Energy Storage Peak Shaving Feasability for Tupper Lake, Lake Placid, and Massena Municipal Electric Departments

Final Report | Report Number 20-17 | May 2020

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Energy Storage Peak Shaving Feasibility for Tupper Lake, Lake Placid, and Massena Municipal Electric Departments

Final Report

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NYSERDA Report 20-17 NYSERDA Contract 132705 May 2020

Notice

Preferred Citation

New York State Energy Research and Development Authority (NYSERDA). 2019. "Energy Storage Peak Shaving Feasibility for Tupper Lake, Lake Placid, and Massena Municipal Electric Departments" NYSERDA Report Number 20-17. Prepared by Thomas Ortmeyer and Tuyen Vu, Clarkson University. nyserda.ny.gov/publications

Abstract

This report provides studies on the costs and benefits of battery energy storage systems (BESS) for three of New York's municipal electric departments. New York's municipal electric utilities generally have contracts to receive hydroelectric energy from the New York Power Authority (NYPA). These hydro allocations provide low-cost energy to the municipal utility. When the NYPA firm hydro allocation is exceeded, the utility must procure energy from other sources, generally at significantly higher prices. Additionally, the municipal utility pays to transmit the energy from the generation source to the utility gateway. As load growth occurs on the utility, electricity charges can rise steeply as the NYPA allocation is exceeded and the wheeling charges increase. The utility can provide value to their customers by managing their energy and power requirements.

At the same time, rapid changes in battery technology are significantly reducing storage costs and improving the feasibility of peak shaving and load shifting applications. This report assesses the potential for BESS systems to provide a cost reduction to the municipal departments, which can be passed on to their customers. The report also discusses demand side actions as an alternative to BESS. Templates for analyzing the cost savings for other similar electric departments are also included.

Keywords

Battery energy storage systems (BESS), municipal electric departments, hydro allocation

Acknowledgments

This project would not have been possible without the close cooperation of: Marc Staves and Michael Dominie, Tupper Lake, Kimball Daby, Lake Placid and Andrew McMahon and Jeff Dobbins, Massena, and colleagues at their respective organizations. We acknowledge the efforts of Nancy Bernstein, ANCA, who saw the need for this project and brought the team together. We also acknowledge Darryl Jacobs on NYPA, for his insights on the rate structures for the municipal departments.

Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

BESS	battery energy storage system
kWh	kilowatt-hours
LPVED	Lake Placid Village Electric Department
MWh	megawatt-hours
m/s	meters per second
MED	Massena Electric Department
MW	megawatts
NYS	New York State
NYPA	New York Power Authority
NYSERDA	New York State Energy Research and Development Authority
TLMED	Tupper Lake Municipal Electric Department
UCAP	Unforced capacity

Executive Summary

This report provides studies on the costs and benefits of battery energy storage systems (BESS) for three of New York State's municipal electric departments. The State's municipal electric departments (MED) generally have contracts to receive hydroelectric energy from the New York Power Authority (NYPA). These hydro allocations provide low-cost energy to the municipal utility. When the NYPA hydro allocation is exceeded, the utility must procure energy from other sources, generally at significantly higher prices. Additionally, the municipal utility pays transmission owners to transmit the energy from the generation source to the utility's gateway. These charges are commonly called wheeling charges. As load growth occurs on the utility, electricity charges can rise steeply as the NYPA allocation is exceeded and the wheeling charges increase. The utility can provide value to their customers by managing their energy and power requirements.

The report identifies three methods through which MED's can benefit from a BESS system:

- Peak shaving to increase allocation
- Optimizing market rate purchases
- Peak shaving in months below allocation

The methods for assessing these benefits are discussed in the report. Results are presented for three municipal electric departments: Tupper Lake, Lake Placid, and Massena. These three departments represent a range of conditions relative to their NYPA allocation. The results presented cover the calendar year 2018, along with data for 2019.

The report provides a benefit-cost analysis for each department. In each case, one or two potentially attractive BESS system sizes are identified. The benefits of having had the BESS system installed during 2018 are estimated. These benefits are compared with projected costs of a BESS system, for a range of battery technologies. At present, BESS costs are declining due to advancing battery technology and improving market conditions. Annual cost data for these units is presented as a function of battery technology and the date of installation. The data suggests that BESS unit installations could be an attractive option for some of New York State's municipal electric departments.

1 Introduction

1.1 Project Overview

This report provides studies on the costs and benefits of battery energy storage systems (BESS) for three of New York State's municipal electric departments. These departments generally have contracts to receive hydroelectric energy from the New York Power Authority (NYPA). These hydro allocations provide low-cost energy to the municipal utility. When the NYPA allocation is exceeded, the utility must procure energy from other sources, generally at significantly higher prices. Additionally, the municipal utility pays transmission owners to transmit the energy from the generation source to the utility's gateway. These charges are commonly called wheeling charges. As load growth occurs on the utility, electricity charges can rise steeply as the NYPA allocation is exceeded and the wheeling charges increase. The utility can provide value to their customers by managing their energy and power requirements.

1.2 Methodology

The report identifies three methods through which municipal electric departments can benefit from a BESS system:

- Peak shaving to increase allocation
- Optimizing market rate purchases
- Peak shaving in months below allocation

Section 2 of the report discusses each of these methods in detail. Templates were developed in the project to complete monthly analyses, which are included in the report, of the load data for allocation shifting, peak shaving to increase the allocation, and peak shaving in months below allocation, Section 2 also discusses demand response as an alternative to BESS for cost-saving.

1.3 Results

Sections 3–5 discuss the results of each of the three case studies. Month-by-month analyses of the load data for each department are presented. These sections are written as semi-independent reports to the three respective electric departments. The analysis of the load data is then used to identify a range of suitable candidate BESS ratings. Finally, potential cost savings are predicted for the one or two most attractive BESS system sizes.

Section 6 includes a brief discussion on the potential for demand response projects as an alternative to the installation of a BESS system. The overall project results and conclusions are summarized in section 7.

2 Study Methodology

Each municipal department provided load data for the study. The data provided was the metered kilowatt-hours (kWh) for each 15-minute period. Data was provided for the entire 2018 calendar year, along with a significant amount of data for 2019.

2.1 Billing Structure

The electric departments are billed on a monthly basis, with each department receiving a bill from the New York Power Authority (NYPA) based on the calendar month. The departments are also billed for wheeling the power from the energy source to the department's location. For Tupper Lake (TLMED) and Lake Placid (LPVED), National Grid wheels the power, and bills TLMED and LPVED for that service. Massena (MED) receives most of its power directly from NYPA and is billed for delivery.

2.1.1 NYPA Rates

The three municipal departments receive a firm hydro power[1] allocation from NYPA. This allocation is adjusted from time to time. The departments also receive a small firm peaking allocation from NYPA. The firm peaking allocation comes with an assumed 12.5% monthly load factor. Due to this low-monthly load factor and the relatively small firm peaking allocations, there is a negligible impact of these firm peaking allocations on BESS cost-benefit studies, and therefore, are not considered further in this report.

NYPA bills the departments for both demand and energy, and the demand charge is currently $4.07 per kilowatt (kW), based on the peak hourly demand in the given month. This demand charge is for the monthly kW demand up to the firm hydro allocation. When demand goes above the allocation, there are no additional demand charges for the demand above the allocation.

NYPA also applies an energy charge for energy in the allocation. The current rate for the energy charge is $0.00492 per kilowatt-hour (kWh), or $4.92 per megawatt-hour (MWh).

It is important to note that the allocation is adjusted by the firm hydro load share percentage in those months when the demand goes above the firm hydro allocation. For every hour of the billing period, the electric department receives hydropower energy (firm hydroelectric energy) equal to the hourly metered load multiplied by the ratio of the department's firm hydro contract demand divided by the maximum hourly metered demand recorded in the given billing period.

In periods when the power draw is above the adjusted allocation, the cost of energy to the electric department is based on the hourly real time-weighted integrated (TWI) real-time zonal locational-based marginal cost (LBMP) for the New York Insurance Services Office (NYISO) zone in which the department is located. The TWI prices are calculated from the real-time market five-minute prices posted by NYISO.

The rates also include a Clean Energy Standard (CES) rate and a NYISO charge. The CES rate is billed at $0.00319 per kWh, regardless of when and how much energy is drawn. As the net energy drawn by the municipal district does not significantly change with the installation of a BESS, the BESS should have minimal impact on this charge. The BESS will draw a net positive power due to its losses. For example, a 1-MW, 2-MWh BESS may lose approximately 15% of energy drawn during a full charge/discharge cycle. In this case, that would be 0.3 MWh loss per cycle. If a unit goes through four full cycles per month as a result of its peak shaving duties, that would amount to 1.2 MWh per month, or approximately a $4 per month increase in the CES charge. This value is negligible for the purposes of this study.

The NYISO charge fluctuation is a product of NYISO charges related to Schedule 1, marginal losses, congestion, and NYPA Transmission Adjustment Charge (NTAC), etc. The monthly bills for this charge are based on best estimates of these charges. Each customer is provided with backup data that includes a NYISO charge breakout related to the monthly bill. Associated NYISO charges will include an adjustment ("true-up") to reflect final results from previous months. The relation of these charges to the monthly demand and energy charges is not clear from the bills, and the analysis in this report does not include any impacts that a BESS system will have on the charge.

2.1.2 Wheeling Charges

National Grid wheels the power for both Tupper Lake and Lake Placid. In January 2019, LPVED was billed at a rate of $6.2164 per MWh, or $0.0062164 per kWh. These rates fluctuate from month to month based on the transmission congestion and other factors, with the municipals' power and energy consumption creating a negligible impact on the rate. In 2018, the monthly rates ranged from just under $6 per MWh to nearly $9.5 per MWh. However, the time of consumption within a month does not impact this rate, and therefore, the installation of a BESS on these systems for daily load cycling will have negligible change on the cost of this service to these municipals.

NYPA provides the bulk of the service to Massena Electric Department (MED). It bills MED for UCAP (unforced capacity), transmission, and independent system operator (ISO) charges. These are discussed further in section 5.

2.2 Analytical Methods

Raw data for these studies is taken from the revenue meters at the respective electric department meter points. This data format is user-selectable, so a variety of formats are possible. The two spreadsheets available from the study are posted for download.[2]

For the templates included in the report, the data should be downloaded with the meter name in column A, the date and time in column B, and the metered energy in column C. Column C is the key column, and must have the kilowatt-hour value for the period. The meter ID in column A and the date/time in B are useful for documenting the data source. The other columns are not used in the template. Fifteen-minute data should be selected for the use with the templates in order to get the best accuracy on the required battery energy rating.

The data should be downloaded in the *.csv (comma separated variable) format, so that is can be conveniently pasted into the templates. These can be downloaded either by individual month, or over a longer period such as a full year. In either case, a block of data needs to be entered into the template for each individual billing period. The first data line for a month would be hour 1 of the first day of the month, and the last data line would be hour 0 of the first day of the following month. Several lines of typical data output are shown in Table 1.

The calculations page of the two templates are password protected to avoid inadvertent changes in the block content. In the event that users would like to modify the calculations, the password for the page is “clarkson.”

INPUT: For these studies, the first template is use for months when the firm hydro allocation is exceeded. The name of the template file is “over allo template_quarterhour.xlsx” and the spreadsheet has two pages—the input/output data page and the calculation sheet. The calculation sheet is password protected.

Table 1. Typical Data Format for the Study

Meter ID	Date / Time	KWH (sec: 1 set:1)	KVARH (sec: 2 set:1)	VOLTS sec: 4 set:1)	VOLTS (sec: 5 set:1)	VOLTS (sec: 6 set:1)
LAKE PLACID	7/1/2018 0:15	3321	963.9	16.905	16.8532	16.8532
LAKE PLACID	7/1/2018 0:30	3272.4	955.8	16.905	16.8532	16.8705
LAKE PLACID	7/1/2018 0:45	3223.8	939.6	16.905	16.8532	16.8705
LAKE PLACID	7/1/2018 1:00	3134.7	923.4	16.905	16.8532	16.8705
LAKE PLACID	7/1/2018 1:15	3102.3	923.4	16.905	16.8532	16.8705
LAKE PLACID	7/1/2018 1:30	3053.7	907.2	16.905	16.8705	16.8705
LAKE PLACID	7/1/2018 1:45	3118.5	931.5	16.905	16.8705	16.8705
LAKE PLACID	7/1/2018 2:00	3029.4	923.4	16.905	16.8532	16.8705
LAKE PLACID	7/1/2018 2:15	3013.2	915.3	16.905	16.8532	16.8705

2.2.1 Template for Months when the Firm Hydro Allocation is Exceeded

For the input data on the file "over allo template.xls," the firm hydro allocation is entered into cell T8 of the xls spreadsheet. The monthly data is entered into columns A-J, starting on row 7. Column A would typically contain the meter name, and column B the date and time. These are included to document the data that is in the file. Column C must contain the hourly metered energy in kWh. Columns D-J are not used in calculations but are included for convenience to allow room for some data output formats.

NOTE: The number of rows of quarter-hour data varies with the length of month. For 31-day months, there will be 2976 quarter-hour data points. Thirty- and 28-day months will have fewer rows. The spreadsheet calculations will be correct for all the data points, as long as blanks or zeros are entered in the rows without data. Cutting and pasting the monthly data will always work if you start fresh from the blank template. If you do not start from a blank template, you must ensure that the lines for the 31st day (29 th–31st in Feb.) are blank or zero when analyzing the shorter months.

In the *.csv file obtained from the meter site, copy the data starting with time 0:15 on the first day of the month, and ending with time 0:00 on the first day of the next month. Paste this starting at cell A7. Do not copy the headers for the data.

CALCULATIONS: The calculation sheet takes the input data and calculates the firm hydro load share percentage for the given month. From this, it determines the firm hydro energy purchased by quarter-hour, and the firm incremental energy purchased at the market rate for that quarter-hour. The sheet then recalculates the firm hydro load share for three peak shaving scenarios—0.5 MW, 1.0 MW, and 2.0 MW. It next determines the firm hydro and firm incremental purchase for each quarter-hour with the respective levels of peak shaving. Finally, the sheet sums these values for the month and determines the increase in firm hydro energy purchased for each of the peak shaving scenarios.

The second set of calculations (in columns X through AH on the calculations sheet) determines the amount of power that the battery must supply to achieve the target peak shave. When peak shaving is active, the strategy is to maintain the average power drawn during each quarter-hour at the targeted peak value. When the average power draw is below the targeted peak value, the battery is allowed to recharge. The final column for each case (Z, AD, and AH) monitors the state of discharge of the battery over time. It is the maximum value in this column that dictates the energy requirement for the battery to maintain the desired peak shaving in that month.

OUTPUT: The spreadsheet calculation results are presented on the input/output data page. First, verify that this page reflects the correct firm hydro allocation.

The following outputs will be available:

Table 2. Output Fields for the Overallocation Template

Cell/ Case	Output Data
T14	Monthly peak demand. Check to make sure that this value is greater than the firm hydro allocation. If it is not, you will need to use the other template for that particular month.
U18	Firm Hydro energy, in MWh. This is the base case, with no BESS unit. It should match the firm hydro energy on the monthly bill, within a fraction of a percent.
U19	Firm incremental MWh. This is the energy purchased on the open market for the month, in MWh. This should match this category of the monthly bill.
0.5 MW Peak Shave Case	U22—firm hydro MWh with 0.5 MW peak shave U23—market MWh with 0.5 MW peak shave U24—battery energy required to attain this peak shaving level, during the particular month in question. V24—MWh benefit of the peak shaving, equal to the increase in MWh purchased at the firm hydro rate.
1.0 MW peak shave	U26- firm hydro MWh with 1.0 MW peak shave U27—market MWh with 1.0 MW peak shave U28—battery energy required to attain this peak shaving level, during the particular month in question. V25—MWh benefit of the peak shaving, equal to the increase in MWh purchased at the firm hydro rate.
2.0 MW peak shave	U30—firm hydro MWh with 2.0 MW peak shave U31—market MWh with 2.0 MW peak shave U32—battery energy required to attain this peak shaving level, during the particular month in question. V26—MWh benefit of the peak shaving, equal to the increase in MWh purchased at the firm hydro rate.

2.2.2 Template for Months when the Firm Hydro Allocation is not Exceeded

The potential benefits of the BESS system change significantly during monthly billing periods when the firm hydro allocation is not exceeded. A different template must be used for analyzing performance in these months. The name of this template file is “template under alloc.xlsx”. The same data files will be used for this template as for the previous case, and the monthly meter data from csv files will be pasted into the template in_out data page as described in the previous section. The password protection and data entry instructions are also the same as the previous template.

