MEMORANDUM

TO: UTILITIES ADVISORY COMMISSION

FROM: UTILITIES DEPARTMENT

DATE: MAY 3, 2017

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SUBJECT: Staff Recommendation that the Utilities Advisory Commission Recommend that the City Council Decline to Set an Energy Storage System Target Due to Lack of Cost-effective Options

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RECOMMENDATION

Staff recommends that the Utility Advisory Commission (UAC) recommend that the City Council decline to set a procurement target for energy storage systems at this time due to the lack of cost-effective options.

DISCUSSION

California legislation Assembly Bill 2514 (AB 2514) requires the governing board of each publicly-owned utility (POU) to "determine appropriate targets, if any, for the utility to procure viable and cost-effective energy storage systems..." In addition to requiring that POUs evaluate the feasibility of energy storage targets every three years, starting in October 2014, AB 2514 also requires that all procurement of energy storage systems by POUs be cost-effective. In February 2014, at the recommendation of staff and the UAC, City Council made a determination not to set energy storage targets for CPAU.

In October 2016, staff presented the UAC an updated analysis on microgrid and energy storage applications (Attachment A). This updated analysis found that energy storage applications in CPAU are still not cost effective. However, staff recommended exploring the feasibility of undertaking a Research Development & Deployment pilot program in order to learn and be ready for the anticipated widespread adoption of customer-sited energy storage systems.

Based on the staff analysis results and UAC feedback at the October 5, 2016 meeting, staff recommends that UAC recommend that Council make a determination that setting a procurement target for energy storage systems is not appropriate for CPAU at this time due to the lack of cost-effective options. Within the next three years, staff will bring the UAC a recommendation regarding a potential energy storage pilot program[1].

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[1] A pilot program with a total budget approx. $250,000 is being evaluated by staff. This will enable CPAU to fund a 50% cost matching rebate of up to $500/kWh for storage cited at residential and customer premises, and made available to the CPAU to dispatch during 'Demand Response' periods. Staff believes that this is a reasonable investment to support the integration of this nascent technology in the Palo Alto community at five to ten customer sites. Design of such a pilot program, including legal and regulatory review, will have to be undertaken by staff before bringing a recommendation to the UAC and Council.

SUMMARY OF OCTOBER 5, 2016 UAC DISCUSSION

Commissioners were supportive of staff's findings that energy storage systems were not cost-effective for Palo Alto. They also wanted to learn the rationale for undertaking an energy storage pilot. Commissioners were open to considering approval of such a pilot program after staff develops the program more fully. Full text of the meeting minutes is provided in Attachment B.

NEXT STEPS

Following UAC consideration of staff's recommendation, if UAC recommends approval of that recommendation, staff plans to seek Council approval of the staff recommendation in June or July, and file with the California Energy Commission by August 2017.

RESOURCE IMPACTS

Not setting an energy storage goal will not have any resource impacts. If an energy storage pilot program is recommended at a later time, it could cost $250,000 in customer rebates and take-up approximately 0.2 FTE to administer the program and leverage the storage system for utility applications.

POLICY IMPLICATIONS

Energy storage is a key technology to enable increased penetration of renewable energy in California and, when installed in customer premises, reduce their utility use. These two aspects conform to Utilities Strategic Plan objectives and Council policy on environmentally sustainable utility and customer programs. Any use of storage systems to benefit from energy market price differentials will be done in conformance with City's energy risk management policies.

ENVIRONMENTAL REVIEW

Council decision not to set energy storage goals is not a Project requiring California Environmental Quality Act review.

ATTACHMENTS

A. Discussion of Energy Storage and Microgrid Applications in Palo Alto – analysis report provided to the UAC on Oct 5, 2016
B. UAC Meeting minutes (excerpts) related to energy storage discussion of 10/5/2016

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APPROVED BY: [signature]

ED SHIKADA
General Manager of Utilities

ATTACHMENT A

MEMORANDUM

TO: UTILITIES ADVISORY COMMISSION

FROM: UTILITIES DEPARTMENT

DATE: OCTOBER 5, 2016

SUBJECT: Discussion of Energy Storage and Microgrid Applications in Palo Alto

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This report is provided for background to elicit input from the Commission on staff's preliminary findings to not set energy storage goals and to explore pilot scale storage programs. A final recommendation on whether to establish a goal for storage will be brought back to the Commission in early 2017. No action is required at this time.

EXECUTIVE SUMMARY

Currently, storage systems are most commonly installed by customers either seeking a higher level of electricity supply reliability or those interested in storing their generated solar electricity onsite. Energy storage systems coupled with solar photovoltaic (PV) systems are becoming increasingly viable technologically and economically. These integrated PV and battery systems sometimes have the capability to maintain electric supply at customer homes or businesses in the event of a power outage,[1] or increasing the self-consumption of solar generated onsite. Combined PV and storage systems that can island from the electric grid and function alone are sometimes called microgrids[2] or nanogrids[3]. Storage systems alone, without PV, can also be configured to reduce customer electric utility bills by storing electricity when prices are low and using stored electricity when prices are high. In addition to the small customer-sited storage systems, large utility-scale storage systems are also becoming more prevalent in California as a result of regulatory mandates and market changes.

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[1] PV systems that are not appropriately coupled with energy storage systems cannot produce energy in the event of an electric grid outage, except in very limited circumstances. Hence such systems cannot enhance customers' electric reliability.

[2] A microgrid is defined as, "a group of interconnected electrical (customer) loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode."

[3] A microgrid which can island from the electrical grid and operates at an individual building or individual customer level is commonly called a "nanogrid". Because of its simplicity, a nanogrid can be developed without the need for active facilitation by an electric utility.

While battery systems and solar PV costs have declined considerably the past three years, cost-effective storage systems are still some years away, particularly in Palo Alto. The primary challenges to cost effectiveness in Palo Alto are the relatively low electric retail rates, the small retail rate differential between on-peak and off-peak periods, and a robust distribution grid providing highly reliable electricity service. Transmission grid-level storage applications are also not currently cost effective for the City of Palo Alto Utilities (CPAU). However, CPAU has incorporated the option into the City's recent purchase power agreements to site storage systems at the PV project sites in case the economics for storage at the transmission grid level become favorable in the future.

In accordance with State law, the City must evaluate storage options and determine whether or not to establish a goal for energy storage every three years. When last evaluated in 2014, the City declined to establish such a goal since there were no cost-effective opportunities. There still appears to be no cost-effective storage options, but staff is evaluating a pilot-scale utility rebate program for energy storage systems installed at customer premises[4]. A small storage pilot program would enable CPAU to gain first-hand experience with storage technologies and to position itself for widespread adoption if and when they become economically favorable in the future.

Staff will return to the UAC and Council in early 2017 with a recommendation on whether to establish a goal for energy storage and whether to undertake any pilot programs related to storage. This report is meant to provide a background for discussion prior to staff's development of these recommendations.

BACKGROUND

In February 2014, after examining a detailed analysis from staff, the City Council found a lack of cost-effective energy storage applications in Palo Alto (Staff Report 4384). This analysis and determination was prompted by State law under AB 2514 that required the governing board of each publicly-owned utility (POU) such as CPAU to "determine appropriate targets, if any, for the utility to procure viable and cost-effective energy storage systems." The law also required "reevaluation of energy storage target determinations not less than every three years."

The findings and recommendations from the 2014 analysis by Palo Alto were:

A. Do not establish an energy storage systems procurement target for Palo Alto.
   This recommendation was made because storage systems were not cost effective from a societal and utility perspective in Palo Alto.

[4] A pilot program with a total budget approx. $250,000 is being evaluated. This will enable CPAU to fund a 50% cost matching rebate of up to $500/kWh for storage cited at customer premises, and made available to the CPAU to dispatch during 'Demand Response' periods. Staff believes that this is a reasonable investment to support the integration of this nascent technology in the Palo Alto community. Design of such a pilot program, including legal and regulatory review, will be undertaken by staff in the coming months before bringing a recommendation to the UAC.

B. Utility incentives for energy storage not recommended.
   The analysis found that Thermal Energy Storage (TES) and Battery Energy Storage (BES) systems were the most relevant for applications in Palo Alto. However, customer incentives were not recommended since at the time neither of these systems was found to be cost effective from a societal perspective.

C. Encourage commercial customers to consider energy storage where cost effective.
   The analysis found that TES and BES could make load shifting strategies cost effective for Palo Alto commercial electric ratepayers, and recommended that CPAU encourage its customers to evaluate installing such systems at their premises.

Energy Storage Systems: Definition and Need

The fundamental purpose of energy storage systems is to absorb energy, store it for a period of time with minimal losses, and then release it. When deployed in the electric power system, energy storage provides flexibility that facilitates the real-time balance between electricity supply and demand. Maintaining this balance on an instantaneous basis becomes more challenging as the share of electricity coming from intermittent renewable energy sources grows.

Typically this supply-demand balance is achieved by keeping some generating capacity in reserve (to ensure sufficient supply at all times) and by adjusting the output of fast-responding resources like hydropower. As the need for fast-responding energy supplies increases, energy storage systems are expected to play a greater role. Rechargeable batteries are perhaps the most familiar energy storage technology. Large battery systems can be connected to the transmission grid to take up excess wind or solar power when demand for electricity is low, and release it when demand is high. Such transmission grid-tied battery installations also provide valuable frequency regulation more effectively than a typical thermal electricity generation facility.

At the other end of the electric grid, customer-sited energy storage can reduce customer costs and increase system reliability while also benefiting the utility by reducing peak demands on the distribution system. Both BES and TES systems can reduce peak demands on the electricity distribution system. TES systems are typically used to shift electricity use of commercial space cooling units from peak to off-peak periods of the day. Alternatively, a common household example of a TES storage device is a networked dispatchable electric hot water heater.

Clearly a variety of technologies can be used for energy storage in a wide range of applications throughout the electric grid. The type, performance and location of an energy storage system determine the benefits it can provide.

Storage Systems in California

In 2014, among the 37 POUs in California, 7 POUs set storage goals under the AB 2514 requirement. The remaining 30, including Palo Alto, declined to set goals, finding storage to not be cost effective for their systems at the time. The storage systems planned by POUs were primarily pumped hydro storage, thermal energy storage, and battery energy storage systems designed for grid service and customer load management service applications. Table 1 lists these goals and highlights that several of the smaller POUs have set very small goals.

Table 1. Publicly-Owned Utility Energy Storage Goals Set in 2014

POU	2016 Target	2020 Target
Cerritos, City of	1 percent of 2015 peak load (**200 kW** based on 2014 peak load of 20 MW).	1 percent of 2020 peak load (**200 kW** based on 2014 peak load of 20 MW)
Corona Department of Water and Power	1 percent of 2015 peak load (**270 kW** based on 2014 peak load of 27 MW).	1 percent of 2020 peak load (**270 kW** based on 2014 peak load of 27 MW).
Glendale Water and Power	1.5 MW	1.5 MW
Los Angeles Department of Water and Power (LADWP)	24.08 MW	154 MW
Redding Electric Utility	3.6 MW	4.4 MW
Silicon Valley Power (City of Santa Clara)	30 kW	30 kW
City of Victorville	1 percent of 2015 peak load (**140 kW** based on 2014 peak load of 14 MW).	1 percent of 2020 peak load (**140 kW** based on 2014 peak load of 14 MW).

Source: CEC, IEPR 2015

While the goals set for POUs were relatively small (~30MW in 2016 and 160 MW in 2020), the California Public Utilities Commission (CPUC) set a 2,485 MW goal for the investor owned utilities (IOUs), with procurement commitments to be made by 2020 and systems operational by 2024. The large volume of storage procurement by IOUs in 2014-15 and current and future plans for procurements have spurred the storage industry to bring several innovative storage products to the marketplace, including better product warranties and long-term financing options.

Microgrid and Nanogrid Applications in Palo Alto

A microgrid is defined as, “a group of interconnected electrical (customer) loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode.”[5] A nanogrid is very similar to a microgrid, except it operates at an individual building or individual customer level. Because of its simplicity a nanogrid can be developed without the need for active facilitation by an electric utility like CPAU.

[5] https://building-microgrid.lbl.gov/microgrid-definitions

There are no microgrid applications in Palo Alto currently nor anticipated in the near future[6]. Nanogrids, on the other hand, are common at buildings that are required to have back-up diesel generation for public health and safety reasons. Examples of nanogrids include hospitals, emergency operations centers such as police and fire stations, and data centers. As PV and energy storage costs decline rapidly, integrated PV and battery systems could provide higher reliability nanogrid services for an expanded group of customers, including residential applications[7].

DISCUSSION

Since 2014, the cost of BES systems has declined and there are a greater number of commercially available storage products in the market place. While small scale TES systems have improved, the application of TES in a mild climate like Palo Alto remains limited. The report analyzes new developments since the 2014 storage assessment and outlines elements of a distributed energy resource plan, including storage systems, for Palo Alto through 2020. This analysis reviews these market changes and outlines a course for storage at CPAU within the broader context of optimizing the value of all distributed energy resources in Palo Alto.

There are a wide variety of energy storage technologies available in the marketplace, and a number of these are discussed in Attachment A. Among these technologies BES is the most applicable for Palo Alto and is also the most commercialized with multiple established vendors. TES systems have only few commercial vendors and such systems have relatively low value in Palo Alto due to our mild climate (Attachment D).

Application of Energy Storage Systems

Figure 1 illustrates that storage systems can serve 13 applications and benefit three broad stakeholder groups: Customers, Utilities, and Transmission operators (Independent System Operators, or ISOs)[8]. Any of these three stakeholder groups could fund and or derive value from energy storage systems. The concentric circles in the figure also illustrate that storage can provide the broadest range of services if located behind the customer meter and the least number of services if located more centrally on the transmission grid. It is important to keep in mind for CPAU that the different available value streams depend on the physical location of the storage system.

