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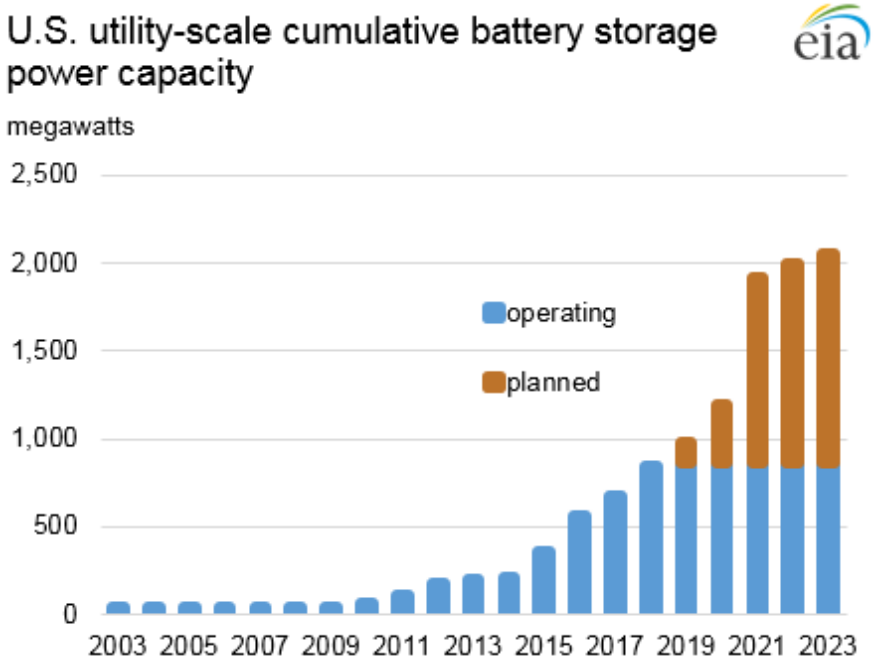
Advances in Electricity Storage Suggest Rapid Disruption of U.S. Electricity Sector

Utility-Scale Batteries Will Provide a Major Lift to Renewables, Further Undercut Coal, Challenge Fracked Gas

Executive Summary

The hype surrounding energy storage occasionally has run ahead of reality, but no longer. The disruption inherent in the technology's potential—the firming of markets for clean, low-cost renewable energy, in particular—is taking hold across the U.S. The utility sector as a result will never be the same.



Battery storage remains a tiny segment of the U.S. electric supply sector—data from the Energy Information Administration (EIA) shows just 122 battery storage units in operation through February of this year with a total nameplate capacity of 866 megawatts (MW).[1] And even though the sector is expected to grow rapidly in terms of its percentage of market share, with the EIA projecting an additional 1,184MW of

[1] Electricity Monthly Update, EIA, March 2019.

battery storage coming online by 2023, these figures pale in comparison to total installed electricity generating capacity nationally of 1,096,424MW.[2]

Small as these numbers seem, they are significant, and so is the enthusiasm with which the technology is being embraced by the U.S. utility sector. The use of storage is being adopted across the board, by the biggest and the smallest utilities, by member-owned co-ops and investor-owned companies, and by developers competing in the utility market. It is this broad backing that is driving the disruption.

This report, in reviewing the major uses of battery storage technologies, finds usage ubiquitous despite its still-tiny installation numbers. We have sought to highlight operational projects or those either in the advanced planning stage or currently under construction. Energy storage is not a pie-in-the sky proposition; these changes are taking place today.

Some takeaways:

- Battery storage in combination with solar can be used to facilitate closure of coal and natural gas plants currently being used largely for peaking or seasonal needs, as shown by the NV Energy decision to close the North Valmy coal plant in Nevada and FPL's plan to shut two aging natural gas units in Florida.

- Battery storage can be used to meet system peak needs, as SCE is doing in California in replacing the two-unit Mandalay natural gas peaker plant.

- Battery storage can be used to provide firm renewable power, as both Arizona Public Service and Hawaiian Electric are demonstrating with projects they have named, respectively, "Solar after Sunset" and "Renewable Dispatchable Generation."

- Battery storage offers utilities significant opportunities to boost system resilience and cut costs at the same time, as is being demonstrated in a number of other projects highlighted in this report.

- Battery storage can be used to enable more residential solar systems to be installed on local distribution lines without requiring potentially costly and time-consuming system upgrades, as can be seen in an existing program in Vermont and as is suggested by a proposed one in New Hampshire.

- Battery storage can be used to improve the economics of existing utility-scale solar generation, as can be seen in the discussion about Vistra's battery storage retrofit at a Texas PV plant.

Beyond these existing projects, this report explores pending developments that offer the potential for broad disruption in the electricity generation sector.

[2] Electric Power Monthly, EIA, March 2019.

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Introduction

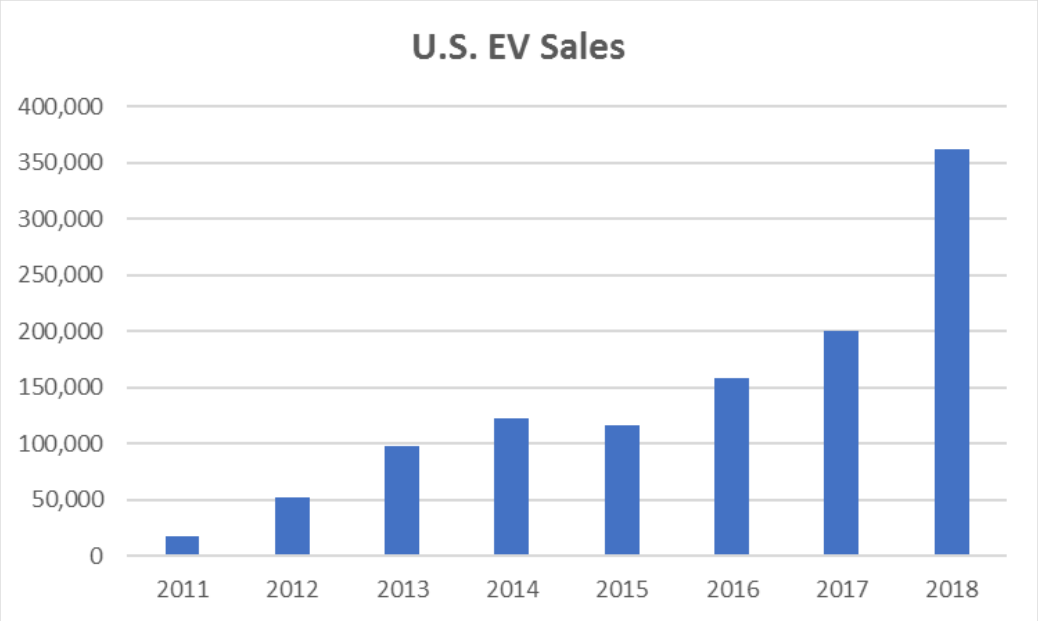
While it is difficult to pinpoint a singular trigger for the recent, rapid development of the utility industry's interest in battery storage, four catalysts stand out.

