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City of Vernon Public Utilities Energy Storage Evaluation Report

Recommendation

Vernon Public Utilities (VPU) staff recommends that the City Council adopt a resolution that a target to procure energy storage systems is not appropriate at this time. This recommendation comes from the absence of cost-effective options, a determination required under California law. This recommendation, however, does not inhibit VPU from evaluating and pursuing cost-effective energy storage solutions that strengthen utility operations in the future.

Executive Summary

Assembly Bill (AB) 2514 (Public Utilities Code 2835 et seq.), the energy storage law in California, 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...” The California Energy Commission (CEC) was given the responsibility to review the procurement targets and policies that are developed and adopted by POUs to ensure that the targets and policies include the procurement of cost-effective and viable energy storage systems. The CEC then reports to the Legislature regarding the progress made by each local POU serving end-use customers in meeting the requirements of AB 2514.

The law establishes definitive deadlines for POU compliance within the statute as follows:

- 1) A POU has the responsibility to evaluate the cost-effectiveness and viability of energy storage systems in their respective electric systems. Additionally, a POU may also consider various policies to encourage the cost-effective deployment of energy storage systems. The initial evaluation was due on October 1, 2014.
- 2) A POU also possesses the authority to deem any, all or no energy system(s) that are evaluated as being “cost-effective and viable”. Taking into account the significant differences between respective POU electric system requirements, the cost-effectiveness and viability of energy storage technology options may vary greatly for each POU.

When the energy storage evaluation was completed in 2014, the City Council adopted a resolution that a target to procure energy storage systems was not appropriate since there were no cost-effective opportunities. 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. Therefore, no later than October 1, 2017, the government body is required to

adopt a target for the amount of appropriate energy storage the POU will procure by December 31, 2020. Policies to encourage the cost-effective deployment of energy storage systems may also be considered by the Governing body.

VPU has completed the Energy Storage evaluation as presented herein. The study defines energy storage systems, how they are used on the grid, the current technologies available and the current defined uses for the technology. VPU reviewed its existing and near future needs and developed case studies to evaluate the use of energy storage systems as an investment to meet its power supply needs.

VPU staff evaluated the costs and associated benefits of various energy storage projects submitted in response to a Southern California Public Power Authority (SCPPA) request for proposals (RFP) to consider local applications from a utility perspective. Software created by Navigant Consulting¹ was used to evaluate the use of an Energy Storage system. Over the next ten years, the costs of utility-owned and operated energy storage technologies exceed the value of the benefits, and hence, do not provide cost-effective, viable opportunities for VPU. More specifically, staff endorses the approach that currently there is no reasonable justification to procure energy storage systems within the City of Vernon for applications of Ancillary Services, outage mitigation, renewable integration, deferral of transmission and distribution upgrades, load leveling, grid operational support or grid stabilization.

To meet the City's obligation under AB 2514 while adhering to VPU's Integrated Resource Plan (IRP), staff proposes that energy storage procurement targets are not adopted by virtue that energy storage is not cost-effective, and therefore not appropriate for the City. VPU will, nevertheless, encourage customers to consider this emerging technology where it is cost-effective. The City is also considering to participate in pilot programs such as working with local technology providers to install energy storage solutions in utility premises. Furthermore, staff is committed as required by AB 2514 to reevaluate this finding once every three years and return to City Council to reassess the recommendation made by the previous processes.

While battery systems and solar PV costs have declined considerably the past three years, cost effective storage systems are still some years away. The primary challenges to cost effectiveness are the small average wholesale price differential between on-peak and off-peak periods, and particularly the high initial cost of the systems that is the most difficult issue to overcome. As additional utility applications are identified, research and innovation will continue to improve the technology and the associated costs will decrease over time. If the trend of negative pricing during peak hours keeps increasing and battery prices keep falling, then there would be scenarios in which batteries would be cost effective.

Staff fully expects that energy storage will substantially impact the overarching electric power system. Staff will continue to perform due diligence in the analysis of energy storage systems

¹ Navigant Consulting, Inc., Valuation of Energy Storage Tool (NVEST) Version 2.1 is an update version of ES Computational Tool (ESCT) Version 1.2, which was prepared for the U. S. Department of energy under DOE contract DE-FE004001 Task 430.05, August 2012.

as they continue to move from the research and development realm to the production realm and as the potential benefits of these systems begin to clearly outweigh the costs.

Introduction

In September 2014, after examining a detailed analysis from VPU staff, the City Council found a lack of cost-effective energy storage applications in City of Vernon. 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 VPU 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 Energy Storage valuation was developed in response to the requirements of the bill. It provides the findings from the VPU’s research on applications and viability of Energy Storage on the City’s electric system. The conclusion of this analysis is to determine the technical feasibility of the various Energy Storage systems and whether they are applicable and cost-effective. That result will serve to identify whether VPU should pursue establishing targeted levels of investment for those systems.

Energy Storage Background

The purpose of energy storage systems is to absorb energy, store it for a period of time with minimal loss, and then release it when appropriate. When deployed in the electric power system, energy storage provides flexibility that facilitates the real-time balance between electric supply and demand. Maintaining this balance becomes more challenging as the contribution of electricity supplied by intermittent renewable resources expands.

Typically the balance between supply and demand 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 such as hydropower. Energy storage systems, however, have the potential to perform this role more efficiently.

Rechargeable batteries are the most familiar form of energy storage technology. Large battery energy storage systems can be connected to the transmission grid to absorb excess wind or solar power when demand for electricity is low and, in turn, release the power when demand is high.

Energy storage also offers a variety of other services such as voltage support, distribution upgrade deferral, regulation of electricity and more, that can benefit the electricity system. Overarching these specific purposes is the intent of AB 2514 bill outlined in the findings and declarations. Energy systems are expected to:

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

Energy Storage Technologies

There are numerous energy storage technologies with varying performance ranges suitable for key electrical applications. It is, therefore, important to understand the different technologies in order to identify the type of storage device that would be appropriate for the use and specific application. The preceding is a brief description of the most notable technologies in this developing industry.

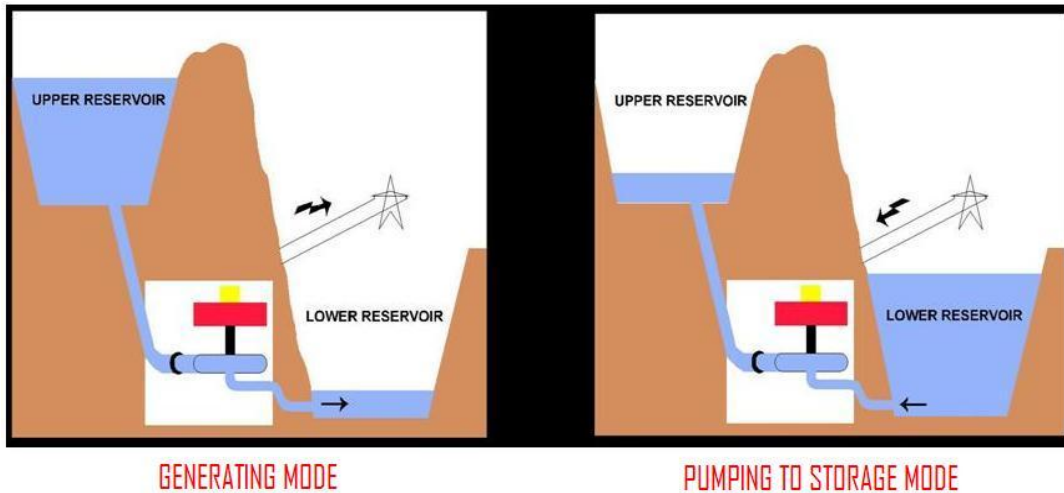
Pumped Hydro

Pumped hydroelectric energy storage is a mature, commercial utility-scale technology that is currently in operation at many locations throughout the country. Pumped hydro draws off-peak electricity to pump water from a lower reservoir to a reservoir located at a higher elevation. When demand for electricity is high, water is released from the upper reservoir, run through a hydroelectric turbine and deposited once again in the lower reservoir in order to generate electricity. Pumped hydro requires sufficient raw land, often hundreds of acres, to create two reservoirs at different elevations. This application has the highest capacity of the energy storage technologies that were studied. The output is only limited by the volume of the upper reservoir.