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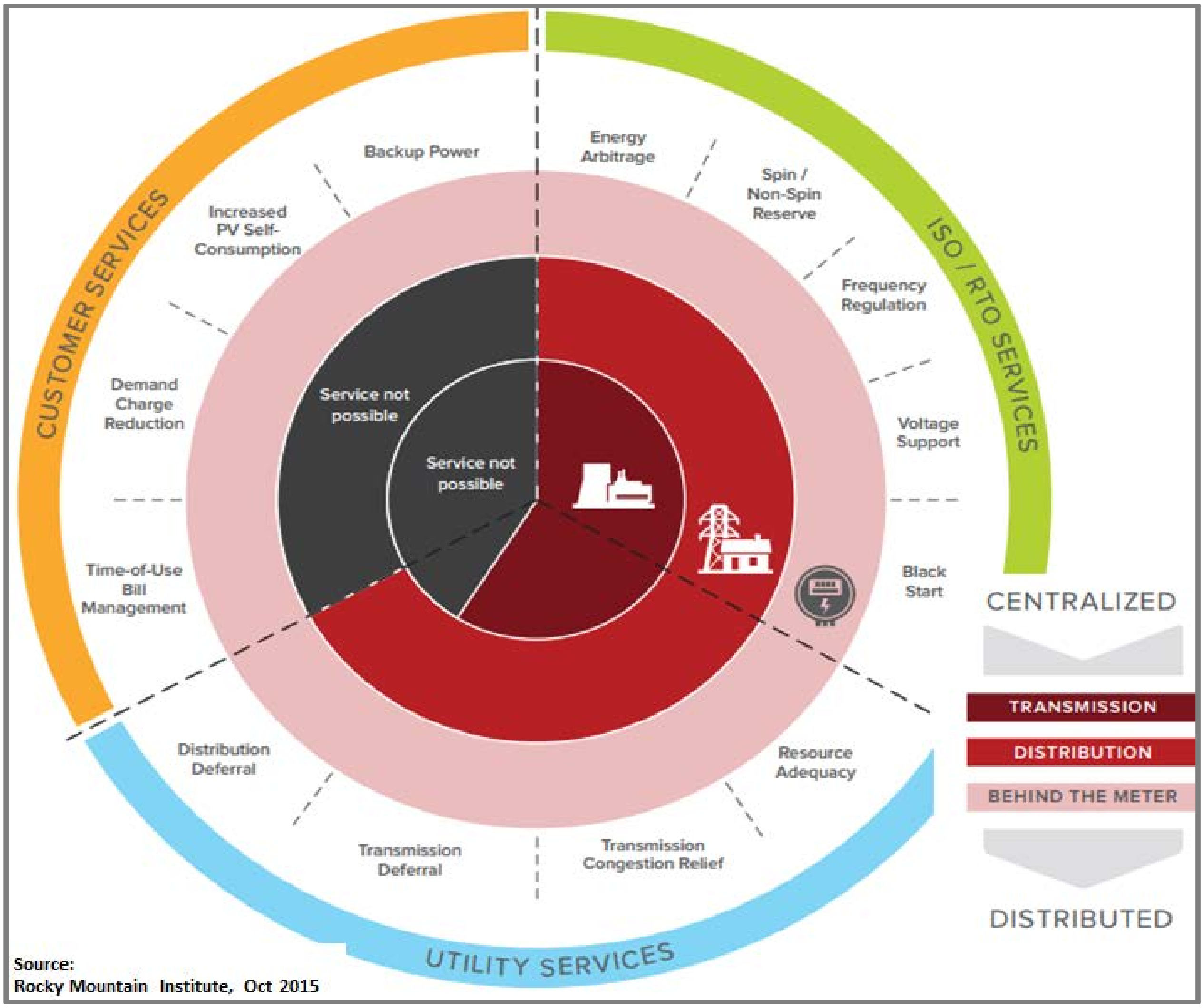
[6] Microgrids are most common in military bases in the U.S, where the entire base must often have the capability to function independent of the larger electrical grid. Microgrid applications are also common in large educational campuses that have onsite generation. In early 2000's Palo Alto considered siting a 50MW natural gas fueled electric generator within Palo Alto. Part of the rationale was to explore the feasibility that that such a large scale generator may enable the City to operate as a microgrid, at a 25% load level, in the event of a natural disaster. The initiative was discontinued due to the lack of available site, cost/complexity, and the pursuit of the carbon neutral electric supply strategy by the community.

[7] New generation of PV system inverters are capable of providing very limited amount of back-up supply to isolated home circuits in the event of a grid outage when PV system is producing energy. The electrical appliances for such application should not need stable power supply (i.e. medical device) because of the inherent variability of solar power. http://www.sma-america.com/products/solarinverters/sunny-boy-3000tl-us-3800tl-us-4000tl-us-5000tl-us-6000tl-us-7000tl-us-7700tl-us.html#Downloads-137455

[8] The Economics of Battery Energy Storage, Rocky Mountain Institute, October 2015

Figure 1. Value streams of Energy Storage Systems in Customer, Utility and Transmission Services



Customer Service Applications

Historically providing backup power (e.g. uninterrupted power supply, or UPS, systems) – has been the primary application of storage systems for customers. Storage could also assist customers in reducing their utility bills as both electricity demand charges to customers increase and the electricity price differential between day time and night time use increases.

In addition, as utility incentives for solar PV systems are phased out, there may be greater incentives to store excess solar energy in batteries at customer sites for use during non-solar production periods. Due to the relatively high cost of storage, the storage projects are currently not cost effective with the benefit-cost ratio from 15% to 20%, i.e. not cost effective. Hence, supply reliability is likely to be the main driving factor for home installations of storage systems. For commercial customers, given CPAU electricity demand charges, electricity retail rates, and the cost of storage systems, the annualized benefit-cost ratio for this application appears to be in the range of 30% to 35%, well below the break-even point.

Storage systems located at customer sites to provide service to customers directly also have the potential to provide utility distribution and transmission system services. The value streams associated with such services to CPAU or to the California Independent System Operator (CAISO) are relatively small, except under very specific conditions such as when distribution or transmission systems constraints prevail. Distribution systems constraints are not common in CPAU currently[9]. However, as the electricity load increases with greater electric vehicles (EV) adoption and electrification of natural gas appliances, constraints may arise which may make storage applications more valuable.

Utility Services to CPAU

As the operator of the electric distribution system, CPAU can utilize storage systems to reduce distribution systems constraints or defer distribution system expansion investments. As outlined above, the value stream associated with such applications in Palo Alto is currently low.

Siting of storage to meet CPAU's resource adequacy requirements imposed by the CAISO, could annually save CPAU approximately $5 to $10 per kWh of energy storage system installed and dispatched during peak load hours[10]. However, the annualized cost of a storage system is currently about $100 to $150/kWh.

The value of transmission congestion relief for Palo Alto load is currently small[11]. The congestion costs experienced by CPAU's central solar resources are expected to increase in the future; however, the value of alleviating congestion costs can only captured by siting storage physically adjacent to the large utility scale solar projects (often located in the Central Valley). This increased congestion cost scenario was contemplated and has been incorporated into CPAU's solar contracts by incorporating an option for CPAU to site storage onsite at the large solar arrays in the future.

Transmission Grid Services to the CAISO

CAISO procures many ancillary services to operate the electric transmission grid. These include frequency regulation, spinning and non-spinning reserves, and voltage support. Among these services, regulation service is the highest value service and storage systems have the 'fast-

[9] Palo Alto has nine distribution system substations with a total of 28 substation transformers serving 68 distribution feeders. While overall the substation transformers and feeders have sufficient capacity to handle Palo Alto's loads (which are currently 10-20% below peak loading levels seen in year 2000), there may be areas of significant load growth (e.g. area around Stanford Medical Center) that will require load transfers to adjacent substations to maintain operating flexibility or increases in electric system capacity at certain substations. The role storage systems could play in deferring such investments are evaluated when designing such projects. Currently storage is not anticipated to be an economical solution in such projects.

[10] CPAU's cost of resource adequacy capacity procurement could be reduced by $20 to $40/year for every kW of storage system that has the ability to discharge over a four-hour duration (i.e. a 4 kWh storage system is needed to meet one kW of resource adequacy capacity requirement). Therefore, the annual value of storage systems is estimated at $5 to $10/kWh.

[11] Internal analysis of CY 2015 CAISO nodal and aggregation point prices shows that on-off peak congestion and marginal loss differential to be 0.05 cents/kWh for loads and up to 0.5 cents/kWh for central resources.

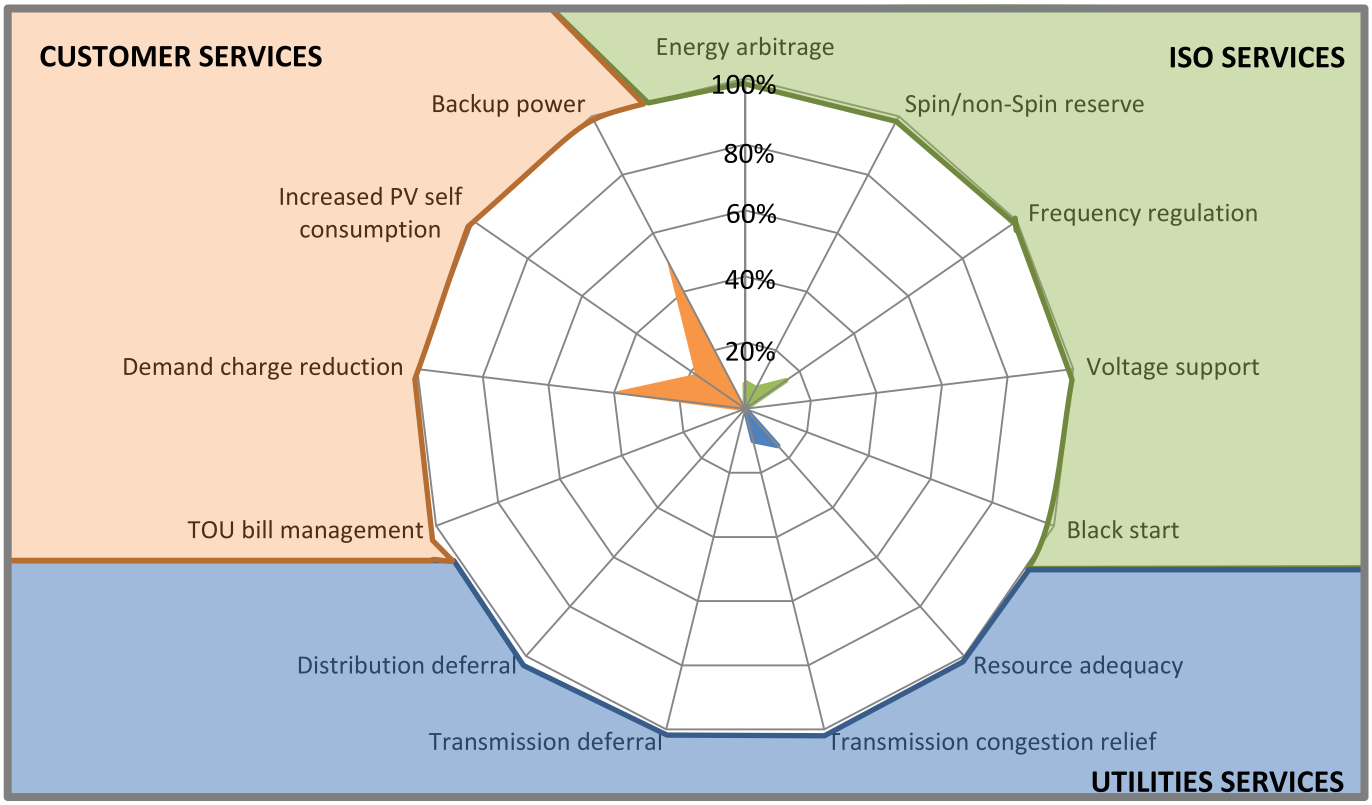
acting' capability to provide this service; however, the compensation for these services is currently too low to justify storage systems. Alternatively, CPAU will be exploring the feasibility of aggregating smaller customer sited systems to bid into the CAISO market to capture both customer service and grid service value streams.

Taking advantage of potential transmission level energy price differences is another value stream that storage systems can capture. This application is similar to time-of-use bill management in the customer-sited storage application, but it should be noted that both of these value streams cannot be harvested simultaneously.

Figure 2 below illustrates the annual value of each 13 storage value streams as a percentage of its annualized cost. This means that over the life of the energy storage system, it will recoup some percentage of its cost. Since all of the systems have value of less than 100% of their annualized cost, the revenues generated are all well below the breakeven point. However, the relative economics of each application are informative for the future as storage costs continue to decline.

As shown in the figure customer-sited storage for demand charge reduction and backup power for commercial customers have the greatest value. The next most valuable uses of storage are for PV self-consumption, frequency regulation, and resource adequacy which all recoup 15% of the current cost. Transmission congestion relief, spinning and non-spinning reserves, and energy price differences currently provide relatively low values currently. It should be noted that it is difficult to generalize the value of backup power and distribution deferral because each application is very case specific and analyzed on a case-by-case basis by both the customer and CPAU.

Figure 2: *Illustration of the Relative Value of Energy Storage Applications (% of Annualized Cost)*[12]



Energy Storage Systems Case Studies for Palo Alto

Staff analyzed the three storage applications most relevant to Palo Alto: residential customer-sited storage with PV, commercial customer-sited storage, and transmission grid-tied storage. A description and summary of results for these applications are outlined below. The first two applications are potential nanogrid applications if the systems were designed with sensors and controllers to operate independent of the electric grid. A detailed description of the full analysis is provided in Attachment C.

I. Residential customer-sited storage with PV: The scenario analyzed storage installed with solar PV panels with the intention of maximizing PV self-consumption and minimizing exports to the electric grid under the net energy metering (NEM) successor program. These systems are small—in the 5 to 10 kWh scale. With an energy cost differential of about 9.5 cents/kWh (difference between the tier 2 rate of 16.901 cents/kWh versus the NEM successor buyback rate of 7.485 cents/kWh) the value of energy storage for this application is about 15% of the annual cost of ownership[13]. If the customer values the enhanced

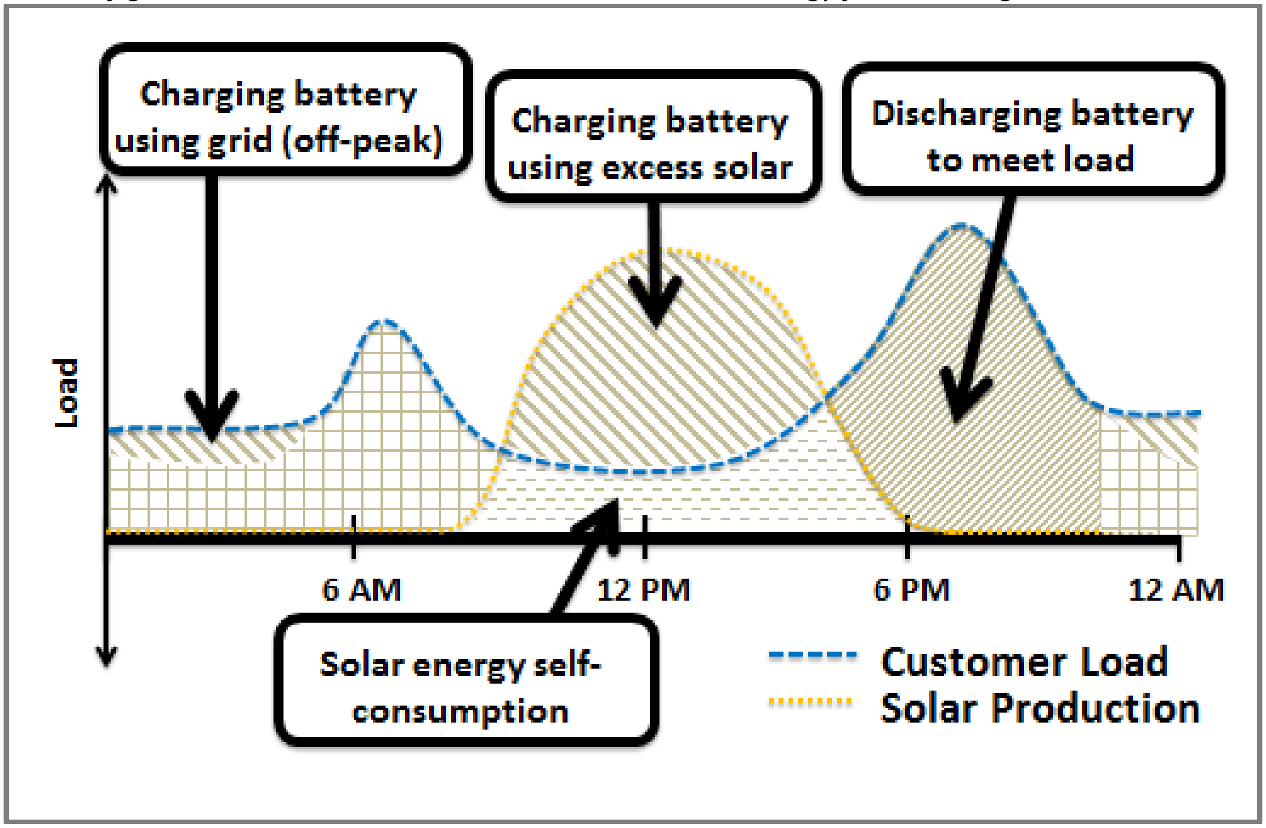
[12] While each application individually is not currently cost effective, a combination of applications may be cost effective. For Palo Alto, such combinations of opportunities are also very limited at this time.

[13] Assumed that PV directly feeds the storage system and the configuration enables the storage system to qualify for the 30% investment tax credit. The annual cost of ownership, net of investment tax credits, was estimated at $42/kWh-year.

reliability provided by such a combined system, this application will become viable solution in the residential market segment.

