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U.S. DEPARTMENT OF ENERGY

On-Site Energy Storage Decision Guide

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Acknowledgments

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Disclaimer

This report should be viewed as a general guide to best practices and factors for consideration by end users who are planning or evaluating the installation of energy storage. A qualified professional engineer or firm should always be contracted to oversee any energy storage project.

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Introduction

When to Use this Guide

This guide is intended for anyone investigating the addition of energy storage to a single or multiple commercial buildings. This could include building energy managers, facility managers, and property managers in a variety of sectors. A variety of incentives, metering capabilities, and financing options exist for installing energy storage at a facility, all of which can influence the financial feasibility of a storage project. However, energy storage is not suitable for all business types or all regions due to variations in weather profiles, load profiles, electric rates, and local regulations.

This guide is broken into three parts:

1. Basics of Energy Storage,
2. Potential Benefits at Your Facility, and
3. Procurement Options.

This document provides information and references to other documents to facilitate these steps, but additional help may be required from professional engineers, accountants, and subject matter experts to facilitate making a final decision.

1. Basics of Energy Storage

Energy storage refers to resources which can serve as both electrical load by consuming power while charging and electrical generation by releasing power while discharging. Energy storage comes in a variety of forms, including mechanical (e.g., pumped hydro), thermal (e.g., ice/water), and electrochemical (e.g., batteries). Recent advances in energy storage, particularly in batteries, have overcome previous size and economic barriers preventing wide-scale deployment in commercial buildings. Although there are significant differences between technologies, energy storage systems (ESS) contain the same basic components:

- Storage Technology – to store and release energy
- Power Conversion - to convert the form (AC or DC) of the incoming and outgoing energy
- Thermal Management – to keep the storage technology within the required operating temperature range
- Software & Controls - to monitor and control the flow of energy

Common Commercial Technologies

The most common technologies currently available for commercial applications of energy storage are shown in TABLE 1. Within a given technology (e.g., lithium ion), there can be large differences in system performance based on the specific cell chemistry. For all of the technologies listed, as long as appropriate high voltage safety procedures are followed, energy storage systems can be a safe source of power in commercial buildings. For more information on specific technologies, please see the DOE/EPRI Electricity Storage Handbook available at:

TABLE 1. COMMON COMMERCIAL TECHNOLOGIES

Type	Key Characteristics	Common Applications
Advanced Lead Acid	By various combinations of adding ultracapacitor technology, doping the anode, and using bipolar plates, advanced lead acid batteries gain increased cycle life and depth of discharge, while maintaining relatively low cost.	Renewables integration, demand charge management, backup power
Capacitors	“supercapacitors,” or “ultracapacitors” have extremely high power densities and cycle life, but very low energy density.	Wind turbine pitch control, Volt/VAR control, frequency regulation, renewable smoothing
Flow	Common chemistries include zinc bromine and vanadium redox. The power and energy density can be changed by varying the size of the storage tanks and membrane.	Long duration (>4hr) energy shifting, backup power
Ice Storage	Water is frozen into ice using grid power during off-peak times. Then air is passed over the ice as it melts to provide air conditioning and refrigeration. Since power is not delivered back to the grid, this may be considered load shifting in some jurisdictions.	Shifting for HVAC or refrigeration loads to off-peak times
Lithium Ion (Li-ion)	Li-ion has both good power and energy density, high round-trip efficiency, and good cycle life. Li-ion prices are being driven down by economies of scale resulting from widespread use in other applications.	Renewables shifting, renewables smoothing, demand response, demand charge management

2. Potential Benefits at Your Facility

By serving as both generation and load, energy storage can provide benefits to both consumers and the grid as a whole. For most commercial customers, the primary energy storage applications are:

- Energy Arbitrage (buy low, sell/use high)
- Demand Charge Management
- Power Factor Charge Management
- Momentary Outages
- Sustained Outages
- Renewable Energy Shifting and Smoothing

Depending on the local utility, some ESSs can also generate revenue by providing services to the larger grid. In these cases, an agreement is made between the system owner and the utility. This is either done directly through the utility, or through a system aggregator who then provides services to the utility. These aggregated groups of systems are sometimes referred to as virtual power plants (VPPs).

