are offering 10-year energy services contracts. • The Department may consider this technology in the future once it matures and is demonstrated viable and cost effective at a utility scale.

ES Technology	Development Status	Availability	Minimum Installed Costs and Levelized Cost of Energy	Contingencies and Applicability for the Department
Iron-Chromium Flow Battery	Laboratory	Small cells and stack in lab setting No utility-scale demonstrations; few niche telecom applications	Installed Cost: \$3,100 / kW Cost of Energy: \$195 / MWh	<ul style="list-style-type: none"> • Uncertain efficiency, cycle-life, and scale up capabilities. Limited definition of product designs. • The Department may consider this technology in the future once it matures and is demonstrated viable and cost effective at a utility scale.
Zinc-Bromine Flow Battery	Demonstration Trials	Small systems deployed in limited field demonstrations No utility-scale demonstrations	Installed Cost: \$12,000 / kW Cost of Energy: \$1,800 / MWh	<ul style="list-style-type: none"> • Uncertain efficiency; limited life and operation experience at greater than 100 kW. Transportable and small systems with lower construction and installation issues. • The Department may consider this technology in the future once it matures and is demonstrated viable and cost effective at a utility scale.
Thermal Energy Storage – Chiller Based	Mature	Commercially Available	Installed Cost: \$4,440 / kW Cost of Energy: \$99 / MWh	<ul style="list-style-type: none"> • The Department will continue to support customers that seek to deploy this type of ES system.
Thermal Energy Storage – Refrigerant Based	Mature	Commercially Available	Installed Cost: \$3,369 / kW Cost of Energy: \$127 / MWh	The Department will continue to support customers that seek to deploy this type of ES system.

Source: Developed from information in Sandia National Laboratories, "DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA," July 2013

Figure 1. The Electric Grid of the Past



Traditional Energy Storage

As mentioned above, the electric grid of yesterday was much simpler than today's grid. Electricity was generated by large, centralized generation plants, transmitted over power lines from the plant to a more local distribution grid and then delivered to the customers. As shown in Figure 1, under this system, electricity flowed in one direction, from the generation facility to the customer. Electricity was generated when customers needed it and not generated when it wasn't needed; power plants could be brought on-line or off-line as needed.

As power plants became larger and more complex, it was recognized by the utility industry that bringing power plants on and off (called cycling) was not the most efficient means of running a plant.¹² Optimizing a power plant's output became a priority. It was recognized that plants needed time to reach their optimal output of electricity. In the 1980's, ES systems in the form of pumped hydro were developed to optimize electricity generation from coal powered plants.¹³ It allowed coal power plants to run at peak performance for longer durations throughout the night minimizing the amount that the plant was cycled up or down as demand changed throughout the course of the day and night. In other words, the output from the plant became levelized versus having large fluctuations in its output.

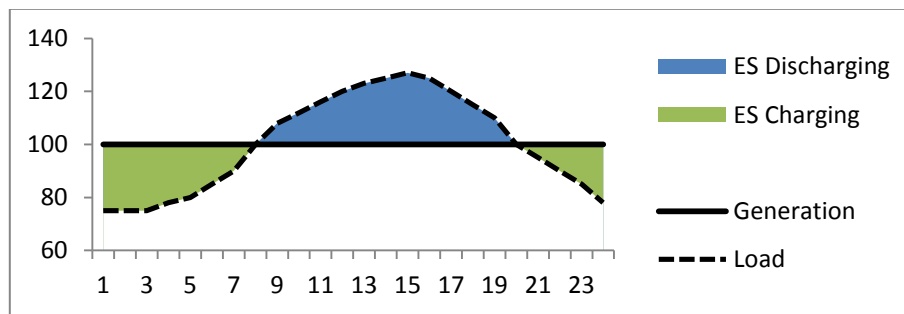
While levelizing output on power plants optimizes their respective operations, the primary objective for utilizing pumped storage is to minimize overall costs for producing electricity. As mentioned earlier, as consumers use more electricity over the course of the day, particularly during summer months for air conditioning needs, the cost for providing that

¹² Sandia National Laboratories, "DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA", SAND2013-5131, New Mexico and California, July 2013.

¹³ Ibid.

power increases. Utilities tend to optimize their resource fleet by operating the lowest cost resources first and as the day progresses and demand for electricity increases, more expensive resources are brought on line. The ability to store electricity, then, is important to capture cheaper energy that can be dispatched later in the day in order to avoid operating the most expensive resources in the utility's fleet. Figure 2 illustrates the time shift.

Figure 2: Using Energy Storage for Time Shifting of Generation



Pumped Hydro Systems

According to Sandia National Laboratories¹⁴, “pumped hydroelectric energy storage is a large, mature, and commercial utility-scale technology currently used at many locations in the United States and around the world. In a pumped hydro system, two reservoirs of water at two elevations are used to store energy (Figure 3). Electricity from the coal power plant is used during off peak periods to pump water from the lower elevation reservoir to the higher elevation reservoir. During peak periods, the water in the higher elevation reservoir is released through a turbine to the lower elevation reservoir and generates electricity. This allows the coal power plant to operate at a steady rate, optimizing its efficiency. Electricity still flows from the generation source to the customer; ES in this case simply provided a means to store the energy when it is most efficient to generate it and then send it to the customer when the customer demands it. Over time, ES has become recognized as a means for managing the daily fluctuations in the demand for electricity to optimize generation. ES also has the ability to either reduce or provide electricity for the peak demand periods and thus avoid the need to build more generation in the long term.¹⁵

Pumped hydro facilities are typically fairly large facilities, up to 4,000 MW in size and covering many acres or even multiple square miles with reservoirs used to store water, that are operated by or for a utility or multiple-utilities. The systems have high efficiency rates of between 75% and 85%. In the United States, California has the most installed pumped hydro with a capacity of 2,943 MW of which 1,679 MW comes from the California Department of Water Resources’ projects along the California Aqueduct.^{16, 17}

¹⁴ Sandia National Laboratories, “DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA,” July 2013.

¹⁵ Ibid.

¹⁶ FERC, “Licensed Pumped Storage Projects Map,” updated 8/1/2013.

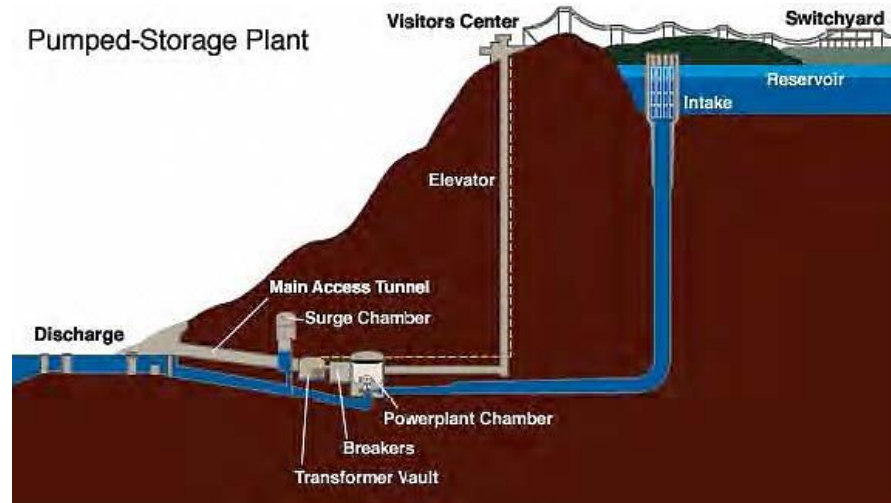
¹⁷ FERC, “Issued Licenses” [for pumped hydro], January 2014.

In addition to peak-shifting, pumped hydro facilities may also perform black start services to the electric grid if they do not require electricity to start.

Despite its proven successes, pumped hydro has been difficult to develop in recent years. It typically requires large land area, often greenfield (land not previously developed), for the reservoirs which also carries additional environmental impacts.

