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CITY OF PALO ALTO UTILITIES

ENERGY STORAGE REPORT

2020

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EXECUTIVE SUMMARY

The adoption of energy storage in the California electricity sector has grown rapidly in recent years due to declining cost, regulatory mandates for investor owned utilities (IOUs) to procure and/or provide rebates for customer-sited storage, availability of reliable system manufacturers/installers, federal tax credits, and increased customer awareness of the benefits energy storage.

In addition, California law (Public Utilities Code § 2836(b)) requires all California publicly owned utilities to investigate if energy storage systems are cost effective every three years. In 2017 City of Palo Alto Utilities (CPAU) staff examined energy storage systems, determined that they were not cost effective for CPAU, and therefore declined to set energy storage targets. This is the 2020 update, and this report includes:

1) An overview of customer adoption of energy storage systems in Palo Alto;
2) Analysis of cost-effectiveness for customer-sited storage within Palo Alto; and
3) Next steps for energy storage both within Palo Alto and sited at utility-scale renewable generation

To investigate if energy storage located in the City of Palo Alto was financially beneficial to all customers, CPAU built an economic battery dispatch model and also worked on a joint analysis with the Smart Electric Power Alliance (SEPA) and other publicly owned utilities in the Northern California Power Agency, as well as the Sacramento Municipal Utility District. The assumptions behind the modeling results shown here can be provided upon request. The final report of the SEPA joint analysis is provided in Appendix A.

The CPAU and SEPA analysis both suggest that for Palo Alto customer-sited energy storage is still not cost effective from a societal perspective (for the utility and customers in aggregate). Since neither energy storage within the City nor on the transmission system were found to be cost effective for the utility or society as a whole, CPAU will not be setting energy storage goals at this time. Instead CPAU will continue monitoring this rapidly maturing space and searching for specific projects which by their location could provide extraordinary resiliency, lower carbon emissions, or lower distribution system costs. Staff is also currently evaluating multiple proposals for utility-scale storage located with renewable generation and will move forward with competitive projects that complement our existing supply portfolio. The system size for this project is expected to be larger scale, in the range of 5 MW and 20 MWh.

1. Introduction

The adoption of energy storage systems in the California electricity sector has grown rapidly in recent years due to declining cost, regulatory mandates for investor owned utilities (IOUs) to procure and/or provide rebates for customer sited energy storage, availability of reliable system manufacturers/installers, federal tax credits, and increased customer awareness of the benefits energy storage.

In 2017 (CPAU) staff examined energy storage systems,[1] determined that they were not cost-effective for CPAU, and therefore declined to set energy storage targets.

Publicly-Owned Utility Energy Storage

In 2017, among the 35+ POUs in California, 11 POUs set storage goals under the PUC § 2836(b) process. The remaining, including Palo Alto, declined to set goals, finding storage to not be cost effective for their utilities 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.

A key purpose of energy storage systems is to absorb energy during low-carbon and or low- value periods of the day, store it for a period of time with minimal losses, and then release it during periods of high value or high carbon emissions. When deployed in the electric power system, energy storage provides flexibility that facilitates the real-time balance between electricity supply and demand.

Typically, this electricity 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 or natural gas generation resources. As we decarbonize the electrical grid and intermittent renewable resources proliferate, the role of fast acting energy storage systems is expected to expand in the electricity marketplace. Rechargeable chemical 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 service to the grid operator effectively.

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 batteries and thermal energy storage (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 and controllable electric hot water heater.

[1] https://www.cityofpaloalto.org/civicax/filebank/documents/57435

SECTION 1: INTRODUCTION

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. The 2017 Rocky Mountain Institute Energy Storage Report[2] developed the schematic below in Figure 1 to show how multiple value streams and benefits could be captured.

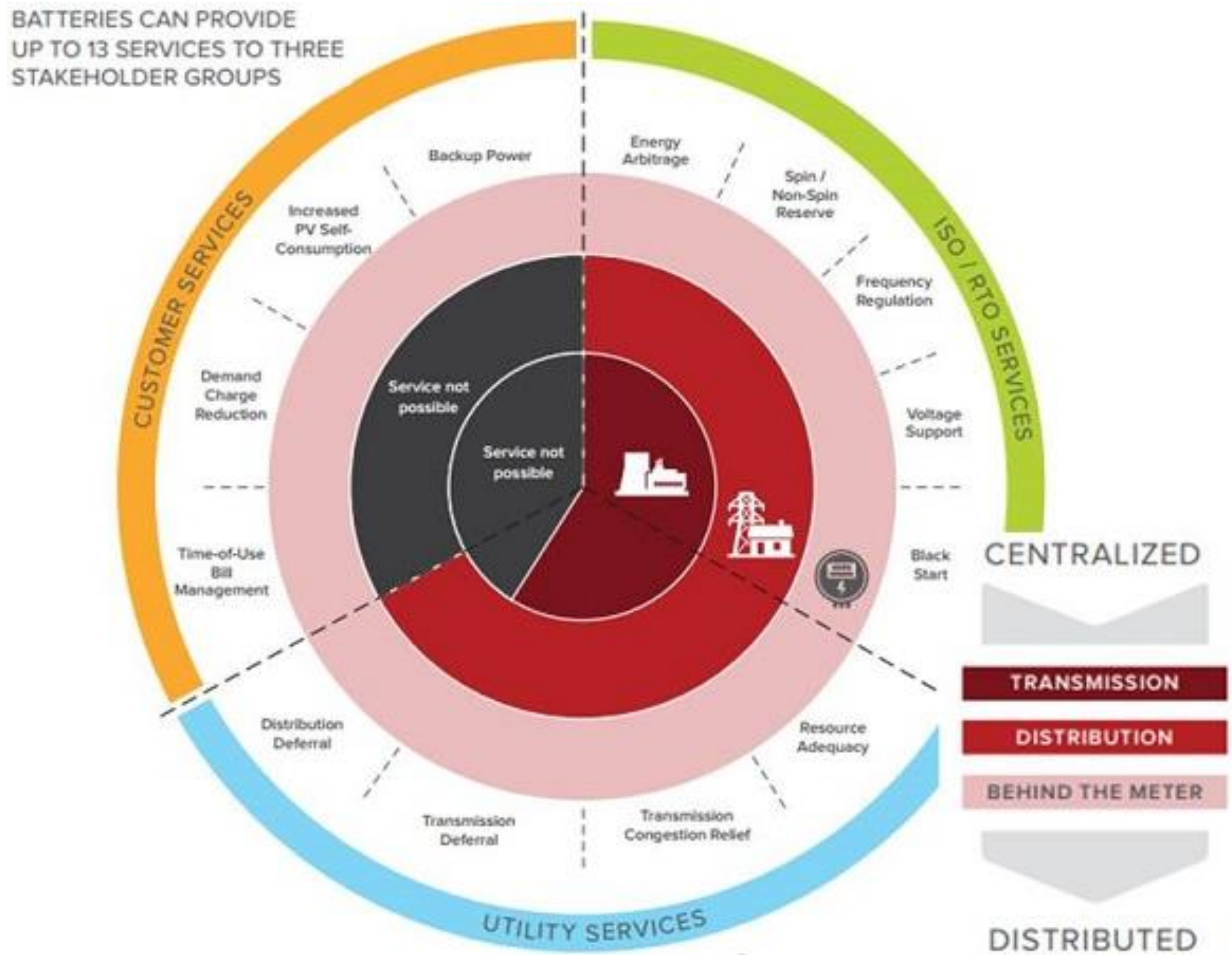

Figure 1. RMI Storage Report graphic showing how multiple value streams can be captured by a single system, depending on the location and how it is used.

Key Differences in Energy Storage Value for CPAU and Adjacent PG&E Territory

Since two separate analyses suggest that energy storage is not currently financially beneficial to CPAU and its customers, it is important to understand why it is considered beneficial for the investor-owned utilities which are required to invest in and subsidize energy storage for their customers. Some of the key differences between CPAU and the IOUs such as PG&E which are required to invest in storage systems via the SGIP are shown below.

[2] https://rmi.org/wp-content/uploads/2017/03/RMI-TheEconomicsOfBatteryEnergyStorage-FullReport-FINAL.pdf

SECTION 1: INTRODUCTION

1. <u>Distribution System Deferral:</u> Lower value for CPAU than PG&E.
    a. *CPAU distribution system is not currently constrained* since electricity sales are 30% below historical peak due to aggressive efficiency, high customer adoption of solar, departure of industrial loads, lack of other load growth, and lower summertime temperatures.
    b. Staff will continue to investigate specific locations on the residential side of the distribution system for opportunities for distribution deferral, especially in neighborhoods switching to all electric homes and with high penetration of electric vehicles.

2. <u>Back-up Power for Outages & Power Safety Power Shutoff Events:</u> Lower value for CPAU than PG&E.
    a. *CPAU's territory is mostly urban*, non-mountainous terrain, low-fire risk and fewer distribution miles per customer, therefore few customers are affected by PSPS.
    b. CPAU also has very high reliability with relatively few outages.

3. <u>Time-of-Use (TOU) Rate Bill Management:</u> Lower value for CPAU than PG&E.
    a. *There is no Residential TOU rate* as CPAU does not have smart meters installed and therefore cannot distinguish when during the day electricity is being used. Price differentials for TOU pilot rates in Palo Alto have historically been small, though this may have changed marginally in recent years.
        i. CPAU expects to have smart meters deployed by 2024.
        ii. Staff is exploring ways to control smart electric vehicle charging, smart building management systems, and smart thermostats to leverage flexible demand response programs. Connected batteries would be eligible in any pilot.
        iii. TOU rate design will be an important topic in a future electric cost of service study.
    b. The price differential in the current CPAU commercial TOU rate is small.
        i. Staff will be evaluating this in the next electric cost of service study as well.

4. <u>Utility-scale Transmission-Connected Energy Storage:</u> Lower value for CPAU than PG&E due to CPAU's highly flexible energy portfolio.
    a. CPAU owns flexible load-following hydroelectricity for 15% of electric supply.
    b. CPAU has already entered into long-term contracts for 110% of its electricity needs through 2024, of exclusively carbon-free resources. If CPAU were currently contracting for new renewable resources, the economics of bundling in utility scale storage during construction would be more advantageous

2. CPAU Progress on Energy Storage to Date

In Palo Alto, it is estimated that about 20 new battery energy storage systems have been installed over the past three years in the residential and commercial sectors. Table 1 summarizes the characteristics of the systems installed since 2017. All systems were installed along with PV systems.

Table 1. Types and capacities of battery energy storage systems installed in Palo Alto since 2017.

System Characteristics	Residential		Commercial
	Installed	In Process	Installed
Number of Systems	26	56	2
Typical size (kW/kWh)	10.5 kW / 28 kWh	9 kW / 24 kWh	500 kW / 1,020 kWh
Total Capacity (kW/kWh)	240 kW / 648 kWh	511 kW / 1327 kWh	1,000 kW / 2,040 kWh
Percent of Systems Installed with PV	100%	100%	100%

Batteries have most commonly been installed by customers seeking higher levels of electricity reliability, rather than for economic reasons. Residential batteries coupled with solar photovoltaic (PV) systems are most common configuration in Palo Alto, although commercial customers are also exploring ways to utilize batteries to improve resiliency and lower their utility demand charge. Staff is currently aware of a relatively large-scale battery and PV project at a commercial campus in at VMWare in Palo Alto, at which is also considering a larger scale fully autonomous microgrid.[3]

Microgrid 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 electric distribution grid. A microgrid can connect and disconnect from the distribution grid to enable it to operate in both grid-connected or island-mode."[4] Currently VMWare is a large commercial campus in Palo Alto considering a microgrid by installing solar PV and batteries on site to supply electricity to all buildings within the campus, with the ability to operate in island-mode if and when the distribution and transmission grid is unable to supply electricity. At this point, the proof-of-concept scale microgrid is nearly completely installed and consists of initial two batteries which total 1 MW / 2 MWh and 250 kW of solar PV. The microgrid project shows how CPAU's low energy rates for electricity and high demand charges combine to make storage economically attractive for large commercial customers. However, due to

[3] VMWare presented on their proof-of-concept scale microgrid at the August 2020 UAC meeting, their presentation is linked here: http://cityofpaloalto.org/civicax/filebank/documents/77713

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

decreasing commercial loads and higher wholesale energy prices in the evening, CPAU may be updating its demand charges and retail rate structure for large commercial customers, potentially focusing on TOU rates to ensure that microgrids incentives are aligned with those of the utility, other utility customers, and with greater society to the extent possible.

Large-scale Transmission Grid-Tied Storage

To date, no transmission grid-tied energy storage system has been added to CPAU's electric supply portfolio, though a project is under consideration. If such a project comes to fruition, it could potentially meet 5% to 10% of Palo Alto resource adequacy capacity needs.