Energy Arbitrage

Due to fluctuations in demand, the price of electricity varies throughout the course of a day, and throughout the year. Although some customers may be charged a flat rate for their electricity, utilities try to incentivize energy used during low-cost off-peak hours by offering customers time of use (TOU) or real-time pricing; inquire with your utility or energy supplier. When TOU pricing is the rate plan in place, an ESS can be charged when the price is low, and discharged to offset the facility's load when the price is high. For this application, the ESS will typically have at least 4 hours of storage capacity and cycle between 200 to 400 times per year.

Demand Charge Management

Demand charges vary based on utility and rate structure but are usually based on a customer's peak demand each month. In markets with high demand charges such as California and New York, demand charges can comprise up to half of the total electric bill.

An ESS can reduce demand charges by discharging when a building is approaching its peak load. This is more effective for buildings with "peaky" loads as opposed to those with a steady "flat" profile. For example, the ESS shown in FIGURE 1, is only able to reduce the peak demand by 50kW for the "flat" profile. However, for the "peaky" profile, the same ESS can reduce the peak demand by 100kW.

SCHOOL CASE STUDY

The Mountain View High School District in Los Altos (MVLA) partnered with Green Charge to install EV chargers and energy storage at their facility. The system was installed at no cost to the school, and uses shared savings to pay for the equipment. The net benefit is expected to be over $1 million over the life of the project.

Situation:

High school with 4,300 students, faculty, and staff

Solution:

Four Level 2 EV Chargers

1.08 MW Li-ion storage

No upfront cost

Benefits:

$86,000 in demand charge savings annually

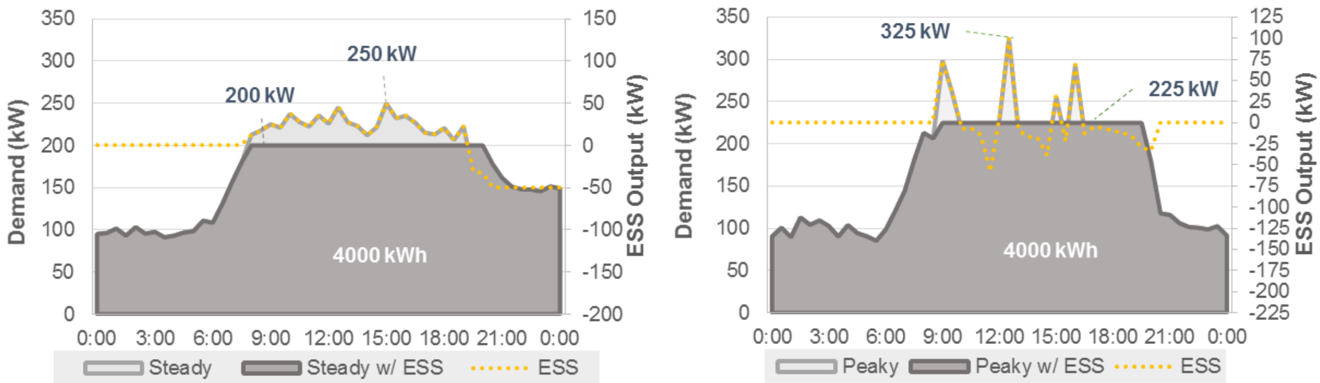
Flat-fee EV charging for faculty and staff

Additional income through CAISO wholesale energy market

Image: System installation at the Mountain View Campus

[1] Green Charge, Mountain View Los Altos, "Customer Success Story," October 6, 2015.

FIGURE 1. FLAT AND PEAKY DEMAND PROFILES[2]



Power Factor Charge Management

Power factor charge management is more common for industrial users but can apply to commercial users that have significant inductive loads on site such as electric motors. An ESS can be used instead of purchasing capacitor banks to correct the power factor or paying power factor charges.

Momentary Outages

For customers with sensitive equipment (e.g., semiconductor manufacturers), momentary outages can cause significant disruptions to their operations. For small loads including computers, control systems, and medical equipment, a small ESS is used. These are referred to as uninterruptible power supplies (UPS) and are connected directly to the load. Larger ESS with additional equipment to allow for islanding can be used to prevent momentary outages across a variety of critical loads, or even across all loads within a building.