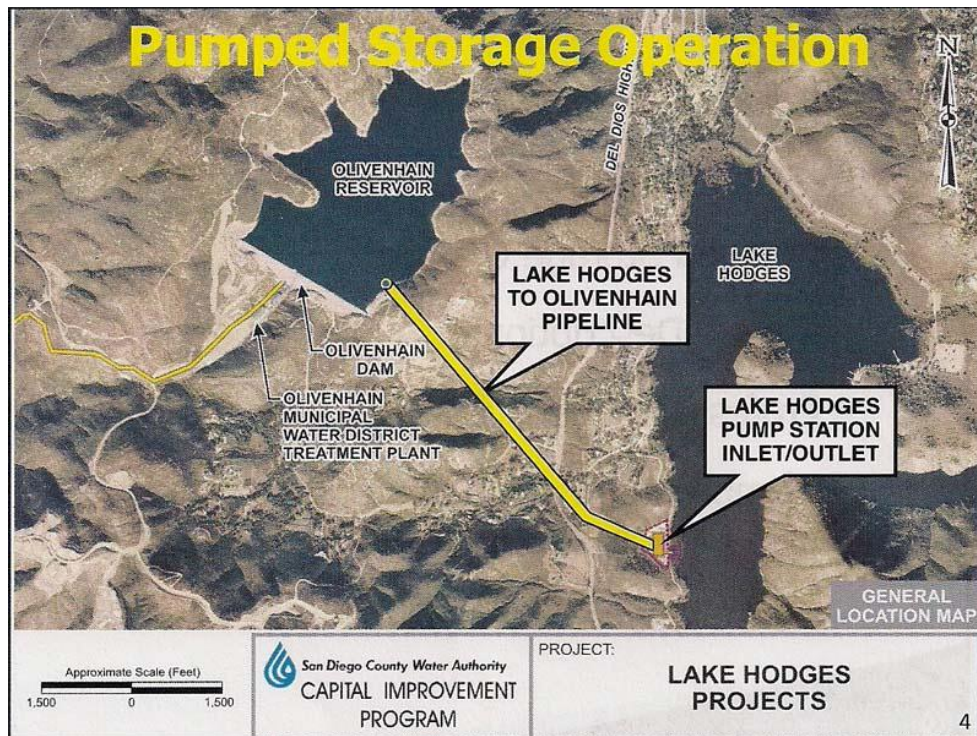
Geology and topography also limit where pumped hydro can be located. Permitting and environmental impact review processes can result in lengthy project start-up costs and delays. Figure 4 provides an aerial image of the existing Lake Hodges Pumped Storage Operation in San Diego County.

Figure 3: Diagram of a Typical Pumped Hydro Plant



Source: Sandia National Laboratories, "DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA," July 2013.

Figure 4: Example of Existing Pumped Storage Facility Serving San Diego Gas and Electric



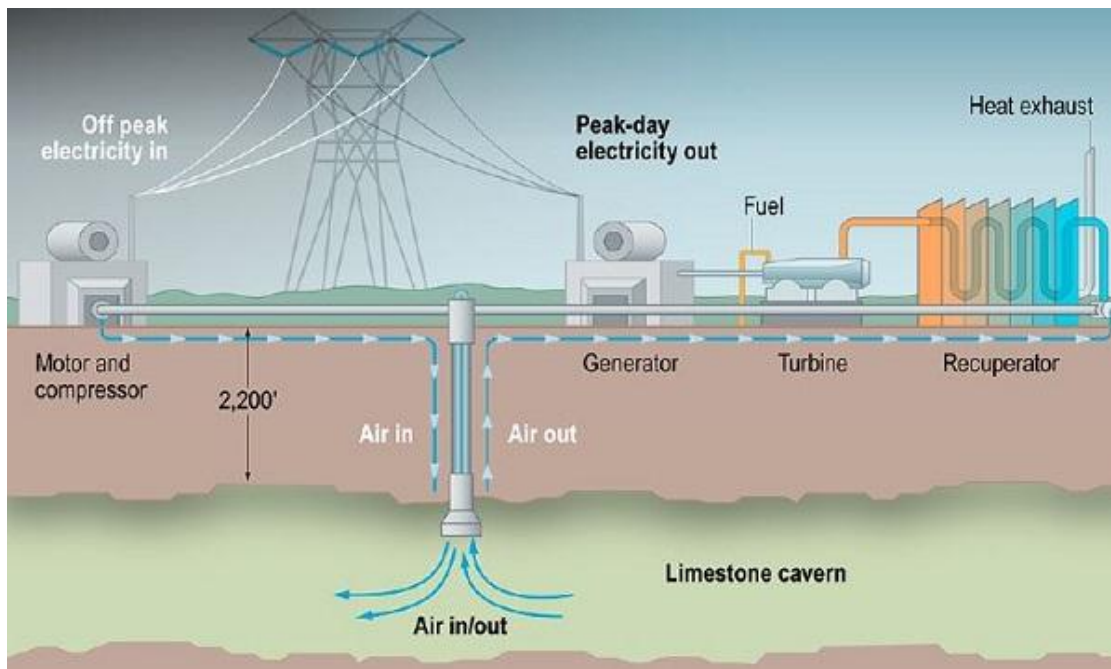
Source: San Diego Water Authority.

In addition to having the appropriate geography for pumped storage location, cost of construction can be 30 to 40% higher in capital investment than conventional peaking alternatives. Finally, for pumped storage to be optimized, the differential between the cost of pumping versus the cost of supplying energy during peak hours has to be sufficiently large enough to be economic. Given the current cost differential between coal-provided energy and that from gas-fired units in the Department's portfolio, the cost spread is not sufficient enough to make pumped storage an economic benefit. In addition, because of the typically large scale nature of pumped hydro projects, it is unlikely that the Department alone would be able to develop a project; however, if the opportunity to work cooperatively with other utilities were available, such a project would be evaluated at that time. If cost-effective, small scale technologies are developed in the coming years, it is possible that the Department could utilize this technology. However, until that point is reached, pumped storage would not be economically viable ES alternative for the Department's consideration for procurement or target setting.

Compressed Air Energy Storage (CAES)

Like pumped hydro, CAES systems are used primarily for bulk energy peak shifting. The systems compress air during off-peak energy use times and store it. Electricity is then generated at a later time by heating the air and directing it through a generator, such as a turbine. CAES systems, which have been around for over 18 years, are the only commercially available bulk energy storage systems available as of mid-2013 other than pumped hydro; however, because of the geologic conditions required, few have been developed. A typical diagram for a CAES system is shown in Figure 5.

Figure 5: Diagram of a Typical CAES System



Source: Sandia National Laboratories, "DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA," July 2013.

Of the two Compressed Air Energy Storage systems that have been deployed, the compressed air is stored in large underground caverns. The reliance on a cavern to store the compressed air will limit the ability to use such systems because the technology is highly dependent on the facility site and geology of the area. Because these systems utilize large caverns, they have the ability to store large amounts of energy that can be released over longer periods of time. Both systems that have been developed have demonstrated both high availability and reliability.

The geology within the City boundaries would not support a CAES system being located here. There is the possibility of participating in a CAES system outside of the City along transmission routes, but, like large pumped hydro systems, the costs, size and other system configurations would be so site and situation dependent that evaluation of such a system would be subject to transmission risk and economic viability. Therefore, the Department has determined that this option is not currently feasible to specify a procurement target for the Department alone based on this technology. Similar to pumped hydro systems, if the opportunity to work cooperatively with other utilities were available, such a project would be evaluated at that time.

New technologies for CAES systems store the compressed air in pipes or vessels above ground are still in the testing phases. These systems will be much smaller than systems that rely on geologic features but will also have higher costs primarily due to the increased costs of the above-ground storage. If the new CAES systems prove successful and have lower costs, they could represent a promising technology for the Department to consider in the future if significant peak-shifting were needed.

Small scale uses: Thermal Energy Storage Solutions

The two systems discussed above address the supply side of the equation but optimizing generation. It is also possible to address the demand side and shift demand from one time period to another through the use of an ES system. ES technologies called thermal energy storage have been developed specifically to reduce electricity demand for air conditioning during the middle of the day.

These systems chill water or generate ice at night when electricity demand is typically lower (and costs to produce electricity are lower), and these use the chilled water or ice to cool the air during the day, thus reducing the need for air conditioning. Systems such as these are typically located at customer sites, on the customer side of the meter. While the utility benefits from the reduced peak demand that offsets the need for additional generation resources, the customer benefits from being able to realize a lower electric bill because electricity in off-peak periods is cheaper than electricity during peak periods.

The Department has successfully used ES for this purpose at several sites throughout the City (Table 2) and was able to accommodate increasing customer needs without procuring additional resources. Generally, the Department's demand for electricity is lowest at night and highest during the middle of the day. In particular, overall demand is greatest in the

mid and late-afternoon hours on hot summer days when customer’s air conditioning comes on.

Table 2: ES Systems Operating in the City of Anaheim

Project	Date Operational	On-Peak kW Shifted
Small Scale Systems		
Fire Station #8	2004	6.70
Customer Sited Systems	2007	125.11
Customer Sited Systems	2008	93.41
Customer Sited Systems	2009	26.82
Canyon Power Plant	2012	23.16
Total of Small Scale System		275.20
Large Scale Systems		
Customer Sited Systems	2011	2,356.00
Anaheim West Tower	1992	519.00
Total of Large Scale Systems		2,874.00
Total Installed kW of Energy Storage		3,149.20

To address the peak needs of the system, the Department implemented both of the types (chilled water and ice) of thermal energy storage mentioned above at some City facilities as well as commercial facilities in the City. This program successfully reduced the demand for electricity during peak demand hours of each day. These systems, still operating today, essentially take the place of mid-day air conditioning. Ice or chilled water is generated and stored at night when demand is low; it is then used to provide the cooling during the day in place of an air conditioner. Thus, the demand for electricity to create the cooling is shifted. Over 3 MW (3,149.20 kW) of thermal ES systems are already installed within the City of Anaheim, as shown in Table 2. The Department offers time-based rates to encourage peak shifting by customers who wish to invest in such systems. The difficulty is in the site-specific nature of thermal storage, and whether it is suited for retrofit applications with existing cooling equipment. By providing time-based rates, customers are able to determine their cost/benefit and associated payback as the basis for their choice, without being prescribed targets or mandates.

