NCSL ENERGY SUPPLY TASK FORCE

# Energy Storage for a Modern Electric Grid

## Technology Trends and State Policy Options

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# Energy Storage for a Modern Electric Grid: Technology Trends and State Policy Options

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# Introduction

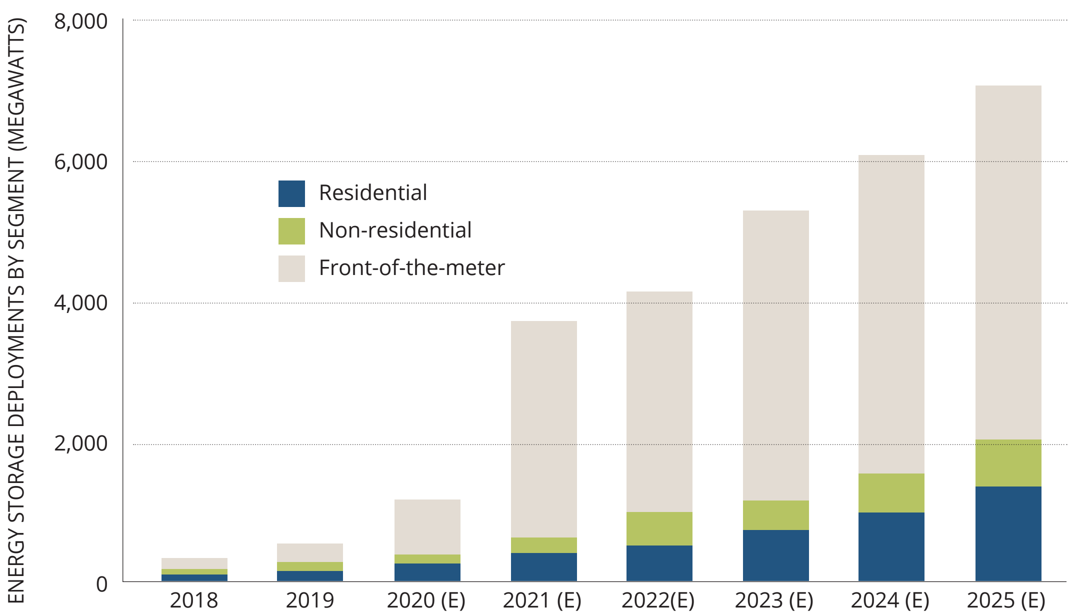
A significant transformation of the electric grid is currently underway, driven by the rapid growth of new energy technologies providing consumers and utilities with an increasing number of options for generating, using and managing energy. The grid is transitioning from a more static system with centralized electricity generation and management operations to one that is more dynamic and adaptable, where consumers also play a role in managing generation and consumption to help balance the grid.

One game-changing technology that is part of this transformation is energy storage, which allows utilities, utility customers and third parties to store or release electricity on demand. Energy storage includes an array of technologies, such as electrochemical batteries, pumped storage hydropower, compressed air and thermal storage. Storage technologies can help meet peak demand when power prices are high, provide backup power during power outages, or help the grid adapt to sudden power generation fluctuations caused by changes in renewable energy production or a traditional power plant outage.

Energy storage provides utilities, grid operators and consumers with an array of new options for managing energy, promising to increase the reliability and stability of the grid, defer capacity and transmission upgrades and help with the integration of renewable resources.

One attribute that makes energy storage unique is its scalability. It can be implemented as a large utility-scale project to help meet peak energy demand and stabilize the grid, or as a small system sited in a residence or commercial facility to manage electricity costs and provide backup power. Figure 1 displays the projected annual amount of U.S. installations for utility scale and "behind the meter" storage, which is expected to top 7,000 megawatts (MW) by 2025-the amount of power generated by more than eight average sized natural gas power plants.

## Fig. 1: Recent and Estimated (E) Annual Installation Rates for Energy Storage




*Source: Wood Mackenzie and the Energy Storage Association, 2020*

Since 2015, no electric resource increased its role in the U.S. electric grid as rapidly as energy storage. At the end of 2020, there was 10 times more battery energy storage than there was in 2014. Falling costs, regulatory changes, and state policies are expected to propel a rapid expansion of utility-scale installations over the next five years, to about 5,000 MW per year. While these numbers capture only large utility-scale storage systems that are directly connected to the electric grid, customer-sited "behind-the-meter" energy storage investments—such as a residential battery pack to complement rooftop solar—are also beginning to accelerate and are expected to account for almost 30 percent of annual energy storage investments within the next few years.

The many ways in which energy storage can benefit the grid and consumers create both opportunities and challenges for state policymakers. Energy storage can increase resiliency, provide backup power during power outages, stabilize the grid, lower the cost of meeting peak power demand, increase the value of wind and solar installations, reduce transmission infrastructure costs, and provide numerous other benefits. Since energy storage is a relatively new and unique technology that does not readily lend itself to established regulatory regimes, many states will need to make changes to their regulations to take advantage of the many services that storage can provide.

State legislatures have an important role to play in creating state policies that remove barriers to adoption and encourage investment in storage technologies. This primer is designed to assist state lawmakers in understanding how energy storage technologies work, the benefits that storage can deliver to the electric grid, the current legal and regulatory barriers to adoption, and policy options for addressing those obstacles.

# Electric Grid Basics

Traditionally, electricity had to be used as it was produced. It could not be stored in significant amounts and grid infrastructure and operations evolved to ensure that electricity generation could be increased or decreased at a moment's notice to exactly match changes in demand. Grid operators, who ensure that electricity supply matches demand, must have resources ready to respond as the need for electricity varies throughout the day and year. If supply is higher or lower than demand for too long, portions of the grid can shut down, creating a blackout. Maintaining this balance is critical and the grid has been designed around this need to quickly match momentary, daily and seasonal fluctuations in demand.

