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ISSUE BRIEF
Energy Storage To Replace Peaker Plants

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ABSTRACT

For the last several decades, the energy & utilities (E&U) sector in the U.S. has been built upon a structure in which utilities and other load serving entities (LSEs), in order to meet demand, have relied upon portfolios of resources that typically have included a few large baseload generation plants, some intermediate plants, and multiple units that offer rapid ramping capability. Baseload units run continuously year-round, often on a 24/7 basis. Intermediate plants are used to meet common fluctuations in demand. The rapid-ramping units, known as "peaker plants" or "peakers," exist to come online quickly (sometimes within minutes) and only stay online during short periods when baseload or intermediate units cannot meet unanticipated surges in demand. Peakers typically run for 10 percent or less of the year and may never run for more than four hours at a time.

The E&U sector in the U.S. relies on approximately 1,000 peaker plants, mostly fueled by natural gas, to meet infrequent peaks in electricity demand. Recent reports[1] have suggested that the E&U sector in the U.S. will need to add 20 GW of peaking capacity to the grid in the next decade, 60 percent of which would need to be installed between 2023 and 2027, to meet demand requirements in states such as California, Texas, and Arizona. Although peaker plants have served a critical need, they are also known to be more expensive and inefficient to run when compared to base unit power plants. Given that they have historically been fueled by fossil-based resources, peaker plants often have higher greenhouse gas (GHG) emission levels when calculated on an hourly basis.

Over the last decade, renewable energy and energy storage systems (ESSs) have been encouraged through procurement mandates or financial incentives set at the state level, and have emerged as a competitive alternative to existing or planned peaker plants. A study released by the National Renewable Energy Laboratory (NREL) in June 2019 found that a "substantial portion" of peaking capacity in the United States could be replaced by ES facilities. The NREL study found that the capacity of the national peaking power fleet is about 261 GW and about 150 GW of that capacity is likely to retire over the next 20 years, creating the potential for about 28 GW of 4-hour battery storage that could serve as peaking capacity.[2]

Grid operators require flexible generation, especially those with rapid ramping capability that can be used to maintain system reliability. This need creates a unique opportunity to use ESSs, either in combination with a renewable resource or as a stand-alone resource, to increasingly replace or displace peaker units presently located throughout the country.

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[1] GTM and Wood Mackenzie

[2] The National Renewable Energy Laboratory (NREL). "The Potential for Battery Energy Storage to Provide Peaking Capacity in the United States." June 2019. Denholm, Paul; Nunemaker, Jacob; Gagnon, Pieter; and Cole, Wesley.

The purpose of this **ISSUE BRIEF** is to summarize the policy and operational considerations associated with increased efforts to use ESSs to meet peak demand fluctuations and replace peaker plants.

BACKGROUND: USE OF PEAKER PLANTS

From a historical standpoint, most utility grids have not typically stored energy due to a lack of enabling technologies and prohibitive costs. Instead, utilities and grid operators have called upon the use of additional fossil fuel burning plants, known as peaker plants, to ramp up or down as needed to help meet demand. Peaker plants, designed to ramp up electricity production during periods when normal production isn't sufficient, have been used for decades to meet peak demand on the grid. Power grid operators—along with utilities, power companies, or other LSEs that own peaker plants—have used them as a means of covering the gap between available electricity supply and demand. Peaker plants may be called to ramp up in infrequent, short periods when baseload capacity, or the minimum demand on a grid, is surpassed, such as when a heatwave drives up air conditioning use.

However, this method is not at all ideal; utilizing these extra peaker plants to smooth out the distribution of energy is creating more pollution than the plants that are burning fossil fuels for the utility's base-load energy demands. Further, across the country, data compiled by the Energy Information Administration (EIA), peaker plants tend to be located in low-income or minority communities, which are then disproportionately impacted by the pollution.