Projects can be sized up to 4000 MW and operate at approximately 76%–85% efficiency. Pumped hydro plants can have a service life of 50 years, yielding rapid response times that warrant participation in voltage and frequency regulation, spinning and non-spinning reserve markets, arbitrage and system capacity support.

While the siting, permitting, and associated environmental impact processes can take many years, there is growing interest in re-examining opportunities in pumped hydro.

Figure 1 Pumped Storage Hydro

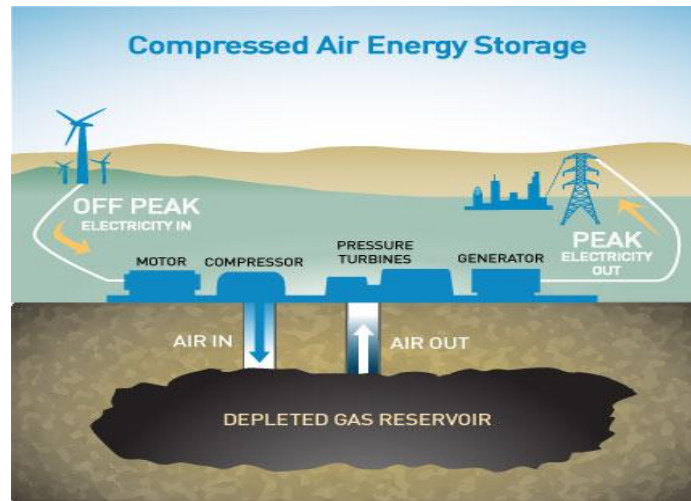


(Source: ClimateTechWiki)

Compressed Air Energy Storage (CAES)

CAES uses off-peak electricity to compress air and store it in an underground reservoir or in above ground pipes. When demand for electricity is high, the compressed air is heated, expanded, and directed through a conventional turbine-generator to produce electricity. Underground CAES storage systems are most cost-effective with storage capacities up to 400 MW and discharge times of between 8 and 26 hours. Siting CAES plants requires locating and verifying the air storage integrity of an appropriate geologic formation within a service territory of a given utility. CAES plants employing aboveground air storage would typically be smaller capacity plants on the order of 3 to 15 MW with discharge times of between 2 and 4 hours. Aboveground CAES plants are easier to site but more expensive to build. CAES systems, which have been around for over 18 years, are the other mature bulk energy storage systems available other than pumped hydro; however, because of the geologic conditions required, few have been developed.

Figure 2 Compressed Air Energy Storage



(Source: PGE)

Lead-Acid Batteries

Lead-acid is the most commercially mature rechargeable battery technology in the world. Valve regulated lead-acid (VRLA) batteries are used in a variety of applications, including automotive, marine, telecommunications, and UPS systems. Transmission and distribution applications are rare for these batteries due to their relatively heavy weight, large bulk, cycle-life limitations and maintenance requirements. Serviceable life can vary greatly depending on the application, discharge rate, and the number of deep discharge cycles. Battery price can be influenced by the cost of lead, which is a commodity. Finally, very limited data is available regarding the operation and maintenance costs of lead-acid based storage systems for grid support.

Figure 3 Lead-Acid Battery Storage



(Source: Energy Source Publishing)

Flow Battery

Vanadium redox batteries are the most mature type of flow battery systems available. In flow batteries, energy is stored as charged ions in two separate tanks of electrolytes, one of which stores electrolyte for positive electrode reaction while the other stores electrolyte for negative electrode reaction. Vanadium redox systems are unique in that they can be repeatedly discharged and recharged. Like other flow batteries, many variations of power capacity and energy storage are possible depending on the size of the electrolyte tanks.

Vanadium redox systems can be designed to provide energy for 2 to 8 hours depending on the application. The lifespan of flow-type batteries is not significantly impacted by cycling. Suppliers of vanadium redox systems estimate the lifespan of cell stacks to be 15 or more years.

Figure 4 Flow Batteries



(Source: Construction21.eu)

Lithium-Ion (Li-ion)

Rechargeable Li-ion batteries are commonly found in consumer electronic products, which make up most of the worldwide production volume of 10 to 12 GWh per year. A mature technology for consumer electronic applications, Li-ion is positioned as the leading platform for plug-in hybrid electric vehicle (PHEV) and electric vehicles (EV).

Given their attractive cycle life and compact nature, in addition to high efficiency ranging from 85%–90%, Li-ion batteries are being considered for utility grid-support applications such as distributed energy storage, transportable systems for grid-support, commercial end-user energy management, home back-up energy management systems, frequency regulation, and wind and photovoltaic smoothing.

Figure 5 Lithium Ion Battery



(Source: Clean Technica)

Flywheels

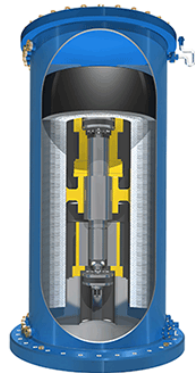
Flywheels are shorter energy duration systems that are not generally attractive for large-scale grid support applications that require many kilowatt-hours or megawatt-hours of energy storage. They operate by storing kinetic energy in a spinning rotor made of advanced high-strength materials, charged and discharged through a generator.

Flywheels charge by drawing off-peak electricity from the grid to increase rotational speed, and discharge when demand is high by generating electricity as the wheel rotation slows. Flywheels enjoy a very fast response time of 4 milliseconds or less, can be sized between 100 kW and 1650 kW and may be used for short durations of up to 1 hour. Flywheels possess very high efficiencies of about 93% with a lifetime estimated at 20 years.

Because flywheel systems are quick to respond and very efficient, they are being positioned to provide frequency regulation services. Flywheels are currently being tested to provide ISOs with frequency-regulation services in the northeast.

While there are several installed flywheel applications, their long-term life and performance characteristics are still uncertain, particularly at a utility scale. Like other technologies, flywheels need to mature for grid-scale applications but would be a viable technology for smaller, customer sited applications. Flywheels are still costly and have not yet been fully vetted at a distribution scale.

Figure 6 Flywheels



(Source: Beacon Power)

Energy Storage Assessment Tool

Navigant consulting was contracted by participating SCPPA utilities to create a framework and decision making tool for identifying, quantifying, and monetizing the benefits of energy storage projects. In the framework, potential benefits are substantiated differently depending on the system characteristics unique to each electric utility. Benefits are realized by analyzing energy storage in the three fundamental categories of load leveling, grid operational support and grid stabilization. Within these categories, each application of energy storage can lead to different economic, reliability, and environmental benefits.

Inputs specific to the VPU system were initially populated in The Navigant Energy Storage Assessment Tool. These inputs included information such as project location, project owner, regulatory environment and technology type. Cost and performance data including installed cost, operation and maintenance costs, round trip efficiency and cycle life were then loaded into the tool. Finally, based upon the applications selected, additional inputs were populated in order to calculate benefits, such as the capacity of energy storage, average wholesale on-peak and off-peak prices of electricity. After inputting and running applicable cases through the assessment tool, the product of the tool is realized in the form of net present costs and benefits of the project. These results were then analyzed by staff.

The tool itself has gone through extensive review and usage. Sandia National Labs and the US Department of Energy (DOE) have both conducted formal peer reviews of the framework. The DOE has adopted this framework for use by the 16 recipients of the Smart Grid Demonstration program to quantify the costs and benefits of energy storage demonstration projects.

Energy Storage Applications and Associated Assumptions

In conjunction with the SCPA Energy Storage Working Group and Navigant Consulting, VPU staff identified 3 basic areas to apply energy storage technologies in relationship to the electrical system.

- 1) Load Leveling
- 2) Grid Operational Support
- 3) Grid Stabilization

Based on this broad range, electricity storage can potentially provide services at the generation, transmission, distribution and customer (behind the meter) levels.