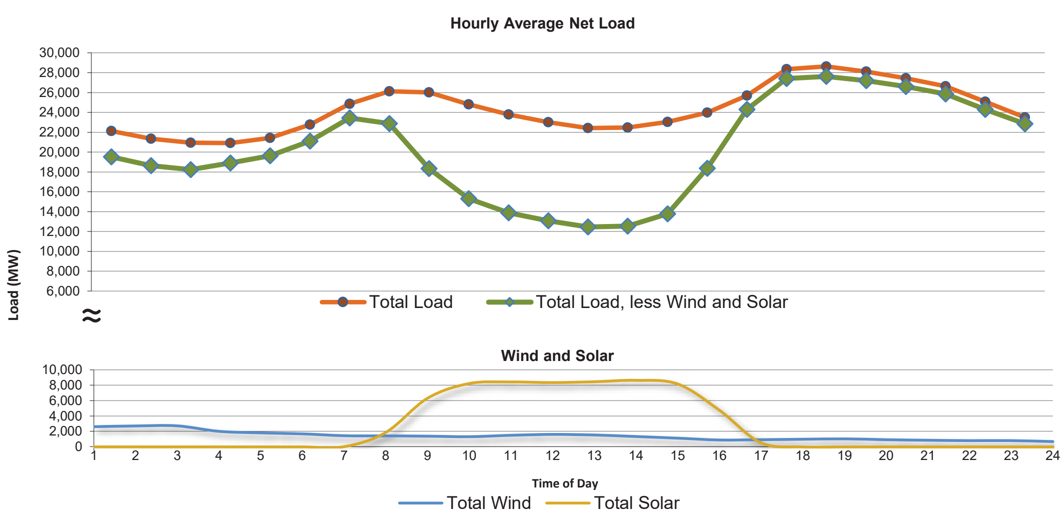
Electricity demand fluctuates widely on a daily and seasonal basis, with more electricity being used on a hot summer day than during a comfortable spring evening. This variation has significant impacts on electricity prices and how the grid is planned for and built. Transmission, distribution and generation infrastructure is built to meet peak system needs, which may occur for only a few hours a year. This may not be the most efficient approach to meeting needs since customers are paying for infrastructure that remains unused for most of the year. Because generators are typically deployed in order of their operating cost, the most expensive generators are used during periods of highest demand, meaning that electricity prices are significantly higher during periods of peak consumption. Other technologies and approaches, such as storage and demand response, in some cases can meet grid needs more cost-effectively than transmission and generation upgrades, especially during high-cost peak load periods.

To ensure the availability of power, system operators use weather and historical consumption trends to forecast demand. They use this data to determine which energy resources should be held in reserve, ready to increase or decrease electricity production at a moment's notice. These "dispatchable" energy sources have tended to be natural gas or hydropower. Flexible, dispatchable resources are on-demand resources that can quickly respond when called upon to meet grid needs. Coal and nuclear plants typically are less flexible resources and are designed to run at full output. As a result, the grid has historically relied on more flexible resources, such as natural gas or hydropower, to meet sudden changes in demand. Energy storage and demand response add additional flexible resources to the system operator's toolkit, providing them with more options for balancing the grid.

Demand response is the ability to reduce demand for electricity in response to either economic signals or requests from grid operators or utilities. Demand response programs enable utilities to adjust a bill payer's heating, cooling or other energy services—or send signals allowing the consumer to make these adjustments—typically in exchange for monetary credits on their monthly electric bills. Demand response programs already are used across much of the country to cost-effectively meet grid needs and help balance supply and demand.

The rapid growth of wind and solar is also influencing how the grid is balanced since the electricity output of these resources varies based on weather, the time of day and the time of year, requiring more flexibility from the grid. Figure 2 provides the power generation and consumption information for a recent day in California, illustrating the "duck curve" shape that can result when solar makes up a larger portion of the energy mix. The red line shows how electric demand, also called "load," changes during the day. Subtracting wind and solar production from total electric demand produces the green "Net Load" line, which is what grid operators look at when balancing the grid.

## Fig. 2: CAISO Net Load for Friday, Dec. 18, 2020



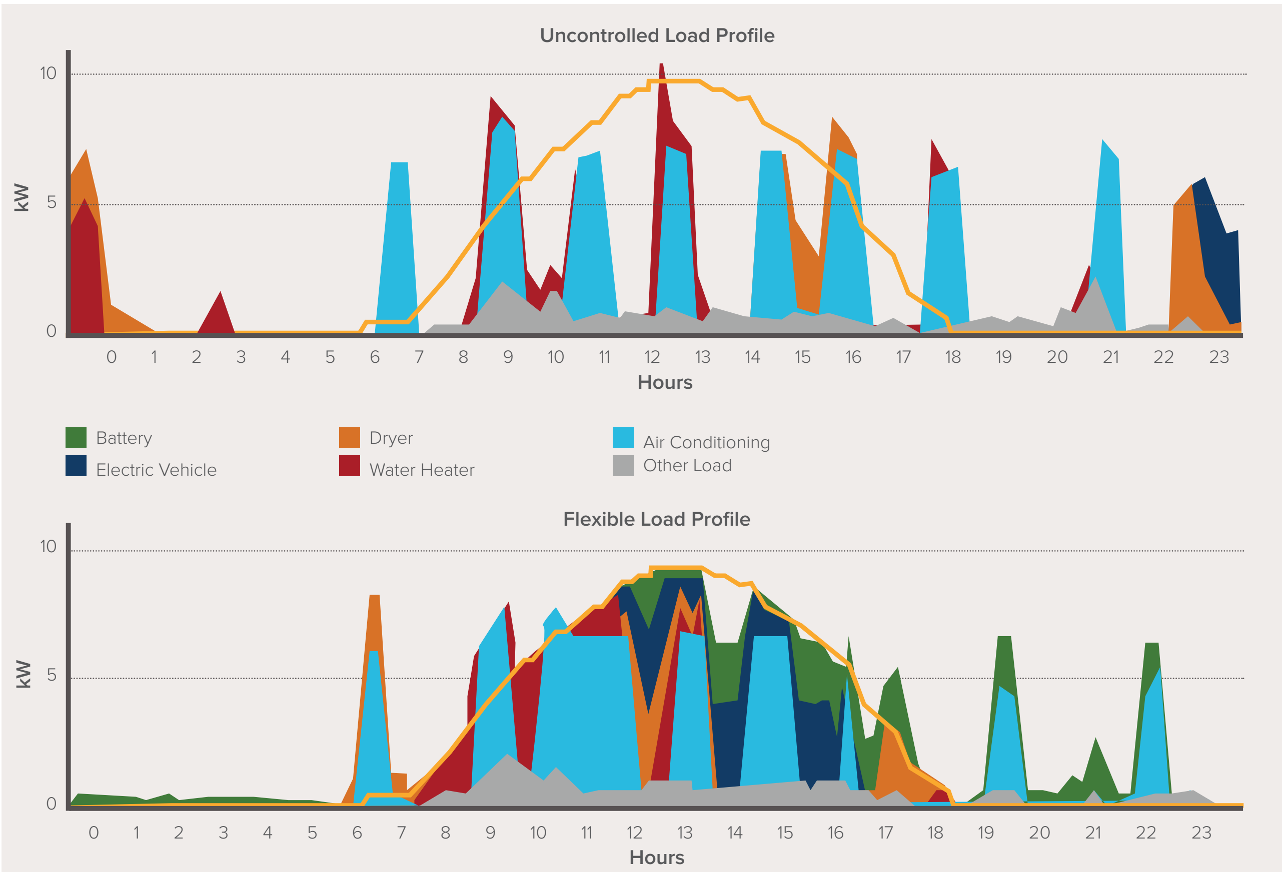

*Source: http://content.caiso.com/green/renewrpt/20201218_DailyRenewablesWatch.pdf*

While less conventional generation is needed to meet the net load, higher amounts of renewables in the mix may create larger swings—note that the morning and evening ramps on the green net load line are much steeper than those on the red load line. Previously, quickly adjusting the output of natural gas or hydropower plants was the only way to meet these rapid changes. Energy storage, along with demand response, offers grid operators a more flexible and a potentially less costly option for balancing the grid.