Peaker plants are unique in that they do not have to continuously generate energy. Based on EIA data, peaker plants generally operate only between 2-7 percent of the total hours in a calendar year. Although they are not run on a continuous basis, peakers need to be available in real-time for when baseload capacity has been surpassed and/or demand spikes. This can occur as frequently as every evening when people return home, or as sporadically as when a heatwave occurs. Peaker plants have traditionally relied upon natural gas, diesel, or other fossil fuels, as these resources provided power grid operators, utilities, and other LSEs far more control and certainty over the complex process of meeting demand with supply.

In addition to being available when needed, peaker plants also support the operational process that is known as "peak-load shifting," which seeks to mitigate the strain of large energy load blocks on the electrical grid during specific time periods. This is accomplished by calling upon temporary support obtained from peaker plants until the electrical grid can readily accept additional load. Sudden changes in peak load can occur due to weather changes and other factors, and as a result grid operators, utilities, and other LSEs need to constantly be prepared for increased and short-term energy strains on the grid. Although peaker plants provide the benefit of being able to be started up and called upon quickly when needed, they are also typically more expensive to run and comparatively inefficient when evaluated against other alternatives (i.e., operational gains when compared against costs, emissions, etc.)

The ways in which peaker plants are being reconsidered against consideration of a number of market factors is a fairly new phenomenon. As one example, the E&U sector's long-standing reliance on coal began to erode around 2016, when natural-gas prices began to decrease to levels that made it a viable alternative to coal. It was around this time also that the Obama Administration enacted a number of policies (e.g., the Clean Power Plan) that included restrictions on the use of coal. As a result of these policies' broader considerations of climate change impacts resulting from power plant emissions became a focus area for national policy discussions on how to combat global climate instability.

Just as natural gas replaced coal due to its economic viability, more recently we have seen a similar shifting of resource considerations due to the economic viability of solar and wind when compared to natural gas, which has become increasingly evident in the last three years or so. This transition is part of a broader transformation as the E&U sector moves away from its historic reliance on centralized fossil fuels and toward a mixture of renewables (e.g., wind and solar), distributed energy resources (e.g., microgrids, ESSs), and demand-side efforts (e.g., energy efficiency and demand response programs), which used together can strategically reduce consumption. This transformation has the potential to create numerous benefits desirable for policymakers, end-use customers, and other stakeholders engaged in the E&U sector, such as reductions of GHGs and health-damaging co-pollutants, economic savings, and enhanced resiliency of the grid.

This transformation is occurring much faster than the displacement of coal occurred. For example, the Solar Energy Industry Association (SEIA) reported that out of the total power generation capacity added to the grid in 2019, 40 percent of that capacity originated from solar. There are many data sets that can be used to support the conclusion that it is now more economical to build new renewables generation sources than to run existing coal or to build new natural-gas plants in specific regions of the U.S. BSEIA predicts that, by 2032, in some specific regions, the cost of building new solar + storage plants will be lower than the cost of running existing natural-gas plants. What these changing economic dynamics could mean is that the currently proposed natural-gas plants scheduled to come online by 2032 could become economically disadvantageous to operate by the time they are commissioned.

This transformation to a grid that will become increasingly reliant on renewable resources brings with it a number of challenges, not the least of which is the intermittency of solar and wind. Intermittency has been thought to be a significant barrier because the erratic power fluctuations that result from an increased use of renewables (e.g., voltage transients, frequency deviation, etc.) can be detrimental to system stability. An example of these challenges can be found in California, where the large amount of solar that is already installed and connected to the state's grid is having a determinantal impact on voltage levels. Grid planners will require greater certainty that renewables—just like any other resource option—can function as reliable generators with stable voltage outputs.

This is where the importance of ES gains momentum, as batteries can be used to control intermittency and enable by-command dispatching. Moreover, batteries can participate in regional grid activities when they are not needed for peak power management, thereby further defraying their cost as a reliability asset. In other words, what once were theoretical applications envisioned by storage developers are now practical and tactical uses of battery technologies.

Consequently, the use of ESSs has become an increasingly important tool for addressing the intermittency concern. As the interest in and use of renewables has increased, so also have the market opportunities for ESSs to partner with solar or wind units. In fact, battery energy storage systems (BESSs), particularly paired with solar facilities, are already competitive with peaker plants fueled by natural gas in select regions and cases. The solar + storage pairing as a solution to address peaking capacity, is roundly expected to gain increasing prominence over the next decade.

