United States Government Accountability Office

Report to Congressional Requesters

May 2018

ENERGY STORAGE

Information on Challenges to Deployment for Electricity Grid Operations and Efforts to Address Them

GAO-18-402

GAO Highlights

Highlights of GAO-18-402, a report to congressional requesters

Why GAO Did This Study

Power plants' electricity output must be matched continuously with demand, which varies depending on the time of day and year. To maintain a reliable supply of electricity, operators of the electricity grid—a complex network of power plants and power lines managed by utility companies and other operators—take steps to ensure power plants are available to generate electricity when needed. Increasingly, renewable sources of energy, such as solar and wind, are being integrated into the grid.

Energy storage allows for electricity to be stored and used later when it is needed and could change the operating capabilities of the electricity grid. Batteries and other energy storage technologies can store energy in one form—such as chemical, mechanical, or thermal energy—and transform that energy to generate electrical power at a later time.

GAO was asked to provide information on the role of energy storage in grid operations. This report describes (1) how energy storage can be used to enhance grid operations and performance; (2) factors that affect the deployment of energy storage for grid operations; and (3) federal and state policies and other efforts that address the deployment of energy storage. GAO reviewed studies published from 2012 through 2017; and interviewed 41 stakeholders, including officials from government agencies and representatives of industry and other groups based on their knowledge of energy storage and grid operations.

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May 2018

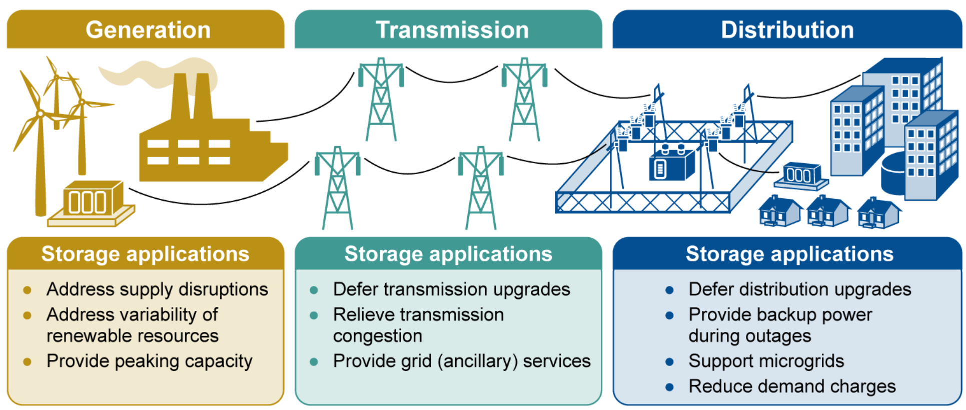
ENERGY STORAGE

Information on Challenges to Deployment for Electricity Grid Operations and Efforts to Address Them

What GAO Found

Energy storage can be used in various ways to enhance the reliability, resilience, and efficiency of grid operations, according to studies GAO reviewed and stakeholders GAO interviewed. Such storage can be deployed throughout the electricity system and act as a generation, transmission, distribution, or customer-sited asset to provide various services, address operational challenges and needs, and potentially reduce costs, as shown in the figure below. For example, storage can help grid operators address supply disruptions and the variability of renewable energy resources, such as solar and wind; relieve transmission congestion; defer the need for transmission or distribution system upgrades; and provide backup power during a power outage.

Examples of Potential Storage Applications on the Electricity Grid



Source: GAO illustration based on studies and documents. | GAO-18-402

Various factors affect energy storage deployment. These include industry and technology readiness, safety concerns and stringency of siting requirements, increasing use of renewable resources, cost-competitiveness of storage and challenges with quantifying the value of storage, and the regulatory environment, according to studies GAO reviewed and stakeholders GAO interviewed. For example, industry and technical challenges include uncertainty about the performance of certain technologies over time and in various operating conditions.

Federal and state policymakers have used various policies and other efforts to encourage the deployment of storage and address market barriers. For example, the Department of Energy has undertaken various efforts, including research and development focused on improving factors that affect the cost and capacity of certain storage technologies. In addition, the Federal Energy Regulatory Commission has issued proposed and final rules to address market barriers to storage deployment in wholesale markets. Lastly, state policies and other efforts that aim to encourage the deployment of storage or to address market barriers include establishing mandates and targets for storage adoption, revising planning requirements, and offering financial incentives and funding.

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Abbreviations List

CRS	Congressional Research Service
DOE	Department of Energy
FERC	Federal Energy Regulatory Commission
GW	gigawatt
ISO	independent system operator
IRS	Internal Revenue Service
MW	megawatt
PNNL	Pacific Northwest National Laboratory
RTO	regional transmission organization

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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May 24, 2018

The Honorable Eddie Bernice Johnson
Ranking Member
Committee on Science, Space, and Technology
House of Representatives

The Honorable Chris Collins
House of Representatives

The Honorable Mark Takano
House of Representatives

Electricity is supplied through a complex network of power plants and power lines—the electricity grid—managed by utility companies and other operators. The operation of electric power systems involves a complex process of forecasting the demand for electricity, and scheduling and operating power plants to meet that varying demand. Generally, electricity cannot be easily stored, so power plants' electricity output must be matched continuously with demand, which varies significantly depending on the time of day and year. To maintain a reliable supply of electricity, operators of the electricity grid take steps to ensure that power plants are available to generate electricity when needed. The ability to store electricity more easily could change the operating capabilities of the electricity grid.

The traditional model for generating and selling electricity in the United States is changing. According to the Department of Energy (DOE), the electric utility industry, regulators, and other stakeholders are working to understand the role of energy storage in grid operations and how to integrate it into the grid. Simultaneously, utilities in the United States are investing in an aging grid with a growing segment in need of replacement and modernization. One trend across the electric sector is a reduced reliance on large, central power plants and greater use of more diverse resource portfolios. The increasing use of variable energy resources such as wind and solar power, the interaction of distributed energy resources—including energy storage—with traditional generation sources, and the changing role of electricity customers have increased the complexity of matching electricity supply with demand at all times.[1]

Batteries and other energy storage technologies can store energy in one form—such as chemical, mechanical, or thermal energy—and transform the energy to generate electrical power. Energy storage technologies are in various stages of development and deployment, and activities are under way in the United States and elsewhere to improve the economic and technical performance of storage options. Historically, electricity storage has consisted of pumped hydroelectric storage projects, which pump water to higher-elevation reservoirs when electricity demand is low and allow it to flow downhill through electricity-generating turbines when demand increases. Other energy storage technologies include

- electrochemical technologies such as batteries (lead acid, lithium ion, sodium sulfur, and flow);
- electromechanical technologies such as flywheels (mechanical devices that harness rotational energy to store and deliver energy) and compressed air energy storage (that uses electricity to compress air, then release it through a turbine to generate electricity later); and
- other forms of storage such as thermal storage.

The Federal Energy Regulatory Commission (FERC), which regulates interstate electricity transmission and oversees wholesale interstate electricity markets, plays a role in addressing barriers to competition in electricity markets as part of its statutory duty to ensure that market rates are just and reasonable and not unduly discriminatory or preferential. State entities, such as public utility commissions, regulate utility management, operations, electricity rate structures, and capacity acquisition within their state. Additionally, in some regions, regional transmission organizations manage electricity transmission and wholesale electricity markets. DOE conducts research and development and provides analytical support for federal and other efforts that support energy storage's role in modernizing the electricity grid.

[1]Distributed generation systems are relatively small-capacity electricity generation systems, such as those installed at residences or other customer locations throughout the grid, generally at or near the site where the electricity will be used.

You asked us to review issues related to the role of energy storage in grid operations. This report examines (1) how energy storage can be used to enhance grid operations and performance; (2) factors that affect the deployment of energy storage for grid operations; and (3) federal and state policies and other efforts that address the deployment of energy storage.

To address the first two objectives, we reviewed studies and documents from research institutions, such as DOE's national laboratories, FERC, and stakeholder groups. The studies we reviewed were published from 2012 through 2017, the five most recent years for which studies were available, and we identified them by conducting database and Internet searches and asking stakeholder groups for recommendations. Specifically, we searched sources including ProQuest and WorldCat, among others, and the websites of national laboratories. We selected studies to review based on their relevance to energy storage, its role in grid operations, and factors affecting deployment of storage for grid operations. We selected 29 studies from the Congressional Research Service (CRS); DOE; national laboratories; government-sponsored research; non-governmental organizations such as nonprofits and research institutes; industry associations; and peer-reviewed scientific and trade journals. We reviewed the methodologies of these studies and determined that they were sufficiently sound for describing the ways energy storage can be used to enhance grid operations and factors affecting deployment. We also reviewed other documents including FERC proposed and final rules, guidance, and conference and meeting transcripts; reports from state agencies, DOE, and national laboratories; and industry papers and reports on topics relevant to our work. We identified the ways energy storage can be used to enhance grid operations and the factors affecting deployment often cited by stakeholders, studies, and documents. Given our methodology, we may not have identified every relevant study and every potential use of storage and factor that affects deployment of storage, therefore our findings may not be generalizable to all energy storage technologies but provide examples of such technologies.

To address the third objective, we reviewed and described documentation of energy storage efforts at DOE and relevant FERC orders and proposed and final rules addressing the deployment of storage. In addition, we reviewed documentation of Internal Revenue Service efforts to solicit comments on regulations that affect how a tax credit can be used for storage projects. We identified state policies and efforts addressing storage deployment by reviewing documents from federal and state agencies, stakeholder groups, relevant databases, and industry news sources and asking stakeholders. To describe these state policies and efforts, we reviewed state government documents, reports, policies, and legislation. Given our methodology, we identified examples that illustrate the range of state policies and other efforts that may encourage the deployment of energy storage or that address market barriers; however, these examples do not represent a comprehensive list of all state policies and efforts.

For all of the objectives, we conducted interviews with officials and representatives of 41 stakeholder groups including federal and state government agencies, industry, and other stakeholders. Specifically, we interviewed officials and representatives from 4 federal agencies (DOE, FERC, CRS, and the Internal Revenue Service); 3 national laboratories (the National Renewable Energy Laboratory, the Pacific Northwest National Laboratory, Sandia National Laboratories); 8 state government agencies; 11 grid operators and utilities; 7 industry associations; 2 nongovernmental organizations; and 6 other market participants, including storage project developers and consultants. We identified stakeholders that were knowledgeable about energy storage, grid operations, and state and federal policies and other efforts by reviewing prior GAO and CRS reports; the 29 studies from research institutions, such as DOE's national laboratories, and other groups; and by asking stakeholder groups for recommendations. Because this was a nonprobability sample of stakeholders, views are not generalizable to all potential stakeholders. For interviews with state entities, we selected a nonprobability sample of four states that have policies encouraging storage deployment, which stakeholders identified as leading in the development and establishment of such policies, and that vary based on geographic location because factors affecting deployment tend to vary in different parts of the country. We also considered information on the extent of energy storage deployed in the state. Throughout the report, we use the following categories to quantify statements identified by studies and stakeholders: "some," which we define as two to five studies and stakeholders collectively; "several," which we define as six to 10 studies and stakeholders collectively; and "many," which we define as more than 10 studies and stakeholders collectively.