## Energy Storage and Demand Response Create a More Flexible Grid

The image below shows how energy consumption, with the aid of energy storage and demand response, can be shaped to help match the changing power output of solar (shown as the yellow line) throughout the day. The image illustrates how electricity demand from drying clothes, storing electricity in a battery, heating water, and cooling a building can be shifted to when cheap solar power is most abundant on the grid. Energy storage will play an increasingly important role as states reach higher levels of renewable energy generation.

## Figure 3. Flexible Versus Inflexible Load Profile




*Source: Rocky Mountain Institute (RMI) , 2018*

# Energy Storage Technology Types

Given recent commercial developments and deployments, energy storage has largely become synonymous with lithium-ion batteries. Energy storage, however, includes many different technologies, each with unique capabilities and limitations.

Unlike a power plant, which can continue providing electricity as long as it remains connected to its fuel source, energy storage can provide electricity for only a limited amount of time before it needs to be recharged. Energy storage systems are given an energy rating, expressed in kilowatt-hours (kWh) or megawatt-hours (MWh) to indicate how much energy the system can hold. Energy storage systems also have a power rating indicating the maximum amount of electricity they can provide at a point in time, expressed in kilowatts (kW) or megawatts (MW). For example, a 100 MW, 400 MWh system could either supply

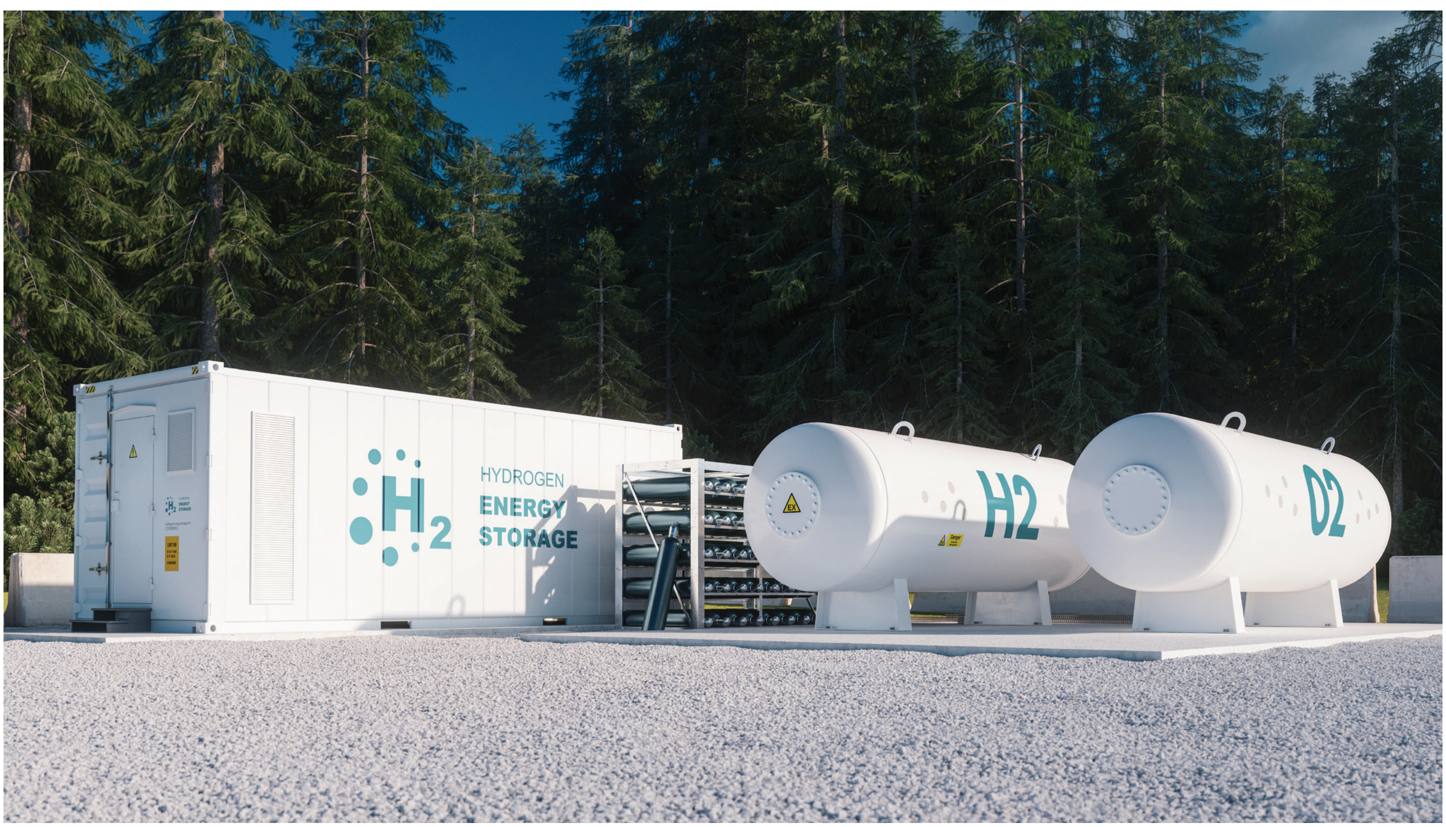
100MW of power to the grid for 4 hours, or 50MW of power to the grid for 8 hours.

There are five major types of energy storage:

- **Potential:** Energy is stored as potential energy, such as water behind an impoundment or compressed air in an underground cavern.
- **Mechanical:** Energy is stored as potential kinetic (physical) energy, such as in a spinning flywheel, which is then used to generate electricity.
- **Electrochemical:** Energy is stored in chemical reactions, which can be reversed to release the stored energy.
- **Thermal:** Energy is stored as heat or cold, which is then used to offset future electrical needs or to generate electricity.
- **Power to Gas:** Energy is used to create a gas, usually hydrogen, that can then be used as fuel to generate electricity.

