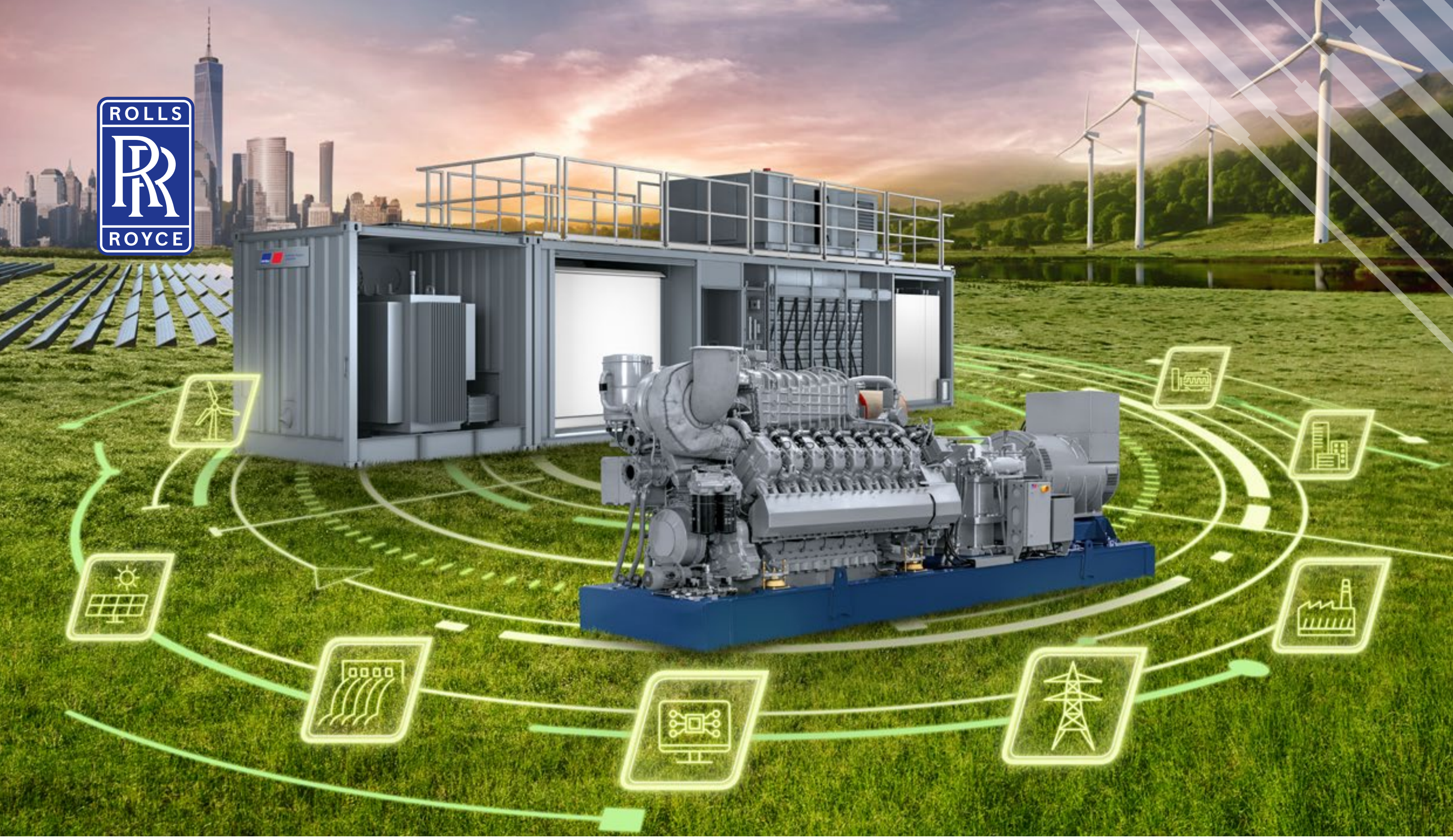

Power Generation

OPTIMIZING MICROGRID SYSTEMS : INTEGRATING RENEWABLE ENERGY SOURCES AND BATTERY STORAGE

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A microgrid utilizes multiple power generation assets to create energy. These assets can be conventional distributed energy resources such as generator sets, or renewable resources such as wind turbines and solar panels. These resources, paired with energy storage are not just technically feasible, but also cost-effective for many applications.