We conducted this performance audit from April 2017 to May 2018 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

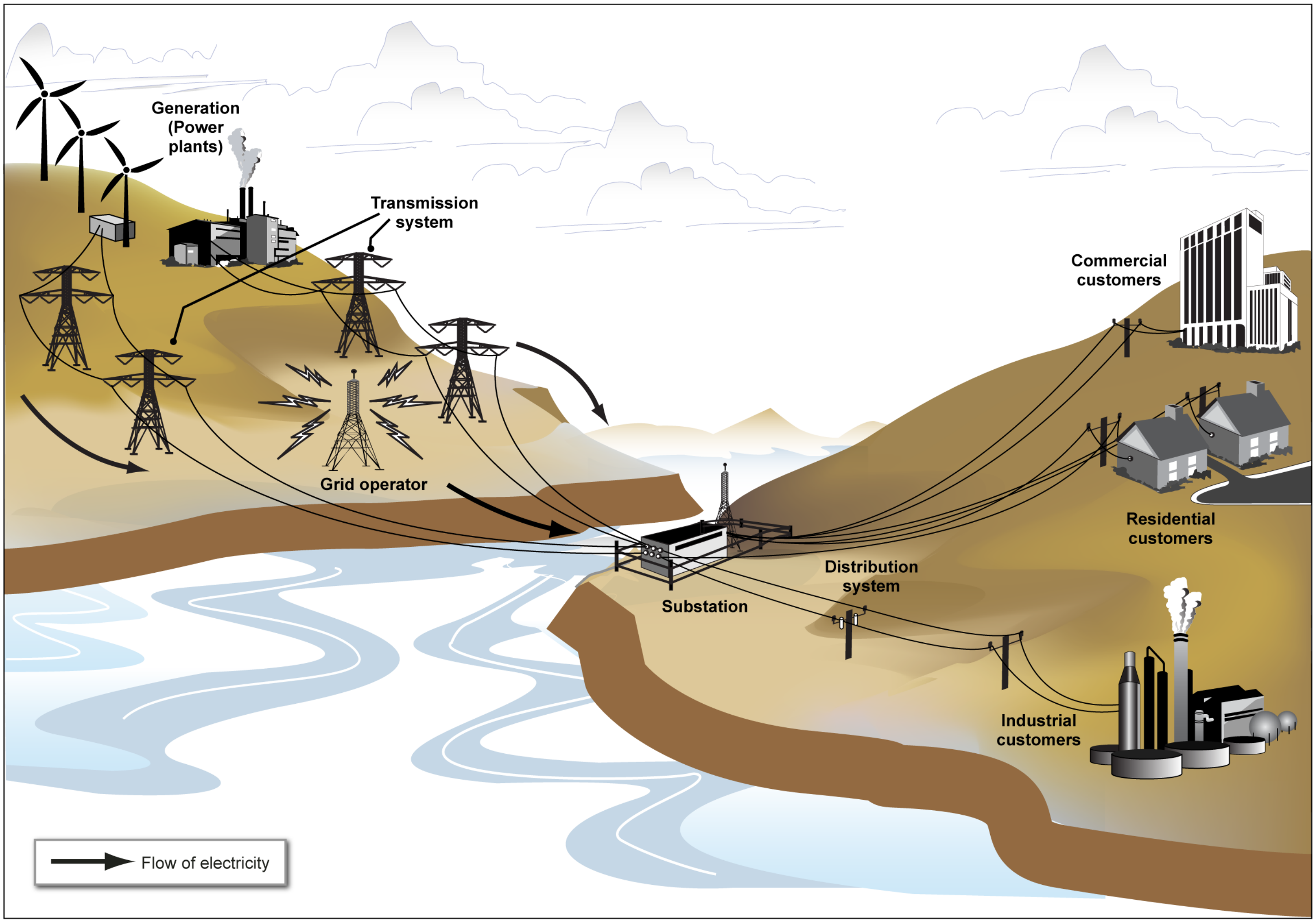
Background

This section describes (1) electricity grid functions, operations, and planning; (2) energy storage operational characteristics, technologies, and deployment; and (3) the electricity regulatory framework.

Electricity Grid Functions, Operations, and Planning

The electricity grid involves four distinct functions: generation, electricity transmission, electricity distribution, and grid operations (see fig. 1). Electricity is generated at power plants by burning fossil fuels; through nuclear fission; or by harnessing renewable sources such as wind, solar, geothermal, or hydropower. Once electricity is generated, it is sent through the electricity grid, which consists of high-voltage, high-capacity transmission systems, to areas where it is transformed to a lower voltage and sent through the local distribution system for use by residential and other customers. Throughout this process, a grid operator, such as a local utility, must constantly balance the generation and consumption of electricity. To do so, grid operators monitor electricity consumption from a centralized location using information systems, and send minute-by-minute signals to power plants to adjust their output to match changes in the demand for electricity.

Figure 1: The Electricity Grid



Source: GAO. | GAO-18-402

As we previously reported, continuously balancing the generation and consumption of electricity can be challenging for grid operators because customers may use sharply different amounts of electricity over the course of a day and throughout the year.[2] For example, in many areas, customer demand for electricity rises throughout the day and reaches its

[2]GAO, *Electricity: Status of Residential Deployment of Solar and Other Technologies and Potential Benefits and Challenges*, GAO-17-142 (Washington, D.C.: Feb. 13, 2017).

highest point—or peak demand—in late afternoon or early evening. Throughout the day, grid operators direct power plants to adjust their output to match changes in demand for electricity. Grid operators typically first use electricity produced by baseload power plants that are the least expensive to operate, then progressively increase the supply of electricity generated by power plants that are more expensive to operate as needed to match increases in electricity demand.[3] As a result, providing electricity to meet peak demand is generally more expensive than during other parts of the day, because to do so, grid operators use power plants that are more expensive to operate. Peak periods are generally short and account for only a few hours per day and, overall, a small percentage of the hours during a year, but can significantly contribute to the overall costs of serving customers.

Grid operators conduct planning to assess the adequacy of existing grid infrastructure, identify capacity needs, and evaluate the cost and effectiveness of potential solutions to address these needs.[4] As we previously reported, to ensure that grid infrastructure has sufficient capacity to meet future peak demand, grid operators typically develop forecasts of future electricity demand based on historical information about customer electricity use combined with assumptions about how customer demand will change in the future based on population growth, economic conditions, and other factors.[5]

Utilities deal with uncertainty partly by producing a range of forecasts based on demographic and economic factors, and by maintaining excess generating capacity, known as reserves. Models help utilities choose the least-cost combination of generating resources to meet demand. If demand forecasts are too high or low, a utility could end up with more or less generating capacity than it needs to serve its customers reliably, or it could end up with a mix of generating capacity that is not cost effective. These outcomes can affect electricity rates as well as the utility's financial situation. To meet demand for electricity, utilities can construct new

[3]A baseload plant is operated close to its maximum output all the time it is available for service and generally includes the units whose energy costs are among the lowest on the system. Peaker plants generally operate at a higher hourly cost and can rapidly be brought online or offline in response to changes in electricity demand.

[4]Grid infrastructure includes the physical parts of the grid necessary to generate and transmit electricity. These parts include power plants, transmission lines, substations, and distribution lines, among other equipment.

[5]GAO-17-142.

plants, upgrade existing plants, purchase power from others, build new transmission and distribution lines, and provide incentives to customers to reduce and shift their demand for electricity through energy efficiency or demand-response programs.[6] In addition, utilities may use time-based pricing—prices that vary throughout the day and year to reflect the costs of serving consumers—to encourage consumers to lower their electricity use at times of high prices or shift their use to times of the day when prices are lower, which can lower their electricity bills.

Energy Storage Operational Characteristics, Technologies, and Deployment

Energy storage includes a number of different technologies that have the ability to store energy for use at a later time. Energy storage systems can be designed with a range of technologies, such as pumped hydro, compressed air, batteries, and flywheels, according to DOE.[7] Each technology has its own performance characteristics that make it more suitable for certain grid services than for others. Specifically, compressed air and pumped hydro are capable of discharge times—the length of time that a storage device can discharge electricity—in tens of hours and have large capacities that can reach 1,000 megawatts (MW).[8] According to DOE and CRS, storage projects involving these types of technologies generally have unique siting requirements, including specific geographical features, or long construction times. In contrast, other storage technologies such as batteries and flywheels are smaller in terms of capacity and have shorter discharge times, ranging from a few seconds to

[6]By helping to reduce demand for electricity, energy efficiency programs can reduce the need for either new generating capacity or power purchases. Demand-response programs provide customers with financial incentives to reduce their electricity use during periods of peak demand.

[7]Several different electrochemical battery technologies are available for commercial applications. Batteries and other energy storage technologies are in various stages of technology advancement. For example, lithium-ion batteries are a popular type of battery used for powering most small or mobile consumer electronics. Lithium-ion batteries are also being used in electric grids and electric vehicles because, among other factors, they are lightweight and have high energy and power densities compared with other commercially available batteries. Energy density of a battery or other energy storage technology is the ratio of energy stored to the mass or volume of the device. For example, energy density of a battery affects the distance a vehicle can travel with a given size battery. Power density is the amount of energy in a given device's mass or volume that can be delivered in a given period of time. For example, power density of a battery affects how fast a vehicle can accelerate.