Because of their unique nature, the capabilities of energy storage technologies are measured in different ways than generation assets. The most commonly used forms of energy storage are summarized below. These summaries describe each technology in these key terms:

- Duration—how long it can provide energy before needing to be recharged.
- Cycle life—how many charge/discharge cycles it can provide.
- Round-trip efficiency—how much of the energy used to charge the device will be returned to the grid when it is discharged.
- Response time—how quickly it can produce electricity.
- Summaries also include the grid applications and the key limitation of each technology.



| | Description | Key Characteristics | Applications | Response Time | Limitations |
|---|---|---|---|---|---|
| ELECTROCHEMICAL | **Lithium Ion Batteries**<br>Small cells aggregated in to projects of various sizes | • Duration: 30 minutes - 4 hours<br>• Cycle life: 3,500<br>• Round-trip efficiency: 85%<br>• Highly flexible | • Capacity<br>• Ancillary Services<br>• Customer | Fast | Flammability, recyclability |
| ELECTROCHEMICAL | **Flow Batteries**<br>Negatively and positively charged electrolytes are circulated around a membrane to generate an electric current | • Duration: 4-8 hours<br>• Cycle life: 10,000<br>• Round-trip efficiency: 70%<br>• Highly flexible | • Capacity<br>• Ancillary Services<br>• Customer | Fast | Limited experience, mechanical challenges |
| ELECTROCHEMICAL | **Sodium Batteries**<br>Use molton or solid sodium technology | • Duration: 15 minutes<br>• Cycle life: 200,000<br>• Round-trip efficiency: 85%<br>• Highly flexible | • Capacity<br>• Ancillary Services | Fast | High operating temperature |
| ELECTROCHEMICAL | **Power to Gas**<br>An electrolyzer uses an electric current to separate the hydrogen from water and capture it as a fuel that can be used in a fuel cell or burned for electric generation. Because electrolyzers can be turned on or off on demand, they can be flexible grid assets. | • Duration: N/A<br>• Cycle life: N/A<br>• Round-trip efficiency: 35% (National Renewable Energy Laboratory)<br>• Highly flexible (elecyrolyzer)<br>• Moderately flexible (hydrogen fuel) | Electrolyzer:<br>• Demand response<br>• Frequency regulation<br>Hydrogen Fuel:<br>• Capacity<br>• Spin/non-spin reserve | Moderate to fast | Lack of delivery infrastructure for hydrogen, very low round-trip efficiency |
| THERMAL | **Ice Thermal Storage Electricity**<br>Used to freeze water, which can later be used to offset air condtioning needs | • Duration: 4 - 6 hours<br>• Can shift up to 95% of HVAC loads to off-peak times | • Demand Response | N/A | Does not return electricity to the grid |
| THERMAL | **Concentrating Solar Mirrors**<br>Directs sunlight at at tour or pipe where a molten salt traps the heat and used it to power a turbine | • Duration: 6 - 12 hours<br>• Round-trip efficiency: 85%<br>• Moderate flexibility | • Capacity<br>• Spinning/ non-spinning reserve | Moderate | Geographic constraints |
| MECHANICAL | **Pumped Storage Hydro**<br>Water is pumped uphill and stored, then released to run back down and power a turbine | • Duration: 8+ hours<br>• Cycle life: 15,000<br>• Round-trip efficiency: 80%<br>• Limited flexibility | • Capacity<br>• Spinning/ non-spinning reserve | Slow-responding Next-generation technologies may achieve moderate response | Geographic constraints |
| MECHANICAL | **Compressed Air**<br>Air is compressed in enclosed space, then the pressurized air is released as need to power a turbine | • Duration: 8+ hours<br>• Cycle life: 10,000<br>• Round-trip efficiency: 50%<br>• Limited flexibility | • Capacity<br>• Spinning/ non-spinning reserve | Slow to moderate | Geographic constraints |
| MECHANICAL | **Flywheels**<br>Energy is stored by spinning a large rotating flywheel/cylinder, a generator attached to the cylinder can convert the rotational energy to electricity as needed | • Duration: 15 minutes<br>• Cycle life: 200,000<br>• Round-trip efficiency: 85%<br>• Highly flexible | • Frequency regulation<br>• Frequency response | Fast | Short duration |

## Benefits of Energy Storage

The electric grid can be broadly divided into four segments: generation, transmission, distribution and customer (also known as "behind-the-meter"). Customers are connected to large, central electric generators by two delivery systems: a high-voltage transmission system that moves large quantities of electricity across long distances, and a low-voltage distribution system that delivers electricity to customers. Energy storage technologies provide several benefits across all four segments:

- At the **generation level**, storage can shift energy produced during low-demand periods to high-demand periods, lowering generation costs and increasing system reliability.
- When deployed at the **transmission** and **distribution levels**, storage can improve reliability by managing power flows or can be sited to reduce congestion on powerlines, deferring or displacing costly system upgrades.
- At the **customer level** energy storage can be deployed on-site to manage their energy costs and provide backup power.

Two primary benefits of energy storage are:

- **Flexibility**: Many energy storage technologies can switch between charging or discharging on a moment's notice and can instantaneously alter input or output based on grid needs, which enables them to provide a wide range of services.
- **Scalability**: Many energy storage technologies are modular in nature, meaning that they can be scaled up to meet the needs of many customers at once or scaled down to support the needs of a single customer.

## Is Energy Storage Clean?

Energy storage is often touted as a clean energy resource. The emissions reduction achieved, however, depends on how the stored electricity was generated. If a storage facility is charged with electricity from renewable resources, then its output is equally clean and emissions-free. When charged with electricity generated from fossil fuel power plants, its output will actually be higher in emissions than the electricity coming directly from the fossil fuel plant. This is due to the energy that is lost when electricity is stored and then discharged. Battery and pumped storage, for example, return about 80 percent of the energy that is initially stored in them. This means that emissions can increase if too much of the stored energy is created by fossil fuels. Since the mix of energy resources on the grid varies by the time of day, the timing of electricity storage and discharge can affect the clean energy benefits of storage. This is a concern for states that are trying to harness clean energy and storage to meet greenhouse gas reduction goals.

The California Public Utilities Commission (CPUC) found, through a storage impact evaluation released in 2018, that some storage projects were increasing emissions. To address this issue, the CPUC changed storage policy incentives to be more reliant on annual emissions reductions. They also developed a platform that provides real-time grid-emissions data to help customers better manage energy storage and other distributed resources. Since battery owners optimize use for financial return, not emissions reductions, sending market price signals that increase financial returns for charging when the grid emissions profile is cleaner can be effective for keeping storage emissions low. The Massachusetts Clean Peak Standard, highlighted in the policy section below, is another approach that is being considered.