There are several unique benefits and challenges when integrating renewable energy sources and battery storage systems into a microgrid. A microgrid transmits and distributes traditional energy and renewable energy assets to a variety of value centers. Battery energy storage systems can be used to support the grid for "behind the meter" customer-specific applications, and for "in front of the meter" or utility support applications. By incorporating intelligent controls, a microgrid can be optimized to maintain an efficient balance between instantaneous and variable energy demands.

A Rolls-Royce solution

Grid support

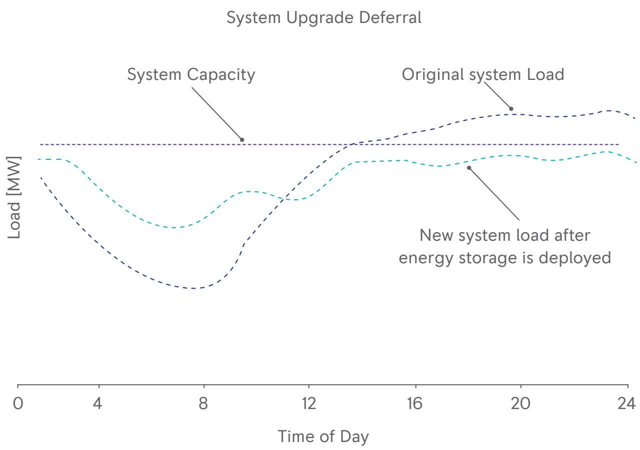


Figure 1 - Generic system load profile before and after energy storage is used to defer a traditional distribution system upgrade. [1]

Behind the meter support

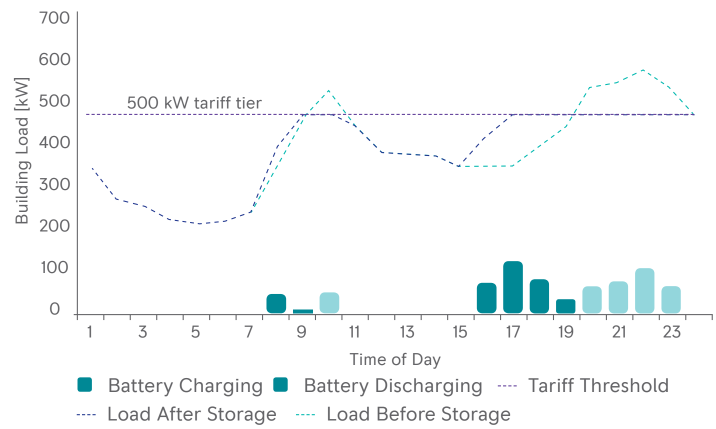


Figure 2 - Building-level load before and after energy storage deployment [1]

The right energy mix

Whether it's energy demand for a grid-scale project or a behind the meter application, delivering the right energy mix for your specific requirements is vital. Not only should it match your energy demand, it must also fit seamlessly with your distributed generation assets. Does your microgrid have wind turbines, solar panels and/or a reciprocating engine that's producing hot or chilled water? Other factors are the types of energy storage in place (if any). Is it thermal storage, such as a hot water tank? Or is it a complex lithium-ion battery storage application? Whether the microgrid is interconnected to the grid or self-supported (island mode), intelligent controls optimize all the assets. The control system determines how the assets will work together with the load and how they're going to interact with the utility and the grid as a whole.

Battery storage is another tool that can be utilized to fit your needs. A microgrid equipped with a battery and generator sets can reduce energy costs. Renewable energy sources can also integrate into a building or grid design. There are a lot of different applications in the microgrid spectrum. Incorporating engines and batteries through a control system can create an intelligent energy solution.

Importance of storage in grid design

The power grid is changing. We are no longer dependent on coal and other traditional types of energy generation sources. The prevalence of renewable energy generation has changed the energy landscape in many ways.

Impact of renewables on grid design

— 62% of new power plant construction utilizes a renewable energy
— 73% yearly increase in solar installations this decade
— 70% increase in renewable energy capacity since 2008
— 244GW of total renewable energy capacity located on the grid

As the world becomes less dependent on coal and nuclear plants, new generation technologies and fuel sources such as wind, solar and natural gas are growing. The increase of renewable energy is good for the environment. But if not properly managed on the grid, it may lead to issues.