Load Leveling

Load Leveling in general terms refers to the practice of generating power off peak when prices and demand are low and using or dispatching this power on peak when prices and demand are high. Four basic areas of Load Leveling are as follows:

- 1) Renewable Energy Shifting – The process of capturing electricity generated from renewable sources during periods of over-generation or low demand then, in turn, dispatching the stored electricity to the grid in times of high demand.
- 2) Wholesale Arbitrage – This method takes advantage of a price difference between markets by capitalizing and profiting from the imbalance between them.
- 3) Retail Market Sales – The practice of capturing electricity off peak in order to sell to the retail market at on peak pricing for profit.
- 4) Asset Management – Energy Storage technologies can be used to store and dispatch certain amounts of electricity so that generating units may be run at the most efficient output level. This practice can save wear and tear on the generating units by allowing them to run in an optimal state.

Vernon Public Utilities Assumptions and Approach to Load Leveling

VPU has entered into a long term power purchased agreement to receive the output of a solar photovoltaic power plant. Energy storage could be used to pair with the solar project to avoid energy curtailment during daytime because of California's famous solar duck curve, help smooth the variability of solar generation, and dispatch energy storage when electricity demand is high. As a consequence, renewable energy shifting is applicable to the City and hence, was considered a viable case to run through the Navigant Energy Storage Assessment Tool in order to determine the cost effectiveness of energy storage.

Wholesale arbitrage is a practice that VPU currently employs, therefore, arbitrage presented a valid, tangible case to run through the Assessment Tool in order to determine the cost

effectiveness of energy storage. As stated in the Navigant Energy Storage Framework, economic benefits in the form of market revenue can be realized by the installation of an energy storage system for the purpose of wholesale arbitrage.

VPU has also entered into a power purchased agreement to receive the output of a combined cycle power plant. When combined with this generation asset, energy storage can also be used to allow the natural gas power plant to minimize generation cost and run at an optimal state.

Grid Operational Support

Grid Operational Support can be defined as ancillary services utilized to effectively match supply to demand. These services are typically performed by an Independent System Operator to maintain the reliability of the electric grid. Five different areas were examined with respect to grid operation support applications:

- 1) Load Following – an ancillary service concerned with maintaining grid balance by adjusting power as demand for electricity fluctuates throughout the day. As mentioned earlier, many renewable generation resources including wind, solar photovoltaic, and solar thermal, are intermittent or variable. They generate electricity based on wind speed or solar intensity which can vary second to second. Energy storage can function to dampen this variability. The energy storage system is located between the generation and the transmission grid. The renewable resource charges the energy system which can accommodate the variability of the generation. Electricity is then fed onto the grid from the energy storage system as it discharges. The discharging energy storage can respond to grid needs for either other uses or simply can discharge a set amount of electricity at a time when called upon by the grid.
- 2) Operating Reserves – an ancillary service charged with maintaining extra capacity that can be called upon when some portion of the normal electric supply resources suddenly become unavailable. These reserves represent generation capacity, or are decreases in load from demand response resources, that are available at any time and can take the place of a normal electric supply resource if it were unexpectedly unavailable. Spinning reserves are those reserves that are already operating and non-spinning reserves are those that will need to be brought online. Supplemental reserves are simply further backup for the spinning and non-spinning reserves. In the CAISO, these reserves could be called upon in increments as short as a ½ hour and would need to provide service within 10 minutes.
- 3) Frequency Regulation – an ancillary service tasked with managing energy flows to reconcile momentary differences between supply and demand. In order to ensure that an electric grid functions correctly, a constant frequency is required to be maintained. For VPU, the grid frequency is maintained by the California Independent System Operator (CAISO). The services are provided in short, four-second adjustments either to increase (regulation –up) or decrease (regulation-down) the system frequency. Energy

storage can potentially provide both regulation-up and –down functions in the required short time increments.

- 4) Renewable Energy Capacity Firming – an application using energy storage to produce more consistent power output when renewable resources temporarily drop.
- 5) Black Start – an ancillary service responsible for providing power to a conventional generator in order to restart after a partial or full shutdown. Energy storage could provide the power necessary to start up a generation resource in such a situation. In the case of energy storage used for black start, it would need to be charged and available at any given time. Therefore, the energy storage system would need to be maintained in a constant charged state and become operational when called upon.

Vernon Public Utilities Assumptions and Approach to Grid Operational Support:

As a metered subsystem of the CAISO, the balancing authority is responsible to provide the services that enable the matching of supply to demand. As merely a market participant, VPU relies upon and pays the CAISO for these contracted services.

Grid Stabilization

Grid Stabilization involves improving reliability. Grid Stabilization can be divided into four components as follows:

- 1) Renewable Energy Ramping – Using energy storage to mitigate volatility from low wind conditions and high wind cutout. Cut out speed, typically between 45 and 80MPH, causes a turbine to shut down, ceasing power generation.
- 2) Renewable Energy Smoothing – Solar and wind resources are intermittent on a second to second basis. Energy storage can assist in smoothing the output volatility of these resources, thus, improving power quality.
- 3) Backup Power – Energy Storage may be used to ensure highly reliable electric service. In the event of a system disruption, energy storage can be used to ride through the outage.
- 4) Power Quality – Energy Storage technologies have the potential to function as capacitors and transformer tap changers by providing voltage support for localized reactive power issues.

Vernon Public Utilities Assumptions and Approach to Grid Stabilization:

As previously stated, VPU does not own any renewable resources and outright ownership of renewable projects is not projected within the VPU integrated resource plan (IRP) at this time. In addition, as a market participant, the CAISO provides these services as the control area balancing authority.

Backup power was discussed in the process of conducting this feasibility study, however, backup power was not considered as a possible application to run through the Assessment Tool. Calling upon an energy storage device to keep services up during a distribution outage carries with it a host of issues. The energy storage device could not be brought online seamlessly to mitigate customers being impacted by the outage due to safety and technical reasons. The energy storage device, if brought online in this scenario could contribute to a fault causing more profound damage. VPU customers that might benefit from this type of system are either on an interruptible contract or have redundant power feeds to their facilities. Last, VPU ranks in the top 10 percent industry-wide in terms of average outage duration and average outage frequency according to a 3rd party reliability benchmarking study utilizing the IEEE 2.5 beta methodology (the accepted industry standard).

In terms of power quality, VPU nominal voltage is very strong, enjoying a power factor of approximately 98%. VPU has a very stable industrial load and has short distribution feeder circuits with considerable capacity. As stated in the Navigant Energy Storage Framework, improved power quality is a potential benefit of integrating an energy storage technology into the existing electric system. However, without any substantial power quality issues, there was no need to evaluate energy storage for this purpose.

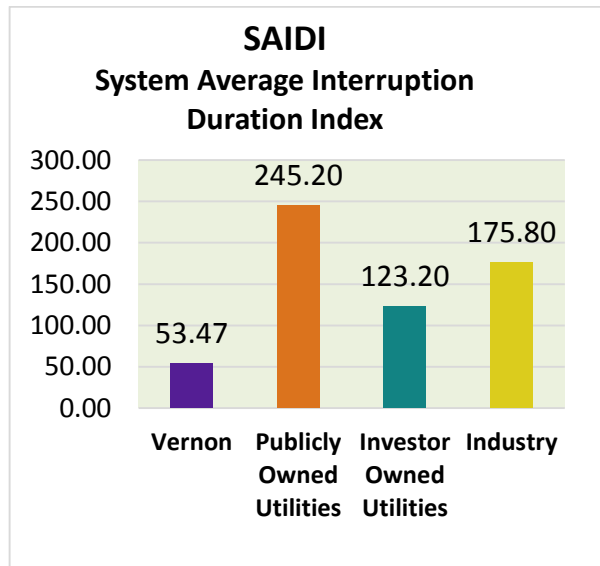
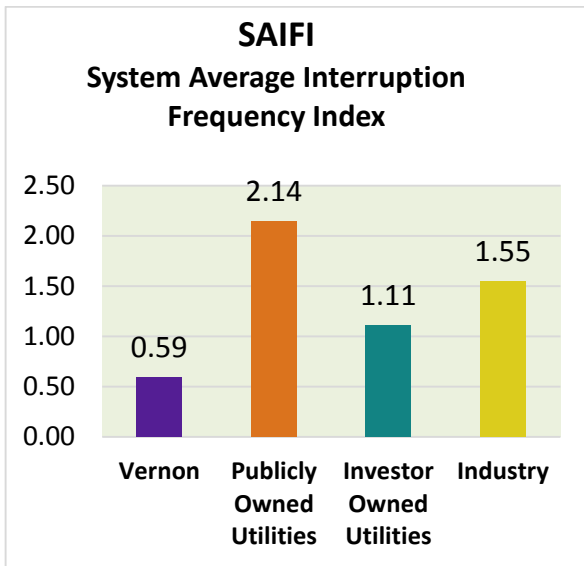
Additional Assumptions and Approach to Running Cases in the Energy Storage Assessment Tool

