*Emerging Opportunities Series*

ACEEE
American Council for an Energy-Efficient Economy

# Energy Storage

The electricity grid paradigm is changing. Yesterday's grid involved a one-directional flow of energy from power generation plant to end user. Today we have more energy-efficient buildings, localized renewable energy, and energy storage systems. Recognizing the grid and efficiency benefits of storing energy, program administrators are piloting new types of offerings focused on behind-the-meter energy storage.[1] One type of storage system, thermal energy storage (TES), has been used for decades. A higher profile type, battery storage, has gained considerable momentum in recent years, with lithium-ion chemistry currently leading the pack. This technical brief outlines the benefits of both types of systems and makes recommendations for efficiency administrators who want to incorporate these resources into their programs. Although it includes a few residential examples, the brief focuses on the commercial sector.

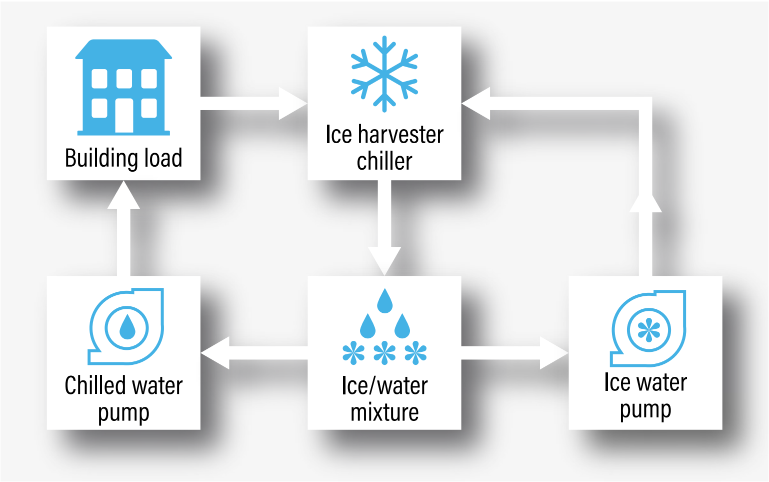


Figure 1. Thermal storage system

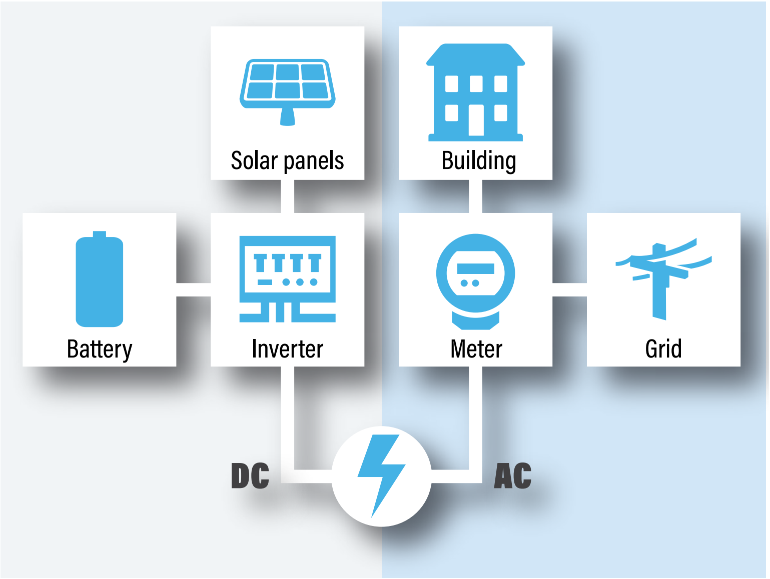


Figure 2. Battery storage system

## Thermal Energy Storage

The most common commercial building TES systems are chilled water or ice storage. During off-peak hours, water is cooled or frozen into ice, and then during on-peak hours, cooling loops extract the cold to provide space conditioning and/or refrigeration. Figure 1 shows a typical ice storage TES system.

TES technologies can store heat as well. For example, excess heat generated from combined heat and power (CHP) plants can be stored by heating salts or other organic oils.[2] Though historically used only in large buildings with access to greater funding and more available space, the recent emergence of small TES systems has opened the thermal storage market to small- and medium-sized commercial buildings, and even residential buildings.[3]

## Battery Storage

Battery cells undergo a chemical reaction to store and release energy. Inside the battery, two materials exchange charged ions. This flow of ions generates an electrical current and a voltage, which provides power.[4] Increasingly, renewable energy sources such as solar panels supply the electric charge to initiate the chemical reaction. An inverter then changes the energy from direct current (DC) to alternating current (AC), which is typically used in buildings. Figure 2 shows a typical battery storage system.