Renewables have a different capacity factor than traditional power generation assets. Nuclear power generation has a 92% capacity factor (time the facility is able to produce maximum power). Coal and natural gas are above 50%. However, wind and solar have a very low capacity factor. These limitations must be considered when designing the grid and matching up battery storage and fast responding reciprocating engines with these new assets.

Since they're not 100% dependable, wind and solar power sources can't be used on demand and dispatched at the request of power grid operators. Even on a sunny day, there will be a curve of power generation. If you're dependent on a solar panel for all your power, you need something that can be turned off and on quickly to match the power you need with the variable power created by the sun or wind.

Not dispatchable

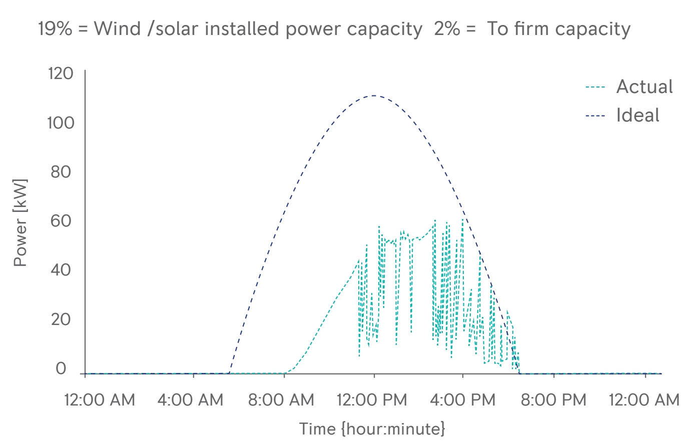
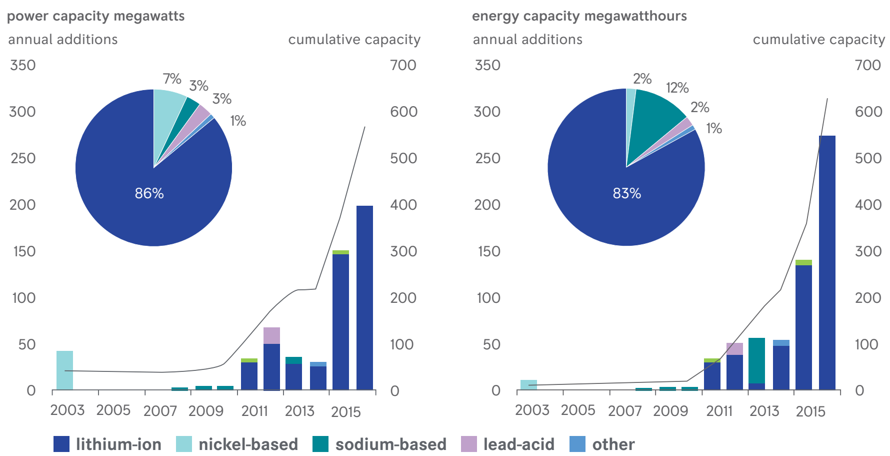


Figure 3 - Installation – CSIRO's Energy Centre at Newcastle

Figure 4 – U.S. Large-Scale Battery Storage Capacity by Chemistry [2]



These are not the same types of batteries used in cars and generators. For lithium-ion technology, storage is defined by C-Rating, or the rate at which a battery can be charged and discharged.

To determine battery levels at any given time, State of Charge indicates how much is remaining, and Depth of Discharge shows how much has been discharged.

A utility company may experience a capacity vs. demand mismatch. In California, there can be an underproduction or underavailability of renewables during the late afternoons and evenings, when energy demand rises as people come home. This is also when power reaches a high price, because it's restricted due to high demand and short supply. Ideally, the energy should be stored--created during the peak of the day and dispatched later when price and demand is highest.

Grid congestion is another issue that may arise as operators stretch the grid further to get the most from their resources. It occurs during periods of high demand greater than existing capacity. What you have to do – potentially – is perform energy efficiency upgrades. But you should also store some energy during the time of day when the demand is lower. Then, it can be dispatched to ensure you match your transmission or substation capacity during those maximum times of the year. To maximize value, you can defer costly upgrades to a later date when it's more affordable.