First, state mandates and incentives have played a role (see appendix) in driving the nascent market.

Second, the surge in solar photovoltaic installations in the past decade at the residential level, in the commercial and industrial sector, and at utility scale has led both to system problems that battery storage could help resolve and to opportunities that storage could tap into.

Third, growth in the electric vehicle (EV) market has created more demand for electricity storage. The global surge in EVs has resulted in massive price declines in lithium-ion batteries over the past decade. According to Bloomberg New Energy Finance (BNEF), lithium-ion prices have plummeted, from $1,160 per kilowatt-hour (kWh) in 2010 to $176/kWh in 2018 (both figures are stated here in 2018 dollars)[3]

Figure 1: Rise of U.S. EV Sales Since 2011



Source: insideevs.com

Fourth, the shifting preferences of the utility industry itself, a force that is harder to quantify, as the examples in the following pages illustrate, but that is unlike the early development phases of the wind and solar industries, which were slower and had fewer forces in their favor. Just two years ago, AES commissioned a 30MW/120 megawatt-hour (MWh) storage project with California's San Diego Gas & Electric; it was, the company said, "the world's largest lithium ion battery-based energy storage

[3] A Behind the Scenes Take on Lithium-ion Battery Prices, BNEF, March 2019.

installation, 50 percent larger than the next largest installation."[4] That record has already been eclipsed, and seemingly ever-larger projects are being announced regularly.

Taken together, these four developments have pushed the battery storage industry forward quickly—to where it is now beginning to disrupt utility decision-making especially. In short, the industry now has an exciting range of new options to address problems and opportunities alike.

But the energy storage market is not just expanding at the top end, it is taking root with smaller utilities and cooperatives, which are among the most enthusiastic backers of the developing technology, albeit at smaller scale.

Rapid change sweeping the battery storage market is evident in Wood Mackenzie's annual market outlooks. Last year, the firm projected that annual installations would total 2,535MW by 2022, up from 295MW in 2017[5] Its latest annual report, released in March, projects that annual installation in 2022 will be well above 3,000MW, and that it will jump to just under 4,500MW by 2024.[6]

The body of this report focuses on operational or soon-to-be operational utility battery storage projects. These projects are broken out by application, but it is important to keep in mind that these are fluid definitions. One of the benefits of battery storage is that it can address more than one problem or can be used to take advantage of more than one opportunity. For example, in the discussion that follows on reducing transmission charges, the batteries in question—in addition to reducing costs—are also providing built-in resilience. In other words, our categories here on where energy storage is making an impact are not hard and fast.

In the interest of space and readability, many new battery storage projects are not detailed in this report, which is more a detailed snapshot of a fast-moving industry rather than a comprehensive accounting.

While the focus here is on utility applications, rapid development is taking place in the behind the meter (BTM) battery storage market as well, particularly in trends toward linking residential solar with co-located storage. These markets are developing more quickly in Europe and Australia than in the U.S. due to higher prevailing electricity prices. But this use is likely to become more common in the U.S., especially in states like California and Arizona that are moving toward time-of-use electricity rates.

[4] SDG&E and AES Energy Storage Unveil World's Largest Lithium Ion Battery-Based Energy Storage Installation, February 2017.
[5] GTM Research / ESA, U.S. Energy Storage Monitor Update Q4 2017.
[6] GTM Research / ESA, U.S. Energy Storage Monitor 2018 Year in Review.

Utility-Scale Applications

Transmission and Distribution Infrastructure Deferral/Grid Resilience

A host of battery storage projects fall under this category, and they all share a common starting point, coming on the heels of corporate evaluations showing that the new technology would be cheaper and easier than conventional upgrades, particularly when it comes to the construction of new transmission infrastructure.

An early project developed by Arizona Public Service for the small community of Punkin Center northeast of Phoenix is typical. Load was growing in the area and forecasts showed that the growth would soon overload the 21-kilovolt transmission line serving the town. The conventional solution to this problem would have been to upgrade the transmission line based on the current need and a forecast of future growth. Once the upgrade was complete, the system would have been, by default, overbuilt, just as often happens when new, large-capacity power generation units are brought online to meet future capacity needs.

But given the area's remote location and the likely expense associated with upgrading 20 miles of transmission line in hilly terrain, the utility examined other options. Its analysis found that it would be significantly cheaper to fix the problem with battery storage, which required "less than half of the upfront expense of the traditional wires approach," according to Erik Ellis, APS transmission and distribution manager for technology assessment and integration.[7]

In the end, APS opted for a 2MW/8MWh battery storage system from AES to meet the community's current needs, which typically include 20-30 high demand days during the summer. As Ellis noted: "[W]e're evolving toward a more sustainable and effective grid where we're no longer forced to make investments in these large, significant steps. We can take much smaller incremental steps to manage the need as it arises and not have to over-invest in some cases, as utilities have traditionally had to do in the past."[8]

Going forward, if the area's demand continues to grow, additional investment may be needed. On the other hand, if more demand does not materialize, APS can repurpose the storage system for use elsewhere. By contrast, a conventional transmission line upgrade would have been a sunk and immovable cost.

Similar development projects are in the pipeline elsewhere as well. New England's Eversource Energy, for example, is moving forward with two projects, one in New Hampshire and a second in Massachusetts, that will rely on battery storage to avoid new transmission construction and boost local grid resilience.

