THE ECONOMICS OF BATTERY ENERGY STORAGE

HOW MULTI-USE, CUSTOMER-SITED BATTERIES DELIVER THE MOST SERVICES AND VALUE TO CUSTOMERS AND THE GRID

EXECUTIVE SUMMARY

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Rocky Mountain Institute (RMI)—an independent nonprofit founded in 1982—transforms global energy use to create a clean, prosperous, and secure low-carbon future. It engages businesses, communities, institutions, and entrepreneurs to accelerate the adoption of market-based solutions that cost-effectively shift from fossil fuels to efficiency and renewables. In 2014, RMI merged with Carbon War Room (CWR), whose business-led market interventions advance a low-carbon economy. The combined organization has offices in Snowmass and Boulder, Colorado; New York City; Washington, D.C.; and Beijing.

EXECUTIVE SUMMARY

UTILITIES, REGULATORS, and private industry have begun exploring how battery-based energy storage can provide value to the U.S. electricity grid at scale. However, exactly where energy storage is deployed on the electricity system can have an immense impact on the value created by the technology. With this report, we explore four key questions:

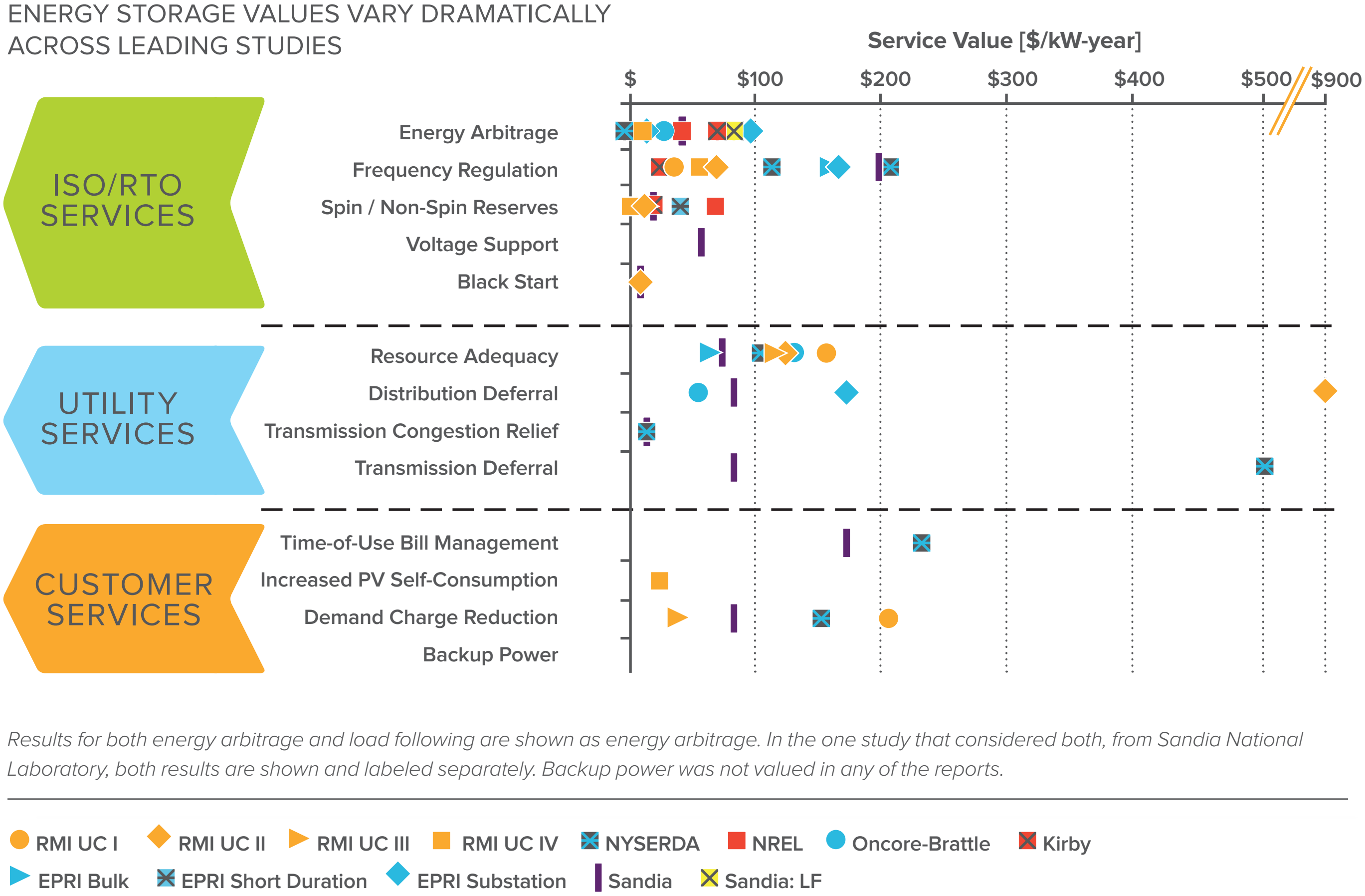
1. What services can batteries provide to the electricity grid?
2. Where on the grid can batteries deliver each service?
3. How much value can batteries generate when they are highly utilized and multiple services are stacked?
4. What barriers—especially regulatory—currently prevent single energy-storage systems or aggregated fleets of systems from providing multiple, stacked services to the electricity grid, and what are the implications for major stakeholder groups?