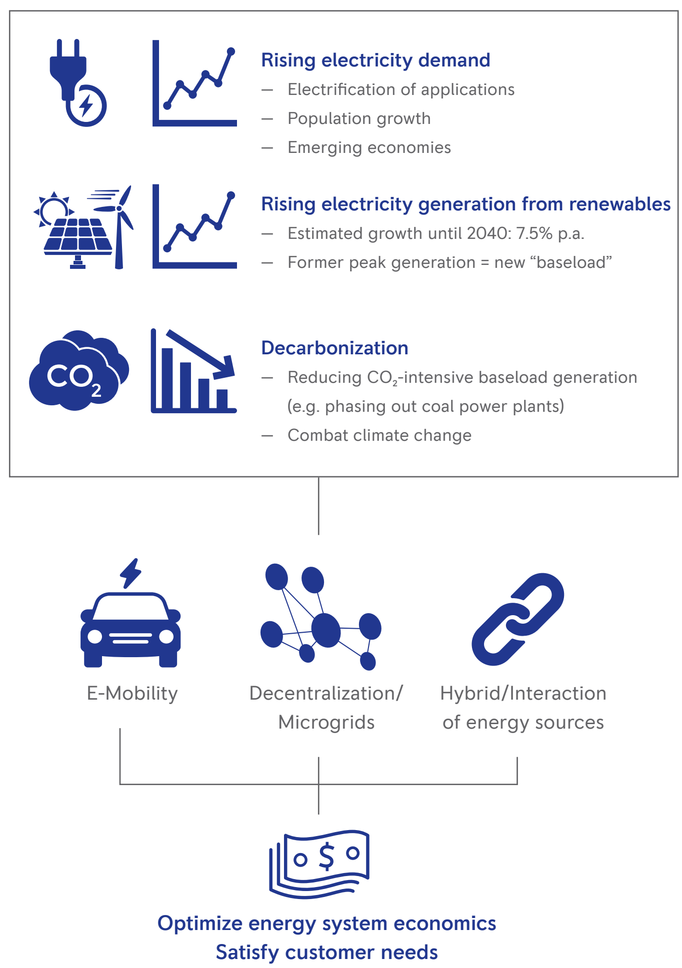
Types of storage

Pumped hydro storage comprises 97% of all storage capacity in the United States. Water is pumped up a hill or into a pond or retention basin when power is at a low price. When it's higher, the pond or retention basin is drained and the water runs through a turbine to make electricity. Huge volumes create many megawatts, but finding land to install new facilities is difficult.

The remaining 3% of U.S. storage capacity has been dominated recently by lithium-ion battery technology. Lithium-ion has captured both the power capacity markets (instantaneous power available from the battery) and energy capacity markets (megawatt hours available from the battery). It has become the technology of choice for these types of applications, due to its high-cycle efficiency and fast response time. The technology is available worldwide, offering high reliability and performance. It's also great for short duration and long duration applications, which are the focus of bridge storage applications in the real world.

Trends in grid storage

New challenges in the energy industry have increased the need for flexible storage solutions. The grid is changing. And battery energy storage is becoming a highly effective tool to optimize energy systems and satisfy customers. Now more than ever, infrastructure customers need interconnected systems designed for lifecycle performance, energy flexibility and responsiveness.



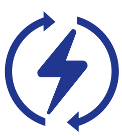
Regional storage trends

In the United States, the types of applications and uses for batteries differ by region. Pennsylvania, New Jersey and Maryland (where PJM is the system operator) focuses on power capacity – short-time, high-power output applications dispatched almost instantaneously for grid and frequency stabilization. The region's power capacity and energy capacity are almost at a 1:1 ratio.

The energy capacity market is in high demand in California, where the California Independent System Operator (CAISO) oversees the electric power system. In this region, there are longer duration outputs. Since energy capacity is three times larger than power capacity, the grid needs to bridge some issues to be able to supply long-term power. Many applications in California are looking for battery storage to accommodate a four-hour duration, or four-hour discharge.