# Barriers to Energy Storage Deployment

Historically, the complex processes by which the U.S. electric grid is planned and operated are geared toward large, centralized generators that can be controlled, but are generally not very flexible. The ways electricity is produced and used, however, are changing, creating a greater need for flexible resources like energy storage. But the ways in which we plan and operate the grid do not recognize the value of those resources nor compensate them for the services they provide.

Energy storage technologies possess a unique combination of flexibility and scalability. While this combination enables storage to provide a wide range of valuable grid services, it also means that the technologies do not naturally fit within traditional regulatory structures, which were developed in an era marked by large, centralized and dispatchable generators serving predictable customer loads through a one-way delivery system.

Valuing energy storage assets is a challenging endeavor. Benefits vary by location and depend on factors like energy market structure, generation mix, utility rates, and transmission and distribution infrastructure.

## SYSTEM RESOURCE PLANNING

While some regions of the U.S. select generation resources through competitive market processes, many states rely on integrated resource plans (IRPs), which utilities prepare to identify the future demand of their customers and the portfolio of grid investments that is most cost-effective in meeting that demand. The objective of the plan is to identify future energy demand and then build a portfolio of resources that will always meet the demand.

To make the complex task of forecasting and meeting demand a manageable process, IRPs often make three assumptions that reduce their ability to identify the value of energy storage technologies:

1. Planners look at the system on an hourly basis—treating customer demand as fixed for that hour despite customer and grid needs being much more variable. The hourly IRP model does not value flexible energy storage resources, which can rapidly respond to the variation that renewable generation and changing customer use patterns introduce into the system.

2. Rather than consider other resources that can support and stabilize the grid, such as energy storage, IRPs tend to focus on keeping a reserve margin of generation to meet grid needs.

3. Finally, IRPs tend to focus on generation only, basically setting aside the transmission and distribution systems that play a large role in balancing the grid.

Since state legislatures created utility integrated resource planning requirements, they have often updated requirements to incorporate new technologies and policy goals. State actions to include storage in the planning process are explored in the legislative action section.

## TRANSMISSION PLANNING

Federal regulations require any utility that owns an interstate transmission system to conduct a transparent planning process to identify transmission system upgrades, and to then participate in a regional transmission planning process to identify opportunities for projects of regional significance. In setting these requirements, federal regulators also directed transmission planners to consider non-transmission alternatives, such as demand response and energy storage, when evaluating their options for meeting an identified system need. FERC's directive for transmission planners to analyze energy storage alternatives, however, only applies when a stakeholder requests the analysis. The lack of clear guidelines for how and when such alternatives should be proposed and analyzed appears to be a limiting factor.

Energy storage is a unique technology that does not naturally fit within the transmission planning process. The U.S. Congress first identified energy storage as a potential transmission solution in the Energy Policy Act of 2005 and FERC's orders on transmission planning in 2007 and 2011 reinforced this approach. Nonetheless, it was not until 2018 that a regional system plan (from the California Independent System Operator, or CAISO) conducted a detailed study of energy storage for transmission purposes and ended up selecting energy storage as the alternative.

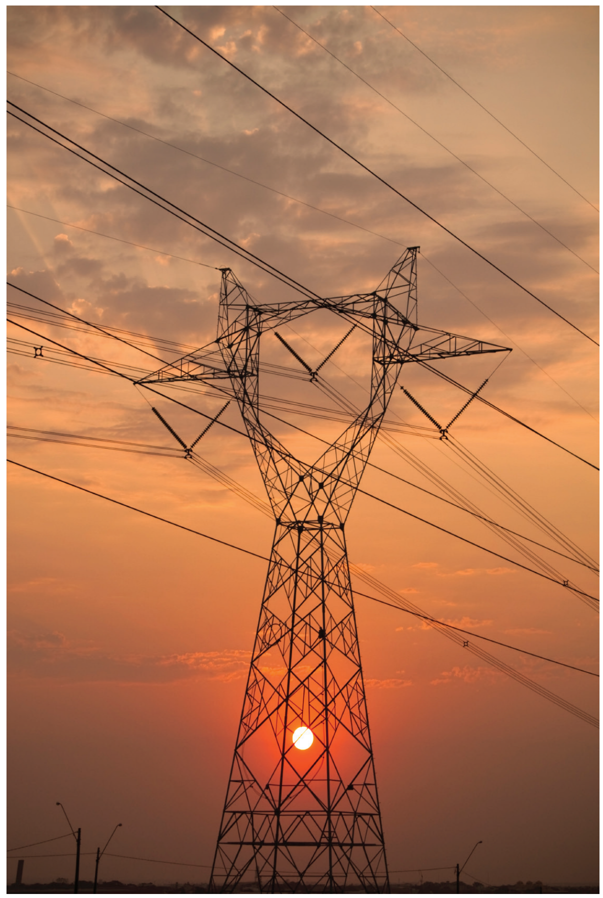
## DISTRIBUTION SYSTEM PLANNING

With the rapid expansion of distributed energy resources (DERs), more states are requiring utilities to engage in integrated distribution system planning, which directs them to assess physical and operational challenges in the distribution system and prepare it for anticipated growth of distributed energy resources and other grid technologies. These efforts require utilities to look at the challenges facing specific sections of their systems caused by load growth, increased penetration of DERs and aging infrastructure. Integrated distribution system planning is intended to be transparent to policymakers and the public.

To promote this process, DOE has supported a joint effort between the National Association of Regulatory Utility Commissioners (NARUC) and the National Association of State Energy Officials (NASEO) to create a forum for states to develop new approaches for utility system and resource planning. The NARUC-NASEO Comprehensive Electricity Planning Task Force recently released its Blueprint for State Action, which supports states seeking to align electricity system planning processes in ways that meet their own goals and objectives. The Blueprint provides a step-by-step approach for states that are preparing for increased integration of many different types of distributed energy or are engaging in new distribution planning efforts.

## MARKET OPERATIONS

In several regions around the U.S., states have permitted the electric utilities serving their residents to join regional energy markets, which are operated by an independent operator known as an independent system operator (ISO) or regional transmission organization (RTO).



Because these market structures were designed when the grid was predominantly served by large, centrally located generators, they limit the ability of smaller, more flexible resources like energy storage, to participate. Some markets defined the resources allowed to provide certain services in ways that excluded or limited storage. For example, energy storage, because of its flexibility and ability to instantly respond to grid operator signals, can provide many grid services more efficiently than traditional generators, which require time to alter their production. Despite this, markets initially provided equal compensation for all participating resources, regardless of their performance.