A. Comparison of CPAU to PG&E: Installations & Authorized Expenditures

A comparison between CPAU and the surround IOU PG&E on the basis of authorized collections is shown below: [5]

- 87% of the total PG&E SGIP funding dedicated to customer-sited energy storage is reserved for equity or resiliency purposes, largely for high-fire-risk customers, those who have had multiple PSPS events in the last two to three years, or low-income customers. CPAU has very few customers with high fire risk due to the mostly urban service territory and has relatively few low-income customers.
- A comparison of the SGIP funding not associated with equity or resiliency shows:
    - An equivalent pro rata amount of funding dedicated to customer-sited energy storage would be $500k in total for CPAU, which would roughly translate to 220 kW / 590 kWh of batteries installed in CPAU territory.
    - As of 2020, Palo Alto already has 240 kW / 648 kWh in residential batteries installed, another 511 kW / 1327 kWh at residential sites in the interconnection queue, and 1,000 kW / 2,040 kWh commercial customer-sited batteries.
- An equivalent amount of funding for transmission interconnected storage would be about $1.3M in total and would roughly translate to 1.1 MW / 4.4MWh batteries installed.
    - CPAU is currently evaluating transmission interconnected storage in the 5 MW / 20 MWh scale

The relatively high customer adoption of batteries by residential customers in CPAU territory appears to be driven by desire for reliability and environmental interests rather than by the economic value proposition. The energy storage market in Palo Alto does not appear to an independent rebate program to ensure equity of service since a) batteries are not currently a cost effective resource for CPAU, b) there are very few low-income customers who live in high fire risk areas in Palo Alto, and c) since a relatively high number of customers are already installing batteries.

[5] The SGIP Program has authorized collection and expenditures in PG&E territory. With retail sales of approximately 74,500 GWh, PG&E is about one hundred times larger than CPAU. https://www.selfgenca.com/budget_public/program_level_summary/pge

3. Analysis of Cost-Effectiveness

Among the different energy storage technologies, batteries are the most widely used at customers sites and were therefore chosen for cost-effectiveness analysis in Palo Alto. To understand the cost-effectiveness of energy storage in Palo Alto, four scenarios were considered, as outlined in the table below. More details of the model can be found in Stanford PhD Candidate Nora Hennessy's presentation[6] of an analysis she did for CPAU during her Stanford summer fellowship program. The model developed was an hourly dispatch model using hourly energy and carbon emissions, as well as calculating the impact on customer demand charges and other utility wholesale costs, such as the reliability product of resource adequacy which utilities are required to purchase.

Table 2. Customer-sited battery use case scenarios examined.

Customer Type	Scenario	Primary Purpose
Residential	Scenario I:	Increase Onsite Solar Usage
Commercial	Scenario II:	Demand Charge Avoidance (No Solar)
	Scenario III:	Demand Charge Avoidance With Solar
	Scenario IV:	Demand Charge Avoidance & Lower Carbon Emissions of Grid

A. Residential Customers

Cost-Effectiveness for Residential Solar PV with Battery: Increased Onsite Solar Usage

Figure 2 below illustrates a battery energy storage application in a residential home with a PV system. The battery provides the ability to store excess PV generation for use at a later time when the homes electrical load is higher than the PV generation.[7] In this residential customer use case, a battery can store electricity produced during low-value periods during the day for use during higher value periods late in the day and at night.[8] Shifting of the energy also lowers the overall greenhouse gas emissions of the electric grid.[9] The size of such systems is typically 5 to 10 kW[10]

[6] PhD Candidate Nora Hennessy's presentation can be found in full here: https://stanford.app.box.com/s/daq9c8iyb2o9iejjltiuffifyhewh8t5

[7] The Net Energy Metering Successor rate compensates electricity that exceeds the local need at CPAU's avoided cost rather than at the retail rate. CPAU's avoided cost is lower than the retail rate because CPAU cannot predict or control when and where the local solar will be exported to the distribution grid.

[8] The average hourly electricity market prices during the 10am to 3pm solar PV production hours are much lower than the average prices during the evening hours of 4 to 9pm. In CY 2019 the average prices during those periods were ~7 cents/kWh and ~3.5 cents/kWh respectively. Therefore, the energy arbitrage value of 3-4 cents per kWh could be captured if energy could be stored during the day and then discharged in the late evening hours.

[9] For example, in 2018 the average electricity emissions of the grid during the 10am to 3pm solar production period was estimated at ~100 lbs/kWh vs. 300 lbs/kWh during the 4 to 9pm period.

[10] Scenario I: Tesla Powerwall: 7 kWp/13.5kWh, 5 kW Solar System, battery used to increase usage of onsite PV.

and a Tesla Powerwall was the technology analyzed in this case. A portion of the battery capacity could also be reserved to power the home in the unlikely event of a power outage, but that was not modeled here.

Another common use for residential storage systems is increased onsite usage of solar generation. Excess PV generation can be stored in a customer's battery and used to meet the customer's energy needs later in the day. While customers can sell surplus PV back to the grid, under CPAU Net Energy Metering Successor rate (NEM 2.0), solar generation that exceeds customer loads and is exported to the distribution grid is compensated at the utilities avoided cost, which is lower than the retail price of the electricity. The value of storing the energy for later use comes from the differential between the NEM 2.0 rate, and the retail electricity rate. Depending on whether customers are displacing Tier 1 or Tier 2 electricity load, the value will differ.

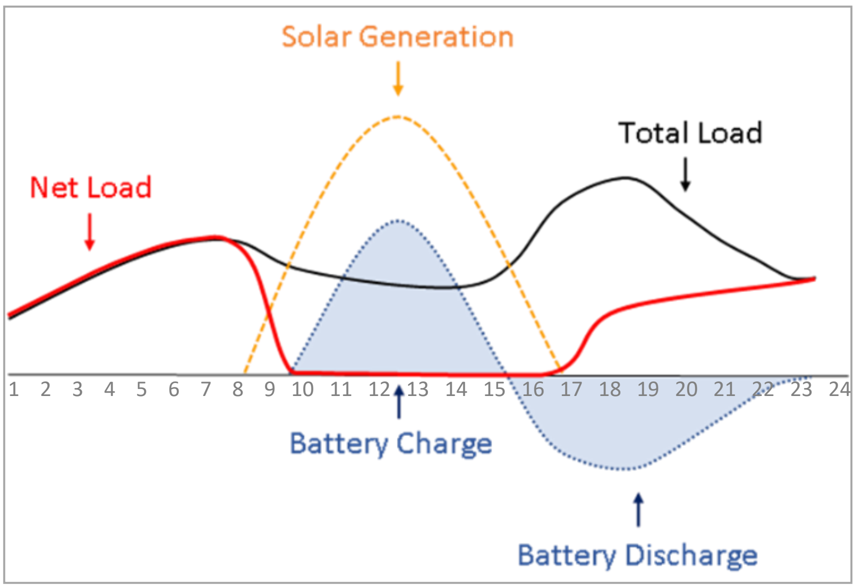

Figure 2. Hourly Load Profiles for Residential Battery for Increased Onsite Solar PV Usage.
These are illustrative hourly load profiles over a 24-hour period. Total Load is a residential customer's typical 24-hour electricity usage on a summer day, and Net Load is what the customer draws from the distribution grid after the onsite solar generation and battery serve part of the customer's electricity demands.

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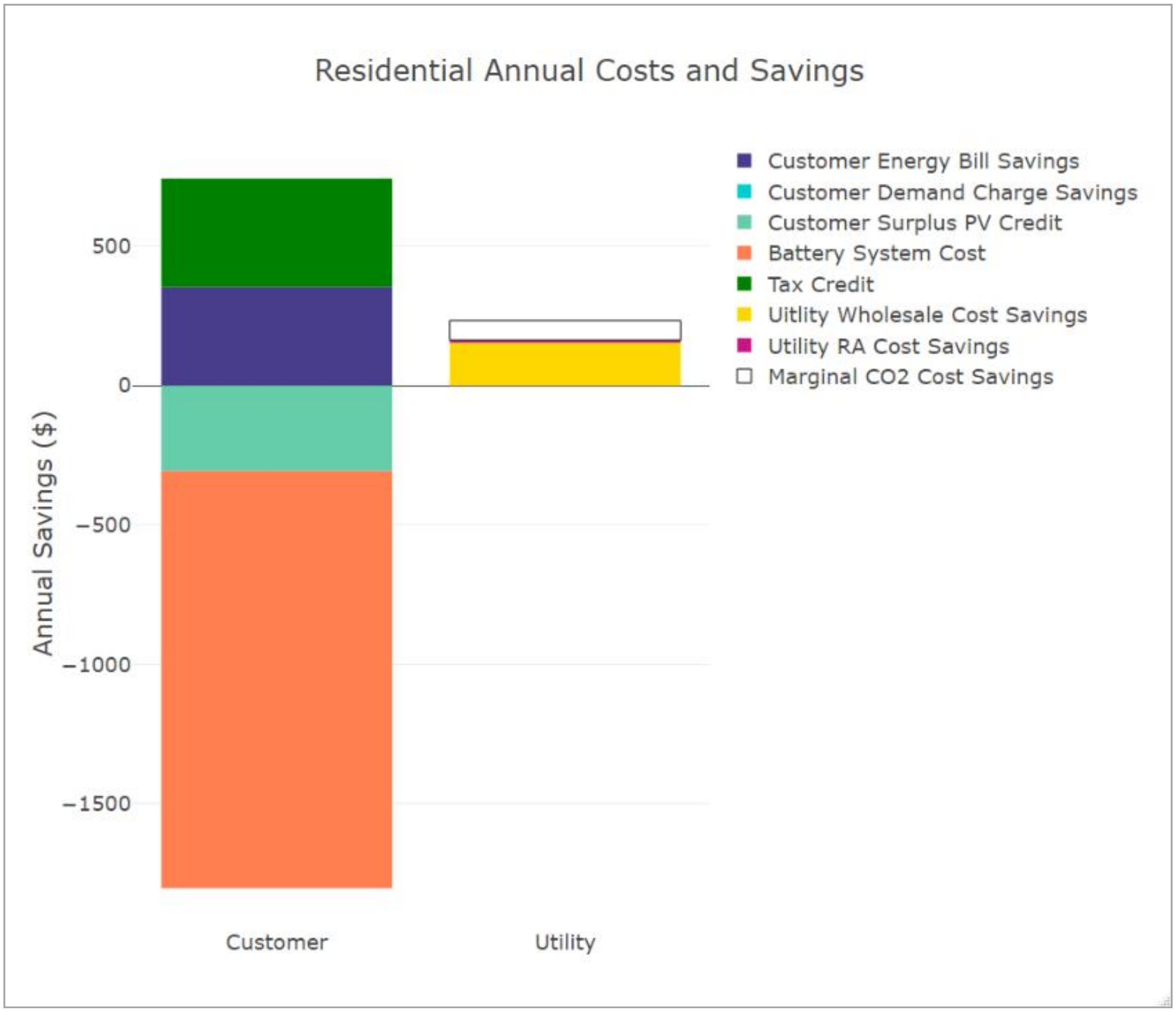


Figure 3. Costs & Benefits for Residential Customer and Utility for Residential Battery & Solar PV
This chart displays the costs and benefits (financial savings) from both the customer perspective and the utility perspective (the case above is a customer purchased battery). The combined costs and benefits (customer + utility in aggregate) determine if the combined benefits outweigh the cost. The numbers here are presented on an annualized basis.

Figure 3 shows that in Palo Alto, for solar customers under the NEM Successor rate, who receive the investment tax credit, the installed cost of a battery system still exceeds the benefit. Even including the small benefit to the utility of lower wholesale energy costs, small potential savings in Resource Adequacy requirements, and lower carbon emissions.[11] This does not currently include any distribution system benefits such as voltage support or distribution system deferral. This is not considering the value of resiliency in the case of outages as that is very personal and CPAU residents are typically not subject to frequent or extended outages such as those in high fire risk areas. It is immediately evident that the total costs exceed the total benefits due to the large system cost of the battery. In addition to facing the battery cost, customers lose revenue

[11] Carbon emissions are valued here at the approximate carbon value of one in-state renewable energy certificate.

from the surplus solar credit paid by the City for excess solar production delivered to the CPAU distribution system. However, while the value of energy savings exceeds the cost of lost solar credit, the full potential value of increasing PV self-consumption is not realized. This is due to three factors: 1) The battery is only 90% efficient, so 10% of the solar energy going to the battery is consumed by losses; 2) The battery has limited storage capacity, and there are times when excess solar must still be exported at the NEM 2.0 rate due to the battery being full; and 3) Minimum bill charges limit the customer energy bill savings. On the utility side, there is a very small decrease in resource adequacy (RA) costs, a decrease in wholesale energy costs, and a small decrease in CO_2 emissions. The value of the decrease in emissions will depend on the accepted price of carbon.

B. Large Commercial Customers

Cost-Effectiveness for Large Commercial Customers: Demand Charge Mitigation

Figure 4 illustrates a commercial customer use-case for battery storage. This application for large commercial customers is to use storage to lower the utility demand charges, by lowering the customer's monthly peak loads by discharging the battery during customers peak load periods. If configured appropriately, with additional battery capacity, the system can also provide the customer back-up power in the event of an electric grid outage. The size of such systems could range from 50 kW to a 1-3 MW.[12]

Table 3. Description of commercial battery scenarios examined.

Commercial Scenarios	Scenario II:	Demand Charge Avoidance Without Solar
	Scenario III:	Demand Charge Avoidance With Solar
	Scenario IV:	Restricted Demand Charge Avoidance With Solar: Charging restricted to lowest carbon hours (10 am- 2pm) Discharging restricted to highest carbon hours (4 pm - 9pm)

Scenarios II & III:

Commercial customers typically use their energy storage systems for demand charge mitigation. By discharging their batteries during peak load events, they can lower their peak net electricity use, and reduce monthly demand charges.

Customers can charge their batteries either from solar PV systems, or from the grid. The charging mechanism used will have an impact on the potential value of the storage system. Due to inefficiencies in the battery, charging from the grid alone will result in an increase in customer energy consumption, and therefore an increase in energy charges. For commercial customers, cost savings due to demand charge reductions will generally outweigh the increase in energy

[12] Cost associated with these larger systems is estimated to range from $300 to $500/kWh depending on the size of the system and whether the system is eligible for federal tax credit.