The proposed New Hampshire project, which has not yet been approved by state regulators, would use a 1.7MW/7.1MWh battery to improve reliability in the rural

[7] APS Buys Energy Storage From AES for Less Than Half the Cost of a Transmission Upgrade, August 2017.
[8] Ibid.

town of Westmoreland,[9] which is currently served by a single transmission line that frequently fails. According to Eversource, the town has been hit with 20 outages in the past five years—or one every three months—compared to an average outage rate of once every 13 months for other areas in the state. Similarly, outages last longer in Westmoreland.[10]

According to the utility, building a second transmission line to improve the town's service would cost $6 million. Installing the battery will cost an estimated $7 million, but the company says ancillary benefits associated with the project, particularly potential savings from cutting the utility's peak demand, will save $2 million in the long term for New Hampshire customers.[11][12]

A second, much larger Eversource project focuses on improving service to Provincetown, which is at the tip of Cape Cod and has been hit with a rising number of service outages from storms in recent years. Instead of building another transmission line to serve the area, which would have to cross through the Cape Cod National Seashore, the utility is building a 25MW/38MWh battery storage unit to provide backup power and boost system reliability.

The utility estimates that the battery system will cost $40 million. This is slightly more than the current projected cost to build a new line, but Charlotte Ancel, the utility's director of clean energy development, says the slight premium is worth it, and could even end up costing less in the end. "Our belief is the price [of the new transmission line] could exceed that cost. Over time, [the battery] should reduce outage costs.... If we build a redundant line, we still have to send out crews if it goes out."[13]

Peak Demand/Transmission Charge Reductions

Green Mountain Power

Green Mountain Power (GMP), a unit of Canada's privately held Gaz Metropolitan, has been actively involved in battery storage development efforts in Vermont since 2015, focusing on using the technology to cut the amount it pays ISO-New England, which operates the region's wholesale transmission system, for access to and use of the grid.

Utilities in New England are subject to two charges from ISO-NE. The first, essentially a capacity charge, is based on each company's peak demand during the region's annual peak demand hour. The amount of this charge is derived from the region's forward capacity market. The second charge, a fee covering the use of

[9] Clean Energy Project to Enhance System Resiliency with Combination of Battery Storage, Energy Efficiency and Customer-Owned Devices, May 2019.
[10] Eversource Plans $7M Battery Storage Demonstration Project In Westmoreland, May 2019.
[11] Ibid.
[12] Eversource turns to non-wires solution in outage-plagued New Hampshire town, May 2019.
[13] Eversource advances Cape Cod battery project, defers 13-mile distribution line, April 2019.

regional network services, is based on a utility's demand during the monthly peak transmission hour in its state.

GMP first demonstrated its ability to lower these costs in 2016, tapping into a small solar-plus-storage microgrid that it built to provide backup power for an emergency shelter in Rutland. That summer, GMP used the microgrid—which includes 2MW of solar PV capacity and 4MW/3.4MWh of battery storage—to cut its demand during the region's peak demand hour on Aug. 12 by 2MW. That reduction saved the utility's customers $200,000.[14]

The company has also targeted residential demand, teaming up with Tesla in mid-2017 in a pilot that offered homeowners one of the storage provider's 13.5 kWh Powerwall batteries in exchange for a monthly $15 fee over 10 years or an upfront payment of $1,500. In return for the monthly fee and a guarantee of backup power during grid outages, participants agreed to let the utility operate the battery. By the summer of 2018, GMP and Tesla had installed 610 of the residential battery systems, enabling the company to cut its demand significantly during the region's August peak.

According to the company, the residential storage systems, coupled with community storage with solar installations (both the Rutland facility mentioned above and a second unit at Panton, which has a 1MW/4MWh battery coupled with 4.9MW of PV[15]), saved the company's customers $600,000 by cutting GMP's demand during the region's peak on Aug. 6.[16]

These results prompted the company to expand the program earlier this year, allowing customers to bring their own battery to the program. In addition, in January the company received regulatory approval to move forward with another microgrid project, this one to be built in the town of Essex.

Eversource

Eversource is also looking to cut its transmission charges from ISO-New England. In May, as part of its proposed Westmoreland battery project in New Hampshire described above, the utility said it would offer customers who install their own residential battery a credit of $200/kW, provided they allow the utility to control the unit's dispatch.[17]

Sterling Municipal Light Department

The small Massachusetts town of Sterling had been hit with significant increases in the amount it owed ISO-New England for its capacity needs and transmission services during the early 2010s, with fees more than doubling, from $500,000 in

[14] GMP's Solar Storage Project Becomes First in New England to Use Solar Battery Storage to Reduce Peak Demand, October 2016.
[15] Tesla Powerwalls and PowerPacks save Vermont $500,000 during heatwaves, October 2016.
[16] GMP Beats New Peak, Delivers Bigger Customer Savings with Growing Network of Stored Energy, August 2018.
[17] Eversource turns to non-wires solution in outage-plagued New Hampshire town, May 2019 .

2010 to $1.2 million in 2017.[18] This prompted a search for ways to cut those costs, which focused initially on adding a natural gas peaking plant that the utility could use during peak periods to cut its demand coming from ISO-New England and thereby lower its annual capacity charge.

A state program designed to boost resiliency changed the discussion, and the town shifted its focus to installing a battery storage system. The 2MW/3.9MWh battery storage unit was installed in late 2016 at a cost of just over $2.5 million.[19] The unit is designed to continue operating in the event of a wider transmission system outage; it is connected to a 2MW solar PV system in the town (which was built previously) and should be able to provide at least a 12-day supply of power for essential town services, notably its police station and the emergency dispatch center for first responders.[20]

Beyond these resiliency benefits, the battery also helped the utility cut its regional transmission and capacity charges substantially during its first year of operation. All told, the utility saved almost $400,000 in one year, cutting its ISO-New England capacity charge by more than $240,000 and its monthly transmission charges by almost $146,000. An additional $12,567 was earned selling power into the market during high-price periods.[21]

Increasing PV Siting Capacity

The success of residential and commercial PV has had a major impact on utility operations, particularly at the local distribution level, where companies are increasingly running into potential overload situations with the increase in power flowing onto the system.

The map below from Green Mountain Power shows the extent of the problem facing the Vermont utility, and is indicative of similar problems facing utilities everywhere. The map, while difficult to read in this rendition, shows the distributed generation circuit capacity available at GMP's substations; the red lines show those substation transformers with less than 10% of their rated capacity still available.[22]

The utility has developed a number of programs to address this overload problem, most recently offering an extra incentive of $150 per kilowatt for customers in the high stress areas who opt to participate in GMP's new bring-your-own-battery program.[23] This enticement is on top of the program's standard $850 per kilowatt incentive for customers anywhere in the state, a combination that substantially cuts the cost of a residential battery installation.