Because the regional energy markets span across states, the Federal Energy Regulatory Commission has authority over their market design. In 2018, the commission issued Order 841, a sweeping order that required regional markets to update all of their market products to account for the unique capabilities of energy storage devices and properly compensate them for the services they provide. Every region's plan for complying with Order 841 has been approved, and the regions are moving forward at various speeds to implement necessary changes over the next few years.

While Order 841 laid the groundwork for utility scale energy storage, FERC Order 2222, issued in 2020, enables distributed energy resources, including energy storage located on the distribution grid or behind a customer's meter, to compete alongside traditional energy resources in regional electricity markets. The rule allows aggregators to combine several sources of DERs to satisfy minimum size and performance requirements needed for market participation. These adjustments to market operations are increasing the business case for energy storage by allowing owners to benefit from the multiple services that their storage assets can provide to the grid—such as demand response, frequency stabilization or meeting peak load. Storage owners can adjust which services they provide based on what the market is paying for these services at different times.

In many states with restructured energy markets, generation assets cannot be owned by the distribution utility. If a state classifies energy storage as a generation asset, a distribution utility will be unable to install storage regardless of its intended use. The implications of this scenario were highlighted in Texas in 2019, when AEP's request to install energy storage on the distribution system was rejected by the PUC since Texas law classifies energy storage as generation.

# State Legislative Actions Supporting Energy Storage

Across the U.S. a growing number of state lawmakers are focused on policies that support energy storage. Nearly 400 energy storage-related measures were introduced in 2019 and 2020 and of those, 77 were enacted or adopted in 27 states. This is more than triple the number of bills introduced in 2017 and 2018. Four states have enacted or adopted more than a dozen measures related to energy storage so far in 2021.

While decisions carried out by federal regulators and regional market operators have an impact on state energy storage policy, state policymakers—and state legislators in particular—are instrumental in enacting policies that remove barriers to adoption and encourage investment in storage technologies. Legislatures have taken varied approaches to accelerate adoption of energy storage, with some states enacting energy storage procurement targets and others focusing on creating programs that promote and fund developing technology.

States have also focused on removing regulatory barriers to adopting energy storage by requiring or authorizing utilities to consider energy storage in resource planning and by creating standards for connecting storage resources to the grid. Additionally, some states are focused on integrating energy storage into existing renewable energy policy and looking to encourage pairing renewables with storage.

As the energy sector in many states moves toward a cleaner and more diverse energy mix, legislatures are also considering policies that promote economic growth in advanced energy industries and provide training to equip the workforce with the skills needed to keep pace with a constantly evolving energy sector. Examples of recently enacted legislation that apply each of these policy tools follows.

## PROCUREMENT TARGETS

One major tool for increasing the deployment of energy storage technologies is setting a storage target that requires the state to procure a certain amount of energy storage, measured in megawatts (MW) or megawatt-hours (MWh), by a specific date. States have accomplished this through a combination of legislative and regulatory actions, with California being the first to enact storage target legislation in 2010.

Since then, six other states— Massachusetts, New Jersey, New York, Nevada, Oregon and Virginia—have followed suit, with New York and Virginia being two of the latest to successfully enact legislation establishing mandatory targets for energy storage. As part of New York's Climate Leadership and Community Protection Act of 2019, the legislature directed the state to create programs to achieve specific deployment targets for renewable energy and storage technologies, including 6,000 MW of solar by 2025, 3,000 MW of energy storage by 2030 and 9,000 MW of offshore wind by 2035. In 2020, Virginia also enacted comprehensive clean energy legislation that in part requires utilities to petition the State Commerce Commission for approval to acquire or construct a combined 3,100 MW of new energy storage resources by the end of 2035.

## MAKING SURE ENERGY STORAGE IS CLEAN

Storage technologies can support state clean energy policy goals when paired with clean and renewable generation. This requires carefully crafting legislation to ensure storage technologies are deployed in a way that supports clean energy resources and reduces emissions. Massachusetts enacted clean energy legislation in 2018 that created the legal framework for the nation's first clean peak standard. The program's implementing regulations require utilities to supply a certain percentage of retail electric sales with "clean peak resources" including stored renewable energy and renewables plus storage.

States have also recently considered more targeted legislation on the topic. For example, Oregon enacted HB 2618 in 2019, which directed the State Department of Energy to adopt rules for a rebate program for purchasing, constructing or installing solar energy systems and solar paired with storage. The program offers a rebate of $7,500 for homeowners installing solar paired with storage. It also allocates 25% of annual rebate funding for serving low- and moderate-income households. Maine's SB 565, enacted in 2019, authorizes the Public Utilities Commission to establish rules to encourage the procurement of distributed generation resources using "renewable fuel or technology" paired with energy storage.

### INCLUDING STORAGE IN THE PLANNING PROCESS

States are also supporting energy storage by implementing policies that encourage or require utilities to integrate energy storage into their resource planning. Virginia enacted SB 632 (2020), which amends the state's utility integrated resource planning requirements to require that utilities consider "developing a long-term plan to integrate new energy storage facilities into existing generation and distribution assets to assist with grid transformation." Colorado's SB 236, enacted in 2019, directs the state Public Utility Commission to establish rules requiring that utilities submit distribution system plans that incorporate "adoption of distributed energy resources" including "energy storage systems connected to the distribution grid" among other technologies. South Carolina's Energy Freedom Act (HB 3659), enacted in 2019, in part requires that utility integrated resource plans include resource portfolios to fairly evaluate "the range of demand-side, supply-side, storage, and other technologies and services available to meet the utility's service obligations."

Some states are also focused on encouraging utilities to invest in broader grid modernization improvements that include a role for energy storage. New Mexico's HB 233, for example, enacted in 2020, authorizes utilities to submit applications to the Public Regulation Commission for approval of grid modernization projects, including energy storage projects that support "grid stability, power quality, reliability or resiliency or provide temporary backup energy supply."

## Energy Storage and the 2021 Winter Storm In Texas

In February 2021, winter weather in Texas caused power outages that left more than 4 million homes and businesses without power for nearly a week, resulting in more than 50 deaths and widespread hardship. Could energy storage have played a role in preventing this disaster?

With widespread grid failures on this scale, energy storage would have to make up a much larger share of system capacity than it currently does to change the dynamics, although it can respond to sudden system fluctuations by providing ancillary services, like frequency and voltage regulation.

Distributed energy storage systems equipped for emergency scenarios, however, do have the potential to soften these types of hardships. These systems could help residents power critical loads, such as heaters during extreme cold or plug-in medical devices, while the power is out. Given that solar PV (photovoltaic) performed well during the winter storm, homes with rooftop solar and battery storage may have been able to recharge battery systems throughout the grid outage.