BACKGROUND: ENERGY STORAGE FOR USE IN PEAK SCENARIOS

ES technologies store energy, produced at one point in time, for use at a later time. There are different kinds of ES technologies that have different capabilities. Not all would be considered suitable or practical for use in addressing peak scenarios. The most ES technology used for grid storage, accounting for more than 95 percent of current storage capacity, is pumped hydropower. The second most common ES technology is thermal storage and the third most third most common is battery storage. Batteries store energy using an electrochemical reaction. When batteries are charged, electricity drives the chemical reaction in one direction and stores electrons. When discharged, the chemical reaction is reversed, electrons are released, and electricity is provided from the battery. The most common form of battery ES is lithium-ion, but there are numerous other ES technologies that can offer benefits in non-peak scenarios.

Instead of generating electricity with peaker plants during times of high electricity and fuel prices, ES can be used to "peak shift" by using lower cost energy stored during off-peak periods to meet the demand. For example, an ESS that relies on lithium-ion batteries can be charged while the ESS is using minimal load and the cost of electricity usage is reduced, such as during nighttime hours. ES can be used to shift the peak generation from the photovoltaic (PV) system to be used when the demand requires it. Excess energy can be stored during peak PV generation. This allows for the distribution of energy when the PV system is not generating adequate power, or not generating at all. The ESS can then be discharged to provide additional power during periods of increased loading, while costs for using electricity are increased. This technique can be employed to reduce costs of utility bills, benefiting end-users. But it can also be used by grid operators to shift the impacts of load. Taken altogether, these capabilities enable the end users to use an ESS to better control their overall energy usage, and allows generators to access a higher value of dispatchable generation.

Operational factors of the battery—such as discharge time, duration, and capacity—are the keys to determining where and how a battery-charged ESS will be used. These operational factors are interrelated to the extent that, as one example, if a battery is discharged at a lower power to extend its duration, this will also positively impact the battery's capacity. Requirements for batteries on the grid are often given in terms of capacity and discharge time. For instance, a battery may be allowed to participate in a capacity market if it can provide four hours of power in one region or if it can provide ten hours elsewhere (e.g. in the mid-Atlantic market, PJM). The capacities of batteries currently on the grid vary widely. A residential ESS, such as the Tesla Powerwall, is approximately 5 kW/14kWh. Meanwhile, Pacific Gas & Electric (PG&E) has broken ground on a 300 MW/1,200 MWh BESS at the Moss Landing substation in Monterey County, CA.

The cost of electricity from batteries has been on a steady decline for the last decade. The cost for a stand-alone ESS now averages about $209 per kilowatt hour (kWh). The cost of utilizing a state-of-the-art ESS, with the additional benefit of zero emissions, is extremely competitive compared to running a fossil fuel peaker plant. Aside from the cost advantage, batteries have much faster response time – they can virtually ramp up and down instantly by following signals from the grid operator. Gas peakers can barely match the flexibility and responsiveness time of batteries. However, not all existing peaker plants in the United States could be easily replaced with ESSs, due to duration limitations. ESSs remain a finite asset with limited duration capability, while peaker plants fueled by natural gas can run for significantly longer durations.

THE POLICY COMPONENT

The correlation between policy and the use of ESSs to replace peaker plants is fluid and evolving. In this context, policy refers to regulatory and legislative activity at the state level and regulatory activity at the federal level (e.g., FERC's regulation of the nation's RTOs/ISOs). Federal legislative activity has not been directly relevant to this issue. When speaking of policy development that would enable ESSs to participate in meeting peak demand, policies at both the federal and state levels are relevant, but arguably most directly impactful at the state level. At the federal level, policy is being formed within the context of FERC's broader Order 841 compliance, which relates to enabling ES to participate (where it can) in the energy, capacity, and ancillary services markets of FERC-regulated ISOs and RTOs.