INPUT: Again, paste the meter data for a month into the in_out data page of the spreadsheet. The first row of data is to be pasted into cell A14 on this page.

The firm hydro allocation for this case is entered into cell O6. The target value for peak shaving is entered into cell O10 (PEAK_SHAVE). PEAK_SHAVE is equal to the rated peak shaving capability of the BESS system and approximately corresponds to the maximum power that can be drawn from or injected into the battery system. The actual VA rating of the BESS inverter will be somewhat higher, to account for inverter VAR flow, system losses, and errors in the peak load prediction algorithms. Again, you should always paste monthly data into the blank template file, due to the varying length of the months.

CALCULATIONS: The calculation sheet takes the input data and processes it. It converts the 15-minute energy kWh into 15-minute average power in column L, and then into a running hourly demand in column M. The peak hourly demand (PEAK_DEMAND) is determined from the maximum monthly value of column M. The projected peak metered demand is calculated at the peak load demand less than the peak shave capability (PEAK_DEMAND-PEAK_SHAVE).

Column V calculates the amount of power drawn by the battery system. It will be 0 except in cases where the load is greater than PEAK_DEMAND-PEAK_SHAVE.

Column W has the power available for recharging the BESS—typically equal to PEAK_SHAVE except in cases where charging the battery at full power would create a metered peak value greater than the target.

Column X is the actual power drawn to recharge the battery—when the battery is not at full charge, it will take as much power as possible without exceeding the BESS power rating or the target metered demand.

Column Y is the battery state of discharge. A value of 0 in this column indicates a fully charged battery. The state of discharge increases when the battery is supplying power to reduce peak metered demand, and it decreases when the battery is recharging. The maximum value in column Y is the required BESS energy rating required for that month to maintain the desired level of peak shaving.

OUTPUT: The spreadsheet calculation results are presented on the input/output data page. First, verify that this page reflects the correct firm hydro allocation. The peak load demand is shown in cell O8. You will need to verify that the peak demand is in fact less than the firm hydro allocation. If peak demand is greater than this allocation, the other template for the month in question will by necessary.

For the given peak shave capability entered in cell O10, the in_out data page cell P14 shows the required battery energy rating needed to achieve the peak shave level specified in O10. This value is in MWh. The other two outputs are the monthly energies drawn by the load (N20) and going through the meter (N21). These two should match (within roundoff error), and should match the load energy shown on the monthly bill.

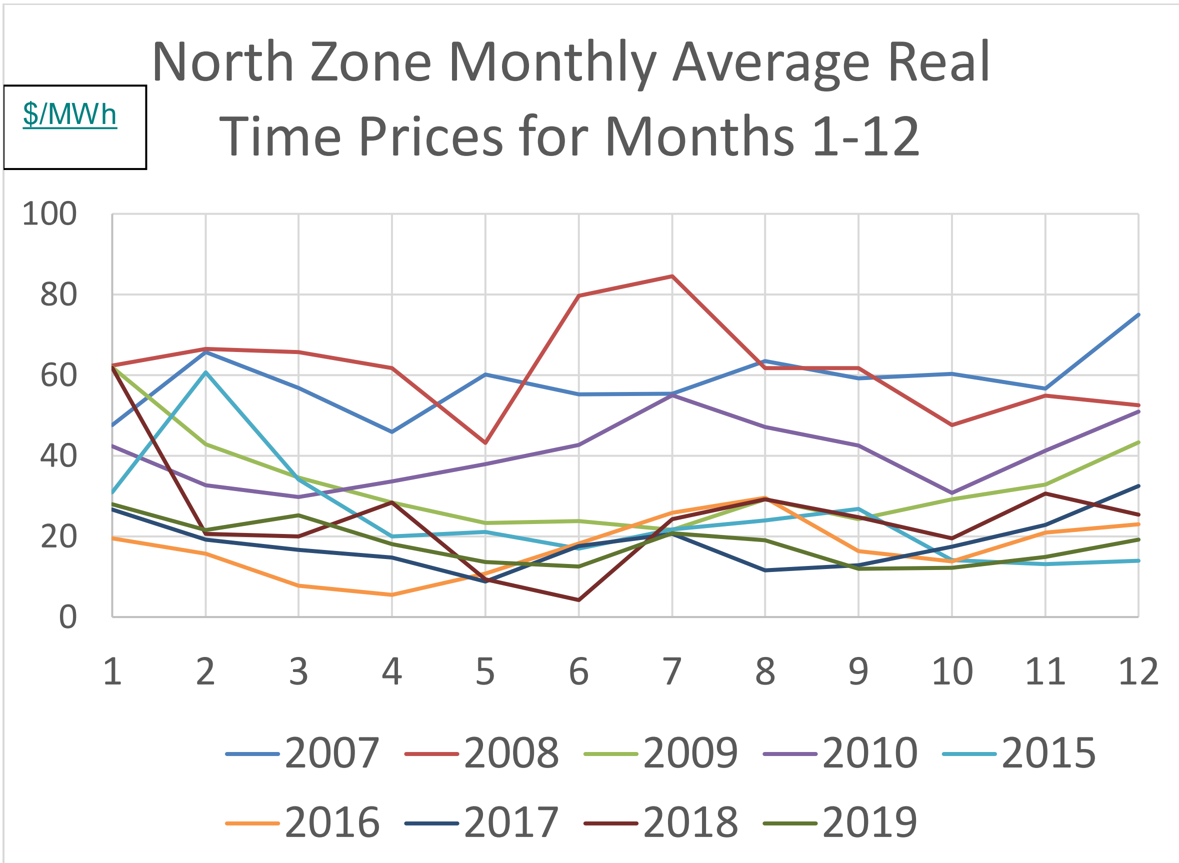
This spreadsheet can be used in two different ways:

1. As explained in the previous paragraph, when the PEAK_SHAVE value entered in O10 equals the desired BESS system peak shaving capability, it will indicate the amount of energy needed in that month to attain this level of peak shaving. This value can be used with the output from other months to determine an energy rating for the BESS.
2. When the BESS system power and energy have specified, the desired level of peak shaving may require more energy than the BESS is capable of supplying. In these cases, PEAK_SHAVE should be reduced in small steps until the battery size in P14 becomes slightly less than the BESS system energy rating. This will be the level of peak shaving that can be expected for the month, under ideal conditions.

2.3 Trends in Energy Prices

The three municipal electric departments in this study are located in northern New York. Lake Placid and Massena are in NYISO's North Zone, and Tupper Lake is in NYISO's Mohawk Valley Zone. In both zones, there has been a downward trend in the market cost of energy in recent years. Figure1 shows the monthly average prices of the NYISO North Zone Real-Time Weighted Hourly costs from 2007–2010 and 2015–2019. These prices are plotted by month over the course of each year. It is clear from Figure 1 that there has been an overall downward trend in these prices in recent years (2015–2019), as compared to the earlier years of 2007–2010. This trend makes forecasting of future benefits of a BESS installation difficult. While it appears that recent costs have been relatively stable, it is possible that some level of cost decline could continue. There is little expectation that energy costs will begin to see significant increases in northern New York in the near term.

Figure 1. Monthly Averages for North Zone Hourly Time Weighted Integrated Real-Time Energy Costs by Year



2.4 Energy Storage Technologies

2.4.1 Summary

There are various Electrical Energy Storage (EES) technologies, which can be applied to small power and energy applications to the large-scale systems. Each technology is applicable for a specific application (e.g., peak shaving or energy shifting). Figure 2 summarizes EES technologies from mechanical to chemical types.

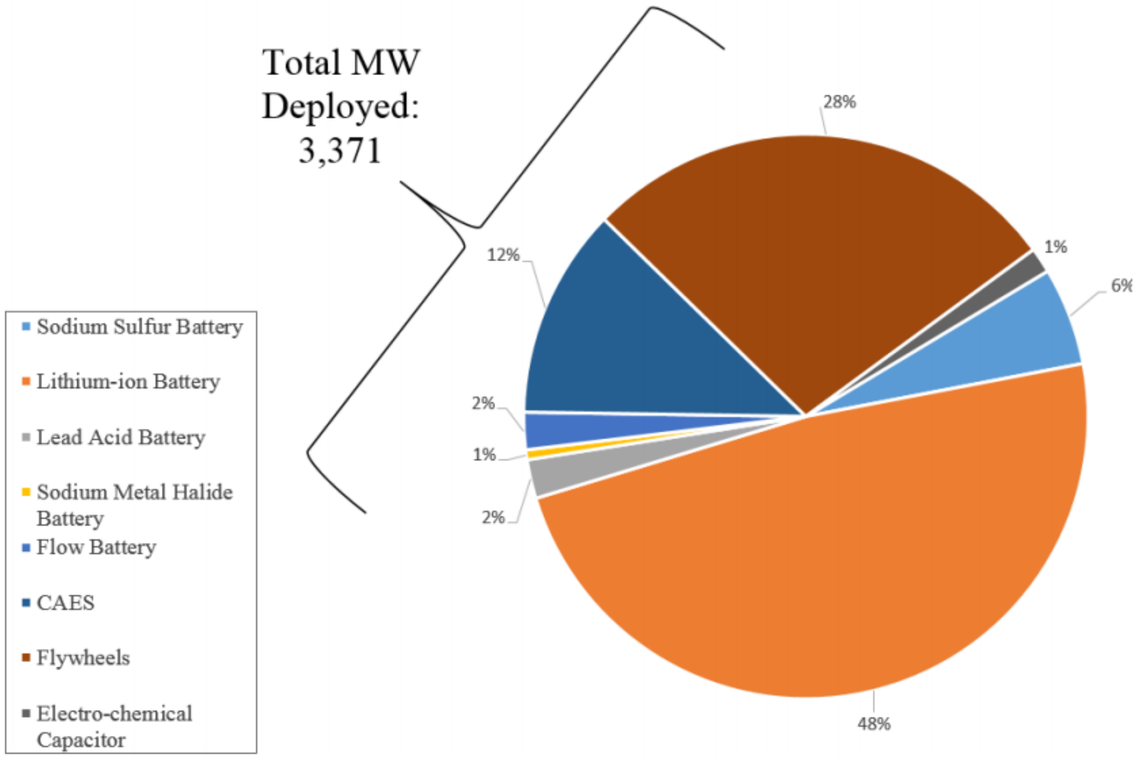
Figure 2. Summary of Energy Storage Technologies

Mechanical	Electro-chemical	Electrical	Thermal	Chemical
PHS - Pumped Hydro Storage **CAES -** Compressed Air **FES** - Flywheel	**LA -** Lead Acid **NiCd -** Nickel Cadmium **NiMH -** Nickel Metal Hydride **Li-Ion -** Lithium-Ion **NaS -** Sodium Sulphur **RFB -** Redox Flow Battery **HFB -** Hybrid Flow Battery	**DLC -** E-layer Capacitor **SMES -** Superconducting Magnetic Coil	**MS -** Molten Salt **CL -** Chillers	**FC** - Fuel Cell **SNG -** Synthetic Natural Gas

Note: NY BEST, "New York Energy Storage Services Fact Sheet," Spring 2018 - NYSERDA Energy Storage Soft Costs Program, NY, 2018.

According to DOE,[3] as of 2018 there is nearly 173 gigawatts (GW) of energy storage worldwide for all smart grid applications, where 98% of the capacity is pumped hydroelectric storage (PHS). In the other 2 GW, li-ion is the leading with the share of 48%, followed by FES (28%), CAES (12%), NaS (6%), lead-acid (2%), flow batteries (2%), and others as shown in Figure 3.

Figure 3. Worldwide Market Share of Energy Storage Technologies for Smartgrid Applications in 2018



Note: https://www.clarkson.edu/cepsr for more information.

2.4.2 Energy Storage Technologies for Peak Shaving

The power distribution systems of Tuper Lake and Lake Placid are in the range of MWs. Therefore, this study will focus on the study of EES technologies at the scales of 1 MW–5 MW in power and 1 MWh–10 MWh in energy. According to IEC-2012 (Figure 4), and New York State Energy Research and Development Authority (NYSERDA)[4] regarding the power and energy capability of EES technologies, the suitable EES for the 1–10 MW application with several hours of operation can be flywheel energy storage (FES), lithium-ion (li-ion), sodium (Na), redox flow battery (RFB), lead-acid (LA), hydrogen (H2), and synthetic natural gas (SNG). Among those, SNG, H2, and flywheel will not be considered in this study for the peak shaving application because of the following reasons:

- The SNG technology is still immature for field deployments. European Parliament's Committee on Industry, Research and Energy (ITRE) provides additional details regarding the maturity of EES technologies.[5]
- Although the H2 technology has a very high energy density compared with other technologies but has a limited round-trip efficiency, which is typically less than 50%. Therefore, the H2 technology still needs more development for higher efficiency improvement for its feasibility in the peak shaving problem.[6] Flow batteries can be considered as regenerative fuel cells. The two most popular types of flow batteries are vanadium redox flow batteries (VRFB) and zinc bromine flow batteries (ZBFB). There are many advantages that RFB batteries could bring. RFB can operate at close to ambient temperatures. The energy to power ratio can be easily manipulated for the suitable application. The batteries offer more than 10,000 life cycles. The DoD level can go almost to 100%. RFB batteries also have disadvantages. First, RFB have low round-trip efficiency, which was around 70% in 2016 and could be improved to 78% in 2030.[7] The complex design and control of the RFB can potentially induce a significant cost in the regular maintenance, especially for the stationary application in this project. The RFB batteries manufactures include but are not limited to Sumitomo Electric, Mersen, and UniEnergy Technologies.
- The flywheel technology has a relatively low-energy density, which drives the energy cost ($/kWh) too high. For example, the 2016 lowest cost of flywheel technology for stationary application is $1500/kWh, while the typically low cost of li-ion technology for stationary application is only $352.[7] Therefore, flywheel is not suitable for the peak shaving/load leveling application. Figure 5 also confirms the unsuitability of flywheel for peak shaving application. Hence, analysis of EES technologies for the cost and benefit analysis in this proposal will be li-ion, sodium, RFB, and LA.

Figure 4. Comparison of Power, Energy Content of Different Electrical Energy Storage Technologies (IEC 2012)

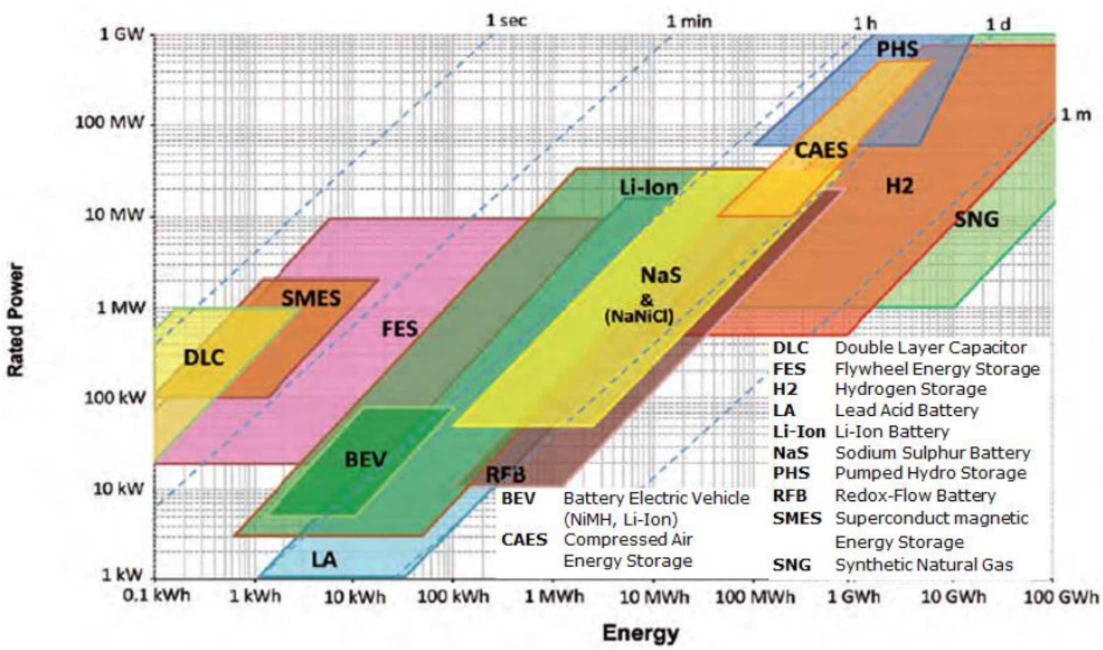
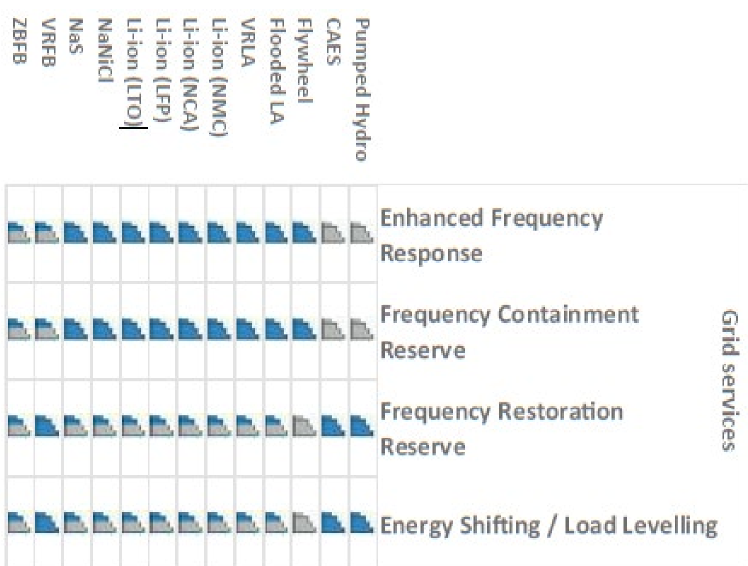


Figure 5. Suitability of Grid-Level Based Battery Storage Technologies



Note: (1) NY BEST, "New York Energy Storage Services Fact Sheet," Spring 2018 - NYSERDA Energy Storage Soft Costs Program, NY, 2018.