Moving Forward: Changing Grid Needs and New Technologies

Managing the cost of electricity is what has historically driven the development of most ES systems, whether it is managing the generation resource most effectively or customers managing electricity demand. In more recent years, ES systems have also been developed to primarily help customers manage power quality or provide uninterruptible power supplies. Solutions for this have gone beyond thermal ES systems and include both batteries and flywheels. The cost-effectiveness of these solutions, however, has been highly dependent on the needs of the customer. These systems provide backup electricity in the event of a power outage, or provide management of the quality of the power, such as through an uninterruptible power supply. Customers with higher reliability business

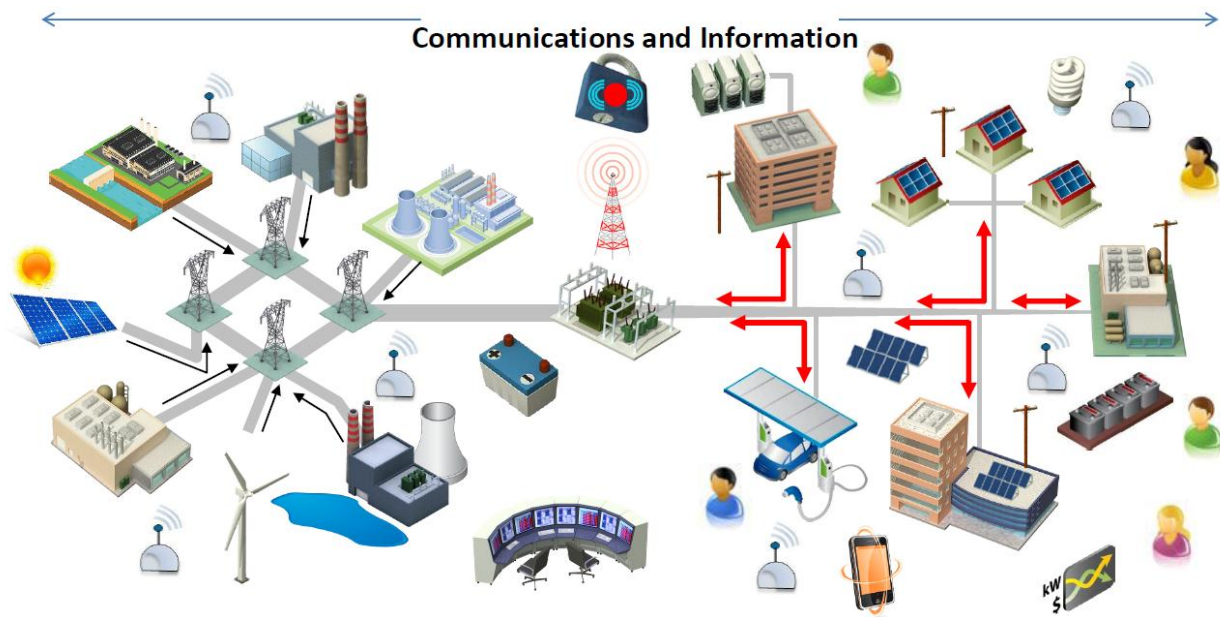
needs, such as data centers or chilled products, already make these types of investments based on their individual circumstances and business drivers.

Today, the electric grid is changing rapidly to a future electric grid, and energy in general, that will become even more complex than in the past. These changes include increased generation produced by intermittent renewable generation resources, distributed generation resources (such as customer-sited rooftop photovoltaic systems), and the need to address changing demand and technological capabilities of the electric infrastructure such as increases in energy efficiency in buildings, implementation of smart grid technologies and integration of electric vehicles.

Figure 6 illustrates how the electric grid is anticipated to look in the future. It is important for the Department to look at all options available as these changes to the grid are addressed. ES systems simply become another tool in the toolbox of available technologies that may be used when appropriate and as driven by utility or customer needs.¹⁸ A key driver changing the grid is the increased integration of variable renewable energy resources as a result of the State's Renewable Portfolio Standard (RPS). Another key change is the increase in small scale distributed generation facilities that are typically located on the distribution grid and often times at a customer's site (e.g. residential rooftop solar), that can change the direction that electricity flows. Integration of these resources and implementation of the policies supporting these resources are changing how the electric grid and supporting infrastructure function.

¹⁸ Southern California Edison, *"Moving Energy Storage from Concept to Reality: Southern California Edison's Approach to Evaluating Energy Storage,"* May 2011.

Figure 6: The Future Electric Grid



In the case of variable renewable resources, such as wind and solar based generation, electricity is produced when the wind blows and sun shines. The generation is disassociated from traditional paradigm of only generating electricity when there is demand for the electricity. Further complicating the implementation of these types of renewable generation is their variability. Unlike a traditional power plant, the generation for variable resources is also not a steady amount, but fluctuates up and down in very short, split-second, time increments. The demand for the electricity is unlikely to always match when the electricity is being generated by variable resources.

ES can provide the balance and store the electricity when it is generated to be provided when there is demand. A simple example would be a wind generation resource that generates the bulk of its electricity at night when there is minimal demand. ES would provide a system that can store the electricity – like a battery – until the demand increases the following day and the electricity can be distributed at that time. Currently, Anaheim has its Canyon Power Plant that effectively serves this function and is available to dispatch within 10 minutes. Each utility needs to consider its portfolio of grid stability and address intermittency according to their system makeup.

Also complicating the electric grid of tomorrow is the increased distribution of electricity generation throughout the grid. As noted earlier, electricity was historically generated at a central power plant and then moved through the grid in one direction to the customer where it was used. With the increases in smaller, renewable generation resources like rooftop photovoltaic systems and other distributed electricity generation systems,

electricity is now sometimes moving from the customer back into the grid. This has the potential to disrupt the flow of electricity to other customers if more electricity is fed into the grid infrastructure than it is designed to accommodate. ES could be used to store the excess electricity close to the generation source until a time when it can be fed into the grid without causing disruption. (Note: Each of these individual uses for ES is discussed in the next section of this chapter.) While the Department is not yet experiencing this type of disruption in its distribution grid, other utilities in the state are, notably SDG&E and SMUD.¹⁹ They are each in the process of developing solutions to better address the integration of distributed photovoltaic systems that are generating more electricity than is being used along some of their systems distribution lines.

Finally, technological developments in ES systems and the systems that control ES devices, as well as changes in the regulatory environment that enable ES systems to interconnect and serve the grid, are making it easier for ES systems to be installed and fully utilized. Regulations, such as AB 2514, are also requiring changes to the electricity market to recognize and facilitate ES systems. Technological improvements in ES devices (discussed later) are making them more reliable and cheaper to implement. Regulatory changes made by the State's California Public Utilities Commission (CPUC), California Energy Commission (CEC) and within the California Independent System Operator (CAISO) are also enabling ES devices to more easily interconnect and are putting the systems in place to allow the services they provide to the grid to be more fully utilized.

The Department is aware of and managing these changes to the electric grid. For example, the installation of rooftop solar systems has been steadily increasing throughout the City. To date, these systems have not resulted in any disruption of the Department's distribution grid services; however, if this situation changes in the future, ES will be included in any analysis to formulate the appropriate solution to address the issue.

The following describes newer and emerging ES system technologies.

Flywheels

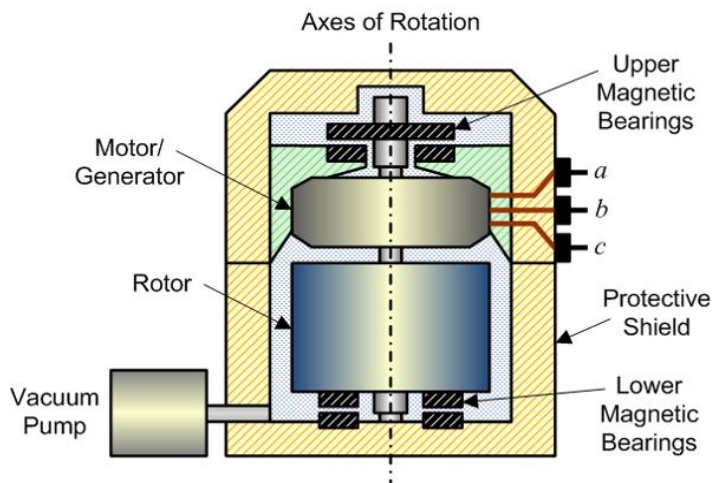
Flywheels store energy kinetically. Electricity is used to wind a rotor which is then held in place (see Figure 7). When needed, the rotor is released and momentum of the rotor unwinding generates electricity. Flywheels generation have an efficiency of about 70%-80%. Currently, only one company develops flywheels in the United States.

