ENERGY STORAGE AND ELECTRICITY MARKETS

The value of storage to the power system and the importance of electricity markets in energy storage economics

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RESILIENT POWER

A project of CleanEnergyGroup

ABSTRACT

Despite the fact that energy storage technologies have the capacity to benefit every segment of the power system, from generation to end-use, it can still be difficult to cost effectively deploy storage across much of the U.S. In order to identify the emerging opportunities and remaining barriers to energy storage deployment, *Energy Storage and Electricity Markets: The value of storage to the power system and the importance of electricity markets in energy storage economics* introduces existing electricity markets where storage has begun to play a significant role. This report examines how these emerging energy storage markets have developed and the potential for realizing additional value streams through new market mechanisms.

ACKNOWLEDGEMENTS

This paper is a product of Clean Energy Group and part of a series of reports issued through the Resilient Power Project, a joint project of Clean Energy Group and Meridian Institute. This project works to expand the use of clean, distributed generation for critical facilities to avoid power outages; to build more community-based clean power systems; and to reduce the adverse energy-related impacts on poor and other vulnerable populations from severe weather events. Special thanks to Clean Energy Group Research Assistant Evan Forward for his extensive research and work on initial drafts of this paper. The author would also like to thank Lewis Milford, Todd Olinsky-Paul, Maria Blais Costello, and Samantha Donalds for their valuable input on this report. This project has been generously funded by The JPB Foundation, The Kresge Foundation, and The Surdna Foundation. The views and opinions expressed in this report are solely those of the author. For more information, please visit *www.resilient-power.org*.

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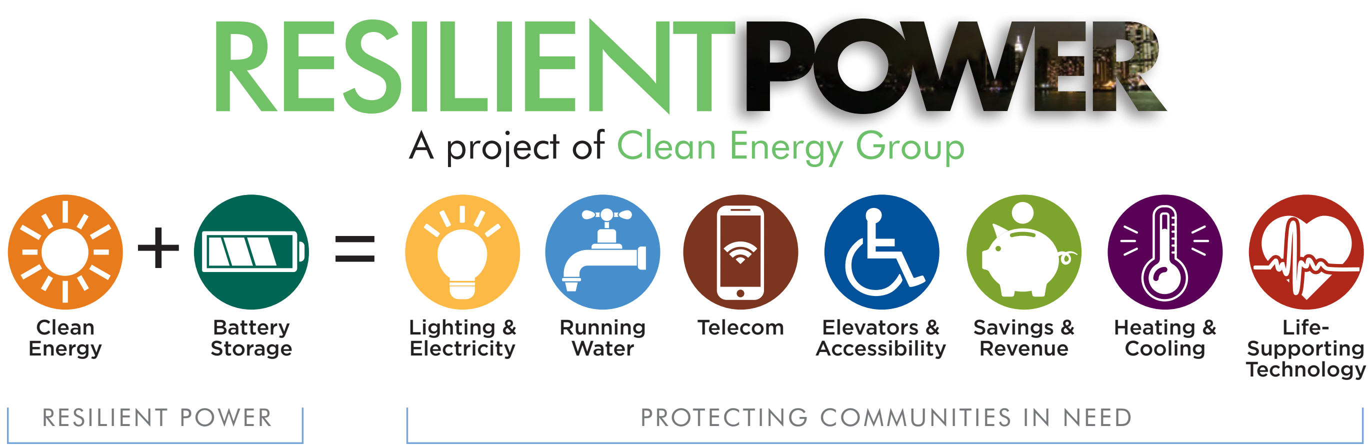


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Introduction

FROM RENEWABLE GENERATION SMOOTHING to demand charge reduction, energy storage technologies have the capacity to benefit each segment of the power system. Energy storage, primarily in the form of batteries, can deliver value not just to utilities and grid operators, but to commercial and residential consumers alike. Unfortunately, the full value of energy storage cannot be realized under current market conditions, which can make it a challenge to find financing for these systems. However, markets are beginning to emerge that provide viable revenue streams for battery storage.

Not only can battery storage improve resiliency as a source of critical backup power, it can also boost the economic resiliency of communities by reducing consumer utility bills and by generating revenue from providing grid services.

New electricity market structures have been developed that allow for the monetization of a portion of the beneficial services that energy storage can provide. This has important implications for resiliency applications of energy storage technologies, such as solar+storage systems that provide emergency power to critical facilities. Not only can battery storage improve resiliency as a source of critical backup power, it can also boost the economic resiliency of communities by reducing consumer utility bills and by generating revenue from providing grid services.

In those regions where federally regulated market conditions and utility rate structures have opened up a clear economic path for energy storage, new business models have been developed to take advantage of these emerging opportunities. Energy storage projects have begun to flourish—forcing utilities and regulators to catch up with demand for deployment, a trend reminiscent of solar markets a decade ago. Additionally, rapidly declining costs and advancing technologies have improved the economic case for battery storage. But the fact remains, until mature

markets have developed across the country, the full potential of energy storage will remain unrealized.

These newly developed market opportunities have the potential to deliver much needed revenue to help finance storage projects, but they are still in their infancy, with regulatory and market structures that tend to be inconsistent from region to region. Because of this, it can still be difficult to make the case for energy storage implementation based purely on economics in most areas.

A recent energy storage solicitation in New Jersey serves as an excellent example of how favorable wholesale electricity market conditions can support resilient power projects, giving evidence of the potential for full market deployment of energy storage technologies. With a budget of $3 million, the New Jersey Board of Public Utilities was able to fund 13 solar+storage projects, with a combined storage capacity of nearly 9 megawatts, located at critical facilities such as emergency shelters and waste-water treatment plants. In addition to supplying resilient power in the event of grid outages, each of the projects intends to generate revenue through participation in regional electricity markets. Without this revenue opportunity, far fewer projects could have received adequate funding.