Sustained Outages

Energy storage can provide a cleaner, quieter alternative to conventional gas or diesel generators in case of a grid outage. However, an ESS cannot be refueled the same way as a conventional generator. As such, some facilities will only use the ESS for critical loads, integrate some form of renewable generation, or pair it with a generator.

Renewable Energy Shifting and Smoothing

Renewable wind and solar energy generation create power intermittently – either when the wind blows or when the sun shines. Energy storage can smooth both the momentary, and longer term fluctuations in power from intermittent renewable resources. There are currently no revenue streams associated with smoothing the short term fluctuations in power since the electric grid provides these same services at no cost. However, energy storage can be used to shift the power from renewable generation to times when it would be of more value. This could either be used to hedge against policy, regulatory or rate structure changes such as new time of use rates, new demand charges, or modifications to net metering tariffs.

[2] Image source: Navigant Consulting, Inc.

For certain customers, the combination of solar plus storage can reduce a customer's bill by more than either solar or storage on their own. This is possible because:

- Solar reduces the amount of electricity drawn from the utility, but since solar power is not dispatchable, it is difficult to reduce the monthly peak and associated demand charges.
- The addition of solar to a facility can make the load more "peaky," which then makes it more economical to install energy storage for demand charge reduction.

BAKER ELECTRIC[3]

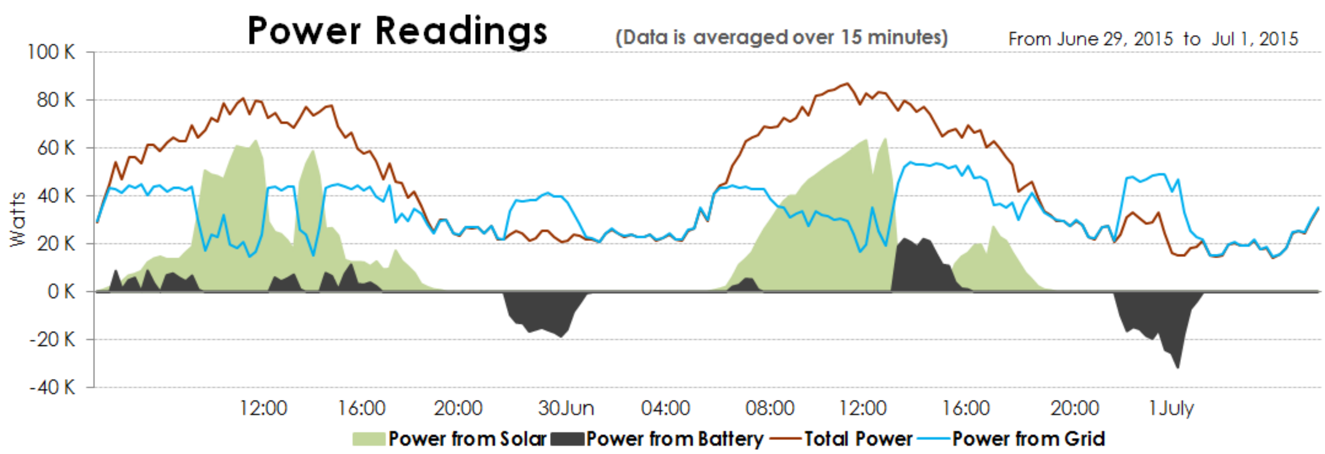
Baker Electric partnered with Sharp to install energy storage alongside solar PV at their headquarters in Escondido California. The system works along with the solar to reduce peak demand. The facility peak load (red) is usually offset by the production of the solar system (green). However, during cloudy periods when the solar output is low, the battery (black) is discharged to reduce the facilities net load from the grid (blue). The result is that the net load from the facility (blue) stays below 50kW despite having a facility load of more than 80kW and intermittent solar generation.