1. What services can batteries provide to the electricity grid?

Energy storage can provide thirteen fundamental electricity services for three major stakeholder groups when deployed at a customer's premises (behind the meter).

To understand the services batteries can provide to the grid, we performed a meta-study of existing estimates of grid and customer values by reviewing six sources from across academia and industry. Our results illustrate that energy storage is capable of providing a suite of thirteen general services to the electricity system (see Figure ES1). These services and the value they create generally flow to one of three stakeholder groups: customers, utilities, or independent system operators/regional transmission organizations (ISO/RTOs).

FIGURE ES1
ENERGY STORAGE VALUES VARY DRAMATICALLY ACROSS LEADING STUDIES



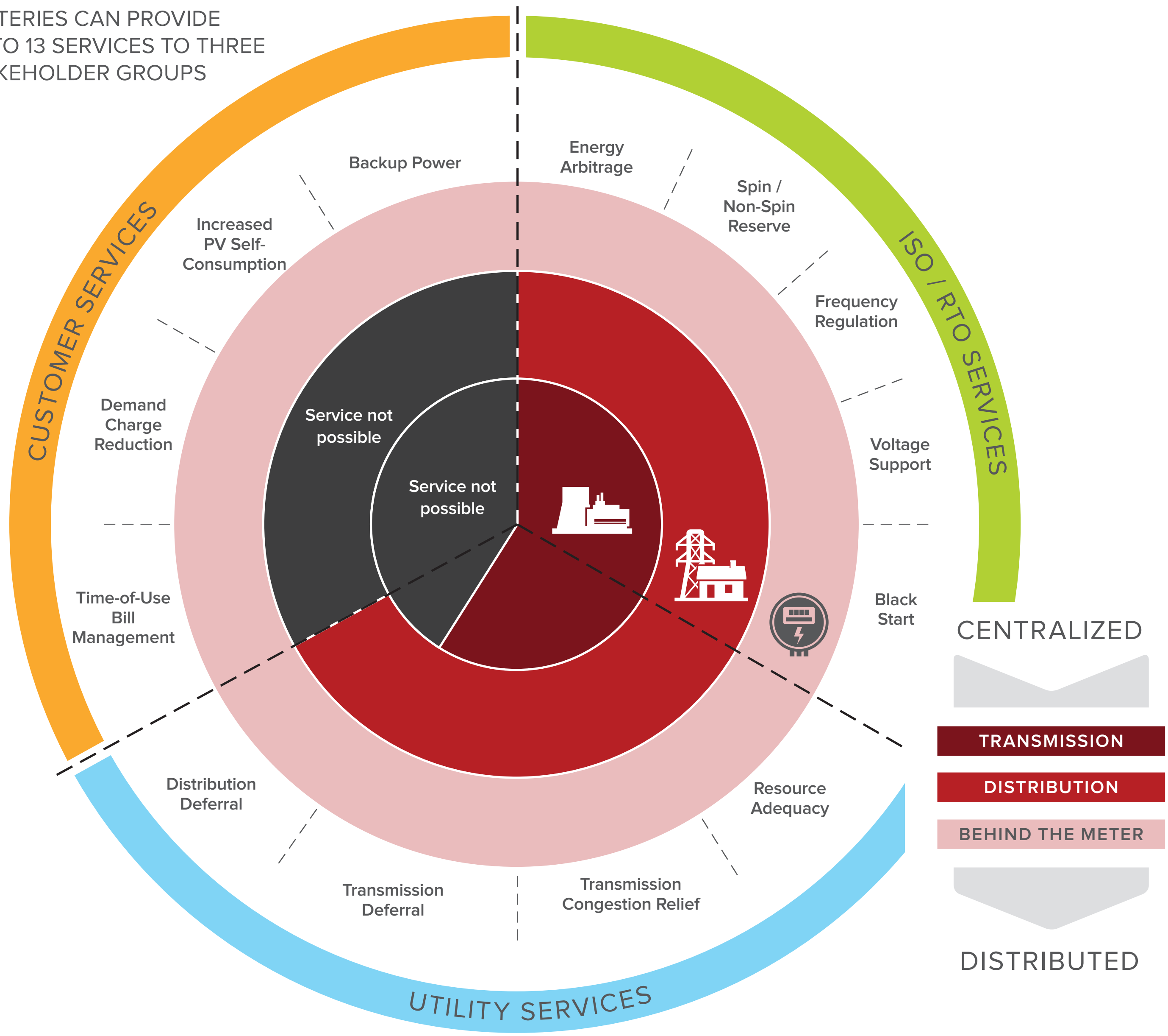
Results for both energy arbitrage and load following are shown as energy arbitrage. In the one study that considered both, from Sandia National Laboratory, both results are shown and labeled separately. Backup power was not valued in any of the reports.