Figure 3 below illustrates how excess solar PV energy could be used to charge the storage system during the day and use the stored energy to meet the electricity needs of the home at night, reducing energy purchases at the retail rate.

Figure 3. *Illustration of Residential Customer Application: Storage + PV under NEM Successor This configuration enables customer to store excess solar energy for use at night.*

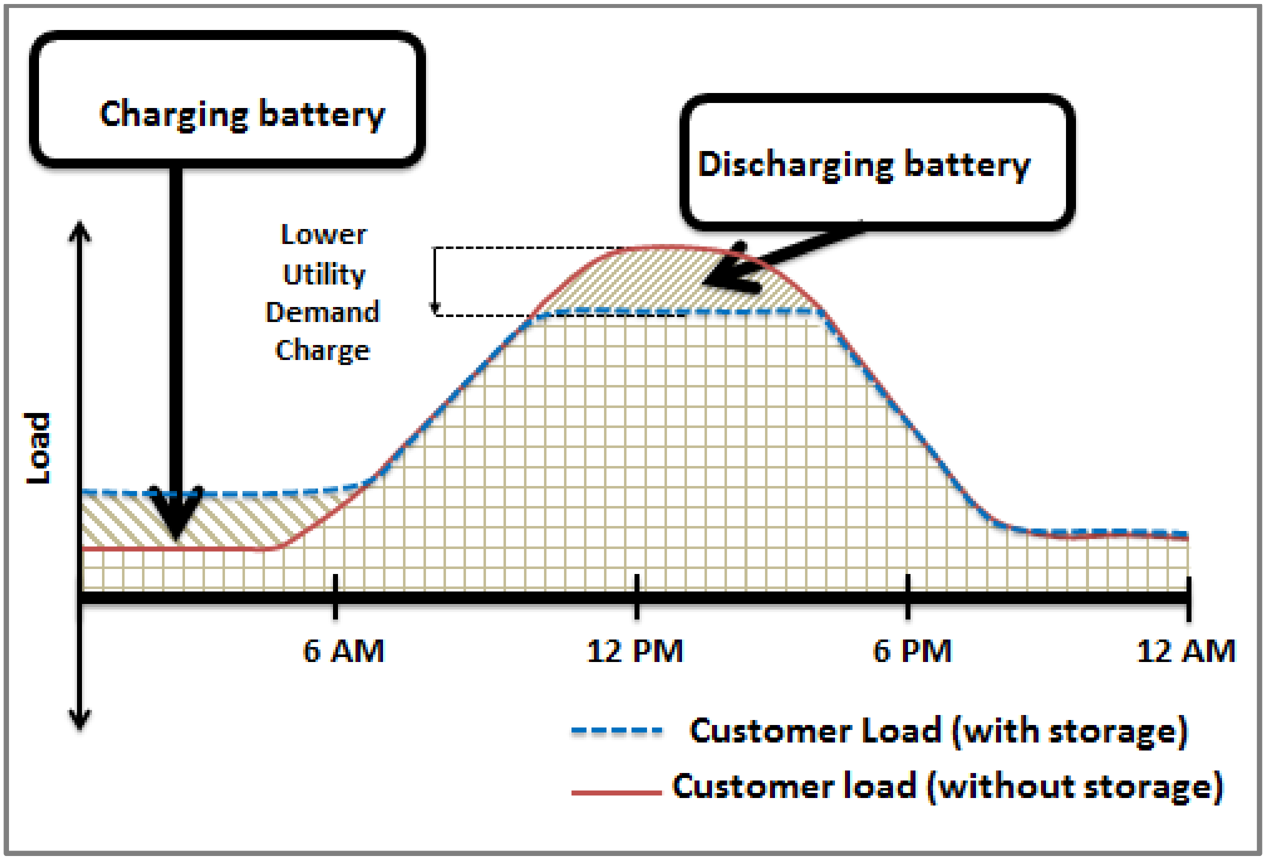


II. Commercial customer sited storage: This application is to use storage to lower the utility demand charge for the commercial customers. At the current demand charge rate for commercial customers in Palo Alto[14], the value of this application is estimated at about 40% of annualized cost of ownership. If CPAU also can harness the storage system to meet CAISO resource adequacy needs, the combined value stream has the potential to break even at the current cost of storage system. If configured appropriately, this storage system in this application can also provide the customer back-up power in the event of an electric grid outage.

[14] Medium and Large Commercial customers pay a demand charge in the range of $14 to $19.70/kW-month depending on the season. Assumes these storage systems do not enjoy tax credits.

Figure 4 illustrates how medium and large commercial customers, who are subject to a utility demand charge based on the peak load consumption for the month, could use energy storage to lower their monthly utility peak demand.

Figure 4. *Commercial Customer Application to Lower Utility Electricity Demand Charge*



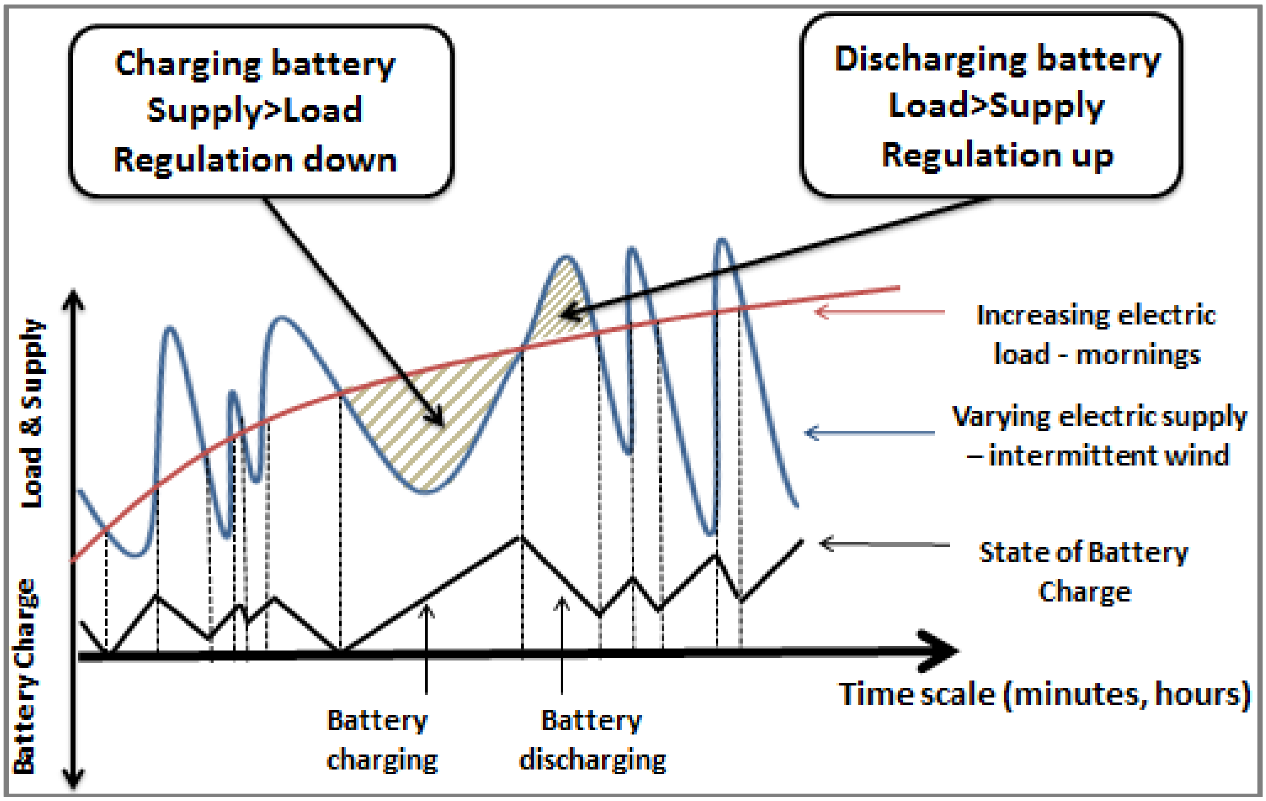
III. Transmission grid-tied storage: This scenario assumes storage to be located at one of Palo Alto's large PV projects in the Central Valley. Such large systems cannot be located within Palo Alto. Storage at such sites could provide CAISO services such as frequency regulation and flexible resource adequacy capacity; could benefit from CAISO energy price differentials when feasible; and could charge the battery with PV output during times when the systems would otherwise be curtailed.

The market value of such systems is estimated at about 30% of current cost of ownership[15]. The analysis found that costs had to decline by about 33% and market value of ancillary services must increase by three fold[16] for such systems to economically viable.

[15] Annualized cost of ownership is estimated at 80/kWh-year – estimates based on purchase power agreement quotes from potential developers. This assumes the projects do not qualify for investment tax credits.
[16] Increase from the current low $9/MW-h levels, back to the $25-30/MW-h levels seen previously.

Figure 5 illustrates how transmission grid-tied storage could be used to keep loads and resources in balance at the transmission grid level—by absorbing excess energy (when supplies exceed demands) to charge the battery and providing energy (when demands exceed supplies) by discharging the battery.

Figure 5. *Transmission Grid-Tied Storage Application for Frequency Regulation & Load Following*



Demand Response, Energy Storage, and Distributed Energy Resources in Palo Alto

Demand Response Program

Customer Demand Response (DR) programs are designed to provide an incentive to customers to change their electricity consumption based on signals provided by CPAU or the CAISO. Customers capable of providing DR services can meet many of the applications identified for storage systems without the need for additional storage hardware investments. Over the past 5 years Palo Alto has implemented a DR program that achieved 500 to 900 kW of demand reduction when CPAU requests load reductions from the large customers participating in the program during hot summer days. The cost of administering and compensating participating customers is about $10,000 per year, with similar value to CPAU[17].

Much of the DR has been achieved by participating customers controlling their air conditioning and lighting loads. To achieve a similar level of load reduction, approximately 2 to 3 MWh of

[17] Details of this program and planned next steps are outlined in the [UAC Report from March 2016]

storage systems would be needed, requiring a capital expenditure in excess of $2 million. Due to the relatively favorable economics of DR programs compared to storage, CPAU anticipates continuing its focus on expanding the DR program to other large customers and investigating residential applications.

Initiative to Leverage Distributed Energy Resources and Meeting Distribution System Needs

Energy storage systems and DR programs are considered distributed energy resources (DER) along with EVs, EV charging equipment, PVs, controllable thermostats and electric water heaters, etc. In February 2016, staff issued a request for proposal to solicit proposals from communicating and controllable DER vendors who already have such systems installed at customer premises in Palo Alto.

Examples of services that can be provided by networked and controllable DER devices include the following:

- Reduced charging of EVs when the value of energy is high. This application is similar to discharging a battery when the value of electricity is high.
- Injecting capacitive energy into the distribution grid from existing PV systems by controlling the inverter operation when CPAU's distribution power factor is low. Smart inverters in BES can also provide this service[18].
- Pre-cooling homes in the morning on hot summer days using thermostat controls in order to reduce electricity consumption during afternoon peak load periods. This is equivalent to charging the batteries in the morning and discharging them at night.

Staff is in the process of evaluating proposals and anticipates making pilot scale commitments to leverage such resources for the benefit of CPAU operations in conjunction with the services customers are already receiving for such DERs. While these commitments will be for services, staff is evaluating the merits of providing incentives for the installation of related hardware such as storage systems.

A comprehensive DER strategy to meet CPAU's needs in the long term, including potential pilot scale storage system incentives at customer locations, will be brought to the UAC and Council for consideration and approval in 2017, along with a recommendation on whether or not to set energy storage goals for the next 3 years.

Role of Distributed Energy Resources in Meeting Palo Alto's Sustainability Goals

To the extent they become cost effective and feasible, DERs such as combined PV and storage systems located at customer premises can enhance customer's electricity reliability, lower customer utility bills, improve community resiliency, and lower electricity transmission losses.

[18] Inverters are becoming more versatile and new inverter standards will enable distributed energy resources such as PV and storage systems to provide fast-acting local grid support services such as responding to changes in system voltage and frequency. CPAU is in the process of testing these features in one of the larger PV systems in town to improve customer and CPAU distribution system power factor during peak load periods.

As initiatives such as Community Solar or Ecodistricts[19] help leverage the value of DERs, CPAU will be well-positioned to facilitate the adoption of these systems where they benefit the community.

Since CPAU's electric supply is already carbon neutral, wide adoption of DERs in Palo Alto will not reduce the community's carbon footprint, but could help the statewide goal of increasing the penetration of intermittent renewable electricity. In addition, Palo Alto's initiative to electrify water heating with efficient heat pump water heaters has the potential to add value as energy storage mechanism in the long run by heating water during the times of day when electricity prices are low[20].

NEXT STEPS

Staff will return to the UAC and Council in early 2017 with a recommendation on whether to set a goal for energy storage and an overall DER strategy. A pilot program may be recommended to site energy storage systems at customer premises, for both residential and commercial applications. Incentives for such a program would be identified as a Resource Impact.

RESOURCE IMPACTS

If an energy storage pilot program is recommended and approved, it could cost $250,000 in customer rebates. Such a program would be administered along with City's existing Demand Response program. The staff resources needed for an expanded Demand Response and Distributed Energy Resource program is anticipated to be 0.2 FTE, and would be managed with existing resources.

POLICY IMPLICATIONS

Energy storage is a key technology to enable increased penetration of renewable energy in California and, when installed in customer premises, reduce their utility use. These two aspects conform to Utilities Strategic Plan objectives and Council policy on environmentally sustainable utility and customer programs. Any use of storage systems to benefit from energy market price differentials will be done in conformance with City's energy risk management policies.

ENVIRONMENTAL REVIEW

The UAC's discussion of energy storage and microgrid technologies is not a Project requiring California Environmental Quality Act review.

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[19] Ecodistrict is a community level project to achieve various sustainability goals. One such goal could be self-sufficiency in energy by a collective subscription to a larger scale community owned PV system.

[20] CPAU's electrification plan incorporates this possible application of using heat-pump water heaters as energy storage devices in the long term.

ATTACHMENTS

A. Description of Energy Storage and Microgrid Technologies
B. Value of Electricity Storage in Providing Services to the City of Palo Alto
C. Case Studies of Battery Energy Storage Applications in Palo Alto
D. Thermal Energy Storage in Palo Alto
E. Outline of Energy Storage Regulations, Policies and Incentives

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Description of Energy Storage Technologies and Microgrid Technologies

1. Energy Storage technologies

Please refer to Staff Report 4384 for a review of energy storage technologies. The vast majority of current grid connected energy storage systems[1] (90%) are pumped hydro projects, with 28 GW installed in the U.S. Thermal storage is the second most installed storage technology with 855 MW of storage in the US (~3%). 740 MW of Compressed Air energy Storage facilities exist in the U.S, which represents 2.4% of the US capacity. Li-ion batteries (1.4%), lead acid batteries (0.5%), flywheels (0.3%) and flow battery 0.1% follow. The fastest growing residential and commercial applications of storage in California use battery energy storage systems (BES), much of the report outlines applications of such systems. Thermal energy storage (TES) system applications were also reviewed.

