To: Honorable Public Utilities Board

Submitted by: ________/s/_________
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Approved by: ________/s/__________
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Subject: By Motion, Accept the Report Findings that Energy Storage Systems are Not Currently Viable and Cost-Effective for Alameda Municipal Power

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RECOMMENDATION

By motion, staff recommends that the Public Utilities Board (Board) accept this report and its finding that energy storage systems are not currently viable or cost-effective for Alameda Municipal Power (AMP) and that procurement of energy storage systems be deferred until further justified. It is also recommended that the Board direct the general manager and staff to conduct a follow-up review of energy storage systems economics and applicability for AMP and report back to the Board regarding the updated information every two years. The purpose of the subsequent review shall be to re-evaluate the procurement of energy storage systems based on more recent information and recommend an appropriate procurement target, should one be justified.

BACKGROUND

On March 19, 2012, the Board directed the general manager to initiate a process to determine appropriate procurement targets of viable, cost-effective energy storage systems, if any, to be achieved by December 31, 2016, and December 31, 2021, and report back to the Board the results of the effort and any recommendations appropriate for Board consideration and potential adoption, by October 1, 2014. The Board also directed that recommendations regarding energy storage procurement targets be reevaluated every three years.

The Board's action was taken in response to California Assembly Bill (AB) 2514, legislation aimed at encouraging electric utilities to "determine appropriate targets, if any, for the utility to procure viable and cost-effective energy storage systems." Energy storage systems are defined in the legislation to be "commercially available technology that is capable of absorbing energy, storing it for a period of time, and thereafter dispatching the energy." Furthermore, to be viable, the energy storage system must "be cost-effective and either 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."

DISCUSSION

Staff has reviewed energy storage systems literature including studies and documents produced by industry organizations, government agencies, and product vendors on the current cost and viability of various forms of energy storage technologies. Staff has also evaluated the economics of providing energy storage services to the California grid in conjunction with AMP's loads and resources to determine the applicability of such systems in Alameda. The following sections summarize the pertinent points from these assessments and provide staff's conclusions.

Energy Storage Technologies

Energy storage technologies have come into favor in recent years, mainly because of the growth in existing and planned renewable technologies that are intermittent in nature. Technologies such as wind turbines and solar photovoltaics are poised to contribute substantially to meeting California's renewable portfolio standards goals. However, the widespread acceptance and use of these intermittent technologies is hindered by their inability to provide power when the wind is not blowing or the sun is not shining. Adoption of energy storage systems is intended to mitigate the impact of this intermittency and provide other valuable services as expanded upon below.

There are numerous energy storage technologies related to electric utility applications, each with a different set of characteristics. These include the following major energy storage technologies:

- **Pumped Storage Hydro**: This technology stores the potential energy of water by pumping and storing it at a higher elevation and using it later to generate electricity. Pumped storage facilities are generally more economical and have by far the greatest penetration in terms of grid connected megawatts of plant in service. However, potential sites are limited, projects are typically large in scale, and they are usually located remote from load centers.

- **Compressed Air Storage**: These systems are capable of the long-duration storage of energy by compressing air and can be relatively cost-effective, especially as below ground storage. However, these systems are restricted to unique geographical locations, such as underground caverns, that are not likely to be found in or around the City of Alameda.

- **Mechanical Flywheels**: This type of storage system utilizes a rotating mechanical device to store rotational energy and is a relatively new technology with limited discharge durations and high costs. Flywheels can be rapidly charged and discharged, making them ideal for providing short and quick bursts of power and would most likely be used for frequency regulation in the future.

- **Capacitors:** Capacitors store energy in an electric field between two separated statically charged plates. Unlike batteries, charging does not involve a chemical reaction, and capacitors, like flywheels, can be charged and discharged quickly, making them ideal for short-term power supply.

- **Thermal Energy Storage**: In the electric sector, thermal energy storage is generally focused on cooling end uses downstream at the end-use customer site. The system converts electrical energy to thermal, typically by cooling a large medium such as water. This medium is later used to provide cooling for a customer site. Thermal energy storage is likely of limited interest in Alameda because of the city's mild climate and minimal air conditioning use.