¹⁹ Energy Storage North America Conference, October 2013.

Typical applications of flywheels to-date are in the commercial applications in which customers need to maintain continuous, high quality power. They have been used to maintain power quality and provide uninterrupted power supply (UPS) services.

Like the commercial applications, flywheels are currently being tested to provide ISOs with frequency-regulation services in the northeast. One facility has been providing frequency regulation with a cumulative capacity of 20MW since 2011²⁰. A new test facility is underway that is intended to test the technology's ability to provide additional ancillary services for voltage regulation and stabilization of intermittent wind resources.

Figure 7. Diagram of a typical Flywheel



Source: Molina, Marcelo Gustavo, "Dynamic Modelling and control Design of Advanced Energy Storage for Power System Applications," on Intech website, www.intechopen.com, January 2010.

While there are several installed flywheel applications, their long-term life and performance characteristics are still uncertain, particularly at a utility scale.²¹ Like other technologies, flywheels need to mature for grid-scale applications but would be a viable technology for smaller, customer sited applications. The Department could consider these technologies to provide neighborhood level energy storage to provide power quality assurance, voltage support, and regulation services on the distribution grid. However, flywheels are still costly and have not yet been fully vetted at a distribution scale. Therefore, the Department has concluded that this technology is not currently viable as an ES solution to pursue.

Batteries

Batteries utilize chemical processes to store energy. A broad range of technologies are being explored for use as ES at a utility scale. Some technologies, such as lead-acid batteries are very mature for small applications, but are only now being developed for use at a utility scale. Other battery systems, such as sodium-sulfur batteries, are further along in being used at a utility scale, but their uses, reliability, and life-cycles are still being tested and analyzed. Overall, most battery use in ES has been in smaller applications of less than

²⁰ Ibid.

²¹ Sandia National Laboratories, "DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA," July 2013.

1 MW. Few battery technologies have been deployed at a utility scale and most have yet to demonstrate their ability to perform and be cost-effective at these scales.²²

The key types of batteries include:

- Sodium-sulfur (NaS)
- Vanadium reduction and oxidation (Redox)
- Iron-chromium (Fe-Cr)
- Zinc-bromine (ZnBr₂)
- Sodium-nickel-chloride (NaNiCl₂)
- Zinc-air
- Lead-acid
- Lithium-Ion (LI-Ion)

The characteristics of each technology and its maturity are described in the following table.

Table 3. Characteristics and Maturity of Specific Battery Technologies

Technology	Characteristics
Sodium-sulfur	<ul style="list-style-type: none"> • Long discharge period • Very responsive to grid needs • Low maintenance costs • Uses hazardous materials that combust upon exposure to air
Sodium-nickel-chloride	<ul style="list-style-type: none"> • Long discharge period • Very responsive to grid needs • Low maintenance costs
Vanadium Redox	<ul style="list-style-type: none"> • Millisecond response to grid needs • Can be fully discharged without shortening its life • Physically large facility
Iron-chromium	<ul style="list-style-type: none"> • Expected to be low-cost systems compared to other types of flow batteries
Zinc-Bromine	<ul style="list-style-type: none"> • Small systems that can be transported • Low construction and installations costs are expected
Zinc-air	<ul style="list-style-type: none"> • Potential for high energy density making it desirable for small scale and transportation related uses • Effectiveness can be negatively affected by humidity and airborne contaminants • However, its internal processes are highly stable and less dangerous than other battery technologies
Lead-acid	<ul style="list-style-type: none"> • Longest history for use – originally invented in the 1800’s • Easy to expand in parallel systems making them very versatile and well suited for large scale use • Fast response time • Degrades quickly if fully discharged leading to questionable life cycles • Must be disposed of correctly at end of life due to the safety hazards associated with lead
Lithium-ion	<ul style="list-style-type: none"> • Fastest growing platform for energy storage. • Wide usage in electric vehicles. • MW class batteries for grid support and PV smoothing are still being tested.

²² Ibid.

Because of the wide variety of both technologies and uses of the technologies, batteries could provide services to the Department at the distribution grid scale. Costs and safety concerns will need to be carefully evaluated if the Department considers installing a battery system. Life cycle costs are also currently only estimated because so few of these systems have been installed at a utility scale and have operated for more than a few years. Therefore, if installed, the Department will need to take into consideration replacement and the potential for other unexpected costs.

How Energy Storage Can Be Used

The next step in identifying how ES can be utilized by the Department was to identify and evaluate the various services or uses that ES can provide. To do this, the operational uses of ES were identified and then evaluated against the Department's current infrastructure needs and those of the future.

Based on literature from both Sandia National Laboratories²³ and SCE²⁴, the Department identified the following list of seventeen distinct functions or operational uses for ES.

1. Bulk Energy Services
 1. Electric Energy Time-Shift (Arbitrage)
 2. Electric Supply Capacity
2. Ancillary Services
 3. Frequency Regulation and Response
 4. Spinning, Non-Spinning, and Supplemental Reserves
 5. Voltage Support
 6. Ramping and Load Following
 7. Black Start
3. Transmission Infrastructure Services
 8. Transmission Upgrade Deferral
 9. Transmission Congestion Relief
4. Distribution Infrastructure Services
 10. Distribution Upgrade Deferral
 11. Improvement of Power Quality/ Voltage Support
 12. Mitigation of System Outages
 13. Integration of Distributed Renewable Generation
5. Customer Energy Management Services
 14. Maintain Power Quality
 15. Ensure Power Reliability – Uninterruptible Power Supply
 16. Retail Electric Energy Time-Shift
 17. Demand Management

The following provides a brief description of each of the ES uses identified above. The use descriptions are summaries of the use definitions in the referenced resources.²⁵

Bulk Energy and Generation Services

1. **Electric Energy Time-Shift:** In electricity markets, arbitrage that would involve ES, is the purchasing of electricity at a lower price at one time and then selling it at a higher price at a later time, or in a different electricity market. It can also include

²³ Sandia National Laboratories, "DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA", SAND2013-5131, New Mexico and California, July 2013.

²⁴ Southern California Edison, "Moving Energy Storage from Concept to Reality: Southern California Edison's Approach to Evaluating Energy Storage," May 2011.

²⁵ Please see footnotes 14 and 15 for referenced sources.

generating electricity when it is cheaper to generate and transport it and then selling or using it when electricity prices are higher. The Department currently is not in need of time shifting load due to its 200 MW Canyon Power Plant. However, because the overarching need to reduce peak demand to relieve grid congestion, the Department does support time-based rates and offers a variety of options for customers.

2. **Electric Supply Capacity (demand shifting):** Like all utilities in California, the Department is required to retain sufficient generation capacity such that it can meet customer demand at any given time – especially during the summer demand peaks when demand is highest and in addition, maintain an additional 15% in the form of reserves. ES can be used to fulfill capacity requirements by discharging electricity when demand is high. The ES system would charge when there is more generation available than demand.

At this time, the Department has sufficient capacity to cover its peak load requirements. With the development of the Canyon Power Plant, in addition to other generation resources that the Department owns or is contracted with, the Department meets all capacity requirements established by the CAISO and does not currently need additional supply capacity. If the Department were to need such a service in the future, ES could be a solution to meet the requirements.

Ancillary Services

The Department does not currently develop infrastructure for the sole purpose of providing ancillary services locally or to the regional grid operated by the CAISO. As the CAISO develops the appropriate tariffs, controls and other technology to effectively facilitate offering the service and as the market for these services more fully develops, the Department will consider the application of any of these ancillary services, as appropriate in conjunction with the development of an ES system.

3. **Frequency Regulation and Response:** In order to ensure that an electric grid functions correctly, a constant frequency is required to be maintained (60 hertz in the U.S.). For the Department, the grid frequency is maintained by the California Independent System Operator (CAISO). The services are provided in short, four-second adjustments either to increase (regulation –up) or decrease (regulation-down) the system frequency. ES can potentially provide both regulation-up and –down functions in the required short time increments once the regulatory and technological requirements will allow its participation in the market. The CAISO is currently developing new regulations for the frequency regulation market. The new requirements will address how ES will be able to participate in the market.
4. **Spinning, Non-Spinning, and Supplemental Reserves:** These reserves represent generation capacity, or are decreases in load from demand response resources, that are available at any time and can take the place of a normal electric supply resource if it were unexpectedly unavailable. Spinning reserves are those reserves that are

already operating and non-spinning reserves are those that will need to be brought online. Supplemental reserves are simply further backup for the spinning and non-spinning reserves. In the CAISO, these reserves could be called upon in increments as short as a ½ hour and would need to provide service within 10 minutes. The Department does not offer these services as a primary use for any of its facilities; the Canyon Power Plant and Kraemer Power Plant, however, may be called upon to provide these services in an emergency situation.