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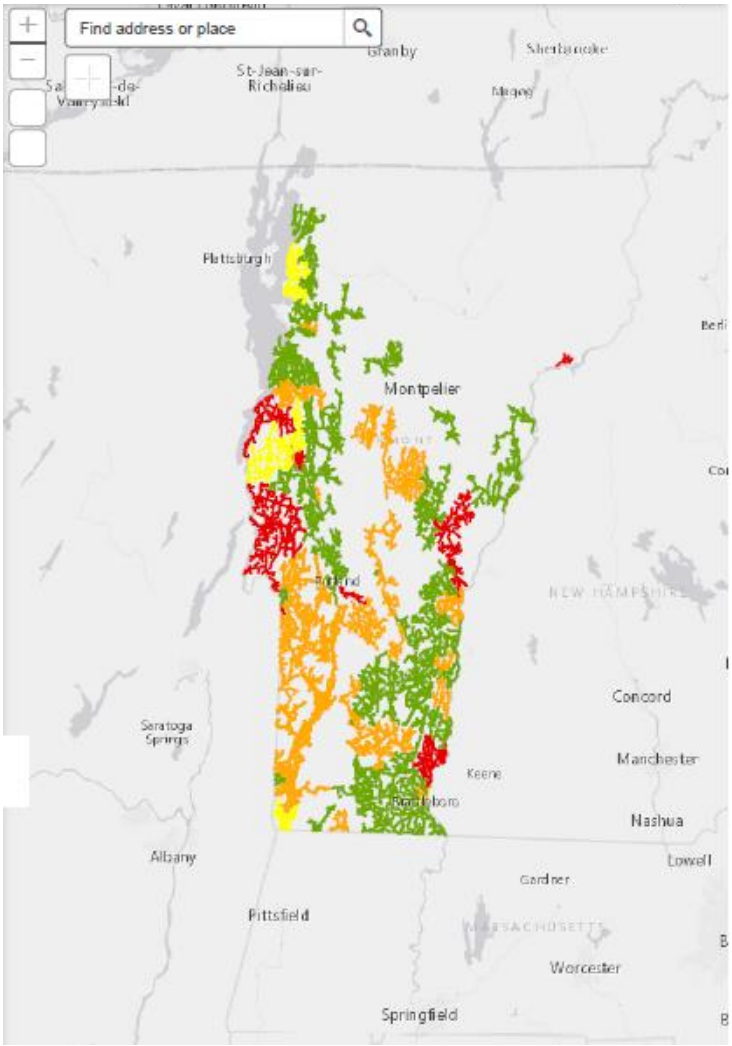
[18] Sterling Municipal Light Department, Resilient Power Project Case Study, Clean Energy Group, March 2018, p. 5.
[19] Ibid, p. 7.
[20] Ibid, p. 5.
[21] Ibid., p. 9.
[22] GMP Solar Map 2.0.
[23] Bring Your Own Device, Green Mountain Power.

In a previous project involving the redevelopment of an affordable housing complex with rooftop solar and Sonnen residential batteries, GMP found that the batteries showed the potential to boost the local distribution system's PV hosting capacity and might even enable the company to defer some transmission and distribution upgrades. The project, called McKnight Lane, was built in one of the red-line areas in the map below identified as being unable to accommodate significant new distributed generation requests. Even so, the company wasn't planning to upgrade the lines as it was not able to justify the cost. But in a webinar discussing the project, a GMP official noted that "small amounts of distributed energy storage may delay, or completely alleviate the need for wire or transformer upgrades that may be overkill for a small increase in capacity in a given area."[24]

Figure 2: GMP's Distribution Lines (Stressed Circuits in Red)



Source: GMP.[25]

[24] Energy Storage for Rural Affordable Housing: The McKnight Lane Redevelopment Project, Clean Energy States Alliance, September 2017.
[25] GMP Solar Map 2.0.

Energy Shifting/Peak Needs

Given their variable nature, solar and wind are not always available when needed, or they are available in quantities that cannot be used in full at a particular time. This latter issue is a special problem for solar, which generates the most electricity from the late morning to the late afternoon, times that do not always correspond to peak demand.

Arizona Public Service has targeted this issue aggressively, pushing ahead with a number of battery storage programs designed to shift solar generation to periods of peak demand later in the day. In its first contract along these lines, APS partnered with First Solar in early 2018 in a deal that specifically targeted the utility's peak demand period, which runs from 3-8 p.m. Under the contract, First Solar is building a 65MW solar photovoltaic unit and a 50MW battery. The combination will enable First Solar essentially to provide APS firm power during its peak five-hour window. Outside that window—and provided it can meet its daily contractual obligation—First Solar is free to use the units as it sees fits.

The project is also noteworthy because it was selected over numerous other bids, including for conventional natural gas peaking plants, submitted in response to the utility's request for proposals.[26]

Following the initial deal with First Solar, APS on Feb. 21 of this year announced a program dubbed "Solar after Sunset" to build 850MW of new battery storage and at least another 100MW of new solar generation in its service territory by 2025.[27] The program will include adding 200MW of battery storage capacity to existing APS solar PV plants and building 500MW of solar-plus-storage or standalone battery storage.

It is worth noting that as recently as 2017, in its integrated resource plan, APS was projecting only an additional 500MW of battery storage, and not reaching that level until 2032.[28]

Arizona is also home to a storage-only peak power project built by Fluence, the joint venture company linking AES and Siemens, for the Salt River Project, which supplies power and water to the Phoenix area. Construction on the 10MW/40MWh battery storage project began last year. The battery, SRP's first standalone unit, will be charged by a utility substation in Chandler and used to inject power into the grid when needed during periods of peak demand.

Another example of solar shifting is taking place in Hawaii, where the state's net energy metering was so successful that distribution lines were becoming overloaded with power flowing back into the system when it was unneeded at generation sources, which typically were residential. To combat the problem, the state now has a smart export program under which customers are not paid for any

[26] First Solar Made Good on Its Promise to Beat Out Gas Peakers With Solar and Batteries, February 2018.
[27] APS customers get solar after sunset with major clean-energy projects, February 2019.
[28] APS Builds its Capacity for Energy Storage Knowledge, February 2019.

power exported to the system from 9 AM-4 PM. The goal of this structure is to have customers install battery storage systems connected with their PV units, and use the PV output during the daytime hours to charge their batteries and then either use that power locally when needed or ship it back into the grid during peak demand periods. A second program, Customer Grid-Supply Plus, allows customers to install solar PV without a battery but pay less for their electricity and are required to install equipment allowing the utility to cut off their electricity exports if needed for system reliability.[29]

New Capacity/Early Coal and Gas Plant Retirements

The NV Energy Example

The role battery storage is playing in the changing electricity market is evident in the saga surrounding NV Energy's two-unit North Valmy coal plant in the northern part of Nevada.

