AB 2514 Energy Storage Systems Evaluation

September 12, 2017

PASADENA
Water&Power

PASADENA
Water&Power

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report is to re-evaluate and update Pasadena Water and Power's ("PWP") October 1, 2014 analysis ("2014 Report") on energy storage systems. This is required by California Assembly Bill 2514 ("AB2514").

AB2514 requires that California Publicly Owned Utilities ("POU"), by October 1, 2014 and October 1, 2017, evaluate the potential to procure viable and cost-effect energy storage systems and that their governing bodies (the Pasadena City Council, in the case of PWP) set appropriate procurement targets for energy storage systems to be procured by December 31, 2016 and December 31, 2021. The law further directs POUs to follow up with triennial re-evaluations of energy storage options.

For the 2014 Report, Staff at PWP with the concurrence of the City Council found that at that time the available energy storage technologies were still not cost effective nor did any fulfill an existing or anticipated unmet need as needed for PWP to comfortably plan for implementation by 2016 or 2021. The findings for 2017 are the same. Staff recommends a 0 MW procurement target for energy storage.

It is important to note that since PWP's initial report in 2014, changes and improvements in the various technologies for energy storage occurred. As well, changes in the makeup of electricity resources due to ratcheting RPS targets, new Greenhouse Gas ("GHG") targets, increasing energy efficiency, and declining electricity usage have occurred. Some southern California POUs, such as Glendale, LADWP and IID have moved forward with either installations or planned installations of pilot programs for energy storage systems. The pilot programs are to explore the possibility of incorporating energy storage within their systems, in the long run. It is important to note that both LADWP and IID are part of their own balancing authority ("BA") and energy storage systems can have more of an impact when POUs control their own BA. Additionally, Glendale is part of LADWP's BA. Since PWP is part of the California Independent System Operator ("CAISO") BA, it is less dependent on energy storage systems to shape load or assist in renewable integration. Further research on energy storage and an in depth analysis will be considered as part of the 2018 integrated resource plan (IRP).

The focus of this report ("2017 Report") is to provide the results of Staff's analysis of various energy storage technologies, as they have evolved since 2014.

ASSEMBLY BILL 2514

DEFINITION OF ENERGY STORAGE SYSTEM (REVIEW)

According to AB 2514, the term "energy storage system" means commercially available technology that is capable of absorbing energy, storing it for a period of time, and thereafter dispatching the energy.

An "energy storage system" may be either centralized or distributed. It may be either owned by a load-serving entity or local publicly owned electric utility, a customer of a load-serving entity or local publicly owned electric utility, a third party, or jointly owned by two or more of the above.

An "energy storage system" must be *cost effective* and:

- Reduce emissions of greenhouse gases,
- 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.

An "energy storage system" must do one or more of the following:

- 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.

ENERGY STORAGE TECHNOLOGIES- WHAT'S NEW

The 2014 Report[1] to the Commission included comprehensive descriptions of the various energy storage technologies available or projected to be available soon. The technologies studied as part of the 2014 Report and 2017 Report are:

- Compressed Air Energy Storage ("CAES") Above Ground
- CAES Below Ground
- Pumped Hydro Storage
- Flywheels
- Advanced Lead-Acid Batteries
- Lithium-Ion Batteries
- Flow Batteries

Table 1 below, summarizes the information for these technologies.