At the state level, ESSs are more likely to be developed and adopted in those states that provide regulatory support for ES. Over the last couple of years, examples have emerged suggesting that states are starting to take action to eliminate the use of existing fossil fuel peaker plants and/or prevent the construction of new fossil fuel peaker plants. Regulatory activity in states such as California, Minnesota, and New York provide the examples to support how ESSs are being selected over traditional peaker plants. Other regulatory initiatives that may appear at first review to be distinct from policy discussions specific to peaker plants may still have indirect impact on peaker plant replacement.

Policy topics that can by extension impact the future of peaker plants include the following:

Related Policy	Associated Impacts on Peaker Plants
Policies primarily intended to enable or incentivize the development of ESSs	To the extent that ES is positioned to serve an ever-greater role in grid management, there is an opportunity to replace existing or new peaker plants with ESSs. State level policies that stimulate the development of ES through financial incentives create favorable market environments that support a significant growth of ES technologies. These technologies, including both in front of the meter (FTM) and behind the meter (BTM) ES applications, can be used for grid management purposes on either a localized distribution network or regional grid.
Procurement mandates for ES	State level polices that require a specific amount of ES send market signals that a state is committed to developing ES solutions. These ES solutions can be positioned to meet multiple industry needs, including the replacement of peaker plants (existing or not yet built) with ESSs.
Resource adequacy policies	Resource adequacy (RA) is a regulatory concept that shapes the creation of rules governing grid planning at both the federal and individual state levels and are germane to wholesale and retail markets, respectively. RA planning includes the determination of load requirements and planning reserve margins (PRMs) that a region must have in place to ensure reliability. RA policies create opportunities for ESSs to help utilities and grid operators fulfil load requirements and accommodate PRMs. Moreover, ES can help meet RA requirements to ensure system reliability during system peaks by charging during off-peak times and discharging during peak times.
Creation of Clean Peak Programs	At its core, a Clean Peak Program (also referred to as a Clean Peak Standard) can be established at the state level to incentivize better utilization of clean energy technologies to supply power when electricity demand is at its peak (for instance, during high demand timeframes in the summer and winter). Thus, there is a direct correlation between the establishment of a Clean Peak Program and the opportunities for ESSs to be used as an alternative to peaker plants. At this time, only Massachusetts has enacted a Clean Peak Program, but other states are evaluating the concept.
Duration requirements for ESSs	Efforts to create duration requirements for ESSs through policymaking is relevant to peak load shifting and peak management at both the state and federal levels. At the state level, California provides an example of state regulators calling for long duration energy storage. At the federal level, the PJM market employs a “10-hour rule” for duration-limited resources in the capacity market. Under this rule, a resource's “capability” for the purposes of the capacity market is calculated by the power output it can provide for 10 continuous hours. Longer-duration requirements placed on ESSs also position ESSs to be a more reliable alternative to replace peaker plants.

FERC Order 841	Issued in 2018, FERC Order 841 seeks to create a level playing field for ES in regional energy, capacity, and ancillary markets at the RTO/ISO level. Each of the RTOs/ISOs regulated by FERC must obtain approval for revisions to existing tariffs, with the revisions intended to remove barriers for ES participation in these markets. This federal policy initiative has a tangential impact on using ES to replace peaker plants due to the enhanced prominence that ES will play in these markets as a result of the policy.
FERC Order 2222	FERC Order 2222, released in September 2020, further removes barriers against the participation of distributed energy resources (DERs) in RTO/ISO markets for electric energy, capacity, and ancillary services. Order 2222 can be seen as an extension of Order 841, as it carves out new policies specific to the “aggregations of DERs,” a term that is defined as combined groups of small independent DERs participating in the RTO/ISO markets as a single resource represented by their aggregators. FERC Order 2222, to the extent that it expands the scope for aggregated DERs, including aggregated ESSs, create greater opportunities for ES to be considered as a replacement for peaker plants.

Activity within specific states, whether they providing explicit policy on peaker plants or related issues, or the approval of utility proposals related to how peaker plants will be used, are all shaping the ES market landscape. In other words, all the different approaches that states have taken play a significant role in shaping the future of peaker plants.