As late as February 2018, the utility was telling state regulators that the best course of action was to keep both units[30] running through 2025. Retiring Unit 1 early, the company said, would require the company to buy power on the open market, exposing ratepayers to "market price fluctuations and [the] potential for energy shortages."[31]

But then, at the beginning of June 2018, the company filed a new integrated resource plan (covering the years 2019-2038) in which it told state regulators its preferred plan for going forward included retiring Unit 1 at the end of 2021.

What changed? In the spring of 2018, developers submitted bids to build 3,774MW of new renewable energy capacity and add 797MW of battery storage capacity in response to a request for proposals from the company. Out of those totals, NV Energy selected six solar projects, with a total nameplate capacity of 1,001 MW; three of those six solar proposals included a storage component.

These three solar-plus-storage projects (see the table on the following page for details) are game changers, all located in northern Nevada, near the North Valmy plant.

[29] Customer Renewable Programs, Hawaiian Electric.
[30] Unit 1 has a net summer capacity of 254MW and was brought online in 1981, Unit 2 is 268MW and entered service in 1985.
[31] NV Energy, North Valmy Life Span Assessment Process, p. 30, Docket #16-07001.

Project Name	Solar Capacity (MW)	Storage Capacity (MW)	Resource Planning Capacity (MW)	Developer
Dodge Flat Solar Energy Center	200	50	117	NextEra Energy
Fish Springs Ranch Solar Farm	100	25	58	NextEra Energy
Battle Mountain Solar Project	101	25	59	Cypress Creek Renewables
Total	**401**	**100**	**234**	

***Source**: NV Energy, S&P.*

In its IRP submission, the company wrote that "North Valmy Unit 1 is a critical supply resource, securing the reliability of the northern system generally, and enabling NV Energy to serve most of Nevada's mining industry located in the Carlin Trend and the commercial and industrial load located east of Reno."[32]

The company felt comfortable enough to move ahead with shuttering the plant, confident that the new solar-plus-storage resources could meet the system's capacity and reliability needs. The three projects will be in commercial operation by the summer of 2022.

FPL's Gas Plant Closure Plan

Rapid transition in battery storage is also on view in Florida, where Florida Power and Light announced in March of this year that it planned to build the world's largest battery, charge it with solar power, and use the combined resource to retire two 40-plus-year-old natural gas generating units.

The battery, called the Manatee Energy Storage Center, will have a capacity of 409MW and be capable of supplying 900MWh of electricity, FPL said. It will be paired with the company's existing 74.5MW Manatee solar farm, which came online in 2016. It is noteworthy here that it was only a year earlier that FPL announced its intentions bring online what at the time was the largest battery in the world, a 10MW/40MWh unit to be built at its Babcock Ranch solar facility that would provide power to the new planned community of Babcock Ranch.[33]

Once the Manatee battery center is completed, now scheduled for 2021, FPL said it plans to retire the two Manatee gas plants at the site. These two units, which came online in 1976 and 1977, each have a net summer capacity of 812MW but have not been producing anything close to their full capability for years. According to S&P data, the units' annual capacity factors have not exceeded 20% in the last 10 years, although there have been occasional months when one unit or the other topped the 30% marker.

The Manatee facility is not a one-for-one replacement for the neighboring gas units, but in combination with other battery systems and PV plants FLP is planning across

[32] NV Energy IRP, Volume 11, p. 16.
[33] Construction begins on FPL's four newest solar power plants, EE News, August 2018.

the state, the utility says it will be able to replace the 1,600MW-plus of generating capacity and save customers more than $100 million in the process.[34]

PG&E's Plan for the Biggest Battery Yet

Last year, California regulators approved four battery storage projects, including one billed at *that* time as the largest in the world, proposed by Pacific Gas & Electric to replace three aging natural gas-fired generators with a combined 676MW of capacity owned by Calpine Corp..[35] The gas plants, notably the 525MW Metcalf unit, were having trouble competing in the California market and had sought extra payments through the state's reliability must-run program. State regulators then authorized PG&E to conduct a solicitation for new capacity, either in the form of battery storage or other preferred energy resources that could replace the gas plants.

The four storage projects included in the PG&E proposal were:

- A 300MW/1,200MWh unit that would be built by Vistra Energy
- A 182.5MW/730MWh facility that would be built by Tesla but owned by the utility;
- A 75MW/300MWh project, known as Hummingbird, to be developed by esVolta; and
- 10MW/40MWh of distributed storage that would be built by mNOC.[36]

Pacific Gas & Electric's wildfire-induced bankruptcy could slow or even bring to a halt work on one or more of these projects. And, in fact, esVolta has already raised concerns about its contract, noting that it is being forced to spend development money now on its project in order not to risk defaulting, even though the whole contract may be rejected later by PG&E as part of the company's restructuring.[37]

But the key point here is what the California Public Utilities Commissions wrote in approving the projects in the first place:

"PG&E also conducted a cost and benefit analysis which revealed that, in considering the benefits of the proposed storage projects in AL 5322-E, the four projects result in a net positive value over the Metcalf RMR…. This tables illustrates a total savings to PG&E ratepayers of $211/kW-year over the Metcalf RMR contracts, which we

[34] FPL announces plan to build the world's largest solar-powered battery and drive accelerated retirement of fossil fuel generation, FPL, March 2019.
[35] Storage will replace 3 California gas plants as PG&E nabs approval for world's largest batteries, Utility Dive, November 2018.
[36] CPUC, Resolution E-4949, 11-8-2019.
[37] PGE Wildfire-Linked Bankruptcy Imperils Big Bay Area Green Energy Project, Mercury News, March 29.

calculate as an estimated $233 million in overall benefit over 10 years, over an extension of the Metcalf RMR agreement."[38]

Implications

The details of these three examples are company specific, but the implications reach across the electric generation sector. These projects should be of particular concern for U.S. coal-fired generators, especially those with low annual capacity factors.

Low annual capacity factors, particularly at 30% or less, are a sign that the unit in question either is being cycled extensively year-round or is hardly running during the shoulder spring and fall months and then generating more consistently during the higher demand summer and/or winter periods. The latter has been true of North Valmy Unit 1 since 2016, when it began operating in seasonal mode; in the past three years its annual capacity factors have been 22.2%, 13.6% and 25.7%, with months of zero generation interspersed with months of generation ranging from 11% of capacity to as much as 78%.

