3 Residential and Small Commercial-Scale Projects

Energy storage systems have a growing role in providing value to residential and small commercial customers. Residential and small commercial-scale ESS, sometimes referred to as "behind-the-meter ESS", are installed on the customer side of the utility revenue meter to provide power directly to their home or business. These energy systems can be used for a range of applications, as identified in the following subsections.

Energy Arbitrage (Time of Use Rates)

As utility-scale ESS can charge with inexpensive power and discharge when electricity prices rise in the wholesale energy markets; some customers with on-site ESS can employ a similar strategy. Homeowners and commercial or industrial facilities that are on a "time-of-use" rate structure often pay high energy prices during peak periods and much lower rates during off-peak times. As such, some customers may find it economical to use an ESS to perform energy arbitrage. This strategy is especially effective when paired with solar photovoltaic (PV) systems. The ESS can charge using low-cost solar generation during the day (when household loads are potentially lower because occupants are away from home) and then discharge that stored energy during evening peak hours. This offsets what would otherwise be a hefty electricity cost for the owner.

Demand Charge Reduction

Many commercial and industrial facilities not only pay for the energy they consume but are also subject to demand charges. Unlike energy charges, demand charges are based on the facility's maximum power draw during the billing period. For example, a facility might be charged according to its highest 15-minute average usage during afternoons in the summer months. This charge reflects the added cost to the utility system of meeting high, short-term power demands. In some facilities, demand charges can be as costly as the energy bill itself. It is therefore easy to imagine that by blunting these peak demand periods, an ESS could be well positioned to save such customers significant money on their electrical bills, even though the ESS is a net consumer of electricity (i.e., uses more energy than it discharges). The demand savings can be quite attractive.

Figure 3-1 illustrates potential demand savings available at a commercial facility using an ESS with solar PV to target demand peaks and reduce them during the day and into the early evening. As you can see, the ESS lowers demand throughout the day, with its greatest impact occurring in the early evening hours as solar output declines. Then, in the late evening, the demand briefly increases compared to the baseline to recharge the ESS in preparation for the next day's operation. This is one of many possible operating strategies that facility owners may employ with an ESS to cut demand charges. However, for example, the simple payback on this particular ESS was less than three years, based mostly on the demand savings. An example of this type of ESS is shown in Figure 3-2.

Resilience or Backup Power

One of the oldest applications of batteries is providing backup power to critical facilities when the utility grid is stressed or unavailable. From island microgrids to backing up data centers, batteries offer a reliable means of improving resilience of facilities against grid outages and related emergencies. With today's energy storage technology, these systems can be cost-effective for homeowners as well, especially when paired with solar PV.

In these applications, when a power outage occurs, the owner can use a transfer switch—often automated—to operate their electrical loads on battery power. This is sometimes referred to as "islanded operation" because the facility temporarily disconnects from the grid