2. Microgrids

a. Microgrids value

The value of microgrids concentrates around four main areas (see Figure A1):

- Security: by offering an uninterruptible power supply for critical loads.
- Reliability: contiguous quality power supply 24/7 with local generation
- Sustainability: allows the integration of local renewable generation
- Cost efficiency: opportunities to do peak shaving, demand-response, and hedge against high grid prices

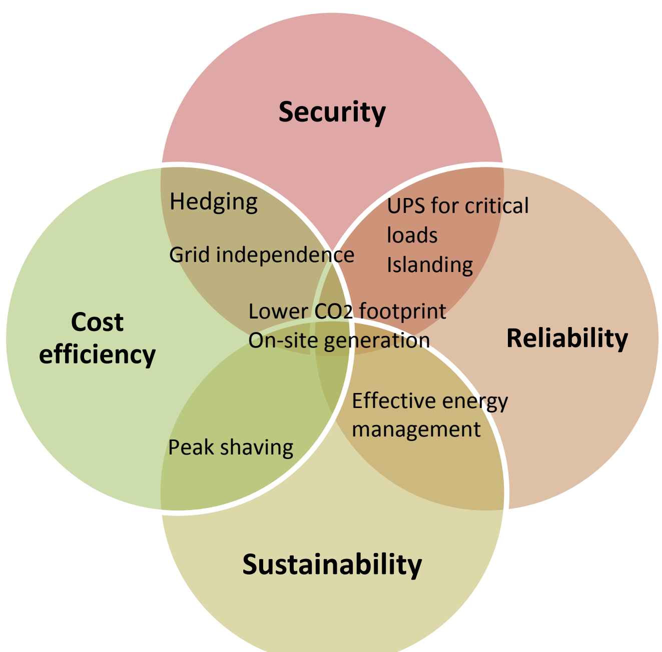


Figure A1: Graphical representation of microgrid values

[1] http://www.energystorageexchange.org/

Microgrids can provide several services to the main grid:

- Ancillary services
- Demand/response, Curtailment
- Ramping, flexible capacity

b. Key components and functions of a microgrid

The microgrid needs to be able to operate the loads and energy sources in grid connected or islanded mode and transition smoothly between the two modes. Hence, the microgrid has the following needs:

- **Islanding detection**: During islanding mode the microgrids is responsible of voltage and frequency regulation. The microgrid controller provides these regulation services. Detection can be done locally, by measuring local variables (voltage, frequency) or remotely by communicating with the main grid.
- **Fault current protection:** The microgrids require detection and protection against fault current flows, i.e. short circuits.
- **Power quality:** Harmonic contents and voltage unbalance. This can also provide ancillary services to the main grid.
- **Black start**: when islanded

Other desirable functionalities of the microgrids include:

- **Energy optimization:** this includes power curtailment, peak shaving, storage management

Those functions are performed by the microgrid master controller (see Figure A2), supported by a strong communication and sensor network. The main function of the master controller is to match loads and generation (See A2 and A3) and to provide monitoring of the microgrid.

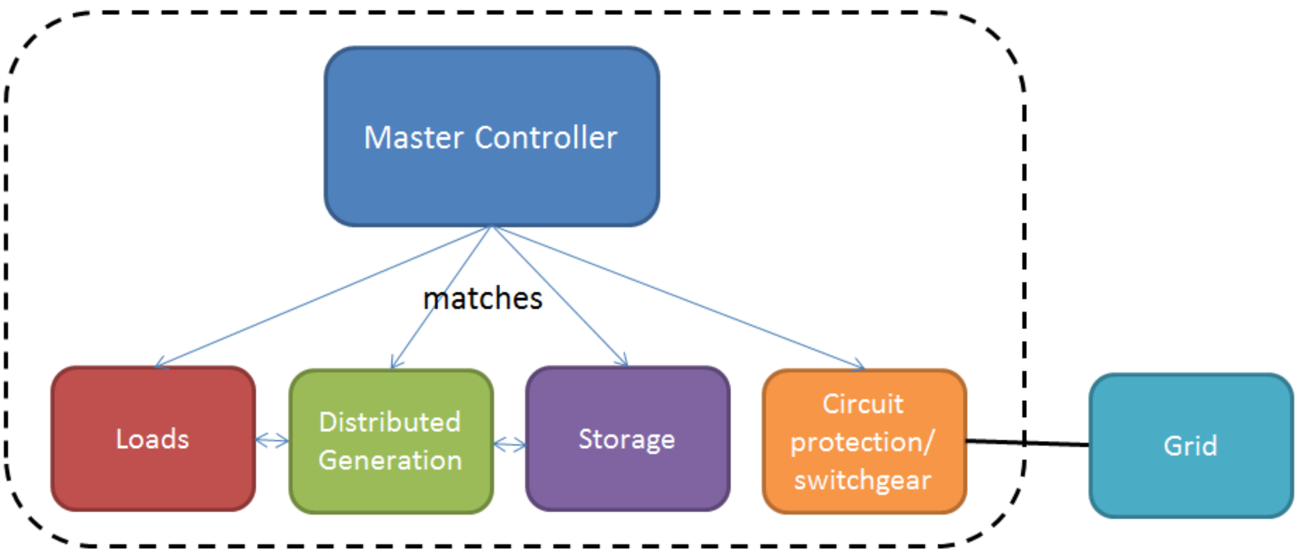


Figure A2: Master Controller functions within the microgrid

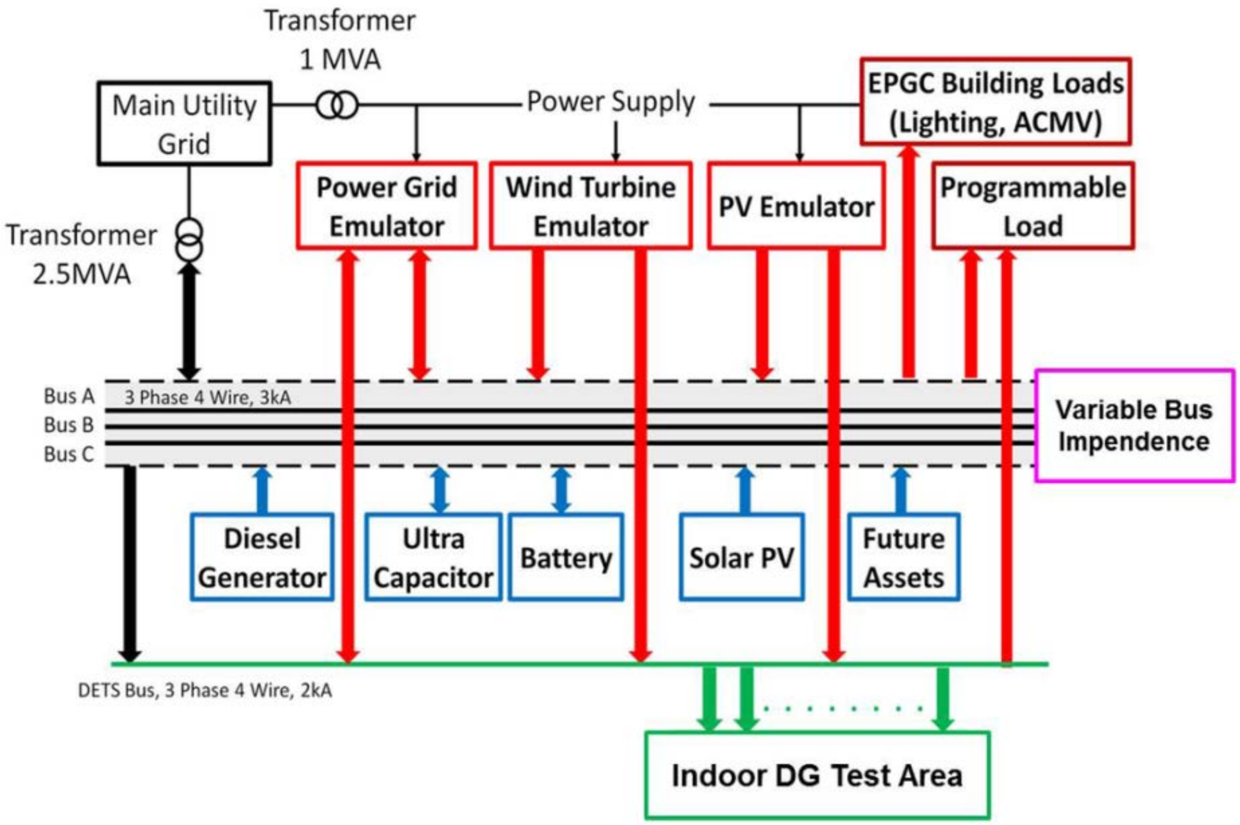


Figure A3: example of microgrid block diagram, Experimental Power Grid Centre (EPGC) microgrid test facility[2]

The main applications of the commercial microgrids are for community-sized systems and campuses that have critical loads to protect (i.e. fire station, police station, and communications) and want to integrate local renewables in the grid.

c. Nanogrids

Nanogrids are microgrids for a single-load or single-building microgrid. Nanogrids can also island from the main grid. The main commercial applications of nanogrids are residential homes and single commercial buildings with solar panels and back-up battery storage.

[2] Thangavelu et al., Integrated Electrical and Thermal Grid Facility - Testing of Future Microgrid Technologies, Energies 2015, 8(9), 10082-10105, http://www.mdpi.com/1996-1073/8/9/10082/htm

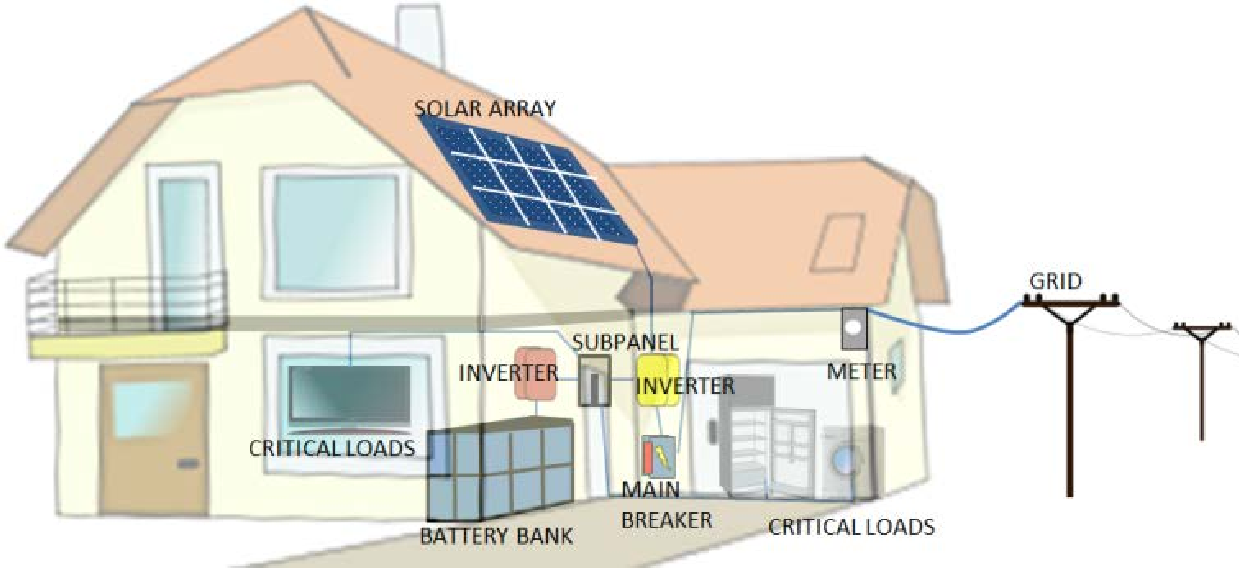


Figure A4: Illustration of a nanogrid in a residential house

The PV panels and battery bank are connected to the inverter. The main breaker is the point at which the house can be islanded from the grid. The battery, PV, critical loads and inverter interaction is managed at the subpanel interface (See Figures A4 and A5). The utility meter is located between the main grid and the main breaker.

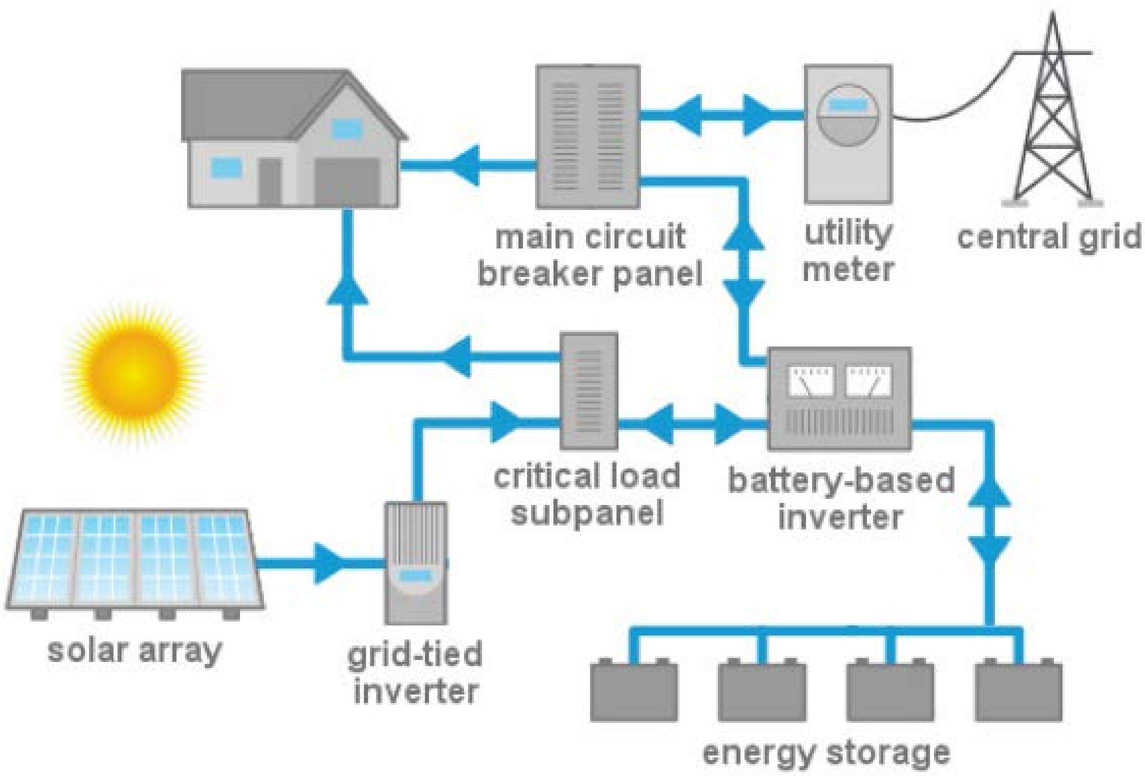


Figure A5: Main elements of a nanogrid

Two different design philosophies can be adopted for nanogrids. Those grids can operate in Direct current (DC) or alternating current (AC) current. The two different strategies and the corresponding systems depicted on Figure A6 depend on how many inverters are used in the system. PV panels produce energy in DC current, and most houses loads requires AC current. Batteries take DC current as well.

In the AC strategy, the DC current from the PV panels in converted to AC through an inverter and can serve house loads or be exported to the grid. When charging the battery, the current is converted back to DC through a second inverter. This type of installation is usually chosen when the storage is added after the PV panels were already installed.

In the DC strategy, the DC current from the PV panels can be used to charge the battery directly or be converted to AC through an inverter to be used for the house or exporter to the grid. Only one inverter is required. Energy from the grid cannot be used to charge the batteries.

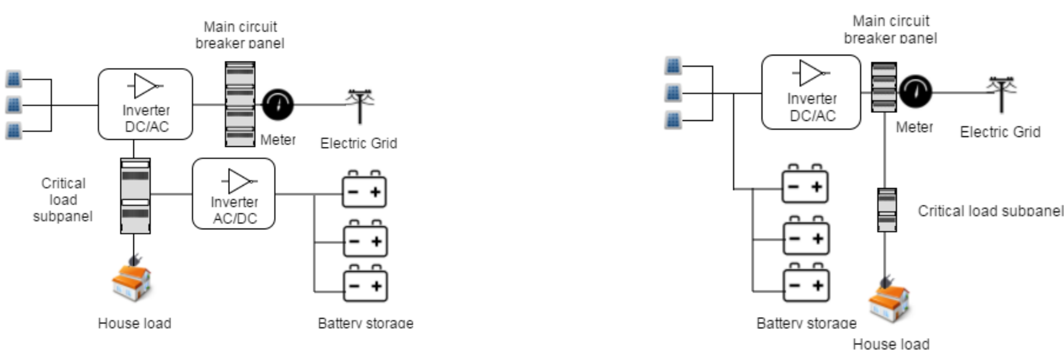


Figure A6: Schematic representation of AC (left) and DC (right) energy storage

The advantages and differences of both systems are outlined in Table A1.