SECTION 3: ANALYSIS OF COST-EFFECTIVENESS

charges. The charging mechanism will also impact the customer's eligibility for the federal Investment Tax Credit, which requires customers to charge their batteries from renewable energy sources at least 75% of the time.[13]

Scenario IV

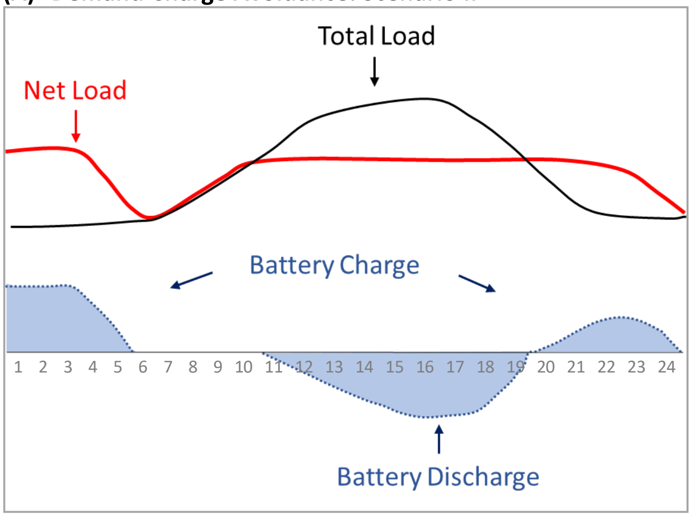
Customer-sited batteries can also have benefits for utilities. Batteries can be operated to perform energy arbitrage in the wholesale market by charging when wholesale energy prices are low and discharging when they are high. Batteries can also be used to reduce RA costs if they are used to reduce peak utility demand. If they work with an aggregator or scheduling coordinator, energy storage systems can also provide value by bidding into the ancillary services market and providing services including frequency regulation, spinning reserves, and non-spinning reserves. Battery systems also have the potential to provide societal benefit if they are operated to reduce greenhouse gas and criteria pollutant emissions.

In addition to the customer lowering their electric bill, if CPAU can partner with the customer to harness the battery to meet resource adequacy capacity needs with the California Independent System Operator (CAISO), the combined value streams have the potential to make such customer investments economically more viable.

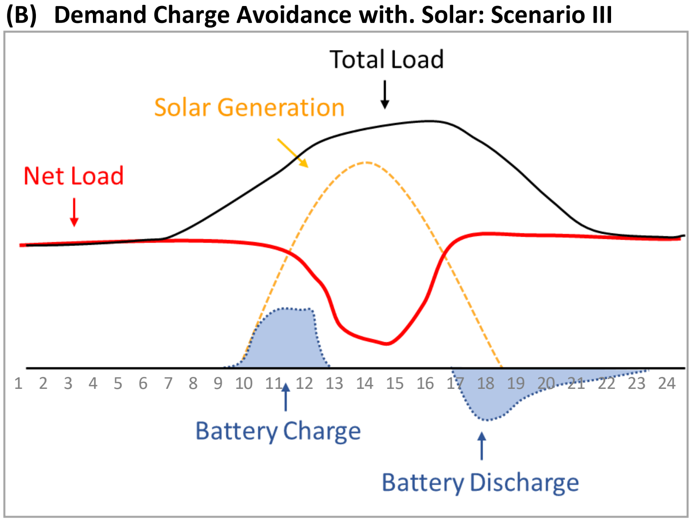
[13] https://www.energysage.com/solar/solar-energy-storage/energy-storage-tax-credits-incentives/

Figure 4. Three Strategies for Commercial Customer Battery Usage (Scenarios II, III & IV)

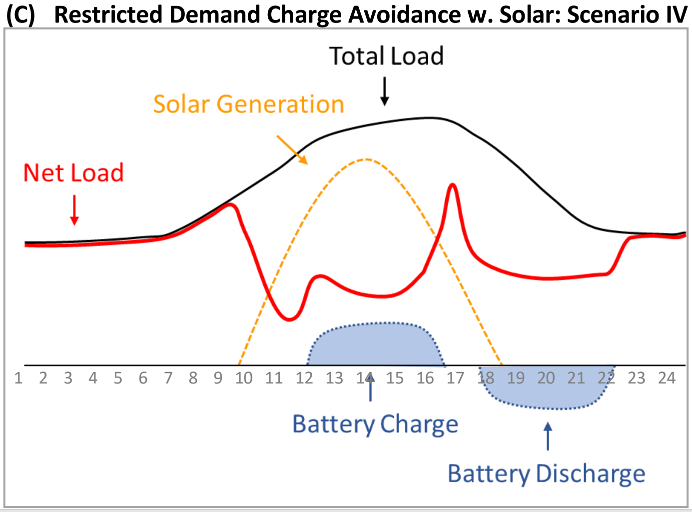
(A) Demand Charge Avoidance: Scenario II



(B) Demand Charge Avoidance with. Solar: Scenario III



(C) Restricted Demand Charge Avoidance w. Solar: Scenario IV



Illustrative hourly profiles of three different strategies large commercial customers could use when operating their batteries. Total Load is a large commercial customer's typical 24-hour electricity usage on a summer day, and Net Load is what the customer draws from the distribution grid after the onsite solar generation and battery serve part of the customer's electricity demands.

(A) shows illustrative hourly profiles for batteries used for demand charge mitigation (Scenario II).

(B) shows illustrative hourly profiles for batteries used for demand charge mitigation for a customer with solar PV installed (Scenario III)

(C) shows illustrative hourly profiles for batteries used for demand charge mitigation but restricted to charging from 10 am – 2 pm (lowest emissions hours) and discharging from 4 pm – 9 pm (highest emissions hours).

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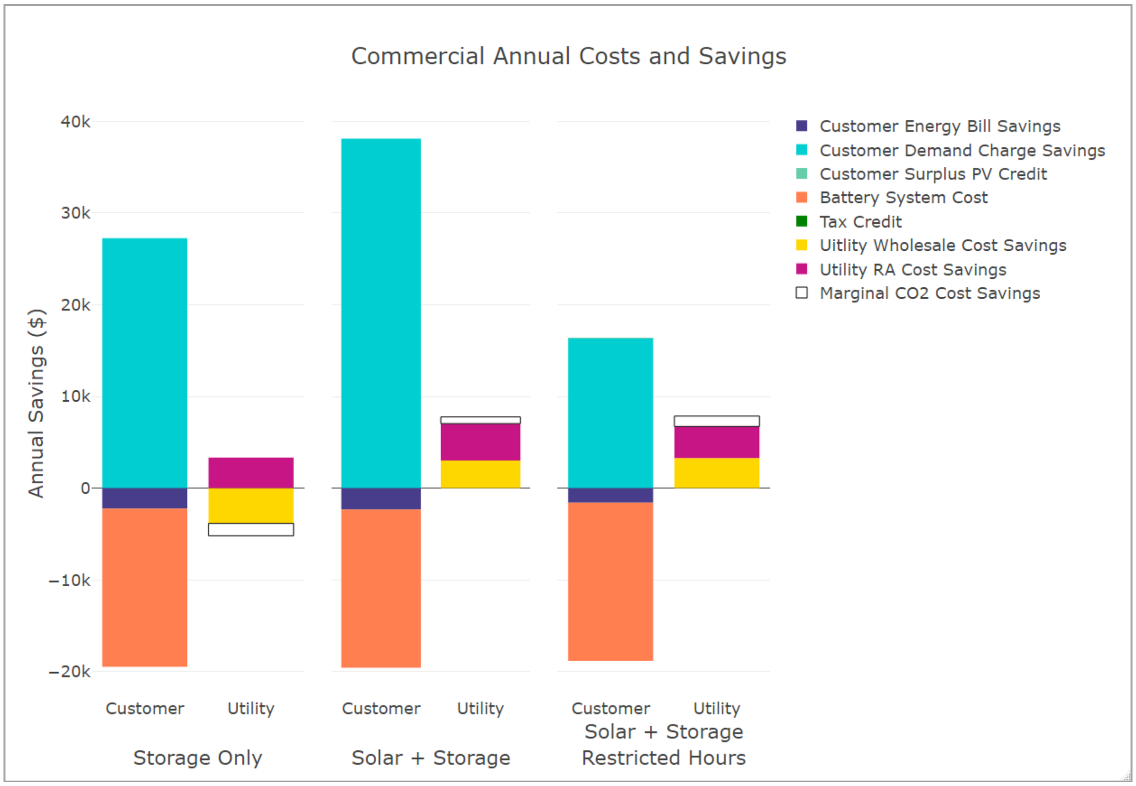


Figure 5: Customer and Utility Savings in Commercial Scenarios

Figure 5 shows the present value of costs and savings for the customer and utility in each of the commercial scenarios examined. As in the residential case, the savings and costs are for storage alone, and do not include any contributions from the solar PV systems.

In the first two commercial cases above, it is clear that savings exceed costs from the large commercial customer perspective. This is driven solely by large demand charge reductions. Battery costs are fairly high and there is a small increase in customer energy bills, but demand charge savings exceed these costs in all cases. It is evident that the value of the battery for demand charge reduction is greater for customers who already have solar installed. While somewhat counterintuitive, this can be explained by the shape of the net load in each case. The original commercial load is relatively flat, but the net load after solar has two peaks, one in the morning before the solar generation ramps up, and a larger one in the late afternoon as solar generation dies down. As these peaks are narrower than the original peaks, the battery provides a greater reduction, and therefore more bill savings.

In the last scenario where charging the battery is restricted to the lowest carbon emissions hours (10 am – 2 pm) and discharging the battery is restricted to the highest carbon hours (4pm – 9 pm) the battery is no longer economically attractive for the customer, due to the reduction in demand charge savings. Overall emissions are reduced, signifying that a larger carbon price will help the value of this use case to the utility in the future.

While customer benefits exceed costs in each case, the utility costs and savings vary more widely. In the storage only case, the utility benefits from a reduction in RA costs, but sees increased wholesale costs, and increased carbon emissions. This is due to the timing of the battery discharge. Because commercial customers peak relatively early, before the carbon intensity of the grid is at its height, the battery discharges when carbon emissions are relatively low. The battery recharges at night, when commercial loads are the lowest, but the carbon intensity of the grid is relatively high. This results in a net increase in emissions.

In both solar and storage cases, both the utility and the customer benefit, but the combined benefits are not greater than the combined costs. The utility sees both wholesale energy cost savings and RA cost savings, and carbon emissions decrease. Restricting the hours in which the battery can charge and discharge increases the carbon savings slightly, but does not greatly increase utility RA cost savings or wholesale energy cost savings. In addition, this greatly reduces the customer demand charge savings. However, the disparities between utility cost savings and demand charge reduction creates the potential for shifts in costs among customers, pointing to a need to continue to monitor the economics of commercial-scale energy storage and customer interest and penetration, and evaluate ways to align utility and customer incentives.

C. Transmission Grid-Tied Utility-Scale Energy Storage Systems

Transmission Grid-Tied Battery: Cost-Effectiveness Analysis

A CAISO 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[14]. Such a grid tied system could be co-located with a central PV system to harness additional benefits: a) resource adequacy capacity, b) congestion or curtailment management, and c) energy price arbitrage within a given day. The application would help meet CPAU's resource adequacy capacity obligations and lower the supply portfolio's hourly greenhouse gas (GHG) emission profile. The size of such systems would be in the 10 to 100 MW scale.

[14] A similar load following service could be performed by battery ESS with Palo Alto's load-resource balancing agent NCPA, under the NCPA MSS arrangement with the CAISO.

4. SUMMARY OF ECONOMIC RESULTS

As previously noted, the 2017 RMI Energy Storage Report[15] describes thirteen different value streams for energy storage to potentially capture. These applications could broadly be categorized as providing customer services, utility services and Transmission/ISO services.

Table 4 below describes the benefits-to-cost (B/C) ratios estimated for each of the thirteen applications, with lithium ion batteries as the energy storage system evaluated.[16] For example, the table illustrates the customer values streams associated with increased onsite usage of solar application has a benefit-to-cost ratio range of about 0.1, while the demand charge mitigation has a value stream of about 1.2. The previous results show that, from the perspective of a large commercial customer, batteries are a cost-effective solution to lowering their overall bill both for customers with solar PV and those without. This lines up with SEPA study since CPAU's current demand charges are fairly high, and the rule of thumb from the SEPA study is that storage will be economical where the demand charges amount to more than 50% of a commercial customers bill.

As mentioned before, there is the opportunity for a specific battery to capture multiple value streams for more than one stakeholder. However, by using an actual hourly dispatch model, hourly energy prices, hourly carbon prices, and hourly load profiles it becomes clear that currently the customer incentives for operating batteries are not exactly aligned with utility and wholesale price signals. An example of this is that the commercial customer's peak electricity usage is earlier in the day than the CPAU citywide peak electricity usage, and it is diverging in time, so that reducing a commercial customer's peak demand does not lower the utility's costs which are assessed on a peak basis, and could actually increase energy costs for the utility. In addition, current market structures often either reduce or eliminate additional value streams as markets are mutually exclusive for frequency and energy in California.

[15] https://rmi.org/wp-content/uploads/2017/03/RMI-TheEconomicsOfBatteryEnergyStorage-FullReport-FINAL.pdf

[16] The value streams are estimated by computing the annualizing the life time cost of the battery ESS and the annualizing the life-time benefits associated with each application and then computing the benefits to cost ratios (B/C ratio).