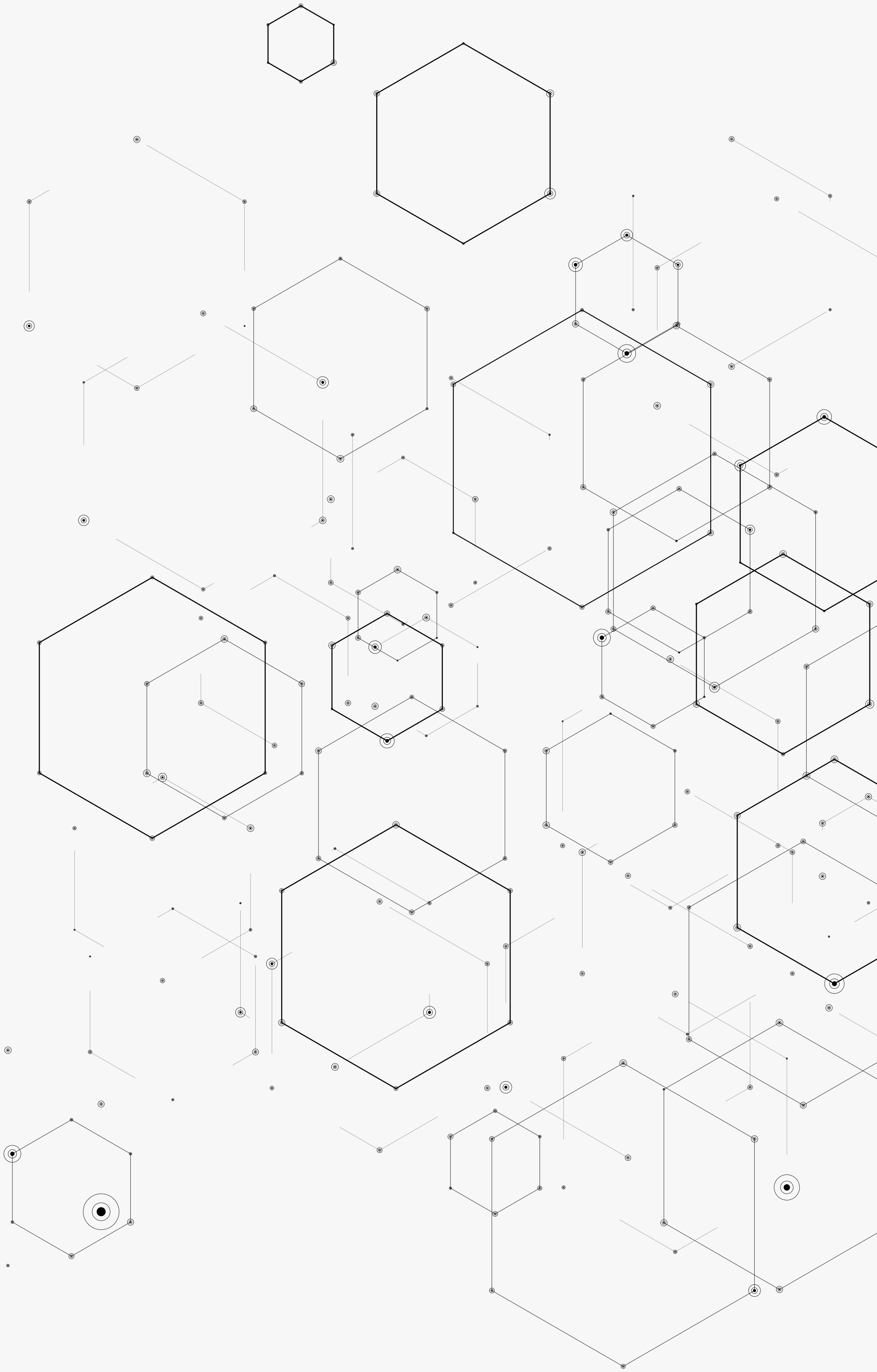
The battery storage sector is currently dominated by lithium-ion chemistry. Compared to other types, lithium-ion batteries exhibit relatively well-balanced characteristics, including power and energy density, efficiency, and cycle life, and often make most sense at a building scale (less than 100 kW). These batteries are also rapidly decreasing in price due to economies of scale from increasing demand.[5] Other battery chemistries may make more economic sense in specific circumstances, such as lead-acid batteries or flow batteries, which can be better suited for larger installations and utility-scale applications, with a system power rating greater than 100 kW up to about 30 MW.[6]