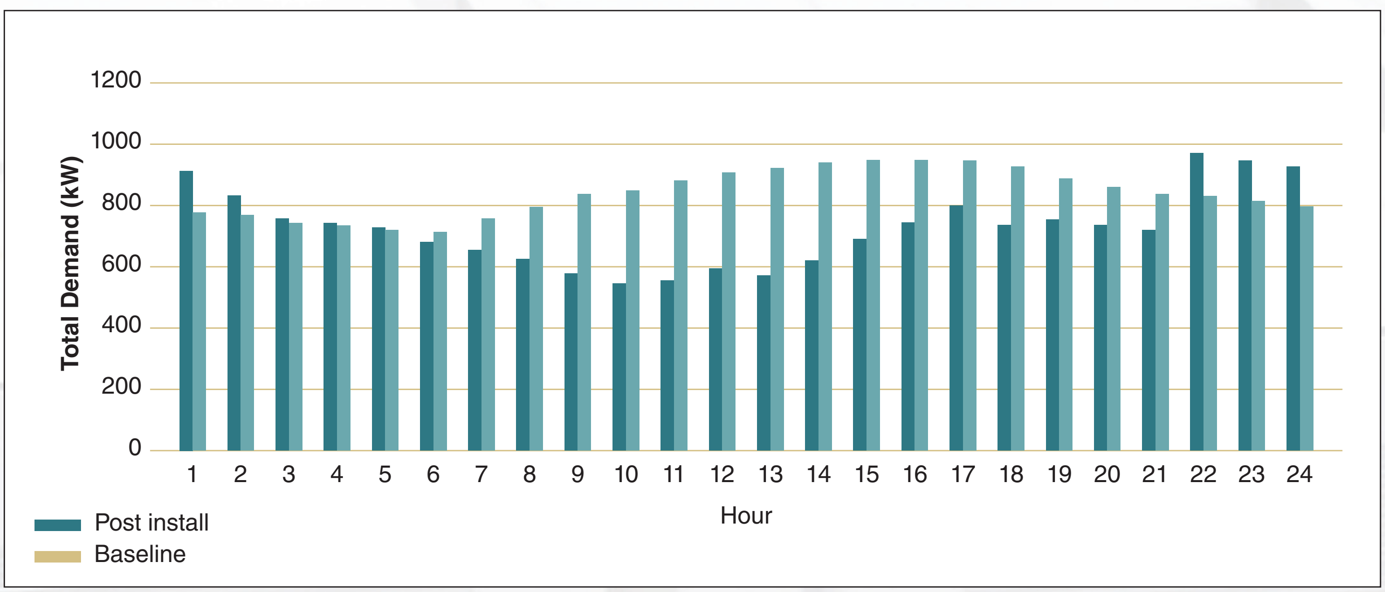

Figure 3-1

Example of a commercial facility using a solar + energy storage system to reduce demand charges. *Image courtesy of Camelot Energy Group.*

Figure 3-2

Some systems, such as the Stem system shown here, use a combination of BESS hardware (as previously discussed) and sophisticated artificial intelligence algorithms to help commercial customers reduce costly peak demand and energy charges. *Photo courtesy of Stem, Inc.*

until the transfer switch is once more flipped back to grid operation. In these cases, facility owners will often designate a subset of the facility's circuits as critical loads, thereby minimizing unnecessary ESS drain. Since these outages may coincide with major storms or natural disasters, the ability to operate for prolonged periods can be a powerful aid to recover efforts.

Virtual Power Plants

In addition to providing backup power, residential and commercial ESS can sometimes be aggregated—as discussed in Chapter 1–into virtual power plants (VVPs). This aggregation allows smaller systems to access potential revenue streams typically reserved for larger-scale assets by combining their capabilities.

Residential and small commercial-scale ESS are more likely to be found in areas prone to power outages (e.g. disaster-prone or grid instability areas), where lucrative incentive programs exist and/or where variable electricity rates present opportunities for time-shifting or energy arbitrage. Residential ESS, as shown in Figure 3-3, also supports electric vehicle (EV) charging by offsetting peak demand charges when vehicles must be charged during high energy price periods. In addition, these systems provide a local storage option for nighttime EV charging by using electricity generated by onsite PV systems during the day since many behind-the-meter ESS are sold and installed by companies that also offer solar PV systems (i.e., solar installers).

Figure 3-3

This Tesla Powerwall 2 installation provides energy storage for household use and facilitates charging for electric vehicles. This type of unit may also be able to participate in virtual power plants in some locations. *Photo courtesy of Tesla.*

The development, installation and ownership structures for these smaller ESS are generally simpler than those for utility-scale ESS. While some of these applications are similar to those of utility-scale ESS, these residential and small commercial-scale systems are more often directly owned by the property owner, although leasing or other commercial arrangements also exist. For example, in Table 3-1, you can see all scales of ESS can play a role in balancing energy charges. However, residential and commercial systems are more aligned with reducing a building's electricity bills, whereas the utility-scale ESS is more focused on offering services directly to the grid operators.

Table 3-1 Summary of ESS Benefits and Revenue Streams Available for Residential, Commercial, and Utility-Scale Systems

ENERGY STORAGE BENEFIT	RESIDENTIAL/ BEHIND-THE-METER	COMMERCIAL/ BEHIND-THE-METER	UTILITY-SCALE/ FRONT-OF-METER
Energy Trading	No	No	Yes
Energy Arbitrage (Time of Use Rates)	Yes	Yes	No
Frequency Regulation	VPP Only	VPP Only	Yes
Capacity	VPP Only	VPP Only	Yes
Black Start	No	No	Potential
Other Grid Services	No	No	Potential
Demand Charge Reduction	No	Yes	No
Energy Resilience/ Backup Power	Yes	Yes	No

4 Fire and Explosion Risk in Lithium-Ion Battery Energy Storage Systems

As with any new technology, there are questions regarding the safety of lithium-ion battery energy storage systems (li-ion BESS). Given its modular nature, the li-ion BESS's technology lends itself to everything, from residential to utility-scale applications. This chapter provides a brief introduction to the main li-ion chemistry and addresses the greatest concerns related to li-ion BESS fires and explosions.