Some applications can capture multiple value streams, possibly allowing value stacking for some users or allowing multiple parties to benefit.

Table 4. Annualized Benefit to Cost Ratio of 13 Applications for Palo Alto.

End User	Potential Battery Value Stream	Applicability for Palo Alto*	Benefit to Cost Ratio Estimate
Customer	1.Backup Power	✓	Variable
	2.Increase Onsite Usage of Solar	✓ (Residential)	0.2
	3. Demand Charge Reduction	✓✓✓ (Lg. Commercial)	1.2
	4. Time-of-Use Bill Management	✓ (Lg. Commercial)	0.1
Utility	5. Distribution Investment Deferral	✓ (Residential)	TBD
	6. Transmission Investment Deferral	✓	0.05
	7. Transmission Congestion Relief	✓	≤ 0.05
	8. Resource Adequacy Capacity	✓✓✓	0.1 - 0.6
Transmission & Wholesale	9. Black Start	TBD	TBD
	10.Voltage Support	TBD	TBD
	11.Frequency Regulation	✓	0.1
	12. Spinning Reserve	✓	0.1
	13. Energy Price Arbitrage	✓✓✓	0.3

* The ✓ symbol denotes the value of the particular application in Palo Alto.

Table 4 summarizes the economic results of different battery applications. For example, the table illustrates that commercial customers (Scenarios II-IV) have a benefit-cost ratio in the range of 0.7 to 1.5 depending on how the batteries are operated and other assumptions. The benefit-cost ratio for use case Scenario I is highly dependent of the value placed by the residential customer on the incremental resiliency value (backup power) provided by the battery. Table 4 also highlights that large commercial customers with and without solar can save money by installing batteries now in Palo Alto due to the high demand charges, the same results that the SEPA modeling exercise found. However, when these large commercial customers operate their battery systems to maximize their financial benefit, the lost revenues to the utility in form of demand charge avoidance exceed the benefits to the utility. As previously noted, this disparity creates the possibility of shifts in costs among customers, so staff will continue to evaluate ways to align utility and customer incentives.

Table 5. Estimated Economics of Different Use Cases (Annualized Benefit-Cost Ratios)

End User (Direct Beneficiary)	Battery Use Cases	Value Streams	Benefit to Cost Ratio Estimate
Customer	Residential Customer with Solar PV System (Scenario I)	• Backup Power	Customer dependent
		• Increase PV Self Consumption	0.2
		• Resource Adequacy Capacity	0.05
		Combined B/C	**≥ 0.2**
	Commercial Customer with & without Solar PV System (Scenario II & III)	• Backup Power	Customer dependent
		• Demand Charge Avoidance	1.2 – 1.5
		• Resource Adequacy Capacity	0.05
		Combined B/C	**≥ 1.2**
Customer & Utility	Commercial Customer without Solar PV System (Scenario IV)	Backup Power	Customer dependent
		Demand Charge Avoidance	0.7
		Resource Adequacy Capacity	0.15
		Combined B/C	**≥ 0.7**
Utility	Transmission Grid-Tied Located at Utility-Scale PV	• Resource Adequacy Capacity	0.5
		• Frequency Regulation & Energy Arbitrage Values	0.3
		• Congestion/Curtailment Relief	0.01 - 0.1
		Combined B/C	**0.8 – 0.9**

D. Improvements of Future Energy Storage Value to CPAU Customers

Although the current analysis suggests energy storage within CPAU territory is not financially beneficial to all customers at this time there are a number of factors that CPAU has adopted that benefit storage both customer-sited and utility scale. Although these factors do not currently outweigh the costs of storage, there is the potential for this to change in the future based on future resiliency needs, statewide energy supply shortages or interruptions, different structure proposed for transmission charges, and rapid electrification of particular residential neighborhoods.

Energy storage can also provide value for residential customers on Time of Use (TOU rates). Having a storage system allows customers to purchase additional energy during off-peak hours to charge their battery, and then discharge during peak hours to reduce their net load. This reduces customer bills. Currently CPAU does not have a residential TOU rate, so this value stream is not available to residential customers in CPAU territory.

SECTION 4:
SUMMARY OF ECONOMIC RESULTS

1. Increased community value of local resiliency: The recent electricity supply shortages at the state level and potential future disruptions from large-scale regional wildfires could lead the community to decide to put a premium on local electricity storage.

2. Increased distribution constraints in residential areas: Energy storage could help distribution system costs, in particular neighborhoods rapidly switching to all electric homes and with high penetration of electric vehicles.

3. Increased wholesale value of flexible resources: The recent supply shortages at the state level could indicate that flexible electricity generation is currently underpriced and undervalued. Flexible resources such as batteries could be worth more in the future if this trend holds, especially as more natural gas generation is retired in California.

4. Reconfiguration of transmission charges: The primary transmission operator of California is considering redistributing transmission charges in a way which would make flattening electricity demand more valuable. This would increase the value of storage as one way to flatten electricity demands, at a City level.

5. CPAU's Hourly Carbon Neutral Standard: In 2020 CPAU adopted an hourly carbon neutral accounting standard. This will ensure that the technologies such as energy storage which can store the lowest carbon hours and then help the grid during the highest carbon hours are properly valued when making investment decisions.

6. Solar Net Energy Metering Rate: Since Palo Alto compensates new solar customers at the value to the utility for the solar exported to the grid, if the value of electricity continues to decline during the day, the value of local solar exported to the grid may decline as well. If the difference between the retail rate of electricity and the value of local solar electricity exported to the grid increases in the future, this will increase the value of local energy storage to customers.

5. Upcoming Work

Since two independent analysis both indicate that energy storage is not cost effective for any customer class from a societal perspective, CPAU will not be setting any energy storage targets at this time. Staff is evaluating transmission grid-tied storage located at utility-scale renewable generation in the Central Valley. CPAU will also consider utility scale and behind the meter storage as supply portfolio options in the next Electric IRP submitted to the CEC in year 2024. Staff will also continue working to develop for specific projects which by their location could provide extraordinary resiliency, lower carbon emissions, or distribution system value.

CPAU also plans to continue facilitating customer adoption of batteries through bulk buy programs such as SunShares for customers who want to purchase batteries, but CPAU has no plans of providing financial rebates for batteries using ratepayer funds.

There are six key areas that staff will continue to explore as these will have the highest value to CPAU and its customers:

A. Examine Using Flexible Loads to Avoid or Minimize Future Rotating Outages

Flexible loads have many of the benefits of energy storage but are much less expensive than purchasing standalone batteries or other energy storage. The recent electricity supply shortages at the state level indicate that flexible electricity loads such as storage, flexible EV charging, flexible building management systems, smart thermostats and smart heat-pump water heaters may be currently undervalued. Staff will be examining ways to use flexible electricity loads to minimize the risk and severity of rotating outages in the future. This could be configured as an Automatic Demand Response program or a Virtual Power Plant. It is important to note that flexible loads like these programs reduce the likelihood and magnitude of future rotating outages, but if Palo Alto is called upon to shed load for the reliability of the statewide grid, CPAU will have to initiating the outages mandated.

i. Consider partnerships with commercial customers who are considering energy storage investments in the hundred-kW scale, for CPAU to partially utilize the system to meet resource adequacy capacity needs.
ii. Facilitate residential customers to leverage batteries in their electric vehicles to avoid charging during the evening and stop charging (demand response) during periods when the system peaks for the month or for the year.[17]

B. Examine Using Flexible Electrification as Distributed Thermal Energy Storage

Electrification of space and water heating has the potential to decrease carbon emissions even more if these systems use electricity during the cleanest hours of the day and coast through the highest emission hours of the day, since heat-pump water heaters and buildings can pre-heat and then when residents are not home and maintain their temperatures with

[17] CPAU is not currently contemplating any pilot projects related to discharging EV batteries to serve loads during high electricity value periods.

excellent insulation. CPAU is already incentivizing electrification of space and water heating and could add extra incentives to those systems which can be dispatched to follow the cleanest hours on the grid.

C. Evaluate Local Energy Storage at Existing Local Solar for Resiliency

Explore partnering with emergency services to add storage to existing local solar sites at City facilities. Storage could be used to mitigate the risk and severity of potential supply shortages in addition to catastrophic emergencies.

D. Evaluate Competitive Proposals for Transmission Grid-tied Energy Storage

CPAU is currently closely evaluating multiple proposals for energy storage located at utility-scale renewable generation. Staff will recommend moving forward if the evaluation finds a project that is a good fit for the electric supply portfolio. The system sizes for these projects is expected to be larger, in the 5-20 MW and 20 to 40 MWh scale.

E. Evaluate Financial and Physical Integration of Storage and Flexible Loads

CPAU is evaluating both the physical impacts of energy storage and flexible loads on utility distribution system operations as well as the costs and benefits to the utility's financial position and other ratepayers. In particular, as the industry evolves, staff will evaluate the impact of storage and flexible loads on cost of service rate design and make adjustments if needed.

F. Evaluate the Potential Resiliency Needs of an Electrified Community

CPAU continues to evaluate current and future resiliency needs, including the potential role of energy storage in the scenarios where the Sustainability and Climate Action Plan goals are fully implemented by means of a completely-electrified community.

Appendix A: SEPA Customer-Sited Energy Storage Summary Report Prepared for NCPA

Customer-Sited Energy Storage

Summary Report Prepared for NCPA
Sept 9, 2020

Smart Electric Power Alliance

Task 1

POU Participant Input

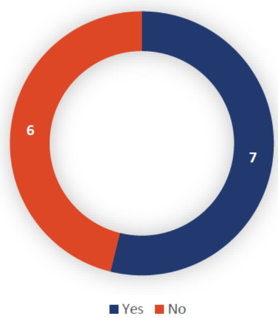
APPENDIX A:
SEPA CUSTOMER-SITED ENERGY STORAGE SUMMARY REPORT PREPARED FOR NCPA

Carbon Reduction & Sustainability Goals

Smart Electric Power Alliance

Utilities with Carbon and/or Sustainability Goals
City of Palo Alto Utilities
Truckee Donner Public Utility District
Turlock Irrigation District
Alameda Municipal Power
SMUD
Silicon Valley Power
Port of Oakland

Utility Survey Feedback



Summary:

- Goals based on SB100 RPS of 60% renewables by 2030 and 100% renewable energy and zero carbon sources by 2050
- Programs to achieve carbon reduction goals:
  - Transportation and building electrification
  - Energy efficiency programs
  - Green house gas accounting and reporting

Program Offerings & Customer Outreach

Smart Electric Power Alliance

Summary:

- 10 of the 13 utility respondents do not currently offer a BTM storage program to customers
- 2 respondents are installing or have previously installed FOTM storage
- Most respondents offer educational material about solar (7) on their website
  - 4 of the 13 respondents offer educational material on both solar and storage
  - 2 respondents offer no educational material on these DERs

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Customer Interest & Incentives

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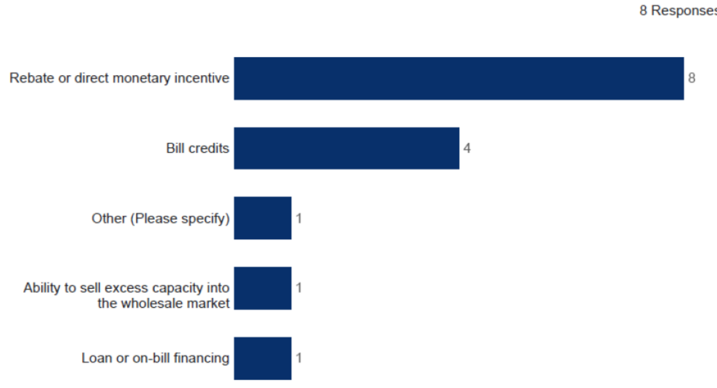
What incentive types have customers mentioned? (select all that apply)



Summary:

All utility respondents noted customer interest in battery storage

- 9 of 13 noted interest from both commercial and residential customers

Most utilities noted customer interest in incentives for storage (8 of 13)

Of these 8 respondents:

- All noted customer interest in rebate or direct monetary incentives
- Half identified interest in bill credits

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Customer Value of Storage Solutions

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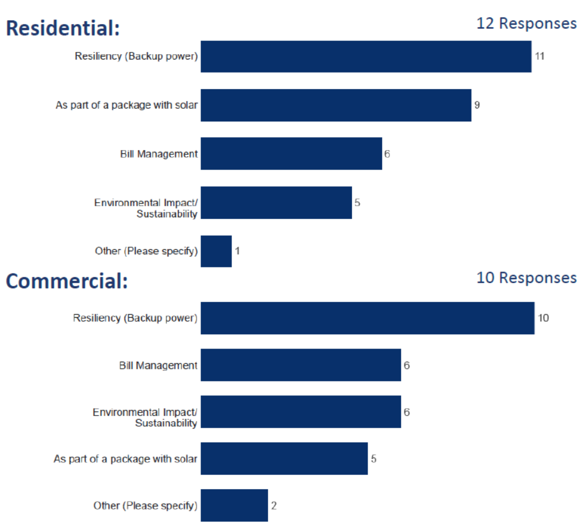

Summary:

- Resiliency and bill management rated high in perceived value for both residential and commercial customer
- Other identified value include:
  - General interest or hobbyists (Residential)
  - Strategic business area controls (Commercial)
  - Demand charge reduction (Commercial)

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Value of Storage (FOTM & BTM)