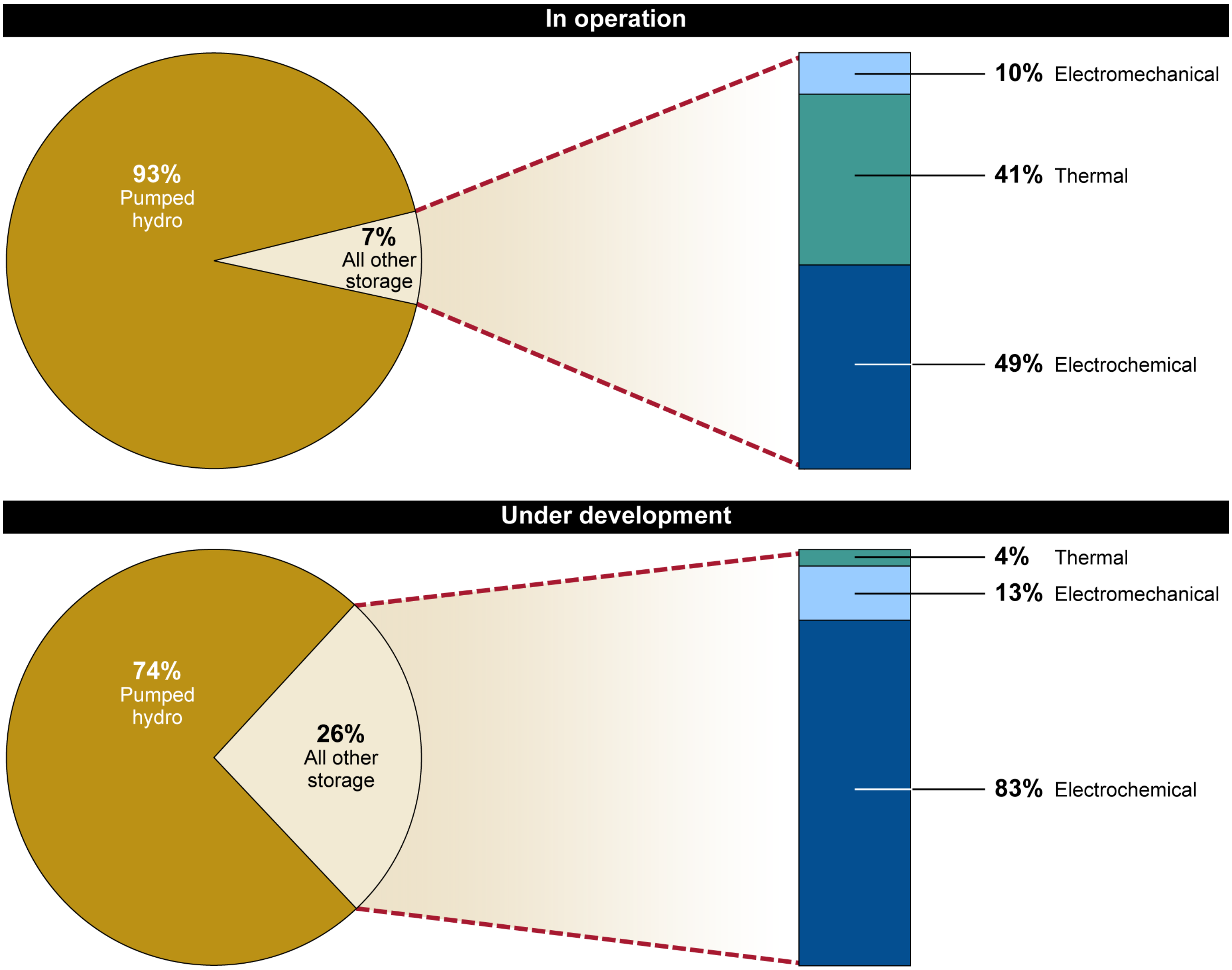
[8]A megawatt is a unit of electric power. A battery with 1 MW capacity and a maximum discharge time at that capacity of, for example, four hours, can supply 4 megawatt-hours of electricity, after which it has to recharge to provide this service at a later time.

several hours, and these technologies can generally be built without specific geographical features at the site. These energy storage systems are comprised of storage technologies and other system components such as inverters, wiring, temperature regulation, and other equipment.

According to DOE's Global Energy Storage Database, about 24 gigawatts (GW) of grid-connected energy storage were in operation in the United States and about 2 GW of storage capacity was under development as of March 20, 2018.[9] Pumped hydro comprises about 93 percent of this storage capacity in operation. Many of the operational pumped hydro systems in the United States were commissioned during the 1960s through the 1980s; the most recent became operational in 2012. See figure 2 for information about the proportion of energy storage capacity in operation or under development in the United States that comes from certain types of technology.

[9]One gigawatt is equal to 1,000 megawatts. According to DOE's Global Energy Storage Database, storage capacity in operation includes projects that were in operation (24 GW) and projects that were offline or under repair (169 MW) as of March 20, 2018. Storage capacity under development includes projects that were under signed contract to be built (2 GW) and projects that were under construction (190 MW). In addition, about 5 GW of storage capacity has been announced, according to DOE's database, but these projects are not under contract to be built or under construction.

Figure 2: Capacity of Energy Storage in Operation and Under Development by Technology Type

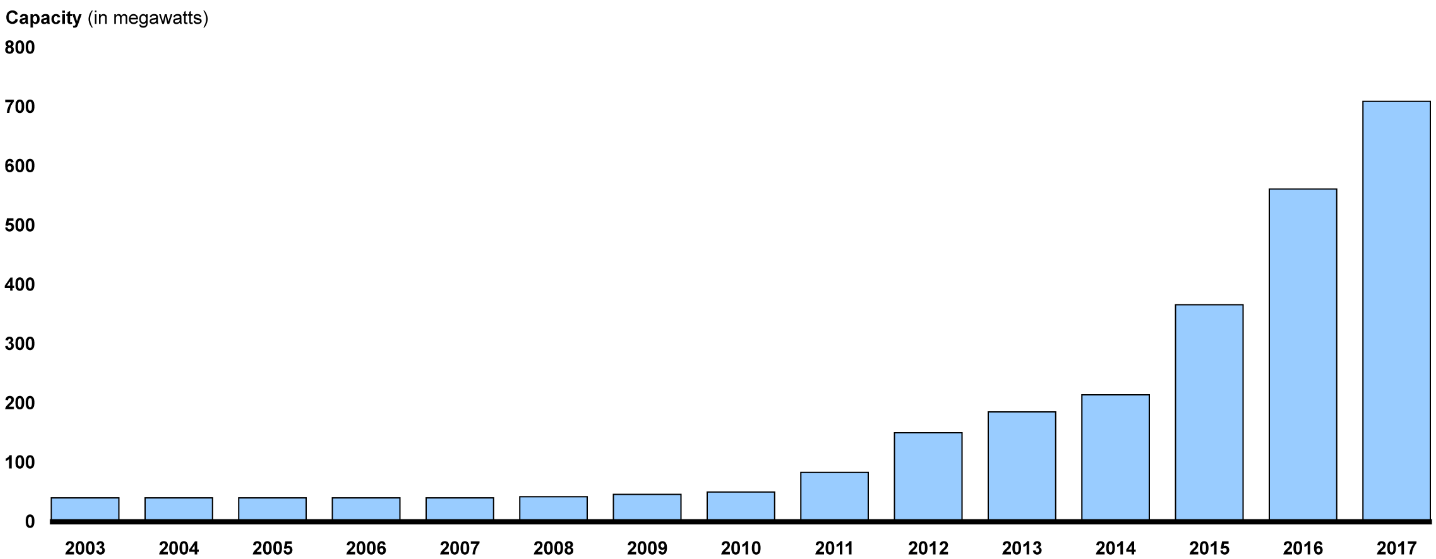


Source: GAO analysis of Department of Energy (DOE) data. | GAO-18-402

Note: The data are from the Department of Energy's (DOE) Global Energy Storage Database, as of March 20, 2018, and include projects in operation (operational and offline or under repair) or under development (under signed contract to be built or under construction). Electromechanical storage includes technologies such as flywheels (devices that harness rotational energy to store and deliver energy) and compressed air energy storage (that uses electricity to compress air, then release it through a turbine to generate electricity later). Electrochemical storage includes technologies such as batteries (lead acid, lithium ion, sodium sulfur, and flow).

While pumped hydro comprises the majority of energy storage in operation, batteries are driving the recent growth in energy storage. Since 2013, the capacity of utility-scale (1 MW or greater) battery deployments grew by 283 percent (from about 185 MW to about 709 MW), though such utility-scale batteries comprised about 0.07 percent of utility-scale generating capacity on the U.S. electric grid, according to data from the Energy Information Administration.[10] See figure 3 for information on the capacity of utility-scale battery installations each year from 2003 through 2017.

Figure 3: Capacity of Utility-Scale Battery Installations, 2003-2017



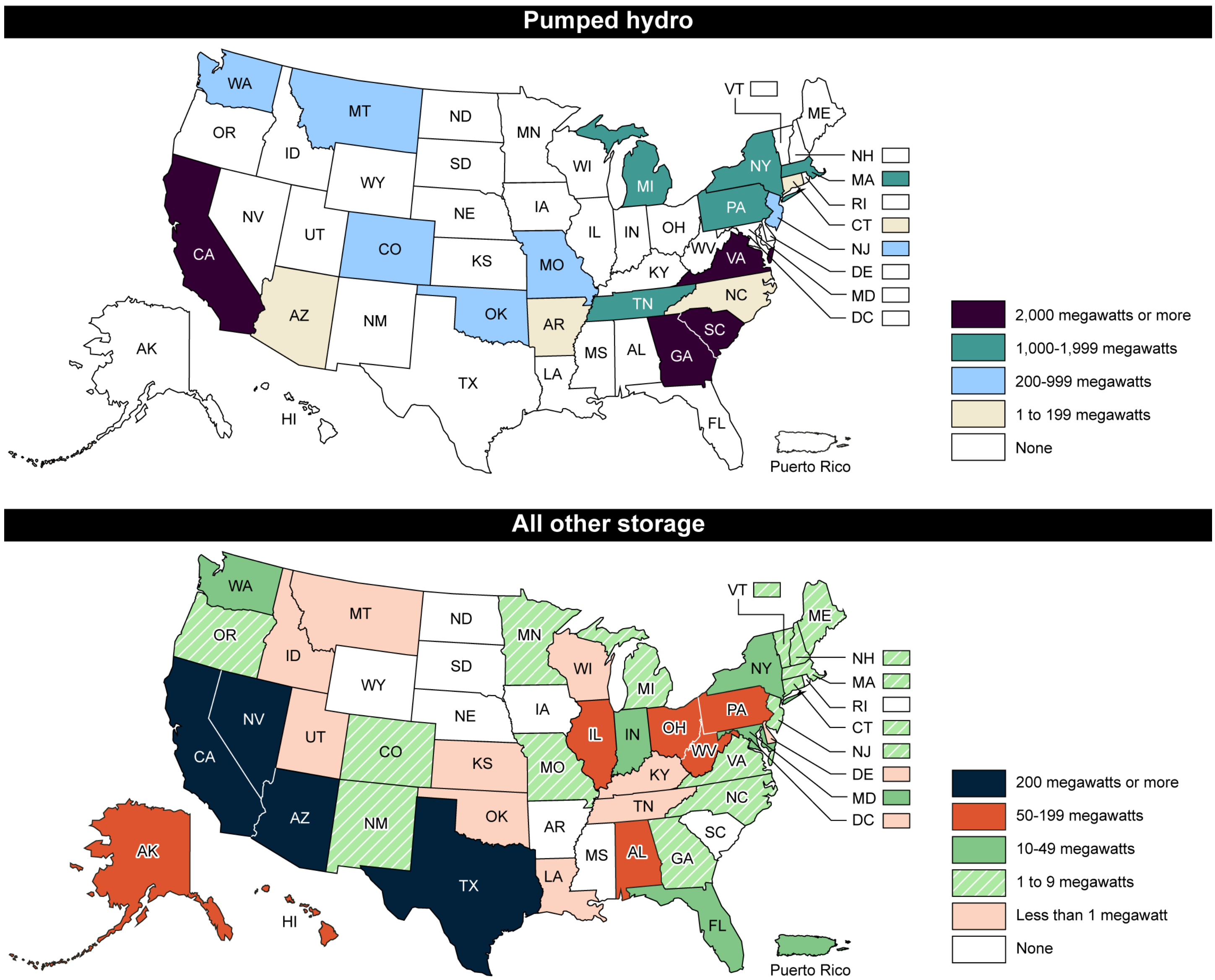
Source: GAO analysis of Energy Information Administration data. | GAO-18-402

Note: The Energy Information Administration uses the EIA-860M form to collect data on generating units with 1 megawatt or greater of combined nameplate capacity.