(2) S. Ugarte, N. Friendrichsen, J. Michaelis, and A. Thielmann, "Energy Storage: Which Market Designs and Regulatory Incentives Are Needed?" European Parliament's Committee on Industry, Research and Energy (ITRE), October 2015.

2.4.2.1 Summaries of Suitable Electrical Energy Storage Technologies for the Peak Shaving Study

- **Li-Ion Batteries:** There are two main categories of li-ion systems, which use liquid electrolyte or polymer electrolyte. The commonly used one in commercial applications is liquid electrolyte based system.[7] The variation of the li-ion battery depends on the chemical combination of the cathode. There are four common li-ion battery types, lithium nickel cobalt aluminum (NCA), combined lithium nickel manganese cobalt oxide/lithium manganese oxide (NMC/LMO), lithium iron phosphate (LFP), and lithium titanate oxide (LTO). The lifetime of the batteries varies from 500 to 20,000 full cycles depending on battery types and environmental conditions. li-ion batteries have been utilized for the portable electronics applications. However, due to their significant cost reduction, low effort in maintenance, high round-trip efficiency, and decent lifetime, these batteries are becoming more attractive for the stationary applications, such as the peak shaving and demand response for utility grid in this proposal. The lowest typical cost of the technology was $352/kWh in 2016 and decreases to $145/kWh by 2030.[7] The round-trip efficiency is high at 92–98%. The lifetime of the batteries will increase from 12–15 years/1,000–10,000 cycles in 2016 to 18–23 years/2,000–20,2000 cycles in 2030. Li-Ion batteries are also considered as the most matured technology for the stationary applications. Global manufacturers, who can supply the EES for this application include, but are not limited to Tesla Motors, LG Chem, Panasonic, Boston Power, and BYD China. Other local manufacturers in Upstate NY can be Imperium3, and General Electric.
- **Sodium Batteries:** Sodium batteries, sodium sulphur (NaS) batteries and sodium nickel chloride (NaNiCl) are high-temperature batteries. Sodium batteries have been widely utilized for smoothing wind power generation in Japan. Sodium batteries have a relatively high-energy density, which is closed to the li-ion energy density, and have a very competitive life cycle, which typically was 5,000 cycles in 2016 and could be close to 7,500 cycles in 2030. Sodium batteries are very environmental-friendly as they do not contain toxic substances and have a high-recyclability rate of 99% after use.[8] Despite the advantages, sodium batteries have a high annual operating cost of $40–70/kW a year because of the high-temperature required for operation.[7] The sodium batteries manufactures include, but are not limited to NGK Insulators, General Electric.
- **Lead-acid Batteries:** Lead-acid (LA) batteries were developed in mid-1900s. There are two main categories of LA batteries, the flooded LA and valve-regulated LA (VRLA). The main advantage of LA batteries is the low cost. The lowest cost in 2016 was $147/kWh and in 2030 could be $74/kWh. However, there are disadvantages. First, LA batteries have a poor life cycle, which can be significantly reduced because of the variation in the ambient temperature. As a rule of thumb, every increment of 15°F in the ambient temperature from the typical operating temperature will reduce the lifetime of these batteries by half. Second, they have low round-trip efficiency, which was 80–82% in 2016 and possibly is 85–87% in 2030. Third, the flooded LA requires regular maintenance, which can induce a significant operating cost. Forth, the DoD level of the batteries is considerably low at around 50%, which reduces the actual energy utilization of the batteries by half. The LA battery manufactures include, but are not limited to U.S. Battery, MK Battery, Crown Battery, and Dyno Battery.

3 Energy Storage Peak Shaving Feasibility for Tupper Lake Municipal Electric Project

This section analyzes the use of battery energy storage systems (BESS) to save costs for Tupper Lake Municipal Electric Department (TLMED). TLMED receives a NYPA allocation based primarily on hydro generation. It pays for this energy, along with a demand charge. When the allocation is exceeded, TLMED purchases energy on the open market at rates that are generally substantially higher than the allocation rates as well as pays the transmission owners a fee to move the power to its department.

This study analyzes three ways that BESS can be used to save costs to the departments:

1. Peak shaving during times when load is above allocation, to increase the allocated allotment.
2. Optimizing market rate purchases. When TLMED load is above allocation for extended periods, buying energy to store in the BESS from the day-ahead market when energy prices are low, and discharging the BESS during high-cost periods will result in cost savings.
3. Peak shaving during times when the TLMED load is below the allocation, to reduce the demand charge.

Study Assumptions:

- The peak shaving portions of the study were conducted based on the actual demand reduction achieved by the BESS installation. Note that the BESS real power output and the BESS inverter apparent power rating will need to be higher than the corresponding level of demand reduction—perhaps 20–40% higher, due to errors in the load forecasting process, system losses, allowance for VARs delivered to the AC bus, etc.
- The study assumes that the BESS system will have real-time access to the power drawn by TLMED, and that the BESS only delivers sufficient power to clamp the power draw at the peak value over the course of each hourly period when the total demand is above the targeted peak level. This will result in a significant reduction in the battery energy required, as compared to BESS units which deliver rated power throughout a discharge period.
- The energy purchased within the NYPA firm hydro allocation is at a base cost of $4.92 per MWh. The energy purchases above the allocation are made at the NYISO hourly time weighted real-time market rate. As this rate fluctuates by hour, exact cost savings can only be calculated after the fact.
- Note that the municipal departments are billed for additional charges by NYPA. These charges include the NYISO charges and the Clean Energy Standard (CES) charges. The CES charges are the same, regardless if the energy received is at the firm hydro rate or the market rate. The NYISO charges are not broken out by MW or MWh in the billings. These additional charges are not considered further in this analysis.

3.1 BESS Energy Analysis—Tupper Lake Municipal Electric Department

3.1.1 Months with Peak Load above the Allocation

Tupper Lake Municipal Electric Department (TLMED) NYPA allocation is 18.845 MW of firm hydro. In 2018, TLMED exceeded its allocation only during January. The yearly peak was 22.6 MW.

TLMED also has a 0.091 MW firm peaking allocation. Due to the small size of this firm peaking allocation and the fact that it is given at an assumed monthly load factor of 12.5%, it is not considered further in this study.

3.1.1.1 Peak Shaving to Increase Allocation

As discussed above, when TLMED exceeds its 18.845 MW firm hydro allocation in a given month, the hydro energy available for purchase in each hour of the month is reduced by an adjustment (firm hydro load share percentage) factor, calculated as

Equation 1.

$$\frac{\boldsymbol{TLMED\ MW\ firm\ hydro\ allocation}}{\boldsymbol{TLMED\ monthly\ MW\ Peak\ Demand}}$$

If the monthly peak demand can be reduced, this factor will increase, and TLMED will qualify for increased purchases of hydro energy during the month.

In this study, the impact of reducing peak demand by 0.5 MW, 1.0 MW, and 2.0 MW is considered. The 2018 monthly study results are given in Table 3.1 for January 2018 and January 2019. Table 3.1 shows the firm hydro MWh and firm incremental (market rate) MWh purchases for each of these months, for four cases: no peak shaving, and 0.5, 1.0, and 2.0 MW of peak shaving. For each level of peak shaving, the net benefit is shown in column e. This is the increase in firm hydro purchases that results from the peak shaving. The peak battery energy required during the month to meet the corresponding level of peak shaving is shown in column f. Note that the BESS power rating will need to be higher than the demand reduction—perhaps 20–40% higher—due to errors in the load forecasting process, system losses, the variability of the power drawn within the 1 hour demand period, etc.

Table 3 shows that a BESS unit that would provide 0.5 MW of peak shaving would have required 0.81 MWh of energy in 2018. This value was only slightly larger in 2019. In both years, this size of BESS would provide the capability to purchase slightly more than 200 MWh at the firm hydro rate rather than the market rate.

To realize 1 MW of peak shaving, the BESS unit would need to be sized to deliver just over 6 MWh in 2018. In January of 2019, however, only 2.48 MWh or energy would have been needed. The predicted benefit of doing this was 434 MWh in 2018 and 482 MWh in 2019.

Table 3. BESS System Requirements Needed to Achieve Savings due to Peak Shaving to Increase Allocation for January 2018 and January 2019

Battery energy ratings given deliverable to the AC bus.

(a) Month	(b) Peak Shaved (MW)	(c) Firm Hydro purchases (MWh)	(d) Market Purchases (MWh)	(e) MWh of peak shaving benefit	(f) BESS energy required (MWh)	(g) Peak Monthly Demand (MW)
Jan. 2018	0.0	9360	1840			22.55
	0.5	9573	1628	212	0.81	
	1.0	9795	1406	434	6.02	
	2.0	10271	930	911	26.03	
Jan. 2019	0.0	9798	1230			21.34
	0.5	10033	1063	235	0.83	
	1.0	10280	816	482	2.48	
	2.0	10811	284	1013	15.40	

Table 4 shows the BESS energy needed by month to realize the 0.5, 1.0, and 2.0 MW peak shaving objectives during months when the allocation is not exceeded. There are several outliers in this data—such as July for the 0.5 MW case, where 4.21 MWh would be required. This is more than double any other month for the 0.5 MW case.

Table 4. Required BESS Energy to Achieve Peak Shaving in Months when Allocation Iis Not Exceeded

	Peak Shave Case			
(a) Month	(c) 0.5 MW peak shave	(d) 1.0 MW peak shave	(e) 2.0 MW peak shave	(f) Peak Monthly Demand
	Required BESS energy (MWh)			(MW)
February	0.80	2.94	21.4	18.4
March	0.47	1.42	4.61	17.7
April	0.57	1.82	8.93	14.6
May	0.46	1.41	5.06	10.7
June	1.37	6.02	39.71	7.6
July	4.21	10.93	88.71	7.8
August	1.94	7.71	55.66	7.6
September	0.81	4.41	18.40	7.9
October	1.26	6.11	26.02	12.1
November	0.78	2.59	8.16	18.1
December	0.78	2.54	9.19	17.3

Based on the data in Tables 3 and 4, an 0.5 MW, 0.83 MWh BESS and a 1.0 MW, 6.11 MWh BESS were selected for further study. With these energy ratings, both units will provide rated peak shaving capability in January, when the firm hydro allocation is exceeded. The units will not provide rated peak shaving capability in several of the other months—those months where the BESS energy requirement exceeds the selected energy rating of the unit. However, these units can be expected to provide a lower level of peak shaving in these months, while staying within the unit energy rating.

Table 5. Peak Shaving Capability for the Selected BESS units in Months where the NYPA Firm Hydro Allocation Is Not Exceeded

	Peak Shave Case		
(a) Month	(c) 0.5 MW, 0.83 MWh unit	(d) 1.0 MW, 6.11 MWh Unit	
	Achievable Peak Shaving, (MW)		
February	0.5	1.0	
March	0.5	1.0	
April	0.5	1.0	
May	0.5	1.0	
June	0.37	1.0	
July	0.18	0.64	
August	0.39	0.86	
September	0.5	1.0	
October	0.37	1.0	
November	0.5	1.0	
December	0.5	1.0	

3.1.2 Optimizing Market Rate Purchase

TLMED will have the opportunity to optimize market rate purchases in months when it exceed the NYPA firm hydro allocation. In 2018 and 2019, it only exceeded the allocation in January, which limits this opportunity. The service could be conducted on days when the monthly peak would not be established. A study of the 2018 North Zone Day-Ahead market prices showed an average hi/lo price difference of around $25 per MWh, with a range from $0 to $100 per MWh. A study of the 2019 Real-Time North Zone Market showed that, on average, the weighted average hourly real-time price was around $45 per MWh, with a range of $0 to $1300 per MWh. The potential future savings from market-rate purchases of a BESS installation would depend on operating strategy and future market conditions.

For this study, a conservative annual savings estimate of $25 per day, per MW of BESS power rating is used. With the BESS unit operating at rated power for one hour of charge and one hour of discharge in 28 days in January, would result in an annual savings of $700. This would not have a significant impact on the BESS unit economics.

3.1.3 Peak Shaving in Months below Allocation

In months when TLMED demand does not exceed its allocation, the demand charge it pays to NYPA could be reduced by a peak shaving BESS. This charge is assessed monthly on the peak demand drawn by TLMED. In the two BESS scenarios selected for study, the units would not be able to achieve rated demand reduction in those months that required greater energy rating than was available. In those months, reduced levels of peak shaving would be available. Table 5 shows the demand reduction that could be achieved in February–December 2018 by the two BESS scenarios selected for the study.

3.2 Summary of Projected Savings

Based on the analysis above, the 0.5-MW and 1.0-MW peak shaving systems are the most practical sizes. For the 0.5 MW system, a battery capable of delivering 0.83 MWh to the AC bus would be a good choice. This system would have been able to provide 0.5 MW of peak shaving in 8 of the 2018 months, with reduced levels in the remaining months. For the 1 MW system, a 6.11 MWh unit would have been able to deliver 1 MW of peak reduction in 10 of the 12 months of 2018. As discussed, the actual volt-amp (VA) rating for the AC output of these BESS units would need to be greater than the 0.5 and 1.0 MW of peak shaving capability that is envisioned.

A candidate BESS unit would benefit TLMED in January of 2018 through peak shaving that would increase the level of firm hydro allocation purchases by increasing the firm hydro load share formula applied by NYPA. TLMED would benefit from the BESS system in the remaining months of 2018 through peak shaving that would reduce its monthly peak and therefore the NYPA demand costs. The NYPA rate for demand is $4.07 per kW when the peak demand is less than the NYPA allocation.

Table 6 shows the benefits analysis for the 0.5 MW BESS system. The predicted benefit for 2018 is $24,877. Table 7 shows the benefits analysis for the 1.0 MW BESS system. The predicted annual benefit for this unit in 2018 is $53,584. These benefits are compared with the BESS installation costs in the next section.

The analysis of January 2019 in Table 3 shows a similar impact in that month, as compared to January of 2018. Studies of additional years would be desirable before making any purchase decisions.

Note that National Grid wheels the NYPA power to the TLMED meter point. National Grid assesses a charge for each MWh transported. The per MWh rate varies by billing cycle. As the BESS will shift the daily energy consumption pattern but will have negligible impact on the total amount of energy consumed, the National Grid wheeling charges are not a factor in these evaluations.