Situation: Corporate headquarters

Solution: 85 kW Solar System along with a 30 kW/80kWh Energy Storage System

Benefits: 36% Demand charge savings over first 12 months, 3.5 year system payback, ITC eligible installation

Image System Performance:



[3] Baker Electric Escondido, California, August 2015. http://www.baker-electric.com/wp-content/uploads/SmartStorage-Baker-Electric-Case-Study-091115-FINAL.pdf.

Assessing Benefits at Your Facility

Before any significant investment in energy technology, an energy audit is highly recommended to identify an optimal strategy that may include technology that is more economical than installing energy storage or renewable generation. Once and energy audit has been performed, there are vendor specific and publicly available tools like the DOE Energy Storage Computational Tool or Electric Power Research Institute's (EPRI) Storage VET available to analyze the potential for storage:

https://www.smartgrid.gov/recovery_act/analytical_approach/energy_storage_computational_tool.html

http://www.storagevet.com/

These tools will help analyze the energy usage at your facility, and determine which (if any) of the applications listed above are suitable for your facility, and the associated monetary value. In addition to the output from these tools, common questions to consider include:

- What is the goal of installing storage?
- What is the net benefit (or cost) of installing a storage system?
- Are there other energy efficiency or load control options which should be made before considering energy storage?
- Does the local utility or state government offer any programs to incentivize energy storage?
- Are there any local regulations that will affect the installation of energy storage?
- What is the current rate structure? Are the rates high and do they include time of use, demand charges, or power factor charges?
- Does the facility have a relatively flat or peaky load profile?
- What are the main loads in the building and are they predictable?
- What are the potential energy storage applications given the load profile and rate structure?
- How much value does the company put on the associated benefits?

Assistance from a certified energy professional and/or the local utility will help inform you on the potential rate options and any financial incentives that may apply.

OCEAN PARK INN[4]

The Ocean Park Inn had high peaks, with demand charges accounting for up to 50% of their monthly bill. They were looking for sustainable solutions which wouldn't adversely affecting guests or operations and decided to partner with Stem Inc. for a sustainable method of reducing their demand charges.

Situation:
72 room hotel

Solution:
18 kW Energy Storage System

Benefits:
10% reduction in demand charges
$4,500 in annual savings

Image: System installation

Stakeholder Engagement

Assuming the initial analysis shows that energy storage is an economically viable option, the final decision to procure an ESS needs to be taken in the broader perspective of the business as a whole. This can include looking at issues of space, noise, and timing for system installation. Once the decision has been made to procure storage, there are several different procurement options.

[4] Stem Inc., "Ocean Park Inn," 2015.

TABLE 2. ENERGY STORAGE BENEFITS

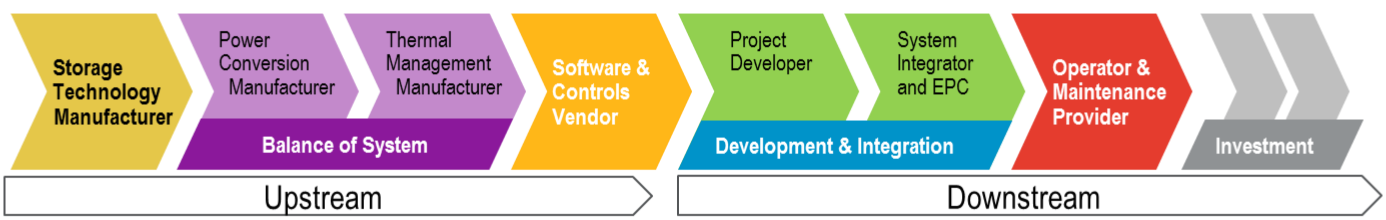
Benefit	Key Characteristics	Common Applications
Cost Savings	ESSs can reduce the total electric bill by changing the way a facility uses electricity.	Energy Arbitrage, Demand Charge Management, Power Factor Charge Management
Reduced Outages	ESSs can be used to prevent momentary and sustained outages for critical loads.	Momentary and Sustained Outage Support
Renewable Integration	ESSs can support the integration of intermittent renewable energy.	Renewable Energy Shifting and Smoothing
Tax Savings	Depending on the application, federal, state, or municipal tax incentives may be available.	Varies based on regional incentives
Being "Green"	Energy storage is considered a "green" power option and promotes a positive public image.	All of the above

3. Procurement Options

Value Chain

Energy storage can be procured directly from "upstream" technology providers, or from "downstream" integration and service companies (FIGURE 2) **Error! Reference source not found.**. Upstream companies provide the storage technology, power conversion system, thermal management system, and associated software. Downstream companies concentrate on site-specific issues including system sizing, project development and system integration. Downstream companies are also often "technology agnostic," and work with multiple upstream vendors.