Table A1: Comparison of AC and DC storage system

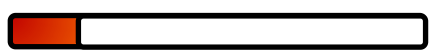
	AC storage system	DC storage system
Installation	Existing PV installation	New installation
Off-grid uninterruptible power supply	✓	✓
Energy storage	From solar panels + grid	From solar panels only
Cost	Higher, unless retrofit of existing system.	Lower ✓
Efficiency	More losses in cycling, but more efficient to power AC load	Higher efficiency for cycling and if mostly DC power
Federal Incentive	Qualifies only partially for 30% ITC if installed with PV	Qualifies for 30% ITC if installed with PV

Value of Electricity Storage in Providing Services to the City of Palo Alto

This section describes in detail the 13 services that storage systems could provide to the three stakeholder classes—customers, utility and the California Independent System Operator (CAISO)—as outlined in the report.

Table B1: Summary table of 13 services provided by storage

	Service	Percentage of cost	Evolution
A. SO/RTO Services	1. Frequency regulation	15%	Possible at medium term. Revenue streams in CAISO are not beneficial at the moment.
	2. Spin/Non-Spin Reserve	7%	Unlikely to become financially viable in the years to come. Regulation is the service generating the most revenue at the moment
	3. Voltage support	N/A at the time	Unlikely since the burden is on the generators.
	4. Energy Price Differentials	8%	Not beneficial for this purpose only, but can provide additional value streams for other usage. Could evolve if gas prices go up.
B. Utility Services	5. Resource Adequacy	15%	Not beneficial for this purpose only, but can provide additional value streams for other usage.
	6. Transmission Deferral	0%	Not beneficial in the case of Palo Alto since transmission is billed by unit of energy.
	7. Transmission Congestion Relief	10%	Could become necessary if congestion becomes a big problem

	8. Distribution Deferral	50% (case by case) – but N/A at the moment in PA	 On a case by case basis. Expensive upgrades unlikely because of current state of transformers.
	9. Distribution loss savings	<1%	 Not beneficial for this purpose only, but can provide additional value streams for other usage.
C. Customer Services	10a. Backup power - residential	<1%	 Not beneficial, especially with high reliability and unlikely to go up enough to justify an investment.
	10b. Backup power - commercial	case by case Can be 100%	 Already financially viable if the industry is highly dependent on electricity and critical loads are low (i.e. server vs full building). Likely to become a package with other services to the grid, although those services might be conflicting.
	11. Time-of-Use Bill Management	<1%	 Highly dependent on TOU rates. Unlikely to go up because peak consumption is not an issue in Palo Alto.
	12. Demand Charge Reduction	40%	 Getting closer to competitive. Likely to become more competitive as more offerings become available.
	13. Increased-PV Self-Consumption	18%	 Unlikely to go up with CPAU low electricity tariffs.

A. ISO/RTO Services

Ancillary services provide the CAISO the resources to reliably maintain the balance between generation and load. The different types of ancillary services are described in Table B2.

Table B2: Ancillary services description[1]

Service	Service Description		
	Response Speed	*Duration*	*Cycle Time*
Regulation	Power sources online, on automatic generation control, that can respond rapidly to system-operator requests for up and down movements; used to track the minute-to-minute fluctuations in system load and to correct for unintended fluctuations in generator output to comply with Control Performance Standards (CPSs) 1 and 2 of the North American Reliability Council (NERC 2002)		
	~1 min	*Minutes*	*Minutes*
Spinning reserve	Power sources online, synchronized to the grid, that can increase output immediately in response to a major generator or transmission outage and can reach full output within 10 min to comply with NERC's Disturbance Control Standard (DCS)		
	Seconds to <10 min	*10 to 120 min*	*Days*
Supplemental reserve	Same as spinning reserve, but need not respond immediately; units can be offline but still must be capable of reaching full output within the required 10 min		
	<10 min	*10 to 120 min*	*Days*
Replacement reserve	Same as supplemental reserve, but with a 30-min response time; used to restore spinning and supplemental reserves to their pre-contingency status		
	<30 min	*2 hours*	*Days*
Voltage control	The injection or absorption of reactive power to maintain transmission-system voltages within required ranges		
	Seconds	*Seconds*	*Continuous*

Storage technologies like batteries and flywheels are most qualified for fast response times, which cheaper gas peakers struggle to achieve at low standby cost. Gas peakers need to be running continuously at low power and burn fuel in order to be online within minutes, a requirement which is easily achieved by a battery.

The City of Palo Alto's 56 MW share of the Calaveras Hydroelectric Project satisfies the ancillary services needs of the city. This study evaluated the possible value that could come from owning new storage technologies for ancillary services.

[1] http://web.ornl.gov/~webworks/cppr/y2001/rpt/122302.pdf

1. Frequency regulation

Most US electric equipment relies on a grid operating at a frequency of 60 Hz with very low tolerance for variation. When the demand and supply are not exactly matching, the grid frequency varies. Storage, by absorbing or releasing power, can provide regulation to increase or decrease the frequency of the grid.

CAISO monthly market performance reports[2] contain average ancillary services prices for regulation in the Day Ahead market for 2015. The average payment for regulation in 2015 was $8.77 per MW and per hour.

It is noteworthy that ancillary services prices have been trending upward in January 2016. Projected average prices for 2020 are about 15$/MW, but should reach at least 35$/MW for several hours per day.[3] FERC Order 755 has stipulated that ISOs implement “a payment for performance that reflects the quantity of frequency regulation service provided by a resource when the resource is accurately following the dispatch signal.”[4] However, in the current CAISO market the mileage payment[5] that act as payment for performance is too low to be relevant with $0.01-$0.03/MWh in the Real Time market and 0.09$/MWh in the Day-Ahead market. Hence this study did not consider a mileage payment.

Data from the model prepared by StrateGen for the California Energy Storage Alliance (CESA)[6] was used to assess the cost and revenue of battery for regulation.

At the assumed price of $600/kWh, batteries for regulations systems only do not make sense financially. An installed price of under $50/kWh would make battery systems for regulation break even under current pricing. Three strategies were considered: 1) several cycling per day; 2) only bid for the highest hour of the day (~15$/MWh); and 3) only bid for the highest ten hours of the month (~50$/MWh).

The optimum is to bid for 5-7 hours a day (see Figure B1) and reserve the use of battery for other services for the rest of the day, which could complement the revenue of the system. The marginal benefice of bidding additional hours on a 20-year system did not map out to a significant increase in revenue because of the replacement cost of the battery. The replacement cost of the battery was assumed equal to the initial installation cost.

The ancillary services payment per MW per hour has been lower in the past years due to the low prices of gas. In 2010 prices were around $30/MW. Prices in 2020 should reach at least

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[2] https://www.caiso.com/market/Pages/ReportsBulletins/Default.aspx

[3] http://energy.gov/sites/prod/files/2015/12/f27/Ancillary%20Service%20Revenue%20Potential%20for%20Geothermal%20Generators%20in%20California.pdf

[4] https://www.ferc.gov/whats-new/comm-meet/2011/102011/E-28.pdf

[5] https://www.caiso.com/Documents/Pay-PerformanceRegulationFERC_Order755Presentation.pdf

[6] http://www.strategen.com/storagealliance/sites/default/files/White%20Papers/CESA_FR_White_Paper_2011-02-16.pdf

35$/MW for 5 hours per day. In this case the breakeven price would be around $150/kWh installed.

Note: The utility would be unlikely to own the system as considered in this study, and would have to contract through a third party to own and manage the storage system. This will likely increase the prices of storage and delay the timeline at which regulation could become profitable.

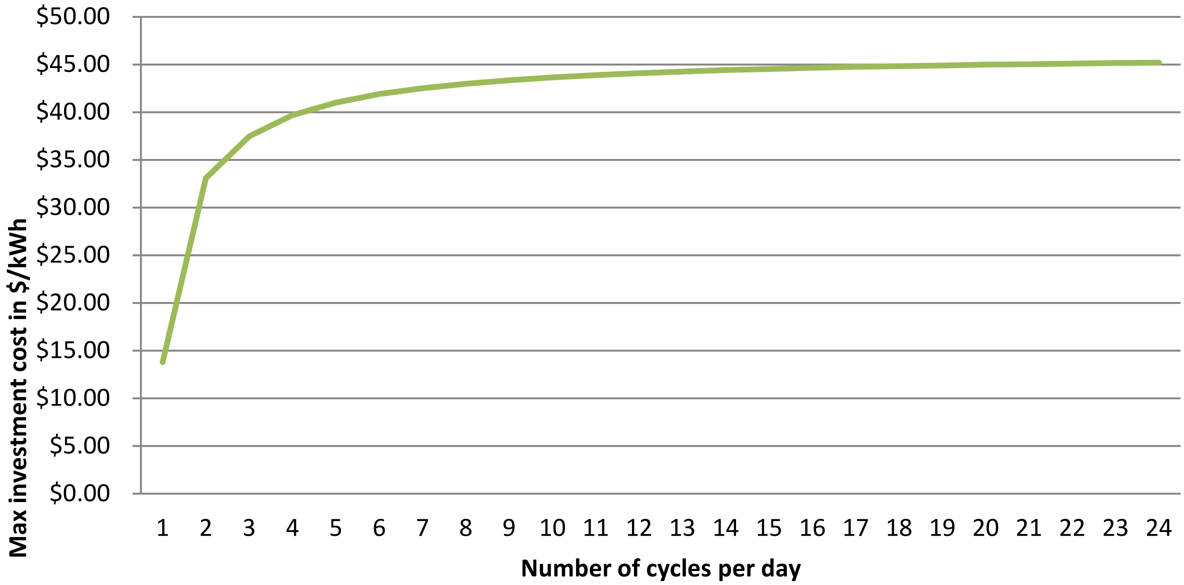

Figure B1: Maximum battery system investment cost per kWh needed for a null 20-year NPV regulation in function of cycles per day

2. Spin / Non-Spin Reserve

Storage can bid as spinning, non-spinning or supplemental reserve. However, the value of those services is lower than frequency regulation by at least 50%. The return on investment of those services would be lower than for regulations. Hence, this study did not consider the economics of those markets.

3. Voltage support

Reactive power is the non-usable part of power (see Figure B2). The power factor is defined as:

$$power\ factor = \frac{P, real\ power}{S, apparent\ power}$$

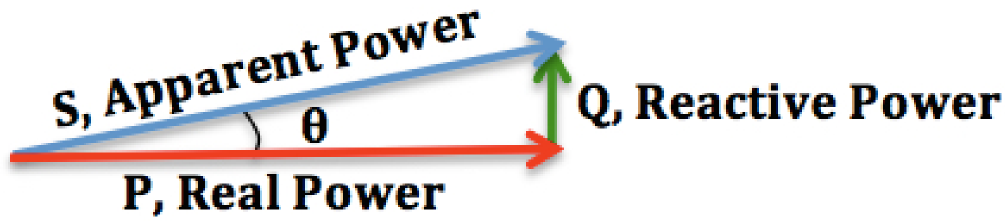

Figure B2: Real, Apparent and reactive power, By Wikieditor4321 - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=45518503

In order to supply a load, the real power must be equal to the load. A high reactive power increases the ratings necessary in the lines, but decreases the efficiency since only "real power" is usable. For example, if the power factor is 0.6, then apparent power is 1.67 times the load, which increases transmission losses. In order to carry this extra power, all the transmission and distribution system would need to be oversized. This is why grid-tied systems are required to supply power above a defined power factor.

However, there might be times where the independent system operator wishes to increase or decrease the apparent power in order to keep the grid operating within the voltage range that it can tolerate. In that case, reactive power is the main source of control of the apparent power experienced by the transmission lines. In order to keep the transmission lines within operational range of voltage, injection or withdrawal of reactive power is necessary.

CAISO "maintains acceptable voltage levels and VAR flow on the CAISO Controlled Grid" through participating generators that are required to operate within a specified power factor band. Participating load at interface points are not compensated, only generators.[7]

Payment to generators is in form of lost opportunity cost to the Locational Marginal Price (LMP) when operating outside of normal conditions. CAISO has also procured voltage control through Reliability-Must-Run facilities at the rate of $50,000/MVAr or $50/kVAr.[8]

Capacitors are best suited to solve reactive power issues, and increase power factor.[9] However, this will need to be procured by power producers. Batteries have been proven effective at controlling power drops from local distributed generation, which would be useful in the case of microgrids.[10] Palo Alto would only be concerned if the local generation power factor became problematic.

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[7] https://www.caiso.com/Documents/3320.pdf

[8] https://www.caiso.com/Documents/CalPeakandMalagaCommentsReactivePowerRequirementsandFinancialCompensationRevisedStrawProposal.pdf

[9] http://www.hv-eng.com/2011CEDCapacitors.pdf

[10] J. Yi, P. Wang, P. C. Taylor, P. J. Davison, P. F. Lyons, D. Liang, S. Brown and D. Roberts, " Distribution Network Voltage Control Using Energy Storage and Demand Side Response", 2012 3rd IEEE PES, ISGT Europe, Berlin

4. Energy Price Differentials

A storage system enables buying electricity when prices are low and use the electricity when prices are high. For Palo Alto, the average price difference between peak and off-peak pricing is 0.00717 $/kWh (expected to rise to $0.011/kWh by 2025). At this revenue, over 10,000 cycles and with 80% round trip efficiency, a battery would only generate $57 per kWh of installed capacity, which does not financially justify such a system.

B. System/Utility Benefits

5. Resource Adequacy

CAISO mandates that each Load Serving Entity (LSE) must submit a resource adequacy plan "to satisfy its forecasted monthly Peak Demand and Reserve Margin for the relevant reporting period."[11] Palo Alto currently procures capacity at the rate of $28/kW-yr. The offers that the utility received from remote storage have been at least double this value. A current flexible resource adequacy policy is being considered[12], but the City's ownership share of the Calaveras Hydroelectric Project would satisfy those requirements.

6. Transmission Deferral

A higher load can trigger a transmission line upgrade to accommodate a higher power rating. However, if the upgrade is triggered by a peak load that happens only a couple hours of the day, months or year, it might be advantageous to procure storage to displace the peak consumption to a later hour of the day instead of upgrading the lines.

CPAU is currently paying for transmission charges per unit of energy (kWh) and does not experience demand charges. Therefore peak shifting for avoiding transmission charges does not offer any financial incentive for CPAU. The demand is satisfied by the resource adequacy described in the previous paragraph and procured at a price that do not justify considering storage.

7. Transmission congestion relief

CPAU has Power Purchase Agreements (PPAs) with generators in California. CPAU then sells this energy at the Locational Marginal Price (LMP) at the node where generation interconnects. Nodes that experience a higher load than the transmission line can accommodate are called congested node and experience a lower price for energy because of congestion charges. In some cases the energy price can be negative and force the curtailment of the generation. This study analyzed one year of LMP data at the interconnection node for the Hayworth solar farm with which the City has a PPA[13] and considered two strategies:

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[11] https://www.caiso.com/Documents/CIRAResourceAdequacyToolUserGuideforMarketParticipants.pdf

[12] https://www.caiso.com/Documents/StrawProposal-FlexibleResourceAdequacyCriteria-MustOfferObligationPhase2.pdf

[13] City of Palo Alto Solar PV PPA Projects - https://www.google.com/maps/d/viewer?mid=zm8TOActUeOA.k1KfA2u9T8u4&hl=en_US&usp=sharing

1. Store the production of the four most congested hours of the day (between 11AM and 3PM) and sell the storage during the highest three hours of the evening peak; and
2. Store the production of the most congested hour of the day (at 12PM) and sell the storage during the highest priced hour of the evening peak.

