ENERGY STORAGE BEST PRACTICES

This factsheet presents an overview of best practices for energy storage systems, or large stationary batteries installed in residential, commercial, and industrial settings.

KEY TAKEAWAYS

Value stacking involves designing an energy storage system **to provide multiple services**, such as resilience, improved reliability of grids with high dependence on variable energy sources such as renewable generation, bill management, and market participation. **Maximizing the utilization of a battery** ensures the greatest potential benefits of the project are realized.

Configuring the battery's operating profile, or charge/discharge strategy, to provide multiple services requires **flexibility** and **forecasting** of **extreme weather events, utility rate tariffs, and market conditions**.

Identifying priority or critical loads can help **extend the battery's ability to survive an extended outage** by switching off, or "shedding", non-critical loads. This can be achieved manually or via a critical loads panel installed with the battery system.

The ability for a battery to participate in local or regional energy markets depends on **state and federal regulations**, where the battery is located, and whether it is in a **residential, commercial**, or **industrial** setting.

When designing and operating a battery system, it is important to keep in mind that batteries have both a **calendar life**, or the expected lifetime of the battery due to the aging of its components over time, as well as a **cycle life**, or the number of charge/discharge cycles the battery is expected to achieve before its capacity falls below usable levels.

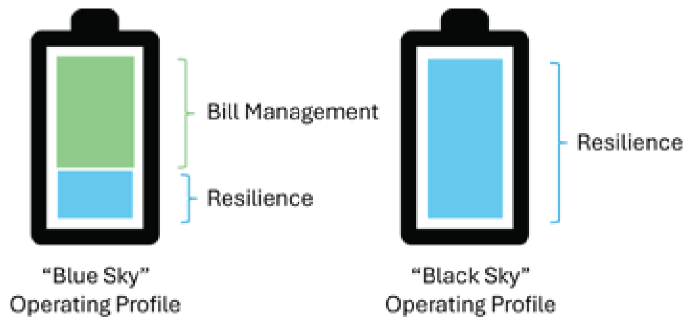
PNNL-SA-214285

Value Stacking

Battery energy storage can serve many purposes depending on where it is located, its size, and the local electricity market. When planning a project, it is important to consider how and when the system will be used, and whether there are opportunities for the system to serve multiple uses—referred to as **value stacking**. For example, a battery project designed to only be used when the electric grid experiences an outage may come at tremendous cost due to low utilization if outages are infrequent. A battery system can be designed to provide support during outages as well as lower monthly electric bills, especially if connected to a rooftop solar array, or if the building is under a time-of-use (TOU) rate tariff. Under a TOU tariff, the battery would discharge electricity to the building at high or peak prices and charge at low or off-peak prices[1], while holding some portion of its capacity in reserve in case of an outage.

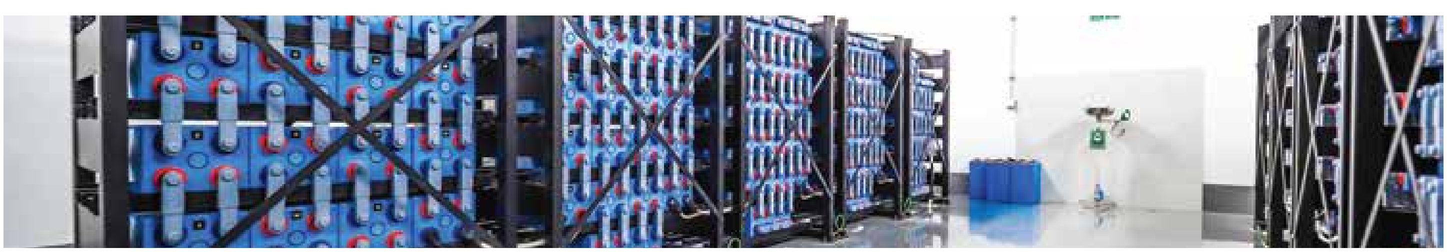
Operating Profile

Multiple services are achievable if the battery **operating profile** is configured for both resilience and bill management goals. This typically involves deciding how much of the battery's capacity to elect for each service. For example, if outages were relatively rare and no more than a few hours long, it might make sense to set 70% of the battery's capacity for bill management, and 30% for reserve in case of an outage. These settings can be adjusted as needed, and many battery management systems are equipped with a weather forecasting feature or are configured to receive alerts from the utility ahead of scheduled outage events or maintenance. In these cases, the battery would be fully charged ahead of the event and hold off on performing bill management services until the event passed. The outcome of these configurations ensures the full resilience capacity of the battery is available to support the building tenants. This kind of battery operation can be called "**blue sky**" under normal conditions, and "**black sky**" under emergency or extreme weather conditions.



Battery operating profiles for every day, "Blue Sky" conditions compared to emergency, "Black Sky" events.

Under black sky conditions or an emergency scenario, it is important to take preparatory steps to maximize the duration that the battery can support its connected load. In most cases, the length of an outage is unknown, though the utility may provide updates and estimates as they perform the necessary work to restore electric service. Regardless, prioritizing loads to support in an outage will extend the time those loads are able to be met by the batteries. The loads determined to be a priority are called **critical loads** and should be identified when the battery is first put into service to best prepare for a resilience scenario.