## Other Types of Storage

By some definitions, buildings with ultra-tight envelopes or storage tank water heaters can be considered forms of energy storage. This is because tight buildings can better maintain interior space temperatures if they shut off HVAC equipment during peak demand events, while water heaters can be superheated during low demand (e.g., at night) and use the stored hot water during high demand (e.g., during the day). Other types of storage include mechanical systems like flywheels, compressed air systems, and pumped hydro, which are not covered in this report. These storage systems are typically used in larger, grid-scale storage applications, and are less likely to be of interest to a commercial building energy efficiency program administrator.[7]

## Energy Storage Software

As the majority of commercial building equipment and systems become integrated through the use of sensors, controls, and software, it will be increasingly important for energy storage to coordinate with HVAC, lighting, and other major systems. Although utility-scale storage is projected to be the largest market for energy storage software (ESS) at 59% between 2016 and 2025, commercial- and industrial-scale systems also represent a large share of the market at 35%.[8] Analytical software platforms can help coordinate otherwise disparate systems and determine the most cost-effective and energy-efficient strategies to maintain a building. For instance, analytics can advise building owners on when to charge and discharge batteries versus other strategies such as pre-cooling certain areas or disabling electric vehicle car charging stations during peak demand events. A combination of multiple strategies is also possible. Additionally, ESS can be enabled to charge batteries when demand is low and discharge when demand is high. This makes the most of variations in the grid, increases the efficiency of the system, and reduces carbon emissions.



# *The Opportunity*

Energy storage systems have the potential to provide valuable services to individual building owners and managers and the entire grid system. These benefits vary depending on factors such as local climate, type of storage system, and utility rate structure. We identify three main benefits: grid flexibility, energy efficiency, and resilience.

## Grid Flexibility

The primary value of energy storage is grid flexibility. Energy storage creates new, flexible possibilities and opportunities for managing the flow of energy within the framework of a relatively inflexible grid system, generating benefits for both the utility/grid and its customers.

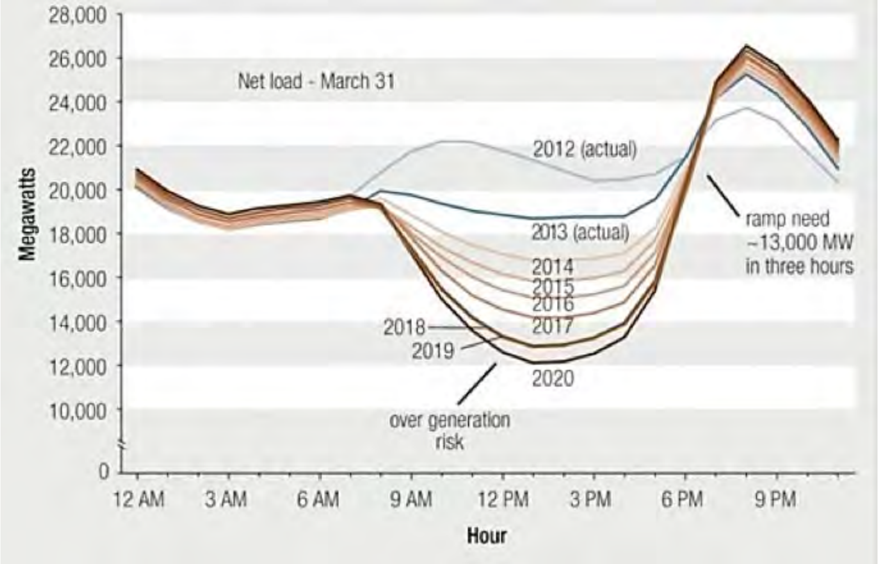


**Figure 3. Net load as aided by energy storage. Source:** www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

Energy storage can also help utilities avoid grid strain and ramping issues. When users on a grid system increasingly adopt distributed resources like photovoltaics, it can result in strain on the grid as the sun goes down. In addition to the higher peak, a steeper electricity demand ramp rate (i.e., the speed at which energy demand increases or decreases) can be especially problematic for the grid as power plants struggle to respond to sudden increases and decreases in output. Energy storage can help mitigate these problems by reducing peak demand and ramping up and down more easily than traditional grid resources allow. As figure 3 shows, it can allow users to charge systems during dips in the middle of the day and then discharge energy when the grid ramps up to meet peak demand.

Storage can also help customers avoid paying higher demand charges in jurisdictions where utilities require customers to pay more during peak demand. Energy storage software can add to this value by responding to changing rates and incentives. For instance, in some jurisdictions, consumers can receive as many as four different incentives for reducing energy. Software can determine in real time which of the demand response programs will earn the consumer the most money.[9] Another major benefit for consumers is that energy storage allows them to participate in a utility's demand response program without requiring them to make major operational changes (such as reducing HVAC usage during high demand periods).