2. Where on the grid can batteries deliver each service?

The further downstream battery-based energy storage systems are located on the electricity system, the more services they can offer to the system at large.

Energy storage can be sited at three different levels: behind the meter, at the distribution level, or at the transmission level. Energy storage deployed at all levels on the electricity system can add value to the grid. However, customer-sited, behind-the-meter energy storage can technically provide the largest number of services to the electricity grid at large (see Figure ES2)—even if storage deployed behind the meter is not always the least-cost option. Furthermore, customer-sited storage is optimally located to provide perhaps the most important energy storage service of all: backup power. Accordingly, regulators, utilities, and developers should look as far downstream in the electricity system as possible when examining the economics of energy storage and analyze how those economics change depending on where energy storage is deployed on the grid.

FIGURE ES2
BATTERIES CAN PROVIDE UP TO 13 SERVICES TO THREE STAKEHOLDER GROUPS



3. How much value can batteries generate when they are highly utilized and multiple services are stacked?

Energy storage can generate much more value when multiple, stacked services are provided by the same device or fleet of devices…

The prevailing behind-the-meter energy-storage business model creates value for customers and the grid, but leaves significant value on the table. Currently, most systems are deployed for one of three single applications: demand charge reduction, backup power, or increasing solar self-consumption. This results in batteries sitting unused or underutilized for well over half of the system's lifetime. For example, an energy storage system dispatched solely for demand charge reduction is utilized for only 5–50% of its useful life. Dispatching batteries for a primary application and then re-dispatching them to provide multiple, stacked services creates additional value for all electricity system stakeholders.

… but the net value of behind-the-meter energy storage to the electricity system is difficult to generalize.

A summary of grid values and services is not enough to answer a fundamental question: How does the value of energy storage shift when deployed at different levels on the electricity grid? Answering this question proves greatly complicated. The net value of providing each of thirteen services at different levels on the grid (transmission level, distribution level, or behind the meter) varies dramatically both across and within all electric power markets due to hundreds of variables and associated feedback loops. Hence, the values energy storage can provide vary dramatically from study to study, driven by grid-specific factors (see Figure ES1).

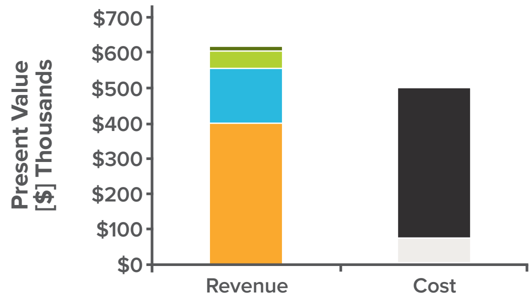
Under prevailing cost structures, batteries deployed for only a single primary service generally do not provide a net economic benefit (i.e., the present value of lifetime revenue does not exceed the present value of lifetime costs), except in certain markets under certain use cases. However, given that the delivery of primary services only takes 1–50% of a battery's lifetime capacity, using the remainder of the capacity to deliver a stack of services to customers and the grid shifts the economics in favor of storage.