Applications

How can battery storage technology be used? The four main application types for battery functions are:



Energy shifting

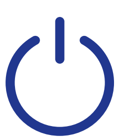
— Charge during low load periods, supply in high load periods
— Renewable power can be stored and later utilized
— Peak shaving—reduce peak demands and avoid demand charges

Power quality and frequency stabilization

— The reactive power capability can provide active voltage support
— Control and regulate energy systems frequency to increase grid reliability

Integration of renewables

— Renewable energy generation ensures smooth fluctuations during defined time period
— Buffer between generation and grid/consumer
— Avoids large ramp rates/rapid voltage and power swings on the infrastructure and increases grid reliability



Backup power

— Maintain network continuity until backup generator can take over loads
— Short reaction times (milliseconds)
— Backup power for a limited time period

Types of service operators

Battery storage is used by a variety of regional and local service operators.

ISO/RTO Services

— Energy arbitage
— Frequency regulation
— Spin/Non-spin reserves
— Voltage support
— Black start

Utility Services

— Resource adequacy
— Distribution deferral
— Transmission congestion relief
— Transmission deferral

Customer Services

— Time-of-use bill management
— Increased PV Self-Consumption
— Demand charge reduction
— Backup power

There are opportunities at every level for applications at different points in the grid—from transmission to distribution to "behind the meter." The further downstream (closer to the customer) battery-based energy storage systems are located on the electricity system, the more services they can offer to the system. And with more services, comes more financial benefits.

Full of potential

Battery storage is mainly dispatched for demand charge reduction, backup power and renewable self-consumption. However, engineers have yet to tap into the full potential of battery technology. Currently, less than 50% of the battery's capacity is used for its primary application. There is more potential energy available to the customer, the end-user and the grid. The best way to tap into the energy is by stacking values. Because the value of a microgrid comes from multiple sources, all value streams must be understood, measured and added up for each project. Combining multiple value streams can increase a grid storage project's profitability.