Energy storage's ability to reduce peak demand on the grid also gives utilities the flexibility to defer or avoid the need for transmission and distribution infrastructure investments to meet increasing system peaks.

## Energy Efficiency

Sometimes energy storage can cause certain parts of a system to use more energy, for example, when a thermal storage system causes chillers to work harder to make ice. However, when installed and operated correctly, energy storage's energy efficiency benefits to the building can outweigh any negatives at the component or system level.

For instance, TES can save energy by allowing a mechanical engineer to design a building with a chiller, pumps, and fans that are smaller than those in a traditional building without TES. A thermal storage system has a greater temperature differential (i.e., colder liquid) and requires less (fluid and air) flow to achieve the same level of cooling. The chiller system may then be downsized as much as 40–50%, which saves cooling energy.[10] For a rough estimate of energy savings, if a building with an 800-ton chiller system used thermal storage to downsize to 400 tons, it would save over 400,000 kWh per year, equivalent to more than $40,000.[11]

Thermal energy storage systems can also save energy by enabling more favorable thermodynamics. For example, chiller systems that create ice usually operate at night. Since outdoor air temperatures are cooler at night, condensing temperatures are lower than those necessary for chiller systems run during warmer daytime temperatures. Lower condensing temperatures ultimately increase the efficiency of the system, saving the building owner energy.[12]

In addition to TES, battery storage systems can also enable energy efficiency when paired with combined heat and power (CHP) systems. Like most systems with motors, CHP has greater electrical efficiency at higher loads, typically between 50% and 75% capacity.[13] Operating these systems at higher loads also generates more heat that can be recovered by the system. One study concluded that CHP systems can increase system efficiency by nearly 50% by including energy storage and allowing the system to run at optimal capacity to charge the battery. This is opposed to normal operation where the capacity varies to meet a fluctuating load.[14]

## Resilience

Given recent trends towards mega-storms like hurricanes Sandy in 2012, Harvey and Maria in 2017, and Florence in 2018, as well as other disasters like California's 2017 forest fires, resilience is becoming an increasingly important issue. Batteries ensure that energy can be stored and ready for use when it is really needed. For instance, energy storage can help keep the power running to medical equipment and ensure patient safety in hospitals during disasters. In addition, keeping the power on during a blackout can help grocery retailers and refrigerated warehouses avoid the costs of disposing of spoiled products.

Energy storage can also turn commercial buildings into havens in the event of an emergency. For example, the city of San Francisco is currently implementing a project to install solar and storage in buildings within 12 disaster preparedness zones. In the event of a major disaster such as an earthquake, the Bay Area could be without grid power for as many as three weeks. Facilities like fire stations, police stations, and medical centers could accommodate large numbers of people and provide power and relief during this time.[15]

## *Savings Potential*

The National Renewable Energy Laboratory (NREL) quantified the economic viability of battery energy storage in commercial buildings and found that a utility's rate structure is one of the biggest determining factors for cost effectiveness. For example, high demand charges can improve the economic benefits of energy storage, and demand charges greater than a threshold of $15 per kilowatt (kW) generally made energy storage cost effective (depending on the building load profile). California and New York, early energy storage program adopters, contain the greatest number of eligible commercial customers at these threshold rates (1.4 million and 648,000, respectively), but a diverse group of states including Massachusetts, Colorado, and Georgia also have at least 100,000 eligible commercial customers, each with high demand rates.[16]

NREL also found that quantifying the economic benefit of resilience (i.e., the losses from grid disruptions) can help make energy storage much more cost effective, even in areas without high demand charges. This study estimated the average dollar losses of commercial and industrial buildings during a power outage from a severe weather event.[17]

The Rocky Mountain Institute (RMI) identified several other value streams for energy storage, including energy arbitrage, frequency regulation, and resource adequacy (see figure 4).[18] Combining multiple value streams, or value stacking, can provide opportunities for buildings that use storage to be compensated for providing grid services. For example, an energy storage system used solely for demand reduction is operated on average 5–50% of its useful life. If the battery also was used for frequency regulation and resource adequacy the remaining 50–95% of the time, it would be used more, creating much more value.[19]

TES systems may have fewer value streams than battery storage, but given the right conditions, they can also reduce peak energy use. TES has typically been most economically viable in large buildings, such as hospitals or universities. For instance, Princeton University saves $700,000 annually through its thermal energy storage system, which produces and stores large quantities of chilled water at night (with low demand prices) and uses it to cool the building during peak demand hours. The university realizes these savings by its ability to turn off its electric chillers when electricity prices are highest, avoiding peak demand charges.[20] Thermal storage also has a quicker payback and longer lifespan than lithium-ion batteries, since it has a lower material cost and will not lose much capacity over time in the way batteries do.[21]

### Case Study: Affordable Housing Generates $136,000/Year through Energy Storage Demand Response Programs

Marcus Garvey Village is a 625-apartment affordable housing complex constructed in the 1970s in Brooklyn, NY. During a major renovation in 2014, the property owner decided to install 300 kW battery storage (to complement a 400-kW solar PV system and 400-kW fuel cell) to help mitigate the complex's unusually high electric heating energy costs.