---

1 http://www.energy.ca.gov/assessments/ab2514_reports/City_of_Pasadena/AB2514_energy_storage_systems_evaluation.pdf

Table 1
Summary of Technologies

Technology	Primary Application	Current Benefits	Current Challenges
Compressed Air Energy Storage (CAES)	• Energy management • Backup and seasonal reserves • Renewable integration	• Better ramp rates than gas turbine plants • Established technology in operation since the 1970's	• Geographically limited • Lower efficiency due to roundtrip conversion • Slower response time than flywheels or batteries • Environmental impact
Pumped Hydro	• Energy management • Backup and seasonal reserves • Regulation service also available through variable speed pumps	• Developed and mature technology • Very high ramp rate • Currently most cost effective form of storage	• Geographically limited • Plant site • Environmental impacts • High overall project cost • Large footprint
Fly wheels	• Load leveling • Frequency regulation • Peak shaving and off peak storage • Transient stability	• Modular technology • Proven growth potential to utility scale • Long cycle life • High peak power without overheating concerns • Rapid response • High round trip	• Rotor tensile strength limitations • Limited energy storage time due to high frictional losses
Advanced Lead-Acid Batteries	• Load leveling and regulation • Grid stabilization	• Mature battery technology • High recycled content • Good battery life	• No utility scale deployments • Low energy density • Large footprint • Electrode corrosion limits the useful life
Sodium-Sulfur Batteries (NaS)	• Power quality • Congestion relief • Renewable source integration	• High energy density • Long discharge cycles • Fast response • Good scaling potential	• Operating Temperature between 250° and 300° required • Liquid containment concerns (corrosion and brittle glass seals)
Lithium-ion Batteries (Li-ion)	• Power quality • Frequency regulation	• High energy density • Good cycle life • High charge/discharge efficiency	• High production cost • Extremely sensitive to high temperatures, overcharge and internal pressure buildup • Environmental impacts unknown
Flow Batteries	• Ramping • Peak shaving • Time shifting • Frequency regulation • Power quality	• Ability to perform a high number of discharge cycles • Lower charge/discharge efficiencies • Long life	• No utility scale deployments • Complicated design • Low energy density
Superconducting Magnetic Energy Storage (SMES)	• Power quality • Frequency regulation	• Highest round-trip efficiency from discharge energy density	• Low energy density • High material and manufacturing costs
Electrochemical Capacitors	• Power quality • Frequency regulation	• Very long life • Highly reversible and fast discharge	• High cost
Thermochemical Energy Storage (TES)	• Power quality • Frequency regulation	• Extremely high energy densities	• High cost

Since the 2014 Report was submitted, additional storage technologies have emerged showing promise to bring cost effective energy storage to the market. However, the energy storage resources listed above are the few with enough data to run an analysis. Overall, for the 2017 Report, the same technologies were modeled, with updates to their installation, maintenance and disposal costs.

TYPICAL ENERGY STORAGE APPLICATIONS/USES

As explained in detail in the 2014 Report, energy storage can have several benefits to any utility (assuming cost effectiveness requirements can be met):

- Electric Energy Time-Shift
- Electric Supply Capacity
- Ancillary Services
- Distribution Infrastructure Services
- Customer Energy Management Services
- Stacked Services—Use Case Combinations

Energy storage can be used for any of the services listed above, but it is rare for a single service to generate sufficient revenue to justify its investment. How these services are stacked or combined depends on the location of the system within the grid and the storage technology used. However, due to regulatory and operating constraints, stacking services is a process that requires careful planning and should be considered on a case-by-case basis. Table 2, below provides analysis on the applications for energy storage systems

Table 2
Navigant Summary of Technologies/Applications

	Economic										Reliability			Environmental		
	Market Revenue			Asset Utilization					Efficiency	Cost	Interruptions		Air		Water
Applications	Arbitrage Revenue	Capacity Revenue	Ancillary Service Revenue	Optimized Generator Operation	Reduced Congestion Cost	Deferred Generation Capacity Investments	Deferred Transmission Capacity Investments	Deferred Distribution Capacity Investments	Reduced Electricity Losses	Reduced Electricity Cost	Reduced Outages	Improved Power Quality	Reduced CO_2 Emissions	Reduced SO_x, Nox, and Particulate Emissions	Reduced Water Use
Electricity Cost Optimization															
Energy Arbitrage	X			X	X	X	X	X	X	X			X	X	X
Demand and PF Charge Management				X	X	X	X	X	X	X			X	X	X
Renewable Energy Shifting	X			X	X	X	X	X	X	X			X	X	X
Capacity															
Generation Resource Adequacy		X	X	X		X							X	X	X
T&D Infrastructure Adequacy				X	X	X	X	X	X	X			X	X	
Routine Grid Operations															
Frequency Regulation			X	X		X							X	X	X
Voltage/VAR Support												X			
Renewable Energy Ramping				X		X							X	X	X
Renewable Energy Smoothing				X									X	X	X
Contingency Situations															
Black Start			X			X									
Sustained Outages											X				
Momentary Outages												X			