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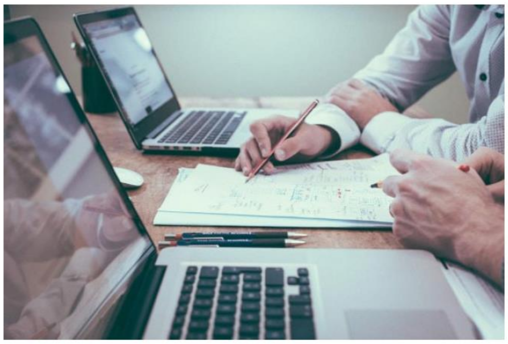

Behind the Meter:

- 8 of 13 utility respondents believe BTM storage can provide value as:
  - Capacity resources for demand reduction (4)
  - Added services to customers (3)
  - Part of a microgrid (1)
- 4 of 13 are unsure if BTM storage can provide value and 1 respondent noted no value

Front of the Meter:

- 8 of 13 utility respondents believe FTM storage can provide value as:
  - Capacity resources for demand reduction (7)
  - Part of a microgrid (5)
  - For grid support (4), as an NWA to distribution of transmission upgrade (4)
- 5 of 13 are unsure if BTM storage can provide value
- Only 2 utilities noted distribution circuits that would benefit from adding energy storage

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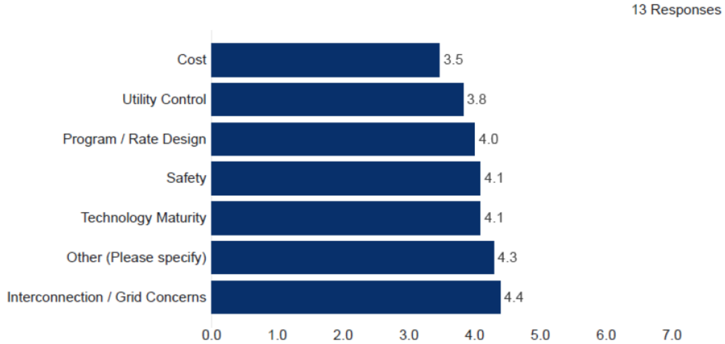
Barriers to Deployment of BTM Storage

Smart Electric Power Alliance

Rank the following from highest to lowest barrier to your utility implementing behind the meter battery storage where 1 is the largest barrier and 7 is the smallest.

13 Responses



Summary:

- Largest barriers to deployment:
  - Cost
  - Utility Control
  - Program / Rate Design
- Smallest barriers to deployment:
  - Interconnection / Grid Concerns
  - Technology Maturity
  - Value Proposition / BCA

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FTM Storage Pricing

Smart Electric Power Alliance

Detail on Pricing Response	Utility name
Shiva Swaminathan already sent Emily Lemei pricing quotes.	City of Palo Alto Utilities
Utility costs for battery storage is not often priced based upon the an install cost. More commonly the price is per MWH delivered or a kW-demand charge (resource adequacy) with energy provided by the purchaser of capacity.	City of Healdsburg
PPA bids received use a $/kW-month pricing structure, so we have estimated capital costs. Certain bids paired with solar may come below $200/kWh.	Alameda Municipal Power
We found that pricing is very dependent upon warranty and on-going O&M considerations. The amount of cycling per day and per year have a major influence on the price and the expected life of the system. The battery module life will vary widely based on this utilization and the impact of that aging impacts the warranty cost. Fire and safety standards, along with communication and interface standards are very nascent and it can be difficult to ensure that selections made today will meet long term requirements.	SMUD
Sample price for 200MW/800/MWh: Total energy for 1 cycle per day = 800*365 =292,000 MWh RA Capacity ~$6/kW-mon and Energy Tolling ~ 13/kW-mon Average cost (6,000*12*200 +13,000*12*2000)/292,000 = $156/MWh	Lodi Electric Utility

Summary:

- 5 of 13 utility respondent have solicited quotes for FTM storage in the past 12 months
- Pricing identified:
  - <200/kWh – 1 respondent
  - $201 - 400kWh – 2 respondents
  - $401 – 800/kWh – 2 respondents

Task 2

Analysis of Existing Market Offerings

APPENDIX A:
SEPA CUSTOMER-SITED ENERGY STORAGE SUMMARY REPORT PREPARED FOR NCPA

Analysis of Existing Market Offerings

National Overview

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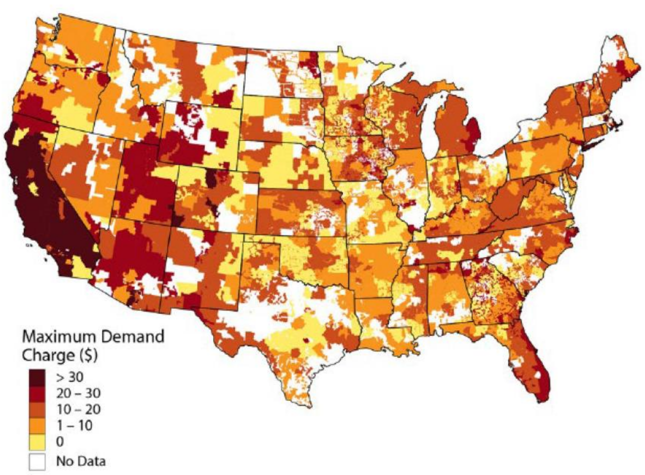
Demand Charge Avoidance

Smart Electric Power Alliance



- Currently the key customer economic driver for energy storage
- Key indicators of cost-effective customer options include
  - Customers where demand charges are 50%+ of their total bill
  - Areas where demand charges are $10/kW+

Source: NREL. 2017. Identifying Potential Markets for Behind-the-Meter Battery Energy Storage: A Survey of U.S. Demand Charges. Golden, CO: National Renewable Energy Laboratory.

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TOU Arbitrage

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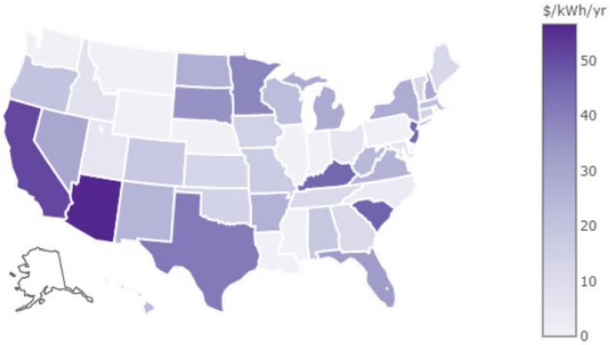
Representative Average Residential Bill Savings – TOU Arbitrage



- TOU tariffs *can* be the next most prominent customer economic driver for energy storage deployments
  - TOU differential varies widely; from <$0.02/kWh to >$0.20/kWh
  - Customer TOU savings typically occur only during peak pricing months

Source: Implications of Rate Design for the Customer Economics of Behind-the-Meter Storage, Lawrence Berkeley National Laboratory

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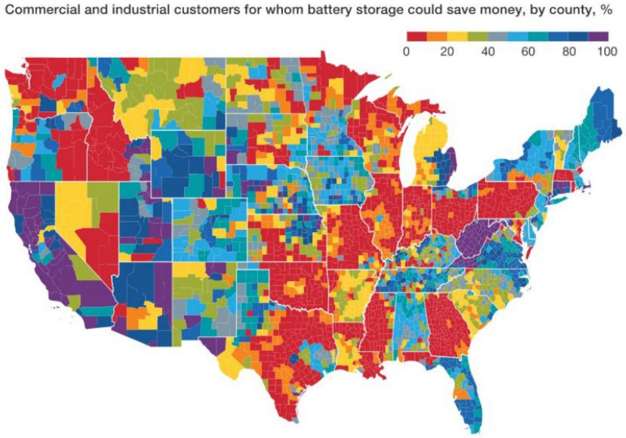
Potential For Bill Savings

Smart Electric Power Alliance

- Majority of electric C&I customers are positioned to see some economic benefit from local energy storage
- As more value streams are captured and storage prices continue to decline, the number of cost-effective deployment opportunities will continue to increase

Commercial and industrial customers for whom battery storage could save money, by county, %



Source: David Frankel and Amy Wagner, "Battery storage: The next disruptive technology in the power sector," June 2017, McKinsey.com

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Impact of Resilience

Smart Electric Power Alliance

- Primary motivation for homeowners adding storage today is not financial
  - Residential solar is growing
  - Energy storage weakens the economic value proposition
  - So, customer interest is primary for back-up power and independence from the grid (Note: This is supported by the survey results)
- Industry attachment rates reflect consumer interest in storage
  - Tesla 40%
  - Sunrun 20% nationwide, 35% in California, 60% in the Bay (April 2020)
  - Vivint <10% (pre-acquisition by Sunrun)
  - Sunpower 30%
- New SGIP “equity resilience” budget - $613M through 2024
- Residential storage sales increased to a record for the 5th consecutive quarter[1]

1. https://www.greentechmedia.com/articles/read/q2-was-second-best-quarter-ever-for-us-energy-storage

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Analysis of Existing Market Offerings

Select Case Studies

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BTM Utility Ownership

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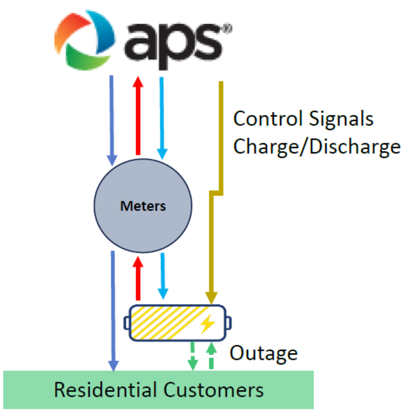

APS – Storage Rewards Program				
Asset Ownership	Utility	Customer	Developer	
Behind-the-Meter	Yes	No		
Storage Control	Utility	Customer	Developer	Shared
Rate Class	Residential	Commercial	All	
Direct Customer Impact	Lease	Demand Credit	Incentive	None
Wholesale Impact	Yes	No		

- Sunverge One battery
- Pilot program currently full
- Participation requires rate switch (with a demand charge)
- One time $500 bill credit
- APS pays property tax increases
- Can be used as back up power during outage

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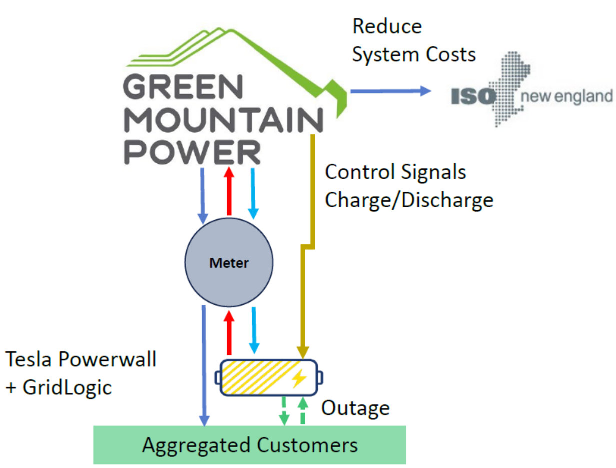
BTM Utility Ownership

Smart Electric Power Alliance



GMP – Tesla Powerwall Program				
Asset Ownership	Utility	Customer	Developer	
Behind-the-Meter	Yes	No		
Storage Control	Utility	Customer	Developer	Shared
Rate Class	Residential	Commercial	All	
Direct Customer Impact	Lease	Demand Credit	Incentive	None
Wholesale Impact	Yes	No		

- Customers pay $55/month for 120 months or $5,500 upfront for two Tesla Powerwalls
  - Up to 500 customer per year can sign up through September 30, 2022
- Customers can use as back up power during outage
- Lowers transmission and capacity expenses by reducing peak demand on the system
- Customer savings from overall system cost reductions

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BTM Customer Ownership

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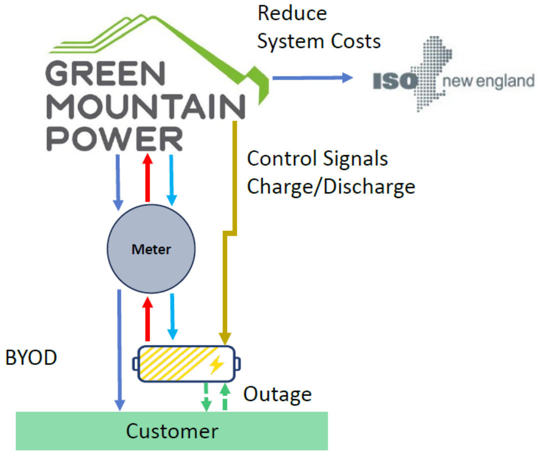

GMP – Bring Your Own Device				
Asset Ownership	Utility	Customer	Developer	
Behind-the-Meter	Yes	No		
Storage Control	Utility	Customer	Developer	Shared
Rate Class	Residential	Commercial	All	
Direct Customer Impact	Lease	Demand Credit	Incentive	None
Wholesale Impact	Yes	No		

- Up front $850 per kW of storage enrolled for 3 hour discharge, $950 per kW for 4 hour discharge
  - Additional $100 per kW applied to installations in GMP identified constrained areas
  - Up to 10 kW for all incentives
- Customer can use battery during non “Peak Events”
  - Program used to offset energy needed to meet peak demand
- $3.97/month charge for communications & software integration

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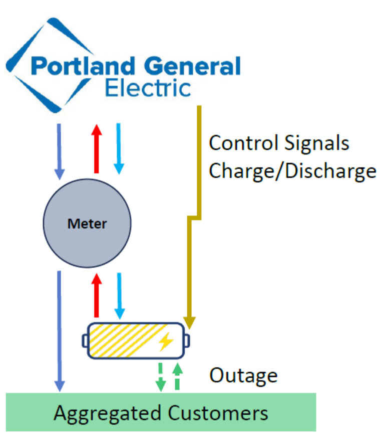
Virtual Power Plant Pilot