The power plant's daily production was estimated using PV watts[14], and assumed roundtrip efficiency around 70%. In each case the storage did not make economic sense. For a high efficiency (93%) battery with one discharge per day, the value per kWh displaced increased to 2 cents, which is still below the required value to break even.

However, if the trend of negative pricing during peak hours keeps increasing and battery prices keeps falling then there would be scenarios in which batteries would be cost effective. For example, if the amount per kWh displaced reached $0.04/kWh on average and the batteries reached $200/kWh then the storage would be cost effective.

8. Distribution Deferral

Distribution deferral uses storage to absorb a growing load on a transformer. The growing load would trigger a transformer upgrade, but with storage peak shaving, the transformer upgrade can be deferred to a later time. This allows for a longer utilization of the infrastructure and lowers the investment risk of the utility.

According to the Sandia study "Electric Utility Transmission and Distribution Upgrade Deferral Benefits from Modular Electricity Storage" by Jim Eyer[15], the distribution deferral is more profitable in its first year, so the study makes a case for reusable and transportable storage that will defer upgrades up to the point that the upgrade is necessary and then be installed on another transformer. In this case, they find that with an average cost of transformer upgrade around $75/kW, the value of reusing the storage system in 5 different locations would reach a cumulative value of $1,700/kW after 10 years. For three hours battery storage, this represents $566/kWh which could be cost effective in the future.

As a case study, data from the 2009 PNNL study "Avoiding Distribution System Upgrade Costs Using Distributed Generation"[16] was used. The cost data of different transformer upgrade projects was compared to the cost to defer the entire upgrade capacity with a battery system:

1. Four-hour Li-ion battery system at $600/kWh
2. Three-hour Li-ion battery system at $600/kWh
3. Three-hour 2020 horizon for Li-ion batteries at $300/kWh

The results show that most transformer upgrades would be more cost effective than a full upgrade with a battery. Certain projects which are especially costly can beneficiate from a battery system compared to an upgrade, as long as the peak is narrow enough that the battery

[14] http://pvwatts.nrel.gov/
[15] http://prod.sandia.gov/techlib/access-control.cgi/2009/094070.pdf
[16] http://www.sandia.gov/ess/publications/SAND2010-0815.pdf

has sufficient capacity. By 2020, if battery costs are halved, more battery systems could become more cost effective than an upgrade. These results are also confirmed in the Sandia report, mentioning the E3/EPRI study[17] which reported values of T&D deferral for PG&E ranging from $230/kW and $1,173/kW, in which the upper range would make batteries close to cost effective.

CPAU's current distribution transformer upgrade costs range from $40 to $220/kW. The best candidates for deferral are transformers where the projected load growth is slow and the peak band is narrow. The smaller the storage needed for the one-year deferral, the more cost effective it is, since the investment is smaller. Smaller upgrades tend to be pretty expensive per kW, but the storage power required is generally too high to make sense for a deferral (>10%). In 2016, the only systems that could be cost effective for a one-year deferral have a slow load growth (under 2%) and high T&D cost (over $100/kW) which is experienced by small distribution overhead transformer upgrades in Palo Alto. However, the storage power required for the distribution overhead transformers is generally above 20%, which makes the deferral not cost effective. In the future, with an average cost of $300/kWh installed for batteries, projects with high cost and moderate growth, or low growth and average cost could benefit from a one-year deferral through battery storage. So far CPAU transformers all have above 20% remaining capacity and the load has been stable, which means that no upgrade will be required in the next years. In the event that several transformers reach capacity in the long-term, mobile battery storage could be beneficial to defer several upgrades.

9. Distribution loss savings

The system experiences on average 3% losses to distribute electricity. However, the losses are higher during peak hours (4%) than off-peak (2%). By storing electricity locally during off-peak hours and distributing it during peak hours, CPAU can avoid 2% distribution losses.

$$Electricity\ saved(kWh) = Electricity\ purchased\ (kWh) \times \left(\frac{1}{0.98} - \frac{1}{0.96}\right)$$
$$Electricity\ saved(kWh) = Electricity\ purchased\ (kWh) \times 2.13\%$$

For peak prices around $30/MWh, that's $0.64/MWh shifted (0.064 cents per kWh). With this revenue, over 10,000 cycles and with 80% round trip efficiency, a battery would only generate $5.10 per kWh of capacity in addition to the $57 per kWh of benefits, which does not justify financially such a system.

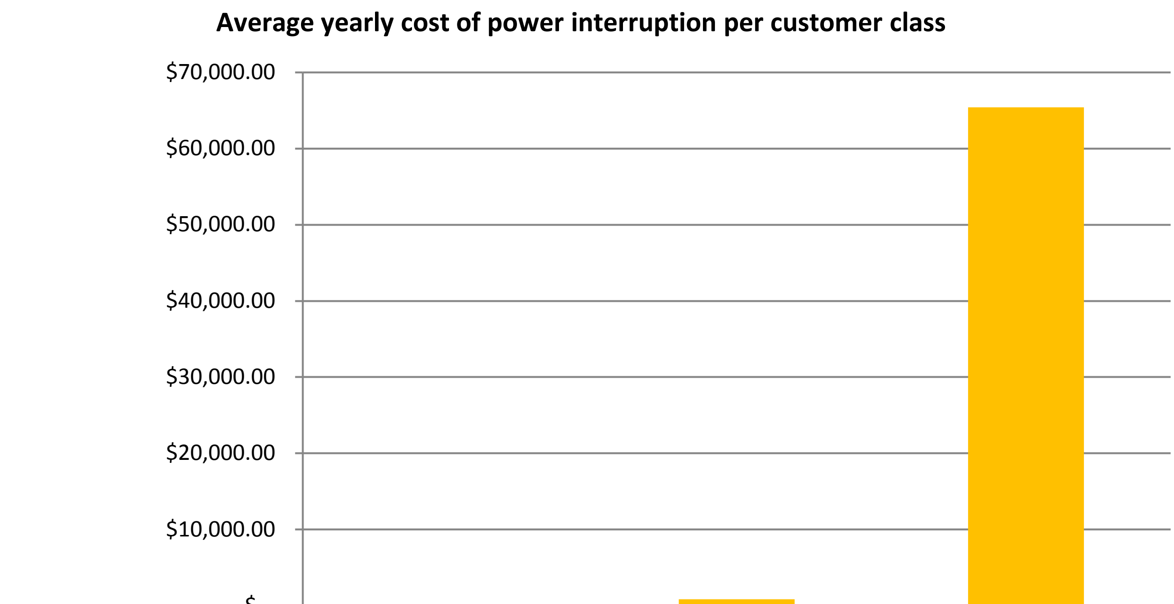
[17] http://connection.ebscohost.com/c/articles/9508071617/marginal-capacity-costs-electricity-distribution-demand-distributed-generation

C. Customer benefits

10. Backup power

In order to estimate the cost of customer outage for the different classes of customers given CPAU's reliability data, the Interruption Cost of Energy tool funded by DOE[18] was used using most default parameters with an adjustment for Palo Alto median income to $123,495 from 2013 data[19] adjusted to 2016 dollar value (see Table B3).

Table B3: Estimation of 2012-2015 average yearly cost of power interruption in Palo Alto for each customer class



	Residential customer	Small commercial customer (<50,000 kWh)	Medium and large commercial customers (>50,000 kWh)
Average yearly cost of power interruption	$26.96	$852.86	$65,413.18

The average yearly cost of outages shows that residential customers would derive very little economic value in having a backup power given that their annual losses are relatively low. However, for certain commercial customers, investing in storage as a backup power for critical loads can be justified to mitigate losses in case of power interruption, especially if the critical loads are small.

Diesel generators cost about $200/kW. However, a 5kW generator will consume about 18 gal/day, which costs about $40-50 per day to run. A larger commercial-scale generator sized at 300 kW will consume 20 gal/hr. A battery system has no running cost. Given the reliability of CPAU, a battery storage system will never be cheaper than a diesel generator for residential or

[18] http://www.icecalculator.com/

[19] http://www.city-data.com/income/income-Palo-Alto-California.html

commercial applications. The exception to this rule would be in case of an extended period of time without power (i.e. earthquake related) and with the inability to supply enough diesel to run a generator, a commercial customer could then beneficiate from a PV+storage system that would allow the critical operations to keep running without a diesel supply.

11. Time-of-Use Bill Management

When a customer is on a time-of-use (TOU) rate schedule, electricity is more expensive during peak hours. Instead of consuming electricity during peak time, it might be more economical to use the energy stored, and recharge using the grid during off-peak hours. The storage system allows customers to optimize when they buy, store or export power. Peak shaving contributes to lowering the demand on the grid during peak hours.

A study carried by Stanford student Tha Zin looked at the net present value (NPV) of peak shaving with current CPAU rates. The dataset used in her analysis was the hourly electricity consumption (load profile) data of 1,923 households in Bakersfield, California from August 1, 2010 to July 31, 2011. To evaluate the NPV of storage, the study varied the following parameters: TOU rates[20], roundtrip system efficiency, and system costs as well as different amount of peak shifted. For the last parameter, the battery was sized to shift at the peak load for only a certain percentages of the days per year (5-100%). If the percentage of the days is 5%, then it means that the battery was sized to shift the highest 5% peaks of the year.

For each household, the NPV of a storage system was calculated. Results show that given the current values in TOU, efficiency and cost only one customer out of the pool would have a positive NPV with a storage system.

12. Demand Charge Reduction Commercial customers

See case study II in Attachment C.

13. Increased-PV Self-Consumption

See case study I in Attachment C.

[20] http://www.cityofpaloalto.org/civicax/filebank/documents/32678

Three Case Studies of BES Storage Applications in Palo Alto

Outlined below is the analysis of three most relevant storage applications for Palo Alto:

I. Residential customer application. Storage is installed after solar PV panels with the intent to do time-of-use bill management under the successor net energy metering program to increase PV-self consumption.
II. A commercial customer application within Palo Alto (Palo Alto City Hall). The size is in the tens or hundreds of kW/kWh range and designed to provide electric customer demand charges reduction and meet CPAU resource adequacy needs.
III. A transmission grid-tied storage unit, either close to Palo Alto or located at one of Palo Alto's central PV plants. Due to the relatively large size, in the MW/MWh scale, it is assumed that the system cannot be located within Palo Alto due to the lack of suitable land. The application would be to provide CAISO services such as frequency regulation and flexible resource adequacy capacity.

I. Residential customer PV+ storage

a) Description of the Storage System & Cost: Residential customer installing battery storage to store the energy produced by the solar panels during the day and to use later during the evening and night. The consumer scenario was identical to the one defined in Attachment C of the NEM Successor Program Staff Report[1]. The three options are: 1) no storage; 2) a 3.3 kW/7 kWh system[2]; and 3) a 6 kW/12 kWh storage system.[3]
b) Application: Increased PV Self-Consumption
c) Value: energy exported to the grid is paid the NEM successor program export rate of $0.07485/kWh; current electric retail rates are $0.11029/kWh for Tier 1 (up to 11kWh/day) usage and $0.16901/kWh for Tier 2 (over 11 kWh/day) usage.
d) Results and Conclusion: Calculations can be found in Table C1 below. Figure C1 shows how the energy delivery is reduced by the battery storage. When taking into account the round trip losses and current energy prices, the 7 kWh system saved $169/year and the 12 kWh system saved $194/year. When taking into account the annualized cost of installation of storage ($130/kWh-yr for a ten-year warrantied system), the benefits are not sufficient to justify the installation of the system, as the payment for solar + storage is higher than solar only (see Figure C2). At a price of $280/kWh installed and a delta between on-peak and off-peak electricity price of $0.10/kWh, storage systems will break even.
e) Assumptions:
   - Round trip efficiency was assumed to be 92%.
   - In both battery scenarios, the customer stores as much power as possible during the day to use it later at night.

[1] https://www.cityofpaloalto.org/civicax/filebank/documents/51848
[2] With the 7 kWh system, the customer might not be able to capture fully the excess energy during the summer days. Installed cost was assumed to $9,500.
[3] With the 12 kWh system, the customer do not export any energy to the grid year round.

- Solar installed cost was assumed to be $3.50/W-DC (group-buy price)
- Investment Task Credit (ITC) was applied toward solar panels but not storage, since the installation of storage was assumed to happen after the customer installed PV.

Figure C1: Representation of energy delivered, exported to the grid, consumed out of storage, netted on site and lost in the three storage cases

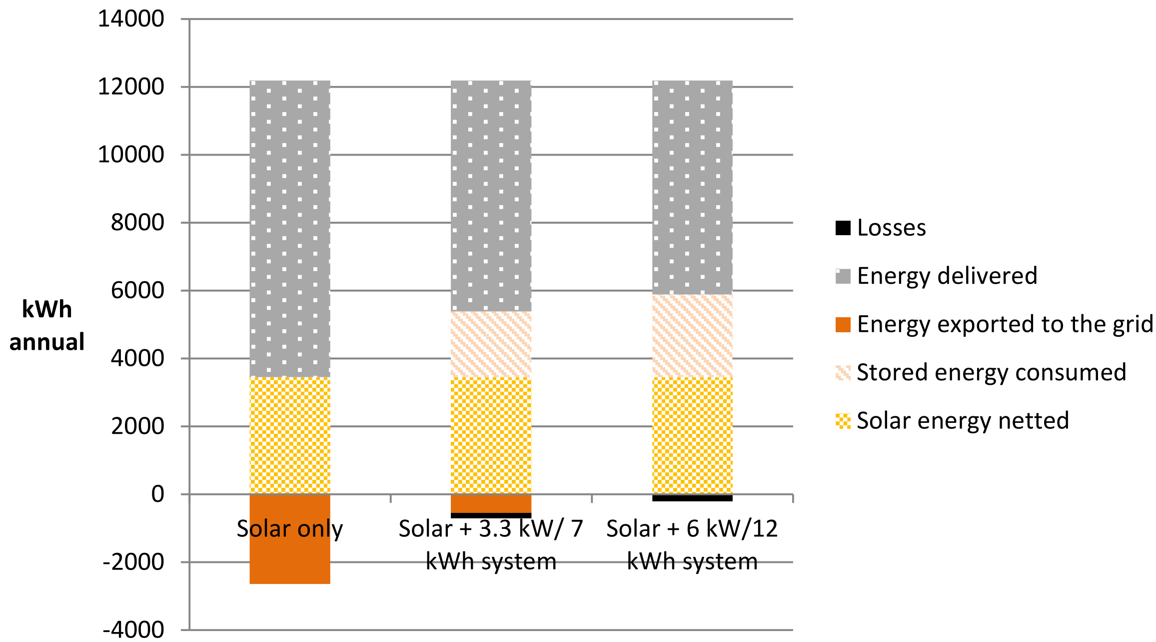
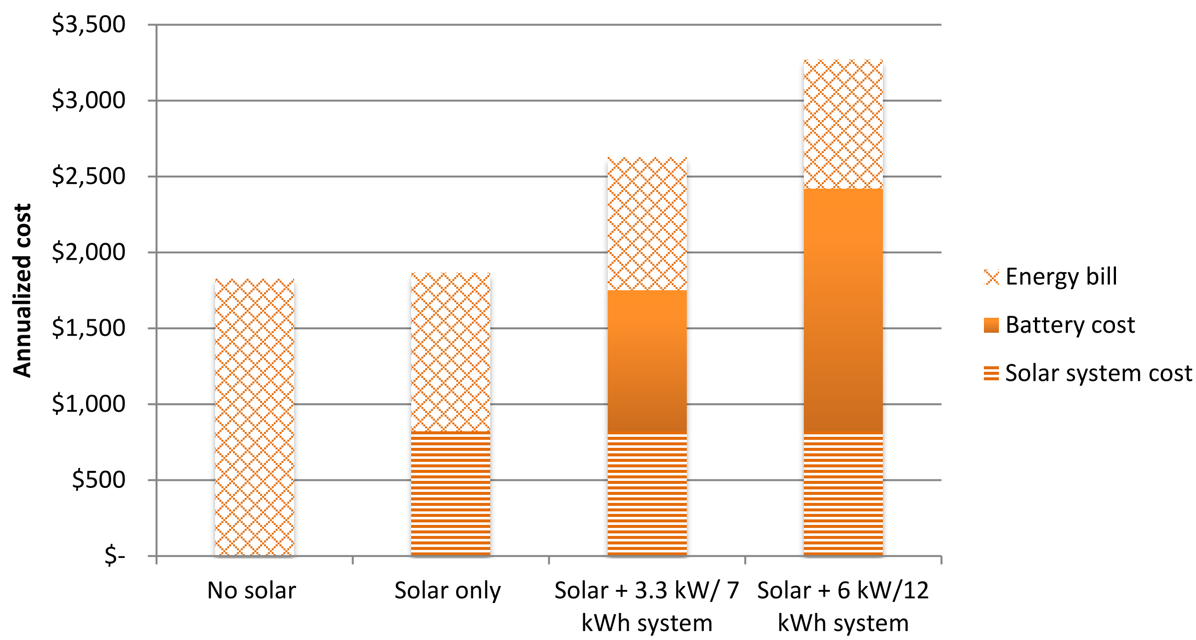


Figure C2: Energy annual cost for no solar and the three storage cases considered, to be compared with no solar case.