PASADENA Water&Power

CITY OF PASADENA INCORPORATED JUNE 1886

PWP ANALYSIS

SCPPA ENERGY STORAGE WORKING GROUP

PWP continues to participate in the Southern California Public Power Authority ("SCPPA") Energy Storage Working Group. As well, PWP, through SCPPA's Request for Information ("RFI") process, continues to seek energy storage proposals, as stand-alone projects or part of intermittent renewable energy resource procurements. To date, such joint renewable/storage systems have pushed the cost of those projects' power to unjustifiably high levels and therefore result in PWP rejecting such projects.

CAISO AND ENERGY STORAGE

The CAISO continues to partner with parties to identify the best uses and implications for energy storage technologies. The CAISO's Stakeholder Process[2] includes analysis on energy storage and its implications to the CAISO grid. The Stakeholder Process started in 2012, with new updates as of June 2017. PWP will continue to monitor the CAISO activities to better understand the energy storage applications in the CAISO market, with particular attention to energy storage for reliability and renewable integration purposes.

ENERGY STORAGE MODELING TOOL

Through the SCPPA Energy Storage Working Group, PWP has chosen to use the Navigant SCPPA Energy Storage Tool, V.2.1b ("ES Tool"). Version 2.1b of the ES Tool provides a framework for evaluating potential energy storage costs and benefits depending on system characteristics (e.g., location on the grid, regulatory structure, and owner). The ES Tool is based on Microsoft Excel and takes advantage of Navigant's market price database, expertise in energy markets, and the latest in energy and storage costs.

Similar to 2014, the user enters the project location, owner, regulatory environment and technology type. Next, the user enters information such as installed cost, operation and maintenance costs, round trip efficiency, and cycle life. Default values are available for many of these inputs, depending on the selected technology. However, PWP replaces as many of these default values with values collected from PWP operations. After selecting which applications to analyze, the user is prompted to enter inputs to help calculate benefits, such as amount of energy storage dispatched by application, market prices and rate structures. It should be noted that "application" refers to the market application, such as load shifting, Ancillary Services, etc., and not to the technology types. Finally, the user has the option of selecting to run various scenarios. After inputting all the necessary information, the tool presents the net present costs and benefits of the project.

2
https://www.caiso.com/informed/Pages/StakeholderProcesses/EnergyStorage_DistributedEnergyResourcesPhase2.aspx

PWP considered the various technologies and functions that energy storage can provide, and narrowed the list to those that PWP believed would have the highest potential viability and best fit for PWP by 2021. The ES Tool is capable of modeling fifteen (15) different energy storage technologies, seven of which were selected by PWP as commercially viable for Pasadena's needs. In order to "level the playing field" between the different technologies, staff standardized all of the energy storage technologies to a 20 MW capacity model, and all costs, outputs, and revenues were scaled accordingly. The 20 MW size was chosen because it seemed to be an applicable energy storage size given the mix of PWP's contracted renewable technologies (for renewable integration), this is the maximum size that can be developed given the limited number of available locations/vacant lots for energy storage within city limits, for economies of scale (the installation costs are lower as the size increases), to alleviate some of PWP's monthly flexible resource adequacy capacity requirements, to maximize market opportunities for ancillary services sales, and to maximize opportunities with the current price differentials between off-peak and on-peak power. It is possible for PWP to consider larger or smaller projects. If PWP considers a larger storage project, it would take an appropriate share, similar to how PWP handles renewable projects through SCPPA. However, as mentioned earlier, larger projects would require financing and relying on equal cost share with partners.