Using intelligent software, the property manages its distributed energy resources, essentially forming its own microgrid. The battery system allows Marcus Garvey Village to reduce its peak load energy use, operate on backup power in an emergency, and ensure that it consumes its own solar PV-generated energy.

The property earns nearly $136,000 annually from ConEdison and New York Independent System Operator (NYISO) demand response programs. In addition, the battery storage system also helped ConEd avoid constructing a new $1.2 billion substation.

**Source:** www.enernoc.com/resources/case-studies/marcus-garvey-village-microgrid

## *Challenges and Ways Forward*

Although energy storage is poised to become an integral part of building and grid energy systems, several challenges remain. High upfront costs are a primary barrier. As we have seen, it is beneficial to stack various value streams to justify the upfront costs of purchasing an energy storage system, yet many of these value streams are not considered under current regulatory schemes.[22] Initiatives such as Federal Energy Regulatory Commission (FERC) Order 841 can help customers take advantage of these opportunities. This order provides guidance to regional markets for removing barriers and creating a level playing field for energy storage technologies 100 kW and larger.[23]

One business approach that could help overcome the upfront cost barrier is the energy storage as a service (ESaaS) model. With this approach, a third party deploys, manages, and maintains an energy storage system (typically lithium-ion batteries, but others can work as well) in exchange for a service contract committing the customer to working with the third party for a period of time. Like other as-a-service ventures entering the market, these services reduce high upfront costs and the need for expertise in maintaining or operating the storage system. (ACEEE will release a more detailed Emerging Opportunities brief on efficiency as a service.)

Conflicting incentives are another barrier for customers using energy storage. During times of high energy demand, customers may have to choose between honoring their commitment to a demand response program (i.e., making their battery available for the utility to use) versus using the battery to reduce the peak demand charges of their own buildings. When this happens, the customer will lose one source of revenue. Enhanced rate structures, such as daily, rather than monthly, peak demand charges, could help mitigate this problem. In addition, if utilities could provide customers with advanced pricing signals from the electric supplier, customers would have greater ability to decide the optimal times to charge and discharge batteries.[24]

In New York City, safety is a concern for large-scale energy storage technologies, particularly given recent small-scale problems with lithium-ion battery explosions in cell phones and laptops. The Fire Department of New York (FDNY) is currently creating standards in collaboration with stakeholders like the New York State Energy Research and Development Authority (NYSERDA), the National Fire Protection Association, and ConEd.[25]