5. **Voltage Support:** Similar to the necessity of maintaining a certain frequency on the electric grid, voltage must also be maintained. Voltage changes in the grid are caused by equipment that connects to the grid and can generate, transmit, or use electricity in a way that is often similar to inductors and capacitors in an electric circuit. Typically, voltage is maintained by designated power plants that perform the functions necessary. ES can be alternative technology to support the maintenance of the constant voltage by either being a voltage source or sink. This use is currently not needed on the City's distribution grid. If the need arises in the future, ES could be considered as a possible option.
6. **Ramping and Load Following for Intermittent Renewable Generation:** As mentioned earlier, many renewable generation resources including wind, solar photovoltaic, and solar thermal, are intermittent or variable. They generate electricity based on wind speed or solar intensity which can vary second to second. ES can function to dampen this variability. The ES system is located between the generation and the transmission grid. The renewable resource charges the ES system which can accommodate the variability of the generation. Electricity is then fed onto the grid from the ES system as it discharges. The discharging ES can respond to grid needs for either other uses or simply can discharge a set amount of electricity at a time when called upon by the grid. This application would be used either along a transmission line that serves one or more renewable generation resources or at the generation site before the electricity is fed into the grid.
7. **Black Start:** A black start is the capability to start-up a generation resource, without the aid of a primary power source, and is used in the event that there is a failure of the electric grid and no power is available to start up the generation plant. ES could provide the power necessary to start up a generation resource in such a situation. In the case of ES used for black start, it would need to be charged and available at any given time. Therefore, the ES system would need to be maintained in a constant charged state and become operational when called upon. The Department does not currently, and is unlikely to offer this service; however, the Canyon Power Plant is capable of black start to power critical loads in the case of a regional emergency.

Transmission Infrastructure Services

Transmission systems are regional systems that transmit electricity from the generation resource to the distribution system. While the Department has an ownership share in

some transmission, it is unlikely that the Department itself would implement transmission level ES systems as it would be cost prohibitive to deploy on our own. If an ES system were to be deployed on a transmission system, it would be in conjunction with the other co-owners of the system. ES systems could provide the following services if they were needed, and the Department would fully consider them in light of the needs and various solutions available.

8. **Transmission Upgrade Deferral:** In the case of a transmission line that may be reaching its capacity during peak hours, ES could be used to defer or avoid the need to upgrade the transmission line. An ES system could be deployed closer to the load center and deferring or avoiding the need upgrade the transmission line to bring the power in.
9. **Transmission Congestion Relief:** In electricity markets, there is a cost associated with the use of transmission lines, particularly if the entity using it to transmit electricity does not own the transmission line. When there is more demand to use a transmission line than it has available, it causes congestion and increases the cost to use the transmission line. ES can be used to avoid the congestion related costs if the transmission system is utilized during off-peak times to transmit lower cost electricity for charging.

Distribution Infrastructure Services

Distribution infrastructure represents the infrastructure that distributes electricity locally to the Department's customers. As such, distribution infrastructure services represent the most practical uses of ES for the Department. Any of the services defined below could be considered for ES deployment.

10. **Distribution Upgrade Deferral:** Deferring installation of, or upgrades to, a distribution system to a point in time when the need for the upgrade can be determined with more certainty, such as for planned growth that may or may not occur. ES could be used to defer re-conductoring of a distribution line with heavier wire. If the ES system is transportable, it could also be moved to another location to provide support services while an upgrade is being made or until it is determined that an upgrade is needed or not. The cost-effectiveness of this use would need to be evaluated at the time that an ES system could be considered. Anaheim is essentially built-out and therefore development activities are typically in-fill projects. Anaheim also has a robust undergrounding program that averages 5 circuit miles per year, which reduces the need for re-conductoring.
11. **Improvement of Power Quality / Voltage Support:** ES has the potential to serve as either a replacement of, or allow the deferral of, investment in equipment that provides voltage control for the distribution grid. However, Anaheim already monitors power quality and deploys capacitors and voltage regulators where necessary to maintain voltage.

12. **Mitigation of System Outages:** ES could provide electricity to an area of the distribution grid that experiences a planned or unplanned loss of electricity if installed at or close to the customer location. If the ES is installed at a substation, it does not relieve the outages experienced on the distribution circuit from vehicles hitting poles, tree branches, metallic balloons, or contractor dig-ins.
13. **Integration of Distributed Renewable Generation:** The Department anticipates that there will be a continued increase in distributed renewable generation, primarily in the form of rooftop photovoltaic (PV) systems. These systems simply generate electricity when the sun is shining and feed it into the distribution grid, called backflow. The Department's distribution grid is designed to accommodate some backflow, but if there are areas in which more there is more backflow than can be accommodated, it could cause disruption to the distribution system. Similar to the ramping and load following use described under Use #6, an ES system could be used to store the excess and variably generated electricity and then feed it into the distribution grid when the generation decreases (e.g. at night when a PV system is not generating electricity). This use can be placed on the distribution grid as well as on the customer side of the meter.

Customer Energy Management Services

The following services that can be provided by ES systems are those that provide a direct service to the customer. There may be opportunities for the Department to provide these services on the distribution grid, but most of the customer energy management services would be highly dependent the customer's needs. Customers will need to evaluate the need and systems to determine the best solution for them.

14. **Maintain Power Quality:** While the Department offers high power quality to our customers, some customers may require certain systems be in place to ensure continuous high quality power, and is not solely dependent on the Department's distribution system. ES can be used to ensure that the quality of power they need is met.
15. **Ensure Power Reliability – Uninterruptible Power Supply:** As with power quality, some customers must maintain continuous power. These customers have historically utilized back-up diesel generators and/or batteries to provide electricity in the event of an outage. An ES system could potentially provide the same service and supplant the need, and costs, associated with providing a separate feed into the facility; however, the ES system would need to be maintained by the customer.
16. **Retail Electric Energy Time-Shift:** In situations in which a utility employs time-of-use rates (charges higher rates during peak times to encourage conservation), an ES can be used by customers to reduce their overall electricity costs. As with electric energy time-shift, the customer can charge an ES device during off-peak hours when electricity is cheaper and then use the electricity during the higher rate time

periods. For the Department's customers that are on time of use rates, this could be a viable and cost-effective use of an ES system.

17. **Demand Management:** These ES systems, installed at customer locations, help to reduce electricity demand during peak use times, such as during the summer. It is this operational use that is performed by the thermal ES systems already installed in the City discussed in the previous section. Conversely, these systems can be used to increase demand by charging the systems when demand is low and to help maintain grid stability.

Additional Considerations for Evaluation of Energy Storage

When determining the operational functions that ES could fulfill, it is also important to identify where on the electric grid the ES would be installed as well as some of the key operational characteristics that would be needed.²⁶ Each characteristic is described below.

Grid Location: Where on the grid the ES system will be located will be determined by the primary use of the ES system but, in order to evaluate the multiple benefit stream potential of an ES system, it will also be a factor in the other types of service and value the ES system can provide. While the electric grid is very complex, it can be divided into four basic components:

- *Generation:* This is the location where electricity is generated. Typically, it is a power plant.
- *Transmission:* These are the power lines that allow large quantities of electricity to move from a generation location to a distribution area.
- *Distribution:* The distribution grid is comprised of the local power lines, substations and other infrastructure that serves the electricity to the customer.
- *Customer (Load):* The customer wants the electricity being generated. This is the point where the electricity moves off of the distribution grid through the customer's meter for their use (hence the term, "customer side of the meter").

Charge and Discharge Characteristics: Charging and discharging times of each operational function are important factors in determining if the ES would be used by the Department as well as the type of technology that would be used.

Some operational uses for ES will require short bursts of either charge or discharge while other uses will require longer charging and discharging times. The short burst uses of ES are primarily for dynamic response uses, such as for maintenance of the power quality

²⁶ Ibid.

(voltage support) on the grid. The primary example of this cited in the literature is the use of ES for load following and ramping support for renewables. ES would be used to dampen the variability of wind and PV system generation, essentially smoothing the flow of electricity from these systems because the electricity generation from these systems randomly fluctuates up and down. For example, wind often does not blow at a steady rate. Rather its speed fluctuates up and down continuously. The megawatts (MW) of electricity generated from wind also similarly fluctuate up and down. An ES system used to smooth this irregularity would store electricity at the peaks and discharge electricity in the brief moments that the wind calms. Such systems must be able to accommodate the changes in time increments smaller than a minute but up to about an hour in time.²⁷

Longer duration charging and discharging is primarily used for energy shifting. This is most comparable to demand response applications, such as reducing peak load at a specific time, or to storing renewable generation for which there was insufficient customer demand at a given time.

Table 4 lists detailed charge, discharge, and cycling characteristics necessary for each of the ES uses described above.

