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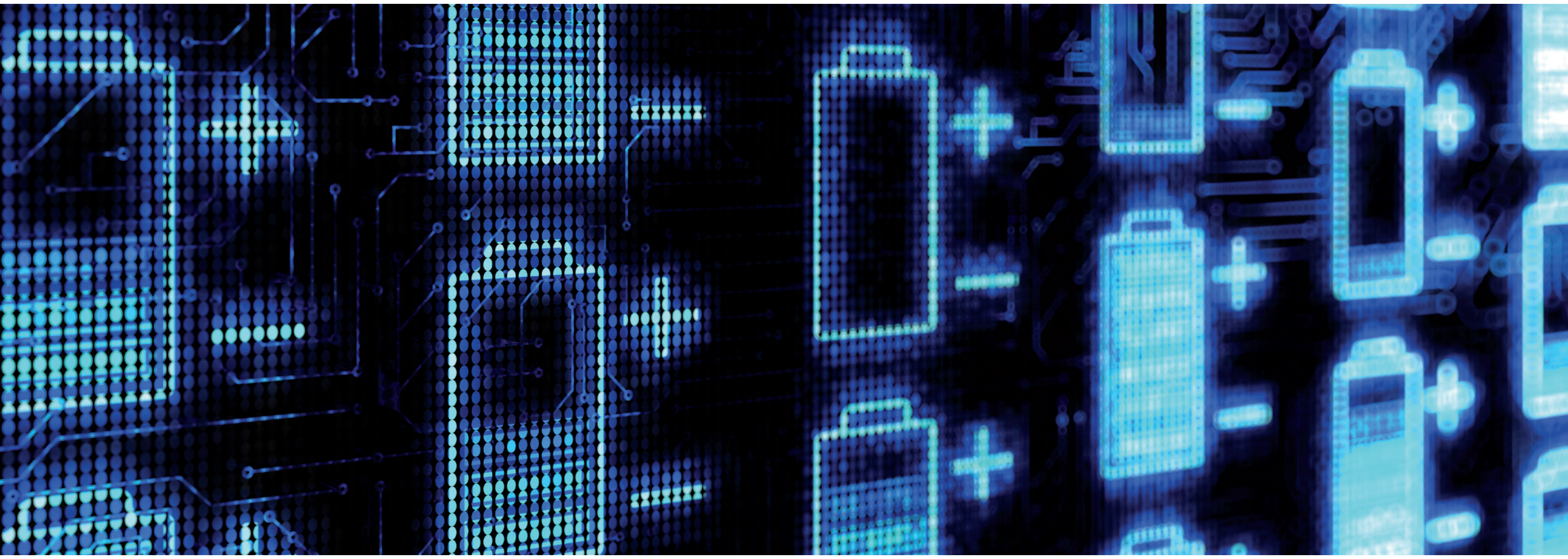

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Sustainability & Resource Productivity

The new economics of energy storage

Energy storage can make money right now. Finding the opportunities requires digging into real-world data.

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Energy storage is a favorite technology of the future—for good reasons.

Many people see affordable storage as the missing link between intermittent renewable power, such as solar and wind, and 24/7 reliability. Utilities are intrigued by the potential for storage to meet other needs such as relieving congestion and smoothing out the variations in power that occur independent of renewable-energy generation. Major industrial companies consider storage a technology that could transform cars, turbines, and consumer electronics (see sidebar, "What is energy storage?").

Others, however, take a dimmer view, believing that storage will not be economical any time soon. That pessimism cannot be dismissed. The transformative future of energy storage has been just around the corner for some time, and at the moment, storage constitutes a very small drop in a very large ocean.[1] In 2015, a record 221 megawatts of storage capacity was installed in the United States,[2] more than three times as much as in 2014—65 megawatts, which was itself a big jump over the previous year. But more than 160 megawatts of the 2015 total was deployed by a single regional transmission organization, PJM Interconnection.[3] And 221 megawatts is not much in the context of a total US generation capacity of more than a million megawatts.

Our research shows considerable near-term potential for stationary energy storage. One reason for this is that costs are falling and could be $200 per kilowatt-hour in 2020, half today's price, and

$160 per kilowatt-hour or less in 2025. Another is that identifying the most economical projects and highest-potential customers for storage has become a priority for a diverse set of companies including power providers, grid operators, battery manufacturers, energy-storage integrators, and businesses with established relationships with prospective customers such as solar developers and energy-service companies.