Figure 4 shows how grid-connected storage of all technology types was distributed nationwide as of March 20, 2018, according to DOE's Global Energy Storage Database.

[10]The Energy Information Administration is the statistical agency within DOE that collects, analyzes, and disseminates independent information on energy issues. The capacity data is based on information from the EIA-860M form that includes information on generating units with 1 MW or greater of combined nameplate capacity.

Figure 4: Capacity of Energy Storage in the United States



Sources: GAO analysis of Department of Energy (DOE) data; Map Resources (maps). | GAO-18-402

Note: The data are from the Department of Energy's (DOE) Global Energy Storage Database, as of March 20, 2018, and include projects in operation (operational and offline or under repair) or under development (under signed contract to be built or under construction). These data do not include about 5,256 megawatts (MW) of storage capacity for announced projects that are not yet under contract or construction in Nevada (3,000 MW); California (1,313 MW); Oregon, Pennsylvania, and Texas (870 MW); and other states (73 MW). All other storage includes electromechanical technologies such as flywheels (devices that harness rotational energy to store and deliver energy) and compressed air energy storage (that uses electricity to compress air, then release it through a turbine to generate electricity later); electrochemical technologies such as batteries (lead acid, lithium ion, sodium sulfur, and flow); and thermal storage.

The Electricity Regulatory Framework

Responsibility for regulating the electricity industry is divided between the states and the federal government. Most electricity customers are served by electric utilities on the retail level that are regulated by the states, generally through state public utility commissions or equivalent organizations. As the primary regulator of electricity on the retail level, state public utility commissions have a variety of responsibilities, such as approving utility investments in generation and distribution assets, the rates retail customers pay, and how those rates are set.[11] Before electricity is sold to retail customers, it may be bought, sold, and traded in wholesale electricity markets that the federal government oversees through FERC.[12] FERC is responsible for overseeing regional transmission organizations' (RTO)[13] development and operation of markets to ensure that wholesale electric rates are "just and reasonable" and not "unduly discriminatory or preferential."[14] To do so, FERC reviews and approves RTO market rules and monitors the competitiveness of

[11]State regulators approve utility investments either in advance of construction or afterwards when the utility seeks to recover costs in the rates it charges customers. Some states have integrated resource planning processes to determine what facilities should be built. The purpose of integrated resource planning is to meet future power demand by identifying the need for generating capacity and determining the best mix of resources to meet the need on a least-cost, system-wide basis. The integrated approach considers a broad range of feasible supply-side and demand-side options and assesses them with respect to financial, economic, and environmental impacts.

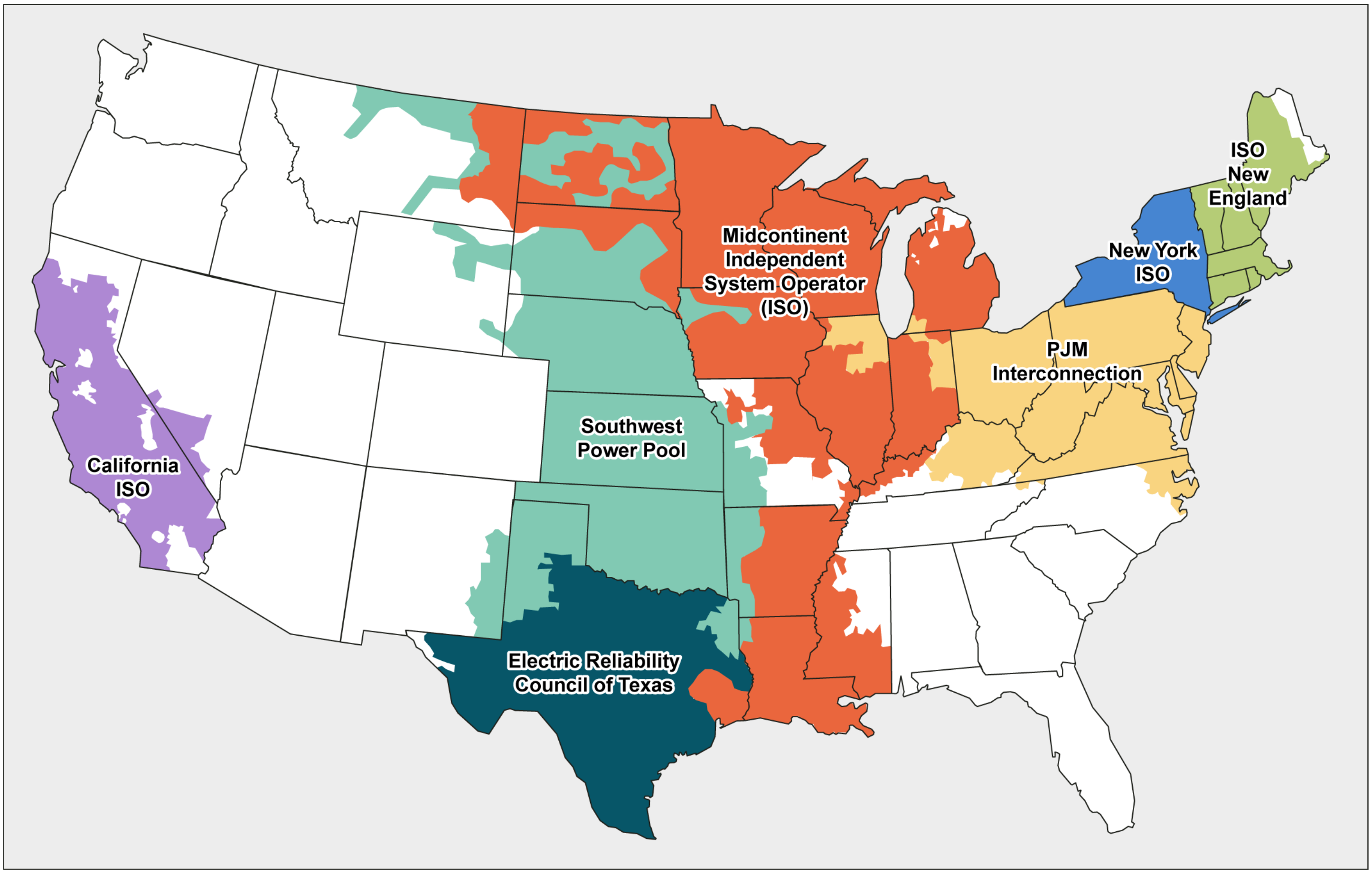
[12]FERC is to be composed of five commissioners who are appointed by the President of the United States with the advice and consent of the Senate. FERC needs a quorum of three commissioners to conduct business. Commissioners serve 5-year terms and have an equal vote on regulatory matters.

[13]Different regions of the country use different approaches to ensure adequate electricity supplies. In some regions, entities called RTOs manage the system of electricity lines that comprise the grid and help ensure enough electricity is available to meet customers' electricity needs in the future.

[14]This authority is granted under sections 205 and 206 of the Federal Power Act, 16 U.S.C. §§ 824d-824e. While major sections of the country operate under more traditional market structures, two-thirds of the nation's electricity is served in RTO regions. Independent operators of the transmission system can be referred to as RTOs or independent system operators (ISO). For the purposes of this report, we use the term RTOs to refer to both RTOs and ISOs. FERC does not regulate wholesale sales of electricity in the ISO market in Texas (the Electric Reliability Council of Texas) which is separate from the rest of the U.S. grid.

RTO markets.[15] Figure 5 indicates the location of major RTOs that have developed in certain regions of the United States.

Figure 5: Map of Seven Regional Transmission Organizations in the United States



Sources: Federal Energy Regulatory Commission; Map Resources (map). | GAO-18-402

[15] In addition, the North American Electric Reliability Corporation, which has been designated by FERC as the U.S. Electric Reliability Organization, establishes mandatory standards of reliability subject to FERC approval. RTOs, utility grid operators, and other participants in the electricity markets must take various actions to comply with these standards. According to the North American Electric Reliability Corporation, reliability is a function of resource adequacy and operating reliability; specifically, resource adequacy is the ability of the system to supply electricity to meet consumer demand; and operating reliability includes resilience and is the ability of the system to withstand sudden disturbances to system stability or unanticipated loss of components.

RTOs serve as grid operators by managing regional networks of electric transmission lines and also operate wholesale electricity markets to buy and sell services needed to maintain a reliable grid. These markets include

- capacity markets—auctions through which owners of power plants can be compensated for agreeing to make their plants available to provide electricity at a specified time in the future—designed to incentivize the building and retention of enough generation and other resources to meet future power demands;[16]
- energy markets for scheduling which power plants will generate electricity throughout the day to maintain the balance of electricity generation and consumption, and at what prices; and
- ancillary services markets,[17] which are designed to maintain electric reliability and ensure that supply and demand remain in balance from moment to moment so that grid operators can deliver electricity within technical standards, such as at the right voltage and frequency.[18]

RTOs are responsible for developing and implementing market rules, approved by FERC, that provide the framework for the design and operation of wholesale electricity markets. RTO market operations encompass multiple services that are needed to provide reliable and economically efficient electric service to customers. Each of these services has its own parameters and pricing. The RTOs use markets to determine the providers and prices for many of these services.

In regions of the country without RTOs, electric utilities generally serve in the role of grid operator. In these regions, the local utility often integrates the delivery of electricity services—energy to maintain the balance of electricity generation and consumption, capacity to meet demand, and a range of ancillary services. Utilities in these regions may build and operate power plants to provide electricity to serve their retail customers. These utilities may also buy electricity from other power plant owners.

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[16]Only four of the seven RTOs have capacity markets.

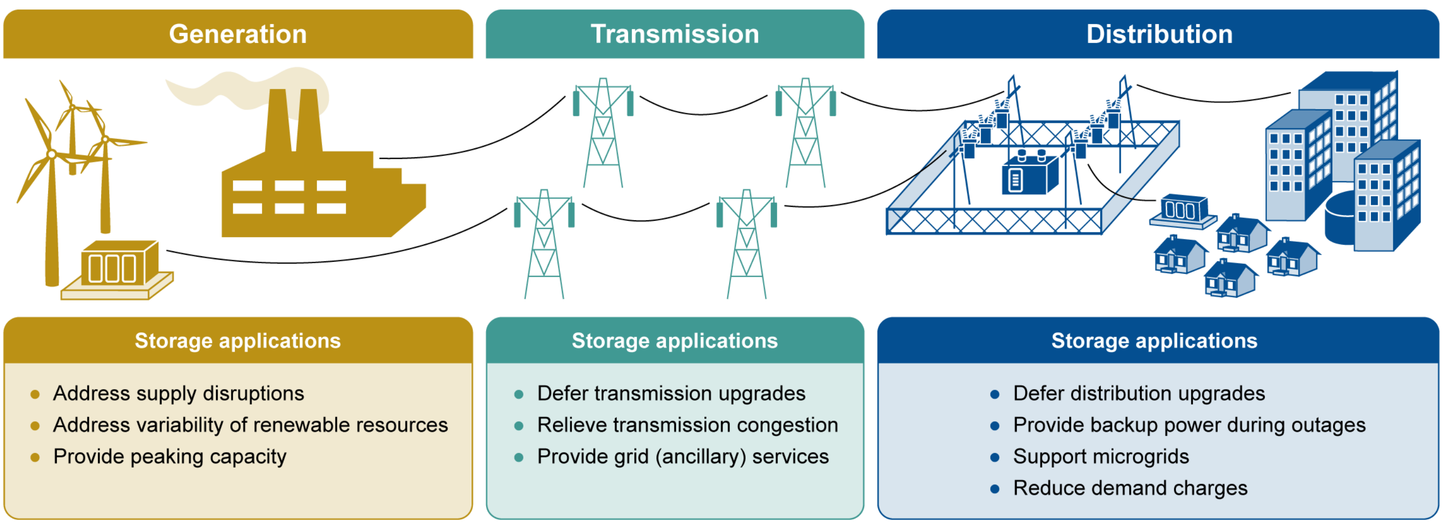
[17]Ancillary services generally involve resources—such as power plants and large consumers of electricity—being available on short notice to increase or decrease their generation or consumption.