Neither operating mode is good for plant equipment, nor is it economically sustainable, but a significant number of coal-fired units are doing precisely that according to IEEFA's analysis of DOE data. IEEFA found that 120 coal-fired units posted a capacity factor of 30% or lower in 2018. The nominal generating capacity of those units totals 26,516MW—well over 10% of the currently installed coal-fired capacity in the U.S.

In our view, these numbers make each of these units a candidate for retirement and for replacement by less costly and cleaner solar-plus-storage, a resource that is quickly maturing and still declining in cost.

Natural Gas Peaker Replacement

Southern California Edison's Changing Approach to New Peak Needs

One of the most intriguing possibilities for battery storage is in its potential to replace natural gas-fired peaking units. Here, the lengthy battle to replace the now-retired two-unit, 430MW Mandalay gas-fired plant in southern California is a good example of the rapidly developing battery storage sector.

The replacement effort began in 2013, when Southern California Edison first issued a solicitation for new capacity to replace the Mandalay facility. That led to the selection of a proposal by NRG, operator of the old plant, to build a new 262MW gas unit at the same site for approximately $300 million.[39] The contract was approved by state regulators in 2016,[40] which is when the real battle ensued.

Regulators may have been on board, but the local community was not. The proposed new gas plant, the Puente Power Project, was vociferously opposed by the host city

[38] CPUC, op. cit., p. 28.
[39] NRG nixes controversial Calif. gas plant proposal as alternatives advance, S&P Global Market Intelligence, December 2018.
[40] California energy interests set to square off over Puente natural gas plant, September 2017.

of Oxnard and its residents and by environmentalists. Given the urban location, local air pollution concerns were one of the driving forces behind the opposition

Opposition was stiff enough that the project was eventually suspended, in late 2017, after siting issues were raised by the California Energy Commission.[41] Despite that setback, Southern California Edison continued to voice its support for the project, saying it would be needed to meet local capacity needs when the Mandalay plant closed in 2021. At the time, the utility also still had questions about the viability of alternatives such as battery storage: "While there are potential solutions to the needs addressed by the Puente project, it is speculative to assume that preferred resources can be developed on the scale and at the cost needed to competitively replace the Puente project by 2021."[42]

Within months, the company tune changed, and it launched a new capacity solicitation that generated almost 300 bids totalling nearly 5,000MW of capacity, more than two-thirds of which was energy storage.[43] [44]

Then, in April of this year, SCE selected a series of bids, led by a 100 MW/400 MWh battery storage project put forward by Strata Solar, to help meet its local capacity needs beginning in 2020.[45] Not one of them involves fossil fuels (see table below for details).

Final Selection Set to Solve LCR Need

Bidder	Project	Resource Type	Location	Capacity (MW)	Average Capacity Price ($/kW-mo)	Commercial Online Date	Regulatory Approval Mechanism
Swell	SC/G	BTM-DR	S & G	14	[redacted]	January 2021	ACES AL
E.ON	Painter	ES-RA Only	G	10		March 2021	ACES AL
Strata	Saticoy	ES-RA Only	S	100		December 2020	LCR Application
Able Grid	Silverstran	ES-RA Only	S	11		March 2021	ACES AL
Ormat	Vallecito	ES-RA Only	G	10		December 2020	ACES AL
AltaGas*	Goleta	ES-RA Only	G	40		December 2020	ACES AL
Enel	Hollister	ES-RA Only	G	10		March 2021	ACES AL

Source: SCE.

The Strata Solar project is designed specifically to serve Southern California Edison's peak needs. Under the terms of the 20-year contract between the two companies, the utility will be able to dispatch electricity from the plant up to 15 days

[41] In lieu of gas plant, Southern California Edison plans 195 MW of batteries, April 2019.
[42] La Puente Gas Plant, Los Angeles Times, October 2017; In lieu of gas plant, Southern California Edison plans 195 MW of batteries, S&P Global Market Intelligence, April 2019.
[43] NRG nixes controversial Calif. gas plant proposal as alternatives advance, S&P Global Market Intelligence, December 2018.
[44] SCE's local capacity requirements RFP, S&P Global Market Intelligence, October 2018.
[45] Southern California Edison Picks 195MW Battery Portfolio in Place of Puente Gas Plant, Greentech Media, April 2019.

per year. Beyond that, Strata Solar will control the battery and its use in the broader California market.

New York City's Need for New Peak Capacity

The use of storage to replace natural gas peaker plants is also under discussion in New York, where regulators are considering new air pollution standards for nitrogen oxides, a precursor to harmful low-level ozone, that could force the closure of thousands of megawatts of aging natural gas-fired peaking plants in New York City.[46] Proposed regulations would not prohibit gas-fired units that can meet the stricter standards, but would almost certainly prompt consideration of alternatives such as battery storage.

An analysis two years ago by Strategen Consulting projected that battery storage in New York City would be cheaper than building a new gas peaker plant, with a net cost for battery storage at an estimated $136/MWh compared to $154/MWh for a new gas unit.[47] In the intervening couple of years, prices for energy storage have fallen significantly.

Arizona Public Service's Very Interesting Gas Peaking Plant Contract

A final example of the developing utility interest in using battery storage to replace natural gas-fired peaking plants can be seen in Arizona Public Service's novel contract this year to meet anticipated peak capacity needs in the coming years. In conjunction with its announcement in February that it intended to build 850MW of new battery storage across the state by 2025 (that announcement is covered in more detail on page 12), the utility said it was also signing a contract with Calpine for 463MW of energy from a natural gas plant. But instead of signing a conventional 20-year power purchase agreement with the developer, APS and Calpine signed a seven-year deal.[48]. The contract, APS said, gives the utility "the flexibility to take advantage of cleaner technologies in the future as they mature. This is part of a long-term clean-energy transition in which renewable and storage technologies will play an increasingly important role."[49]