In this article, we describe how to find profitable possibilities for energy storage. We also highlight some policy limitations and how these might be addressed to accelerate market expansion. These insights could help forward-thinking companies win an early toehold in a market that in the United States could reach $2.5 billion by 2020—six times as much as in 2015.[4] The ultimate prize, of course, is much bigger. As the technology matures, we estimate that the global opportunity for storage could reach 1,000 gigawatts in the next 20 years.

Where to compete: Model insights

Identifying and prioritizing projects and customers is complicated. It means looking at how electricity is used and how much it costs, as well as the price of storage.

Too often, though, entities that have access to data on electricity use have an incomplete understanding of how to evaluate the economics of storage; those that understand these economics have limited access to real-world data on electricity use. Moreover, there has been a tendency to average the data when doing analyses. Aggregating numbers, however, is not useful when evaluating prospects for energy storage because identical buildings next door to each other could have entirely different patterns of electricity use. Conclusions drawn based on averages therefore do not have the precision needed to identify which customers would be profitable to serve.

What is energy storage?

Energy storage absorbs and then releases power so it can be generated at one time and used at another. Major forms of energy storage include lithium-ion, lead-acid, and molten-salt batteries, as well as flow cells. There are four major benefits to energy storage. First, it can be used to smooth the flow of power, which can increase or decrease in unpredictable ways. Second, storage can be integrated into electricity systems so that if a main source of power fails, it provides a backup service, improving reliability. Third, storage can increase the utilization of power-generation or transmission and distribution assets, for example, by absorbing power that exceeds current demand. Fourth, in some markets, the cost of generating power is significantly cheaper at one point in time than another; storage can help smooth out the costs. Historically, companies, grid operators, independent power providers, and utilities have invested in energy-storage devices to provide a specific benefit, either for themselves or for the grid. As storage costs fall, ownership will broaden and many new business models will emerge.

In our research, we were able to access data from both utility and battery companies. On this basis, we found that it is quarter-hour-by-quarter-hour or even minute-by-minute use that reveals where the opportunities are.

To identify today's desirable customers, we built a proprietary energy-storage-dispatch model that considers three kinds of real-world data:

- electricity production and consumption ("load profiles"), at intervals of seconds or minutes for at least a year
- battery characteristics, including price and performance
- electricity prices and tariffs

Using both public and private sources, we accessed data for more than a thousand different load profiles, dozens of batteries (including lithium ion, lead acid, sodium sulfur, and flow cell), and dozens of electricity tariff and pricing tables.

Our model, shown in the exhibit, identifies the size and type of energy storage needed to meet goals such as mitigating demand charges, providing frequency-regulation services, shifting or improving the control of renewable power at grid scale, and storing energy from residential solar installations.

The model shows that it is already profitable to provide energy-storage solutions to a subset of commercial customers in each of the four most important applications—demand-charge management, grid-scale renewable power, small-scale solar-plus storage, and frequency regulation.

Demand-charge management

Some customers are charged for using power during peak times (a practice known as a demand charge). Energy storage can be used to lower peak consumption (the highest amount of power a customer draws from the grid), thus reducing the amount customers pay for demand charges. Our model calculates that in North America, the break-even point for most customers paying a demand charge is about $9 per kilowatt. Based on our prior work looking at the reduction in costs of lithium-ion batteries, this could fall to $4 to $5 per kilowatt by 2020. Importantly, the profitability of serving prospective energy-storage customers even within the same geography and paying a similar tariff can vary by $90 per kilowatt of energy storage installed per year because of customer-specific behaviors. Another interesting insight from our model is that as storage costs fall, not only does it make economic sense to serve more customers, but the optimum size of energy storage increases for existing customers.

Grid-scale renewable power

Energy storage can smooth out or firm wind- and solar-farm output; that is, it can reduce the variability of power produced at a given moment. The incremental price for firming wind power can be as low as two to three cents per kilowatt-hour. Solar-power firming generally costs as much as ten cents per kilowatt-hour, because solar farms typically operate for fewer hours per day than wind farms.

Small-scale solar-plus storage

At a residential level, the combination of solar and storage is only worthwhile when specific market and regulatory conditions are in place to make the value of storage greater than the cost of installing it. This can happen, for example, when excess production can be stored for later consumption; in that case, consumers need to buy less power from the grid and thus cut their costs.