Arizona

Arizona has 17 natural gas- and oil-fired peaker plants and units at larger plants. Arizona is an example of a state in which utilities are taking it upon themselves to meet peak demand through renewables and ES. For example, Arizona Public Service (APS) has signed a contract with FirstSolar, which has been approved by the Arizona Corporation Commission. Under the contract, FirstSolar will build, own, and operate 65 MW of solar power to energize a 50 MW bank of lithium-ion batteries to provide energy to the utility during peak demand time of 3:00-8:00 p.m. The batteries have a nameplate capacity of 135 MWh and will be capable of delivering energy for at least three hours. APS signed a 15-year power-purchase agreement with FirstSolar for power from the array. The concept of a clean peak standard, as has been adopted in Massachusetts, has also been raised in Arizona.

California

Across California, nearly 80 natural-gas-fired peaker plants are used to help meet statewide peak electric demand. These plants include 65 combustion turbines designed to ramp quickly and over ten aging steam and combined cycle turbines (now used infrequently). California has enacted numerous policies and incentives that could both directly and indirectly facilitate the replacement of peakers with solar and storage. Key initiatives include but are not limited to:

- A procurement mandate of 1,825 MW of ES, 500 MW of which must be from behind the meter (BTM) applications.
- State regulations stipulate that ESSs with four hours of continuous discharge capability are eligible to meet the state’s resource adequacy requirements.
- The California Public Utilities Commission (CPUC) adopted a Proposed Decision in March 2020 that identified a specific, state-wide need for 1GW of long-duration energy storage by 2026.

- PG&E has received approval for 300 MW of ES to replace three natural gas peaker plants. This approval reflects the most significant example to date of batteries replacing fossil fuel generation on the power grid anywhere in the United States. As with any approved infrastructure investment, PG&E is allowed to recover the costs of the batteries from ratepayers through regulated rates.
- Southern California Edison, at the behest of regulators, halted a new gas peaker slated to be built in Oxnard, CA, and ordered a suite of batteries in its place.

Massachusetts

Across Massachusetts, 23 oil- and natural gas-fired peaker plants and peaking units at larger plants help meet statewide peak electric demand. Two-thirds of Massachusetts peaker plants burn primarily oil, and more than 90 percent are over 30 years old. Massachusetts has enacted a suite of policy targets to support clean energy adoption and GHG reductions that could facilitate replacement of peaker plants with solar and storage and other clean resources. Key policy initiatives include:

- A procurement mandate of 1,000 MW of ES by 2025.
- A renewable portfolio standard that requires 35 percent of electricity from renewable resources, including a solar carve-out, by 2030.
- Through legislation, Massachusetts has established Clean Peak Standard. The law requires every retail electric supplier to provide a minimum percentage of kilowatt-hours sales to end-use customers from clean peak resources.
- The Northeast Massachusetts/Boston (NEMA) and Southeastern Massachusetts (SEMA) load zones are import-constrained, meaning that local deployment of clean resources such as solar and storage may also be required to replace local peaker plants in these regions.
- Federal regulation is also influencing the future of peaker plants in Massachusetts because the state is operated by the New England Independent System Operator (ISO-NE), which determines local requirements for power capacity on the grid.

Minnesota

Minnesota has been one of the more recent states to consider grid-scale ESSs as a possible alternative to natural-gas peaker plants. The new state law requires that regulated utilities in the state either include ES as part of their integrated resource plans (IRPs) or prove that ES cannot meet customer demand in a more cost-effective or operationally beneficial manner The legislative provision was included as part of an omnibus ES legislation that codifies a level playing field for ES against natural-gas plants and other resources. Accordingly, utilities that submit long-term resource plans are now required to acknowledge the capabilities storage can provide when compared against fossil fuel resources, including existing or new peaker plants. Presently, Minnesota does not have an ES procurement mandate or financial incentives for end-use residential or commercial customers.