II. Commercial Customer Storage Application, Located at Customer Premises

a) Description of the Storage System & Cost: Commercial customer installing batteries with the goal to reduce demand charges and provide resource adequacy value to CPAU. Using the Palo Alto City Hall's load, the recommended size for a leased system for the building was about 18 kW/36 kWh (i.e. 18 kW capacity with 2 hours of charge) for an annual cost of about $5,000.

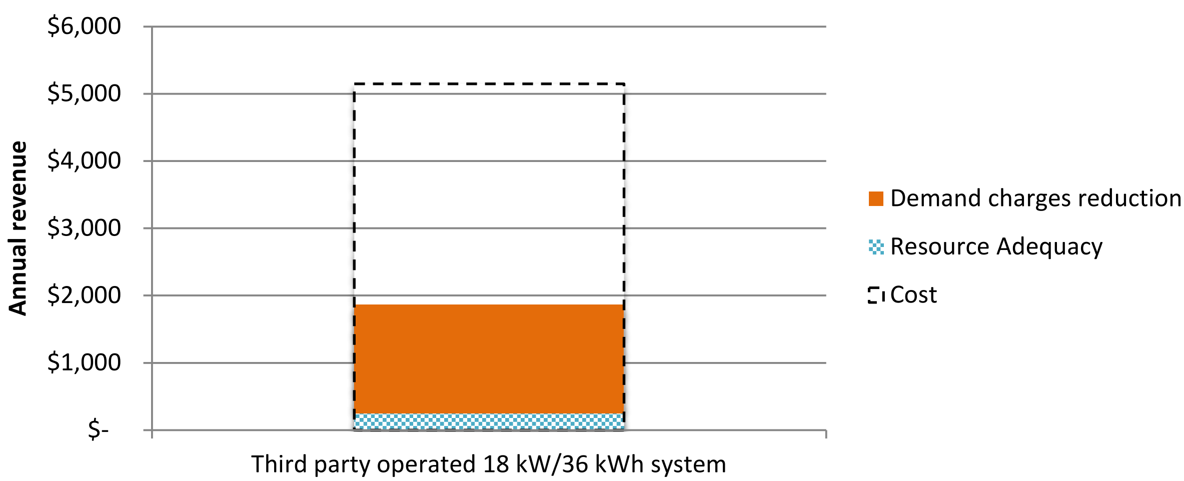
b) Application: Demand charges reduction for commercial building customer and (flexible) resource adequacy value to the utility.

c) Value: The customer's cost for demand charges can be reduced (current demand rates on the E-4 Rate Schedule are $14.04/kW-month during the winter and $19.68/kW-month during the summer). In addition, if CPAU is able to dispatch these systems to meet resource adequacy needs, these systems can harness higher value stream currently valued at $28/kW-yr. Since most of these storage systems also come with telemetry and dashboards profiling entire building loads in real time, building operators are able to garner greater insights to more optimally operate the building. However, this value was not considered in this analysis since it is not directly derived from storage.

d) Results and Conclusion: The annual cost of the system is compared to the annual revenue stream as shown in Figure C3. Because of the flatter load profile shape, the required capacity to shave off the peak is higher than if the peak was narrow and tall. Resource adequacy related values are also relatively small. Thus, such commercial systems are not cost effective in Palo Alto.

e) Assumptions:
- System life: 10 years
- O&M cost are considered negligible for the self-operated system
- Winter peak is 3-hour long and summer peak is 5-hour long.

Figure C3: Comparison of yearly revenue to cost of commercial battery storage for Palo Alto City Hall



Notes: The commercial systems considered do not offer the ability to island, which would harness additional value, although at a potentially higher cost.

III. Transmission Grid-Tied Storage Located Outside Palo Alto

a) Description of the Storage System & Cost: Battery Energy Storage (BES) located outside Palo Alto and tied to the CAISO grid at 115 kV and sized at 20 MW/80 MWh (i.e. 20MW capacity with 4 hours of charge). Annual capital cost was assumed to be around $190/kW-yr, and O&M cost around $20/MWh with a maximum number of discharge cycles allowed per year (about once per day).

b) Application: provision of CAISO ancillary services of frequency regulation and flexible resource adequacy capacity

c) Value: Regulation services valued at $9/MW-hour[4] (now) and $25/MW-hr (after 2020); capacity is currently valued at $28/kW-yr, flexible capacity valued at $50/kW-year (after 2020)

d) Results and Conclusion: The annual cost for the system is compared to the projected revenue stream on Figure C4. While the potential maximal revenue through regulation is high, the charges for battery discharge and the limitation of one discharge per day do not provide an incentive for use for regulation services. The revenue from resource adequacy only would be too low to justify the investment. Currently, additional revenue of $2 million per year would be necessary to break even with being paid twice a day for only one discharge. Being paid four times per day with only one charge-discharge cycle, the revenue could break even by 2020. However, a better understanding of the amount of energy dispatched per period called by the CAISO would be critical to improve the understanding of the revenue stream from the provision of regulation services, since the bidding strategy is essential in deriving value from this investment.

e) Assumptions:

- Current prices for round-trip regulation are around $8-9/MW-h but prices are expected to rise to $20-30/MW-hr within the next years.
- Arbitraging the CAISO energy price differential and relieving economic curtailment could not be considered because they would compete with frequency regulation, as the high frequency regulation prices would happen at the time of curtailment and high energy prices.
- Capacity for regulation can be rated from a 320 MW for a 15-minute discharge to 20 MW for a four-hour discharge. However, the payment occurs per MW-hr, so all combinations are equivalent in our calculations.
- Capacity for flexible capacity was rated for four0-hour discharge period (20 MW).
- The analysis considered the following two cases for regulation dispatching:
    1. Paid twice a day: the analysis assumed that the system gets dispatched on average half of the hours that were bid and awarded. In that case the system can bid twice the capacity of regulation-up and regulation-down
    2. Paid four times a day: the analysis assumed that the system gets dispatched on average a quarter of the hours that were bid and awarded. In that case the system can bid four times the capacity of regulation-up and regulation-down.

[4] Regulation and other ancillary services procured by CAISO is in the form of a capacity payment for every hour.

Figure C4: Comparison of economics of grid-tied batteries based on utilization of batteries in CAISO market

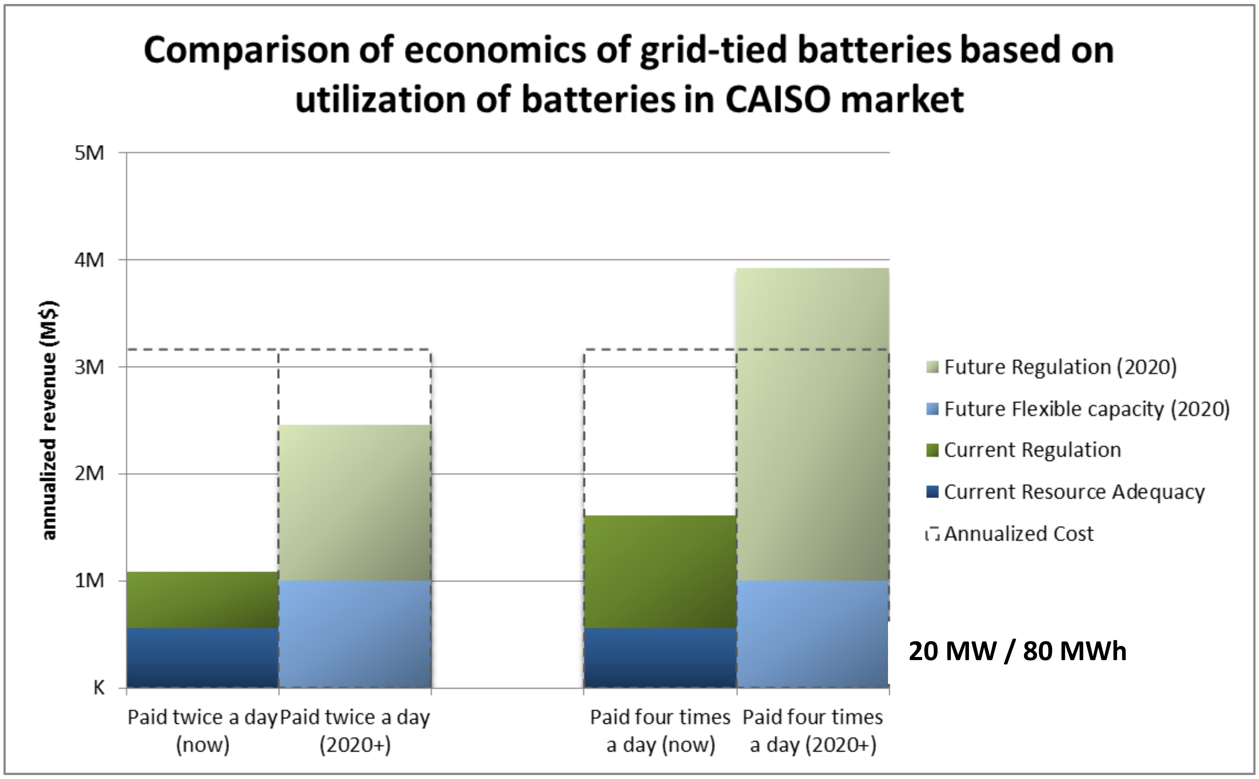


Table C1: Bill Illustration of a Residential Customer with a Solar PV System only, Solar + 7 kWh system and Solar + 12 kWh battery system under the NEM Successor Rate

	1. Total Energy Consumption (kWh)	2. Solar Energy Production (kWh)	3. Energy Netted On-site (kWh)	4. Solar Energy Sent to the Grid - solar only (kWh)	5. Energy Delivered to Customer - solar only (kWh)	6. Energy Delivered to Customer - Solar + 7 kWh system (kWh)	7. Energy Delivered to Customer - Solar + 12 kWh system (kWh)	8. Bill Charges for Energy Delivered - Solar only	9. Bill Charges for Energy Delivered - Solar + 7 kWh system (kWh)	10. Bill Charges for Energy Delivered - Solar + 12 kWh system (kWh)	11. Bill Credit for Energy Sent to the Grid - Solar only	12. Bill Credit for Energy Sent to the Grid - Solar + 7 kWh system	13. Monthly Bill with Solar only	14.Monthly bill with Solar + 7 kWh system	15.Monthly bill with Solar +12 kWh system
Jan	1,400	327	244	84	1,156	1,079	1,079	$175	$162	$162	($6)	$0	$169	$162	$162
Feb	1,204	314	250	64	954	895	895	$143	$133	$133	($5)	$0	$138	$133	$133
Mar	1,061	519	309	210	752	559	559	$107	$74	$74	($16)	$0	$91	$74	$74
Apr	918	610	311	299	607	414	332	$83	$51	$37	($22)	($7)	$61	$44	$37
May	885	704	341	363	543	343	209	$72	$38	$23	($27)	($11)	$45	$27	$23
Jun	882	659	352	307	530	337	248	$70	$38	$27	($23)	($7)	$47	$30	$27
July	929	711	377	334	552	352	245	$73	$40	$27	($25)	($9)	$48	$31	$27
Aug	894	582	312	270	582	382	334	$78	$45	$37	($20)	($4)	$58	$41	$37
Sep	930	551	301	250	629	436	399	$87	$54	$48	($19)	($3)	$68	$51	$48
Oct.	943	467	266	201	677	492	492	$94	$63	$63	($15)	$0	$79	$63	$63
Nov	954	348	191	157	764	620	620	$110	$85	$85	($12)	$0	$98	$85	$85
Dec	1,184	299	198	101	985	892	892	$147	$131	$131	($8)	$0	$139	$131	$131
Tot:	12,184	6092	3452	2640	8732	6,801	6,302	$1,240	$914	$848	($198)	($41)	$1042	$873	$848

Thermal Energy Storage Costs in Palo Alto

Thermal Energy Storage

Thermal energy storage (TES) is a "technology that stocks thermal energy by heating or cooling a storage medium so that the stored energy can be used at a later time for heating and cooling applications and power generation. TES systems are used particularly in buildings and industrial processes."[1] This study focuses on the use of ice for deferring electric consumption for cooling purposes in HVAC systems. In this process, cheaper night-time electricity is used to freeze a fluid, which then reduces the electricity needed to provide air conditioning when electricity is more expensive during the day.

History of TES in Palo Alto

In the late 1980s and early 1990s the City of Palo Alto Utilities (CPAU) had a generous incentive program for TES through for commercial customers. These incentives were motivated by steep and ratcheted demand charges imposed on Palo Alto by PG&E. Most of the systems installed under this program have been dismantled or decommissioned due to failures, need for space, or a lack of engaged operation and maintenance staff.

A TES study was carried out in 2013 an provided in the 2014 Energy Storage Procurement report (see Attachment E (Thermal Energy Storage in Palo Alto) of Staff Report 4384.[2])

TES benefits

The goal of the incremental addition of a TES system to existing chiller-based cooling systems' is to be able to turn off (completely or partially) the chiller during peak hours. This results in the following benefits:

- Reduction of demand charges for commercial customers
- For customers on Palo Alto's large commercial TOU rate, a TES system also delivers energy charge savings by shifting energy consumption from high-price periods to low-price periods
- Increased reliability of the cooling system
- Potential participation in Demand-response program

However, the need for large spaces for the TES system can be a challenge.

Utility-Owned and Operated Thermal Energy Storage

Another model for deploying TES which has become more popular is based on utility-ownership and control. The utility-ownership model has been developed by Ice Energy, which makes the "Ice Bear", a packaged roof-top ice storage units that integrate with refrigerant-based (direct exchange, or DX) roof top units (RTUs) commonly found in commercial cooling applications. When called on by the utility, the Ice Bear will shut down the RTU compressor and condenser

[1] https://www.irena.org/DocumentDownloads/Publications/IRENA-ETSAP%20Tech%20Brief%20E17%20Thermal%20Energy%20Storage.pdf

[2] https://www.cityofpaloalto.org/civicax/filebank/documents/38915

fans and provide cooling by sending ice-cooled refrigerant through a new evaporator coil placed in series with the RTU's existing coil.

Potential benefits of utility-controlled TES are:

- Resource adequacy cost reduction for the utility
- On-peak/off-peak energy purchase differentials
- Transmission and distribution deferral
- Control of additional Demand-Response assets
- Energy efficiency upgrade with TES installation

The value of TES is substantially lower in Palo Alto due to the milder climate and rather flat load profile during the summer.

Update of 2013 study

Staff updated the 2013 model with the most current data of the system and utility cost and confirmed that none of the TES systems considered makes economic sense currently. The benefit-cost ratio is 0.39 for a full TES system and 0.7 for a partial TES system. A utility-controlled Ice Bear program had a benefit cost ratio of 0.46.