Deferral of Distribution System Upgrades

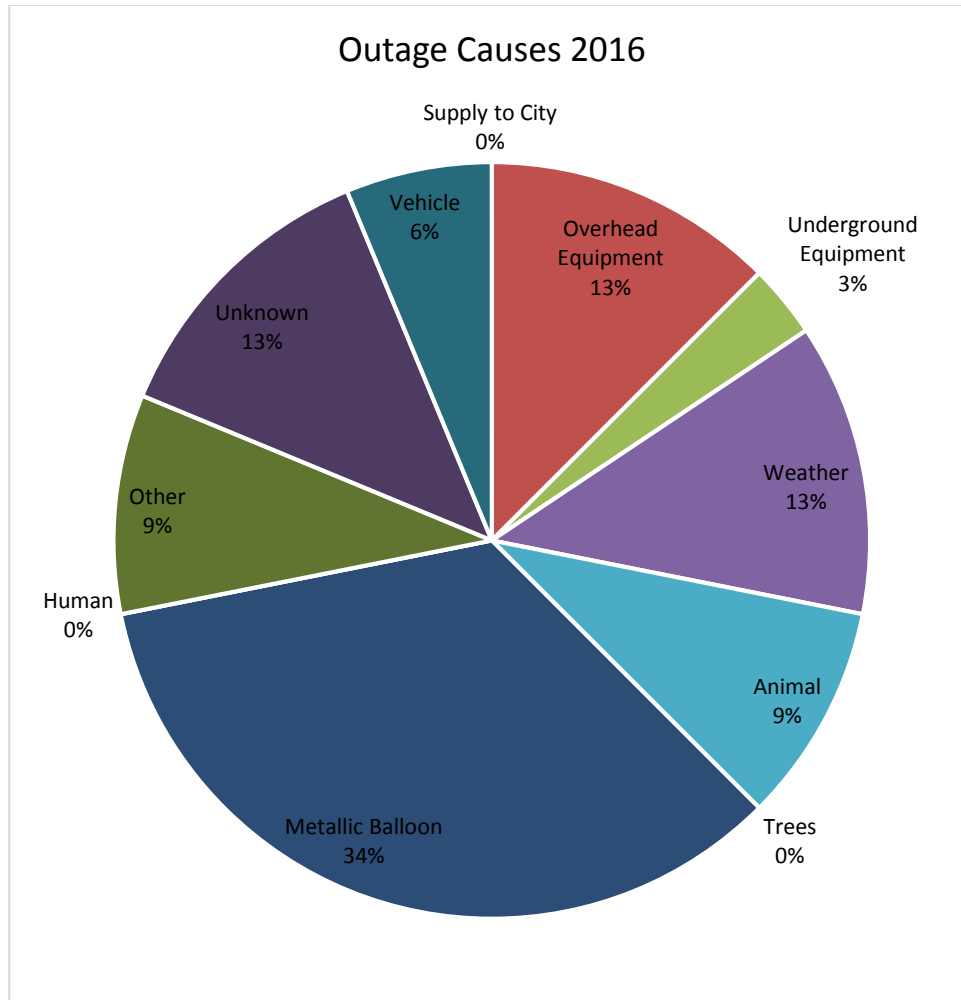
Provided that VPU does not own or operate significant generation or transmission resources, the focus of this feasibility study centered on the VPU distribution system. Energy Storage systems can defer the need for distribution system upgrades. Typically, as systems evolve and grow, upgrades are made to serve loading requirements and meet the needs of customers. Installing Energy Storage systems on impacted feeders that are near full-load capacity can defer or eliminate the need for large capital investments to upgrade the system in that specific region. Assuming that the storage system reduces loading on existing equipment, the energy storage system could improve or increase the life of the existing distribution equipment, including transformers and cables.

IR.W. Beck Inc. was retained to perform a comprehensive assessment on the VPU electric distribution system. In their most recent study, R.W. Beck recommended that system upgrades be implemented when the City peak load reached 400 MW. As the national economy has struggled since the mid 2000's, the VPU load has remained flat and peak load is currently 194 MW. The VPU resource planning group, in performing a ten year forecast does not see any appreciable load growth, and therefore, deferral of distribution system upgrades was not an application staff considered when running cases in the Energy Storage Assessment Tool.

VPU runs an extremely reliable electric distribution system as evidenced by a 2015 benchmarking study conducted by PA Consulting. The nation-wide survey concluded that VPU ranks in the top ten percent for reliability industry-wide. On average, VPU customers spent 53 minutes during the year without power (SAIDI – System Average Interruption Duration Index). In addition, the number of outages the typical VPU customer experienced during 2015 was less than 1 or .59 (SAIFI – System Average Interruption Frequency Index). In other words, almost a half of VPU customers experienced no interruptions in 2015.



Since 2007, VPU experiences on average, 32 electrical system outages per year. Outages in the City of Vernon are typically caused by events that are beyond control such as metallic balloons, vehicles striking utility poles, birds and weather related circumstances.