This report is designed to introduce and examine those electricity markets where energy storage has already begun to play a significant role—chiefly, in emerging regulated markets where smaller storage systems can provide grid support services. It will also explain the potential for increased market participation for energy storage going forward. The first sections discuss today's markets in general terms and how they are organized and regulated. The paper then expands on the topic of energy storage participation in these markets and the importance of regulation that allows energy storage access to markets originally structured for other technologies. It concludes with a look at additional energy storage economic opportunities and future value streams.

Electricity Markets Explained

WHILE IT MAY NOT ALWAYS SEEM like it, electricity is just another commodity, which is typically bought and sold a number of times before ultimately reaching the consumer. And, like other commodities, there are wholesale markets for electricity. However, unlike most commodities, electricity itself cannot be stored—it must first be converted to another type of energy such as chemical energy stored in batteries, kinetic energy stored in flywheels, or potential energy stored behind a hydroelectric dam.

Electricity can also be a lot trickier to move around than more traditional commodities, such as cars or food. In part, this is because electricity must be delivered within a very narrow frequency[1] range, otherwise the transmission system can completely break down. The ideal frequency at which the North American power system operates is 60 hertz. A frequency too high above this target (too much generation for too little electricity demand) or too far below (not enough generation to meet demand) can cause serious damage to the power system and lead to grid failure and cascading black-outs. This means that a delicate balance between electricity supply and consumer demand must be monitored and maintained at all times. Due to the lack of energy storage capacity available to grid operators, this balance has historically been maintained almost exclusively by inefficiently ramping fossil-fuel generators up and down to meet fluctuations in electricity supply and demand.

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The need to operate within this narrow frequency range, in addition to not exceeding available generation capacity, has led to the creation of a number of specifically targeted electricity markets, each representing a unique form of valuable grid service. While different electricity service territories may have different market products and different guidelines for participation in these markets, they all use similar tools to deliver energy within the same bounds.

Energy storage has the potential to provide a number of these valuable grid services and has begun to play an important role in two of the most widely adopted and integral electricity market products: ancillary services and demand response.

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Ancillary services

Ancillary services encompass a suite of products that support power system reliability. These products may vary depending on the grid operator but typically include the services listed in Table 1.

Energy storage has the capability to provide all of these services, though it currently only plays a significant role in certain frequency regulation markets. Unlike frequency regulation and spinning/non-spinning reserve, voltage control and black start services do not currently have auction-based markets in most regions, which can hinder the participation of new resources like energy storage.

Demand response

Demand response provides another dimension of control to power system operators, who have traditionally focused solely on the supply side of the equation. Demand response programs were developed to help operators avoid power interruptions at times when consumer electricity demand threatens to exceed available generation supply.

Demand response programs address these potential supply shortfalls by calling on large electricity users and aggregated smaller users to scale back their use of nonessential electrical devices—such as manufacturing equipment and water heaters. Utilities benefit from demand response programs by being able to delay or completely eliminate the need to build additional power plants to meet these infrequent occurrences of high demand. Demand response can also be deployed as a less costly alternative to expensive power generation provided by peaker plants.

Several states are beginning to explore the use of energy storage in demand response programs. Energy storage has the ability to quickly respond to demand response calls by discharging stored energy to meet the electricity demand needs of local loads; because these local loads no longer need electricity supplied by the grid, overall demand on the power system is reduced.

Additional grid services suited to energy storage technologies, such as flexible ramping capability and flexible capacity, are currently being investigated in some regions and are likely to evolve into viable market products in the future.

TABLE 1
Common ancillary services and their description

Ancillary Services	
Frequency regulation	Balancing of electricity supply and demand to keep frequency within operational bounds. Includes services for responding to both increases and decreases in system frequency.
Spinning reserve	Generation capacity that is connected to the power system but not generating electricity until needed, with the ability to respond immediately, within 10 minutes.
Non-spinning reserve	Generation capacity that is not connected to the system but can be brought online after a brief delay.
Voltage control	Similar to frequency regulation but using reactive power to maintain proper transmission system voltage.
Black start	Ability to restore power to part of the grid after failure occurs.

Electricity Market Regulation and ISOs

IN ADDITION TO UNDERSTANDING WHY electricity markets exist, it is also important to have a grasp on how the markets are structured and how they are regulated. How markets are organized is key to understanding how they operate. This is particularly important in regard to energy storage monetization.