Looking further at Minnesota, it is noteworthy how state-specific policy can drive the actions of regulated utilities that operate in multiple states. Consider Xcel Energy, which operates in both Minnesota and Colorado. In Minnesota, the new law requires consideration of ES in long-range plans, but at this point Xcel Energy does not have any announced plans for ES applications in Minnesota (a proposal submitted several years ago was rejected by the Minnesota PUC). However, in Colorado, regulators have encouraged the adoption of clean energy technologies (and allow for cost recovery of investments in such technologies), and so Xcel Energy has been the first to present an IRP in the state that includes ES. Xcel's Colorado-specific plan calls for a reduction by 2030 and zero-carbon electricity production by 2050. Xcel clearly sees storage playing a more integral role in the future as costs come down and technologies advance.

Nevada

In Nevada, five natural-gas-fired peaker units located at four power plants are used to help meet state peak electricity demand. These plants include one stand-alone gas turbine peaker plant and four units co-located with natural gas combined cycle facilities but used for peak capacity. Policies within Nevada that could facilitate the replacement of peakers with solar and storage include the following:

- A renewable portfolio standard requiring that 50 percent of electricity come from renewable resources by 2030.
- A carbon reduction policy that requires a reduction in green-house gas emissions to 45 percent below 2005 levels.
- The Public Utilities Commission of Nevada has also drafted a proposal for 1,000 MW of energy storage by 2030, which could help reduce reliance on peaker plants while integrating solar and other renewable resources.

New Jersey

Across New Jersey, 15 natural-gas- and oil-fired peaker plants and peaking units at larger plants help meet statewide peak electric demand. These facilities are primarily reliant on combustion turbines designed to ramp up quickly and meet peak demand. One-third of New Jersey peaker plants primarily burn oil, and two-thirds are over 40 years old.

New Jersey has adopted policies that, in the long-term, can be viewed as enabling the potential replacement of the state's 15 peaker plants with ES. These policies include:

- A procurement mandate calling for 2,000 MW of ES by 2030 with an intermediary 2021.
- An RPS that calls for 50 percent of electricity from renewable resources, including a solar carve-out and offshore wind targets.
- A carbon reduction strategy that calls for an 80 percent reduction in GHG emissions below 2006 levels by 2050.

New Mexico

New Mexico has 11 natural gas- and oil-fired peaker power plants and units that are used to help meet statewide peak electricity demand. New Mexico, however, still has significant coal generation on the electric grid, and regulations may be required to ensure that ESSs are not charged with coal generation and inadvertently increase grid-wide emissions. However, energy policy in New Mexico has potentially created a platform to replace a number of peaker units with clean energy alternatives through a number of initiatives that support clean energy adoption and emissions. Key initiatives include:

- Achieving a target of generating 50 percent of electricity by renewables resources by 2030.
- Achieving GHG emissions to 45 percent of 2005 levels by 2030.
- Achieving 100 percent of electricity from zero-carbon resources by 2045.

New York

New York has 49 oil- and natural gas-fired peaker power plants and peaking units at larger plants, a third of which burn oil. Of these, there are 16 operating peaker plants in New York City that fit into the New York Power Authority's market and send their energy to the city's power grid. The energy is then distributed according to demand across the city by companies like ConEdison and National Grid. New York has a suite of initiatives that support the replacement of these facilities with ES and other clean resources, many of which were outlined in the broader policy platform known as the Reforming the Energy Vision (REV) which has been evolving since 2014. The REV platform includes a number of policies that encourage distributed resources and efforts to increase grid resilience.

REV initiatives in New York that have the potential to support the replacement of peaker plants with alternative resources include:

- Establishing a new limit on emissions of nitrogen oxides from peaker plants by 2025.
- Deployment of 6 GW of distributed solar and 1,500 MW of ES by 2025.
- Deployment of a 3,000 MW ES by 2030.
- Achieving a target of 70 percent of electricity sourced from renewable resources.
- Achieving full carbon neutrality and GHG reductions of 85 percent below 1990 levels by 2050.

Further, New York's 2019 Climate and Community Protection Act sets the state on a path toward carbon neutrality by 2050 and includes provisions prioritizing the replacement of peaker plants with renewable energy and ES. Additionally, policymaking specific to the state of New York has included market rules set by the New York ISO (regulated by FERC) that allows ESSs with minimum durations of four hours to participate in the ISO's capacity market.