Smart Electric Power Alliance



PGE – Virtual Power Plant Pilot				
Asset Ownership	Utility	Customer	Developer	
Behind-the-Meter	Yes	No		
Storage Control	Utility	Customer	Developer	Shared
Rate Class	Residential	Commercial	All	
Direct Customer Impact	Lease	Demand Credit	Incentive	None
Wholesale Impact	Yes	No		

- 525 residential energy storage batteries (12kWh – 16kWh each) aggregated into 4MW virtual power plant
- Test new smart-grid control devices to allow for bi-directional power exchange between PGE and participants
- Monthly $40 rebate on utility bill ($20 if battery is solar charged)
- $5,000 rebate off the cost of home battery storage for income-qualified households
- Customer can use as back-up power during an outage

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Public Power Storage Incentive

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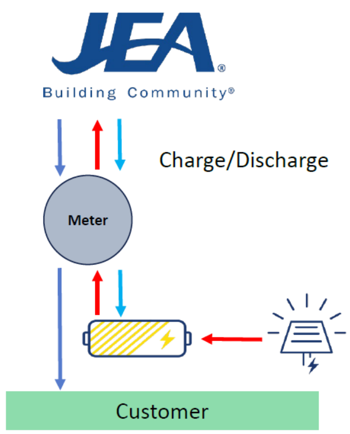

JEA – Battery Storage Incentive				
Asset Ownership	Utility	**Customer**	Developer	
Behind-the-Meter	**Yes**	No		
Storage Control	Utility	**Customer**	Developer	Shared
Rate Class	Residential	Commercial	**All**	
Direct Customer Impact	Lease	Demand Credit	**Incentive**	None
Wholesale Impact	Yes	**No**		

- Program aimed to encourage residential and commercial renewable energy adoption
- 30% rebate on the cost of the energy storage system up to $2,000
- Customers must have approved renewable distributed generation systems (DG) on-site
- Reduce the amount of excess energy flowing back onto the JEA grid

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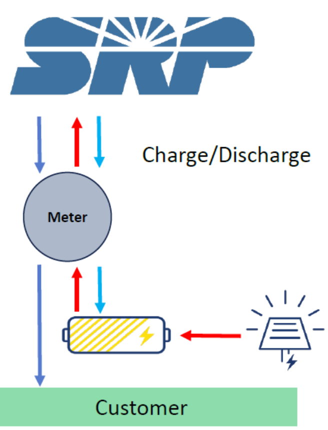
Public Power Storage Incentive

Smart Electric Power Alliance



SRP – Battery Storage Incentive				
Asset Ownership	Utility	**Customer**	Developer	
Behind-the-Meter	**Yes**	No		
Storage Control	Utility	**Customer**	Developer	Shared
Rate Class	**Residential**	Commercial	All	
Direct Customer Impact	Lease	Demand Credit	**Incentive**	None
Wholesale Impact	Yes	**No**		

- $300 per kWh-DC (up to $3,600) for approved residential participants
- Incentive available for 36 months or until limit of 4,500 residential customers is reached
- Program as part of a study to determine customer storage usage, battery storage performance, and system affects to the grid

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Task 3

Economic Modeling

Economic Modeling Overview

Smart Electric Power Alliance

- Overview
  - Customer controlled battery storage
    - Customer economics from owning and dispatching battery
      - Customer goal is to reduce bill
  - Dispatch battery to achieve bill savings
    - Strategy for dispatch changes by rate type, load shape and solar profile
  - Impact to utility and society from customer actions
    - Lost revenues from customer
    - RA and TAC demand components impact from customer behavior
    - DLAP energy price impact from customer behavior
    - CO_2 emissions (no economic value included) impact from customer behavior
  - 8760 data
    - Load shapes, DLAP energy prices, CO_2 emission profile

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Battery Storage Run Matrix

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Run designation	Load Shape	Energy Rates	Demand Rates	Solar
Run 1	TID residential	Time-of-use	No	No
Run 2	TID residential	Tiered with NEM2	No	Yes
Run 3	TID Industrial	Flat	Yes	No
Run 4	TID Industrial	Time-of-use	Yes	No
Run 5	SVP residential	Time-of-use	No	No
Run 6	SVP residential	Tiered with NEM2	No	Yes
Run 7	CPAU commercial	Flat	Yes	No
Run 8	CPAU commercial	Time-of-use	Yes	No

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Battery Storage Rate Structures

Smart Electric Power Alliance

	Residential Rates									
#1	Time of Use	Customer charge	June 1-Sept 30, M-F, 5pm-8pm	June 1-Sept 30, M-F, 12pm-5pm, 8pm-12am	June 1-Sept 30, M-F, 12am-12pm	June 1-Sept 30, weekends and holidays	October 1-May 31,weekday s 5pm-8pm	October 1-May 31, all other hours		
		$ 28.83	$ 0.2941	$ 0.1671	$ 0.1209	$ 0.1209	$ 0.1430	$ 0.1035		
#2	Solar NEM 2.0		Export $	Customer Charge	Summer Tier I - 0-317 kWh	Tier II - 318 kWh - 412 kWh	Tier III - over 412 kWh	Winter Tier I - 0-581 kWh	Tier II - 582 kWh - 756 kWh	Tier III - over 756 kWh
			$0.07096	$17.30	$0.11168	$0.17953	$0.27233	$0.11168	$0.17953	$0.27233
	Commercial Rates									
#3	Demand charge, flat	Customer charge	Demand charge, Per kW	Winter (Nov 1-Apr 30) Per kWh	Summer (May 1- Oct 31) per kWh					
		$60.38	$4.18	$ 0.12701	$ 0.15859					
#4	Demand TOU Combo (Updated)	Customer charge	Demand charge, per kW peak over 12 months	June 1-September 30 demand charge, max kW used M-F between 2pm-8pm	June 1- Sept 30, M-F, 2:00pm-8:00pm	June 1-Sept 30, M-F, 12:00pm-2:00pm, 8:00pm-10:00pm	June 1-Sept 30, All other hours	Oct 1-May 31, M-F, 12:00pm-10:00pm	Oct 1-May 31, All other hours	
		$ 113.15	$ 3.98	$ 8.02	$ 0.2103	$ 0.1437	$ 0.1143	$ 0.1127	$ 0.0894	

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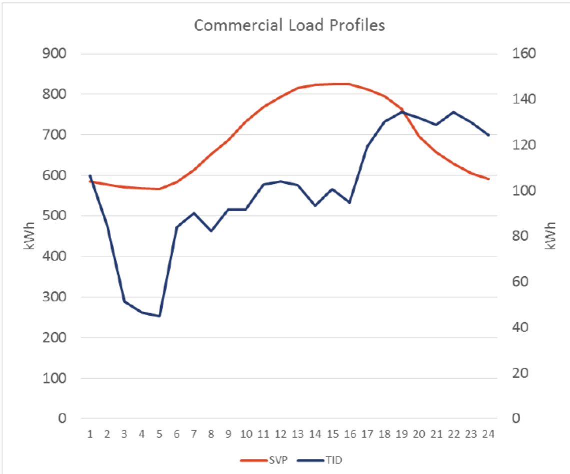
Commercial Load Profile

Smart Electric Power Alliance



- TID is a low load factor customer while SVP is a normal commercial load factor customer
- Peaks occur at different times
- SVP profile makes battery dispatch more predictable

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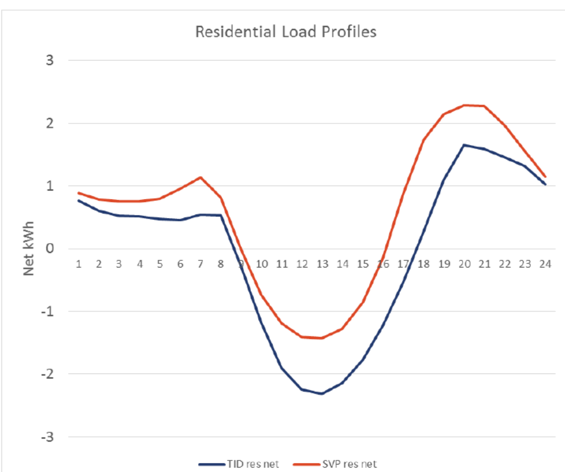
Residential Load Profile

Smart Electric Power Alliance



- TID is lower load than SVP and higher solar volume
- Similar net load shapes
- Should have similar results

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APPENDIX A:
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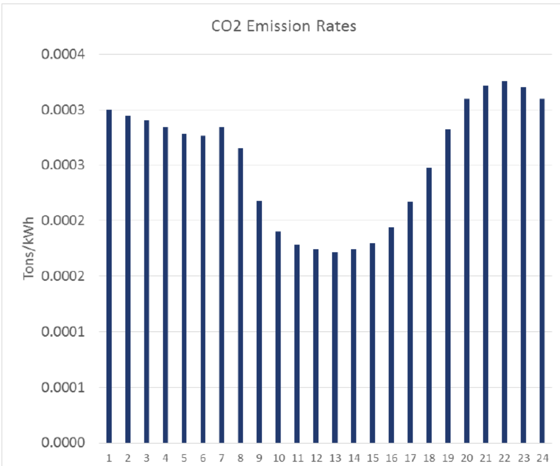
CO2 Emissions



- Emission rates follow the familiar "Duck Curve"
- Higher during fossil generation and lower during solar

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Battery Storage Run Summary

	Customer Savings - $/kW-yr	Benefit-Cost-Ratio	Required Rate Increase - %	Co2 Tons	Palo Alto Cost/(Savings) - $/kW-yr	TID Cost/(Savings) - $/kW-yr
Run 1	$47	0.2	140%	0.2	($47)	($70)
Run 2	$13	0.3	274%	(0.4)	($6)	($6)
Run 3	$11	0.1	286%	0.1	$2	$2
Run 4	$37	0.2	93%	0.6	($31)	($7)
Run 5	$47	0.2	140%	0.2	($47)	($70)
Run 6	$17	0.3	278%	(0.3)	($4)	($11)
Run 7	$17	0.1	273%	0.6	($32)	$21
Run 8	$66	0.4	78%	0.6	$35	$70

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Battery Run Storage Summary

Smart Electric Power Alliance

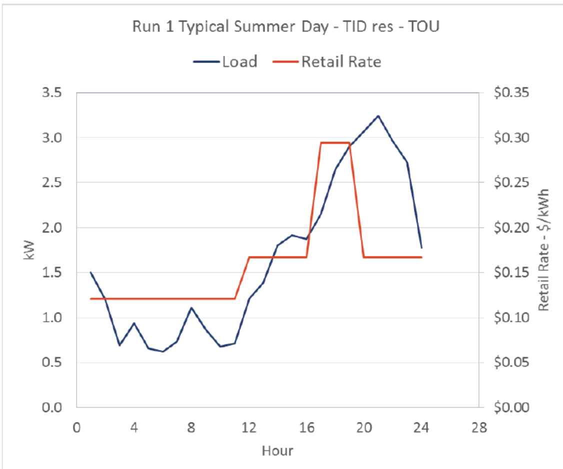
- No foreseeable battery cost reductions or retail rate increase prove economical absent any additional ancillary benefits
- Customer bill savings for all runs
- Rate 1 showed highest utility benefit
- Rate 4 with SVP commercial load (Run 8) had the worst utility value but mostly due to customer savings

Economic Modeling Results

APPENDIX A:
SEPA CUSTOMER-SITED ENERGY STORAGE SUMMARY REPORT PREPARED FOR NCPA

Run 1 - Residential TOU Retail Rates

Smart Electric Power Alliance

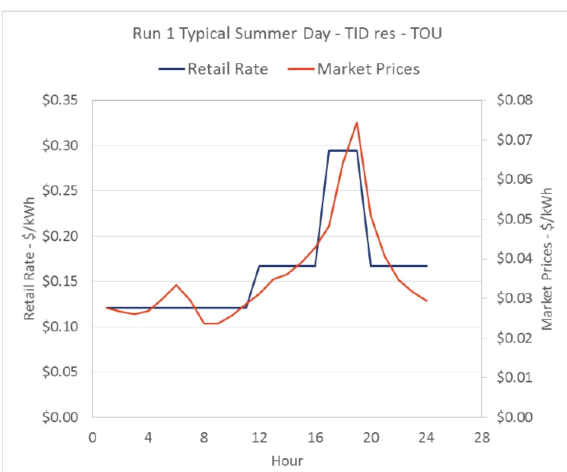


- Customer load has good alignment with retail rates
- Since there is no demand rate, customer peak demand and load shape are not important
- TOU price spread in periods where available will allow for customer savings through price arbitrage

 33

Run 1 - Residential TOU Energy Prices

Smart Electric Power Alliance



- Since retail rates and energy prices have similar profile, utility energy savings are expected even though battery dispatch results in increased energy usage
- Previous slide also showed alignment with customer load

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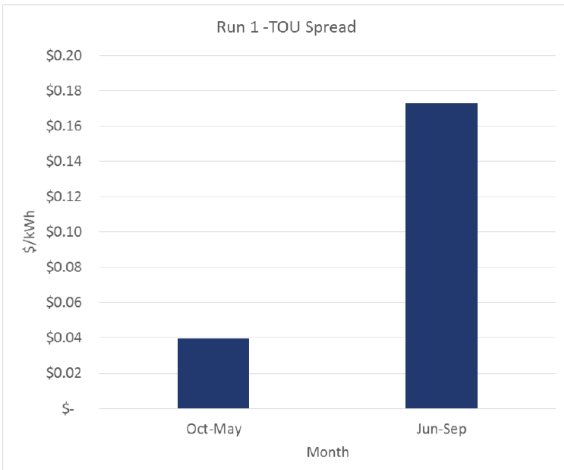
Run 1 - Residential TOU Spread