4.1 Battery Fire and Explosion Risk Background

Numerous news reports, photos and videos have shown startling failures of li-ion BESS (Figure 4-1). Some jurisdictions have used these reports and videos as the basis for imposing potentially overly burdensome or nonsensical safety requirements for an ESS, especially a BESS. As a stored energy medium, batteries must always be treated with care and respect. However, it would be overly simplistic to equate

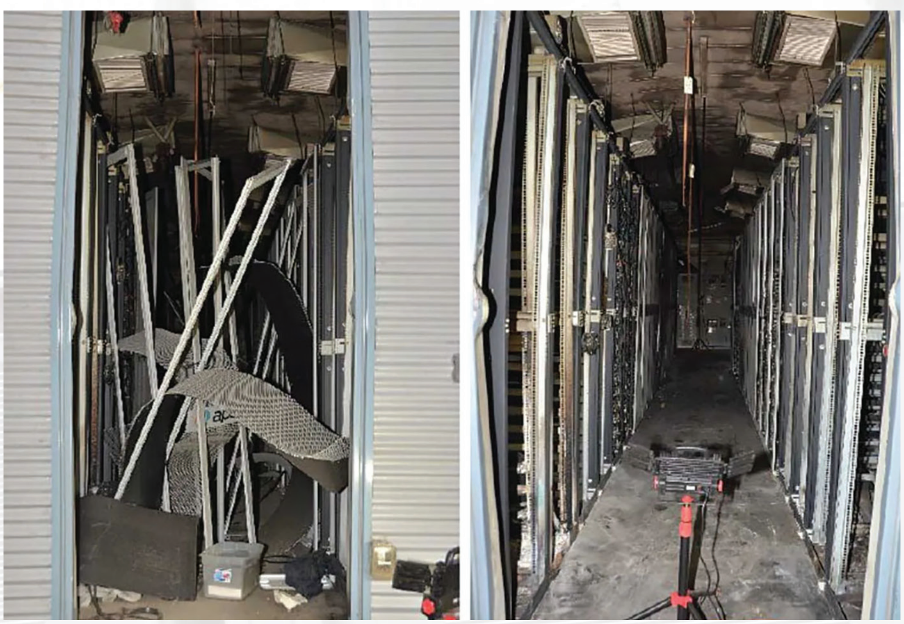

Figure 4-1

This image shows the dramatic aftermath of the 2019 BESS fire at the APS McMicken facility. The left image was taken directly after the incident; the right image shows the enclosure with debris removed. *Photos accessed at IEEE Spectrum and attributed to Arizona Public Service.*

the types of battery failures seen in poorly regulated consumer products with the behavior of a properly designed, installed and listed ESS. Nevertheless, there are credible reports of thermal events associated with ESS that are important to be familiar with in order to understand their potential risks. It is also important to bear in mind that the industry's understanding of failure mechanisms, mitigation measures, codes and standards is evolving and improving at a rapid pace. Modern battery energy storage systems are, for example, markedly safer than those installed even two or three years ago.

There are two major areas of concern for BESS: fire and explosion. These two risks, often combined, are distinct from one another and have a complex relationship that may not be obvious at first glance. The following sections provide more context on these conditions, as well as provide a brief overview of the thermal runaway process, a key factor in designing safety systems for li-ion BESS.

Fire Risk

Fire risks in a BESS arise from multiple sources, including failures in electrical equipment and the unique characteristics of batteries. While any utility infrastructure or energy system can be susceptible to the risk of fire, BESS projects have specific risks due to the use of batteries, particularly around thermal runaway and electrical faults. While this guide primarily focuses on fire risks specific to BESS, it is important to acknowledge that transformers, switchgears and HVAC systems can also pose fire risks in energy storage infrastructures.

The risk of fire in a BESS could be influenced by several factors:

- Battery/cell chemistry
- Battey/cell design
- Module design
- Battery management system (BMS) sensing and controls
- Thermal management
- How the system operates
- Maintenance activities
- Weather and environmental conditions

Understanding how these factors interact with BESS safety and design may provide some insights but require a deeper knowledge of BESS and subsystem technologies. For this reason, recommendations for specific design requirements (such as specifying only cells with specific separator materials or banning the use of certain bat-