[18]RTOs do not own transmission or generation assets, perform the actual maintenance on generation or transmission equipment, or directly serve end-use customers.

Energy Storage Can Be Used in Various Ways to Enhance the Reliability, Resilience, and Efficiency of Grid Operations

Energy storage can be used in various ways to enhance the reliability, resilience, and efficiency of grid operations, according to studies we reviewed and stakeholders we interviewed. Storage can be deployed throughout the electricity system and act as a generation, transmission, distribution, or customer-sited asset to provide various services, address operational challenges and needs, and potentially reduce costs. For example, storage can help grid operators address supply disruptions, relieve transmission congestion during periods of high demand, defer the need for transmission or distribution system upgrades, and provide backup power during a power outage. Figure 6 illustrates examples of potential applications across the electricity grid.

Figure 6: Examples of Potential Storage Applications on the Electricity Grid



Source: GAO illustration based on studies and documents. | GAO-18-402

Energy storage can support the reliability of grid operations by helping grid operators respond to fluctuations in electricity supply resulting from the variability of renewable energy resources, such as solar or wind, or disruptions to the grid, such as the loss of a transmission line or a generating unit. Specifically, according to some studies we reviewed, the fast-ramping nature of some storage technologies that can change generation output quickly—within a few seconds or minutes—makes them suitable for addressing short-term changes in variable energy generation resources (referred to as variable resources) such as when the sun sets and output from solar resources quickly declines. Moreover, storage can provide ancillary services needed to maintain system reliability and support the transmission of electricity. Specifically, according to some studies we reviewed, storage can provide frequency regulation services—which entail moment-to-moment reconciliation of the difference between supply and demand—to maintain the stability of the system.[19] The services that storage provides can be performed by traditional assets but because certain storage technologies are fast-ramping they can be better-suited to provide certain services, according to several studies we reviewed and stakeholders we interviewed.

Systems with a large portion of generating capacity from variable resources can face reliability challenges because the intermittent nature of these sources can cause fluctuations in voltage and frequency, according to some studies we reviewed.[20] Grid operators are adopting storage to support increasing use of renewable energy and address the associated challenges. For example, in 2017, San Diego Gas & Electric deployed a 30 MW energy storage facility at its Escondido substation to help improve regional reliability and support greater amounts of renewable energy in the region's energy supply (see fig. 7).[21] According to San Diego Gas & Electric, the Escondido storage facility is helping to enhance grid reliability and increase the use of renewable energy; the facility is capable of the equivalent of serving 20,000 customers over a period of 4 hours.

[19]In the United States, grid frequency must be maintained at roughly 60 hertz or the grid becomes unreliable; for example, if the frequency falls below a certain level, generators can get damaged, which could ultimately result in blackouts.

[20]In addition to grid frequency, another reliability requirement for electric grid operation is to maintain grid voltage within specified limits.

[21]San Diego Gas & Electric expedited ongoing plans to build the 30 MW project after the Governor of California declared a state of emergency in January 2016 related to the Aliso Canyon natural gas leak. To ensure reliability in the region due to limited operations of the Aliso Canyon gas storage facility after the leak, California regulators took a series of mitigation measures, including energy efficiency programs and an expedited procurement process for energy storage projects.

Figure 7: San Diego Gas & Electric's 30 Megawatt Escondido Energy Storage Facility

The 30 megawatt energy storage facility is comprised of 400,000 batteries, similar to those in electric vehicles, installed in nearly 20,000 modules and placed in 24 containers.

Source: Photos courtesy of San Diego Gas & Electric. | GAO-18-402

Similarly, in 2017, according to Tucson Electric Power documents, the utility installed two 10 MW battery storage projects to support its ability to achieve long-term renewable energy goals without compromising the reliability of service. According to representatives from the utility, the projects provide frequency control and voltage support and the deployment shortened the reaction time to system disruptions and supported the utility's compliance with reliability standards in its role as balancing authority.[22]

Storage can also provide services that support resilience by helping the grid adapt to changing conditions and potentially disruptive events and, if a disruptive event occurs, to rapidly recover, according to several studies we reviewed and stakeholders we interviewed.[23] Specifically, in the event of an outage during which power sources or power lines become

[22]A balancing authority is responsible for balancing loads and resources so that frequency remains at or near 60 hertz, or 60 cycles per second.

[23]The National Infrastructure Advisory Council defines infrastructure resilience as the ability to reduce the magnitude and/or duration of disruptive events. The effectiveness of a resilient infrastructure or enterprise depends upon its ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event.

unavailable, storage can respond quickly to provide backup power or black start services—the provision of the power necessary to restore a generation plant when power from the grid is unavailable during a major outage. In addition, storage can also support microgrids—systems that can connect and disconnect from the grid depending on operating conditions—that could maintain power for a small area independent of the grid. For example, in 2015 a Vermont utility installed a 4 MW energy storage system in conjunction with a 2.5 MW solar project at a school that serves as an emergency shelter. In case of grid failure or an extended emergency, the facility can separate from the rest of the grid and operate independently. In addition, in 2016 in Massachusetts, the Sterling Municipal Light Department installed a storage system that can isolate from the main grid in the event of a power outage and provide emergency backup power to the Sterling police station and dispatch center, a facility providing first responder services. In the event of an outage, the 2 MW storage system could provide the police station with up to 12 days of power, according to the utility.

Storage also has the potential to improve efficiency of grid operations and help reduce operating costs, according to studies we reviewed and stakeholders we spoke with. For example, storage has the potential to reduce costs by capturing energy generated during low-cost periods to be used to meet demand later during more expensive periods, according to studies we reviewed. Specifically, energy time-shift, also referred to as arbitrage, involves utilities purchasing inexpensive electric energy, available during periods when prices or system marginal costs are low, to charge the storage system so that the stored energy can be used or sold at a later time when the price or costs are high. In addition, storage can help make the capacity of variable resources more consistent by storing electricity during periods of high generation, such as a sunny afternoon, and releasing it later during periods of high demand, such as the early evening. Moreover, storage can provide similar energy time-shift by storing excess energy production from renewable sources, which could otherwise be curtailed.[24]

Storage also has the potential to reduce costs by avoiding or delaying investments in infrastructure. Specifically, storage may be used to reduce the capacity demands on existing generation, transmission, and

[24]Curtailment is a reduction in the output of a generator from what it could otherwise produce given available resources.

distribution infrastructure. As a result, according to many studies and stakeholders we interviewed, utilities may be able to avoid or delay investments in generation, transmission, and distribution infrastructure that would otherwise be necessary to maintain adequate supply.[25] For example, in 2017, a utility that serves customers in Massachusetts announced plans to install a 6 MW energy storage system with an 8-hour duration alongside a new diesel generator on Nantucket Island to provide backup power and postpone the need to construct a costly submarine transmission cable to bring electricity from the mainland to meet anticipated growth in electricity demand. In some cases, an investment in a storage system could be a more cost-effective way to manage peak demand, and in such cases, utilities could reduce the need for operation of peaking resources or investment in new peaking resources, such as a natural gas plant.[26]

Additionally, according to many studies we reviewed and stakeholders we interviewed, storage can help customers reduce demand charges. Demand charges are fees included on electricity bills in many parts of the country to cover the cost of ensuring that sufficient generation and transmission resources are available to serve customers during periods of peak demand.[27] Energy storage provides an opportunity for potential

[25]According to DOE, storage can be used to increase throughput of existing transmission capacity by reducing congestion and offsetting unhelpful electrical effects, and can reduce the need for new transmission capacity through a constrained portion of the transmission system. This requires that the storage device be located downstream from transmission constraints and that it be charged at night when the transmission system is not heavily loaded. Using storage, more electricity can be transmitted using the same infrastructure and the need for additional transmission capacity is reduced. Outside of congestion and capacity issues, energy storage can also play a role in deferring transmission upgrades for system stability purposes. For example, it may provide voltage support or a fix for an unreliable transmission interconnection.

[26]Throughout the day, grid operators direct power plants to adjust their output to match changes in demand for electricity. Grid operators typically first use electricity produced by plants that are least expensive to operate; operators then increase the use of electricity generated by more expensive power plants, as needed to match increases in electricity demand. As a result, providing electricity to meet peak demand is generally more expensive than during other parts of the day, because to do so, grid operators use power plants that are more expensive to operate.

[27]Because system operators must ensure that resources are available for any level of electricity usage even when resources are not being utilized, demand charges are generally assessed based on an individual consumer’s peak electricity usage during a certain time frame, then billed at various rates, including a fixed rate, for an entire year. For consumers who pay demand charges, reducing electricity consumption during periods of peak demand may reduce the demand charge for an entire year.

savings by helping a customer to manage their peak demand. Using storage can also allow some utilities to avoid charges that they might incur when purchasing wholesale electricity to serve their customers during a system's peak demand; this could allow them to pass savings on to their customers in the form of lower rates. For example, although the Sterling, Massachusetts, Municipal Light Department installed its storage system to provide emergency backup power, the primary benefits of the project since its installation have resulted from using it to reduce peak demand which has reduced the utility's transmission charges, and, in turn, has allowed it to reduce rates paid by its customers, according to utility representatives.

Various Factors Affect the Deployment of Storage for Grid Operations, Including Industry and Technology Readiness, Cost-Competitiveness, and the Regulatory Environment

Studies we reviewed and stakeholders we interviewed identified a variety of factors that affect energy storage deployment. These factors include industry and technology readiness, safety concerns and stringency of siting requirements, increasing use of renewable resources, the cost-competitiveness of storage and challenges with quantifying the value of storage, and the regulatory environment.

Industry and Technology Readiness

Grid operators and utilities have limited experience with storage and face technical challenges integrating storage into existing systems, according to studies we reviewed and stakeholders we spoke with. For example, according to some studies and stakeholders, grid operators may not have experience planning for the integration and operation of storage and they may not consider it as an option. The models that grid operators typically use to help make decisions about investments in generation, transmission and distribution infrastructure are based on traditional resources with better-understood capabilities. Moreover, storage can be more challenging to integrate than other resources, such as solar, because it changes its function in the system from charging—consuming electricity—to discharging—generating electricity, according to some stakeholders.