Table 3 lists the technologies and costs that were modeled by PWP using the ES Tool, including Compressed Air Energy Storage (above and below ground), Pumped Hydro Storage, Flywheel Energy Storage, Advanced Lead Acid Batteries, Lead Batteries and Lithium Ion Batteries.

Table 3
Investigated Technology List for Projects Scaled to 20MW (ES Tool)

Inputs	Lead Acid	Advanced Lead Acid	Lithium Ion	Flywheel	Pumped Hydro	CAES Above Ground	CAES Below Ground
Nameplate Power Output (MW)	20	20	20	20	20	20	20
Nameplate Energy Storage Capacity (MWh)	40	40	46 67	5	186 67	200	200
Response Time (s)	001	001	001	001	60	60	60
Nameplate round-trip efficiency	88%	90%	94%	85%	81%	90%	90%
Nameplate calendar life (yrs.)	20	20	20	20	20	20	20
Expected lifetime (yrs.)	20	20	20	20	20	20	20
Total installed cost ($)	$75,427,200	$42,240,000	$46,989,333	$26,535,600	$26,540,000	$42,053,333	$13,146,667
Average O&M Costs not related to energy ($/yr.)	$730,600	$545,530	$606,867	$245,700	$112,000	$300,000	$300,000
Expected Decommissioning costs	$34,000,000	$4,060,800	$35,096,920	$14,393,333	$2,004,167	$2,349,756	$2,306,784
Installed Cost per kw ($/kW)	**$3,771**	**$2,112**	**$2,349**	**$1,327**	**$1,327**	**$2,103**	**$657**

PWP compared some of the ES Tool findings to another SCPPA vendor, Det Norske Veritas and Germanischer Lloyd ("DNV GL"). DNV GL provides advisory services for various energy market analyses, including energy storage. Table 4 shows DNV GL Study and analysis concerning Energy Storage costs as commissioned by SCPPA. Clearly, the ranges for installed costs ($/kW) vary, depending on energy storage size and type. Pumped Hydro was not included in their analysis. Overall, in both cases, the $/kW is quite high, especially compared to existing PWP generation resources.

Table 4
Investigated Technology List for Projects (SCPPA- DNV GL Study)[3]

Technology [1]	Lithium-Ion NCM	Lithium-Ion LFP	Lithium-Ion LTO	Vanadium Redox Flow Battery ("VRB")	Flywheel	CAES	TES
Size (kW)	20,000	20,000	20,000	20,000	20,000	100,000	50
Duration (Hour)	2	2	2	4	25	24	6
Total Installed Costs($)	$33,800,000	$35,800,000	$45,300,000	$78,750,000	$48,150,000	$136,000,000	$129,500
Installed costs ($/kW)	**$1,690**	**$1,790**	**$2,265**	**$3,938**	**$2,408**	**$1.360**	**$2,590**

The ES Tool can evaluate up to sixteen (16) applications for each energy storage technology. Applications which serve a common purpose were bundled into one of four scenarios to maximize the potential savings and/or revenues from each technology option. The applications and scenarios are summarized in Table 5 below. Analysis was focused on Scenarios 1 through 4, which evaluate transmission and generation level energy storage systems.

Table 5
Energy Storage Applications and Scenarios (ES Tool)

SCENARIOS	APPLICATIONS
Scenario 1 **Electricity Cost Optimization**	1. Energy Arbitrage 2. Renewable Energy Shifting
Scenario 2 **Capacity**	3. Operating Reserve Ancillary Service 4. Wholesale Capacity Market
Scenario 3 **Routine Grid Operation**	5. T&D Infrastructure Adequacy 6. Frequency Regulation
Scenario 4	7. Voltage/VAR Support 8. Renewable Energy Ramping 9. Renewable Energy Smoothing 10. Black Start

[3] Det Norske Veritas and Germanischer Lloyd (DNV GL), ES Study for NCPA and SCPPA, May 2017.