Case #1 Commercial demand-charge management – San Francisco

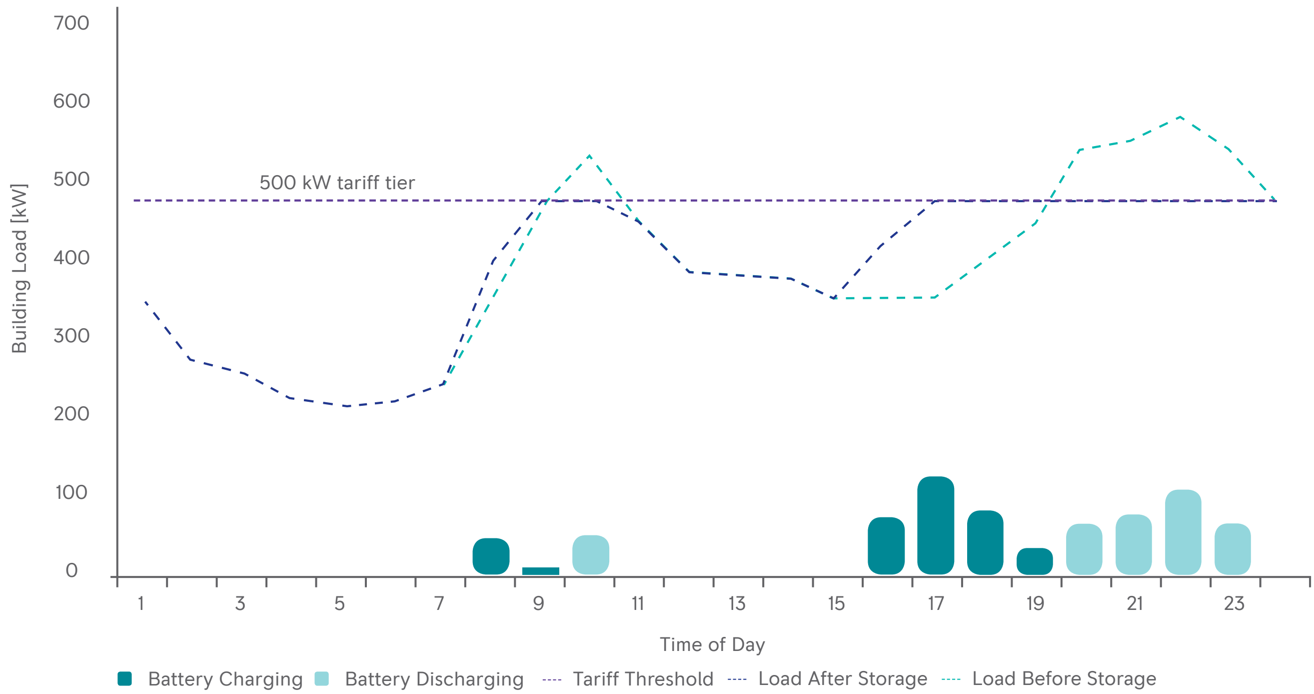


FIGURE 5 - Building-level load before and after energy storage deployment [1]

How does this look from a real-world commercial perspective? The graph above shows load levels before and after energy storage deployment for a building in San Francisco. The building is used from 1am to 12pm. The tariff for the demand management is about 500KW. To save energy costs, the battery in the utility charges when energy costs are low, and discharges when it approaches the 500KW tariff. As the pie chart illustrates, the building uses about 53% of the time on the demand charge reduction, roughly twice a day. This is projected to produce $400,000 out of $600,000 total revenue.

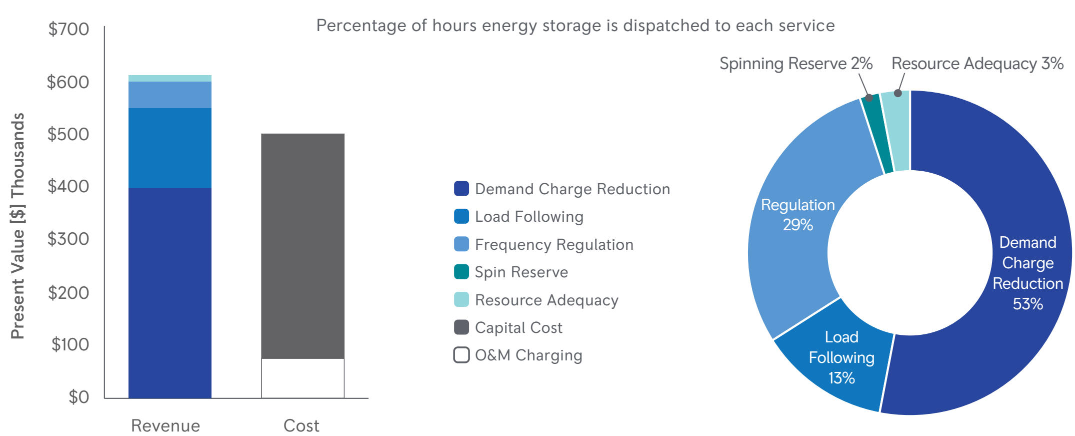


FIGURE 6 - Use Case 1 – Modeling results: Commercial demand-charge management in San Francisco [1]