Table 6. Benefits Analysis for the 0.5-Megawatt, 0.83 Megawatt-Hours BESS Unit for TLMED

Month	Peak Shaved	Savings from Allocation Shifting	Savings on Demand Charge	Total
January	0.5MW	$5300		
February	0.5MW		$2035	
March	0.5MW		$2035	
April	0.5MW		$2035	
May	0.5MW		$2035	
June	0.37MW		$1506	
July	0.18MW		$733	
August	0.39MW		$1587	
September	0.50MW		$2035	
October	0.37MW		$1506	
November	0.50MW		$2035	
December	0.50MW		$2035	
Total		**$5300**	**$19577**	**$24,877**

Table 7. Predicted Savings from Installing a 6 Megawatt-Hours BESS with Capability to Provide 1 Megawatt of Peak Shaving

Month	Peak Shaved	Savings from Allocation Shifting	Savings on Demand Charge	Total
January	1MW	$10850		
February	1MW		$4070	
March	1MW		$4070	
April	1MW		$4070	
May	1MW		$4070	
June	1MW		$4070	
July	0.64MW		$2604	
August	0.86MW		$3500	
September	1MW		$4070	
October	1MW		$4070	
November	1MW		$4070	
December	1MW		$4070	
Total		**$10850**	**$42734**	**$53,584**

3.3 Cost Analysis: Tupper Lake Municipal Electric Department

The BESS system costs were analyzed for the two options identified in the previous section. This analysis is based on BESS cost data from the International Renewable Energy Agency for the reference case[9] [2].

- Factors considered:
  - Annual maintenance rate: 1.5%
  - Interest rate: 3%
  - Energy efficiency depends on type of battery and the year
  - Power conversion efficiency: 98%
  - Self-discharge: Small and can be ignored
  - Depth of discharge (DoD): Depends on the technologies
- The annuity is calculated as follows:

$$\text{Annualized(Present Value)} = \text{Present Value} \times \frac{i}{(1-(1+i)^{-n})\times(1+i)}$$

Total Annuity = Annualized(Cost_Storage) + Annualized(Cost_PowerConv) + Maintenance + Loss

Loss in this case is converted to 5 cents/kWh and is also accounted with day-ahead market cost

The analysis provides costs for five battery technologies:

- Lithium nickel manganese Cobalt Oxide (NMC)
- Lithium iron phosphate (LFP)
- Sodium sulfur (NaS)
- Flooded lead acid (FLA)
- Valve regulated lead acid (VRLA)

Data is presented in Figures 6–10, based on the year that the unit would be installed. The figures include investment cost, lifetime, and annualized cost of the installation over its projected lifetime.

3.3.1 Option 1: 0.5 Megawatts and 0.83 Megawatt-Hours

The data predicts that the NaS and FLA technologies will have the lowest cost over the next decade, with the NMC approaching FLA in annualized costs around 2030. Comparing the costs of Figure 6 with the benefits of Table 6, the NaS unit would be at near breakeven for a 2020 installation. By 2025, several battery technologies would be comfortably below the predicted benefit of $24,877 for 2018. It would be useful to predict future benefits in making an investment decision.

Figure 6. Investment on Energy Storage and Power Conversion Units—0.5-Megawatt Peak Shave Case

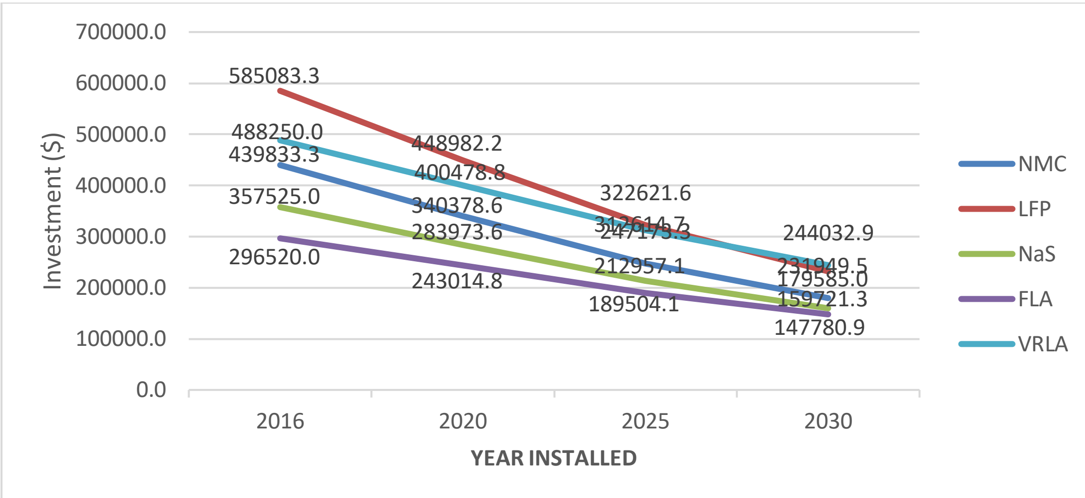


Figure 7. Battery Lifetime

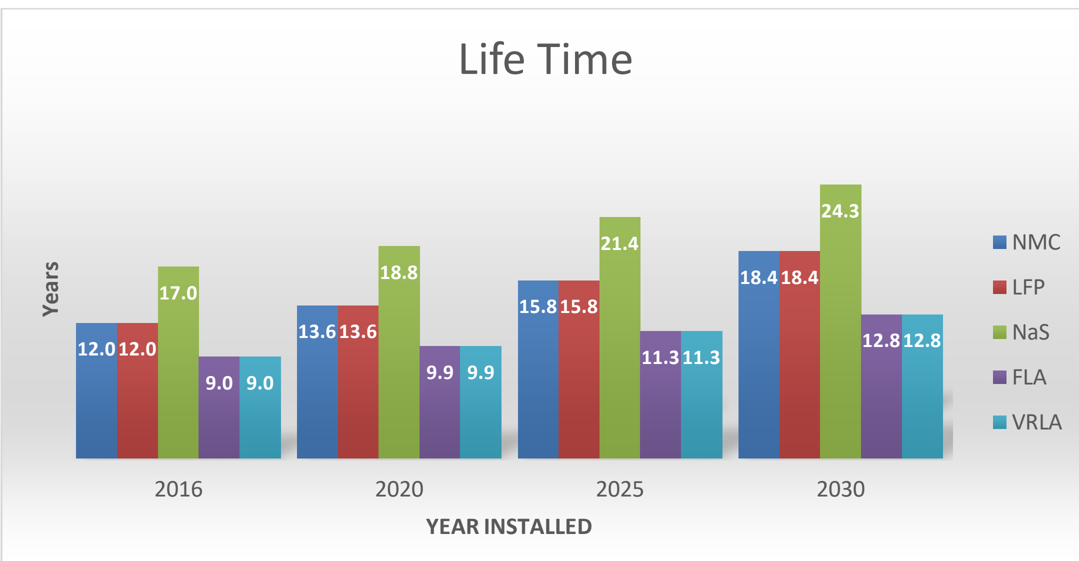
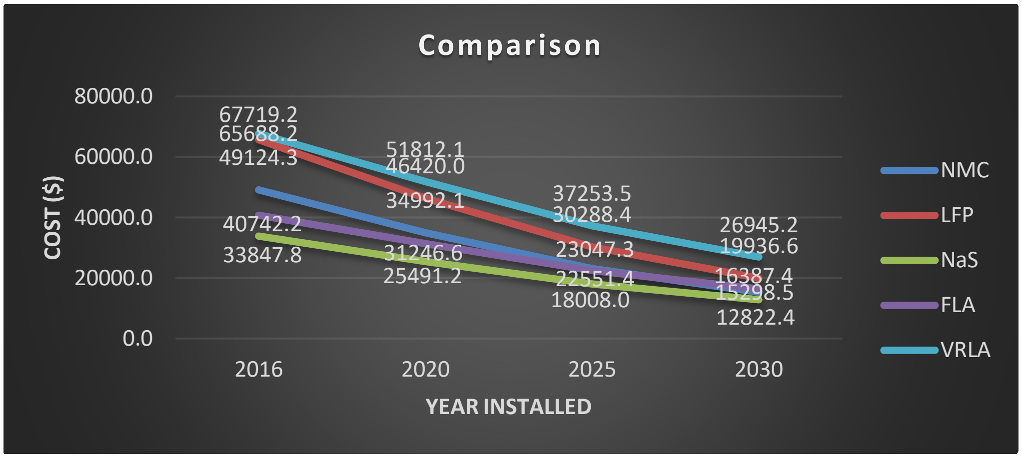


Figure 8. Annualized Cost Comparison among Storage Technologies for the 0.5-Megawatt, 0.83 Megawatt-Hours Peak Shaving Scenario

The annual cost refers to the annualized value of the life cycle of the BESS. The factors considered are DoD, efficiency, interest rate, and maintenance rate.



3.3.2 Option 2: 1 Megawatt and 6 Megawatt-Hours

For Option 2, the predicted annual benefit of 2018 is nearly $55,000 (Table 7). Figure 9 shows that the NaS unit would have a predicted annualized cost of $116,000 if installed in 2025 and $82,730 in 2030. This makes the installation of a large energy storage of 6 MWh not economically feasible.

Figure 9. Investment on Energy Storage and Power Conversion Units—1.0-MW Case

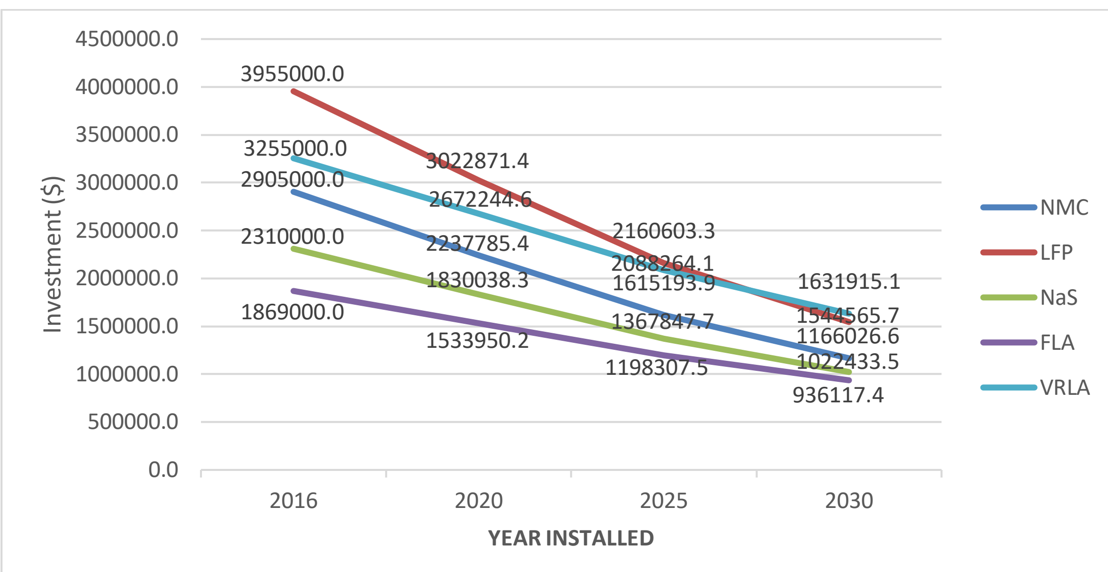
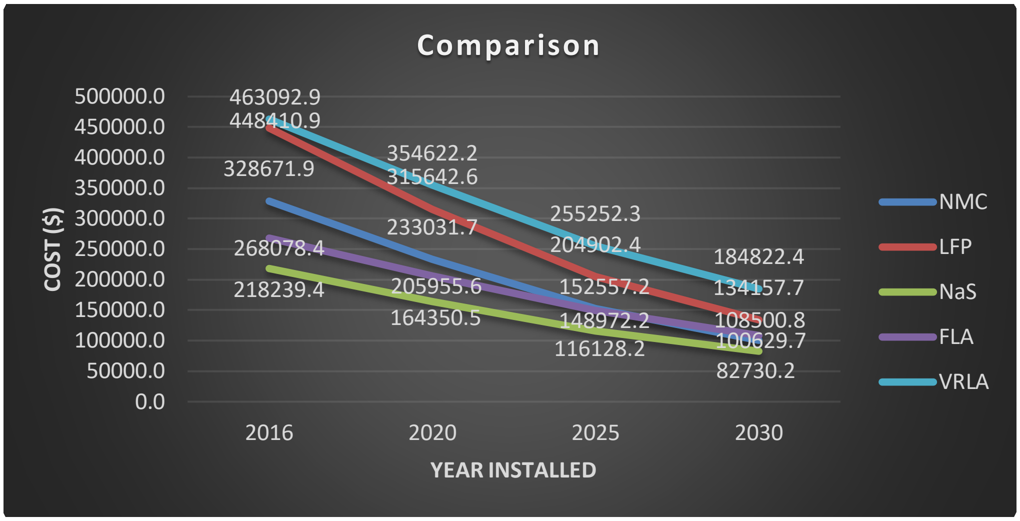


Figure 10. Annualized Cost Comparison among Storage Technologies for the 1.0-Megawatt and 6 Megawatt-Hours Peak Shaving Scenario

The annual cost refers to the annualized value of the life cycle of the BESS. The factors considered are DoD, efficiency, interest rate, and maintenance rate.



3.4 Summary

The results show that the installation of a BESS system with 0.5-MW peak shaving capability in Tupper Lake Village Electric Department merits further investigation. It is recommended that future benefits of the system be conducted, based on predictions of Tupper Lake's demand growth, load shape, and future energy costs. The 1.0-MW peak shaving case studied will not be economically feasible for installation in the foreseeable future.

4 Energy Storage Peak Shaving Feasibility for Lake Placid Village Electric Department

This section analyzes the use of battery energy storage systems (BESS) to save costs to for Lake Placid Village Electric Department (LPVED). LPVED receives a NYPA allocation based primarily on hydro generation. LPVED pays for this energy, along with a demand charge. When the allocation is exceeded, it purchases energy on the open market at rates that are generally substantially higher than the allocation rates. LPVED also pays the transmission owners a fee to move the power to its department.

This study analyzes three ways that BESS can be used to save costs to the departments:

1. Peak shaving during times when load is above allocation, to increase the allocated allotment.
2. Optimizing market rate purchases. When LPVED load is above allocation for extended periods, buying energy to store in the BESS from the day-ahead market when energy prices are low, and discharging the BESS during high-cost periods will result in cost savings.
3. Peak shaving during times when the LPVED load is below the allocation, to reduce the demand charge.

4.1 Study Assumptions

- The peak shaving portions of the study were conducted based on the actual demand reduction achieved by the BESS installation. Note that the BESS real power output and the BESS inverter apparent power rating will need to be higher than the corresponding level of demand reduction—perhaps 20–40% higher—due to errors in the load forecasting process, system losses, allowance for volt-amp reactive (VARs) delivered to the AC bus, etc.
- The study assumes that the BESS system will have real-time access to the power drawn by LPVED, and that the BESS only delivers sufficient power to clamp the power draw at the peak value over the course of each hourly period when the total demand is above the targeted peak level. This will result in a significant reduction in the battery energy required, as compared to BESS units which deliver rated power throughout a discharge period.
- The energy purchased within the NYPA firm hydro allocation is at a base cost of $4.92 per MWh. The energy purchases above the allocation are made at the NYISO hourly time weighted real-time market rate. As this rate fluctuates by hour, exact cost savings can only be calculated after the fact.
- Note that the municipal departments are billed for additional charges by NYPA. These charges include the NYISO charges and the Clean Energy Standard (CES) charges. The CES charges are the same, regardless if the energy received is at the firm hydro rate or the market rate. The NYISO charges are not broken out by MW or MWh. These additional charges are not considered further in this analysis.

4.2 BESS Energy Analysis—Lake Placid Village Electric Department

4.2.1 Months with Peak Load above the Allocation

The Lake Placid Village Electric Department (LPVED) NYPA allocation is 28.915 MW of firm hydro (28.934 in early 2018). In 2018, LPVED exceeded its allocation for 6 months: January, February, March, April, November, and December. The yearly peak was 51.3 MW, which occurred in January.

LPVED also has a 0.137 MW firm peaking allocation. Due to the small size of this firm peaking allocation and the fact that it is given at an assumed monthly load factor of 12.5%, the firm peaking allocation is not considered further in this study.

Peak shaving to increase allocation: As discussed above, when LPVED exceeds its 28.915 allocation in a given month, the hydro energy available for purchase in each hour of the month is reduced by an adjustment (firm hydro load share percentage) factor, calculated as

Equation 2.

$$\frac{MW\ firm\ hydro\ allocation}{LPVED\ monthly\ MW\ Peak\ Demand}$$

If the monthly peak demand can be reduced, this factor will increase, and LPVED will qualify for increased purchases of hydro energy during the month.

In this study, the impact of reducing peak demand by 0.5 MW, 1.0 MW, and 2.0 MW is considered. The 2018 monthly study results are given in Table 8 for those months when the firm hydro allocation was exceeded. Table 8 shows the firm hydro MWh and firm incremental (market rate) MWh purchases for each of these months, for four cases: no peak shaving, and 0.5, 1.0, and 2.0 MW of peak shaving. For each level of peak shaving, the net benefit of the peak shaving is shown in column e. This is the increase in firm hydro purchases that results from the peak shaving. The peak battery energy required during the month to meet the corresponding level of peak shaving is shown in column f.