The results of the ES Tool modeling are summarized in Table 6 below.

Table 6
Energy Storage Net Benefit for Projects Scaled to 20 MW

Scenario #	Scenario Name	Details	Lead Acid	Advanced Lead Acid	Lithium Ion	Flywheel	Pumped Hydro	CAES Above Ground	CAES Below Ground
1	**Energy Cost Optimization**	**Payback (yrs)**	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Net Benefit($/KWh)	-$ 304	-$ 128	-$ 1627	-$ 7505	-$ 0169	$ 0225	$ 0104
2	**Capacity**	**Payback (yrs)**	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Net Benefit($/KWh)	$0 317	-$0 147	-$0 188	-$0 786	-$0 015	-$0 026	-$0.0071
3	**Routine Grid Operation**	**Payback (yrs)**	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Net Benefit($/KWh)	$0 250	-$0 080	-$0.130	-$0 7256	-$0 0135	-$0.013	-$0 0056
4	**Contingency Situations**	**Payback (yrs)**	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Net Benefit($/KWh)	$0 331	-$0 1606	-$0.1995	-$0.8947	-$0.0180	-$0 0290	-$0 0099

Adjusting for the appropriate uses for energy storage, as applied to PWP, no technology had a positive benefit-to-cost ratio. Generally, to be cost effective, the energy storage project must have a benefit-to-cost ratio ≥ 1, indicating that the net present value ("NPV") of the project benefit outweighs the NPV costs. However, a few technologies were close. Pumped Hydro had the highest benefit-to-cost ratio at .78, meaning that the expected benefits of Pumped Hydro are $.78 for each $1 of its cost. Simply put, PWP would not recoup its investment in Pumped Hydro projects, at this time. In addition, according to the Department of Energy Global Energy Storage Database ("DOE Database")[4] the existing Pumped Hydro facilities in California are older and much larger than the scale needed for PWP. For details on these Pumped Hydro facilities, please refer to Table 7, below.

Lithium-ion Batteries had the second highest benefit-to-cost ratio at .75, meaning that the expected benefits of Lithium-ion Batteries are $.75 for each $1 of its cost and PWP would not recoup its investment. Lithium-ion Batteries are becoming popular, but there is not enough history to analyze the success of those installations at the scale needed for PWP. In fact, according to the DOE Database, there have only been four installations of Lithium-ion batteries above 10 MW. These were all installed in 2016 or 2017. For details on these Lithium-ion Battery installations, please see Table 8, below. Though they are not cost-effective, an extensive analysis of Lithium-ion Batteries and Pumped Storage will be modeled as part of the 2018 IRP.

[4] https://www.energystorageexchange.org/

Table 7
DOE Database (Pumped Hydro Installed)[5]

Facility Name	City	Utility	Utility Type	MW	Commissioning Date (or planned)
Edward Hyatt(Oroville) Power Plant	Oroville, CA	Pacific Gas & Electric (PG&E)	Investor Owned Utility (IOU)	819	1/1/67
San Luis Pumped Hydro Power Plant	Gustine, CA	NA	NA	424	1/1/68
Thermalito Pumping Generating Plant	Oroville, CA	PG&E	IOU	120	1/1/69
Castaic Pumped-Storage Plant	Pyramid Lake, CA	Los Angeles Department of Water and Power (LADWP)	Publicly Owned Utility (POU)	1,247	1/1/73
O-Neill Pumped-Generating Plant	Los Banos, CA	NA	NA	25 2	1/1/73
Helms Pumped Hydro Plant	Fresno County, CA	PG&E	IOU	1,212	6/30/84
Big Creek Pumped Storage	Shaver Lake, CA	Southern California Edison (SCE)	IOU	199 8	1/1/87
Olivehain-Hodges Storage Project	Escondido, CA	San Diego Gas & Electric (SDG7E)	IOU	40	9/14/12
Eagle Mountain Pumped Storage Project	Desert Center, CA	NA	NA	1,300	Contracted
Lake Elsinore Advanced Pumped Storage	Lake Elsinore, CA	NA	NA	500	TBD
San Vicente Pumped Storage	San Vicente, CA	NA	NA	500	TBD