Case #2 Distribution upgrade deferral – New York

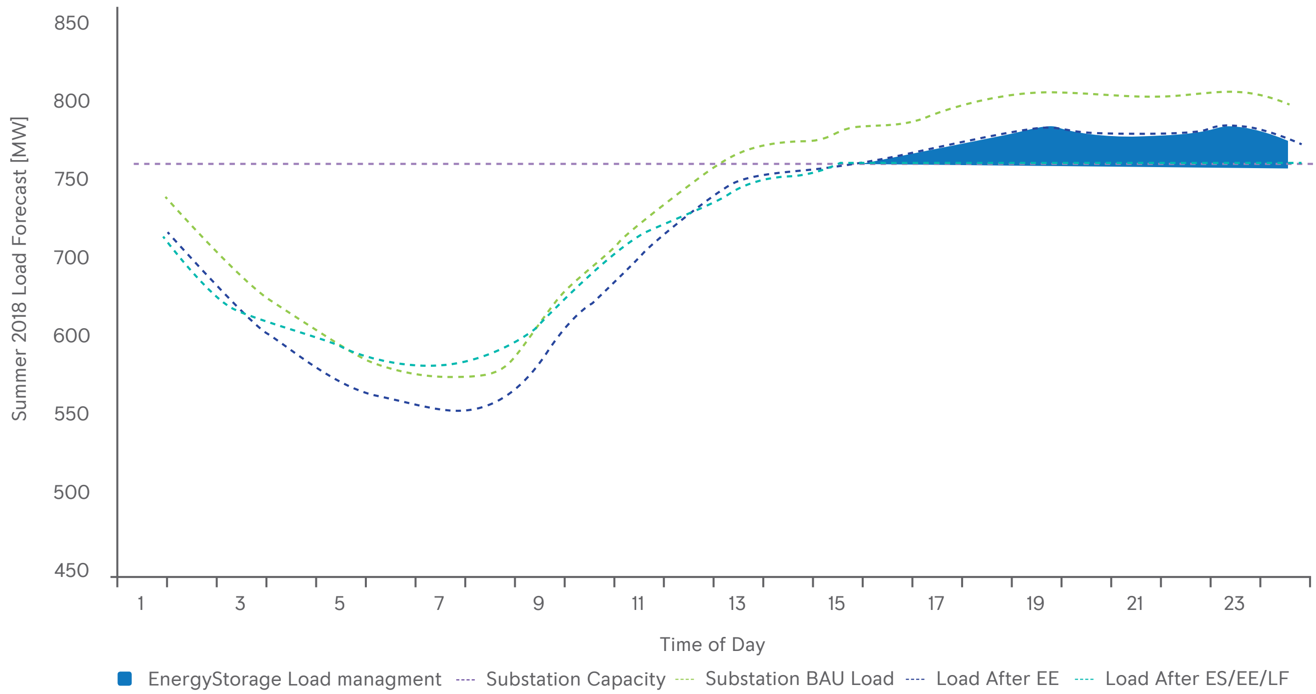


FIGURE 7 - BQDM system-level load before and after distributed energy storage deployment [1]

The graph above shows how a distribution network is applied to an area with a traditional infrastructure in place. In this application, when the time of day reaches the afternoon, without energy efficiency or energy storage, the substation will be over capacity, which will lead to severe issues. Combining grid storage with different energy efficiency measures creates an opportunity to manage the load to make sure it doesn't exceed substation capacity.

The different revenue streams, resource adequacy and distribution upgrades are a very small portion of the percentage used. But they're very high on the revenue scale. In this case it's a mismatch on the cost of the project -- this is also a study in deferred costs as well. These are some of the factors that utilities must consider as they look at these kind of projects. There are upfront costs on the installation and operation of the system, along with long-term costs to defer these upgrades to ensure a stable and secure grid.

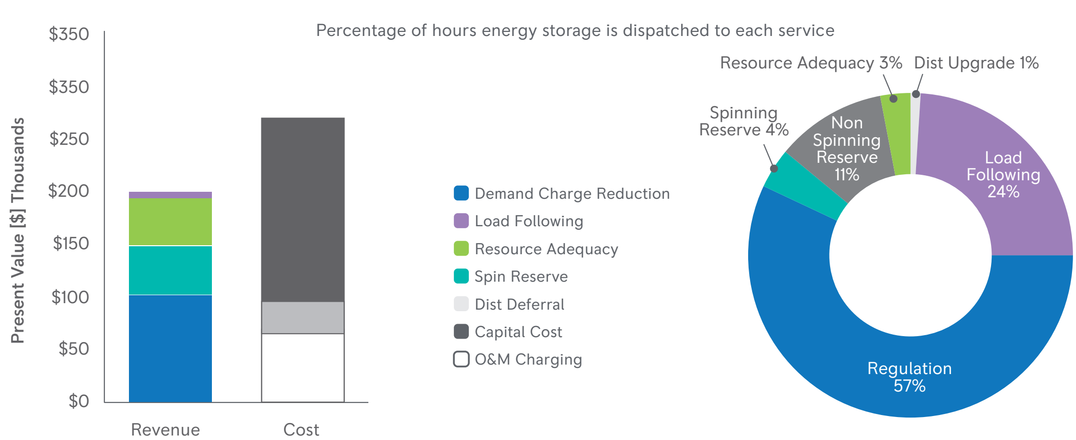


FIGURE 8 - Use Case 2 – Modeling results: Distribution upgrade deferral in New York [1]

Applications

Example #1:
Off-Grid Greenhouse – California

Site details
- 160,000 sq. ft. European-designed facility
- Limited three-phase power available for office area only
- Abundant natural gas available
- Cooling loads are the major challenge