Table 9 shows the needed BESS energy rating to reduce these levels of peak shaving during those months when LPVED does not exceed its firm hydro allocation.

Table 8. BESS System 2018 Monthly Requirements Needed to Achieve Savings due to Peak Shaving to Increase Allocation

Battery energy ratings given deliverable to the AC bus.

(a) Month	(b) Peak Shaved (MW)	(c) Firm Hydro purchases (MWh)	(d) Market Purchases (MWh)	(e) MWh of peak shaving benefit	(f) BESS energy required (MWh)	(g) Peak Monthly Demand (MW)
Jan	0.0	14292	11059			51.3
	0.5	14433	10918	141	0.71	
	1.0	14576	10775	284	2.03	
	2.0	14872	10479	580	13.9	
Feb	0.0	13215	6220			42.525
	0.5	13372	6063	157	0.60	
	1.0	13533	5902	318	1.68	
	2.0	13867	5568	652	5.04	
March	0.0	14760	4781			38.3
	0.5	14955	4585	195	0.54	
	1.0	15156	4385	396	1.63	
	2.0	15573	3967	814	4.94	
April	0.0	14760	993			30.9
	0.5	15003	750	243	0.53	
	1.0	15254	499	494	1.84	
	2.0	15753	0	993	5.87	
Nov	0.0	12689	5425			41.3
	0.5	12844	5270	156	0.44	
	1.0	13004	5110	315	1.50	
	2.0	13335	4779	646	4.72	
Dec	0.0	16014	5797			39.4
	0.5	16220	5591	206	0.58	
	1.0	16431	5380	417	1.54	
	2.0	16871	4940	857	4.45	

Tables 8 and 9 show a range of choices for the BESS system energy rating for the three BESS power ratings studied. For example, Table 8 shows that an energy rating of 0.71 MWh would be required for the BESS to achieve peak shaving of 0.5 MW in each of the months when the LPVED firm hydro allocation is exceeded. However, Table 9 shows that a BESS energy rating of 2.88 MWh would be needed in order to provide 0.5 MW of peak shaving in August of 2018, which is significantly higher than other months. Analysis of the data shows that several summer months do have significantly higher energy requirements for peak shaving, which likely would not be economical. In the remainder of this study, the BESS energy rating is chosen to provide the state peak shaving during months when the allocation is exceeded. The unit could provide at least some level of peak shaving in the other months with this design.

Table 9. Required BESS Energy to Achieve Peak Shaving in Months when Allocation is not Exceeded

(a) Month	(b) Peak Shave Case	(c) 0.5 MW Peak Shave	(d) 1.0 MW Peak Shave	(e) 2.0 MW Peak Shave	(f) Peak Monthly Demand
		Required BESS energy (MWh)			(MW)
May		0.43	1.25	3.85	19.6
June		1.21	4.15	15.86	17.4
July		0.76	5.78	18.88	18.9
August		2.88	8.94	22.28	16.8
September		0.58	1.80	5.98	17.1
October		0.67	2.12	10.99	27.0

Table 10 provides an annual summary of the peak shaving for the year 2018. The table shows that a BESS unit that would provide 0.5 MW of peak saving in each month of 2018 would be required to have an energy rating of 0.71 MWh. This unit would increase the MWh of firm hydro purchased by 1098 MWh during 2018. In order to provide 1.0 MW of peak shaving in these months, a BESS energy rating of 2.03 MWh would be required. For the 2.0 MW unit, a MWh rating of 13.9 MWh would be needed. However, in this case it is noted that January is a significant outlier. If the goal of achieving 2.0 MW of peak shaving in January is omitted, then the size of this unit could drop to just under 6 MWh.

Table 10 also includes a summary for 2019. In 2019, the required BESS energy ratings were slightly higher in 2019 than in 2018 at the 0.5 MW and 1.0 MW sizes. At the 2.0 MW peak shave size, the requirement in 2019 was significantly lower than 2018. The 2019 energy shifting numbers were similar to 2018, again with the 2.0-MW peak shaving case having the most significant change. It is good to see this consistency over the two years.

These numbers are based on a BESS system that operates at variable power output while peak shaving, in order to clamp the metered power flow to a constant value, a predicted level below the expected peak value.

Table 10. Summary of LPVED Results for Years 2018 and 2019

BESS Peak Shaving Power Capability		0.5 MW	1.0 MW	2.0 MW
BESS System Delivered Energy Required	2018	0.71 MWh	2.03 MWh	13.9 MWh
Energy Shifted from Market Rate to Hydro Allocation		1098 MWh	2224 MWh	4542 MWh
BESS System Delivered Energy Required	2019	0.72 MWh	2.16 MWh	8.85 MWh
Energy Shifted from Market Rate to Hydro Allocation		1125 MWh	2279 MWh	4241 MWh

4.2.1.1 Optimizing Market Rate Purchase

In days when LPVED's demand exceeds their allocation, the opportunity exists to charge the BESS during low-energy cost periods and discharge the battery during high-cost periods. This service could be conducted on days when the monthly peak or weakly peak would not be established. A study of the 2018 North Zone Day-Ahead market prices showed an average hi/lo price difference of around $25 per MWh, with a range from $0 to $100 per MWh. A study of the 2019 Real-Time North Zone Market showed that, on average, the weighted average hourly real-time price was around $45 per MWh, with a range of $0 to $1300 per MWh. The potential future savings from market rate purchases of a BESS installation would depend on operating strategy and future market conditions.

For this study, a conservative annual savings estimate of $3,750 per MW BESS power rating is used. This is based on the BESS unit operated at rated power for one hour of charge and one hour of discharge for 25 days in each of the six months when LPVED demand exceeds its NYPA firm hydro allocation, with an average savings of $25 per day per MW.

4.2.2 Peak Shaving in Months below Allocation

In months when LPVED demand does not exceed its allocation, the demand charge it pays to NYPA could be reduced by a peak shaving BESS. This charge is assessed monthly on the peak demand drawn by LPVED. Table 9 shows the BESS energy ratings needed to achieve the specified peak shaving in each of the months when LPVED does not exceed its firm hydro allocation.

In the design case studied, the BESS system energy rating was chosen to meet design peak shaving goals only in those months when the allocation is exceeded. During the remaining months, the peak shaving goal may not be met. Table 11 shows the predicted level of peak shaving achievable in these months, for each of the three BESS units considered.

Table 11. Peak Shaving Capability for Summer Months for the Potential BESS Units Studied

(a) Month	(b) Peak Shave Case	(c) 0.5 MW, 0.75 MWh Unit	(d) 1.0 MW, 2.20 MWh Unit	(e) 2.0 MW, 13.9 MWh Unit
		Achievable Peak Shaving		
May 18		0.5 MW	1.0 MW	2.0 MW
June 18		0.38 MW	0.72 MW	1.85 MW
July 18		0.48 MW	0.69 MW	1.62 MW
Aug 18		0.27 MW	0.43 MW	1.37 MW
Sept 18		0.5 MW	1.0 MW	2.0 MW
Oct 18		0.5 MW	1.0 MW	2.0 MW
May 19		0.26	0.55	1.74
June 19		0.32	0.47	1.40
July 19		0.39	0.76	1.69
Aug 19		0.50	0.93	1.85
Sept 19		0.42	0.80	2.00
Oct 19		0.50	1.00	2.00

4.3 Summary of Projected Savings

Based on the analysis above, the 0.5-MW and 1.0-MW peak shaving systems are the most practical sizes. For the 0.5 MW system, a battery capable of delivering 0.75 MWh to the AC bus would be a good choice. This system would have been able to provide 0.5 MW of peak shaving in 9 of the 2018 months, with reduced levels in the remaining months. For the 1 MW system, a 2.20 MWh unit would have been able to deliver 1 MW of peak reduction in 8 of the 12 months of 2018. As discussed, the actual volt-amp (VA) rating for the ac output of the BESS would need to be greater than the 0.5 and 1.0 MW of peak shaving capability that is envisioned.

The BESS benefits that are unique to New York State's municipal electric departments are the savings from allocation shifting. The per MWh savings due to allocation shifting are difficult to predict, as the market rate (firm incremental energy) purchases depend on the real-time market prices in the zone where the electric department (ED) resides. In order to provide a conservative yet realistic estimate of future savings, the monthly average savings in 2018–2019 were computed in two ways: (1) from the monthly invoices and (2) from the monthly average of the NYISO time weighted integrated hourly energy cost. These numbers are reasonably consistent. In the following analysis, method (2) numbers are used. These values for the firm incremental energy were reduced by the rate for firm hydro energy, $4.92 per MWh to get the incremental benefit from moving energy consumption from the market rate to the firm hydro rate. Also, the real-time rate in January of 2018 ($61.83) was considered to be unusually high. A value of $25 per MWh was used in Tables 5 and 6 to avoid being unrealistically optimistic in these estimates.

Additionally, for LPVED, the NYPA rate for demand is $4.07 per kW when the peak demand is less than the NYPA allocation. There is no additional charge for demand above the firm hydro rate.

Table 12. Predicted 2018 Savings from Installing an 0.75 Megawatt-Hours BESS with Capability to Provide 0.5 Megawatt of Peak Shaving

Note about the day-ahead and real-time market: The number of days that real-time market can apply is adjusted accordingly.

(a) Month	(b) Peak Shaved (MW)	(c) MWh's Shifted	(d) Per MWh Value	(e) Monthly Benefit, Allocation Shifting	(f) Demand Savings in Months below Allocation	(g) Estimated Potential for Saving from Market Rate Purchase Optimization	(h) Total Projected Annual Benefit
January	0.5	141	$25.00	$3525			
February	0.5	157	$15.65	$2457			
March	0.5	195	$15.04	$2933			
April	0.5	243	$22.99	$5586			
May	0.5				$2035		
June	0.38				$1547		
July	0.48				$1954		
August	0.27				$1099		
September	0.5				$2035		
October	0.5				$2035		
November	0.5	156	$25.71	$4011			
December	0.5	206	$20.48	$4219			
Total				$22731	$11641	$1875	$36247

National Grid wheels the NYPA power to the LPVED meter point. National Grid assesses a charge for each MWh transported. The per MWh rate varies by billing cycle. As the BESS will shift the daily energy consumption pattern but will have negligible impact on the total amount of energy consumed, the National Grid wheeling charges are not a factor in these evaluations.

Tables 12 and 13 show the predicted benefits of the 0.5-MW peak shaving and 1.0-MW peak shaving cases, respectively. Column e shows the monthly and annual savings from allocation shifting. Column f shows the projected savings from demand reduction in those months where the allocation is not exceeded. Column h shows the project annual savings of $36,247 per year for the 0.5-MW peak shaving case and $69,476 per year for the 1.0 MW peak shave case. In the next section, these benefits will be compared with cost data for the BESS installations.

Table 13. Predicted 2018 Savings from Installing a 2.20 Megawatt-Hours BESS with Capability to Provide 1.0 Megawatt of Peak Shaving

Note about the day-ahead and real-time market: The number of days that real-time market can apply is adjusted accordingly.

(a) Month	(b) Peak Shaved (MW)	(c) MWh's Shifted	(d) Per MWh Value (per Method 2)	(e) Monthly Benefit, Allocation Shifting	(f) Demand Savings in Months Below Allocation	(g) Estimated Potential for Saving from Market Rate Purchase Optimization	(h) Total Projected Annual Benefit
January	1.0	284	$25.00	$7100			
February	1.0	318	$15.65	$4977			
March	1.0	396	$15.04	$5956			
April	1.0	494	$22.99	$11357			
May	1.0				$4070		
June	0.72				$2930		
July	0.69				$2808		
August	0.43				$1750		
September	1.0				$4070		
October	1.0				$4070		
November	1.0	315	$25.71	$8099			
December	1.0	417	$20.48	$8540			
Total				$46028	$19698	$3750	$69476

4.4 Cost Analysis: Lake Placid Village Electric Department

The BESS system costs were analyzed for the two options identified in the previous section. The analysis is based on BESS cost data from the International Renewable Energy Agency for the reference case [2].

- Factors considered:
  - Annual maintenance rate: 1.5%
  - Interest rate: 3%
  - Energy efficiency depends on type of battery and the year
  - Power conversion efficiency: 98%
  - Self-discharge: Small and can be ignored
  - Depth of discharge (DoD): Depends on the technologies

- The annuity is calculated as follows:

$$\textit{Annualized(Present Value)} = \textit{Present Value} \times \frac{i}{(1-(1+i)^{-n})\times(1+i)}$$

Total Annuity = Annualized(Cost_Storage) + Annualized(Cost_PowerConv) + Maintenance + Loss

Loss in this case is converted to 5 cents/kWh and is also accounted with day-ahead market cost

The analysis provides costs for five battery technologies:

- Lithium nickel manganese cobalt oxide (NMC)
- Lithium iron phosphate (LFP)
- Sodium sulfur (NaS)
- Flooded lead acid (FLA)
- Valve regulated lead acid (VRLA)

Data is presented in Figures 11-13 based on the year that the unit would be installed. The figures include investment cost, lifetime and annualized cost of the installation over its projected lifetime.

4.4.1 Option 1: 0.5 Megawatt and 0.75 Megawatt-Hours

The data predicts that the NaS and FLA technologies will have the lowest cost over the next decade, with the NMC approaching FLA in annualized costs around 2030. Comparing the costs of Figure 13 with the benefits of $36,247 (Table 12), several battery options would be at the break-even point for a current installation. By 2025, most battery technologies would be comfortably below the predicted benefit of $36,247 for 2018. It would be useful to predict future benefits in making an investment decision.

Figure 11. Investment on Energy Storage and Power Conversion Units—0.5-Megawatt Case