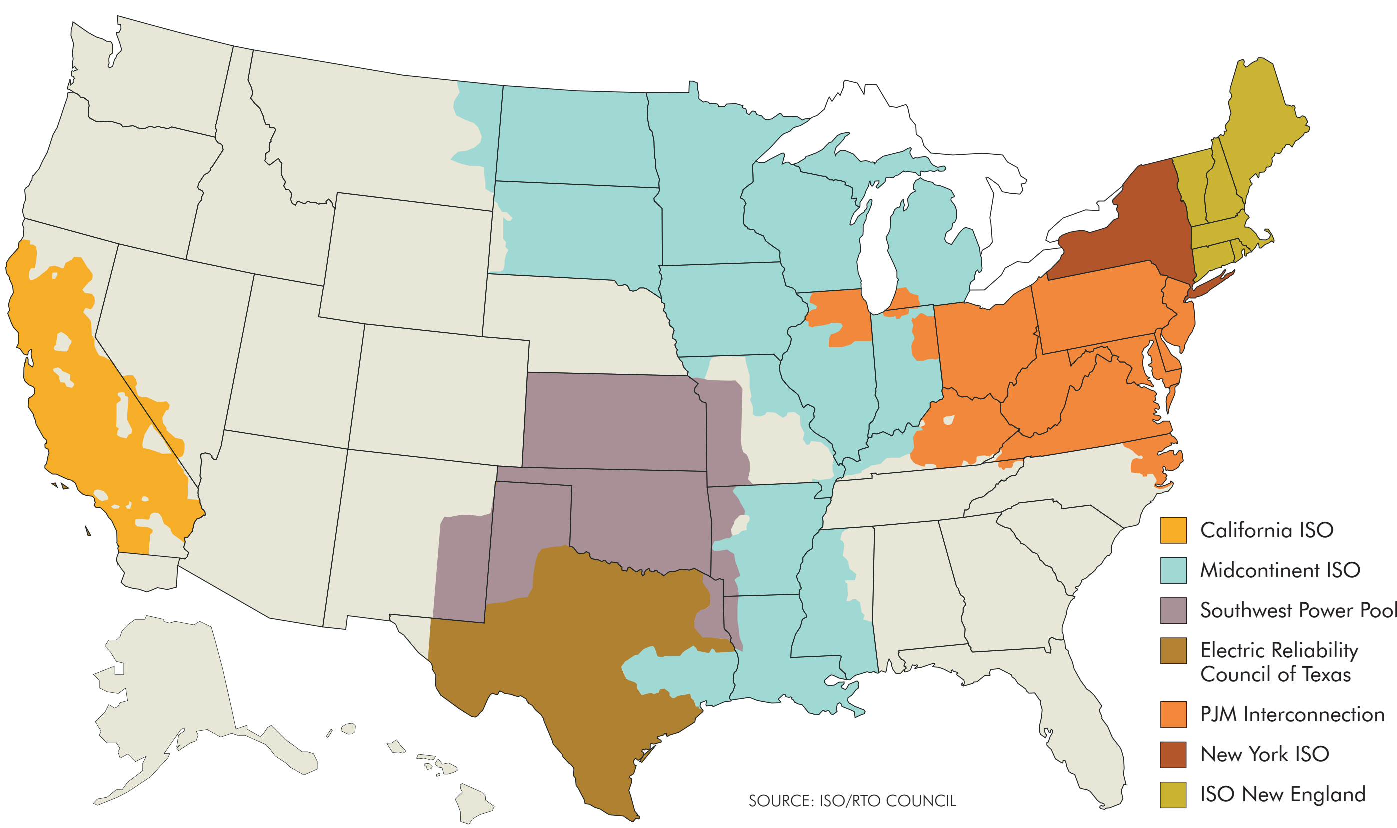
Prior to the passage of several key regulatory measures, most electricity markets were not structured to allow effective participation by energy storage and other small, distributed energy resources. As a result, very few competitive power markets had emerged that would encourage energy storage deployment. But, with the implementation of new regulatory mandates addressing the valuation of specific energy storage services, this has begun to change.

Because grid network interconnections frequently cross state lines, electricity market sales are generally understood to occur across multi-state regions. Due to the interstate nature of these transactions, regional electricity markets are subject to regulation by the Federal Energy Regulatory Commission (FERC). The Electric Reliability Council of Texas (ERCOT) is an exception to this rule, as the entire transmission grid that it administers lies solely within the state of Texas and is not synchronously interconnected to the rest of the country.

Regional electricity markets come in two varieties—those organized under an independent system operator (ISO) and those that have retained a more traditional regulatory model. Under the traditional model, transmission systems are under the control of utilities, who determine which generation resources get dispatched to meet electricity demands. As shown in Figure 1, this is the dominant structure throughout the Southeast, Southwest, Northwest, and Mountain West regions.

FIGURE 1

North American independent system operators (ISOs) and regional transmission organizations (RTOs)



ISOs, also known as regional transmission organizations (RTOs), are structured such that the transmission system is managed by an entity independent of the utilities. This structure typically allows for a more open and competitive market environment. Along with California (CAISO) and Texas (ERCOT), these independent structures are prevalent throughout the Northeast, with ISO New England (ISO-NE) and New York ISO (NYISO); in the Mid-Atlantic, with PJM Interconnection (PJM); and in much of the Midwest and Plains, with Midcontinent ISO (MISO) and Southwest Power Pool (SPP).

FERC orders mandating electricity market practices apply directly to ISO territories and are often expanded to regulate operation in traditional utility regions as well. As ISO markets fall more directly under FERC regulatory jurisdiction (except for ERCOT), FERC orders generally have a greater impact in these regions.

Prior to the passage of several key regulatory measures, most electricity markets were not structured to allow effective participation by energy storage and other small, distributed energy resources.

Energy Storage and Electricity Markets

A HANDFUL OF FERC ORDERS ISSUED over the past few years have helped facilitate electricity storage participation in regulated electricity markets. Two of these, FERC Order 1000[2] and FERC Order 792,[3] have helped to ensure that storage projects receive fair interconnection and transmission treatment as a grid resource. Additionally, FERC Order 755[4] and FERC Order 784[5] specifically target equitable compensation in the ancillary services markets.

A handful of FERC orders issued over the past few years have helped facilitate electricity storage participation in regulated electricity markets.

Frequency regulation

Essentially, FERC Order 755 states that the speed and accuracy of response to calls for frequency regulation services should be adequately rewarded through market compensation mechanisms. If a resource provides a quicker and more precise response to frequency regulation signals, it should be paid more for providing a superior service. This pay-for-performance incentive structure is defined as "mileage" in the FERC Order. FERC Order 784 expands on Order 755 and addresses participation through third-party ownership models.

Prior to FERC Order 755, the frequency regulation market was dominated by fossil fuel plants, typically natural gas plants. These plants take time to ramp up to full power after receiving a signal, often several minutes. Because FERC regulations mandate that higher-quality performance should be adequately compensated, energy storage technologies are now able to play an increasing role in the market.

Energy storage technologies, particularly batteries and flywheels, are well suited for frequency regulation applications. In fact, a study by the Department of Energy's Pacific Northwest National Laboratory found that these technologies could be as much as 17 times more effective than conventional fossil-fuel regulation resources.[6] They are able to quickly respond to calls for both regulation up (adding stored energy into the system) and regulation down (soaking up excess electricity). Energy storage systems have the ability to respond to these signals with extremely high accuracy within a few seconds or even a few fractions of a second.

Currently, FERC Order 755 has been implemented in PJM, MISO, NYISO, CAISO, and ISO-NE. FERC has also ruled that non-ISO/RTO markets must comply with Order 755. ERCOT, though outside FERC jurisdiction, is currently considering developing a similar market regulation.