Challenges
- Island mode operation
- Load swings based on changing loads
- Annual uptime guarantees
- Low transient and load acceptance of natural gas generators
- High ambient temperatures

Solutions
- Engines sized to match loads (1 x 1151kW, 2 x 1550kW)
- Battery used for load leveling and backup generation during low load periods
- Full heat recovery for chilled water system
- Control of system from MTU microgrid controller with inputs from greenhouse building management system

Example #2:
Off-grid hospital – Caribbean

Site details
- Renewable self-consumption healthcare facility serving island community
- 99,000 patients annually

Challenges
- Only 30% of residents have access to electricity
- Electricity is costly - $.30kW/hr

Solutions
- 650kW installed PV
- 600kW / 350 kW / 200kW diesel generators
- 450kWh battery – Reduced fuel 35 gallons/day, offset 2,000 tons CO_2/year and saved 500,000 Euro/year

Barriers and incentives

As new technologies and new ways to distribute, store and use energy emerge, system operators and transmission operators have to figure out how to use those assets. Many FEC (Federal Energy Commission) regulations are outdated, but evolving. A lot of these regulatory restrictions make it harder to stack the value of those batteries. The grid was originally designed when customers were strictly power users. Significant upgrades are necessary to handle new ways customers use electricity.

Rules and regulations that place behind-the-meter energy storage on an equal playing field with large central generators have been developed and implemented slowly. A three-year rollout of FERC Order 755 required ISO/RTO markets to provide compensation to resources that provide faster-ramping frequency regulation. In addition, regulatory restrictions make it difficult or impossible for a utility to collect revenue from a behind-the-meter energy storage asset that provides value to multiple stakeholder groups. Under prevailing ISO/RTO rules, utilities can't stack the value of batteries.

New policy actions for energy storage

- California – The California Public Utility Commission (CPUC) implemented Assembly Bill 2514 by setting a mandate for its investor-owned utilities to procure 1,325 MW of energy storage across the transmission, distribution, and customer levels by 2020
- California – The California Self-Generation Incentive Program designated $48.5 million in rebates for residential storage systems 10 kW or smaller, and $329.5 million for storage systems larger than 10 kW
- Federal - Energy storage installed at a solar or wind facility can be considered part of the energy property of the facility and can receive a portion of the Investment Tax Credit (ITC)
- Maryland - Offers a tax credit of 30% on the installed costs for residential and commercial systems
- Massachusetts - Set an energy storage target of 200 MWh by 2020
- Nevada - Allows storage systems to be included in renewable portfolio standards
- New York - Announced a target of 1.5 GW of energy storage by 2025
- Oregon - Passed a law directing two electric utilities to each procure 5 MWh by 2020

Conclusion

Microgrids optimize the use of solar, wind, energy storage and other resources to allow communities to obtain renewable, low-cost energy and maintain reliability. As renewable generation capacity continues to grow, more dispatchable power through battery storage is needed to provide grid stability. Placing a value on microgrids is challenging, since each individual project is unique. The microgrid must be carefully designed with services as close to the end user as possible with intelligent controls that optimize the interaction between energy sources. When considering the benefits of all value streams, cost savings and risk management, you may find that a microgrid is well worth the investment.

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Glossary

BESS - Battery Energy Storage System
C Rating - The rate that the battery can be charged or discharged, ex. a battery rated 2000kWh would provide 2000kW for one hour
Dispatchable gener ation - Sources of capacity that can deliver power on demand, through starting and stopping, and varying power output.
DoC - Depth of Charge
Energy capacity - Total amount of energy that can be stored or discharged or MMh
ISO / RTO - Independent System Operator and Regional Transmission Organization
Large-scale storage - Connected to the grid and are 1MW or greater
Lifecycle - Number and types of discharges and the effect on battery life
Power capacity - Maximum instantaneous power output or MW
Regional transmission organizations

- CAISO California Independent System Operator
- ERCOT Electric Reliability Council of Texas
- ISO-NE Independent System Operator of New England
- MISO Mid-Continent Independent System Operator
- PJM Pennsylvania-New Jersey-Maryland Interconnection

Small-scale storage - 1MW or below and connected to a distribution network
SoC - State of Charge

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