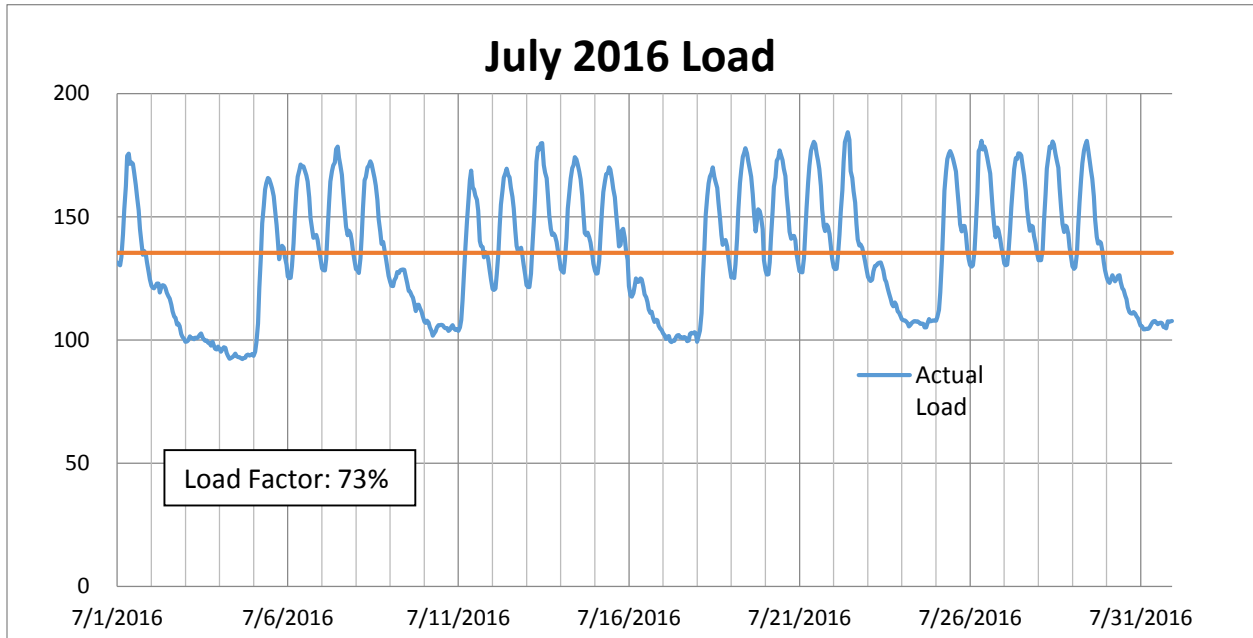


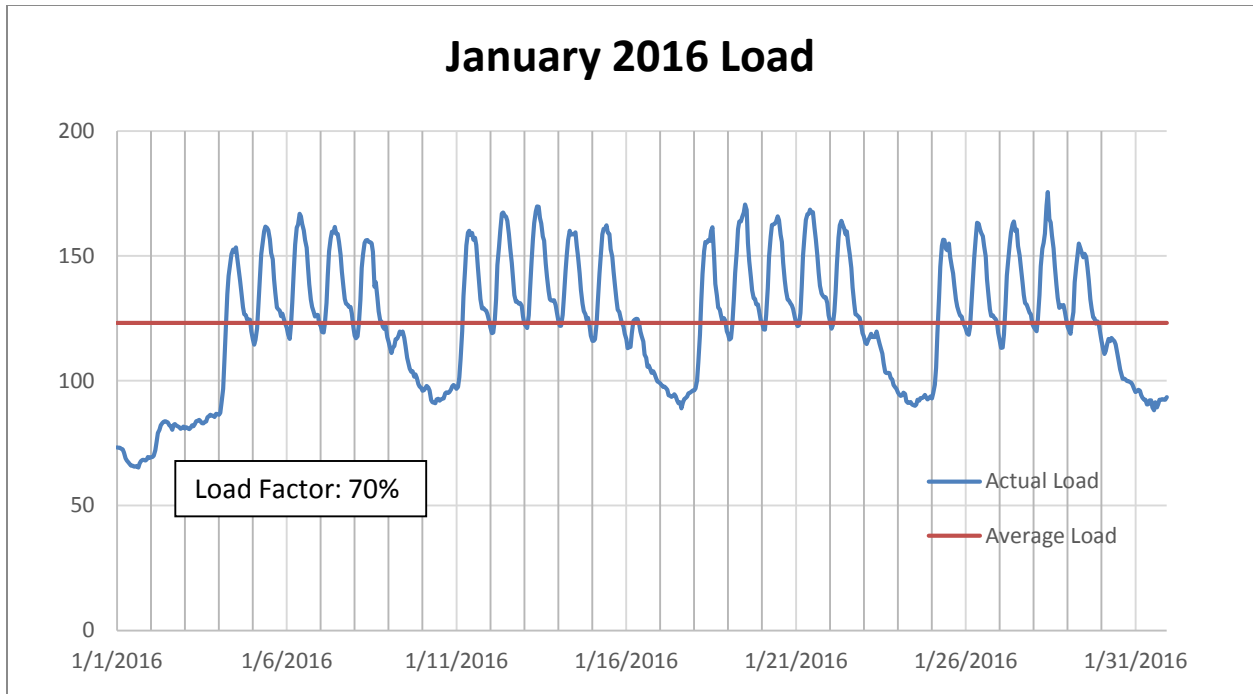
As stated in the Navigant Energy Storage Framework, reduced outages can be a potential measurable benefit of implementing an energy storage technology. However, with a robust system, a manageable amount of outages, reliability in the top ten percent nation-wide, the need for an energy storage system to bolster reliability did not present itself and consequently was not considered. As an example, energy storage installed at a substation would help if electric system outages occurred; however, those incidents are uncommon, and the more routine outages that occur due to vehicles hitting utility poles or tree branches getting caught in utility lines would not be mitigated by an energy storage at a substation. Customers who wish to increase their reliability already have business justifications for the higher costs and are free to invest in backup systems, generators, or Uninterruptible Power Supplies (UPS) without a utility procurement target.

Electrical System Characteristics

The Vernon Public Utilities system enjoys a stable load base. The City of Vernon is very unique as the city motto would suggest, as it is “exclusively industrial.” The utility is focused on supporting the electrical needs of the industrial manufacturing processes that define the City’s

customer base. Vernon Public Utilities offers time-of-use (TOU) rates to many of the larger industrial users. This type of rate structure encourages off peak activities for many of these larger customers. All of these factors combine to produce an extremely stable load profile and very high load factor (i.e. the peak load is not significantly higher than the average load). Due to the efficiency, capacity, and stable nature of the electrical system, along with the TOU incentives to the customers to perform high usage processes off peak, there is no significant need for energy storage peak shifting especially considering its high cost at this time.





VPU Cost Effectiveness Methodology

SCPPA RFP for Renewable and Energy Storage Projects

The RFP process is one power procurement method that the City uses to purchase electric and gas products. VPU works with Southern California Public Power Authority (SCPPA) to gain greater access to a broader pool of power resources, through a competitive power procurement bidding process. In accordance with California Renewable Energy Resources Program (Public Resources Code sec. 25740) and the California Renewables Portfolio Standard Program (Public Utilities Code sec. 399), including amendments enacted in 2011 by passage of California Senate Bill X1 2 (SB X1 2), and energy storage, on February 1, 2017, SCPPA launched a Request for Proposals to electric market participants for competitively-priced Renewable Energy and Energy Storage Projects. The RFP asked vendors to provide details such as: project description, name and location, contract quantity, installation costs and the delivery term for the benefit of SCPPA Member Agencies. Between February 2017 and June 2017, SCPPA received 29 proposals for energy storage projects. All 29 proposals came from vendors touting the benefits of Lithium Ion, Vanadium Flow, and other type of battery systems for energy storage purposes.

As VPU attempted to take a comprehensive, prudent and reasonable approach to assess the merits of energy storage as a feasible and valuable platform, the substantive, tangible results of an RFP proved the obvious foundation to start from. This cornerstone advanced the

assumption that VPU would evaluate battery technologies only at the pricing submitted in the RFP responses versus evaluating hypothetical scenarios.

VPU Approach to Use of the Navigant Energy Storage Assessment Tool

VPU staff evaluated all proposals submitted to the SCPPA RFP for Energy Storage Projects using the Energy Storage Assessment Tool developed by Navigant Consulting firm. The Navigant tool identifies and quantifies the benefits and associated costs of each operational Energy Storage project. The tool takes into account all benefits including those that accrue to the asset owner, and ratepayer/consumer. The tool determines potential benefits and estimates the monetized value for each energy storage project based on the project details and application specified by VPU. The tool also optimized the size, type, and location of the Energy Storage system.

Energy Storage Applications Benefit Basis

VPU staff utilized a basic net present value analysis in evaluating each energy storage technology. In this analysis, the present value of expected costs is subtracted from the present value of expected benefits for the lifetime of the Energy Storage project. The following sections discuss the major components of benefit and cost that were used in the model.

Market Energy & Market Revenue

The primary benefit evaluated by VPU staff for Lithium Ion and Vanadium Flow battery technologies is energy arbitrage revenues. Wholesale energy market revenue is calculated as a function of the difference between wholesale on-peak and off-peak LMP (locational marginal pricing or node pricing) prices of electricity and total energy discharged by the energy storage project for arbitrage. VPU researched historical day-ahead hourly LMP prices at the Substation PNode where the energy storage project is located to arrive at annual estimates of on and off-peak pricing data used in the model to quantify the upper bound of profit (\$/MWh) that may be realized for energy arbitrage.

Capacity Market Revenue

Like all utilities in California, VPU is required to retain sufficient generation capacity such that it can meet customer demand at any given time – especially during the summer demand peaks when demand is highest and in addition, maintain an additional 15% in the form of reserves. As such, the device could be used to reduce the need to purchase capacity in the wholesale market to fulfill resource adequacy requirements.