- **Batteries**: Batteries are perhaps the most promising energy storage technology. There are many traditional and emerging battery technologies (lead-acid, nickel, lithium-ion, sodium-sulfur) that are expected to decline in price as utilization increases. As a result, staff's investigation focused mainly on battery technologies that could be located in or around the City of Alameda.

Table 1 below is compiled from the 2013 Energy Storage Systems Cost Update from Sandia National Laboratories and shows the upfront cost and efficiency of various battery types along with staff's preliminary estimation for the levelized cost of energy (LCOE). The upfront costs of energy storage systems are reported both in terms of the power component ($/kW of rated power capacity) associated with the power conversion equipment and an energy component ($/kWh of per cycle energy capability) associated with the energy storage device; in this case the battery. These cost components are used to price projects based on their rated power output (kW) and storage capability (kWh). The LCOE depends on these parameters and is heavily influenced by how the storage is used (how many discharge cycles per day, charging depth, efficiency, financing costs, etc.) Efficiency is the round-trip, AC to AC efficiency.

Table 1: Battery Costs

Technology	Power Subsystem ($/kW)	Energy Storage Subsystem ($/kWh)	Levelized Cost of Energy Storage ($/kWh)	Efficiency
Advanced Lead-Acid Batteries	**$796**	**$847**	**$0.37**	**90%**
Sodium/Sulfur Batteries	**$516**	**$426**	**$1.03**	**75%**
Zinc/Bromide Batteries	**$484**	**$238**	**$0.14**	**60%**
Vanadium Redox Batteries	**$635**	**$620**	**$0.73**	**75%**
Lithium-Ion Batteries (Large)	**$728**	**$906**	**$0.57**	**90%**

Characteristics and Benefits

Energy storage provides many attributes that can be beneficial to system operations, ranging from customer power quality and the potential to support local distribution systems to providing grid services that enhance and aid the effectiveness of transmission and generating resources. Each benefit must be evaluated within the context of the individual utility's operations and cost structure.

Important energy storage technology characteristics include:

- Installation size (MW)
- Operating Life (years)
- Cycle duration (discharge time)
- Cycle capability (cycles per year)
- Cycle rate (ramp rate)
- Efficiency (%)

While individual characteristics vary significantly between the various energy storage technologies, they all share two valuable common characteristics: the ability to shift electric power utilization in time, sometimes called energy price arbitrage; and exceptional operating flexibility that allows fast response to changing conditions. The value of energy price arbitrage is based on the differential between the price of energy when it is stored and the price when the stored energy is utilized. The value of operating flexibility is based, at least in part, on the price established through the California Independent System Operator's (CAISO) ancillary services market. Operating flexibility is especially valuable when loads change dramatically, such as during peak periods when air conditioning loads surge or when net requirements change due to the output of intermittent renewable resources. As the use of wind and solar grows in California, energy storage is viewed as a promising additional technology for integrating an increasingly intermittent resource mix. In support of this perspective, the California Public Utilities Commission (CPUC) recently implemented an energy storage goal of 1,325 MW by 2024 for California's three major investor-owned utilities.

Other potential benefits of energy storage, such as distribution and transmission system support, have not yet been fully evaluated under existing operating practices and regulations, but could gain greater acceptance with experience and as the regulatory situation evolves. The following table summarizes energy storage end uses from the 2012 Energy Storage Framework Staff Proposal from the CPUC Proceeding R.10-12-007, which shows the wide range of energy storage values and applications.

Table 2: Energy Storage End Uses

Category		Storage "End Use"

Describes where justification of energy storage resides within the value chain storage		Describes energy storage application
ISO/Market	1	Ancillary service: frequency regulation
	2	Ancillary service: spin / non-spin / supplemental reserve
	3	Ancillary service: ramp
	4	Black start
	5	Real time energy balancing
	6	Energy price arbitrage
	7	Resource adequacy
Generation	8	Intermittent resource integration: wind (ramp / voltage support)
	9	Intermittent resource integration: photovoltaic (time shift, voltage sag, rapid demand support)
	10	Supply firming
Transmission/Distribution	11	Peak shaving
	12	Transmission peak capacity support (upgrade deferral)
	13	Transmission operation (short duration performance, inertia, system reliability)
	14	Transmission congestion relief
	15	Distribution peak capacity support (upgrade deferral)
	16	Distribution operation (voltage / VAR support)
Customer	17	Outage mitigation: micro-grid
	18	Time-of-use (TOU) energy cost management
	19	Power quality
	20	Back-up power