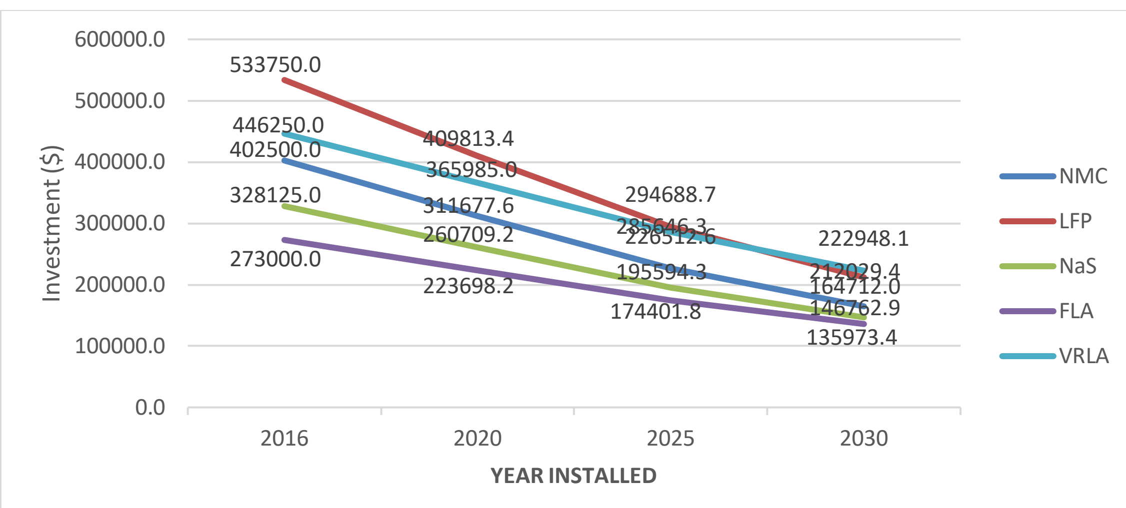


Figure 12. Battery Lifetime

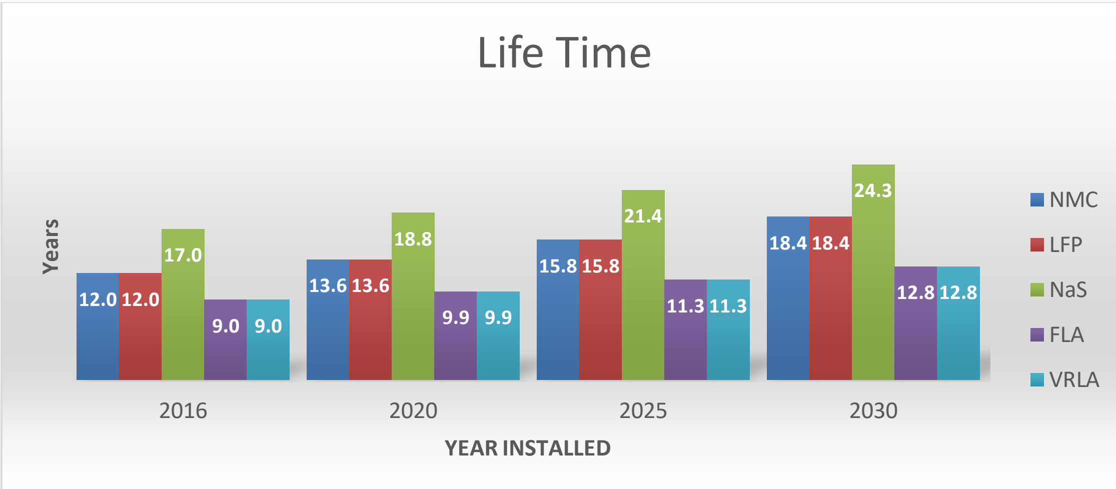
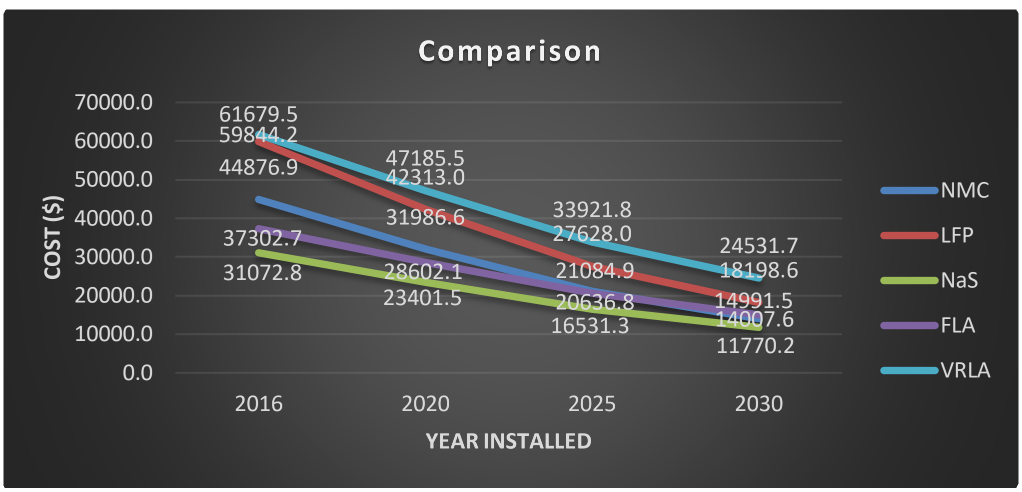


Figure 13**. Annualized Cost Comparison among Storage Technologies for the 0.5-Megawatt Peak Shaving Scenario**

The annual cost refers to the annualized value of the life cycle of the BESS. The factors considered are DoD, efficiency, interest rate, and maintenance rate.



4.4.2 Option 2: 1 Megawatt and 2.2 Megawatt-Hours

For option 2, the predicted annual benefit of 2018 is nearly $70,000. Figure 13 shows that the NaS unit would have a predicted annualized cost of $65,000 if installed in 2020 making the unit cost-effective if installed now. The cost of this unit is predicted to drop to $46,000 by 2025, making this installation much more cost-effective at that point in time.

4.5 Summary

The results show that the installation of a BESS system in Lake Placid Village Electric Department merits further investigation. Both the 0.5 MW and 1.0 MW units show the potential for significant cost saving at present and increasing benefits in the near future as battery technology continues to improve and costs decline. It is recommended that future benefits of the system be conducted, based on predictions of Lake Placid's demand growth, cost of capital, BESS peak shaving capability, load shape, and future energy costs.

Figure 14. Investment on Energy Storage and Power Conversion Units

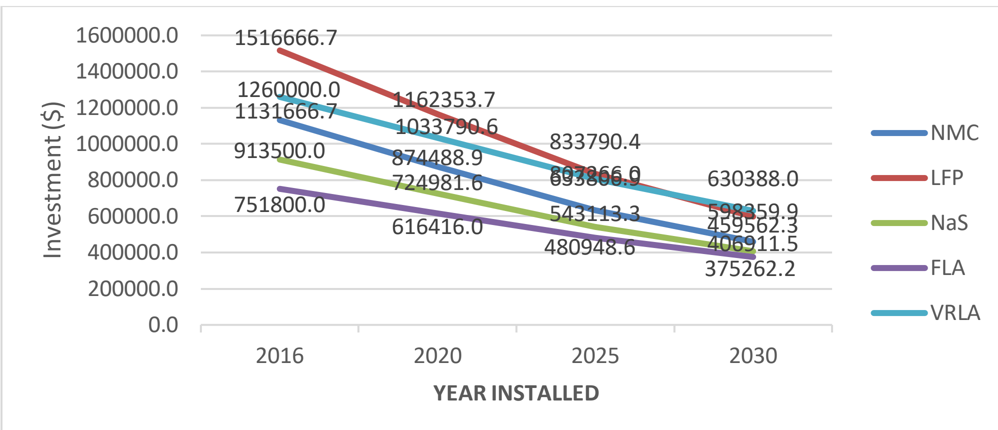
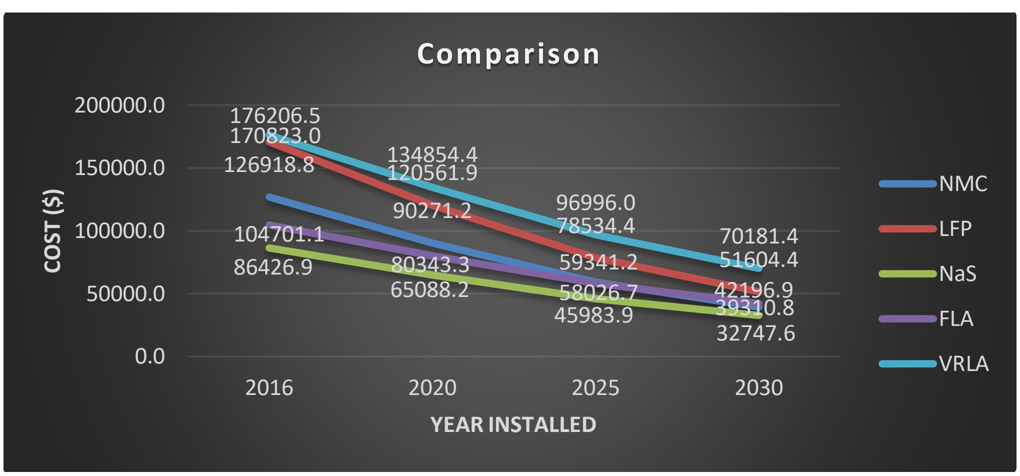


Figure 15. Annualized Cost Comparison among Storage Technologies for the 1.0-Megawatt Peak Shaving Scenario

The annual cost refers to the annualized value of the life cycle of the BESS. The factors considered are DoD, efficiency, interest rate, and maintenance rate.



IRENA (2017), Electricity Storage and Renewables: Costs and Markets to 2030, International Renewable Energy Agency, Abu Dhabi.

5 Energy Storage Peak Shaving Feasibility for Massena Electric Department

This section analyzes the use of battery energy storage systems (BESS) to save costs for the Massena Electric Department (MED). MED receives a NYPA allocation based primarily on hydro generation. It pays for this energy, along with demand-based charges. When the allocation is exceeded, MED purchases energy on the open market at rates that are generally substantially higher than the allocation rates. It also can pay the transmission owners a fee to move the power to their department.

This study in general analyzes three ways that BESS can be used to save costs to the departments:

1. Peak shaving during times when the load is above allocation to increase the allocation allotment.
2. Optimizing market rate purchases. When MED load is above allocation for extended periods, buying energy to store in the BESS from the day-ahead market when energy prices are low, and discharging the BESS during high-cost periods will result in cost savings.
3. Massena Electric Department receives the majority of its power directly from NYPA. For this service, it is billed at a rate of $300 per MW of the weekly maximum demand. It also assessed an Incremental UCAP (unforced capacity) charge, based on the peak demand during the annual peak period as defined by NYISO. This is billed monthly at a variable rate in the range of around $1.30 per kW, based on a demand of 3600 kW during the 2019 billing cycle.

5.1 Study Assumptions

- The peak shaving portions of the study were conducted based on the actual demand reduction achieved by the BESS installation. Note that the BESS real power output and the BESS inverter apparent power rating will need to be higher than the corresponding level of demand reduction—perhaps 20–40% higher—due to errors in the load forecasting process, system losses, allowance for VARs delivered to the AC bus, etc.
- The study assumes that the BESS system will have real-time access to the power drawn by MED, and that the BESS only delivers sufficient power to clamp the power draw at the peak value over the course of each hourly period when the total demand is above the targeted peak level. This will result in a significant reduction in the battery energy required, as compared to BESS units which deliver rated power throughout a discharge period.
- The energy purchased within the NYPA firm hydro allocation is at a base cost of $4.92 per MWh. The energy purchases above the allocation are made at the NYISO hourly time weighted real-time market rate. As this rate fluctuates by hour, exact cost savings can only be calculated after the fact.

- Note that the municipal departments are billed for additional charges by NYPA. These charges include the NYISO charges and the Clean Energy Standard (CES) charges. The CES charges are the same, regardless if the energy received is at the firm hydro rate or the market rate. The NYISO charges are not broken out by MW or MWh. These additional charges are not considered further in this analysis.

5.2 BESS Energy Analysis—Massena Electric Department

5.2.1 Months with Peak Load above the Allocation

The Massena Electric Department (MED) NYPA firm hydro allocation was 23.556 MW in 2018. MED also has a 0.107 MW firm peaking allocation. Due to the small size of this firm peaking allocation and the fact that it is given at an assumed monthly load factor of 12.5%, MED is not considered further in this study. In 2018, MED exceeded its allocation during all twelve months of the year. In 2019, it exceeded the allocation in 11 of the 12 months.

5.2.2 Peak Shaving to Increase Allocation

As discussed above, when MED exceeds its 23.556 allocation in a given month, the hydro energy available for purchase in each hour of the month is reduced by an adjustment (firm hydro load share percentage) factor, calculated as

Equation 3. $$\frac{MW\ firm\ hydro\ allocation}{MED\ monthly\ MW\ Peak\ Demand}$$

If the monthly peak demand can be reduced, this factor will increase, and MED will qualify for increased purchases of hydro energy during the month.

In this study, the impact of reducing peak demand by 0.5, 1 MW, and 2 MW is considered. The 2018 monthly study results are given in Table 14. Table 14 shows the firm hydro MWh and market MWh purchases for each month for four cases: no peak shaving and 0.5, 1.0, and 2.0 MW of peak shaving. For each level of peak shaving, the net benefit of the peak shaving is shown in column e. This is the increase in firm hydro purchases that results from the peak shaving. The peak battery energy required during the month to meet the corresponding level of peak shaving is shown in column f.

Table 15 provides an annual summary of the peak shaving for the year of 2018. The table shows that a BESS unit providing 0.5 MW of peak saving in each month of 2018 would be required to have an energy rating of 1.2 MWh. This unit would increase the MWh of firm hydro purchased by 2245 MWh during

2018. Table 15 also includes a summary for 2019. In 2019, the required BESS energy ratings were a bit below what was required in 2018. The energy shifting numbers were similar to 2018. It would be desirable to analyze more years to determine if other years also show results consistent with 2018 and 2019.

To achieve 1.0 MW of peak shaving, the BESS would need to be sized to deliver just over 3.9 MWh to its AC bus to provide this capability in 2018. This size unit is predicted to shift 4559 MWh from market rate to the firm hydro rate in 2018.

In order to achieve 2.0 MW of peak shaving, the BESS unit would need to be increased in size by over a factor of 3, to 12.62 MWh, while doubling the number of MWh that would be shifted to the firm hydro rate.

These numbers are based on a BESS system that operates at variable power output while peak shaving, in order to clamp the metered power flow to a constant value a predicted level below the expected peak value.

Table 14. BESS 2018 System Monthly Requirements Needed to Achieve Savings due to Peak Shaving

Battery energy ratings given deliverable to the AC bus.

(a) Month	(b) Peak Shaved (MW)	(c) Firm Hydro Purchases (MWh)	(d) Market Purchases (MWh)	(e) MWh of Peak Shaving Benefit	(f) BESS Energy Required (MWh)	(g) Peak Monthly Demand (MW)
Jan	0.0	12778	13487			48.4
	0.5	12911	13354	133	0.93	
	1.0	13047	13218	269	2.03	
	2.0	13328	12936	550	5.92	
Feb	0.0	11754	8592			40.8
	0.5	11901	8446	146	1.78	
	1.0	12050	8297	296	3.84	
	2.0	12361	7986	606	8.84	
March	0.0	13310	7121			36.2
	0.5	13496	6935	187	0.50	
	1.0	13688	6743	379	1.08	
	2.0	14089	6342	779	4.26	

Table 14 continued

(a) Month	(b) Peak Shaved (MW)	(c) Firm Hydro Purchases (MWh)	(d) Market Purchases (MWh)	(e) MWh of Peak Shaving Benefit	(f) BESS Energy Required (MWh)	(g) Peak Monthly Demand (MW)
April	0.0	12745	4796			32.8
	0.5	12942	4796	197	1.23	
	1.0	13146	4592	401	4.02	
	2.0	13573	4165	828	16.00	
May	0.0	12259	570			24.7
	0.5	12513	317	253	1.52	
	1.0	12778	52	518	4.50	
	2.0	12830	0	570	13.93	
Jun	0.0	11460	1806			27.3
	0.5	11674	1592	214	1.60	
	1.0	11897	1369	436	4.50	
	2.0	12367	899	907	12.46	
Jul	0.0	12286	3769			30.8
	0.5	12489	3567	203	1.28	
	1.0	12699	3357	413	3.10	
	2.0	13140	3357	854	11.14	
Aug	0.0	11866	3895			31.3
	0.5	12058	3702	193	0.93	
	1.0	12257	3503	392	2.93	
	2.0	12676	3085	810	8.10	
Sep	0.0	10226	3070			30.6
	0.5	10396	2900	170	1.36	
	1.0	10571	2723	345	3.89	
	2.0	10941	2356	714	11.12	
Oct	0.0	12930	2258			28.1
	0.5	13164	2258	234	1.00	
	1.0	13407	2015	477	2.09	
	2.0	13921	1501	991	8.10	
Nov	0.0	12072	7504			38.2
	0.5	12232	7344	160	0.52	
	1.0	12396	7180	325	1.86	
	2.0	12739	6837	667	5.57	
Dec	0.0	13783	9353			39.6
	0.5	13960	9176	177	1.14	
	1.0	14141	8995	358	2.64	
	2.0	14518	8618	734	7.40	

5.2.2.1 Optimizing Market Rate Purchase

In days when MED's demand exceeds their allocation, the opportunity exists to charge the BESS during low-energy cost periods and discharge the battery during high-cost periods. This service could be conducted on days when the monthly peak or weakly peak would not be established. A study of the 2018 North Zone Day-Ahead market prices showed an average hi/lo price difference of around \$25 per MWh, with a range from \$0 to \$100 per MWh. A study of the 2019 Real-Time North Zone Market showed that, on average, the weighted average hourly real-time price was around \$45 per MWh, with a range of \$0 to \$1300 per MWh. The potential future savings from market-rate purchases of a BESS installation would depend on operating strategy and future market conditions.

For this study, a conservative annual savings estimate of \$7500 per MW BESS power rating is used. This is based on the BESS unit operating at rated power for one hour of charge and one hour of discharge for 300 days in the year, with an average savings of \$25 per day.

Table 15. Summary of MED Results for the Year 2018 and 2019

BESS Peak Shaving Power Capability		0.5 MW	1.0 MW	2.0 MW
BESS System Delivered Energy Required	2018	1.80MWh	4.50 MWh	16.00 MWh
Energy Shifted from Market Rate to Hydro Allocation		2267 MWh	4609 MWh	9010 MWh
BESS System Delivered Energy Required	2019	1.05 MWh	4.08 MWh	14.9 MWh
Energy Shifted from Market Rate to Hydro Allocation		2181	4435	8478

5.2.3 Peak Shaving to Reduce Demand Charges

If MED were to use a BESS system to successfully reduce peak demand during the annual peak demand period, it would save $1.69 per kW of reduction attained, for each month of the year. If it use a BESS to reduce the weekly peak demand, MED would save $0.30 per kW per week for this reduction. The potential savings on these charges are given in Table 16, assuming the BESS system would achieve its design peak reduction.