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While this is generally good news for energy storage developers, PJM stands as the only territory where current market conditions actively support the deployment of energy storage projects for frequency regulation market participation. This is partly due to the load and generation profiles of each territory and partly due to the way in which FERC Order 755 has been implemented. FERC takes the position that it should not mandate how market rules are established. This leaves the responsibility of formulating a compensation methodology for Order 755 compliance up to each individual ISO/RTO or local public transmission utility.

For instance, the capacity threshold for resources to participate in the PJM frequency regulation market is 100 kilowatts, whereas NYISO and ISO-NE require 1,000 kilowatts (1 megawatt)—a serious obstacle to most distributed behind-the-meter projects. While all of these participation standards are technically compliant with FERC regulations, a high-capacity participation threshold can drastically impede the ability of non-grid-scale, behind-the-meter resources to participate in these markets. In PJM, smaller systems, less than 100 kilowatts, have been aggregated to meet the 100 kilowatt participation threshold. This becomes a much more burdensome task when ten times the capacity must be coordinated. (See Box 1, p. 10, "How PJM Changed Frequency Regulation" to learn more about the steps taken by PJM to create a more competitive frequency regulation market.)

In non-ISO/RTO regions, market participation can be even more challenging. Market price signals are often not readily available, making it difficult to determine the potential value of energy storage in the regional power system.

The structure of the PJM ancillary services market has already spurred the development of numerous energy storage projects—from small aggregated systems to large microgrids. In fact, about two-thirds of the 62 megawatts of energy storage deployed in U.S. in 2014 was located in the PJM territory.[9] Developers have estimated that participation in the PJM frequency regulation market can reduce solar+storage project payback times to as little as a few years[10]—much less than the life expectancy of these systems. Some third-party storage providers are even offering energy storage systems to developers for virtually no cost.

BOX 1

How PJM Changed Frequency Regulation

In October 2012, PJM implemented FERC Order 755, successfully opening its frequency regulation market to participation by battery storage and other quick-response resources that had previously been unable to economically enter the market.

Four changes to the structure of PJM's frequency regulation market structure were key to opening the market:[7]

- **Two-part compensation**: Instead of solely compensating resources based on the magnitude of regulation services provided (measured in megawatts), a second performance-based compensation mechanism was implemented that takes into account the speed and accuracy of response to calls for frequency regulation.
- **Effective megawatt compensation**: Regulation capacities offered into the market are scaled based on historic performance and incremental benefits associated with the resource response time. So, quick-response resources with high levels of historic performance will be compensated at a higher effective megawatt rate than slower resources or resources with a less dependable performance track record.
- **Five-minute interval lost opportunity cost**: Lost opportunity costs account for the revenue that could have been generated by a resource if it had been providing an alternative service, in this case grid capacity. By shifting market clearing price calculations from an hourly basis to five-minute intervals, lost opportunity costs more accurately reflect true market values, allowing regulation compensation mechanisms to account for short duration market fluctuations.
- **Mileage compensation**: The PJM market has two signals: one for traditional regulation (RegA) and one for fast regulation (RegD). According to PJM's year-one program analysis,[8] RegD resources are called upon about three times more than RegA resources on an hourly miles-of-regulation basis. Because RegD resources serve a higher regulation mileage, they correspondingly receive greater compensation.

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Participation in the frequency regulation market generates revenue for the third-party owner while the associated facility gains the added benefit of resilient power during grid failures, something not provided by most solar-only systems. (See the Box 2, p. 11, "PJM Frequency Regulation Economics" for an example of one project's experience participating in the PJM market and Box 3, p. 11, "How Big Is the Frequency Regulation Market" for a cautionary note on the size of frequency regulation markets.)

Demand response

While the PJM ancillary services market may represent the biggest market victory for energy storage in the U.S. to date, it is not the only electricity market where energy storage has gained traction. Recently, energy storage has begun to make headway into demand response markets as well.

Specifically, CAISO has been exploring the role of energy storage in demand response through a pilot program.[12] Last June, an energy storage software and systems company, Stem, announced that it would be bidding an aggregated array of behind-the-meter[13] energy storage installations into the pilot demand response program. As in the PJM ancillary services market, the threshold for participation in CAISO's demand response market is only 100 kilowatts. New York utility Con Edison and utilities in Hawaii have also been exploring the demand response potential of energy storage. If these programs can successfully make the case for energy storage as a demand response resource, additional markets will open to developers. (See the Box 4, p. 12, "Stem Takes on Demand" to learn more about Stem's behind-the-meter storage projects.)

FERC has also played a pivotal role in demand response markets through its Order 745,[14] which mandates that demand response resources receive the same level of compensation as traditional generation resources in wholesale energy markets. The validity of Order 745 has been challenged by the Electric Power Supply Association and, in 2014, the U.S. Court of Appeals for the District of Columbia Circuit ruled that the Order may have overstepped FERC's authority. However, in January of this year, the Obama administration filed an appeal to the U.S. Supreme Court to uphold FERC Order 745, and the Court has now agreed to take up the issue. Regardless of the final decision on Order 745, demand response is expected to continue playing an important and increasing role in the power sector.

New market opportunities are anticipated to emerge as grid operators become more familiar with energy storage

BOX 2

PJM Frequency Regulation Economics

A vast array of companies have rushed in to participate in the burgeoning energy storage sector formed around the PJM frequency regulation market. These frequency regulation projects range in size from grid-scale, multi-megawatt endeavors down to small, behind-the-meter systems aggregated to reach the 100-kilowatt capacity participation threshold. Few companies are willing to share hard data on the economics and performance of their storage systems, but one company, S&C Electric Co., reported that their system could potentially pay for itself in as little as two to three years.[11]

In October 2014, S&C announced that it would be joining with software developer Intelligent Generation to provide frequency regulation services for the PJM market. The system, located at S&C's Smart Grid Solutions Demonstration Center in Chicago, is composed of six 25-kilowatt energy storage systems, aggregated to provide a total of 150 kilowatts.