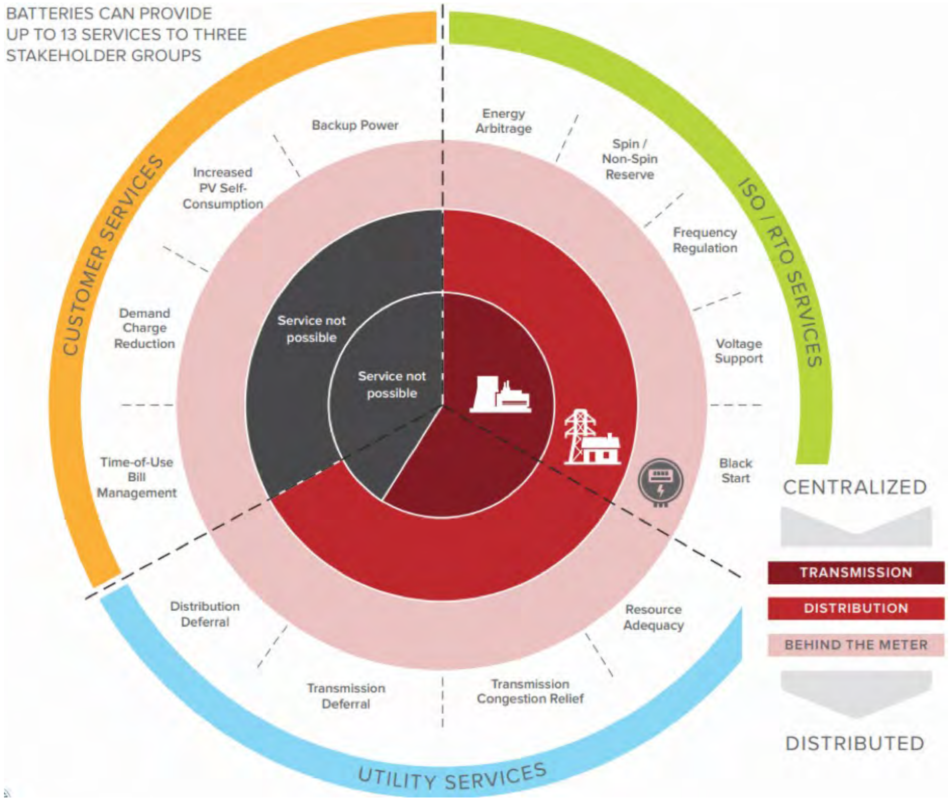


**Figure 4. Benefits of battery storage to various stakeholders. Source:** www.rmi.org/wp-content/uploads/2017/03/RMI-TheEconomicsOfBatteryEnergyStorage-FullReport-FINAL.pdf

Although this concern is primarily concentrated in New York City now, other jurisdictions may begin expressing similar concerns as the adoption of energy storage technologies continues to grow.

Another challenge to installing energy storage systems is determining how to appropriately size the system. If the battery is oversized, then much of its capacity may be wasted, and the consumer will have wasted money on the initial cost. If a customer's battery is undersized and the battery has emptied its charge before the peak demand, then she may not achieve any savings from demand charge reduction.

**Figure 5. Tesla Powerpack. Currently, Green Mountain Power offers incentives for the residential version (Tesla Powerwall); however, future programs could incentivize commercial Tesla batteries.**
***Source:*** [www.tesla.com/presskit](www.tesla.com/presskit)

## *Program Approaches*

Program administrators have implemented and/or piloted energy storage programs ranging from technical assistance and simple rebates to real-time storage management. An example of a simple technical assistance program, NYSERDA's Customer Assistance program managed by ERS, offers customers a free technical and financial analysis of energy storage options. ERS reviews interval data and conducts site visits where necessary and provides the customer site-specific recommendations about the feasibility of, and potential barriers to, energy storage.[26]

California can currently boast the most widespread and robust behind-the-meter energy storage incentive program. The state's Self-Generation Incentive Program (SGIP) has been in existence since 2001 and was restructured in 2017 to encourage greater adoption of energy storage and not just solar-only installations.[27] When the restructured program was reintroduced in 2017, it featured a lottery system for its incentives that prioritized solar-plus-storage facilities. Lottery "winners" for commercial projects could receive an incentive based on the size of their systems, starting at $0.50/watt-hour (or $0.36/watt-hour if they take an investment tax credit). Once this tier was sold out, customers could receive less money in a second tier until that also sold out, and so on.[28] California's SGIP clearly aligns with its mission of achieving zero energy buildings.[29]

Other states and jurisdictions are currently conducting pilot programs to determine the most cost-effective energy storage programs for their areas, in both the residential and commercial sectors. For instance, a utility might take responsibility for installing, owning, and managing the energy storage asset, such as ConEd's Commercial Battery Storage pilot[30] or Southern Company's Smart Neighborhood pilot[31] (part of a larger effort to combine high performance homes, energy-efficient equipment, connected systems, and a community microgrid). For programs of this type, a utility can use the battery primarily to benefit the grid by shedding load at peak times, but also to serve the customer by functioning as backup power.