Using a simplified dispatch model, we illustrate the value of four behind-the-meter energy storage business cases and associated capital costs in the U.S. (conservatively, \$500/kWh and \$1,100–\$1,200/kW). Each case centers on delivery of a primary service to the grid or end user: storage is dispatched primarily to deliver this service and then secondarily provides several other stacked services based on the relative value of the service, battery availability, and other user-defined inputs to the model (see Figure ES3).

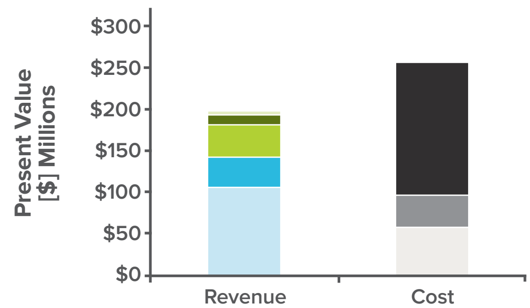
Our results come with one major caveat: for any of the scenarios illustrated herein to manifest in the real world, several regulatory barriers to behind-the-meter energy storage market participation must be overcome.

FIGURE ES3
BATTERY ECONOMICS GREATLY IMPROVE WHEN SERVICES CAN BE STACKED: FOUR EXAMPLES

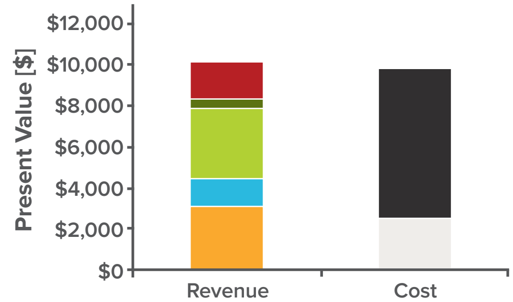
USE CASE I. Commercial demand-charge management in San Francisco. **Primary service:** commercial demand-charge management. **Secondary services:** frequency regulation, resource adequacy, and energy arbitrage.



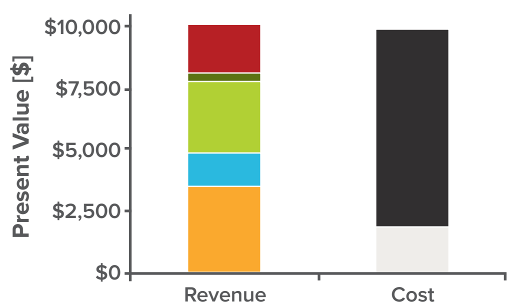
USE CASE II. Distribution upgrade deferral in New York. **Primary service:** distribution upgrade deferral. **Secondary services:** a suite of ISO / RTO services and resource adequacy.



USE CASE III. Residential bill management in Phoenix. **Primary service:** time-of-use optimization / demand-charge reduction. **Secondary services:** a suite of ISO / RTO services and resource adequacy.



USE CASE IV. Solar self-consumption in San Francisco. **Primary service:** solar self-consumption*. **Secondary services:** time-of-use optimization, a suite of ISO/RTO services, and resource adequacy.



ISO/RTO SERVICES: Load Following, Frequency Regulation, Spin Reserve, Non-Spin Reserve, Black Start
UTILITY SERVICES: Resource Adequacy, Dist Deferral **CUSTOMER SERVICES:** TOU, Self-Consumption, Demand Charge Reduction
COSTS/TAX: Capital Cost, O&M & Charging, Tax Cost, Tax Benefits

** This analysis is based on a hypothetical scenario in which net energy metering is replaced with a value-of-solar tariff at 3.5 cents per kWh. While RMI does not think this scenario is likely (nor would we advocate for it) we did want to understand the economics of solar and storage under an avoided-fuel-cost compensation model.*

Energy storage business models that deliver multiple, stacked services can provide system-wide benefits. With appropriate valuation of those services, such battery business models can also provide net economic benefit to the battery owner/operator. As illustrated by the three cases analyzed in this report that modify customer load profiles in response to rate structures, energy storage systems deployed for a single customer-facing benefit do not always produce a net economic benefit. However, by combining a primary service with a bundle of other services, batteries become a viable investment.[i] Importantly, the positive economics for bill management scenarios (e.g., demand-charge reduction, time-of-use optimization) even without applying a value to backup power suggests that customers are likely to seek out behind-the-meter energy storage. In light of the fact that these assets can be used to provide grid services on top of this primary use, creating business models that take advantage of this capability—rather than procuring ultimately redundant centralized solutions—should be a high priority for grid operators, regulators, and utilities.