It is rare that a single energy storage system can provide all of, or even most of, the above benefits. Uses are generally application specific and highly related to position in the power supply chain (generation, transmission, or distribution). They require a focused approach that may conflict with other benefits. For example, an energy storage system that provides multiple market services such as energy price arbitrage cannot also simultaneously provide frequency regulation. Another example is that an energy storage system that provides location specific services such as distribution peak shaving may not also satisfy the requirements of intermittent resource integration.

Economics

Studies have shown that the economic justification of storage technologies remains a concern. These economics must take into account not only the cost of the storage facility, but also the cost of the initial charging energy as well as the energy market incentives and disincentives specific to the area. Although the costs of some energy storage technologies are expected to decline in the future, presently the lifetime levelized cost of delivered energy from conventional generation technologies is substantially lower those of commercial energy storage technologies. More specifically, a 2010 report by the Electric Power Research Institute called Electric Energy

Storage Technology Options shows the cost of energy from energy storage systems to be much higher than the cost of energy from a combined cycle gas turbine.

A combined cycle plant cannot provide all of the attributes of energy storage plus the environmental impacts are greater. Therefore, to be cost-effective energy storage must compete economically with these alternatives. Studies have also indicated that energy storage systems will not be fully utilized until higher levels of penetration of intermittent renewable resources have been reached. Additionally, not all of the attributes of energy storage have been valued in practice so a complete economic benefit cannot be realized until the market and regulatory situation envisioned materializes.

From AMP's perspective, there are currently three main drivers that may create value and economic viability for an energy storage system:

1) **Energy Price Arbitrage** – based on the differential between peak and off-peak energy pricing. In practice this means extracting value from the energy storage system by charging the system when wholesale electricity prices are low and providing output/discharging when prices are higher.
2) **Capacity Value** - the maximum output capability of the energy storage system with value established by resource adequacy requirements and the resulting market. While AMP currently has excess generating capacity, each year AMP typically sells much of this surplus.
3) **Ancillary Services** – the value of power supply related services such as spinning reserve and frequency regulation presently provided by the ancillary services markets of the CAISO. However, these markets are sometimes limited and the rules governing the applicability of ancillary services to energy storage systems are still under development.

Application of these drivers value may improve the economic viability of energy storage systems in the future. For example, there is potential value to AMP from energy storage in the event that time-varying transmission rates are adopted by the CAISO to replace the existing flat transmission pricing.

AMP's customers may be able to extract value from energy storage, but these direct customer benefits are dependent on the individual customer's perspective and on locating the energy storage system on the customer's site. For these reasons, direct customer benefits are not considered further in this report.

For investment in an energy storage system to be economical, the arbitrage over a specified time period, combined with the value of capacity, ancillary services and other attributes, must be greater than the annualized cost of the energy storage system.

Staff has compiled much of the cost information from the various studies and publications that were reviewed in preparation for this report. Cost information was found to vary considerably for similar technologies. While some of this variation could be attributed to differences in the specific application, much of it was not. A spreadsheet analysis tool was developed integrating the cost information and the relevant values as seen from a utility perspective. The values incorporated were those mentioned above, namely: energy price arbitrage, capacity value, and ancillary services. Even using some of the lowest compiled costs for the energy storage technologies studied, the preliminary results show that the technologies are currently not cost-effective. Staff estimates that the cost of energy storage, which again is highly dependent on the type of technology and application, can range from $0.14 to over $1.00 per kWh. This cost is *in addition* to the cost to *generate* the power in the first place. These results tend to confirm to findings of many of the reports reviewed that for energy storage systems to be cost-effective they must capture multiple benefits. Because of the variability and uncertainty of the energy storage cost data incorporated, the analyses are not shown here.