According to Intelligent Generation, the system has been earning about $42 per megawatt-hour on average through providing frequency regulation services. Assuming a 1 megawatt system costs around $1 million ($1,000 per kilowatt), this translates to an investment payback period in the range of four to five years. Access to investment tax credits for systems deployed alongside an appropriately sized solar PV system and participation in additional savings and revenue streams, such as demand charge management and demand response programs, could shorten payback periods even further.

BOX 3

How Big Is the Frequency Regulation Market?

It is worth noting that frequency regulation markets are quite small in comparison to wholesale capacity markets. The size of U.S. frequency regulation markets is typically limited to about 1 percent of peak energy demand. In PJM, this amounts to approximately 700 megawatts. PJM has determined that the optimal mix for fast-response (RegD) resources is 42 percent of this market, amounting to about 300 megawatts of fast-response capacity.

This fast-response capacity segment may soon be filled by energy storage projects reportedly planned and under development. It is unclear exactly what the market implications will be as the need for fast-response frequency regulation resources becomes saturated. While storage is capable of acting as either a traditional or fast-response regulation resource, without fast-response compensation it may be difficult for storage to realize significant economic returns. However, PJM may reevaluate its optimal fast-response needs as capacity nears the current target. Higher levels of variable renewable penetration may also lead to an increasing need for frequency regulation resources.

BOX 4

Stem Takes on Demand

In November 2014, Southern California Edison (SCE) committed to purchasing 85 megawatts of behind-the-meter storage capacity from Stem. The multi-year agreement is part of SCE's energy storage procurement target as defined under California's ambitious mandate of deploying 1.3 gigawatts of energy storage by 2022.

Stem's sophisticated control software enables management of demand on both the customer and utility sides of the meter. By aggregating a number of smaller systems for participation in utility demand response programs, the company can reliably ensure that enough capacity will be available when calls for demand response are issued. This allows energy storage owners the ability to manage on-site demand, while still participating and generating revenue as an aggregated resource in utility demand response programs.

This functionality has already been tested through Stem's participation in Pacific Gas & Electric's Intermittent Renewable Management Pilot Phase 2 (IRM2).[15] Stem successfully bid 160 kilowatts of aggregated energy storage into the program as demand response resources, while continuing to effectively manage customer demand charges. The company was the first behind-the-meter storage solution to participate in this demand response market.

Stem expects to perform a similar service in SCE's territory. The planned 85 megawatts of storage will be aggregated as a fully dispatchable resource, which can be harnessed to improve the reliability of the Western Los Angeles Basin power system.

When cost reductions from demand charge management and income from demand response participation are combined with incentives available through the California Public Utility Commission's Self-Generation Incentive Program (SGIP), the resulting economics look very favorable for Stem's systems. The estimated payback period for these projects is less than three years.[16] Stem also provides a leasing model, further reducing upfront costs for their behind-the-meter storage customers.

technologies and the multitude of services they can provide. For instance, CAISO and MISO are currently in the process of developing flexible ramping products to balance variable generation resources. Energy storage technologies will likely play a significant role in these and other emerging flexible capacity markets.

New market opportunities are anticipated to emerge as grid operators become more familiar with energy storage technologies and the multitude of services they can provide.

Beyond Electricity Markets

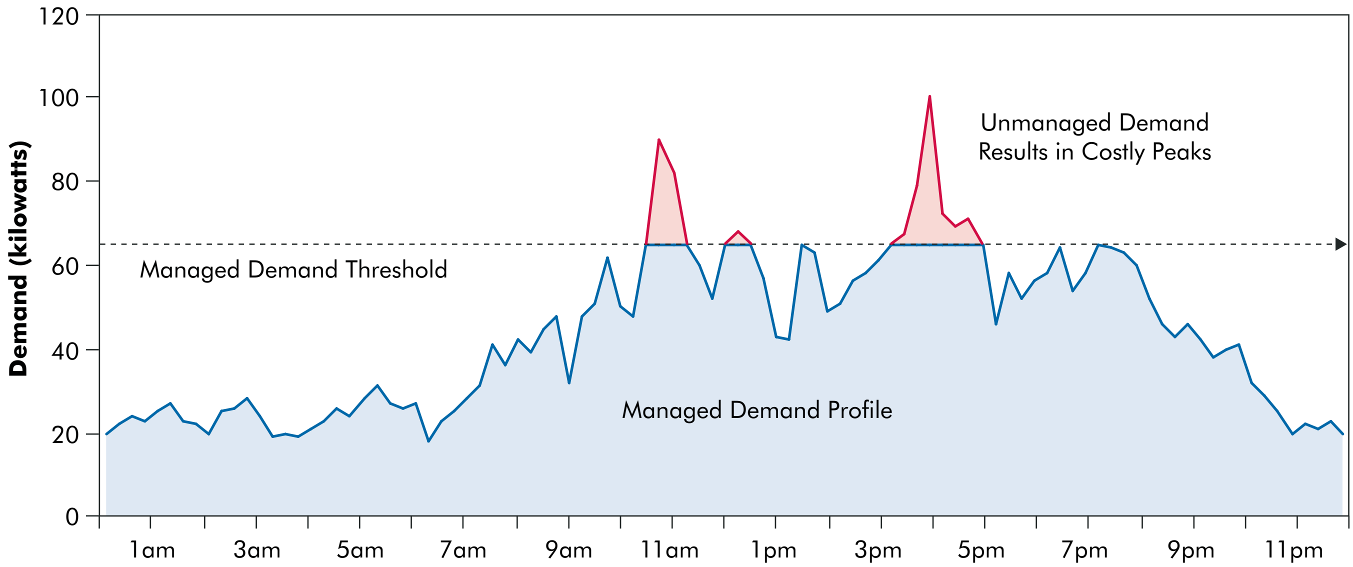
THE ECONOMIC POTENTIAL OF ENERGY storage systems is not limited to electricity markets alone. Market mechanisms have not yet developed to properly value many of the beneficial roles energy storage can fulfill. However, under certain utility rate structures, some of these benefits are being economically realized today.