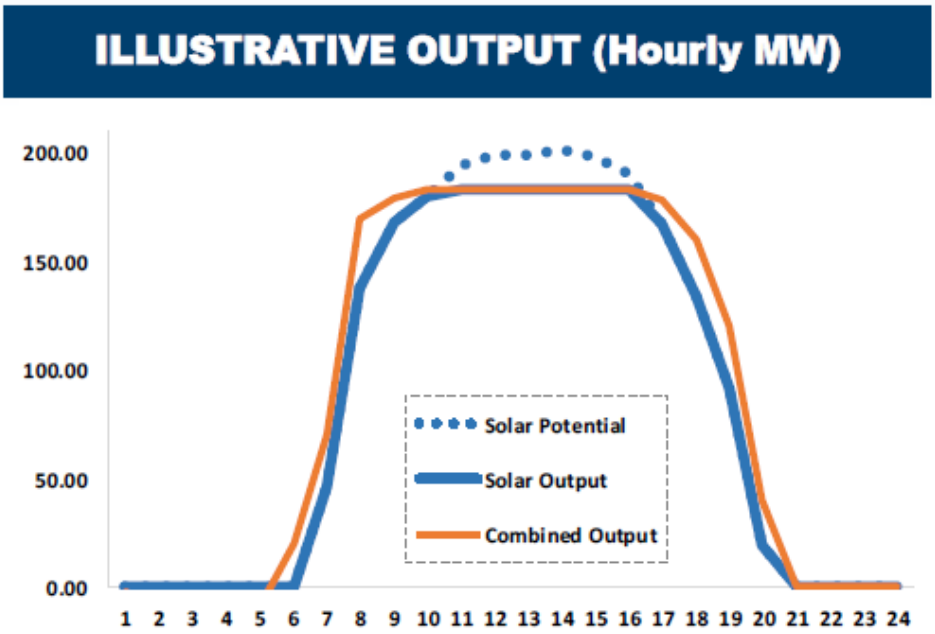
Asset Optimization

In competitive electricity markets, every kilowatt-hour produced or dollar saved matters. And that admonition is doubly important in the Texas market overseen by the Electric Reliability Council of Texas, which is an energy-only market, meaning if your power isn't cheap enough, you are out of the money.

Here, Vistra Energy partnered last year with FlexGen to add a 10MW/42MWh battery to its existing 180MW Upton 2 solar project. The solar facility's transmission interconnection is limited to 180MW, but during certain peak periods, the unit can

[46] New York moves to phase out older peaking plants as it targets 100% clean energy, Utility Dive, March 2019.
[47] Strategen Consulting, New York City's Aging Power Plants: Risks, Replacement Options, and the Role of Energy Storage, Sept. 20, 2017, p. 6.
[48] APS customers get solar after sunset with major clean-energy projects, APS, February 2019.
[49] Ibid.

produce up to 200MW of power (see the company graphic below), meaning that without its battery component, its production would be clipped, or wasted. The company estimates that the battery project can provide investment returns in the mid-to-high percentage teens—even in cutthroat Texas.



Source: Vistra Energy.

Providing New Capacity, Especially When Linked With Solar

Hawaiian Electric's New Renewable Dispatchable Generation PPAs

In March of this year, Hawaiian Electric received approval from state regulators for six solar-plus-storage projects that will add 247MW of new solar generation and 980MWh of linked storage to the utility's island grid.

The table below provides details on the projects.

Project Name	Island	Developer	Solar Size	Storage Size	Cost Per kWh
Waikoloa Solar	Hawaii	AES	30 MWdc	30MWac/120 MWh	$0.08
Hale Kuawehi	Hawaii	Innergex	30 MW	120 MWh	$0.09
Kuihelani Solar	Maui	AES	60 MW	240 MWh	$0.08
Hoohana Solar 1	Oahu	174 Power Global	52 MW	208 MWh	$0.10
Mililani I Solar	Oahu	Clearway	39 MW	156 MWh	$0.09
Waiawa Solar	Oahu	Clearway	36 MW	144 MWh	$0.10

Source: Hawaiian Electric.

What stands out here is the price of the six contracts—all at or below $0.10 per kilowatt-hour. In contrast, the utility's average price for its fossil fuel generation is about $0.15/kWh.

But it is not just the power's cost that is worth noting. All six of the contracts are structured to give the utility control over each unit's dispatch—a significant improvement over earlier contracts that required Hawaiian Electric to accept all the energy produced at a given facility.

For example, under the terms of its power purchase agreement with AES for the Waikoloa Solar project, the developer will receive a lump sum from Hawaiian Electric every month based on the facility's energy potential and availability rather than being paid for every kilowatt-hour delivered. This arrangement, which Hawaiian Electric is calling a renewable dispatchable generation PPA, gives AES payment certainty and eliminates the threat of curtailment while allowing the utility to manage the facility. This will be particularly important going forward, the utility said, as the state moves toward its 2045 100% renewable energy goal.[50]

El Paso Electric

Other utilities are also moving forward with new solar-plus-storage capacity development projects. For example, late last year, El Paso Electric announced that it would tap both solar-plus-storage and natural gas to meet its near-term electricity supply needs, Specifically, the utility said it would procure 200MW of solar and 100MW of battery storage to help meet summer supply needs beginning in 2022-2023. Specific projects have not yet been named, but the company stressed in its announcement that the winning bidders "will enable us to meet the growing need for power in our region in a safe, clean, reliable and cost-effective manner."[51]

Sunrun's Ground-breaking New England Contract

In February, solar supplier Sunrun was awarded a contract by ISO-New England to supply 20MW of capacity into the regional grid starting in 2022. To be sure, 20MW is a small number, but Sunrun intends to fulfil the contract using residential solar and storage installations—a first for the region.

This year's capacity auction marked the first time so-called hybrid resources were allowed to participate in the New England market; this change is largely attributable to the Federal Energy Regulatory Commission's Order 841, which requires transmission system operators to allow battery storage resources to participate in wholesale energy, capacity and ancillary services markets.