Table 8
DOE Database (Lithium-Ion Batteries Installed>10MW)[6]

Facility Name	City	Utility	Utility Type	MW	Commissioning Date
SCE LM6000 Hybrid EGT – Center	Norwalk, CA	Southern California Edison (SCE)	Investor Owned Utility (IOU)	10	3/30/17
SCE LM6000 Hybrid EGT – Grapeland	Rancho Cucamong a	SCE	IOU	10	4/3/17
Escondido Energy Storage	Escondido, CA	San Diego Gas & Electric (SDG&E)	IOU	30	3/24/16
Imperial Irrigation District BESS - GE	El Centro, CA	Imperial Irrigation District (IID)	Publicly Owned Utility (POU)	30	10/1/16

[5] https://www.energystorageexchange.org/
[6] https://www.energystorageexchange.org/

Overall, based on work completed to date, PWP has not identified any viable energy storage technologies that are cost-effective at a scale that is practical for PWP at this time. The energy storage industry is still evolving, and cost-effectiveness expected to improve rapidly over the coming years. PWP will continue to monitor the situation and continue to provide updates as conditions warrant. Additionally, energy storage will be modeled as part of the 2018 IRP process.

RECOMMENDATIONS

PROCUREMENT TARGETS

PWP recommends that the City Council establish a 0 MW energy storage system procurement target to be achieved by December 31, 2021. Even though energy storage technologies have improved over the past three years, they still do not provide the level of cost-effectiveness and guaranteed viability desired by PWP.

ONGOING EVALUATION

As storage technologies continue to evolve and improve and as the State's power mix transitions to a greater percentage of renewable resources, the need and ability to implement energy storage to maximize the benefits of those renewable resources will grow. Towards that end, PWP staff will continue to look for appropriate opportunities for energy storage systems as it executes its 2018 IRP and procures future renewable and conventional energy. PWP staff will continue to work with the SCPPA to evaluate various energy storage technologies through solicitation of proposals for energy storage systems as standalone offers as well as in conjunction with renewable and conventional energy projects.

PWP will reevaluate the issue of energy storage system procurement targets and policies with the City Council at least once every three years.

CEC REPORTING

PWP will report to the California Energy Commission ("CEC") regarding energy storage system procurement targets and policies adopted by the City Council.

If the City Council adopts any energy storage system procurement targets or policies to encourage the cost effective deployment of energy storage systems, then by January 1, 2022, PWP will submit a report to the CEC demonstrating that it has complied with the energy storage system procurement targets, if any, and policies adopted by the City Council. This report, with confidential information redacted, will be made available to the public by being published by the CEC and/or PWP on their respective websites.

REFERENCES

- Department of Energy, *Global Energy Storage Database,* website, http://www.energystorageexchange.org/
- California Public Utilities Commission ("CPUC") Order Instituting Rulemaking ("OIR") 10-12-007 Pursuant to Assembly Bill 2514 to Consider Adoption of Procurement Targets for Viable and Cost-Effective Targets for Energy Storage Systems, Decision 13-10-040, issued October 17, 2013
- Greentech Media, *Storage Costs Come Down Across Technologies and Applications According to Lazard Report*, website, https://www.greentechmedia.com/articles/read/energy-storage-costs-lcos-lazard-lithium-ion-flow-batteries, December 19, 2016.
- Det Norske Veritas and Germanischer Lloyd (DNV GL), ES Study for NCPA and SCPPA, May 2017.