Demand charge management

Commercial electricity customers are typically charged in two ways for their energy use. One charge, which is also applied to residential customers, is for the volume of electricity consumed and is measured in kilowatt-hours (kWh). The other charge, usually not applied to residential bills, is for the highest level of power demand during a billing period. This is called peak demand and is measured in kilowatts (kW). Commercial customers face demand charges based on their peak demand for each period. It can account for well over half of a commercial customer's bill in certain areas, such as parts of California and New York.

Customers in areas with high demand charges can employ energy storage to reduce their peak demand, a process known as peak shaving. As shown in Figure 2 (p. 13), when power use reaches a certain threshold, the energy storage system kicks in, so that additional demand is served by the

FIGURE 2
Energy storage can reduce customer peak demand charges



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Through the deployment of an energy storage system, peak demand can be effectively capped at a specified level—significantly reducing utility demand charges. Assuming a demand charge of $10 per kilowatt and peak demand reduction from 100 kilowatts to 65 kilowatts each period (as shown here), energy storage could reduce the customer's demand charge by $350 per billing period, amounting to an annual savings of $4,200.

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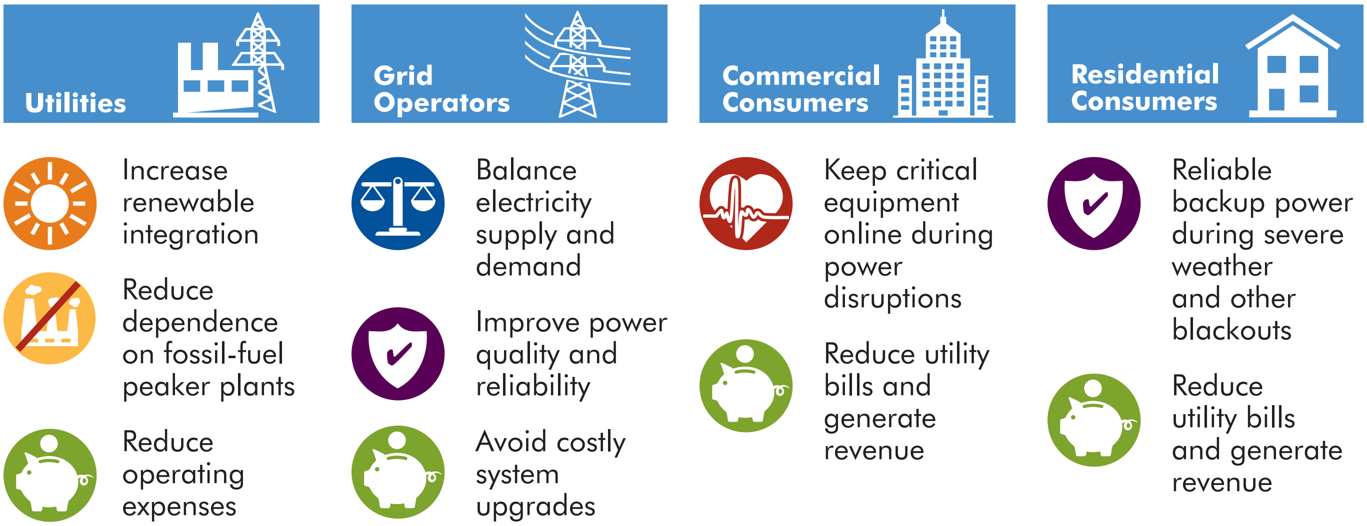
The Value of Storage

Energy storage technologies have the capacity to benefit each segment of the power system.



battery instead of the grid. This effectively caps peak demand at a specified level and subsequently reduces utility demand charge fees. In this manner, a moderately sized storage system can significantly reduce a facility's total utility bill.

Customers can offset their electricity demand during peak periods by discharging stored energy from the battery. During off-peak periods, the battery can be recharged through the grid or on-site generation.

Energy time-shift

Both residential and commercial customers under time-of-use rate structures have the ability to lower utility bills by using energy storage to shift when they draw power from the grid. Time-of-use rate structures are used by some utilities to charge different rates for electricity at different times of day: higher prices are charged during periods of high demand (*peak* periods), and lower prices are charged during periods of low demand (*off-peak* periods). The rate structure may also include transition periods, called partial peak periods. In order to encourage customers to limit energy use during peak times, rates during peak periods are significantly higher than rates during off-peak periods.

With an energy storage system in place, a customer can offset their electricity demand during peak periods by discharging stored energy from the battery. During off-peak periods when prices are lower, the battery can be recharged through the grid or on-site generation like solar PV. This energy time-shift not only benefits consumers through lower electricity bills, it can also benefit utilities by helping to reduce the magnitude of peak period demand on the power system, potentially enabling utilities to delay or avoid adding additional generation capacity to the power system.

Additional opportunities

These market and cost reduction applications are just a few examples of how energy storage can be deployed to benefit parties on both the customer and utility side of the meter. Table 2 (p. 15) presents a more comprehensive list of valuable energy storage applications. Additional beneficial applications are still being developed and explored.

TABLE 2

Energy storage applications with the potential to provide value to the electric power system[17]

Customer Energy Management	
Demand charge management	Utility customers subject to demand charges can deploy stored energy to lower their peak power draw during each billing period, reducing the overall cost of electricity service.
Energy time-shift	Charging through free on-site generation or inexpensive grid electricity at times of low price (off-peak) to increase stored capacity, which can be dispensed at a later time when electricity prices are higher (peak).
Power reliability (uninterruptible power supply)	Discharging stored energy to ensure continuous power to local loads during times of brief supply interruption and to improve power quality and protection to downstream loads against short-duration power disturbances.
Power resiliency (backup power)	Discharging stored energy for prolonged periods to supply power to specified loads when the grid is unavailable.

Utility Demand Management	
Demand response	Discharging stored energy to supply on-site electricity demand in response to utility signals for demand response, which occur at times when power system demand is approaching available supply.
Peak capacity	Generation capacity deployed when electricity demand is higher than available supply of normal capacity resources, often provided by natural gas-fired combined cycle power plants.