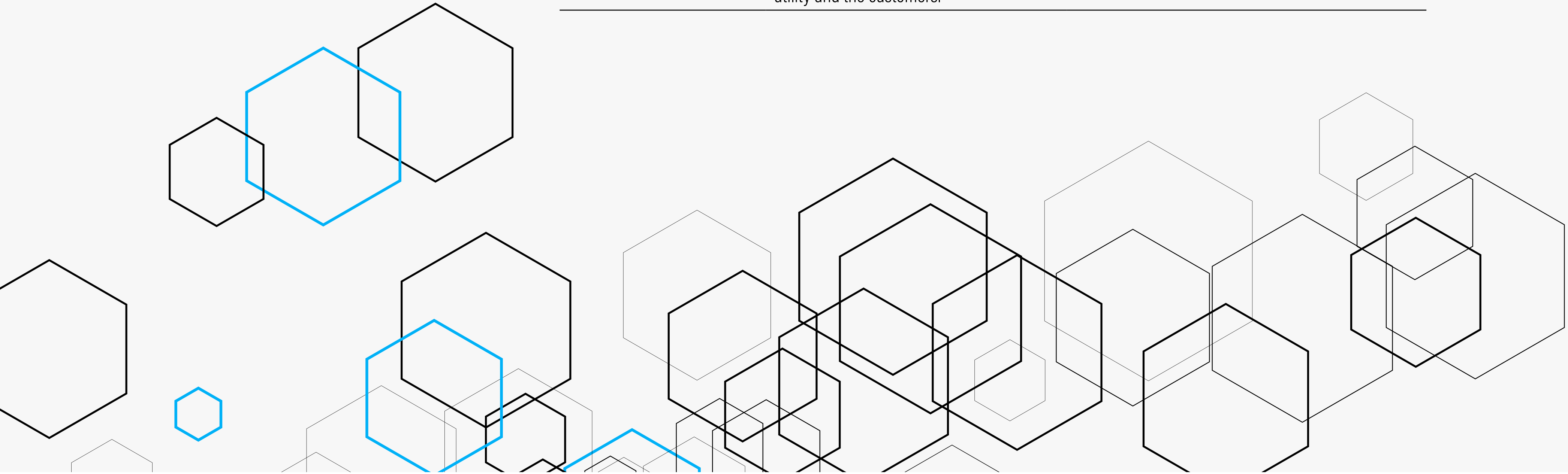
The utility reaps most of the storage benefits from ConEd's pilot,[32] whereas Southern Company's pilot is currently experimenting with a 50-50 split, where half of the capacity is used by the utility to shed peak demand loads, and the other half is reserved for customers to use as backup power.[33] Similarly, Green Mountain Power's Residential Storage Program allows customers to rent a Tesla Powerwall battery (for $1,500 or $15/month, substantially less than the purchase price), which is used for both customer benefit (backup power) and grid benefit (reducing peak demand).[34] Future programs could incentivize commercial batteries such as the one in figure 5.

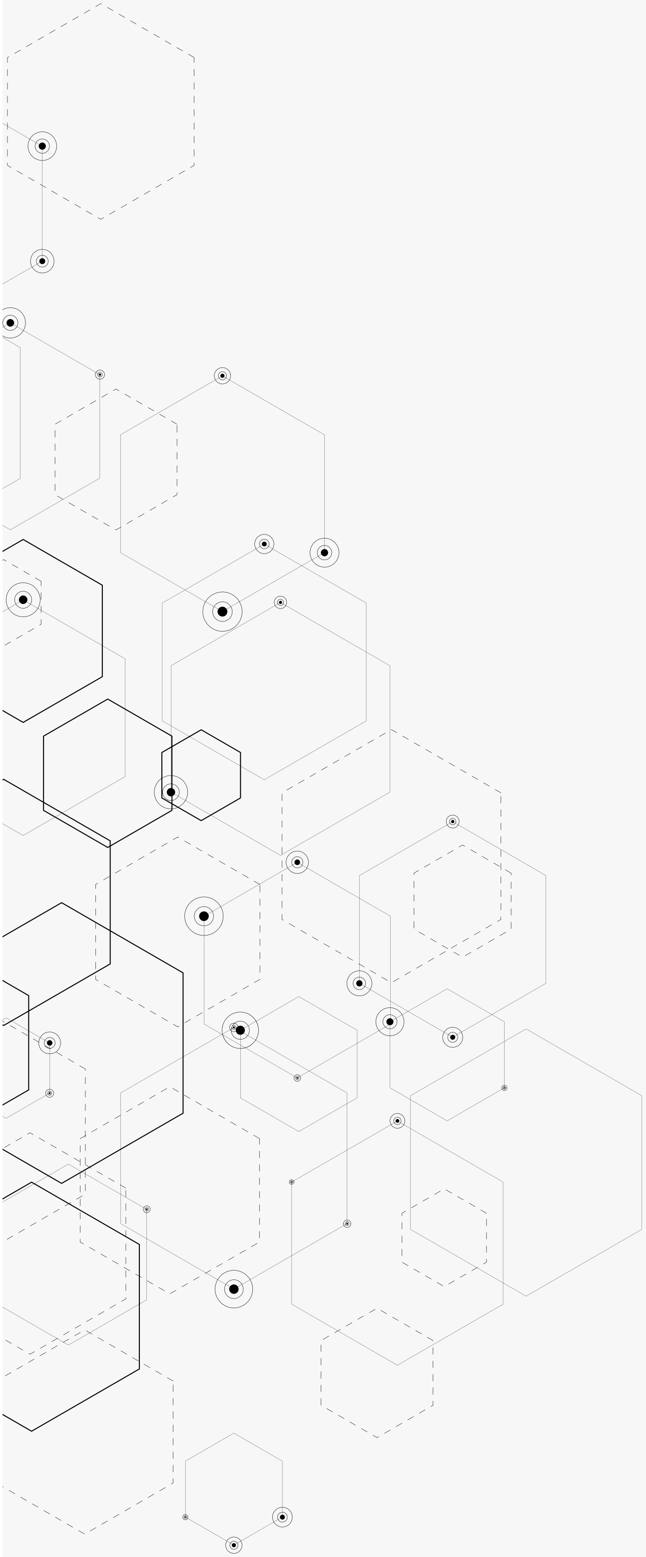
Another program offered by Green Mountain Power, the bring-your-own-device (BYOD) pilot, requires the customer to purchase her own battery and enter an agreement with the utility allowing it access to control the battery during peak events.[35] Future programs may feature more advanced software controls and analytics. For example, Alectra Utilities based in Ontario is piloting a program that uses large-scale software management to maximize a customer's economic outcome.[36] Additionally, Alectra is exploring the possibility of using blockchain to enable trading between the utility and its customers.[37]