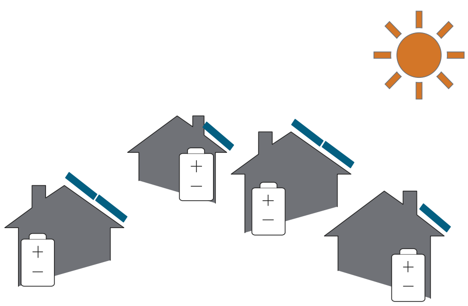


[1] Charging (buying energy) at low prices and discharging (selling energy) at high prices is called energy arbitrage. Commercial and industrial customers with a demand of 1,000 kVA or greater fall under a TOU rate under the Puerto Rico Electric Power Authority (PREPA) and may therefore participate in energy arbitrage. Peak hours are 9AM-10PM Weekdays.www.lumapr.com/current-rates-for-electric-service-in-puerto-rico/

Critical Loads

There are two ways to manage critical loads in an outage, the first is to do it manually. By turning off non-essential appliances and lighting, the battery can provide prologued electric supply to essential equipment like refrigeration. The other option is to manage critical loads automatically using a **critical loads panel**. A **critical loads panel** ensures that the connected battery only supplies electricity to priority loads during an outage; this contingency management practice can be referred to as load shedding, which is a strategy to help the battery last longer by only providing electricity for the most important uses in the building. A critical loads panel can either be integrated with the building's electric panel or installed as a separate device. During installation, the electrician will work with the building owner to identify these priority or critical loads. Often, these loads include the refrigerator, critical equipment, and lighting and outlets to a select few rooms where people will gather, or critical services are performed during an outage.

Market Participation



Energy storage paired with rooftop solar can increase local consumption of generated electricity.

The potential services that a battery can provide will depend on its size relative to the load it is designed to support, and whether it is combined with a generating source like rooftop solar. It is important to note that battery charging and discharging are not perfectly efficient, meaning that a small percentage of the electricity transferred to or from a battery will be lost, resulting in a slight increase in overall electric demand. There are also market and regulatory factors that determine what battery services can receive compensation. For example, in many jurisdictions, customer-owned batteries are not allowed to export electricity to the grid. This means that the battery can only offset the load of its building and not receive compensation for any excess electricity available to export the grid. Where batteries are able to export to the grid, they may also be able to provide ancillary services to the utility, such as frequency and voltage support. Larger, commercial and utility-scale batteries can even provide bulk energy services to the local grid, such as capacity support and resource adequacy. The landscape of possibilities for energy storage market participation is constantly changing, and the recently passed *FERC Order 2222*[2] is intended to enable distributed energy resources like energy storage and rooftop solar to participate in electricity markets. Similarly, *FERC Orders 2023* and *2023a*[3] strive to ensure that energy storage resources are more accurately studied during the interconnection process to avoid unnecessary, costly, and time-consuming network upgrades.

Battery Lifetime

The **operating profile**, or the way in which the battery is operated, will impact the lifetime of the battery. Batteries have a **calendar life**, or the expected lifetime of the battery due to the aging of the battery's components with passage of time. Batteries also have a **cycle life**, or the number of charge/discharge cycles the battery is expected to achieve before its capacity

[2] See FERC Order No. 2222 Explainer: Facilitating Participation in Electricity Markets by Distributed Energy Resources. https://www.ferc.gov/ferc-order-no-2222-explainer-facilitating-participation-electricity-markets-distributed-energy

[3] See Final Rules Establishing and Revising Standard Interconnection Agreements and Procedures for Large Generators. https://www.ferc.gov/electric-transmission/generator-interconnection/final-rules-establishing-and-revising-standard

falls below usable levels[4]. The estimated cycle life is complicated by the fact that a battery is not always fully discharged and charged every cycle. When a battery is only discharged slightly before being charged, it is called shallow cycling, which usually does not impact the battery life as much as a full cycle. The extent to which a battery is used before being charged is called the **depth of discharge** and is an important consideration for an operating profile. Not all batteries respond the same way to these operating considerations, which depend on the **battery's chemistry**. Lithium-ion batteries make up the majority of energy storage chemistries for stationary batteries and electric vehicles, while lead-acid batteries have traditionally been used as car batteries. There are many different battery chemistries with different benefits and drawbacks. The conditions and factors that increase efficiency, calendar life, cycle life, operating temperatures, and safety are regularly studied. The goal of evaluating these conditions is to reduce costs and improve the efficient use of battery materials[5].

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4 Note that the acceptable degradation in battery capacity depends on the battery's application. For example, electric vehicle batteries are typically replaced when their capacity has been reduced to 80% of the original value. Battery recycling programs help ensure that these batteries continue to be useful in a second life application, such as a stationary backup or paired with solar or wind generation. After the second life, batteries are recycled, the raw materials are extracted, and any hazardous materials are disposed of appropriately.

5 For more information on the different types of battery chemistries, how they work, and how they can benefit the grid, see the PNNL Explainer Article: **www.pnnl.gov/explainer-articles/types-batteries**

PNNL-SA-214285