FIGURE 2. ENERGY STORAGE VALUE CHAIN



Contracting Structures

There is a rapidly changing landscape of ownership and operation models for energy storage. TABLE 3 lists the high-level contracting structures which currently exist or are expected to exist in the near future. The structures generally vary based on who has control of the system, the potential benefits from the system, and which party assumes which risks. Please note that there are also many subtle variations within each category.

TABLE 3. POTENTIAL CONTRACT STRUCTURES

Model	Ownership	Control	Notes
Sale/Lease	Customer	Customer/ Developer	Gives the customer the control over the ESS, but the customer assumes the majority of the technical and business risk.
Power Purchase Agreement (PPA) or Shared Savings	Third-Party Owner (TPO)	Customer/ Developer	Customer is charged based on services (kW, kWh, reactive power) or based on a percentage of the bill savings. Generally, no or low money down, and transfers most risks to the ESS vendor. May limit the cost-effectiveness of future energy efficiency upgrades.
Holistic Energy Management	Third-Party Owner (TPO)	Developer	Complete energy management solutions including energy audits, energy efficiency, bill management, distributed generation, and load control.
Sale/Lease + Utility Tariff	Customer	Utility or Aggregator	Customer purchases the ESS but “shares” it with the utility. Customer receives lower bills but may have restrictions on when or how they operate the ESS.
Utility Procurement	Third-Party Owner (TPO)	Utility or Aggregator	Utility purchases the ESS and locates it at the customer’s facility. Customer receives lower bills, but may have restrictions on when or how they operate the ESS.

Assessing Business Risk

Regardless of the contracting structure selected, there are business risks to be aware of including:

- What happens if there is a change in the utility rates with respect to the types and price of charges or in the structure of the rate itself?
- What happens if there is an increase, decrease, or shift in the way your facility uses electricity? How will that change the monetary value of the system benefits?
- What happens if the energy storage system fails or does not perform reliably?
- What happens to the system and its operation after the lease or shared savings contract expire?
- What happens in the event of the insolvency of any of the involved parties?

Soliciting Bids and Selecting a Winner

Once the appropriate business model has been decided, an RFP can be created, or it may be simpler just to meet with the potential suppliers. Unfortunately, there are not standard RFP templates, nor is there a standard method of responding for vendors. The common issues resulting from this are:

- Customers may provide incomplete or incorrect information to vendors.
- Vendors may quote different sized systems for the same facility and application.
- Vendors may quote different levels of shared savings for a given system based on different assumptions.
- Vendors may propose different ownership structures based on local regulations, the tax structure of either the client or the vendor, and who is entitled to revenue from any capacity payments or renewable energy credits if applicable.

It is also important to consider who is responsible in case of warranty or support issues.

Construction and Commissioning

In most cases, the installation of the ESS should cause no more issues than any other similarly sized construction project at your facility. For larger systems, several vendors use “containerized” designs which dramatically reduce the amount of setup time required on site. The final step will be the commissioning process where the system is turned on, and gradually “learns” how your facility is operated and adjusts its behavior to maximize the savings. Note that the degree of automation in this learning process varies dramatically by vendor and application.

Next Steps

For further information, please contact your local utility or energy services provider. Other useful resources include:

- DOE Better Buildings Alliance: For information on the Better Buildings Alliance events, publications, and energy efficiency for commercial buildings.
- Electricity Storage Handbook: For an overview of energy storage technologies, applications, benefits, and procurement guidance.
- Energy Storage Association: For policy updates, case studies, events, and industry resources.
- DOE Energy Storage Computational Tool: For a free, high-level analysis of potential projects.