Table 1 summarizes various types of behind-the-meter energy storage programs and pilots.[38]

**Table 1. Behind-the-meter energy storage**

| Program type | Design | Program example |
|---|---|---|
| Energy storage technical assistance | Free site-specific technical assistance is provided for customers interested in implementing energy storage projects. | NYSERDA Customer Assistance (managed by ERS) |
| Renewable energy + storage rebate | The program administrator provides a rebate based on system capacity for installing renewable energy, energy storage, or renewable with storage. | California Public Utilities (PG&E, SCE, SoCalGas, SDG&E): Self-Generation Incentive Program (SGIP) |
| Utility owned and controlled | Either the customer rents the battery from the utility or the utility leases space from a customer. Used primarily for utility need and secondarily for customer. Technically ahead-of-the-meter. | ConEdison: Commercial Battery Storage (commercial pilot); Southern Company Smart Neighborhood (residential pilot); Green Mountain Power Residential Storage Program (residential) |
| Third-party battery with utility management | Customers purchase batteries from any supplier, enter into an agreement to provide the utility access to battery power during peak events, and receive a monthly credit on their bills. | Green Mountain Power: BYOD (Bring Your Own Device) (residential pilot) |
| Real-time storage management | Customers select how much of their battery is used for backup power versus peak demand load shedding. Software manages battery use in real time. The program allows trading between the utility and the customers. | Alectra Utilities Power.House (residential pilot) |





## Next Steps

Considering the energy efficiency, grid flexibility, and resiliency benefits of energy storage, program administrators and policymakers should address barriers in order to install it in commercial buildings. More specifically, we recommend the following:

**Improve data access.** Utility program administrators can encourage energy storage by removing obstacles for energy storage implementers and installing smart meters to enable greater access to data. With at least a year of 15-minute interval electricity demand data, implementers can understand important data points like the building's baseload energy use, how often it peaks, and what type of energy storage (and possibly also renewable energy) system would be the best fit.[39] These data will ultimately enable implementers to optimize the size of the storage system, benefiting both the customer and the utility.

**Address high upfront cost.** Utility program administrators can help minimize the high upfront costs of energy storage through incentives, rate design changes, and market/contractual changes to allow value stacking. Even small changes to programs could help mitigate upfront costs. For example, program administrators could consider reducing or eliminating size thresholds for programs. Some limit their energy storage incentives to systems that are at least 100 kW; however many small and medium commercial buildings that might be interested in installing energy storage systems may not meet this requirement. Even smaller systems—5, 10, and 25 kW—can have a substantial benefit for the grid in the aggregate.

**Target small commercial buildings.** It may also make sense for a program administrator to develop separate programs for small independent commercial buildings. Third-party energy storage implementers tend to target major commercial customers (e.g., universities, real estate owners, commercial franchises, etc.); however small independent commercial buildings like non-chain restaurants or small apartment complexes may have a more difficult time finding parties to implement storage systems. This is where utilities and program administrators can capitalize on their relationships with these building owners and target their programs.

Like many areas of the energy industry, the technology is here but policy and regulation must catch up. Energy storage has the potential to improve building operation in a variety of ways, but most utility rate structures do not adequately reflect its benefits, which include grid flexibility, energy efficiency, and resilience. In addition, programs and policies must be robust enough to anticipate the continual evolution of the technology. States like California and New York, as well as Massachusetts and Hawaii, are paving the way with energy storage programs and adoption, but many more states and jurisdictions could benefit by making a conscious effort to include energy storage in their program portfolios.

# Notes

1. Located at the building level, behind-the-meter energy storage benefits both the building and the grid. In-front-of-the-meter storage primarily involves utility-scale systems.

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17. Nick Laws and Kate Anderson, Valuing the Resilience Provided by Solar and Battery Energy Storage Systems (Golden, CO: National Renewable Energy Laboratory, 2018). www.nrel.gov/docs/fy18osti/70679.pdf.

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