Table 4: Charge, Discharge, and Cycling Characteristics for Energy Storage Uses

Potential Energy Storage System Use		Energy Storage Device Parameters		
		Size	Duration	Cycles Per Year
Bulk Energy and Generation Services				
1.	Electric Energy Time-Shift (Arbitrage)	1-500 MW	<1 hour	250+
2.	Electric Supply Capacity	1-500 MW	2-6 hours	5-100
Ancillary Services				
3.	Frequency Regulation and Response	10-40 MW	<1minute to 60 minutes	250-10,000
4.	Spinning, Non-Spinning, and Supplemental Reserves	10-100 MW	15 minutes to 60 minutes	20-50
5.	Voltage Support	1-10 mega volt-ampere reactive (MVAR)	Not applicable	Not applicable
6.	Black Start	5-10 MW	15 minutes to 1 hour	Up to 10-20
7.	Ramping and Load Following	5- 400 MW	15 minutes to 10 hour	Up to 10-20 300-500
Transmission Infrastructure Services				
8.	Transmission Upgrade Deferral	10-100 MW	2-8 hours	Up to 10-50
9.	Transmission Congestion Relief	1-100 MW	1-4 hours	50-100
Distribution Infrastructure Services				

²⁷ Sandia National Laboratories, "DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA," July 2013.

Potential Energy Storage System Use		Energy Storage Device Parameters		
		Size	Duration	Cycles Per Year
10.	Distribution Upgrade Deferral	500 kilowatts (kW) – 10 MW	1-4 hours	50-100
11.	Improvement of Power Quality / Voltage Support	500 kilowatts (kW) – 10 MW	1-4 hours	50-100
12.	Mitigation of System Outages	5-20 MW	15 minutes to 24 hours	Up to 10-20
13.	Integration of Distributed Renewable Generation	25-200 kW 1-phase 25-75 kW 3-phase Small footprint	2-4 hours	100-150
Customer Energy Management Services				
14.	Maintain Power Quality	50-500 kW	<15 minutes	<50
15.	Ensure Power Reliability – Uninterruptible Power Supply	50 kW - 1 MW	4-10 hours	<50
16.	Retail Electric Energy Time-Shift	1 kW – 1 MW	1 to 6 hours	50 to 250
17.	Demand Management	1 kW – 1 MW	1 to 6 hours	50 to 250

Source: Adapted from SCE’s “Moving Energy Storage from Concept to Reality” and Sandia National Laboratories, “DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA”.

Ongoing Challenges for Energy Storage

Even with all of the progress supporting the implementation of ES, there are still significant challenges to its implementation.²⁸ Costs, complexity and perceived safety concerns will need to be overcome in order to successfully implement ES solutions. The following illustrate the hurdles ES confront that makes their applications difficult to include in the utility’s portfolio:

1. *ES system costs are more difficult to justify:* There are other technologies available to perform the services that ES can provide. For single use applications, ES systems are often much more expensive than these traditional solutions. In a July 2013 publication by Sandia Laboratories, it is stated that “...it is rare for a single service [ES system] to generate sufficient revenue to justify its investment.”²⁹ This means that to effectively justify investment in an ES system, the system will most likely need to be able to be utilized for more than a single primary service. If the multiple-values of the ES system can be identified, however, ES may be a cost-effective solution.
2. *ES systems are complex:* Implementation of ES systems is more complex than traditional utility solutions due to the need to more actively manage the multiple services they provide in order to achieve their full utilization. For some uses, they also require more complex computer control and communications systems than

²⁸ Lyons, Chet, *Grid Scale Energy Storage Opportunities in North America*,” GTM Research, October 2013.

²⁸ Sandia National Laboratories, “DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA”, SAND2013-5131, New Mexico and California, July 2013.

²⁹ Ibid.

traditional infrastructure. For example, an ES system that could be used to defer distribution circuit upgrades needs to be able to communicate back to the utility in order to be dispatched to charge or discharge to maintain grid stability.

3. *Perception of safety concerns still exists:* Chet Lyons identifies that “within the last several years, several battery facilities have experience high-profile fires that resulted in the total loss of the battery storage facilities and related infrastructure.”³⁰ Battery manufacturers are very focused on improving safety of their devices.

In order to justify the use of an ES system, these challenges, whether real or simply a perception, must be overcome.

Conclusion

The functions and services provided by ES technologies need to be considered on a case-by-case basis. Understanding customer needs will help them make the necessary investments, and the Department will assist with time-based rates to encourage those choices. As for the Department, many of the attributes of ES are already addressed through its peaking capabilities, robust undergrounding and reliability, or are limited by factors such as cost and space constraints.

Therefore, most ES deployment by the Department will be challenging. Some ES technologies may not be suitable to be located within the City (pumped hydro and underground CAES), are still being developed (tank storage CAES and many battery technologies). Deployment of these systems would be highly situational and need to be evaluated at the time that a project was needed and proposed. The systems are also often still a very costly solution when competing against traditional infrastructure technologies for a distribution grid.

Successful deployment of ES by the IOUs and other entities have been in locations that have an issue that an ES system uniquely can resolve, such as the ability to provide services to an isolated community that has limited distribution grid service (e.g. islands or small, rural communities). Other uses of ES that have been successful and demonstrated cost effectiveness, have been those located where the electricity markets are structured and priced such that the multiple uses, such as providing ancillary services, are profitable. These types of unique situations or having an electricity market that prices the services provided by ES will be factors the Department will need to consider when evaluating any ES system.

Thermal storage is an ES technology that the Department already has deployed and will continue to support where appropriate. Customers and the Department have both found that it can be cost effective and viable in specific situations. However, as a facility-sited technology, applications of thermal storage, including the size and amount of energy

³⁰ Lyons, Chet, *Grid Scale Energy Storage Opportunities in North America*,” GTM Research, October 2013.

shifted from on to off peak, are dependent on the facilities operations and needs, and therefore a pre-determined procurement target would be difficult to implement.

While ES systems are viable technologies and can provide a variety of services that the Department can utilize, the Department must have an issue that ES can resolve, have a location suitable for the ES device, and consider the ES system against other, traditional infrastructure technology solutions. Costs for ES systems and the commercial availability of the systems are currently limiting factors for many technologies and those that are available will need to be evaluated on a case-by-case basis. The Department's focus has and will continue to be delivering high quality service at reasonable rates in order to benefit the City of Anaheim. To the extent that ES can be integrated seamlessly, the Department will look for those opportunities; however, setting a threshold procurement target is not a viable or cost-effective at this time.

Section 3: Energy Storage for the City of Anaheim

As discussed in the previous section, there are a wide variety of uses for ES and the technology landscape is varied and rapidly changing. Each of the uses has specific requirements: location, duration of charge and discharge, number of cycles, availability of the system, and more. Additionally, the effectiveness of ES system is also determined by the existing conditions at the grid location at which the device(s) will be installed and the purpose it is installed for. The ability of the existing grid system to both charge and discharge the ES device, as well as the feasibility of utilizing the ES device for more than a single function, also affect the determination of whether an ES solution is the best.

To evaluate the viability and cost-effectiveness of an Energy Storage System on the Department's electrical infrastructure, the U.S. Department of Energy's Energy Storage Computational Tool (ESCT) was utilized to evaluate the costs of various ES devices against multiple benefits or value that it could offer. One demonstration project was evaluated: Use of a battery in place of a traditional distribution circuit. Three types of battery systems were evaluated: lithium-ion, sodium sulfur, and advanced lead-acid.

Evaluation Process

Because each application of energy storage will need to consider multiple uses as well as how it will integrate into an existing infrastructure system, careful planning on a case-by-case basis is necessary to properly evaluate whether ES will be cost-effective.^{31, 32} As discussed previously, numerous reports, including those by the Sandia National Laboratories and the studies completed as part of the CPUC Energy storage proceedings (R.10-12-007) have identified that it is difficult to justify the investment in energy storage unless the ES system will be used for more than one use.^{33, 34, 35} In California, SCE, PG&E, SDG&E, and Sacramento Municipal Utilities District (SMUD), Palo Alto have all undertaken or are in the process of evaluating ES systems and applications for their grids.

Staff evaluated the existing distribution system in the City and determined that an area of the City expected to experience growth in the next 10 years offered the best use case for which to evaluate an ES solution. Other uses for ES, such as at substations to provide

³¹ Sandia National Laboratories, *DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA*, SAND2013-5131, July 2013.

³² Rittershausen, Johannes and McDonagh, Mariko, et. al.; Southern California Edison, *Moving Energy Storage from Concept to Reality: Southern California Edison's Approach to Evaluating Energy Storage*, 2011.

³³ Sandia National Laboratories, *DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA*, SAND2013-5131, July 2013.

³⁴ Electric Power Research Institute, *Economic and Greenhouse Gas Emission Assessment of Utilizing Energy Storage Systems in ERCOT*, 1017824, Technical Update: November 2009.