Grid Balancing	
Ancillary services	Ensuring the quality and reliability of electricity production, transmission, and distribution. See Table 1 (p. 6) for a detailed description of the most common ancillary services.
Power quality	Energy storage can insulate downstream loads from power quality disruptions, such as voltage spikes or dips, frequency imbalances, or a low power factor.
Ramping	Charging or discharging energy over a sustained period in response to rapid increases or decreases in supply and demand. This function is particularly beneficial in areas of high solar penetration when solar production ramps up in the morning and down in the evening.

Energy Transmission & Distribution	
Transmission system support	Improving the performance of transmission and delivery systems by correcting for voltage and resonance issues.
Transmission system congestion relief	Discharging energy downstream of points of high demand during peak periods when transmission systems can become overloaded and congested or charging to relieve periods of excess supply.
Transmission & distribution upgrade deferral	Similar to congestion relief, by deploying energy storage downstream from regions of congested transmission, the need for more costly transmission and distribution system upgrades can be delayed or entirely eliminated.
Utility substation power	Providing power to substation control equipment, switching components, and communications systems when grid power is unavailable.

Renewable Generation	
Energy arbitrage	Storing renewable energy produced during periods when wholesale electricity prices are low, to be sold into the power systems at a later time when market prices are higher.
Renewable capacity firming	Pairing energy storage with intermittent renewable resources to fill in supply gaps. By combining technologies, inherently variable resources can be managed as an integrated system producing a constant, dispatchable supply of electricity. This can enable variable renewable generation resources to actively participate in electricity markets that require a dispatchable supply of power.
Renewables integration	Smoothing supply fluctuations and storing excess energy production for later use to facilitate increasing penetration of renewable resources.

Conclusion

THE U.S. IS EXPECTED TO DEPLOY MORE energy storage in 2015 than in any previous year, about 220 megawatts in total.[18] This is evidence of cost reductions and technological advances in energy storage, as well as the emergence of new market mechanisms, but it represents only a tiny fraction of the estimated potential for storage—over 64 gigawatts for energy time-shift applications alone according to Sandia National Laboratories.[19]

There is currently no location in the U.S. where an energy storage system can realize its full economic potential for the multitude of services it is capable of providing.

By looking at locations where energy storage projects are being deployed, it is easy to see which regions are beginning to value the benefits that energy storage can provide. The PJM territory, with its well-structured ancillary services market, is the most extensive region where energy storage has begun to develop a presence in the power system. In New York and California, where commercial customers face high demand charges, energy storage has found another niche with favorable economics. Both utilities and residential customers have also embraced energy storage in Hawaii, where high levels of solar penetration and high electricity prices have highlighted the value of storage.

Each of these regions provides an example of what can occur when a portion of the potential benefits of energy storage are monetized; however, there is currently no location in the U.S. where an energy storage system can realize its full economic potential for the multitude of services it is capable of providing. Additionally, the various benefits that energy storage can provide are split amongst different entities—utilities, grid operators, end-use customers—making it difficult, if not impossible, for any single entity to realize the full value of a storage system. Even with energy storage costs on the decline, it will still be important for developers to have the option of tapping into multiple revenue streams to optimize the economic benefits of energy storage systems, so it is critical that these emerging markets continue to develop and spread.

Pockets of energy storage deployment have popped up in other areas as well, in response to limited incentive programs or government supported project solicitations, but these are not sustaining solutions for expanding energy storage deployment in the U.S. These programs are often targeted to demonstrate some of the important benefits energy storage systems can provide that are not traditionally supported or valued by markets, such as power resiliency and power equity for low-income populations. According to a report prepared by The Brattle Group that assesses the value of distributed energy storage in Texas, 30 to 40 percent of the total system-wide benefits of storage are not reflected in wholesale market prices.[20] While developing market-based power solutions are essential for the continued growth of energy storage deployment, these additional non-market benefits should not be overlooked and should be valued accordingly in any cost-benefit analyses.

Across the nation, the power system will be able to fully benefit from the many services that energy storage can provide only when the electricity markets and energy investment valuations have been developed to adequately account for the benefits of energy storage and are structured in a way that is open and accessible to all energy storage systems. Only then will energy storage development have the opportunity to achieve its true potential.

ENDNOTES

1 Electrical frequency, measured in units of Hertz, is the rate at which alternating current (AC) power oscillates between positive and negative charge. 1 Hertz is equal to 1 oscillation cycle per second.

2 Issued in June 2010, FERC Order 1000 requires that non-transmission alternative solutions must be considered during regional transmission planning. *http://www.ferc.gov/industries/electric/indus-act/trans-plan.asp*

3 Issued in November 2013, FERC Order 792 allows energy storage to be eligible for grid interconnection under the Small Generator Interconnection Procedures and enables it to participate in the accelerated interconnection process known as Fast Track, reducing the time, cost, and regulatory burden of storage project interconnection procedures. *http://www.ferc.gov/whats-new/comm-meet/2013/112113/E-1.pdf*

4 Issued in October 2011, FERC Order 755 requires that RTOs and ISOs adopt a two-part, market-based compensation method for frequency regulation services, composed of capacity and speed/accuracy payment mechanisms. *http://www.ferc.gov/whats-new/comm-meet/2011/102011/E-28.pdf*

5 Issued in July 2013, FERC Order 784 requires that all public utilities consider response speed and accuracy in frequency regulation compensation. The Order also reduces barriers to third-party entry into ancillary services markets. *http://www.ferc.gov/whats-new/comm-meet/2013/071813/E-22.pdf*

6 *Assessing the Value of Regulation Resources Based on Their Time Response Characteristics*. June 2008. *http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17632.pdf*

7 *Faster Frequency Regulation Triples in PJM*. November 2013. *http://www.greentechmedia.com/articles/read/faster-frequency-regulation-triples-in-pjm*

8 *Performance Based Regulation: Year One Analysis, Regulation Performance Senior Task Force*. October 12, 2012. PJM Interconnection.