Table 16. Potential 2018 Annual Savings from Reducing the Peak Charges for UCAP Demand Services

Peak Demand Reduction Provided	Annual Savings, Weekly Demand Charges	Annual Saving, Incremental UCAP charges	Total Annual Savings, Transmission Charges
0.5 MW	$7800	$7080	$14880
1.0 MW	$15600	$14160	$29760
2.0 MW	$31200	$28320	$59520

5.3 Summary of Projected Savings

The BESS benefits that are unique to New York State's municipal electric departments are the savings from allocation shifting. The per MWh savings due to allocation shifting are difficult to predict, as the market rate (firm incremental energy) purchases depend on the real-time market prices in the zone where the electric department (ED) resides. In order to provide a conservative yet realistic estimate of future savings, the monthly average savings in 2018–2019 were computed in two ways: (1) from the monthly invoices and (2) from the monthly average of the NYISO time weighted integrated hourly energy cost. These numbers are reasonably consistent. In the following analysis, method 2 numbers are used. These values for the firm incremental energy were reduced by the rate for firm hydro energy, $4.92 per MWh, to get the incremental benefit from moving energy consumption from the market rate to the firm hydro rate. Additionally, the real-time rate in January of 2018 ($61.83) was considered to be unusually high. A value of $25 per MWh was used in Tables 17 and 18 to avoid being unrealistically optimistic in these estimates.

Table 17 and 18 show the predicted benefits of the 0.5-MW peak shaving and 1.0-MW peak shaving cases, respectively. Column e shows the monthly and annual savings from allocation shifting. Column f shows the projected savings from peak shaving to reduce the weekly demand and UCAP demand costs.

Column h shows the project annual savings, of $55,826 per year for the 0.5-MW peak shaving case, and $112,800 per year for the 1.0 MW peak shave case. In the next section, these benefits will be compared with cost data for the BESS installations.

Table 17. Predicted 2018 Savings from Installing a 1.80-Megawatt-Hours BESS with Capability to Provide 0.5 Megawatt of Peak Shaving

Note about the day-ahead and real-time market: The number of days that real-time market can apply is adjusted accordingly.

(a) Month	(b) Peak Shaved	(c) MWh's Shifted	(d) Per MWh Value	(e) Savings from Allocation Shifting	(f) Savings from Weekly Demand and UCAP Demand Reductions	(g) Estimated Savings from Market Rate Purchase Optimization	(h) Total Projected Annual Benefit
Jan	0.50MW	133	$25.00	$3325			
Feb	0.50MW	146	$15.65	$2285			
Mar	0.50MW	187	$15.04	$2812			
Apr	0.50MW	197	$22.99	$4529			
May	0.50MW	253	$4.39	$1111			
Jun	0.50MW	214	$0.00	$0			
Jul	0.50MW	203	$19.35	$3928			
Aug	0.50MW	193	$24.21	$4673			
Sep	0.50MW	170	$19.80	$3366			
Oct	0.50MW	234	$14.65	$3428			
Nov	0.50MW	160	$25.71	$4114			
Dec	0.50MW	177	$20.48	$3625			
Total				$37196	$14880	$3750	$55826

Table 18. Predicted 2018 Savings from Installing a 3.9-MWh BESS with Capability to Provide 1.0 MW of Peak Shaving

(a) Month	(b) Peak Shaved	(c) MWh's Shifted	(d) Per MWh Value	(e) Savings from Allocation Shifting	(f) Savings from Weekly Demand and UCAP Demand Reductions	(g) Estimated Savings from Market Rate Purchase Optimization	(h) Total Projected Annual Benefit
Jan	1MW	269	$25.00	$6725			
Feb	1MW	296	$15.65	$4632			
Mar	1MW	379	$15.04	$5700			
Apr	1MW	401	$22.99	$9219			
May	1MW	518	$4.39	$2274			
Jun	1MW	436	$0.00	$0			
Jul	1MW	413	$19.35	$7992			
Aug	1MW	392	$24.21	$9490			
Sep	1MW	345	$19.80	$6831			
Oct	1MW	477	$14.65	$6988			
Nov	1MW	325	$25.71	$8356			
Dec	1MW	358	$20.48	$7332			
Total				$75539	$29760	$7500	$112800

Note about the day-ahead and real-time market: The number of days that real-time market can apply is adjusted accordingly.

5.4 Cost Analysis: Massena Electric Department

The BESS system costs were analyzed for the two options identified in the previous section. This analysis is based on BESS cost data from the International Renewable Energy Agency for the reference case [2].

- Factors considered:
  - Annual maintenance rate: 1.5%
  - Interest rate: 3%
  - Energy efficiency depends on type of battery and the year
  - Power conversion efficiency: 98%
  - Self-discharge: Small and can be ignored
  - Depth of discharge (DoD): Depends on the technologies
- The annuity is calculated as follows:

$$\textit{Annualized(Present Value)} = \textit{Present Value} \times \frac{i}{(1-(1+i)^{-n})\times(1+i)}$$

Total Annuity = Annualized(Cost_Storage) + Annualized(Cost_PowerConv) + Maintenance + Loss

Loss in this case is converted to 5 cents/kWh and is also accounted with day-ahead market cost

The analysis provides costs for five battery technologies:

- Lithium Nickel Manganese Cobalt Oxide (NMC)
- Lithium Iron Phosphate (LFP)
- Sodium Sulfur (NaS)
- Flooded Lead Acid (FLA)
- Valve Regulated Lead Acid (VRLA)

Data is presented in Figures 16–20 based on the year that the unit would be installed. The figures include investment cost, lifetime and annualized cost of the installation over its projected lifetime.

5.4.1 Option 1: 0.5 Megawatt and 1.8 Megawatt-Hours

The data predicts that the NaS and FLA technologies will have the lowest cost over the next decade, with the NMC approaching FLA in annualized costs around $26,000 by 2030. Comparing the costs of Figure 18 with the benefits of Table 17, the NaS unit would be at breakeven for a 2020 installation. By 2025, several battery technologies would be comfortably below the predicted benefit of $55,826 for 2018 (Table 17). It would be useful to predict future benefits in making an investment decision.

Figure 16. Investment on Energy Storage and Power Conversion Units: 05.0-Megawatt Peak Shaving Case

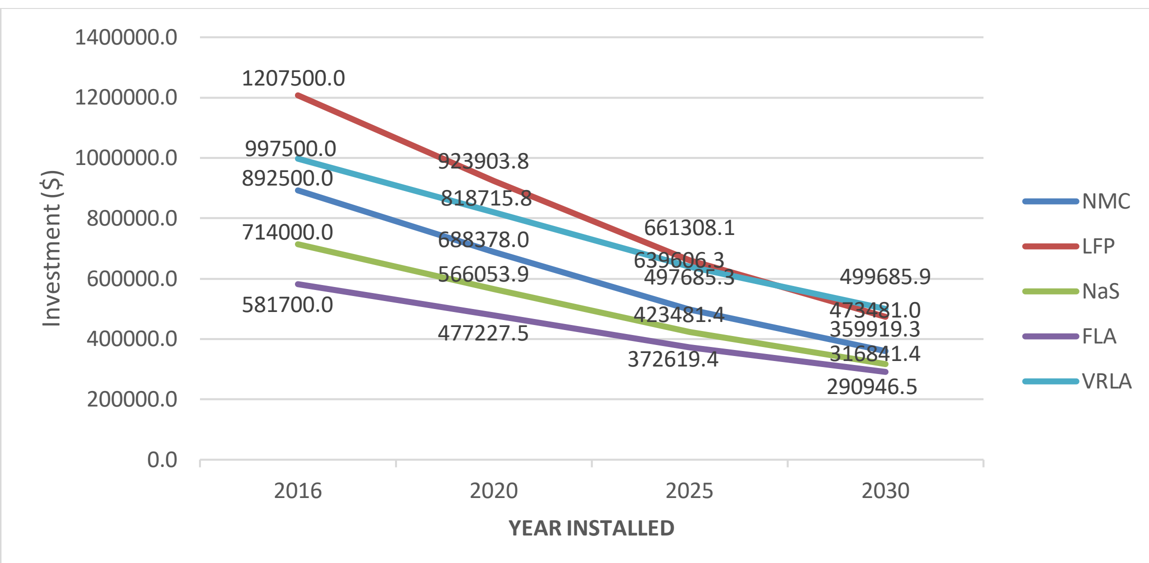


Figure 17. Battery Lifetime

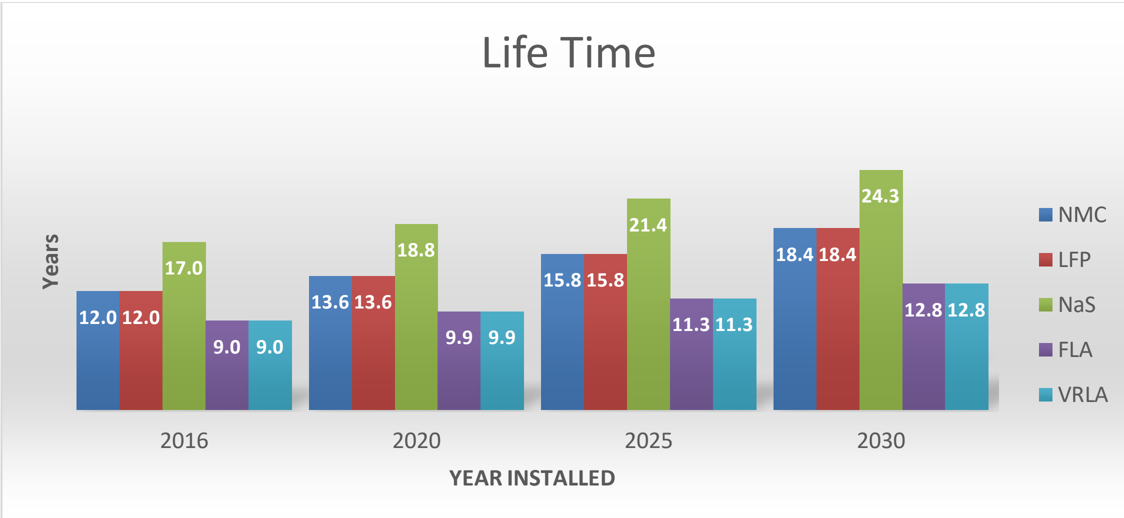
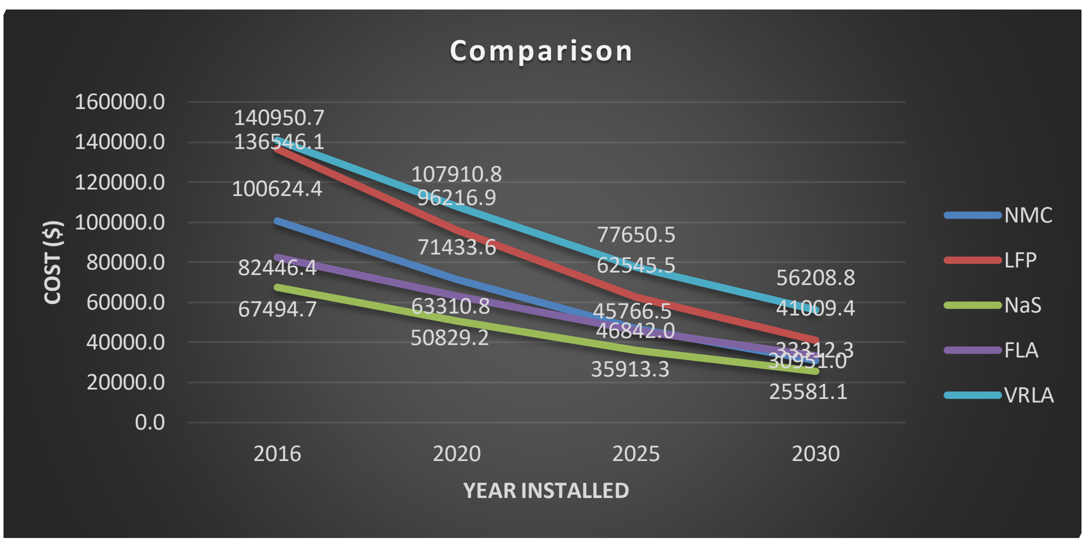


Figure 18. Annual Cost Comparison among Storage Technologies: 0.50-Megawatt Peak Shaving Case

The annual cost refers to the life cycle of the battery. The factors considered are DoD, efficiency, interest rate, and maintenance rate.



Option 2: 1 Megawatt and 3.9 Megawatt-Hours

For option 2, the predicted annual benefit of 2018 is just over $110,000. Figure 20 shows that the NaS unit would have a predicted annualized cost of $109,495 if installed in 2020, making the installation near the break-even point. The cost of this unit is predicted to drop to $77,364 by 2025, and $55,108 in 2030, making this option increasingly more cost-effective at that point in time.

5.5 Summary

The results show that the installation of a BESS system in the Massena Electric Department merits further investigation. Both the 0.5-MW and 1.0-MW peak shaving units show nearly equal costs and benefits now. Decreasing BESS cost in the near future will provide opportunities for significant benefits. It is recommended that future benefits of the system be conducted, based on predictions of Massena's demand growth, cost of capital, load shape, and future energy costs.

Figure 19. Investment on Energy Storage and Power Conversion Units

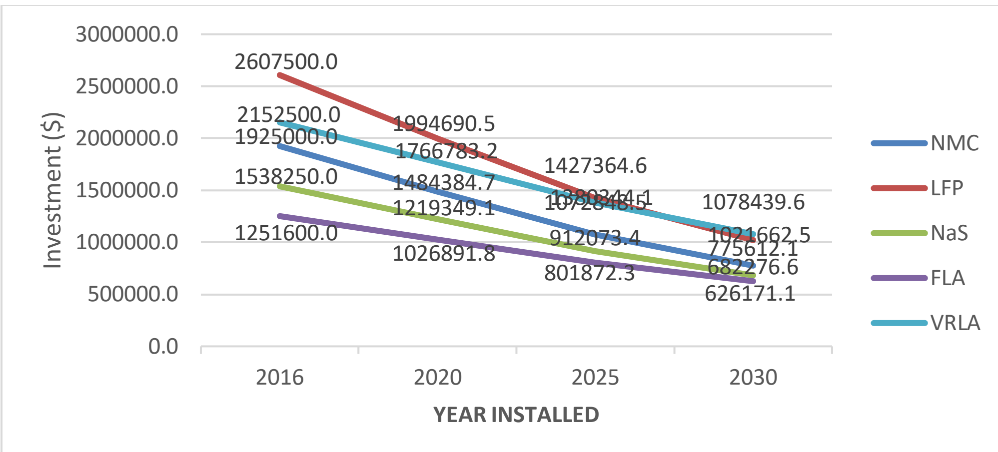
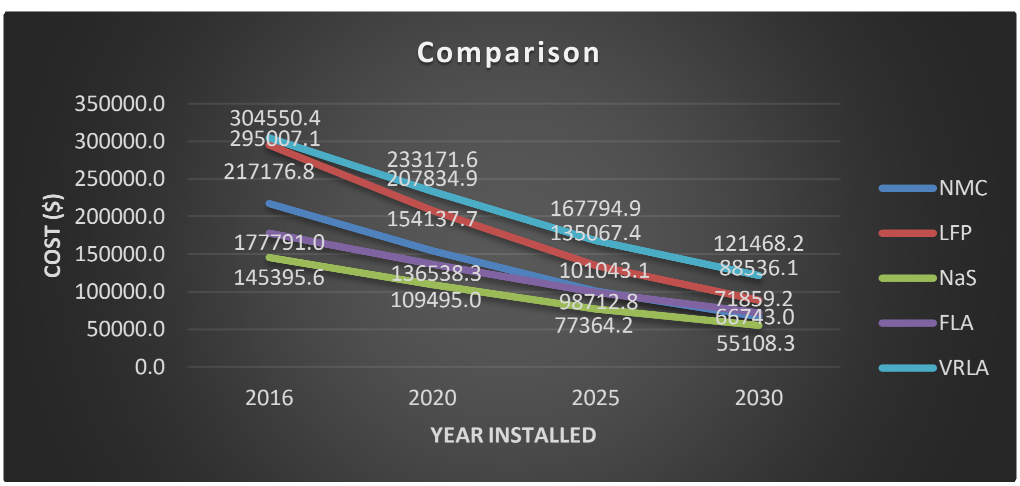


Figure 20. Annual Cost Comparison among Storage Technologies

The annual cost refers to the life cycle of the battery. The factors considered are DoD, efficiency, interest rate, and maintenance rate.