Smart Electric Power Alliance



- Small rate spread in 8 months but large rate spread in 4 months
- Strategy - Take advantage of TOU rate spread (weekday)

 35

Run 1 - Customer Economics

Smart Electric Power Alliance

No foreseeable battery cost reductions or retail energy rate increase prove economical

- Inputs
  - 3.5% WACC
  - 2.5% savings escalation
  - Battery installed cost - $2,460/kW
  - 15 year battery life
- Outputs
  - Customer savings - $47/kW-yr
  - Benefit cost ratio - 0.2
  - NPV - ($2,060)/kW
  - Metric tons CO_2 - 0.2
- Outputs - TOU increase needed to achieve BCR = 1
  - Benefit cost ratio -1.0
  - NPV - $0
  - TOU increase - 140%

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Run 1 - Utility Impact

Smart Electric Power Alliance

- Observations
  - Battery charges at low TOU retail rate and discharges at peak TOU rate
  - Battery charges at low market prices and discharges at high market prices, approximately $31/MWh spread

Component	Palo Alto Shape	TID Shape
Customer revenues	$47	$47
DLAP Energy	($17)	($17)
RA Demand	($53)	($69)
TAC Demand	($23)	($31)
Total Cost / (Savings)	**($47)**	**($70)**

All values in the table above are $/kW-yr

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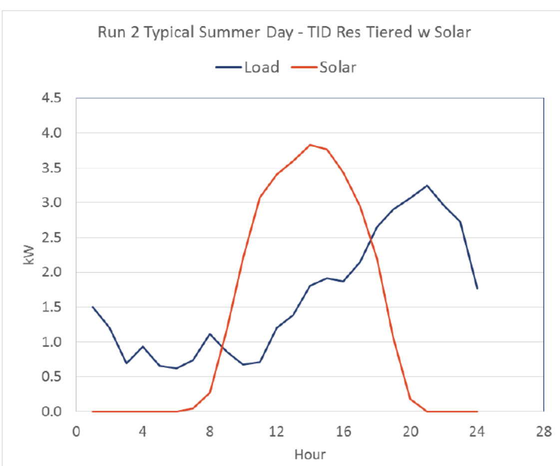
Run 2 - Solar

Smart Electric Power Alliance



- Solar size results in negative net load
- Since there is no demand rate, customer peak demand is not an issue
- Arbitrage available due to excess solar credit being lower than retail rates

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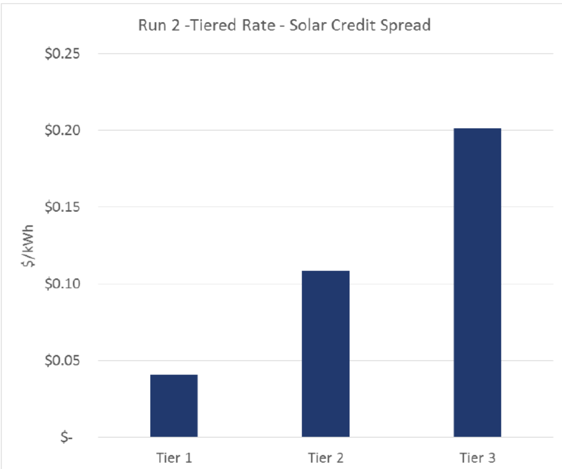
Run 2 - Residential Tiered Rates

Smart Electric Power Alliance



- Tiered rates allow for larger price arbitrage
- However because of solar system size these higher tiered rates are never achieved, only Tier 1 spread
- Strategy - minimize solar export (weekday and weekend)

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Run 2 - Customer Economics

Smart Electric Power Alliance

No foreseeable battery cost reductions or retail energy rate increase prove economical

- Inputs
  - 3.5% WACC
  - 2.5% savings escalation
  - Battery installed cost - $2,460/kW
  - 15 year battery life
  - ITC because of solar
- Outputs
  - Customer savings - $13k/W-yr
  - Benefit cost ratio - 0.3
  - NPV - ($1,901)/kW
  - Metric tons CO2 - (0.4)
- Outputs - Rate increase needed to achieve BCR = 1
  - Benefit cost ratio -1.0
  - NPV - $0
  - Rate increase - 274%

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APPENDIX A:
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Run 2 - Utility Impact

Smart Electric Power Alliance

- Observations
  - Battery charges to reduce excess solar credit
  - Battery charges at low market prices and discharges at high market prices, approximately $15/MWh spread

Component	Palo Alto Shape	TID Shape
Customer revenues	$13	$13
DLAP Energy	($12)	($12)
RA Demand	($6)	($5)
TAC Demand	($2)	($2)
Total Cost / (Savings)	**($6)**	**($6)**

All values in the table above are $/kW-yr

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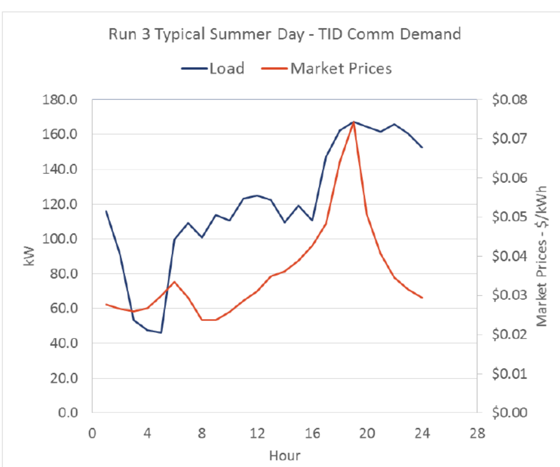
Run 3 - Commercial Demand Rate

Smart Electric Power Alliance



- No price arbitrage available
- Savings can only occur by reducing peak
- Peak load near peak market price
- Low load factor customer - 35%

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APPENDIX A:
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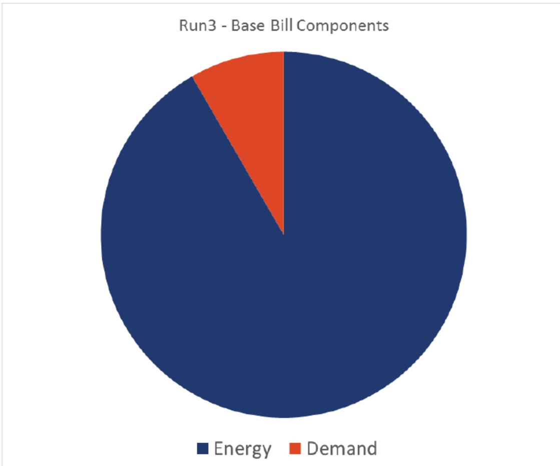
Run 3 - Bill Components

Smart Electric Power Alliance



- Majority of bill is from energy rates
- Energy rates vs demand rates make bill savings difficult but demand savings do occur
- These are partially offset since the battery uses more energy
- Strategy - dispatch to reduce demand cost

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Run 3 - Customer Economics

Smart Electric Power Alliance

No foreseeable battery cost reductions or retail demand rate increase prove economical

- Inputs
  - 3.5% WACC
  - 2.5% savings escalation
  - Battery installed cost - $1,880/kW
  - 15 year battery life
- Outputs
  - Customer savings - $11/kW-yr
  - Benefit cost ratio - 0.1
  - NPV - ($1,909)/kW
  - Metric tons CO2 - 0.1
- Outputs - Demand rate increase needed to achieve BCR = 1
  - Benefit cost ratio -1.0
  - NPV - $0
  - Demand rate increase - 286%

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Run 3 - Utility Impact

Smart Electric Power Alliance

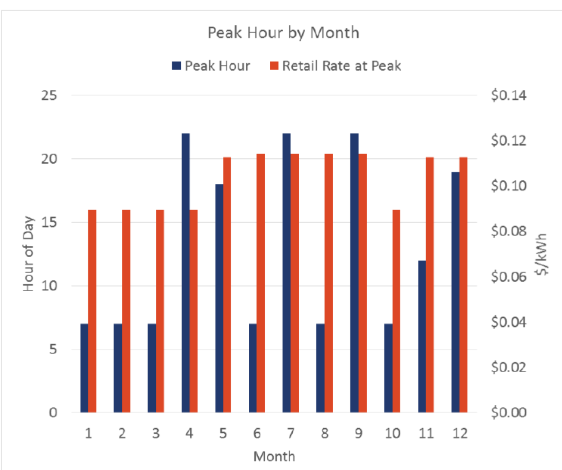
- Observations
  - Battery discharges to reduce peak demand
  - Battery charges at low market prices and discharges at high market prices, approximately $13/MWh spread

Component	Palo Alto Shape	TID Shape
Customer revenues	$11	$11
DLAP Energy	($9)	($9)
RA Demand	$0	$0
TAC Demand	$0	$0
Total Cost / (Savings)	**$2**	**$2**

All values in the table above are $/kW-yr

Run 4 - TOU Rate and Demand Rate

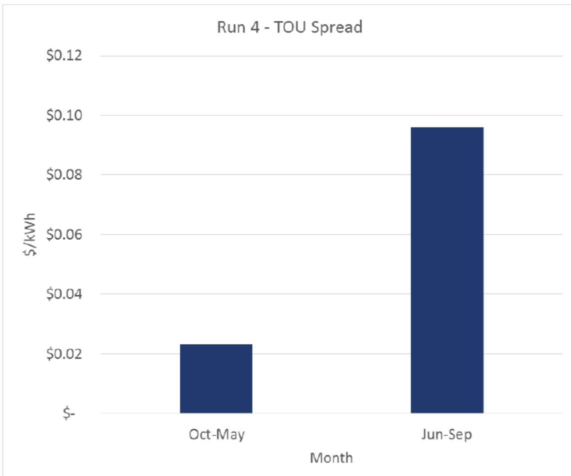
Smart Electric Power Alliance



- Monthly peaks can occur early in the morning making peak load reduction difficult during months when demand rates occur
- Low load factor customer - 35%

Run 4 - TOU Rate Spread

Smart Electric Power Alliance

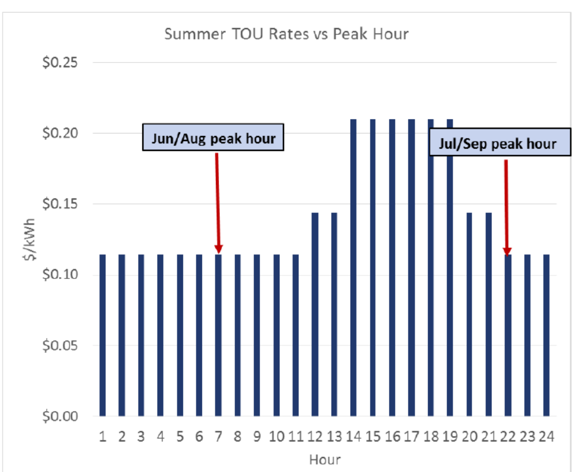


- Price arbitrage available
- Summer has highest rate spread
- Most savings will occur in the summer

47

Run 4 - TOU Rates / Demand Rates

Smart Electric Power Alliance



- Monthly demand rates Jun-Sep
- Peak times in these months do not overlap high TOU rates
- Secondary demand rate on yearly peak
- Strategy - maximize TOU arbitrage (weekday)

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Run 4 - Customer Economics

Smart Electric Power Alliance

No foreseeable battery cost reductions or retail energy rate increase prove economical

- Inputs
  - 3.5% WACC
  - 2.5% savings escalation
  - Battery installed cost - $1,880/kW
  - 15 year battery life
- Outputs
  - Customer savings - $37/kW-yr
  - Benefit cost ratio - 0.2
  - NPV - ($1,555)/kW
  - Metric tons CO2 - 0.6
- Outputs - TOU rate increase needed to achieve BCR = 1
  - Benefit cost ratio -1.0
  - NPV - $0
  - TOU rate increase - 93%

Run 4 - Utility Impact

Smart Electric Power Alliance

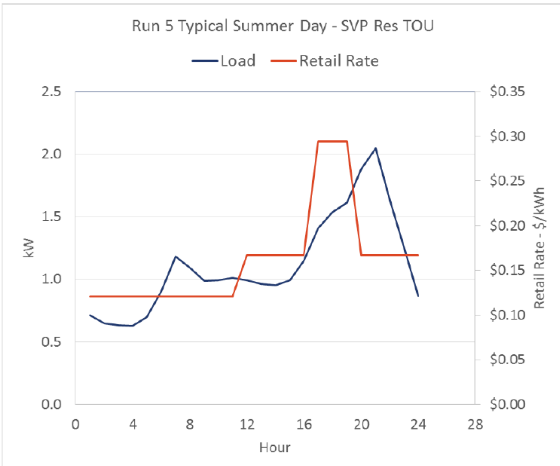
- Observations
  - Battery charges at low TOU rate and discharges at highest TOU rate
  - Battery charges at low market prices and discharges at high market prices, approximately $6/MWh spread

Component	Palo Alto Shape	TID Shape
Customer revenues	$37	$37
DLAP Energy	($2)	($2)
RA Demand	($46)	($29)
TAC Demand	($20)	($13)
Total Cost / (Savings)	**($31)**	**($7)**