COST & DURATION ARE KEY CONSIDERATIONS

While it may be obvious to some market participants, it is important to acknowledge that not every form of ES will be capable of meeting peak demand. Energy can be stored using electrical, mechanical, thermal, and chemical storage systems. All of these have their own benefits and appropriate application options. Battery ESSs are the most common type of mechanical ES largely because of the flexibility, including fast response times and ability to control size and other operational factors specific to the need.

Until recently, lead-acid batteries have been the preferred choice for BESSs, but lithium-ion batteries are becoming more prominent. In contrast to lead-acid batteries, lithium-ion batteries provide increased energy density, efficiency, and have more than double the life span of a typical lead-acid system, averaging 5,000 cycles of operation. According to a report issued by the Rocky Mountain Institute[3], the cost of lithium-ion batteries has dropped about 90 percent. Prices that had been as high as $1,000 a kilowatt-hour (kWh) are now sub $200/kWh and falling[4]. The report projects that in order for a battery-based ESS to compete on price with a natural-gas peaker plant, ES costs would need to fall to the range of $5/kWh[5]. However, that projection is only for scenarios in which solar and/or wind can meet power demand 100 percent of the time. If other sources meet demand just five percent of the time, storage could work at a price of $150/kWh, according to the report.[6]

Along with price considerations, there are fundamental operational considerations that will impact, either positively or negatively, the prospects for using ES as an alternative to meet peak demand. The size of an ESS is typically measured in both power and energy. Power measured in megawatts (MW) or kilowatts (kW), is a rate measure reflecting how much energy can be provided in a second. Power plant capacity is typically given in MW: a small peaker plant might be 25 MW while a large nuclear power plant could be 1,000 MW. The energy stored reflects how much time a battery could continue to discharge at the rated power, and is often given in megawatt-hours. Discharge capability is related to the energy stored within the ESS and is measured by time, typically the number of hours that the ESS can be operated to provide services to the grid (a four-

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[3] Rocky Mountain Institute. "The Economics of Clean Energy Portfolios." Dyson, Mark; Engel, Alexander; Farbes, Jamil. 2018.

[4] Rocky Mountain Institute.

[5] Rocky Mountain Institute.

[6] Rocky Mountain Institute.

hour duration is viewed as a baseline requirement, although some markets are developing requirements for longer durations. We are seeing this in the PJM market and in California.)

Duration considerations have a direct impact on utility and grid planning exercises. For instance, in planning studies conducted by Xcel Energy, it was determined that based on current technology, Xcel concludes that storage is not the answer to intermittency in a grid that relies more heavily on renewable energy. "The current state of battery storage technology does not have the ability to match the duration of such events without significant (and very expensive) over-build of those resources," the report stated.[7] This analysis was based on a standard four-hour duration of a battery-based ESS. As deployment of ES increases, the peaking events it serves become longer and ESSs may be called upon to serve a longer demand curve, thereby reducing an ESS's ability to act as a peaking resource. ES developers are actively striving to achieve longer durations of battery-based ESSs, so that six- or eight-hour storage durations (or a longer-term goal of 10-hour durations) can compete against conventional peaking plants.

Accordingly, utilities and grid planners are taking steps to understand the shape of their peak needs and assemble a portfolio of resources that can provide a range of durations. This process is generally referred to as "peak planning," and it is in many cases driving decisions to install an ESS that can be charged when demand is low and discharged when demand cannot be met by the primary generation source. The process of using an ESS in this manner supports deferrals of T&D upgrades that would be significantly more costly.

Moreover, the ability of ESSs to provide peaking capacity will likely become an increasingly important service the ES provides to the E&U industry. Enabling policies developed at the state and federal levels can further support the use of ESSs within peak management approaches in both retail and wholesale transactions. The absence of enabling policies at either the state or federal level can (or inevitably will) become a barrier to using ESSs in peak management strategies.

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[7] Xcel Energy, "Upper Midwest Integrated Resource Plan 2020-2034."