Deferred Power Generation Investment Benefits

Deferring an investment for a power generation to a point in time when the need for the investment can be determined with more certainty, such as for planned growth that may or may not occur. Energy Storage could be used to defer or substitute for an investment in a new generation facility power generation.

Energy Storage Technology Cost Basis

SCPPA RFP responses were the VPU source of cost data for battery storage systems used in the model. A summary of energy storage costs considered in the analysis include:

- Investment cost of storage. The Energy Storage system capital expenditure (CAPEX) is calculated as a function of the size of the units and the battery type. During the analysis period, storage units are replaced based on estimated actual life. Storage actual life is calculated as a function of the number of charge/discharge half-cycles and the amount of energy that is charged/discharged in each half-cycle, and its calendar life. A fixed charge rate is used to levelize the total cost.
- Cost of replacement. The cost of replacing storage at the end of its actual life is assumed to be a fraction of initial investment cost. The number of replacements during the project analysis period depends on the storage actual life.
- Operation and maintenance cost. Annual operation and maintenance costs are assumed to be proportional to storage power capacity.
- Cost of electricity. This cost element is defined as the cost of energy used to charge the battery. A set of electricity wholesale price time series data is used to approximate the cost of electricity.

To evaluate the cost-effectiveness of energy storage under a range of cost information that was provided by battery vendors to the SCPPA RFP, VPU staff used average values of the battery storage device by type (Lithium-Ion and Vanadium Flow Battery) to conduct the analysis.

Inherent Risk

There are some real challenges when assessing the feasibility of energy storage systems that cannot necessarily be accounted for in using the Energy Storage Assessment tool. First and foremost, energy storage technologies at the grid level are not mature and do not have a long track history that can be analyzed. Attempting to calculate the cost of emerging technologies is problematic in that many of the technologies still find themselves in the research, testing and development stage rather than in an actual production or in-service environment. Being a small scale publically owned utility subject to many budgetary constraints, the approach to procuring energy storage technologies as a viable, cost effective component of the electrical system must take place after thorough vetting and after considerable in service data is available. One component VPU places a high priority on is safety to personnel. Limited safety data is available when considering emerging technologies that are still in the development stage. Last, with newer technologies and relatively short life expectancy, accurate replacement costs are simply not available. When attempting to perform a rigorous cost-benefit analysis, valuating the replacement cost of various energy storage technologies is speculative at best.

Land Area for Energy Storage Systems

A primary challenge for energy storage applications will be finding the land area for the energy storage facility to be located on. Energy storage devices that employ batteries are very large. For example, the batteries being evaluated in case studies for Vernon will require almost 2 acres to accommodate about 10 trailers (approximately the size of a semi-trailer) and the associated transformers and other infrastructure. Each 1 MW battery bank is about the size of a semi-trailer, and an additional area is required for the controls and transformers that will be associated with the installation. Land costs would need to be added to the overall cost of the energy storage project.

Energy Storage Systems Cases Studies for Vernon

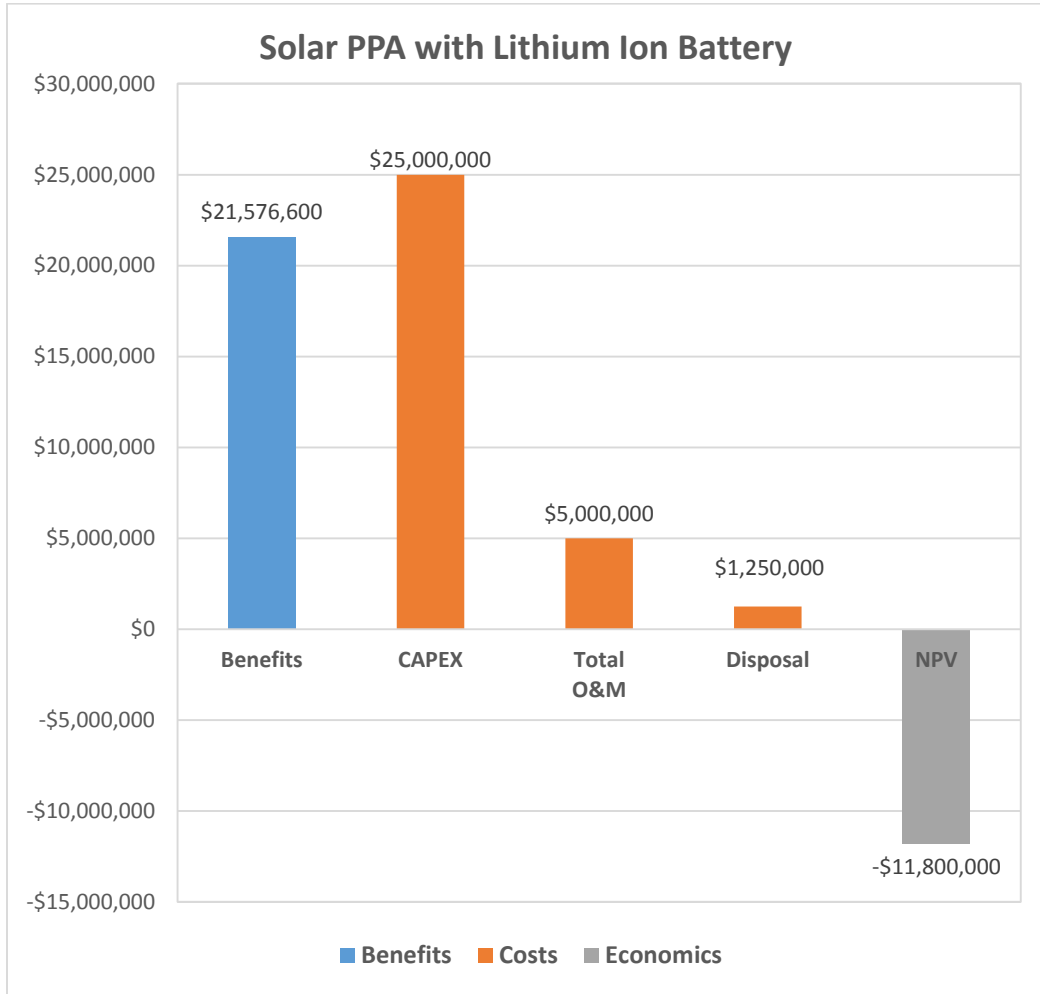
Outlined below is the analysis of two most relevant storage applications for the City of Vernon:

- 1) Battery storage is installed after solar PV panels with the intent to store the energy produced by solar panels during the day and to use later during the evening when prices are high to smooth the variability of the PV generation, improve operational efficiency, and avoid solar curtailment.
- 2) Battery storage is installed with a combined cycle plant, Malburg Generating Station (MGS), located in the City of Vernon. The plant supplies 134 MW and is the primary source of power for the City. The benefits to combine a battery storage with MGS would be to allow the plant to run at a lower operating level of 70 MW, minimize generation cost when prices are low, use the stored energy to meet the electricity needs when prices are high, provide ancillary service products, such as regulation and operating reserves, and defer generation capacity for the City of Vernon.

Energy Storage Modeling Results: Solar PV Plus Storage: Lithium Ion Battery

A 10 MW, 40 MWh Lithium Ion battery storage system participating in CAISO wholesale market via a solar project (Power Purchase Agreement), from 2018 to 2027 has a Net Negative Present Value of \$12 million. Results indicate that the installation of a Lithium Ion battery storage system for arbitrage, resource adequacy, and generation facility deferral is not cost-effective. The 10 year annual revenues and costs for the Lithium Ion battery storage system are detailed in Figure 1. The large capital expenditure is derived from the construction and installation of the storage device. Annual loan payments are then made to pay down the remaining principal on the loan at the fixed charge rate of 11% over the 10- year life. Operating and maintenance (O&M) costs and the cost used to charge the battery represent the other costs incurred by the storage device. Every 10 years, the entire battery stack is replaced because of the annual reduction in energy capacity due to cycle life degradation. The total revenue generated by arbitrage, capacity market, and deferred generation investments is depicted in blue. No land cost was assumed in this evaluation as it would be highly variable and there may be land available in Lancaster, CA where the solar project is located.