9 *What's Next in the Energy Storage Boom, and What Utilities Need to Know*. April 2015. *http://www.utilitydive.com/news/whats-next-in-the-energy-storage-boom-and-what-utilities-need-to-know/382465*

10 *Battery Storage Payback Takes Only a Few Years in PJM, S&C Finds*. May 2015. *http://www.greentechmedia.com/articles/read/battery-storage-pays-back-in-less-than-five-years-sc-finds*

11 *Ibid.*

12 *Stem Pulls Behind-the-Meter Storage Into an Aggregated Demand Response Resource*. June 2014. *http://www.greentechmedia.com/articles/read/aggregating-building-batteries-into-grid-resources*

13 Behind-the-meter, also known as customer-sited, energy storage systems are located on the owner's property, literally behind the utility meter, as opposed to front-of-the-meter, utility-side systems, which are located directly on the utility distribution system.

14 *Demand Response Compensation in Organized Wholesale Energy Markets*. March 2011. *http://www.ferc.gov/EventCalendar/Files/20110315105757-RM10-17-000.pdf*

15 *PG&E IRM2 Pilot*, *http://olivineinc.com/irm2*

16 *Stem Well Positioned In On-Site Energy Storage Market*. January 2015. *http://www.forbes.com/sites/peterdetwiler/2015/01/29/stem-well-positioned-in-on-site-energy-storage-market*

17 Sandia National Labs, *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide*. February 2010. *http://www.sandia.gov/ess/publications/SAND2010-0815.pdf*

18 *The US Deployed 5.8MW of Energy Storage in Q1 2015, Up 16% Over Q1 201*. May 2015. *http://www.greentechmedia.com/articles/read/The-US-Deployed-5.8MW-of-Energy-Storage-in-Q1-2015-Up-16-Over-Q1-2014*

19 Sandia National Labs, *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide*. February 2010. *http://www.sandia.gov/ess/publications/SAND2010-0815.pdf*

20 The Brattle Group, *The Value of Distributed Electricity Storage in Texas*. November 2014. *http://www.brattle.com/system/news/pdfs/000/000/749/original/The_Value_of_Distributed_Electricity_Storage_in_Texas.pdf*

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OTHER RESILIENT POWER PROJECT RESOURCES

Clean Energy Group's Resilient Power Project has produced reports and analysis on a wide range of resilient power policy, finance, and technology application issues. Please see a sample of those reports below. For a complete list of the Resilient Power Project's other informational resources, please visit *www.resilient-power.org* to access its extensive knowledge base, including webinars, blogs, and presentations.

2015

What States Should Do: A Guide to Resilient Power Programs and Policy, by Todd Olinsky-Paul, Clean Energy Group. States are making important progress in deploying clean, resilient power technologies that can keep the power on at critical facilities during grid outages caused by extreme weather events. In this first-of-its-kind report, Clean Energy Group profiles the leading state programs and makes recommendations for what other states can do to support the deployment of clean, resilient power systems. New resilient power technologies such as solar PV combined with energy storage can provide electricity during outages as well as valuable grid services year-round. This guidebook is intended to help states establish new policies and support new markets to advance clean resilient power nationwide. June 2015.

Solar + Storage 101: An Introductory Guide to Resilient Solar Power Systems, by Seth Mullendore and Lewis Milford, Clean Energy Group. This guide provides a basic technical background and understanding of solar+storage systems. It is meant as a starting point for project developers, building owners, facility managers, and state and municipal planners to become familiar with solar+storage technologies, how they work, and what's involved in getting a new project off the ground. March 2015.

What Cities Should Do: A Guide to Resilient Power Planning, by Robert G. Sanders and Lewis Milford, Clean Energy Group. This paper describes a plan of action for cities to become more "power resilient" using new technologies like solar and battery storage, which can be more reliable than diesel generators to protect vulnerable populations from harm due to harmful power outages in severe weather. March 2015.

Ramp Up Resilient Power Finance: Bundle Project Loans Through a Warehouse Facility to Achieve Scale, by Robert G. Sanders, Clean Energy Group. This report outlines a new clean energy finance model for many resilient power systems to protect vulnerable communities and critical infrastructure from severe weather events. January 2015.

2014

Financing for Clean, Resilient Power Solutions, by Robert G. Sanders, Clean Energy Group. This paper describes a broad range of financing mechanisms that are either just beginning to be used or that have a strong potential for providing low-cost, long-term financing for solar with energy storage. The goal is to identify financing tools that can be used to implement projects and that will attract private capital on highly favorable terms, thereby reducing the cost of solar and resilient power installations. October 2014.

Resilient Power: Evolution of a New Clean Energy Strategy to Meet Severe Weather Threats, by Clean Energy Group. This paper describes the progress of "resilient power" efforts since the New York City blackouts in 1999 to Superstorm Sandy. It outlines the dangers that power outages can pose to our most vulnerable populations, the failures of traditional backup power sources, and the opportunities to develop distributed energy systems with clean and dependable energy technologies. The paper goes on to announce the launch of Clean Energy Group's Resilient Power Project and describes the importance of new technologies like solar PV with energy storage to provide resilient power as weather patterns become increasingly volatile and longer power outages become more frequent. September 2014.

Clean Energy for Resilient Communities, by Robert G. Sanders and Lewis Milford. In the first blueprint of how a city could become more "power resilient," this report shows how Baltimore and other cities could use clean energy to create a more reliable electric system that protects vulnerable citizens during power blackouts. The report was written by Clean Energy Group for The Abell Foundation, a leading private foundation in Baltimore. February 2014.

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Clean Energy Group (CEG) is a national, nonprofit organization that promotes effective clean energy policies, develops low-carbon technology innovation strategies, and works on new financial tools to advance clean energy markets. CEG works at the state, national, and international levels with stakeholders from government, the private sector, and nonprofit organizations. CEG promotes clean energy technologies in several different market segments, including resilient power, energy storage, solar, and offshore wind. Above all, CEG also works to create comprehensive policy and finance strategies to scale up clean energy technologies through smart market mechanisms, commercialization pathways, and financial engineering. CEG created and now manages a sister organization, the Clean Energy States Alliance, a national nonprofit coalition of public agencies and organizations working together to advance clean energy through public funding initiatives.

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