³⁵ California Energy Commission and DNV KEMA Energy & Sustainability, *DRAFT – Energy Storage Cost-effectiveness Methodology and Preliminary Results*, Public Interest Energy Research (PIER) Program, Interim/Final Project Report, Draft 3 CEC-xxx-xxxx-xxx, June 2013.

voltage and other regulation support to the distribution grid, will be evaluated as need arises. The Department anticipates the evaluation of ES, including, but not limited to, battery and flywheel systems, in various locations to be completed when a need arises, such as instability in the grid. At that time, better data will be available on the impacts on the distribution grid that ES is intended to alleviate will best support the evaluation of cost effectiveness. As stated previously, ES systems must be tested against an actual application to determine cost-effectiveness because the ability to fully utilize the options offered by an ES system is dependent on the need for those uses. The use case selected offered the best opportunity to utilize known data for modeling purposes.

For a test case, staff determined that the evaluation of the use of a battery ES system in place of a new circuit to support summer peak load conditions was a potentially viable use for ES in the near future. In order to remain technology neutral, lithium-ion, sodium-sulfur and advanced lead acid types of batteries were for cost purposes under the assumption that each would operate similarly. These three technologies were selected for their capacity and discharge characteristics and because each is commercially available. For evaluation purposes, it was assumed the ES system would be needed and installed in 2017.

Other ES system technologies such as flow batteries and liquefied-air (similar to a CAES) may also be able to be used; however, these systems are still being developed and pricing information and demonstrated operational characteristics for the test case were not available. Pumped storage was not evaluated because the systems require too much land area and are typically larger than the scale of this project. Pumped storage would be more applicable to larger (more than 5 MW) scale time-shifts of electricity. Flywheels, which operate for shorter duration and fast response times, do not provide the operational characteristics necessary for the application as they typically do not offer the discharge duration needed in this area. Flywheels are most appropriate to support high power quality and provide voltage and regulation support. Therefore, these technologies were not evaluated in this use case.

A primary challenge for this type of application will be finding the land area for the ES facility to be located on. ES devices that employ batteries are very large, and are not as small as distribution circuits which can be placed underground. For example, the batteries being evaluated in this use case will require almost 1 acre of land to accommodate about 5 trailers (approximately the size of a semi-trailer) and the associated transformers and other infrastructure. Each 1 MW battery bank is about the size of a semi-trailer, and additional area is required for the controls and transformers that will be associated with the installation. Availability and cost of land in developed areas of the City would need to be evaluated at the time of a future circuit replacement to determine feasibility; however, current land values based on recent sales are between \$800,000 to over \$2 million for an acre of commercial or industrial land. This cost would be added to the overall cost of the project.

It is important to note that the use case could also be applied in other areas of the City to augment existing infrastructure, but would need to be evaluated for each application specifically.

Use Case Project Description

The demonstration project area is expected to be in a fully developed region of Anaheim with 2,500 single and multiple-family homes, a fire station, water pump facility, an elementary school and several parks. The peak demand at project completion is forecasted to be 17 MW. In order to maintain the Department's system reliability standards, multiple 12 kV distribution circuits are required. The traditional system design would require 3 circuits with a 50% capacity at the peak load. For non-peak periods of the year, the forecast load for the development is at or below 13 MW. During peak summer months, the load is above 13 MW for up to 8 hours a day about 10 days per month.

An ES device was evaluated to take the place of the third circuit, which is only needed for a small portion of the year and would allow the City to utilize the additional functionality of the device the remainder of the year. Existing infrastructure in the area is comprised of two traditional distribution circuits and has the capacity to serve the growth area for the majority of the year; however, this existing system does not have the capacity to serve the area's demand in the peak summer months and will require the addition of a third distribution circuit for the planned growth to occur. Therefore, the primary service that the ES device would provide is electricity capacity, peak-shifting, for six months of the year.

Because this application is for a permanent installation of an ES device that will also serve load during peak periods, the commercial availability and viability of the system was important. At this time, many of the ES technologies discussed in this document are still being tested or developed. Pricing for these technologies is also still uncertain. A bank of lithium-ion (LI-ion) batteries was selected as the preferred technology. LI-ion batteries are commercially available, have been installed for such uses in other areas throughout the world, and have known publicly available price information that could be used in the evaluation. As stated previously, to remain technology neutral, sodium-sulfur and advanced lead acid battery systems are also evaluated. They are also commercially available. Of note, thermal storage was not considered for this use case because of it is difficult to anticipate that sufficient saturation of thermal storage devices in 2,500 homes would occur.

As discussed above, the system would be required to provide the additional 4 MW capacity above the available 13 MW capacity demanded during the summer months for 8 hours each day for about 10 days each month. For evaluation, the study assumes a 5 MW/20 MWh battery system, which provides a 25% margin. The system would be expected to discharge between noon and 7 p.m. each day with the peak occurring at 4 p.m. The battery would need to recharge during the remaining 17 hours of the day during the off-peak periods.

Secondary Uses

In most of the test cases identified in the literature, it is noted that it is possible that the ES system for this project could provide spinning and non-spinning reserves, frequency regulation on the distribution system, supply capacity, and arbitrage, in addition to its primary function of peak-shifting.

- **Spinning and Non-Spinning Reserves:** Spinning and non-spinning reserves are ancillary services that the Department could offer into the CAISO. They are reserves of electricity that can be called upon dispatch to ensure that they regional electric grid has sufficient electricity to serve load.
- **Frequency regulation:** Frequency regulation is used to ensure that the regional system maintains a frequency of 60 hertz. Frequency fluctuates as generation on the grid changes. Frequency regulation can also be used on the distribution to regulate the changes on the system that result from intermittent resources such as rooftop solar.
- **Supply capacity:** The electricity in the device could be sold into the CAISO market if it is not used within the City. As such, the device could also be used to fulfill resource adequacy requirements.
- **Arbitrage:** The Department could use the device to time-shift the cost of generation, charging the battery when electricity prices are lower and discharging it when prices are higher.

However, because this test case is at the end of a distribution line and not connected directly to the transmission system or CAISO, there is limited ability of the Department to use the device for ancillary services. Since the using the device for ancillary services is unlikely, arbitrage or simple energy-time shift would be the secondary use tested. If the system were installed in a different location on the distribution grid or was in a location that would also benefit from secondary uses to support the distribution grid itself, such as provision of voltage support or frequency regulation (e.g. in locations with high penetration of installed distributed and variable generation rooftop solar), the benefits of these secondary uses may contribute to the cost-effectiveness. However, the anticipated characteristics of energy usage for the type of development and deployment of roof-top solar in the area for this installation, these secondary uses would not be necessary.

System Costs and Benefits Evaluation

The costs and the benefits of the ES system were evaluated and compared against the costs and benefits of a traditional circuit. To evaluate the various options for this use case, the Energy Storage computational Tool (ESCT) Version 1.2 created by Navigant Consulting, Inc. for the U.S. Department of Energy was utilized.³⁶ Input for the model was based on information from the Department supplemented with information from the various reports and literature available as well as default values in the model itself, where appropriate.^{37, 38} Appendixes A and B provide the full model inputs and resulting outputs as well as the ESCT's User Guide.

³⁶ Navigant Consulting, Inc., *ES Computational Tool (ESCT) Version 1.2*, Prepared for the U. S. Department of energy under DOE contract DE-FE004001 Task 430.05, August 2012.

³⁷ Sandia National Laboratories, *DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA*, SAND2013-5131, July 2013.

³⁸ Electric Power Research Institute, *Cost-Effectiveness of Energy Storage in California: Application of the EPRI Energy Storage Valuation Tool to Inform the California Public Utility Commission Proceeding R. 10-12-007*, 3002001162: Technical Update, June 2013.

A traditional, underground circuit, located along with the existing two circuits would be about \$1.3 million with annual operations and maintenance costs of between \$20,000 and \$30,000. The circuit would only provide capacity for the peak load in the area as demanded. The cost of the circuit, as well as operating and maintenance costs, and interest rates were based on Department costs for similar improvements.

As described above, the ES system is expected to be a bank of five, 1-MW batteries. Table 6 shows the cost estimates used for the evaluation. This price includes the costs of the system itself, installation of the system controls, training, and permitting. No land costs were assumed in this evaluation as it would be highly situational and there may be land available in this area. It should be noted that this price is highly variable and relies on comparisons of current projects. Other costs included financing costs and operating costs. The operational characteristics of each battery, including efficiencies and replacements were also considered in the evaluation.