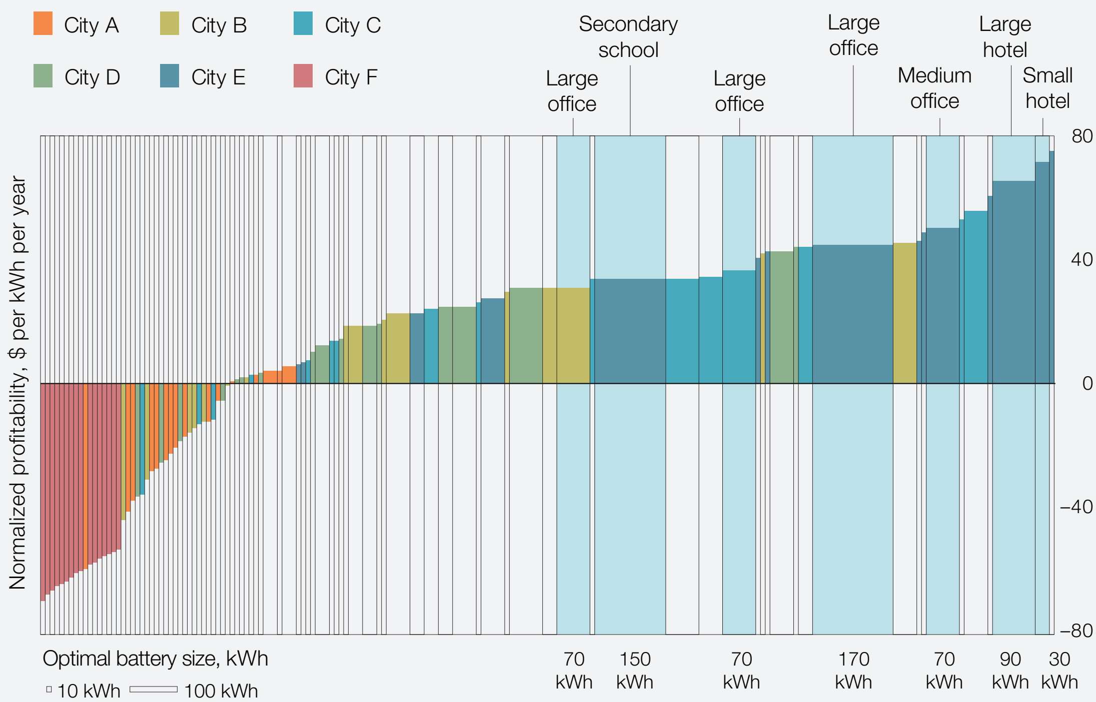
Frequency regulation

Electricity grids experience continuous imbalances between power generation and consumption because millions of devices are turned on and off in an uncorrelated way. These imbalances cause electricity

Exhibit

Customer-by-customer analysis of energy-storage economics shows significantly different profitability within the same city.

Lithium-ion-battery storage, 4% weighted average cost of capital, 2015
Normalized profitability, $ per kWh per year, **compared with optimal battery size,** kWh



- **58% of profitable buildings represent 71% of total demand**
- **Average optimal battery size of 31 kWh for profitable buildings**

Source: McKinsey analysis

frequencies to deviate, which can hurt sensitive equipment and, if left unchecked and allowed to become too large, even affect the stability of the grid. Storage systems are particularly well suited to frequency regulation because of their rapid response time and ability to charge and discharge efficiently.

Our model confirms that storage can be profitable in select frequency-regulation markets. The economics depend on the context. Ideally, batteries hover around a specific state of charge to minimize the amount of storage required.

How to compete: The state of batteries

Battery technology, particularly in the form of lithium ion, is getting the most attention and has progressed the furthest. Lithium-ion technologies accounted for more than 95 percent of new energy-storage deployments in 2015.[5] They are also widely used in consumer electronics and have shown promise in automotive applications, such as plug-in hybrids and electric vehicles. Prices for lithium-ion batteries have been falling and safety has improved; moreover, they can work both in applications that require a lot of energy for a short period (known as power applications) and those requiring lower amounts of energy for longer periods (energy applications). Collectively, these characteristics make lithium-ion batteries suitable for stationary energy storage across the grid, from large utility-scale installations to transmission-and-distribution infrastructure, as well as to individual commercial, industrial, and residential systems.