Alameda's Load Characteristics and Resource Mix

Alameda's overall use of electricity is flat and consistent. Monthly electricity consumption ranges from about 30 gigawatt-hours (GWh) in the summer to 36 GWh in December and January. Due to its location and climate, Alameda does not have a significant air conditioning load, minimizing load swings and limiting the need for fast response resources. Monthly load factors (average use divided by maximum use) are consistently greater than 70 percent – much higher than most utilities in California and indicative of a relatively flat, "non-peaky" load. These load characteristics do not support the need for the kind of power supply attributes that are provided by energy storage systems.

Furthermore, AMP's existing resource mix is one of the main factors limiting the value and usability of energy storage systems. AMP's power supply consists mainly of renewable resources, but most of these renewables are baseload, i.e. they run around the clock and are not intermittent like other renewables such as wind and solar. As such, AMP's renewable resources do not require energy storage to smooth, or shape, intensely varying outputs.

Geothermal and landfill gas generated over 60 percent of AMP's energy in 2013. These resources provide consistent output that is as stable and constant as any large baseload power plant.

AMP gets approximately 25 percent of its power from hydroelectric facilities, mainly from NCPA's Calaveras project. This project is a very flexible peaking resource, already providing benefits similar to energy storage such as regulation to the ISO's market along with the ability to follow load swings.

Only a small portion of AMP's power portfolio is made up of intermittent renewables that could benefit from energy storage. AMP has one wind turbine resource that provides seven percent of its power. Alameda's total installed solar photovoltaics under its rebate program stands at 2 MW today and is expected to reach 3 MW by 2017. This represents energy production of just over 1 percent of the expected total city load.

The above generating resources, taken together with AMP's peaking combustion turbines, allow AMP to be surplus in generating capacity. AMP is well positioned to meet its limited need for peaking and load following capabilities, without the use of energy storage systems.

AMP is, however, taking steps to acquire some of the benefits of energy storage systems by other means. For instance, AMP is currently in the process of implementing several energy efficiency projects and funding them through the sale of its renewable energy credits (RECs). These projects will reduce AMP's peak demand and GHG emissions. This will require AMP to purchase less additional market power – all of which provide similar benefits to those of energy storage. However, AMP can recognize the benefits more quickly and much more cost-effectively by increasing its energy efficiency efforts rather than developing energy storage. Other projects that AMP is exploring, such as the implementation of smart meters and/or an eventual move toward more time-of-use (TOU) pricing for its customers can also provide benefits similar to energy storage, but at a much lower cost.

AMP is nonetheless committed to continued exploration of the cost-effectiveness and benefits of energy storage in the future. Particularly, as costs are expected to decrease, AMP could foreseeably utilize energy storage to smooth generation from increased solar generation on the island, capture and store low-cost wind energy produced overnight in order to shift the power to higher demand usage times, or take advantage of other benefits like capacity and ancillary services that energy storage could provide. AMP will also continue to facilitate the development of cost-effective energy storage by partnering with city officials, local businesses and energy storage manufacturers as new opportunities arise. This will allow AMP staff to fully master the learning curve of this new technology by taking a role in potential energy storage pilot projects on the island.

Conclusion

Due to AMP's load, planned projects, and resource characteristics, the applicability of energy storage systems for Alameda is currently limited. Also, studies have shown that applicable energy storage systems for AMP are not justified based on economics. Staff recommends that the Board accept this report and its finding that currently energy storage Systems are not viable and cost-effective for AMP and that procurement of such systems be deferred as further specified in the recommendations above. Staff will continue to review AMP's situation. This conclusion may be revised when the economics of energy storage systems become favorable due to any combination of the following: a decline in the costs of energy storage systems, a change in market conditions, and/or an increase in the penetration of intermittent renewable resources.

FINANCIAL IMPACT

There is no near-term financial impact from the recommendation to not pursue energy storage systems.

LINKS TO BOARD POLICY AND OBJECTIVES

Strategy 10: Manage short-term and long-term power supply reliability and cost, while maintaining a loading order of efficiency and demand response, renewable energy resources, and clean and efficient fossil generation.

<u>EXHIBIT</u>

None.