Because storage must provide power when called upon but also must be recharged from another resource at a later time, tools that planners rely on must keep an accurate accounting of the amount of energy stored and available to supply power to meet demand. According to one stakeholder, installation of storage requires grid operators to develop operating requirements and identify control and mitigation strategies for proper coordination with larger grid operations. In addition, existing utility systems may not be designed to incorporate storage and may require customization to integrate storage, according to several stakeholders.

Industry and technical challenges affecting deployment of storage include uncertainty about the performance of certain storage technologies over time and in various operating conditions. Energy storage systems generally are expected to last for a decade or more, but the actual degradation of battery storage under various conditions is still largely unknown, according to some studies we reviewed and stakeholders we spoke with. The electric utility industry has historically been slow to adopt new technologies and, unless new storage technologies prove highly reliable, utilities may be slow to deploy these assets, according to several studies we reviewed and stakeholders we spoke with.

Safety Concerns and Stringency of Siting Requirements

Although the adoption of storage has been increasing, safety codes and standards for storage are still under development, and questions have been raised about safety risks and how to mitigate those risks, according to studies we reviewed and stakeholders we interviewed.[28] Efforts are under way to ensure that safety codes and standards address energy storage systems, but these types of standards tend to lag behind the

[28]According to DOE, various codes and standards are developed by entities such as the Institute of Electrical and Electronics Engineers and the National Fire Protection Association. These codes and standards cover energy storage system safety and are intended to cover any and all aspects of the system including: design, manufacture, installation, construction, commissioning, operation, and maintenance of the system and its component parts. More specifically, they include standards that address installation in, on and adjacent to buildings or private and public areas; renewal or refurbishing or decommissioning of the system or its components; and incident response. The details and criteria of codes and standards applicable to energy storage systems cover a wide range of topics, each of which may vary depending on system size, type of system or chemistry used, and location of the system inside, on, adjacent to or otherwise in proximity to a building or private or public space. These topics include, but are not limited to, signage, clearances, first responder access, protection from natural and manmade hazards, fire detection and suppression, ventilation, exhaust and thermal management, and electrical safety.

development of storage technologies, according to some studies and stakeholders. Until existing codes and standards are updated, or new ones are developed and adopted, entities seeking to deploy energy storage or needing to verify a storage system's safety may face challenges with applying existing codes and standards, according to some studies we reviewed.

In addition, concerns about the operational safety of large storage systems as a fire hazard can be a barrier to their deployment in urban areas or in proximity to other grid resources such as substations, and local entities such as fire departments may not allow the deployment of storage on certain sites. Moreover, local jurisdictions and emergency responders, along with storage system installers, insurers, and others may not have a complete understanding of the hazards associated with storage and best approaches to addressing these hazards, such as the appropriate fire protection measures, according to some studies and stakeholders. In addition, local entities' review of energy storage systems, for example, can add additional time to the permitting process, given that these entities may not be familiar with storage systems and potential safety concerns, according to some studies.

On the other hand, in some locations siting requirements may be less stringent for some types of energy storage projects than for other resources such as a large power plant that must comply with more stringent environmental requirements, according to some studies and stakeholders. In some cases, according to some studies, the permitting process may be simpler for storage projects and construction timelines considerably shortened for a variety of reasons, including that energy storage systems do not need to complete modifications to comply with air quality standards because they do not produce emissions. In addition, certain storage projects require a much smaller footprint than conventional power plants, whereas building new power plants or transmission lines can involve large land requirements.

Increasing Use of Renewable Resources

As mentioned previously, storage can help address reliability issues associated with the variability of renewable energy generation resources making them attractive to grid operators. Consequently, the increased use of solar and other renewable energy resources has in turn encouraged the installation of storage, according to some studies we reviewed and stakeholders we interviewed. According to the Energy Information Administration, utility-scale solar installations grew at an average rate of 72 percent per year between 2010 and 2016, faster than any other generating technologies. Moreover, increasing use of these resources is expected to continue, which could drive the adoption of storage deployment in the future, according to some studies we reviewed and stakeholders we spoke with. The Energy Information Administration estimated in January 2018 that nearly half of the approximately 25 GW of new utility-scale electric generating capacity added to the grid in 2017 used renewable technologies, particularly wind and solar.

Moreover, according to some studies and stakeholders, states with aggressive renewable portfolio standards—such as Hawaii, which aims to achieve 100 percent renewable sources by 2045—will need to adopt storage resources to meet those goals. In addition, California's renewables portfolio standard includes targets of 33 percent by 2020 and 50 percent by 2030. According to some stakeholders and documents we reviewed, California is experiencing excess solar and wind generation and curtailment at certain times of the day and year and, as the state moves toward a target of 50 percent renewables, storage could help address these challenges. According to some stakeholders we spoke with, long-duration technologies will support greater integration of renewable energy on the grid. As mentioned previously, pumped hydro and compressed air energy storage can provide long duration storage, and other technologies, including flow and lithium ion batteries, have the potential to provide for long duration storage, according to some studies we reviewed and stakeholders we spoke with.[29]

Cost-Competitiveness and Challenges with Quantifying the Value of Storage

Grid operators' decisions to invest in energy storage must consider both costs and benefits. While the cost of some technologies has fallen in recent years, the cost of storage systems—including all the system components, installation, and integration costs—is still high when compared to more traditional resources available to electric utilities, according to many studies we reviewed and stakeholders we spoke with. On the other hand, the adoption of storage for certain purposes, such as supporting increased use of renewable resources or providing backup power, includes potential benefits such as reducing greenhouse gas and other harmful emissions, or enhancing the resilience of the grid.

[29]Flow batteries differ from conventional batteries in that energy is stored in the electrolyte (fluid) instead of the electrodes. The electrolyte solutions are stored in tanks and pumped through a common chamber separated by a membrane that allows for transfer of electrons—flow of electricity—between the electrolytes. Some flow batteries are commercially available while other types are under development.

While the cost of lithium-ion batteries has declined in recent years, the storage device is one component of a storage system, and estimates of the device's share of the total cost of an energy storage system range from about 25 percent to 50 percent of the total costs, according to studies we reviewed. According to some stakeholders, the cost of the system components and other costs to integrate storage with the grid can be substantial and are not declining as quickly as the cost of storage devices. In addition to the cost of the storage device, other system component costs include power conversion electronics, software, and monitoring and control systems, among others, that are essential to maintain the health and safety of the entire system, according to some studies.

Moreover, valuing investments in energy storage must consider both the cost and benefits, but assessing the potential benefits and costs of storage can prove challenging, according to several studies we reviewed and stakeholders we spoke with. These challenges identified in these studies and by these stakeholders include the following:

- **Quantifying benefits.** Benefits can be difficult to quantify, as they depend on the application, location, and ability to capture multiple benefits. Specifically, the compensation for services that storage can provide reflects local market conditions, and these vary across regions. In addition, the value of certain storage applications can be harder to quantify than for others. For example, if a utility is considering deployment of storage in order to defer an investment in a transmission and distribution infrastructure upgrade, then determining the value of the storage asset involves analyzing the avoided cost of that investment, which is quantifiable. However, it is more difficult to quantify the value of less tangible benefits of storage, such as improvements to operational flexibility and grid resilience, which are not monetized and therefore are difficult to quantify.
- **Life expectancy.** For certain storage technologies, much is still unknown about their useful life, which depends on the number of charge and discharge cycles, among other things. Reliable estimates of the expected life of an asset are necessary for accurately estimating lifecycle costs and benefits. Given the fact that battery technologies are evolving, the lack of data makes it more challenging for utilities to estimate expected costs and benefits to justify their investment expense.
- **Limited information on cost**. Sufficient information on the cost of storage systems is not readily available, limiting utilities' ability to

include storage in modeling and investment decisions, according to some stakeholders. Energy storage price and cost data vary among sources because of aggregation to protect proprietary interests, which unit is chosen to present price and cost data, and limited information about how projects operate. Specifically, information on the operational conditions, specifications, and performance of energy storage systems is difficult to obtain. In addition, according to some studies we reviewed, uncertainty exists about the future cost outlook and pace of technological maturity.

Regulatory Environment

The regulatory environment can pose barriers to the deployment of energy storage. Specifically, market rules and regulations do not always clearly address whether entities may own and operate storage assets and how, if at all, the cost of investments in storage assets can be recovered, according to several studies we reviewed and stakeholders we interviewed. In addition, each RTO establishes the rules in a different way, and their implementation of reforms to accommodate storage varies, according to studies and documents we reviewed and stakeholders we spoke with. According to a FERC document, under current market rules, resource bidding parameters—the physical and operational constraints that a resource identifies when submitting offers to sell services in electricity markets—vary greatly among the RTOs.[30] Moreover, state regulators and RTOs may be slow to change their policies and rules to address energy storage, and delays in such changes hinder deployment, according to some studies we reviewed.

In RTO regions, some states do not allow utilities to own generation assets, and when storage is classified as a generation asset, an electric utility can be prevented from owning storage. Moreover, when market rules do not clearly define what type of asset they consider storage to be, this can make it difficult to determine whether storage can participate in the market or to receive compensation, making storage in that market financially unviable, according to some studies and stakeholders. One RTO, the California Independent System Operator (ISO), has established participation models to accommodate resources, such as storage, that

[30] *Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators*, 157 FERC ¶ 61,121, 81 Fed. Reg. 86,522 (Nov. 30, 2016).

are operationally unique.[31] In addition, uncertainty exists about the ability of storage project owners to recover costs of storage used for multiple applications, according to documents and studies we reviewed and stakeholders we spoke with.

Moreover, the variation in rules and regulations across regions makes it difficult for energy storage project developers to navigate different potential markets because each has its own characteristics, stakeholders, regulations, and market designs, according to some stakeholders. Storage project developers must keep abreast of the activities of multiple regulatory agencies and the variation by region makes potential revenue streams difficult to predict. In addition, according to one study we reviewed, the inconsistency of rules adds a level of complexity for project developers that want to deploy storage resources across multiple markets because they must conduct separate analyses to determine the regulatory outlook, market requirements, and profit potential in each region.

Various Federal and State Policies and Other Efforts Aim to Encourage the Deployment of Energy Storage and Address Market Barriers

Federal and state policymakers have used a variety of policies and other efforts to encourage the deployment of storage and address market barriers. For example, DOE has undertaken various efforts in response to several challenges to the deployment of storage, but funding to continue these efforts is uncertain. In addition, FERC has taken steps to address market barriers to storage deployment in wholesale markets but the final impact of these steps depends on implementation by RTOs. Moreover, the Department of the Treasury and the Internal Revenue Service (IRS) are considering changes that could clarify the eligibility of energy storage for a tax credit. Lastly, state policies and other efforts aim to encourage the deployment of energy storage or to address market barriers; these include establishing mandates and targets for storage adoption, revising

[31]Depending on the physical characteristics of the storage resource and the service the owner of the storage resource intends to provide in the California ISO markets, storage resources can participate as non-generator resources, pumped storage hydro units, or as a demand-response entity. The California ISO defines non-generator resources as resources that operate as either generation or load and that can be dispatched to any operating level within their entire capacity range but are also constrained by a megawatt-hour limit to (1) generate energy, (2) curtail the consumption of energy in the case of demand response, or (3) consume energy. Electric storage resources connected to the distribution system within the California ISO's balancing authority area may also participate in the California ISO markets through a distributed energy resource aggregation or as a participating generator through a wholesale distribution access tariff.

interconnection rules and planning requirements, and offering financial incentives and funding.