Attachment 2: List of Comparable Energy Storage Projects in California [DOE Database]

#	Project Name	Technology Type	Rated Power in kW	Duration	Status	City	Commissioning Date	ISO/RTO	Utility	Utility Type
1	Eagle Mountain Pumped Storage Project	Closed-loop Pumped Hydro Storage	1,300,000	n/a	Contracted	Desert Center		CAISO		
2	Castaic Pumped-Storage Plant	Open-loop Pumped Hydro Storage	1,247,000	10 0	Operational	Pyramid Lake	1/1/1973	N/A	Los Angeles Department of Water and Power	Public Owned
3	Helms Pumped Hydro Storage Project	Open-loop Pumped Hydro Storage	1,212,000	n/a	Operational	Fresno County	6/30/1984	CAISO	Pacific Gas & Electric (PG&E)	Investor Owned
4	Edward Hyatt (Oroville) Power Plant	Open-loop Pumped Hydro Storage	819,000	n/a	Operational	Oroville	1/1/1967	CAISO	Pacific Gas & Electric (PG&E)	Investor Owned
5	*Lake Elsinore Advanced Pumped Storage*	*Closed-loop Pumped Hydro Storage*	*500,000*	*12.0*	*Announced*	*Lake Elsinore*		*CAISO*		
6	*San Vicente Pumped Storage*	*Closed-loop Pumped Hydro*	*500,000*	*8 0*	*Announced*	*San Vicente*		*CAISO*		
7	San Luis (William R Gianelli) Pumped Storage Hydroelectric	Open-loop Pumped Hydro Storage	424,000	298.0	Operational	Gustine	1/1/1968	CAISO		
8	*PG&E Advanced Underground Compressed Air Energy*	*Compressed Air Storage*	*300,000*	*10*	*Announced*	*San Joaquin Co*	*01.01.2020*	*CAISO*	*Pacific Gas & Electric (PG&E)*	*Investor Owned*
9	Big Creek (John S. Eastwood) Pumped Storage	Open-loop Pumped Hydro Storage	199,800	17.67	Operational	Shaver Lake	1/1/1987	CAISO	Southern California Edison	Investor Owned
10	Thermalito Pumping - Generating Plant	Open-loop Pumped Hydro Storage	120,000	n/a	Offline/Under Repair	Oroville	01.01.1969	CAISO	Pacific Gas & Electric (PG&E)	Investor Owned
11	Olivenhain-Hodges Storage Project	Open-loop Pumped Hydro Storage	40,000	6 0	Operational	Escondido	9/14/2012	CAISO	San Diego Gas & Electric (SDG&E)	Investor Owned
12	*Escondido Energy Storage*	*Lithium-ion Battery*	*30,000*	*4 0*	*Operational*	*Escondido*	*3/24/2016*	*CAISO*	*San Diego Gas & Electric (SDG&E)*	*Investor Owned*
13	Imperial Irrigation District BESS - GE	Lithium-ion Battery	30,000	0.67	Operational	El Centro	10/1/2016	IID	Imperial Irrigation District	Public Owned
14	Modesto Irrigation District - Primus Power	Flow Battery	28,000	4 0	Offline/Under Repair	Modesto		BANC	Modesto Irrigation District	Public Owned
15	O'Neill Pump-Generating Plant	Open-loop Pumped Hydro Storage	25,200	n/a	Operational	Los Banos	1/1/1973	CAISO		
16	*20 MW / 80 MWh - Energy Nuevo - Amber Kinetics*	*Flywheel*	*20,000*	*4.0*	*Contracted*	*Fresno*	*01.05 2020*	*CAISO*	*Pacific Gas & Electric (PG&E)*	*Investor Owned*