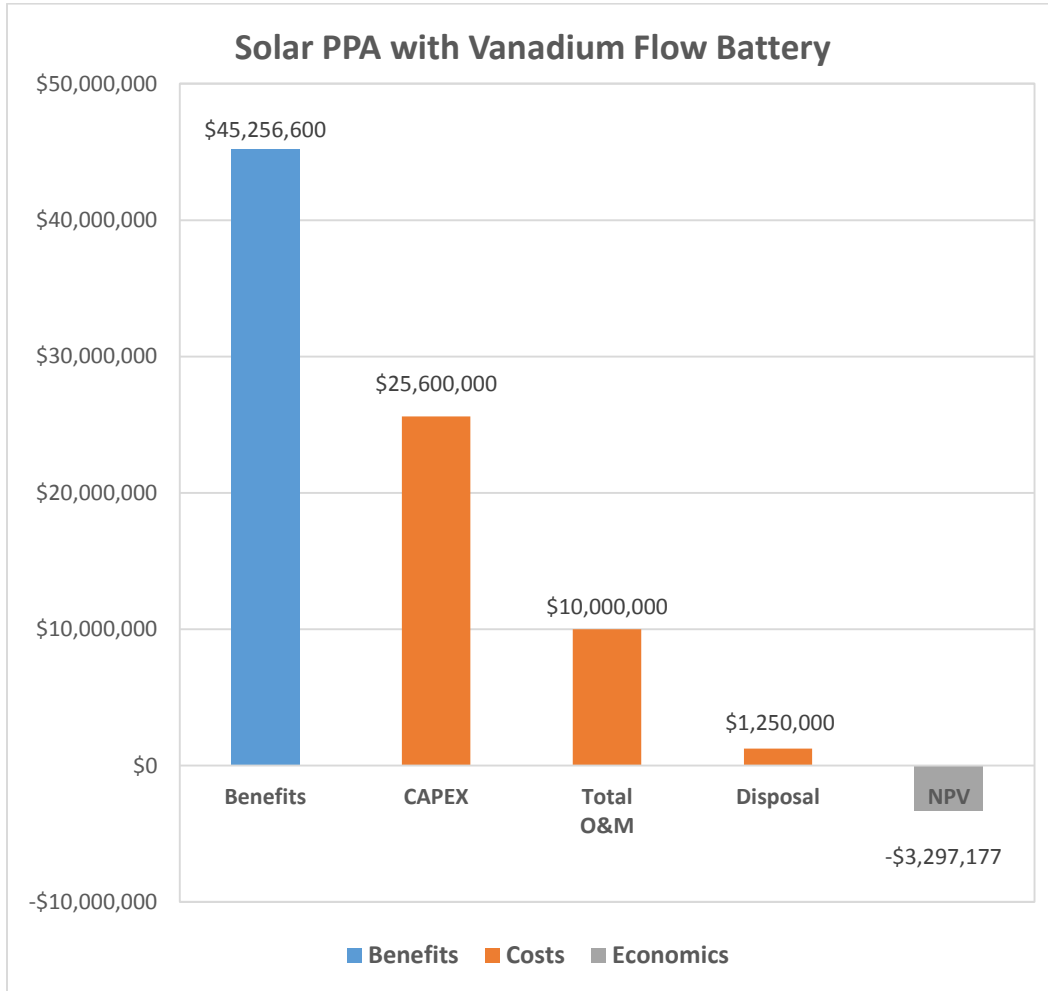
Figure 1: Chart of 10 Year Economic Analysis for Solar PPA with Lithium Ion Battery



Energy Storage Modeling Results: Solar PV Plus Storage: Vanadium Flow Battery

A 10 MW, 40 MWh Vanadium Flow battery storage system participating in CAISO wholesale market via a solar project from 2018 to 2037 has a Net Negative Present Value of \$3 million. Results indicate that the installation of a Vanadium Flow battery storage system for arbitrage, resource adequacy, and generation facility deferral is not cost-effective. The 20 year annual revenues and costs for the Vanadium Flow battery storage system are graphed in Figure 2. The large capital expenditure is derived from the construction and installation of the storage device. Annual loan payments are then made to pay down the remaining principal on the loan at the fixed charge rate of 11% over the 20-year life. Operating and maintenance (O&M) costs and the cost used to charge the battery represent the other costs incurred by the storage device. Every 20 years, the entire battery stack is replaced because of the annual reduction in energy capacity due to cycle life degradation. The total revenue generated by arbitrage, capacity market, and deferred generation investments is depicted in blue. No land cost was assumed in this evaluation as it would be highly variable and there may be land available in Lancaster, CA where the solar project is located.

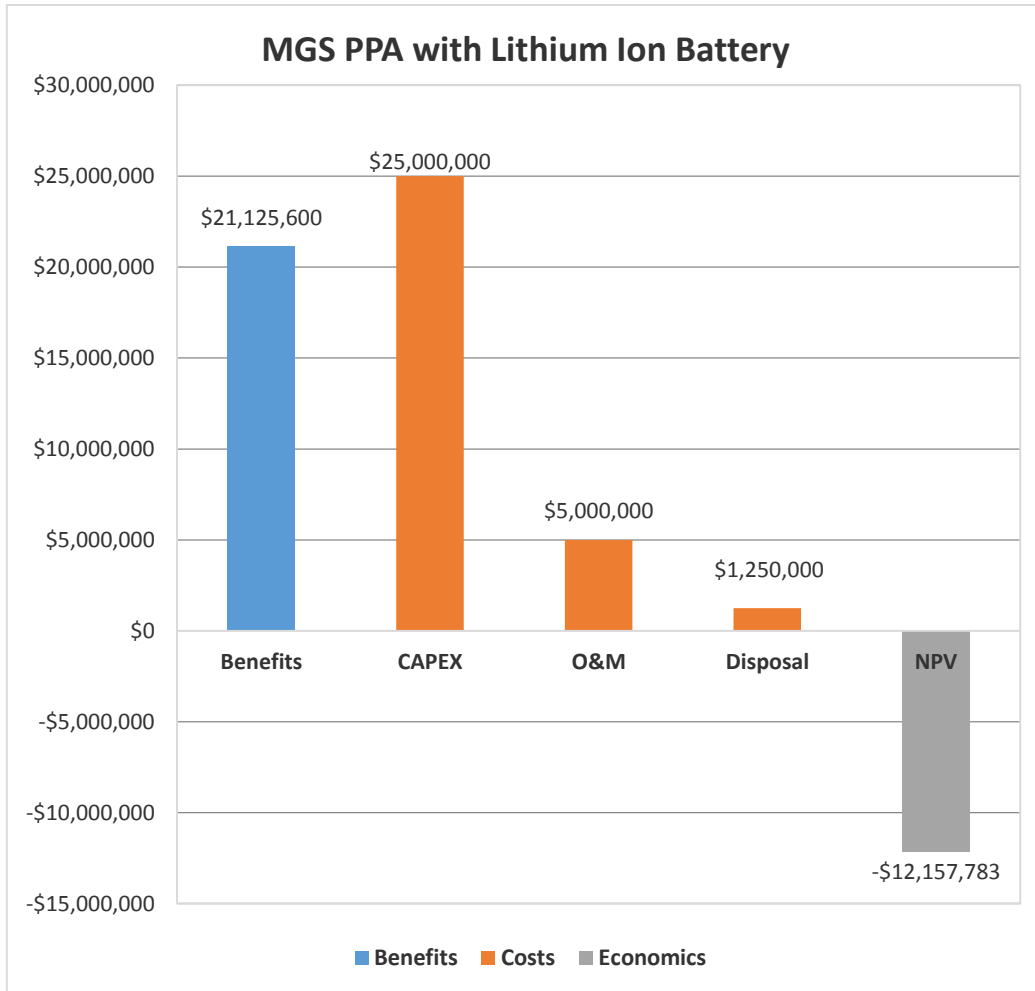
Figure 2: Chart of 20 Year Economic Analysis for Solar PPA with Vanadium Flow Battery