Our model confirms the centrality of lithium-ion batteries to utility-scale energy storage, but with two important caveats. First, it is critical to match the performance characteristics of different types of lithium-ion batteries to the application. For example, we looked at two major lithium-ion-battery providers that were competing to serve a specific industrial application. The model found that one company's products were more economic than the other's in 86 percent of the sites because of the product's ability to charge and discharge more quickly, with an average increased profitability of almost $25 per kilowatt-hour of energy storage installed per year.

Second, in some specific applications, nonlithium-ion technologies appear to work better. For demand-charge management and residential solar-plus storage, certain lead-acid products are more profitable than lithium-ion cells. For large-scale firming of wind power, our model shows that flow cells can be more economic than lithium-ion cells for all but the shortest periods (less than an hour) and are projected to continue to lead on cost through 2020.

Policy and market limits

Our model suggests that there is money to be made from energy storage even today; the introduction of supportive policies could make the market much bigger, faster. In markets that do provide regulatory support, such as the PJM and California markets in the United States, energy storage is more likely to be adopted than in those that do not. In most markets, policies and incentives fail to optimize energy-storage deployment. For example, the output from intermittent renewable-energy sources can change by megawatts per minute, but there are few significant incentives to pair renewable energy with storage to smooth power output.

Another issue is that tariffs are varied and not consistently applied in a way that encourages energy-storage deployment. Thus, customers with similar load profiles are often billed differently; some of these tariffs provide incentive for the adoption of storage to the benefit of the electrical-power system, while others do not. Pairing load profiles with appropriate tariffs and ensuring that tariffs are stable could help build the economic business case for energy storage.

Finally, the inability to bring together detailed modeling, customer data, and battery performance (due in part to policy choices and rules limiting data access) makes it difficult to identify and capture existing opportunities.

What the future may hold

Our work points to several important findings.

First, energy storage already makes economic sense for certain applications. This point is sometimes overlooked given the emphasis on mandates, subsidies for some storage projects, and noneconomic or tough-to-measure economic rationales for storage (such as resilience and insurance against power outages).

Second, market participants need to access the detailed data that could allow them to identify and prioritize those customers for whom storage is profitable. Given the complexity of energy storage, deployment is more likely to follow a push versus a pull sales model, favoring entrepreneurial companies that find creative ways to access and use these data.

Third, storage providers must be open-minded in their design of energy-storage systems, deciding whether lithium-ion, lead-acid, flow-cell, or some other technology will provide the best value. A strategy that employs multiple technologies may carry incremental costs, but it may also protect against sudden price rises.

Fourth, healthy margins are likely to accrue to companies that make use of battery and load-profile data. The unique characteristics of individual customers will favor tailored approaches, including the development of algorithms that find and extract the greatest value. Strong customer relationships are required to access relevant data and to deliver the most economical solution as regulations and technologies evolve.

Fifth, how to use storage to reduce system-wide costs will require some thought. Examples might include price signals that are correlated with significant deviations in power generation and consumption, rules that reward the provision of storage to serve multiple sites in close proximity, and tariffs that favor self consumption (or load shifting) of renewable electricity.

The most important implication is this: the large-scale deployment of energy storage could overturn business as usual for many electricity markets. In developed countries, for example, central or bulk generation traditionally has been used to satisfy instantaneous demand, with ancillary services helping to smooth out discrepancies between generation and load. Energy storage is well suited to provide such ancillary services. Eventually, as costs fall, it could move beyond that role, providing more and more power to the grid, displacing plants. That moment is not imminent. But it is important to recognize that energy storage has the potential to upend the industry structures, both physical and economic, that have defined power markets for the last century or more. And it is even more important to be ready. ■

[1] This article does not consider pumped storage, the most common type of storage. It is used for hydro projects.
[2] Peter Maloney, "After record year, U.S. energy storage forecasted to break 1 GW capacity mark in 2019," *Utility Dive*, March 7, 2016, utilitydive.com.
[3] PJM serves all or part of Delaware; Illinois; Indiana; Kentucky; Maryland; Michigan; New Jersey; North Carolina; Ohio; Pennsylvania; Tennessee; Virginia; Washington, DC; and West Virginia.
[4] "The 2015 year-in-review executive summary," GTM Research, March 2016, greentechmedia.com.
[5] Ibid.

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