DOE Has Undertaken Various Efforts to Address Challenges Affecting Storage Deployment, but Funding to Continue these Efforts Is Uncertain

According to documents we reviewed, DOE has undertaken various efforts in response to the challenges to deploying energy storage identified in a 2013 report,[32] including challenges concerning the safety and reliability of such storage, its acceptance by industry, the regulatory environment, and cost-competitiveness.

- **Efforts to Address Safety and Reliability Challenges.** In 2017, DOE developed, through its Pacific Northwest National Laboratory (PNNL) and Sandia National Laboratories, the DOE safety roadmap, which established a goal to foster confidence in the safety and reliability of energy storage systems.[33] The roadmap built on previous efforts including an Energy Storage Safety Forum that Sandia held in 2017 for stakeholders to share information and identify future needs.[34] The objectives of the roadmap include research and development, codes and standards, and collaborative resources with a focus on electrical safety, fire and smoke hazard detection and mitigation, health and environmental hazards, natural and man-made disasters, ventilation and thermal management, and system controls. The roadmap aims to cover the development of energy storage systems through their decommissioning or refurbishment and includes design, installation, commissioning, operation and maintenance, repair, decommissioning, and reuse.

  DOE has also supported efforts to develop and deploy energy storage safety codes with industry groups, according to documents we reviewed. For example, DOE established working groups focused on safety and standards, including the Energy Storage Systems Safety Working Group, which aims to facilitate the timely development and deployment of safe energy storage systems by implementing the DOE

[32] DOE, *Grid Energy Storage* (December 2013).

[33] In June 2016, PNNL led a workshop on behalf of DOE's Energy Storage Program that focused on the reliability of energy storage systems and included stakeholders from industry, utilities, and government to develop a strategic roadmap of issues facing the reliable operation of energy storage technologies.

[34] Previous DOE efforts also include sponsoring an energy storage safety workshop in 2014 and, with stakeholder input, development of a DOE Energy Storage Safety Strategic Plan in 2014.

safety roadmap through collaboration with stakeholders. In addition, as part of these efforts, a DOE working group on codes, standards, and regulations monitors the development of standards and model codes and provides input to those activities. Additionally, DOE coordinates with industry-led and international code-setting agencies such as the National Fire Protection Association and the International Code Council, as well as companies that conduct testing. In addition, PNNL published several resources including an inventory of codes and standards, an overview of the development and deployment of codes and standards, and a compliance guide.[35] The compliance guide prepared by PNNL and Sandia, which includes safety codes and standards, aims to facilitate the timely deployment of storage systems and assist with documenting compliance with current safety-related codes and standards and verifying compliance with codes and standards.

- **Efforts to Support Industry Acceptance**. DOE has provided technical assistance and funded demonstration projects to help utilities and other entities install, procure, and evaluate storage projects, according to documents we reviewed. For example, DOE provided funding and technical support in the deployment of a storage project at an emergency shelter in Vermont that can separate from the rest of the grid and operate independently in case of an emergency. DOE also supported the development of documentation and tools to assist utilities in the design, deployment, and operation of energy storage systems including valuation models, procurement guidelines, commissioning procedures, and data acquisition guidelines. In addition, Sandia published guidance to provide information for municipalities on the elements that should be included in a solicitation for procurement and installation of an energy storage project and a handbook to provide information and tools to guide investors' evaluations of energy storage opportunities.[36] DOE has a proposal under way for a study to gather pricing information for energy storage technologies that will be used as part of future updates to the

[35]Pacific Northwest National Laboratory, *Inventory of Safety-related Codes and Standards for Energy Storage Systems* (September 2014); *Overview of Development and Deployment of Codes, Standards and Regulations Affecting Energy Storage System Safety in the United States* (August 2014); and *Energy Storage System Guide for Compliance with Safety Codes and Standards* (June 2016).

[36]Sandia National Laboratories, *Energy Storage Procurement Guidance Documents for Municipalities* (September 2016) and *DOE/EPRI Electricity Storage Handbook in Collaboration with NRECA* (September 2016).

handbook. DOE also held a financial summit in June 2017 to provide information to the financial community on solicitations and contracts. In addition, to evaluate storage projects, DOE and the Washington Department of Commerce established a memorandum of understanding to have PNNL characterize and analyze the technical and economic attributes of storage projects. DOE also supports new deployments through funding, including the Grid Modernization Laboratory Consortium awards aimed at integrating conventional and renewable sources with energy storage.

- **Provide Technical Assistance to Regulators.** According to documents we reviewed, DOE has hosted workshops and provided technical assistance for several state public utility commissions and other entities aimed at providing them with information on storage technology development, project procurement, and valuation. In addition, in 2012 Sandia developed guidance for state regulatory authorities and planning personnel to provide information about opportunities for energy storage to play a greater role in the electricity grid.[37]
- **Research and Development to Improve Cost-Competitiveness.** DOE's Energy Storage Program's research and development activities focus on improving materials and system factors that affect the cost, efficiency, and capacity of certain energy storage technologies, including flow batteries.[38] DOE's fiscal year 2018 budget request includes a performance goal to improve the cost-benefit ratio of storage to compete with current peak generation resources and, by 2020, increase to 5 percent the commercial use of grid-scale storage to buffer renewables.[39]

A DOE advisory committee in 2016 conducted an assessment of DOE's energy storage-related research, development, and deployment programs

[37]Sandia National Laboratories, *Evaluating Utility Procured Electric Energy Storage Resources: A Perspective for State Electric Utility Regulators – A Study for the DOE Energy Storage Systems Program* (Albuquerque, NM: November 2012).

[38]According to DOE, the Energy Storage Program performs research and development on a wide variety of storage technologies including batteries, flywheels, power electronics, control systems, and software tools for storage optimization and sizing.

[39]The fiscal year 2019 budget request does not include the performance goal for improving the cost-benefit ratio of storage and increasing commercial use of grid-scale storage to buffer renewables.

that produced 15 recommendations.[40] The recommendations included, among others, improving the visibility of DOE's efforts; addressing the need for storage models and studies of market impediments; and providing additional funding and resources for energy storage research, development, and deployment programs.

While DOE has undertaken a range of efforts over the past several years to address challenges to deployment, future funding of these efforts is uncertain. In 2017, DOE allocated $31 million to work on energy storage within its Office of Electricity Delivery and Energy Reliability.[41] DOE's fiscal year 2018 budget request proposed reducing this funding by about 74 percent, to $8 million, and proposed eliminating, among other efforts, work related to

- engagements with states, utilities, and storage providers for conducting tests and trials;
- engagements with state and federal regulatory officials on efforts to understand regional market barriers to deployment;
- validation of system performance and analysis of regional use cases; support to states and regional entities for the procurement, commissioning, and analysis of deployed systems;
- the development of enhanced tools and data for sharing with industry for the development and use of grid-scale batteries; and
- participation in both industry-led and international codes and standards development.[42]

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[40]Department of Energy, Electric Advisory Committee, ***2016 Storage Plan Assessment, Recommendations for the U.S. Department of Energy*** (September 2016). The Energy Storage Technologies Subcommittee of the Electric Advisory Committee was established in March 2008 in response to a requirement of the Energy Independence and Security Act of 2007. According to the subcommittee, the 2016 assessment is intended to meet two requirements of the 2007 act: (1) to develop five-year plans for integrating basic and applied research so that the United States retains a globally competitive domestic energy storage industry for electric drive vehicles, stationary applications, and electricity transmission and distribution; and (2) to assess, every 2 years, the performance of DOE in meeting the goals of the plans and make recommendations to the Secretary of Energy on programs or activities that should be established or terminated to meet those goals.

[41]In addition to these efforts, DOE's Office of Energy Efficiency and Renewable Energy conducts research on solar energy and hydropower through the Solar Energy Technologies and Water Power Technologies offices, respectively, which include efforts related to energy storage.

[42]Department of Energy, FY 2018 Congressional Budget Request, Vol. 3 (May 2017).

Because fiscal year funding through March was provided under continuing resolutions, energy storage funding remained on par with fiscal year 2017 levels for the first half of the fiscal year, and the Consolidated Appropriations Act, 2018, increased funding for energy storage to $41 million. However, DOE's fiscal year 2019 budget request again proposes reducing the funding for energy storage work to $8 million.[43] According to DOE's fiscal year 2019 budget request, DOE plans to focus on accelerating the development of new materials and technologies that can lead to improvements in the cost and performance of utility-scale energy storage systems and accelerate the adoption of energy storage systems into the grid infrastructure.

FERC Has Taken Steps to Address Market Barriers to Storage Deployment, but the Final Impact of these Efforts Depends on Implementation by RTOs

FERC has taken several steps to address market barriers to energy storage deployment, but the impact of these efforts will depend on implementation by RTOs. In March 2018, FERC published a final rule that aims to address barriers to integrating storage into organized wholesale markets. The rule requires that RTOs establish participation models consisting of market rules that recognize the physical and operational characteristics of electric storage resources to facilitate their participation in the RTO markets.[44] In prior years, FERC issued several orders that also aimed to address barriers to storage participation in organized wholesale electric markets. For example, FERC Order 792—issued in 2013—revised the definition of a small generating facility in the pro forma Small Generator Interconnection Agreement—which establishes the terms and conditions for interconnection of resources no larger than 20 MW—to specifically include energy storage devices. In addition, FERC Order 755—issued in 2011—required RTOs to compensate frequency

[43]Department of Energy, FY 2019 Congressional Budget Request, Vol. 4 (February 2018). In the fiscal year 2019 budget request, the Office of Electricity Delivery and Energy Reliability—which includes the energy storage program's funding—is split into two accounts totaling $157 million (a decrease of about 30 percent from $228 million); this includes $61 million for grid reliability (Electricity Delivery) and about $96 million for cybersecurity, energy security, and emergency response.

[44]*Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators*, 162 FERC ¶ 61,127, 83 Fed. Reg. 9,580 (Mar. 6, 2018) (to be codified at 18 C.F.R. pt. 35). In the notice of proposed rulemaking, the Commission also proposed reforms related to distributed energy resource aggregations. In the final rule, the Commission did not take final action on these reforms but determined that FERC will continue to explore these reforms and hold a technical conference to gather additional information to help determine what action to take. Several entities have requested clarification or a rehearing on the final rule.

regulation resources in a manner that acknowledges the performance of faster-ramping resources, such as batteries and flywheels.