Other TES systems

Heat pump or electric resistance water heaters for homes can also be used as TES. Water is heated during off-peaks hours (either at night or with PV during the day) and then stored in a tank for a later usage (see Figure D-1). As CPAU embarks on electrifying natural gas appliances, it may want to evaluate the merits of encouraging customers to install controllable water heaters that can be called upon by the electric utility to meet electric grid optimization needs.

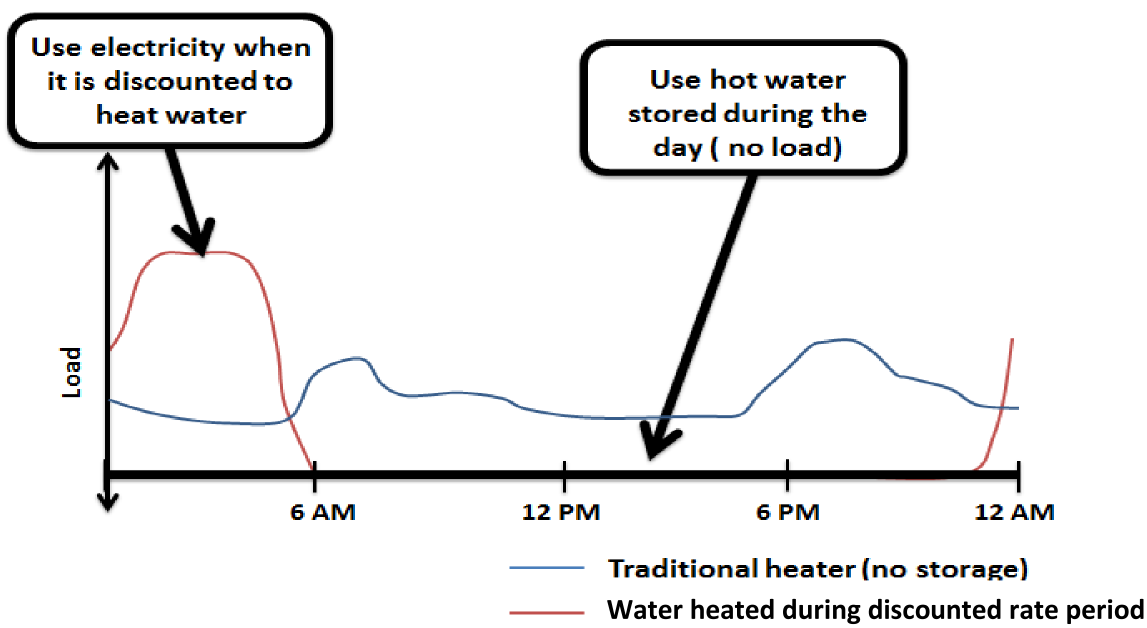


Figure D-1: Load profile of traditional water heater vs. use during discounted rate periods

Energy Storage Regulation, Policies and Incentives

Energy Storage Regulations and Policies

California's AB 2514[1] and the associated regulations are among many state policies designed to encourage energy storage. In October 2013 the California Public Utilities Commission (CPUC) established an energy storage target of 1,325 megawatts for Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E) by 2020, with installations required by the end of 2024. The CPUC decision also establishes a target for Community Choice Aggregators and electric service providers to procure energy storage equal to 1% of their annual 2020 peak load by 2020 with installation no later than 2024, consistent with the requirements for the Investor Owned Utilities (IOUs)[2]. On February 28, 2015, the three IOUs (PG&E, SCE and SDG&E), filed their Energy Storage (ES) Application containing a proposal for the first ES procurement period (2014-2016).[3]

In 2015, Oregon became the second state to approve energy storage targets. According to House Bill 2193[4], electric companies with more than 25,000 customers will have to put 5 MWh of energy storage in service by January 1, 2020, but it may not exceed 1% of the company peak load (as of 2014). Laws promoting energy storage in New York and Texas have also been passed, although these do not specifically require energy storage targets. Arizona, Connecticut, Minnesota and Vermont added legislation that will clarify and promote storage.[5] Washington State gave $14.3 million in matching grants for utilities' energy storage projects, and their 2015 budget included additional grants. Con Edison in NY offered $2,600/kW for thermal energy storage (TES) and $2,100/kW for battery storage for projects completed by June 2016.[6] New Jersey offers $300 per kWh of storage capacity up to $300,000 or 30% of the project cost.[7] Several states including Florida, New Jersey and Massachusetts offers loan and grants for the development of resilient solar + storage systems.[8] Other legislation indirectly supports the use of storage systems in the case of rooftop solar installation. For example, Docket No. 2014-0192[9] in the state of Hawaii will support self-supply and benefit from temporal or locational energy price differences with the use of batteries for rooftop solar owners. Hawaiian Electric Company (HECO) issued an RFP for 0 to 200 MW of Energy Storage for Oahu in 2014.[10]

At the federal level, the Storage Act provide a 20% investment tax credit for grid-connected energy storage systems and a 30% credit for behind-the-meter systems.[11] The Federal Energy Regulatory Commission (FERC) is also seeking to level the playing field for energy storage to participate in energy markets. In 2007 and 2008, FERC issued Orders 890 and 719, which

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[1] http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200920100AB2514
[2] http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M079/K171/79171502.PDF
[3] http://www.cpuc.ca.gov/General.aspx?id=3462
[4] https://olis.leg.state.or.us/liz/2015R1/Downloads/MeasureDocument/HB2193
[5] http://www.renewableenergyworld.com/ugc/blogs/2016/01/state_energy_storage.html
[6] http://www.coned.com/energyefficiency/demand_management_incentives.asp
[7] https://njcepelectricstorage.programprocessing.com/content/home
[8] http://solaroutreach.org/wp-content/uploads/2015/09/SLStorage.pdf
[9] http://puc.hawaii.gov/wp-content/uploads/2015/10/DER-Phase-1-DO-Summary.pdf
[10] https://www.hawaiianelectric.com/clean-energy-hawaii/request-for-proposals---energy-storage-system
[11] http://www.energy.senate.gov/public/index.cfm/files/serve?File_id=FEDB4A77-7073-422D-B259-C8AF7F59E627

opened the door for non-generation resources such as energy storage to participate in ancillary services markets. In response, CAISO made changes to its ancillary services operating and technical requirements to enable these non-traditional resources to participate, such as reducing the minimum size and output duration capability for eligible resources.[12]

In 2011, FERC enacted Order 755 specifically addressing frequency regulation services. As described in Attachment A, some energy storage technologies are able to provide frequency regulation services more quickly and accurately than conventional generating facilities; however, markets for frequency regulation services typically do not differentiate between more effective regulation providers. Order 755 attempts to rectify this by requiring appropriate "pay for performance" in organized ancillary services markets. FERC notice proposes rules to reduce other barriers that prevent energy storage facilities from participating in markets for ancillary services as well as imposing similar "pay for performance" requirements on transmission providers in traditionally regulated states. In July 2013, FERC issued Order 784 which eased the market entry for third-part Ancillary Services providers and improved market transparency.

In response to FERC Order 755, CAISO modified the regulation up and regulation down product in May 2013 with a market based mileage payment with accuracy adjustment.

Energy Storage Incentives and procurement activities in California

In 2009, the CPUC ruled that California's IOUs must develop a Permanent Load Shift (PLS) program to encourage TES directly. A statewide pilot PLS program from 2008-2011 provided $500/kW of peak demand reduction. The current incentive for IOUs is $875 per kW of electric load shift on the highest on-peak cooling load day of a customer's annual cooling load profile. The incentive is capped at 50% of project cost and $1.5 million per customer.

Customers of California's IOUs are also eligible for the Self Generation Incentive Program (SGIP), which includes a $1.31/Watt incentive to advanced energy storage systems.

California's IOUs are also actively involved in energy storage project development to satisfy the targets mandated by the CPUC. The first round of procurement RFOs was released in 2014 and the next round of procurement will happen in 2016. The current progress of PG&E, SCE and SDG&E has been summarized in Tables E1 and E2.

Most publicly owned utilities (POUs) declined to procure storage in 2014 for lack of cost effective options. Seven POUs did set some procurement targets (see Table E3). Most POUs set smaller goals, except the Los Angeles Department of Water and Power (LADWP). LADWP relied mostly on a 21 MW pumped hydro upgrade to set its 2016 target, in addition to 3 MW of TES systems. 2020 target includes 60 MW of TES at the generation level and 40 MW of TES at the customer level, in addition to 50 MW of transmission level and 4 MW of distribution-level batteries. Redding electric utility and Glendale Water and Power procured Ice Bear TES.

[12] 2020 Strategic Analysis of Energy Storage in California, 2011. Public Interest Energy Research for the CEC. CEC-500-2011-047

Table E1: IOUs current projects and projects in development by storage technology

MW	Li-Ion	Zinc	Sodium-Sulfur	Flywheel	PHS	Thermal	Other	TOTAL
PG&E	**42**	**13**	**6**	**20**			**10**	**91**
SCE	**246**		**16**			**26**	**69**	**357**
SDG&E	**20**				**40**		**19**	**79**

Table E2: Storage location of current and in-progress projects and comparison to 2020 target

Current-in progress (MW)/2020 target (MW)	Transmission	Distribution	Customer	Total
PG&E	50MW/310MW	33.5 MW/185 MW	8.2MW/85 MW	91 MW/580 MW
SCE	100 MW/310 MW	32.3 MW/185 MW	224.4 MW/85 MW	356.7MW/580 MW
SDG&E	60 MW/80MW	6.2MW/55MW	13MW/30MW	79 MW/165 MW

Table E3: 2016 and 2020 storage procurement target of the seven POUs who elected to procure cost-effective storage

POU	2016 Target	2020 Target
Cerritos, City of	1 percent of 2015 peak load (**200 kW** based on 2014 peak load of 20 MW).	1 percent of 2020 peak load (**200 kW** based on 2014 peak load of 20 MW)
Corona Department of Water and Power	1 percent of 2015 peak load (**270 kW** based on 2014 peak load of 27 MW).	1 percent of 2020 peak load (**270 kW** based on 2014 peak load of 27 MW).
Glendale Water and Power	1.5 MW	1.5 MW
Los Angeles Department of Water and Power (LADWP)	24.08 MW	154 MW
Redding Electric Utility	3.6 MW	4.4 MW
Silicon Valley Power (City of Santa Clara)	30 kW	30 kW
City of Victorville	1 percent of 2015 peak load (**140 kW** based on 2014 peak load of 14 MW).	1 percent of 2020 peak load (**140 kW** based on 2014 peak load of 14 MW).

ATTACHMENT B

CITY OF PALO ALTO

UTILITIES ADVISORY COMMISSION MEETING
FINAL MINUTES OF OCTOBER 5, 2016 (EXCERPTS RELATED TO ENERGY STORAGE DISCUSSION)

CALL TO ORDER

Vice Chair Danaher called to order at 7:05 p.m. the meeting of the Utilities Advisory Commission (UAC).

Present: Vice Chair Danaher, Commissioners Forssell, Johnston, and Trumbull
Absent: Chair Cook, Commissioners Ballantine, Schwartz, and Council Liaison Scharff

ITEM 3. DISCUSSION: Discussion of Energy Storage and Microgrid Applications in Palo Alto

Senior Resource Planner Shiva Swaminathan presented the study results on the application of microgrid and energy storage systems in Palo Alto. He outlined that the study did not find any cost-effective application for such system at present, but anticipated the proliferation of energy storage in the coming years as cost decline and value for such services increase. He also outlined elements of a potential storage pilot project for 125kW/500 kWh at a cost of $250,000.

Commissioner Trumbull noted the Commission's recent discussion of potentially encouraging customers to switch from natural gas to electricity, and asked about reliability if a customer used only electricity. Swaminathan acknowledged that, having two fuel sources coming to your home—electricity and natural gas—will have diversification value in the event of an emergency like an earthquake. However, there may be other customers who want to eliminate the smoke coming out of their smoke stacks at home by burning gas; for them, electrification may be the solution. Swaminathan said that it is a trade-off each person has to make.

Vice Chair Danaher asked staff to explain the State's establishment of storage mandates. Swaminathan explained that the State is interested in storage to manage intermittent renewables like solar and wind. Since storage is a fast-acting resource and can respond to the vagaries of intermittent resources, storage is expected to take on a larger role in the coming years.

Commissioner Forssell noted that backup power is one value stream shown in the analysis, but there are other values too such as frequency regulation. Swaminathan concurred. Commissioner Forssell asked which customers value backup generation. Swaminathan indicated that many customers such as hospitals and location with computer servers need higher reliability service. He said that if a customer is totally reliant on electricity and does not use natural gas, they may wish to have energy storage systems to improve reliability.

Vice Chair Danaher noted to the visiting students in the audience that the City has large utility-scale solar resources and other renewable supplies, but that the City relies on others to manage the transmission grid to deliver this power to Palo Alto.

Vice Chair Danaher mentioned that the energy price arbitrage is a low value. Swaminathan concurred.

Commissioner Forssell asked whether the pilot project proposal was to partner with a customer to install storage at their site and learn from the operations. Swaminathan agreed, but mentioned that the objective is to have more than one customer participate in the pilot.

Commissioner Johnston asked if staff had identified any customers to participate in the pilot. Swaminathan said no, but that there have been inquiries.

Vice Chair Danaher agreed with the analysis finding that there was low value proposition at this time and asked for the rationale for spending $250,000 for a pilot project. Swaminathan said the objective was to learn about the technology, the permitting rules, how to optimally operate the system, and the impact on such systems on the retail rate-making process. Vice Chair Danaher asked if there was a way to reduce the cost. Swaminathan said that the project could be scaled down, but the minimum size to bid ancillary services into the CAISO is 100 kilowatts (kW), the size of the proposed pilot. Vice Chair Danaher mentioned the value is to determine how to bid these resources into the CAISO system.

Vice Chair Danaher asked if we have control of Calaveras hydro project operation. Swaminathan replied in the affirmative.

Vice Chair Danaher asked about the objective of a pilot. Swaminathan responded that this technology is coming and the idea is to learn about how we could have a win-win solution in conjunction with our customers; the question of whether we can afford such a pilot is part of this discussion. Swaminathan indicated that staff believes that spending $50k/per year for 5 years in R&D funds may be a good use of funds to better prepare for the future.

Vice Chair Danaher asked for an explanation of the value chart. Swaminathan outlined the multiple value chains shown in the "spider-chart" in the report.

Commissioner Trumbull again asked what storage techniques could be used to protect customers from electrical outages if the City adopted an electrification strategy. Assistant Director Jane Ratchye mentioned that the current reliability level is very high. She also pointed out that no decision has been made about electrification and we are not walking down the road of wholesale electrification yet. Commissioner Forssell added that the purpose of this discussion today is to meet a legislative requirement under AB 25142 and not the topic of electrification at the Commission's prior meeting.

Vice Chair Danaher asked how Demand Response (DR) differs from storage. Swaminathan mentioned that DR resources tend to be less expensive, but storage is faster acting and more reliable.

Vice Chair Danaher asked if there are other DR programs that would be more productive than storage, such as EV batteries. Swaminathan mentioned that staff is working on a program with EVs and expect to come to the Commission in the spring along with the storage recommendation.

Vice Chair Danaher asked if staff could describe the City's new technology program. Swaminathan explained the elements of the Program for Emerging Technology (PET), which is designed to provide an opportunity to demonstrate new technologies on City facilities or using willing Utilities customers, at no cost to the City. Technologies tested under PET include PV on streetlights with a grid monitoring sensor and motion sensing LED lights installed in City Hall's parking garage.

Commissioner Forssell said she supported the R&D pilot like Commissioner Danaher and that she was looking forward to seeing a fleshed out pilot project proposal from staff.

Respectfully submitted,
Marites Ward
City of Palo Alto Utilities