This situation highlights the limitations battery storage technologies have to address disasters. The current discharge limitations would have restricted the effectiveness of most of the newer energy storage systems during an event that lasted many days. These types of events highlight the need for storage systems with the capacity to supply power over a longer period of time. On a larger system level, if energy storage were to be positioned to support the widespread generation failures seen in Texas, it would have required not only a massive increase in storage capacity, but also storage projects with weeks-long or seasonal capacity reserves.

## RESILIENCY AND LONG-DURATION STORAGE

Several states have turned to energy storage not only to complement clean energy policies, but also to protect residents and critical services during disasters. Some of the most destructive natural disasters in our nation's history have occurred in recent years—from hurricanes in the Gulf and flooding in the Midwest to wildfires in the West. Many of the states affected by such events have looked for ways to mitigate the destruction of future disasters by making electric service more resilient, and energy storage has increasingly played a role in policymakers' considerations. In some cases, resiliency measures focus on energy storage specifically or on backup power and microgrids more broadly—with energy storage as one of several potential tools.

In California, lawmakers enacted AB 1144 in 2019, which requires state regulators to allocate a certain percentage of the state's Self-Generation Incentive Program to community storage pilot projects focused on districts at high risk of wildfires. That same year, California enacted SB 167, which requires electric companies to identify ways to mitigate the impacts of de-energization events—when utilities shut off power to portions of the grid to avoid sparking a fire during periods of elevated fire risk. The bill authorizes financial assistance for customers who use medical equipment that requires electricity, to assist in acquiring adequate backup power resources. Similarly, Virginia and Puerto Rico enacted legislation requiring certain places—such as assisted living facilities and daycare centers—to have sufficient backup power on-site for use during power outages. Virginia also enacted SB 350, which established the Emergency Shelters Upgrade Assistance Grant Fund to provide matching grants to localities to upgrade backup energy systems at emergency shelters. Hawaii considered HB 1583 (2019) that would have authorized the state Department of Education to evaluate renewable-powered backup energy systems at its schools, which serve as emergency shelters.

Most lithium-based technologies are limited to around four-hour discharges. Entities often opt to deploy backup diesel or natural gas generators because backup generation resources typically must be serviceable for up to three days. To address the current shortcomings of storage technologies, some states have sought to incentivize competing technologies with different technical characteristics, such as long-duration pumped hydro facilities. Oregon adopted SCR 1 in 2019, declaring the legislature's support for pumped storage projects that offer longer-duration discharge, and California has considered at least four bills—Assembly Bill 1720 (2019), Assembly Bill 2255 (2020), SB 597 (2019) and SB 772 (2019)—seeking to establish incentives for long-duration storage. Most recently, California Assembly Bill 64 (pending 2021) "would require the the development of 5 gigawatts (GW) of "clean, long-term backup electricity" by 2031, and an additional 5 GW of long-term backup power each of the following years through 2045. In order to leave the target open to new storage and technological developments, the legislation only defines this type of resource as being able to "deliver electricity for weeks at a time.

Some states are continuing to evaluate pumped storage hydropower as an effective source of long duration storage. For example, Washington enacted HB 2819 (2020), which designates pumped storage projects be located in a county near the Columbia River for expedited permit processing. Garnering support for pumped-storage hydropower, however, can be challenging given the potential negative environmental impacts associated with such projects.

## INTERCONNECTION

To create a regulatory environment that supports energy storage as a distributed energy resource, legislatures have also focused on interconnection requirements and ensuring that distributed resources can connect to the grid in a timely and efficient manner. South Carolina's Energy Freedom Act (HB 3659) enacted in 2019, in part directs the Public Service Commission to establish interconnection standards for renewable energy facilities that provide for timely and efficient processing of requests and provide a process for "amending existing requests to include energy storage." In 2018, Colorado lawmakers enacted SB 9, which establishes the right of customers to interconnect energy storage systems to the grid and directs the Public Utilities Commission to establish rules for customers seeking to install and interconnect energy storage. And, legislators in California enacted AB 546 in 2017, which requires certain cities and counties to make all permitting documentation and requirements for advanced energy storage systems available on public websites, including providing applications, guidance, best practices and other factors under consideration by local governments.

## FINANCING AND TAX INCENTIVES

States also often consider creating tax credits or other tax incentives to encourage individuals and businesses to purchase and install energy systems, including systems for renewable energy and energy storage. For example, in 2020 Maryland enacted HB 980, which defined taxpayers eligible for the state's energy storage tax credit to include individuals and businesses and increased the maximum allowable credit amount for systems installed on commercial properties from $75,000 to $150,000 or 30% of the total installed cost, whichever is less. New Hampshire also recently enacted an energy storage tax incentive through HB 464 (2019), which authorizes localities to adopt a property tax exemption for energy storage systems.

Additionally, states are looking to provide financing for energy storage projects and upgrades. Some states have accomplished this by updating existing or creating new residential or commercial Property Assessed Clean Energy (PACE) programs (which offer residential or commercial building owners low-cost financing for renewable energy and energy efficiency improvements) to also include financing for energy storage. Illinois lawmakers enacted HB 3501 (2019) amending PACE laws to provide for financing of resiliency improvements, including energy storage. And the Washington Legislature enacted HB 2405 (2020) authorizing localities to implement a commercial PACE program that provides financing for improvements related to increasing resilience, including energy storage.

## TECHNOLOGY DEMONSTRATION PROGRAMS AND STUDIES

State legislatures are also supporting emerging energy storage technologies and capabilities by facilitating pilot and demonstration programs. In many cases, state legislatures appropriate funding and issue directives to state PUCs to implement these programs, which provides both regulators and utilities with clear guidance over how to proceed with this emerging suite of technologies. California's Assembly Bill 1144, mentioned previously, is focused on amending an existing technology demonstration program to allocate funding for certain distributed generation and storage projects that bolster resiliency. California's SB 676, enacted in 2019, is focused on exploring and developing strategies to maximize vehicle-to-grid integration technologies. In developing such strategies, the state PUC is directed to consider incorporating national standards for reliability and cybersecurity protocols.

States are also developing expert task forces and committees to evaluate storage technologies and opportunities for growth. Maine, for example, enacted HB 1166 (2019) creating a commission to study the benefits of energy storage in the state's electric industry. The legislation charges the commission with evaluating how energy storage could resolve some of the state's transmission-related challenges and improve resiliency. It also requires the commission to consider the economic benefits of establishing energy storage procurement targets. Also, Virginia HB 1183 (2020) directs the State Corporation Commission to establish a task force "to evaluate and analyze the regulatory, market and local barriers to the deployment of distribution and transmission-connected bulk energy storage resources to help integrate renewable energy into the electrical grid, reduce costs for the electricity system, allow customers to deploy storage technologies to reduce their energy costs, and allow customers to participate in electricity markets for energy, capacity and ancillary services."