The New York distribution upgrade deferral case was the only one without positive economics examined in this report. However, after delivering the primary service of distribution deferral, if the batteries were secondarily dispatched to deliver customer-facing services, like demand charge reduction or backup power (instead of wholesale market services), the economics would likely flip in favor of storage. Accordingly, this case demonstrates the importance of considering all services, including customer services, when building an economic case for battery storage.

Batteries are often deployed for primary reasons that use the battery only a small fraction of the time, leaving an opportunity for other, stacked services. For example, distribution deferral typically demands only 1% of the battery's useful life; demand charge reduction represents a 5–50% utilization rate. Building business models that, at the outset, only plan to utilize batteries for a minority of the time represents a lost opportunity. While the stacked-use business models we analyzed are not necessarily the right ones for all real-world situations, the development of robust stacked-use business models should be a priority for industry.

4. What barriers—especially regulatory—currently prevent single energy storage systems or aggregated fleets of systems from providing multiple, stacked services to the electricity grid, and what are the implications for major stakeholder groups?

Distributed energy resources such as behind-the-meter battery energy storage have matured faster than the rates, regulations, and utility business models needed to support them as core components of the future grid. Even though behind-the-meter energy storage systems have the potential to economically provide multiple, stacked benefits to all stakeholder groups in the electricity system, many barriers largely prevent them from doing so. In order to address these issues, we recommend the following next steps to enable behind-the-meter energy storage to provide maximum benefits to the grid:

[i] This report considers where batteries should be deployed to enable the broadest suite of multiple, stacked services. The issue of who would make the investment in those batteries—such as customers, utilities, or third parties—remains an open question.

For Regulators

- Remove barriers that prevent behind-the-meter resources such as battery energy storage from providing multiple, stacked services to the electricity grid that benefit all stakeholder groups, including customers, ISOs/RTOs, and utilities.[ii]

- Require that distributed energy resources (including storage) be considered as alternative, potentially lower-cost solutions to problems typically addressed by traditional “wires” investments and/or centralized peaking generation investments.

- Across all markets, require utilities to use a standardized, best-fit, least-cost benefit methodology that compares energy storage providing a full suite of stacked services with incumbent technologies.

For Utilities

- Restructure utility business models and rates to reflect the value that storage can provide to the grid via temporal, locational, and attribute-based functionality, making utilities indifferent to the distinction between distributed and centralized resources.

- Prior to considering new centralized assets, look first for opportunities to leverage existing assets, such as storage, via stacking of uses; provide education so that distribution planners, grid operators, and rate designers can work together to leverage storage’s full suite of capabilities.

For the Research Community

- Develop a widely recognized modeling tool or a consistent methodology and approach capable of comparing, on an equal basis, the net cost of stacked services provided by energy storage and other distributed energy resources as compared to incumbent technologies such as combustion turbines and traditional infrastructure upgrades.

- Develop a detailed state-by-state roadmap that specifically identifies policy and regulatory changes that must be adapted or revised to enable widespread integration of energy storage and other distributed energy resources.

For Battery and Distributed-Energy-Resource Developers

- Pursue business models that fully utilize the battery.

- Pursue cost reduction efforts for all power-focused elements of energy storage systems (all $/kW components) in order to unlock more energy storage markets.

- Collaborate with utilities and regulators to help them understand what values distributed energy storage can provide and what new utility business models will be needed to scale them.

[ii] *Ongoing efforts that tend towards this outcome include New York’s Reforming the Energy Vision proceeding, California’s order for development of distributed resource plans, Massachusetts’ Grid Modernization Plan, ERCOT’s proposed rules and regulations on distributed energy resource integration, Minnesota’s e21 initiative, ongoing regulatory proceedings in Hawaii, and others.*