Energy Storage Modeling Results: Natural Gas-Fired Plant Plus Storage: Lithium Ion Battery

A 10 MW, 40 MWh Lithium Ion battery storage system participating in CAISO wholesale market from 2018 to 2027 has a Net Negative Present Value of \$12 million. Results indicate that the installation of a Lithium Ion battery storage system to MGS is not cost-effective. When taking into account the annualized cost of installation of storage (\$131/kwh-yr.) for a ten-year warranted system, the benefits mentioned above for pairing a combined cycle plant with a battery storage are not sufficient to justify the installation of the system. The 10 year annual revenues and costs for the Lithium Ion battery storage system are graphed in Figure 3. The large capital expenditure is derived from the construction and installation of the storage device. Annual loan payments are then made to pay down the remaining principal on the loan at the fixed charge rate of 11% over the 10-year life. Operating and maintenance (O&M) costs and the cost used to charge the battery represent the other costs incurred by the storage device. Every 10 years, the entire battery stack is replaced because of the annual reduction in energy capacity due to cycle life degradation. No land cost was assumed in this evaluation. However, there is no vacant land available in the City of Vernon. 2 acres of commercial or industrial land in the City of Vernon would cost about \$5 million which will be added to the overall cost of the project.

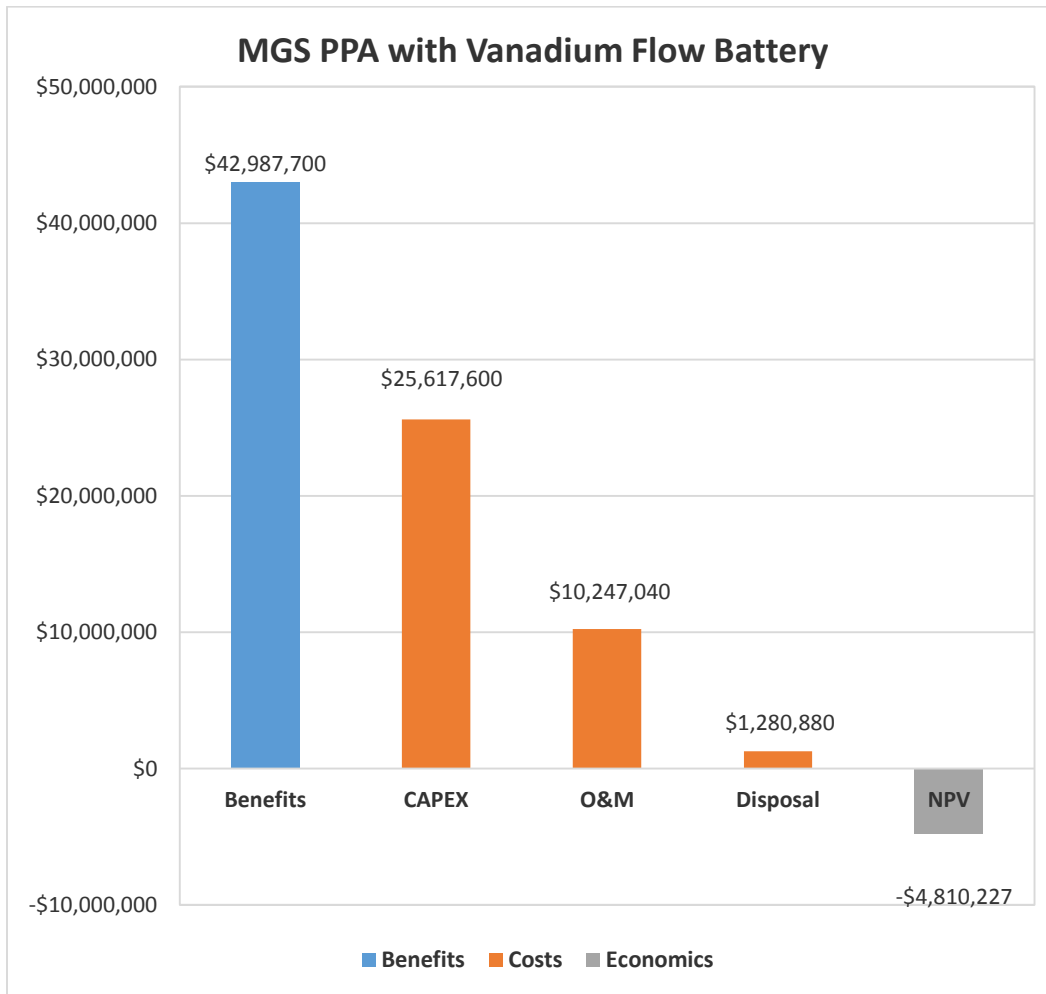
Figure 3: Chart of 10 Year Economic Analysis for MGS PPA with Lithium Ion Battery



Energy Storage Modeling Results: Natural Gas-Fired Plant Plus Storage: Vanadium Flow Battery

A 10 MW, 40 MWh Vanadium Flow battery storage system participating in CAISO wholesale market from 2018 to 2037 has a Net Negative Present Value of \$5 million. Results indicate that the installation of a Vanadium Flow battery storage system to MGS is not cost-effective. When taking into account the annualized cost of installation of storage (\$115/kwh-yr.) for a twenty-year warrantied system), the benefits mentioned above for pairing a combined cycle plant with a battery storage are not sufficient to justify the installation of the system. The 20 year annual revenues and costs for the Vanadium Flow battery storage system are graphed in Figure 4. The large capital expenditure is derived from the construction and installation of the storage device. Annual loan payments are then made to pay down the remaining principal on the loan at the fixed charge rate of 11% over the 20-year life. Operating and maintenance (O&M) costs and the cost used to charge the battery represent the other costs incurred by the storage device. Every 20 years, the entire battery stack is replaced because of the annual reduction in energy capacity due to cycle life degradation. No land cost was assumed in this evaluation. However, there is no vacant land available in the City of Vernon. 2 acres of commercial or industrial land in the City of Vernon would cost about \$5 million which will be added to the overall cost of the project.

Figure 4: Chart of 10 Year Economic Analysis for MGS PPA with Vanadium Flow Battery



In all energy storage systems case studies for Vernon, the use of any of the energy storage systems is technically viable but would not be cost-effective. The results above illustrate that over the life of the energy storage system, it will recoup some value of its cost. Since all of the systems have negative NPV, the revenues generated are all well below the costs. However, the relative economics of each application are informative for the future as storage costs continue to decline.

Conclusion

VPU staff performed a thorough evaluation of the cost and associated benefit of various energy storage projects submitted in response to the SCPA RFP for local energy storage applications. Over ten or twenty years of storage actual life, the costs of utility-owned and operated energy storage technologies exceed the value of the benefits, and hence, do not provide cost-effective, viable opportunities for VPU. More specifically, VPU staff endorses the approach that currently

there is no reasonable justification to procure energy storage systems within the City of Vernon for applications of ancillary services, outage mitigation, renewable integration, deferral of transmission and distribution upgrades, load leveling, grid operational support or grid stabilization.

To meet the City's obligation under AB 2514 while adhering to VPU's Integrated Resource Plan (IRP), staff proposes that energy storage procurement targets are not adopted by virtue that energy storage is not cost-effective, and therefore inappropriate for the City. VPU will, nevertheless, encourage customers to consider this emerging technology where it is cost-effective. The City is also considering to participate in pilot programs such as working with local technology providers to install energy storage solutions in utility promises. Furthermore, AB 2514 requires that the City reevaluate this determination regarding the viability to procure an energy storage target within three (3) years. VPU staff will return to the City Council to reassess the position recommended in this Staff Report within that time frame.

It is the belief of the VPU staff that in the long term, energy storage is expected to have an impactful role in the overarching electric power system. Staff will continue to perform due diligence in the analysis of energy storage systems as they continue to mature from the research and development realm into the production realm and as the potential benefits of these systems begin to clearly outweigh the costs.