### WORKFORCE AND ECONOMIC DEVELOPMENT

States are growing increasingly concerned about the availability of a qualified workforce to replace the impending large-scale retirement of energy sector workers necessary to power a modern electric grid. Additionally, as new technologies and resources come online, policymakers are developing programs focused on ensuring the energy workforce is adequately trained. Hawaii's HB 560 (2019) creates a technology training course for county employees focused on energy systems, including training on energy storage. State legislators are also focused on identifying opportunities for economic development and job creation in highly technical fields, including advanced energy technologies like energy storage. New Mexico's HB 233 (2020), mentioned earlier, in part charges the Energy, Minerals and Natural Resources Department with implementing a Grid Modernization Grant Program. In approving projects for funding under the grant program, the department is required to consider whether a project "stimulates in-state economic development, including the creation of jobs and apprenticeships," among other factors. Maryland's HB 436 (2020) creates a Task Force On the Economic Future of Western Maryland responsible for studying and making recommendations regarding economic development in the state's western counties, including evaluating opportunities to expand technology-driven industries, such as energy storage and cybersecurity.

## Conclusion

As the energy system undergoes a massive technological transformation, energy storage in its many forms provides energy planners, utilities and policymakers with a multitude of additional options as they work to create a more flexible, reliable and efficient energy system.  As this document has discussed, state regulatory policies may need to be adjusted to address the unique characteristics of this relatively new technology.  State legislators in several states are already demonstrating that they have a significant role to play in ensuring that storage can fairly compete and be adequately valued for the many services it can provide. These lawmakers have acted on a number of fronts, from setting storage targets and requiring the integration of storage into energy planning to funding research and development and pilot projects. As storage technology options expand and costs decrease, storage is likely to play an increasingly important role in the transition to the clean, responsive and resilient electric grid of the future.  State policymakers have the opportunity to play a pivotal role in this transition.

# Case Studies of Energy Storage Solutions

## ■ GENERATION (ANCILLARY SERVICES): INDIANAPOLIS POWER & LIGHT—HARDING ST. STATION (IND.)

Indianapolis Power & Light (IPL) deployed a 20 MW battery project in 2016 to help the utility balance and integrate its growing fleet of renewable generation. It was the first large-scale battery storage project built within the Midcontinent Independent System Operator (MISO), which operates the electric grid for all or part of 14 states in the central U.S. The utility also planned to use the battery to participate in MISO's ancillary services markets but found that those markets were not designed to account for the technical capabilities of the battery, resulting in limited opportunities for market participation.

Indianapolis Power & Light filed a complaint with the Federal Energy Regulatory Commission (FERC), which regulates the operations of regional energy markets like MISO, arguing that MISO's ancillary service markets unfairly discriminated against energy storage. FERC agreed with the utility and directed MISO to change its rules to recognize storage's capabilities more accurately. More importantly, the case is credited with being one of the factors that drove FERC to take more sweeping action on the role of energy storage in regional energy markets.

## ■ GENERATION (PEAK REDUCTION): SOUTHERN CALIFORNIA EDISON—MIRA LOMA BATTERY STORAGE FACILITY (CALIF.)

When the Aliso Canyon Natural Gas Storage Facility outside of Los Angeles began leaking in late 2015, it severely reduced the amount of natural gas available to Southern California Edison (SCE) to fuel its natural gas-fired generators to serve its customers. For an expedited replacement of some of that lost generation capacity, SCE procured a 20 MW/80 MWh battery storage system. The system stores energy from solar generation during the day to meet local needs during high-demand periods in the evening after the sun goes down.

The Mira Loma Battery Storage Facility took just 88 days to build and activate, which was incredibly fast in an industry where it takes years to site and build new generation facilities. The Mira Loma project entered service less than a year after the Aliso Canyon leak was contained (Southern California Edison 2017).

## ■ TRANSMISSION/DISTRIBUTION (THERMAL MANAGEMENT): MIDCONTINENT INDEPENDENT SYSTEM OPERATOR—WAUPACA ENERGY STORAGE SYSTEM (WIS.)

MISO prepared a regional transmission plan in 2019 which identified a scenario in which an outage on a given transmission line would cut service to the town of Waupaca, WI. To ensure reliable service to the area, grid planners looked at two options: building new transmission lines or adding an energy storage device to serve one part of town and doing a minor reconfiguration of the existing line to ensure continued service to the other part of town. The energy storage option resulted in lower costs and is expected to be in service in late 2021 (MISO 2019).

## ■ TRANSMISSION/DISTRIBUTION (INFRASTRUCTURE DEFERRAL): NATIONAL GRID—NANTUCKET ISLAND (MASS.)

Faced with a growing demand during the summer tourist season, the utility identified a need for a third undersea transmission cable to maintain reliable service. However, analysis showed that by adding a small combustion turbine and a battery system to Nantucket Island, the National Grid could defer the third line for about 20 years and improve electric reliability on the island while saving millions of dollars (Balducci et al. 2019).

### ■ CUSTOMER (RATE MANAGEMENT/BACKUP POWER):
GREEN MOUNTAIN POWER—RESIDENTIAL ENERGY STORAGE PROGRAM (VT.)

In 2015, Green Mountain Power in Vermont launched a first-of-its-kind program in the U.S. in which the utility offered incentives and low-cost leases to enable its residential customers to purchase or lease an energy storage device for their home. Through this partnership, the utility retains operational control of the device, with the promise that it will use the battery to reduce the customer's time-of-use rates and provide backup power in the event of an outage.

By leveraging all the individual storage devices from participating customers, Green Mountain Power can meet peak electricity demand while lowering the cost it pays to its regional grid operator for generation and transmission services, resulting in lower energy costs for all customers. The growing network of connected storage devices enabled Green Mountain Power to reduce system costs for all customers by about $3 million in 2020 (Green Mountain Power 2020).

# Resources

- U.S. Department of Energy's Energy Storage Grand Challenge: https://www.energy.gov/energy-storage-grand-challenge/energy-storage-grand-challenge.
- U.S. DOE/Sandia National Laboratories Energy Storage Site: https://www.sandia.gov/ess/
- Pacific Northwest National Laboratory Energy Storage Site: https://www.pnnl.gov/energy-storage
- Energy Storage Association: https://energystorage.org/
- NCSL's The Growing Role of Energy Storage in Clean Energy Policy: https://www.ncsl.org/research/energy/the-growing-role-of-energy-storage-in-clean-energy-policy.aspx
- NCSL's Energy Storage Legislative Database: https://www.ncsl.org/research/energy/energy-legislation-tracking-database.aspx.

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