All values in the table above are $/kW-yr

Run 5 - Residential TOU Retail Rates

Smart Electric Power Alliance



- Customer load has good alignment with retail rates
- Since there is no demand rate, customer peak demand and load shape are not important
- TOU price spread in periods where available will allow for customer savings through price arbitrage

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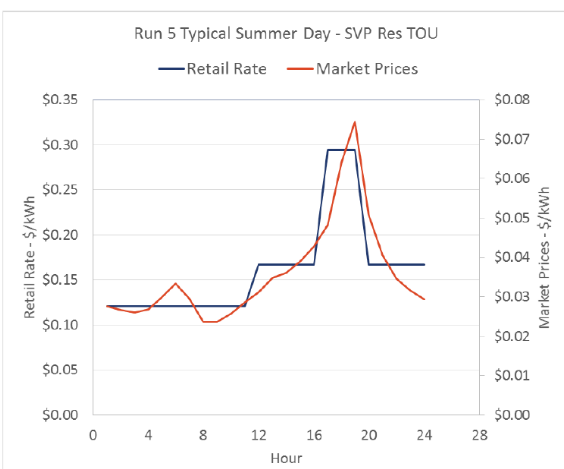
Run 5 - Residential TOU Energy Prices

Smart Electric Power Alliance



- Since retail rates and energy prices have similar profile, utility energy savings are expected even though battery dispatch results in increased energy usage
- Previous slide also showed alignment with customer load

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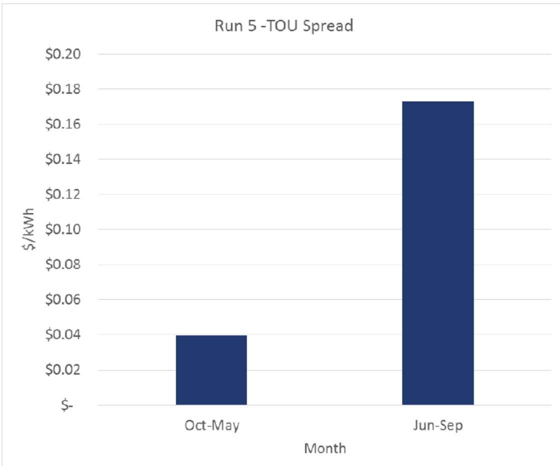
Run 5 - Residential TOU Spread

Smart Electric Power Alliance



- Small rate spread in 8 months but large rate spread in 4 months
- Strategy - Take advantage of TOU rate spread (weekday)

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Run 5 - Customer Economics

Smart Electric Power Alliance

No foreseeable battery cost reductions or retail energy rate increase prove economical

- Inputs
  - 3.5% WACC
  - 2.5% savings escalation
  - Battery installed cost - $2,460/kW
  - 15 year battery life
- Outputs
  - Customer savings - $47/kW-yr
  - Benefit cost ratio - 0.2
  - NPV - ($2,060)/kW
  - Metric tons CO2 - 0.2
- Outputs - TOU rate increase needed to achieve BCR = 1
  - Benefit cost ratio -1.0
  - NPV - $0
  - TOU increase - 140%

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Run 5 - Utility Impact

Smart Electric Power Alliance

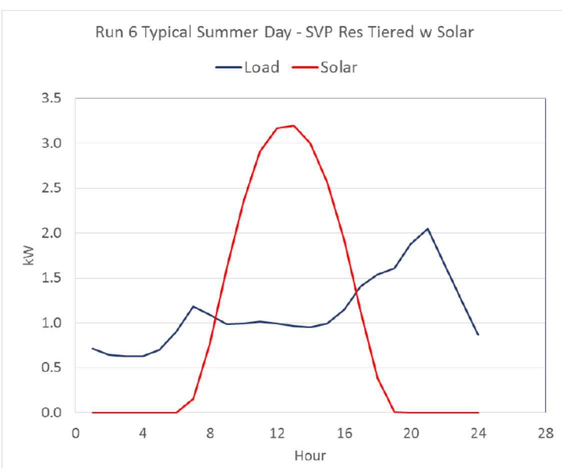
- Observations
  - Battery charges at low TOU retail rate and discharges at peak TOU rate
  - Battery charges at low market prices and discharges at high market prices, approximately $31/MWh spread

Component	Palo Alto Shape	TID Shape
Customer revenues	$47	$47
DLAP Energy	($17)	($17)
RA Demand	($53)	($69)
TAC Demand	($23)	($31)
Total Cost / (Savings)	**($47)**	**($70)**

All values in the table above are $/kW-yr

Run 6 - Solar

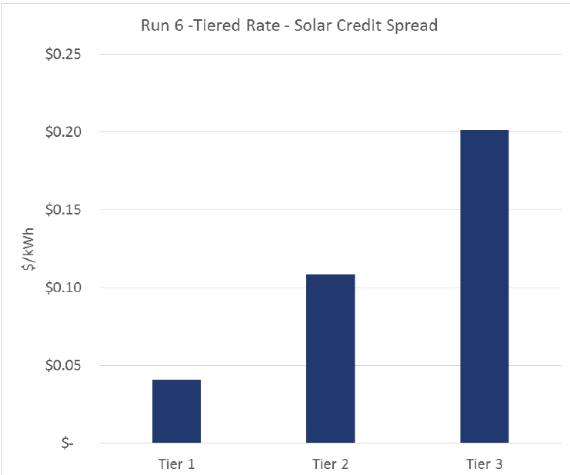
Smart Electric Power Alliance



- Smaller solar size and larger load size than Run 2, results in positive net load
- Since there is no demand rate, customer peak demand is not an issue
- Arbitrage available due to excess solar credit being lower than retail rates

Run 6 - Residential Tiered Rates

Smart Electric Power Alliance



- Tiered rates allow for larger price arbitrage
- Tier 2 and tier 3 spreads are available for arbitrage approximately 10% of the time
- Strategy - minimize solar export (weekday and weekend)

 57

Run 6 - Customer Economics

Smart Electric Power Alliance

No foreseeable battery cost reductions or retail energy rate increase prove economical

- Inputs
  - 3.5% WACC
  - 2.5% savings escalation
  - Battery installed cost - $2,460/kW
  - 15 year battery life
  - ITC because of solar
- Outputs
  - Customer savings - $17/kW-yr
  - Benefit cost ratio - 0.3
  - NPV - ($1,844)/kW
  - Metric tons CO2 - (0.3)
- Outputs – TOU rate increase needed to achieve BCR = 1
  - Benefit cost ratio -1.0
  - NPV - $0
  - Rate increase - 278%

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Run 6 - Utility Impact

Smart Electric Power Alliance

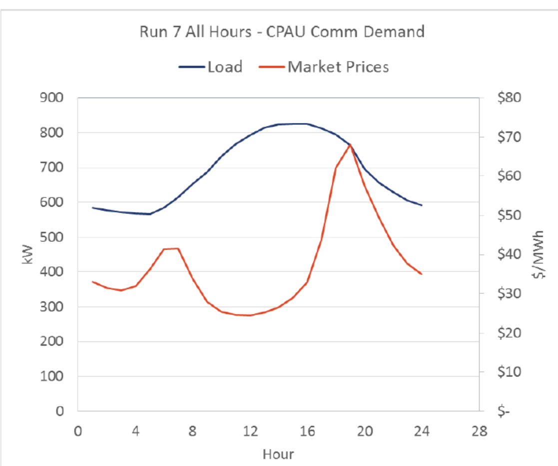
- Observations
  - Battery charges to reduce solar excess credit
  - Battery charges at low market prices and discharges at high market prices, approximately $17/MWh spread

Component	Palo Alto Shape	TID Shape
Customer revenues	$17	$17
DLAP Energy	($13)	($13)
RA Demand	($6)	($11)
TAC Demand	($2)	($5)
Total Cost / (Savings)	**($4)**	**($11)**

All values in the table above are $/kW-yr

Run 7 - Commercial Demand Rate

Smart Electric Power Alliance



- No price arbitrage available
- Savings can only occur by reducing peak
- Peak load occurs earlier than peak market price, discharge occurs at low market prices
- Normal commercial customer load factor - 62%

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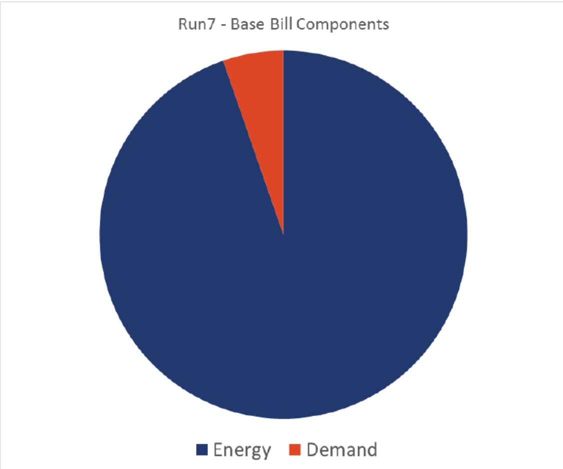
Run 7 - Bill Components

Smart Electric Power Alliance



- Majority of bill is from energy rates
- Energy rates vs demand rates make bill savings difficult but demand savings do occur
- These are partially offset since the battery uses more energy
- Strategy - dispatch to reduce demand cost

 61

Run 7 - Customer Economics

Smart Electric Power Alliance

No foreseeable battery cost reductions or retail demand rate increase prove economical

- Inputs
  - 3.5% WACC
  - 2.5% savings escalation
  - Battery installed cost - $1,880/kW
  - 15 year battery life
- Outputs
  - Customer savings - $17kW-yr
  - Benefit cost ratio - 0.1
  - NPV - ($1,827)
  - Metric tons CO2 - 0.6
- Outputs - Demand rate increase needed to achieve BCR = 1
  - Benefit cost ratio -1.0
  - NPV - $0
  - Demand rate increase - 273%

 62

Run 7 - Utility Impact

Smart Electric Power Alliance

- Observations
  - Battery discharges to reduce peak demand
  - Battery charges at slightly higher prices than discharge, approximately ($1)/MWh spread

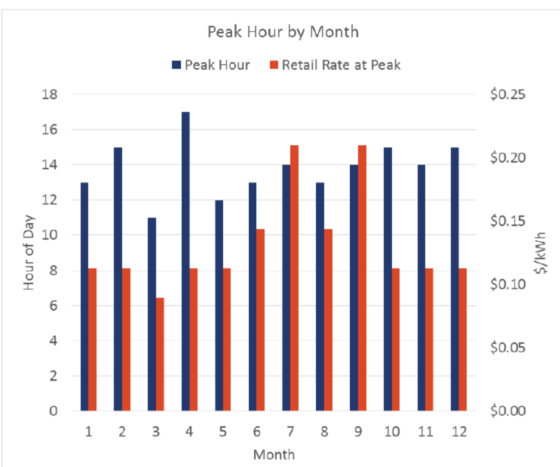
Component	Palo Alto Shape	TID Shape
Customer revenues	$17	$17
DLAP Energy	$4	$4
RA Demand	($37)	$0
TAC Demand	($16)	$0
Total Cost / (Savings)	**($32)**	**$21**

All values in the table above are $/kW-yr

63

Run 8 - TOU Rate and Demand Rate

Smart Electric Power Alliance



- Monthly peaks have good alignment with TOU rates during summer when demand rates also occur, allowing for TOU arbitrage and demand savings

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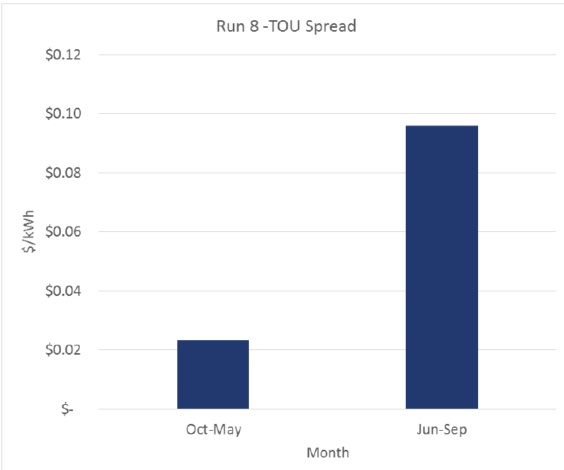
Run 8 - TOU Rate Spread

Smart Electric Power Alliance



- Price arbitrage available
- Summer has highest rate spread
- Most savings will occur in the summer due to TOU price arbitrage and peak time alignment with these TOU rates

 65

Run 8- Customer Economics

Smart Electric Power Alliance

No foreseeable battery cost reductions or retail energy rate increase prove economical

- Inputs
  - 3.5% WACC
  - 2.5% savings escalation
  - Battery installed cost - $1,880/kW
  - 15 year battery life
  - No ITC
- Outputs
  - Customer savings - $66/kW-yr
  - Benefit cost ratio - 0.4
  - NPV - ($1,174)/kW
  - Metric tons CO2 - 0.6
- Outputs - TOU rate increase needed to achieve BCR = 1
  - Benefit cost ratio -1.0
  - NPV - $0
  - TOU rate increase - 78%

 66

Run 8 - Utility Impact

Smart Electric Power Alliance

- Observations
  - Battery charges at low TOU rate and discharges at highest TOU rate
  - Battery charges at slightly higher prices than discharge, approximately ($2)/MWh spread

Component	Palo Alto Shape	TID Shape
Customer revenues	$66	$66
DLAP Energy	$5	$5
RA Demand	($25)	$0
TAC Demand	($11)	$0
Total Cost / (Savings)	**$35**	**$70**

All values in the table above are $/kW-yr

67

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