To secure the 20MW, Sunrun will need to sell about 5,000 households in New England on BrightBox, its solar-plus-storage product, and then effectively tie them together. Through the end of 2018, the company had installed just 5,000 of the units

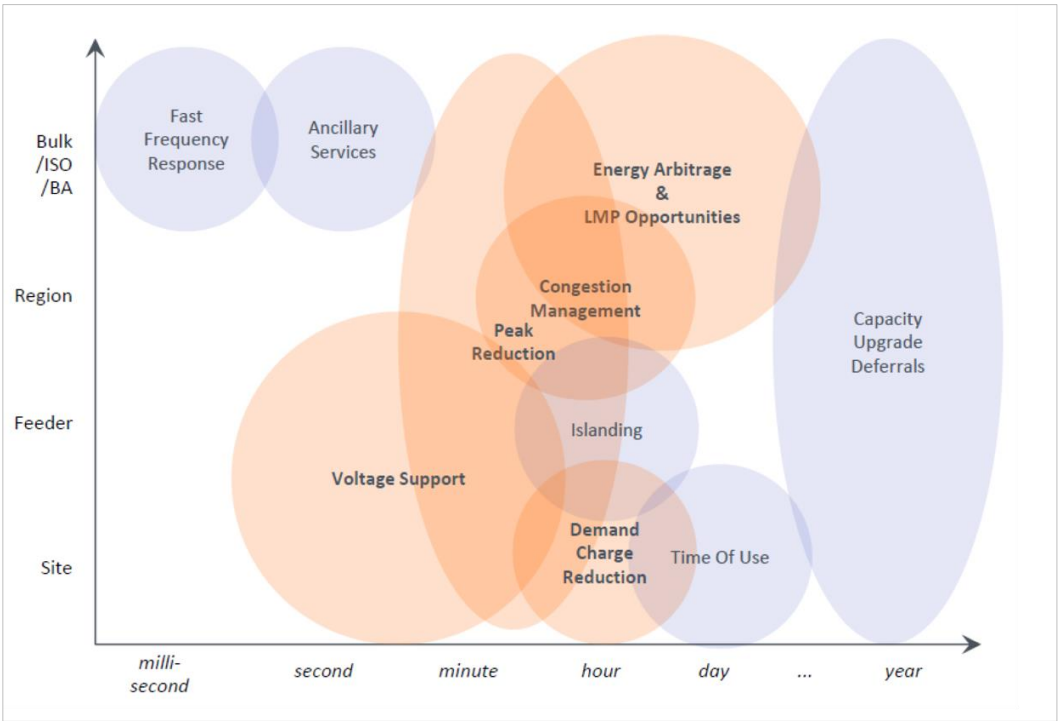
[50] Hawai'i Electric Light Company application for power purchase agreement with AES Waikoloa Solar, Docket #2018-0430.
[51] Plans to Add Hundreds of MWs of Solar Energy, Battery Storage by 2023, El Paso Electric, January 2019.

nationwide,[52] so this is a major step forward, and the company is optimistic. Customers get lower-cost electricity and backup power, the region pays a little less for capacity, and Sunrun makes money and gains a competitive edge.

The Future

Current developments clearly show the impact battery storage is having on the utility industry, but bigger changes loom. In the examples presented above, each project, by and large, was driven by one of several value streams—cutting transmission charges, providing grid resilience, offering peak power, allowing for early plant closures and the like—even if other benefits were accrued.

Figure 3: Potential Battery Storage Uses and Combinations



Source: DOE SHINES Program.

However, going forward, it is likely that developers and utilities will be able to stack these benefits, making storage even more economically competitive. The graphic above shows the overlap between various battery storage uses and where opportunities exist for future operational links.

While the residential storage market is beyond the scope of this report, we note that it is a sector of the battery storage market that is likely to grow quickly in the years to come, particularly in areas with high residential PV solar uptake and time-of-use (TOU) rates. For example, in California, which already has a significant amount of

[52] Sunrun Wins Big in New England Capacity Auction With Home Solar and Batteries, Greentech Media ,February 2019.

residential PV, the state's three investor-owned utilities are in the process of moving residential customers to TOU rates, which are higher during periods of higher demand, with the highest rates during summer weekday evenings (roughly 4-9 PM). With that rate structure and with existing rooftop PV, homeowners may soon be able to add a battery to capture electricity generated onsite during the day and saving it to use during the higher price period in the evening.

At the other end of the size spectrum, solar-plus-storage can already compete in certain regions of the country with what are commonly known as mid-merit natural gas combined cycle plants, units that are used in load-following operations rather than for baseload. A Fluence report, "Solar + Storage as a Mid-Merit, Utility-Scale Generating Asset," found that solar-plus-storage would cost from $39-$48/MWh (even with the storage upsized to six hours instead of the more conventional four). In contrast, the cost of power from these mid-merit gas plants ranges from $60-$116/MWh.[53] This finding is likely to have a major impact on utility resource planners going forward.

Finally, the Brayton Point redevelopment project in Massachusetts announced last month by Anbaric is another example to watch, combining battery storage with the country's just-beginning-to-develop offshore wind sector. As announced by the developer,[54] the project will include a 1,200MW direct current conversion station plus a 400MW battery storage unit to serve as a landing point for the state's new offshore wind assets. High-capacity-factor offshore turbines coupled with onshore storage would yield a highly dispatchable renewable energy resource.

How these developments will play out is impossible to predict with any certainty, but it is clear that battery storage is changing the utility industry and making a cleaner grid possible.

[53] Beyond Peaker Replacement: Solar+Storage Finds a New Job, Fluence, April 2018.
[54] CDC, Anbaric sign agreement for $650M renewable energy investment at Brayton Point, Anbaric, May 2019.

Appendix

Federal Regulation/State Incentives

The Federal Energy Regulatory Commission adopted Order 841 in February 2018 requiring regional transmission organizations and independent system operators to develop market rules allowing for energy storage to participate in wholesale energy and capacity markets. Under the terms of the order, RTOs/ISOs were given until the end of 2018 to develop and file their new participation rules, with an additional year to fully implement the new market structures.[55]

A subsequent challenge to the order, which took issue with FERC's interstate commerce justification for mandating the creation of markets for battery storage installed on local distribution circuits or behind the meter, was dismissed by the commission.

Another driver behind the development of the battery storage market has been state-specific mandates. The box below summarizes the existing mandates.

Storage Mandates/Incentives				
States	**Target**	**Enacted**	**Deadline**	**Notes**
California	1,325 MW	2010	2020	SB 700 enacted in 2018 includes $830 million for state's self-generation program, likely to boost storage installations
New York	3,000 MW	2018	2030	Interim goal of 1,500 MW in 2025, with even earlier targets in 2022
Massachusetts	1,000 MWh	2018	2025	State's new Clean Peak Standard likely to boost storage as well
New Jersey	2,000 MW	2018	2030	Interim mandate is for 600 MW by 2021
Oregon	5 MWh	2015	2020	Requirement applies to both Portland General and PacifiCorp

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[55] https://www.ferc.gov/media/news-releases/2018/2018-1/02-15-18-E-1.asp#.XPVpKBZKi70

- https://www.utilitydive.com/news/new-york-psc-sets-states-energy-storage-target-at-3-gw-by-2030/544371/
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