Table 5: Use Case ES System Cost Estimates³⁹

	Lithium-Ion	Sodium-Sulfur	Advanced Lead Acid
Costs			
Total Installed Cost Estimate	\$22,101,310	\$17,171,780	\$26,672,165
Average Annual O&M Costs	\$56,000	\$50,000	\$51,000
Replacement Costs	\$1,000,000	\$0	\$363,000
Decommissioning and Disposal⁴⁰	\$900,000	\$825,000	\$737,500
Device Characteristics			
Nameplate Power Output	5 MW	5 MW	5 MW
Capacity	20 MWh	20 MWh	20 MWh
Response Time	.001 sec	.001 sec	.001 sec
Round-trip Efficiency	90%	75%	90%
Expected Life	15 years	15 years	15 years
Cycle life	365 / year	365 / year	365 / year

** Land for the facility would cost an additional \$800,000 to \$2 million.

Other factors input in the model include the following information:

- Fixed-charge rate for annualized cost of deployment: 4.5%
- Average inflation rate: 2.5%
- Average year-over-year demand growth on the distribution grid: 0.5%

³⁹ ES system cost information derived from Sandia National Laboratories, *DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA*, SAND2013-5131, July 2013.

⁴⁰ Default model values. Navigant Consulting, Inc., *ES Computational Tool (ESCT) Version 1.2*, Prepared for the U. S. Department of energy under DOE contract DE-FE004001 Task 430.05, August 2012.

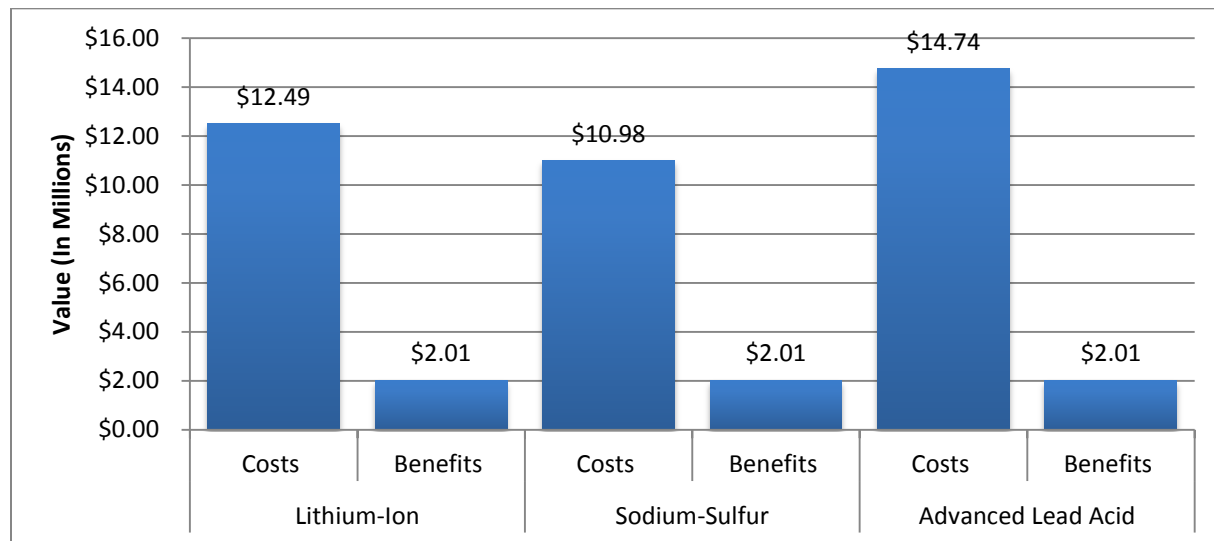
The benefits of the system included the deferral/replacement of the investment that would have been made for the distribution circuit and the electricity sales (balance sales of electricity – charging costs).

Table 6: Summary Use Case Analysis Costs and Benefits in Net Present Value

	Lithium-Ion		Sodium-Sulfur		Advanced Lead Acid	
	Costs	Benefits	Costs	Benefits	Costs	Benefits
Capital Expenditure	\$10.68		\$8.29		\$12.89	
Operating Costs	\$1.45		\$2.25		\$1.45	
Decommissioning and Disposal	\$0.36		\$0.44		\$0.40	
Distribution Deferral		\$0.95		\$0.95		\$0.95
Electricity Sales		\$1.06		\$1.06		\$1.06
Total	\$12.49	\$2.01	\$10.98	\$2.01	\$14.74	\$2.01
Benefit/Cost Ratio	0.16		0.18		0.14	

For this use case, none of the battery ES systems evaluated was shown to be a cost-effective alternative to the traditional circuit infrastructure (Table 6). While there was benefit from the shift from peak of off-peak energy costs for arbitrage, the benefits were minimal when compared with the initial costs of the various batteries (Figure 8). In all cases, the benefit to cost ratio was less than 0.2 when we were seeking a ratio of 1 or greater.

Figure 8: Costs and Benefits Results for Use Case



Conclusions from the Use Case Analysis

For all three technologies evaluated in this use case, the use of any of the ES systems is technologically viable but would not be cost-effective. As mentioned previously, these technologies were selected because they have the operational characteristics to provide the services needed in this use case. Other ES technologies were not evaluated because they

were either not commercially available or did not have the operational characteristics needed for this application.

The limited secondary benefits in this specific situation were not sufficient over the life of the batteries to compensate for the high initial costs. For the ES systems to be more cost-effective, a different location that could better utilize any secondary benefits of the ES system could help to offset costs; however, it is the high initial cost of the systems that is the most difficult issue to overcome to demonstrate cost-effectiveness for this situation which required a long (up to 8 hour) discharge time.

As discussed above, however, the costs and benefits will be highly situational. It is expected that as more energy storage technology is developed, the costs for ES systems will likely decrease. Costs, which currently are high for all ES, are expected to decrease as there is further development of existing and new technologies, such as flow batteries, flywheels, and others, are developed and become commercially available. Therefore, ES systems will be evaluated in the future for use in the City for these and other types of uses. A reevaluation of this use case, in particular, may be completed at the time that the circuit upgrade is needed to determine if an ES system could be effectively used.

Section 4: Findings and Conclusions

AB 2514 required the Department to determine appropriate targets, if any, to procure viable and cost-effective energy storage. As part of the process, the City Council could consider 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. When considering the potential adoption of procurement targets, viability and cost-effectiveness were to be the main factors in making the determination.

To this end, the Department has evaluated its transmission, distribution and customer resources. Additionally, staff reviewed the current technological services, availability, and costs for ES systems. Based on this evaluation and research, the following findings are made:

1. **ES is not cost effective for most applications at this time:** Many ES technologies that are relatively new, such as battery systems, are expensive. For example, one 5 Megawatt (MW) system installed at a substation would cost approximately \$20M. This is the amount of the Department's annual routine capital program (replacement of wires, transformers, switches, etc.), and would require a 6% rate increase or issuance of additional bonds. Since ES systems do not replace existing infrastructure, this would be an added cost to Anaheim ratepayers. In the City, only thermal ES technologies have been cost effective for customers under specific circumstances.
2. **Because the City is essentially built-out, siting ES systems will be difficult:** ES technologies are space intensive and difficult to site in urban settings such as Anaheim. As an example, a 5 MW battery system would require enough space to house 5 semi-trailer sized containers, in addition to all the wiring and balance of plant to connect the batteries to a substation. Limited space is available at the Department's existing substations. Finding locations in areas that are best suited to ES systems, such as in West or Central Anaheim where there is a higher density of electric demand would be difficult and costly because of the need to purchase parcels of land.
3. **Peak reduction is a one of the primary uses for ES systems but has already been addressed by the Department with the construction of the Canyon Power Plant:** One of the key benefits of ES is that it addresses shortfalls in energy supply and allows a utility to call upon it when needed; however, the Department has Canyon Power Plant which effectively performs the same function with many other benefits of reducing California Independent System Operator (ISO) fees, providing local and regional grid support, and the ability to bid into the wholesale energy market.

4. **Use of ES systems to improve reliability is not currently needed by the Department:** The Department already has a prominent track record of high system reliability, and has been recognized as a Reliable Public Power Provider (RP3) by the American Public Power Association since 2006. The installation of ES would have a marginal impact. As an example, ES installed at a substation would help if a broader supply issue occurred; however, those incidents are uncommon, and the more routine outages that occur due to vehicles hitting utility poles or tree branches getting caught in utility lines would not be mitigated by an ES at a substation. Customer who wish to increase their reliability already have business justifications for the higher costs and are free to invest in backup systems, generators, or Uninterruptible Power Supplies (UPS) without a utility procurement target.
5. **Many ES technologies are still maturing:** For example, battery systems have been available for many years at locations such as data centers. As additional utility applications are identified, research and innovation will continue to improve the technology and the associated costs will decrease over time. And, the corresponding safety concerns such as batteries catching on fire will need to be addressed by manufacturers. The Department will continue to support customers who wish to install systems to reduce their peak demand, and already offers time-based rates to encourage this behavior in lieu of prescribed targets of ES procurement.

From the findings above, the Department concludes the following:

1. Adoption of procurement targets for either the December 31, 2016 or the December 31, 2021 time periods is premature at this point based on the findings related to costs and viability;
2. Since technology improvements will continue to be made given mandates for investor-owned utilities to invest in ES systems, the Department will closely monitor other utility projects; and,
3. The Department will continue to offer customer choice programs such as time-based rates that encourage shifting energy consumption to off-peak hours.

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