IRENA (2017), Electricity Storage and Renewables: Costs and Markets to 2030, International Renewable Energy Agency, Abu Dhabi.

6 Direct Control Demand Response

This project includes an assessment of direct control demand response as an alternative to the installation of a BESS system. In the EDs involved in this study, direct control demand response would most commonly be applied to electric heat and hot water systems in residential consumers and to chillers, pumps, zonal HVAC systems, and lighting in large commercial and industrial consumers.[1]

At present, Massena Electric Department (MED) has a residential direct load control water heater program in place as well as a conservation voltage reduction program. Both Tupper Lake (TLMED) and Lake Placid (LPVED) have investigated residential direct load control of hot water heaters, and do not view these as viable alternatives at this point. This is primarily due to the cost of installation and cost and complexity of maintenance for the communications and control systems that would be involved.

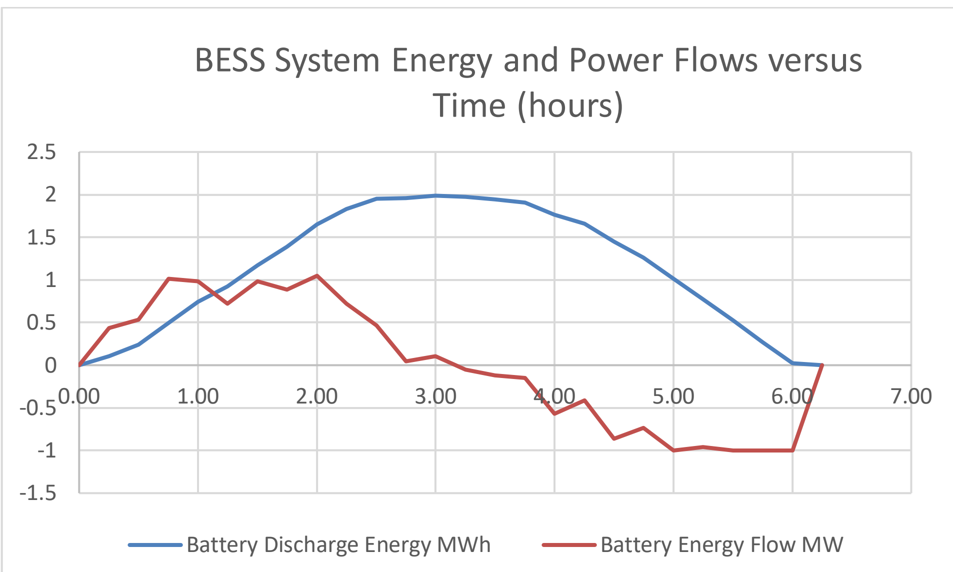
In Lake Placid, there is a large commercial facility which has potential use for peak shaving by direct load control of its ice making plant. This plant is rated in the MW range. In a previous section, the benefits of a 1 MW peak reduction are determined for a BESS system. These benefits would be similar for a 1 MW peak reduction from direct load control of the ice making equipment. However, further study would be needed to determine the feasibility of interrupting this load for required durations in each of the billing periods of a given year. If this is not possible, the resulting benefit would be reduced. Costs of these systems include communication equipment and installation, control equipment and installation, customer recruitment and incentives, and electric district operating costs. Historically, many occasional (used a few times a year) direct control, demand response systems involved operator action to initiate. Currently, for this type of system, particularly those with increased operations per year, fully automated systems are becoming preferred. Fully automated systems have the potential to reduce operating costs and increase reliability. Smart meter technology can impact the overall cost of these systems, particularly in cases where the meters and communications equipment are already in place for other reasons. The vintage and number of discrete pieces of equipment to be controlled will also have a significant impact on costs.

Lawrence Berkeley National Lab[10] analyzes several field studies for similar systems and shows a wide range of project costs. The study found that "median costs are about $200/kW with more than a factor of 10 difference in minimum and maximum costs from the field data." A National Rural Electric Cooperative Association report[11] also documents costs of implementing demand response.

Consider LPVED's projected savings of $69,476 per year based on a project that consistently realizes 1 MW of peak shaving capability each month, deferring up to 2.2 MWh of energy consumption to off peak periods. Note that this energy level is determined for a battery system capable of adjusting its discharge rate to maintain the meter point loading at the desired peak value. The discharge and charge cycle for one of the high energy events is shown in Figure 21. This figure shows an event that starts at hour 0 and discharges the battery at a variable rate for 3.25 hours. There is then a period of 1.75 hours when the demand response (DR) equipment can only consume a portion of the 1 MW rated power of the system. In this case, full power of the system could be resumed at hour five. The direct control demand response equipment may not have the capability to follow this demand curve.

Figure 21. Discharge Energy and Power Curves for a Peak Shaving Event that Requires 2.9 Megawatt-Hours of Energy Storage

Taken at a variable rate to maintain a constant power flow at the meter point.



Assume a 20-year project life, 3% cost of capital and $35,000 annual cost for operating and customer incentive. With the annual benefit of $69,476 predicted for this installation, a project installed cost $513,000 would provide breakeven. This is equivalent to $513 per kW for this 1 MW project.

7 Interconnection Assessment

The New York State Public Service Commission published New York State Standardized Interconnection Requirements and Application Process for New Distributed Generators and Energy Storage Systems 5 MW or Less Connected in Parallel with Utility Distribution Systems (SIR) in December 2019. This document provides a framework for the interconnection requirements for both Distributed Generation and Battery Energy Storage Systems connected in parallel with utility distribution systems and located on the customer side of the point of common coupling. National Grid follows this document on their distribution system. It is expected that the municipal departments also follow the SIP.

In addition, National Grid established Electric System Bulletin No. 756, Supplement to Specifications for Electrical Installations: Requirements for Parallel Generation Connected to a National Grid owned EPS. Bulletin 756 covers transmission, sub-transmission, and distribution. National Grid's PSC220 Electricity Tariff defines the municipal electric departments as "municipal utilities." However, this term does not appear in Bulletin 756. It can be assumed, however, that National Grid would expect to be informed of changes on the Tupper Lake or Lake Placid ED's that involve the Standardized Interconnection Requirements on those distribution systems. The same is expected of other utilities that provide wheeling of NYPA hydro power to other municipal utilities.

Additionally, NYISO has a draft Manual 23 Transmission and Interconnection Manual, currently available for comments. This manual applies to proposed transmission projects, therefore does not appear to apply for this distribution project.

The SIP document provides a comprehensive set of requirements within the range of applications covered in this report. However, it does not exactly match the situation for the battery installations considered as these three electric departments own and operateg their distribution system as well as own and operate the proposed BESS. These departments would be concerned with managing any impacts of the BESS on their system.

There are four primary concerns in connecting a BESS of this size to a distribution system:

- Steady-state voltage
- Maintaining effective grounding and avoiding temporary overvoltage
- Providing anti-islanding control
- Maintaining safe and effective fault sensing and clearing

A comprehensive list with potential issues over the full range of DER interconnection is listed in Bulletin 756.

The SIR provides a preliminary screening tool in appendix G and encourages all applicants to follow the screening process. To pass screening, the BESS inverter is required to meet the standard UL 1741. In the simplified penetration test of Screen 3, the BESS must have a power rating less than 15% of the minimum load on the network, and less than 50% of the minimum load on the transformer(s) in the area. In Screen C, it must be demonstrated that the installation does not cause any of the power system components to exceed their ratings. The one caution here is that the BESS transformer does not cause significant increases in ground fault current as a result of its winding and grounding configurations. Screen D involves effective grounding. For the three phase four wire line configuration of these systems, the result would be Fail, with the statement “To pass aggregate DER AC Nameplate rating must be less than or equal to 10% of the line section peak load.” If this ratio is met and with proper phase balancing, the screen would Pass. Screen E involves load levels beyond an upstream automatic sectionalizing device. Screen F involves short circuit capacity and requires a short circuit capacity of greater than 25 times the BESS power rating. Again, this would be readily met due to the relatively small size of the proposed installations.

Of the Supplemental Screening Analysis, Screen I (Operating Limits, Protection Adequacy and Coordination Evaluation requires that several design criteria are met, as would be the case with a well-designed system.

7.1 Specifics for Tupper Lake, Lake Placid, and Massena Electric Districts

7.1.1 Location of a Potential BESS System

The location of a BESS system on the respective distribution system was discussed with all three ED’s. None of them experience voltage issue on their systems, as could be expected for these geographically compact service territories. As a result, the capability of a BESS smart inverter to regulate voltage would not benefit these departments. Similarly, they do not have line overloading issues on their systems where a BESS could add value by alleviating the problem(s).

As a result, the preferred location for a BESS installation is at the ED's primary substation. The following list identifies the benefits for installation at the primary station:

- The site is already owned by the municipality and already accommodates high-power equipment.
- The site is a center of activity for the ED and generally hosts the department's SCADA system.
- The NYPA revenue meters at the point of common coupling are on the high side of the substation transformer. The electric district's power and energy meters will be at this location as well.
- The BESS system could be fed directly from the substation bus. It could therefore be directly controlled to operate only when the substation transformer is in service, so that it would rely on the substation transformer to maintain effective grounding. This would also eliminate the possibility of an unintentional island forming the ED's distribution network.
- A BESS connected at the bus would have no impact on the feeder protection systems.
- Depending on the design, the BESS installation should cause no significant increase on fault currents for balanced or unbalanced faults.

7.2 Application of BESS Smart Inverter Settings

Settings to Satisfy SIR Requirements

A number of the IEEE 1547-2018 smart inverter settings will result from the SIR process. In particular, the fault ride through and anti-islanding settings will likely come from this process and could be mandated by the transmission provider.

Based on the discussion above, it is recommended that the inverter be operated in the unity power factor mode. It is also recommended that the inverter only be allowed to operate when the substation transformer low-side circuit breaker is closed.

Inverter Controls that Go Beyond IEEE 1547-2018

As discussed in previous chapters, the BESS installations studied in this report rely on two controls in order to achieve the level of benefits reported:

- Load forecasting software. An accurate load forecasting software is necessary to achieve the design peak shaving capability of the system. This software must be able to give an accurate prediction of the monthly peak load, and then set the BESS to shave the peak below that value. Incorrect peak demand predictions would reduce the benefit of the unit. There are commercial software packages that provide this function. The software would typically monitor current load data, current and forecasted weather, and historical load data, and would provide the peak load estimate to the BESS inverter.

- The peak shaving algorithm must function to maintain the ED metered load at the firm hydro allocation when it is active in the peak shaving mode. To do this, it must monitor the actual load drawn through the revenue meter and adjust BESS output accordingly. This function provides a significant reduction in the battery energy rating required to achieve the design peak shave, and thereby improves the project benefit significantly.

8 Project Results and Conclusions

This NYSERDA Research Project 132705 Energy Storage Peak Shaving Feasibility for Tupper Lake, Lake Placid, and Massena Municipal Electric Departments examines the potential for battery energy storage systems (BESS) to provide cost savings for New York State's municipal electric departments. These organizations purchase energy from the New York Power Authority (NYPA) and have allocations from NYPA to purchase hydroelectric energy at low cost. Many of these departments, however, exceed their NYPA allocations, and then make a portion of their purchases at market rates. The project examines three electric departments—Tupper Lake Municipal Electric Department (TLMED), Lake Placid Village Electric Department (LPVED), and Massena Electric Department (MED). The three departments cover a range of performance, with Tupper Lake rarely exceeding their allocation, Lake Placid exceeding their allocation in about half of the monthly billing cycles, and Massena nearly always exceeding their allocation.

Section 2 presents an overview of the rates that the electric departments pay to purchase their energy and deliver it to their respective sites. It also discusses the declining energy rates that are being experienced in the State, including in NYISO's North Zone where Lake Placid and Massena are located.

The primary ways that a BESS installation will lead to reduced costs is through peak shaving. Peak shaving in months where demand exceeds the NYPA hydro allocation will increase the firm hydro load share, which in turn, leads to increases in the amount of firm hydro energy purchase. Peak shaving in months when the allocation is not exceeded will generally lead to a reduction in the demand charge. This latter is dependent to some extent on the delivery contract that the electric department has with a transmission company that wheels the energy.

There is also potential for savings when the departments are above their hydro allocation, through daily peak shaving to optimize the differing costs for energy experience throughout a given day. For the three electric departments studied, the market optimization savings, while significant, are relatively small. The spread in market energy prices over the course of a day is also volatile, making it difficult to predict future savings based on historical analysis. For this reason, the study projects a conservative annual value for the savings for each district, based on its load history. It is noted that these departments are in the North Zone and Mohawk Valley Zone, and it is possible that larger market optimization savings could be realized in other zones in New York State. Section 2 also presents the study methodology, and an introduction to the use of the two spreadsheet templates that electric departments across the State can use to analyze their systems.

Sections 3–5 focus on BESS installations that provide peak shaving in the 0.5- to 2.0-MW range. In order to successfully peak shave at these power levels, BESS energy ratings in the range up to 4 MWh are needed to provide peak shaving for all months when the firm hydro allocation is exceeded. While there is some difference in energy rating required across the three departments examined and the two years examined (2018 and 2019), these differences tend to be relatively small.

The other trend is that the BESS energy rating increases faster than the BESS power rating need for increased levels of peak shaving. This is because the duration of time that BESS is required to supply energy increases with the level of peak shaving. For this reason, peak shaving in the range of 0.5 to 2.0 MW is the most practical range at present due to BESS costs and performance.

The results show that BESS installations can be cost-effective now in some cases, and that the benefit/cost relationship will improve with time, as battery prices continue to fall, and performance continues to improve. The consistent trend in the cases studied shows that the benefits from peak shaving increase with the amount of time that a district exceeds its allocation. As a result, there would be no financial benefit for Tupper Lake to install a BESS for peak shaving at this time, but there could be a benefit as early as 2025 with projected BESS cost declines.

Lake Placid would be about at breakeven, currently with a 0.5-MW peak shaving installation, and both a 0.5- and 1-MW installation is projected to be attractive within the current decade. The benefit-cost relationship for Massena is better, with 0.5- and 1.0-MW peak shaving installations reasonably attractive now and increasingly so in future years.

Finally, an overview and analysis of the relative merits of direct control demand response is presented in section 6. Direct load control of electric hot water heaters is considered the most likely residential application (and Massena has a voluntary program for this currently in place). While costs have declined as the automatic metering infrastructure (AMI) technology has matured, this technology is not in place in the three departments, and the lack of AMI hardware and communications infrastructure are currently hurdles to installation. There is interest in industrial-level demand response in Lake Placid, and the benefits of this type of installation are discussed in the Lake Placid section.

Endnotes

1 The meaning of ‹‹Firm Power›› is set forth in Service Tariff No. RNY-2B, as power the New York Power Authority is authorized to sell to eligible participants in accordance with PAL § 1005(13-a) and EDL § 188-a.

2 https://www.clarkson.edu/cepsr for spreadsheets and more information.

3 www.energy.gov/sites/prod/files/2019/07/f65/Storage%20Cost%20and%20Performance%20Characterization%20Report_Final.pdf

4 NYSERDA Energy Storage and NY-BEST Program: Market Characterization and Assessment, EMI Consulting, Feb 2017.

5 S. Ugarte, N. Friendrichsen, J. Michaelis, and A. Thielmann, "Energy Storage: Which Market Designs and Regulatory Incentives Are Needed?" European Parliament's Committee on Industry, Research and Energy (ITRE), October 2015.

6 D. Steward, G. Saur, M. Penev, and T. Ramsden, "Lifecycle Cost Analysis of Hydrogen Versus Other Technologies for Electrical Energy Storage," Technical Report NREL/TP-560-46719, November 2009.

7 IRENA (2017), Electricity Storage and Renewables: Costs and Markets to 2030, International Renewable Energy Agency, Abu Dhabi.

8 Díaz-González, et al., "A review of energy storage technologies for wind power applications," Renewable and Sustainable Energy Reviews, Elsevier, 2012.

9 IRENA (2017), Electricity Storage and Renewables: Costs and Markets to 2030, International Renewable Energy Agency, Abu Dhabi.

10 Costs to Automate Demand Response—Taxonomy and Results from Field Studies and Programs. Report LBNL-1003924, Lawrence Berkeley National Laboratory. November 2015.

11 Cost-Benefit Analysis of Demand Response Programs Incorporated in Open Modeling Framework. National Rural Electric Cooperative Association, 2016.

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