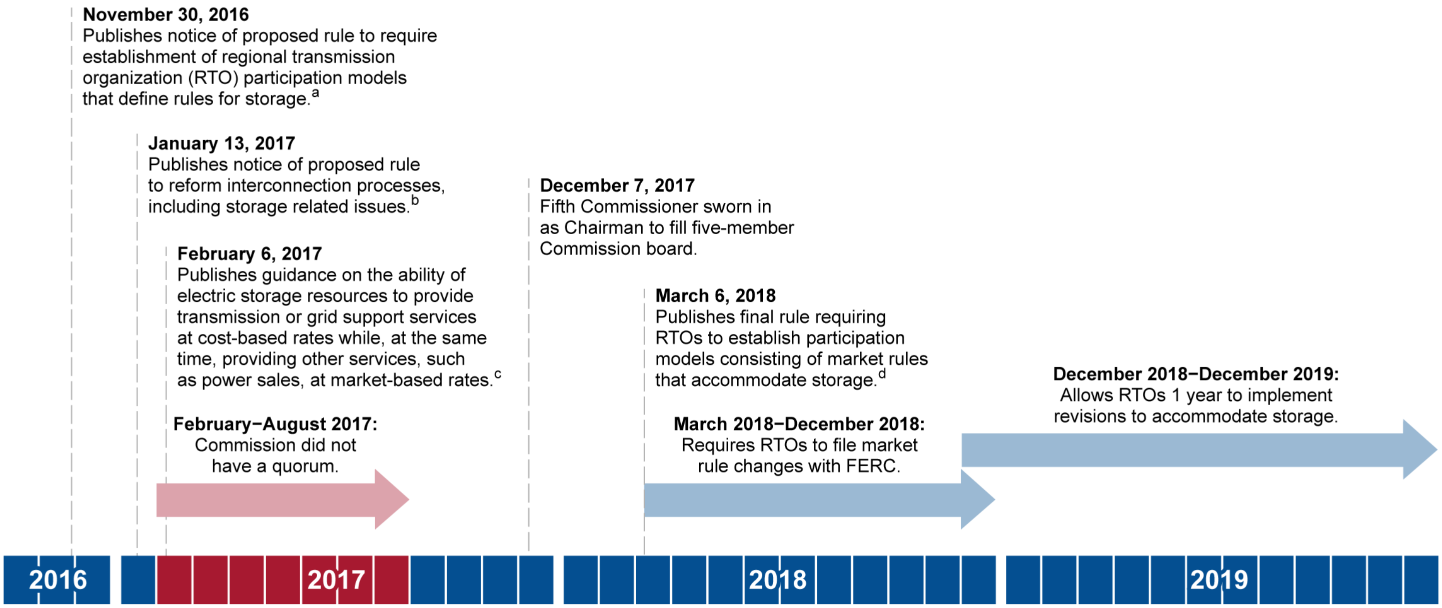
Additionally, in May 2018, FERC published a final rule that revised the definition of a generating facility in the pro forma Large Generator Interconnection Procedures and pro forma Large Generator Interconnection Agreement—which establishes the terms and conditions for interconnection of resources larger than 20 MW—to explicitly include electric storage resources.[45] FERC also published guidance in February 2017 on the ability of electric storage resources to provide transmission or grid support services at cost-based rates, while providing other electric storage services, such as power sales, at market-based rates.[46]

According to some studies we reviewed and stakeholders we spoke with, FERC orders have helped alleviate some of the barriers to storage participation in wholesale markets, but the impact of these orders depends on RTO implementation. Moreover, RTO implementation of FERC's requirement to establish participation models to accommodate storage may not occur until the end of 2019 or later. Figure 8 shows the timeline of key FERC efforts that aim to address market barriers to the deployment of storage and time frames for implementation from November 2016 through 2019.

[45] *Reform of Generator Interconnection Procedures and Agreements,* 83 Fed. Reg. 21,342 (May 9, 2018) (to be codified at 18 C.F.R. pt. 37).

[46] *Utilization of Electric Storage Resources for Multiple Services When Receiving Cost-Based Rate Recovery*, 158 FERC ¶ 61,051, 82 Fed. Reg. 9,343 (Feb. 6, 2017). In November 2016, FERC held a technical conference on storage that included discussion of storage and its potential uses and ways to avoid over-compensating resources performing multiple functions simultaneously. The guidance aims to clarify that providing both cost and market-based rate services and receiving associated revenues is permissible and to address concerns about the potential for double-recovery of costs from ratepayers, adverse market impacts, and RTO independence from market participants.

Figure 8: Timeline of Key Federal Energy Regulatory Commission (FERC) Efforts to Address Market Barriers to the Deployment of Energy Storage Resources and Time Frames for Implementation, 2016 through 2019



Source: GAO analysis of FERC documents. | GAO-18-402

Note: The Commission cannot finalize rules and issue an order without a quorum, which it did not have from February 2017 through August 2017.

[a]*Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators*, 157 FERC ¶ 61,121, 81 Fed. Reg. 86,522 (Nov. 30, 2016).

[b]*Reform of Generator Interconnection Procedures*, 157 FERC ¶ 61,212, 82 Fed. Reg. 4,464 (Jan. 13, 2017).

[c]*Utilization of Electric Storage Resources for Multiple Services When Receiving Cost-Based Rate Recovery*, 158 FERC ¶ 61,051, 82 Fed. Reg. 9,343 (Feb. 6, 2017).

[d]*Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators*, 162 FERC ¶ 61,127, 83 Fed. Reg. 9,580 (Mar. 6, 2018) (to be codified at 18 C.F.R. pt. 35).

[e]*Reform of Generator Interconnection Procedures and Agreements,* 83 Fed. Reg. 21,342 (May 9, 2018) (to be codified at 18 C.F.R. pt. 37).

According to FERC's final rule, RTO implementation of the requirement to establish participation models could take 21 months from the publication of the final rule. RTOs will need to develop the participation models, obtain input through their stakeholder review processes, and may need to update modeling and dispatch software.

IRS May Revise Regulations to Clarify the Eligibility of Storage for a Tax Credit

Treasury and the IRS are considering changes that could clarify the eligibility of energy storage for a business tax credit under section 48 of the Internal Revenue Code, according to IRS documents.[47] Currently, customers who install storage systems may be eligible for this tax credit when they use the storage system to store energy from renewable energy systems more than 75 percent of the time;[48] however, at this time there is no federal tax incentive for stand-alone storage.[49] Since 2011, the IRS has issued some written determinations that the storage portion of a renewable energy system would be eligible for the credit. However, only the specific taxpayer addressed by a determination can rely on it as precedent.[50]

In October 2015, Treasury and IRS solicited comments from the public on how to define certain types of property that qualify for this tax credit, including whether property such as storage devices may also be considered energy property.[51] According to IRS documents, comments filed in response requested revisions to the tax credit that include, among other things, providing a technology-neutral definition of energy storage property, providing a specific list of types of energy storage property that

[47] 26 U.S.C. § 48 (2018).

[48] IRS regulations provide that solar and wind energy property eligible for the energy credit under 26 U.S.C. § 48 may include storage devices. Storage systems that are charged by a renewable system more than 75 percent of the time are eligible for a portion of the credit; only systems charged by the renewable energy system 100 percent of the time may claim the full 30 percent tax credit. 26 C.F.R. §§ 1.48-9(d)(3), (d)(8)(h)(1), (e) (2018).

[49] A bill has been introduced in Congress to amend the tax code to allow the tax credit to be used for energy storage without regard to the charging source and for stand-alone storage. Energy Storage Tax Incentive and Deployment Act of 2017, S. 1868, 115th Cong. § 2(b) (2017).

[50] See 26 U.S.C. § 6110(k)(3) (2018). Written determinations are the IRS Chief Counsel's letters to, or memorandums regarding, specific taxpayers. Private letter rulings are issued to taxpayers who request (for a fee) answers to technical questions about tax consequences of particular transactions. IRS provided us with four private letter rulings that it has issued regarding energy storage as property eligible for credit under section 48. In addition, the IRS issued another private letter ruling in March 2018 regarding similar issues under section 25D of the Internal Revenue Code, which governs residential energy efficient property.

[51] Specifically, this notice requested comments on the definition of certain equipment using solar energy; certain equipment used to produce, distribute, or use energy derived from a geothermal deposit; qualified fuel cell property; qualified microturbine property; combined heat and power system property; qualified small wind energy property; and equipment using the ground or ground water as a thermal energy source.

qualify for the credit, and determining that storage is eligible for the credit on a stand-alone basis. According to some stakeholders we interviewed, the requirement for storage to be paired with renewable energy to obtain the tax credit is limiting because there are other potential applications and benefits storage can provide to the grid that are unrelated to renewable energy integration. Additionally, one stakeholder we spoke with said that regions with relatively small renewable energy resource capacities are unable to receive federal support for energy storage, even though it may benefit their grid.

State Policies and Other Efforts Include Mandates and Targets, Revision of Rules and Planning Requirements, and Financial Incentives and Funding

Through interviews with stakeholders and our review of documents, we identified examples of state policies and other efforts that have encouraged the deployment of energy storage or aim to address market barriers. Appendix I includes a detailed list of state policies and other efforts encouraging deployment of energy storage we identified. In summary, these policies and other efforts include:

Mandates and Targets. Several states have established or proposed mandates or targets that require or encourage electric utilities to procure a specific amount of energy storage capacity. States have taken a range of approaches to implementing these mandates and targets. For example:

- The California Public Utilities Commission requires investor-owned utilities to collectively procure 1.3 GW of energy storage by 2020.
- Oregon is in the process of implementing a requirement for certain utilities serving more than 25,000 retail customers to procure energy storage systems with at least 5 megawatt hours of energy storage capacity by January 1, 2020.
- The Massachusetts Department of Energy Resources adopted a 200 megawatt-hour energy storage target for electric distribution companies to collectively meet by January 2020.
- In November 2017, New York State enacted legislation requiring the state public service commission to adopt an energy storage target. In January 2018, the Governor of New York announced an energy storage goal of 1.5 GW by 2025.
- A number of other states are also considering the adoption of targets for storage capacity in the state.

Mandates and targets that require or encourage utilities to procure energy storage can help create certainty in the market for energy storage by assuring that there is a demand for storage, according to some stakeholders we interviewed. Additionally, according to one document we reviewed, mandates and targets may impact deployment by encouraging the development of model regulatory frameworks that serve as examples to other states. States with storage mandates and targets may also serve as case studies to demonstrate the impact of energy storage deployment on a large scale and provide the industry with operational experience, examples of how to best integrate storage, and opportunities to evaluate storage.

Changes to Interconnection Rules. Some states have changed or are considering changes to interconnection rules to account for energy storage.[52] States are taking a number of approaches to revising interconnection rules. For example:

- In 2015, Hawaii's Public Utility Commission made changes to interconnection standards and energy policies to provide for the interconnection of energy storage to the grid.
- The Arizona Corporation Commission is developing statewide interconnection rules for distributed generation. Draft rules include interconnection requirements for energy storage systems and Commission officials told us that stakeholders are debating the scope and nature of those requirements.

Planning. Some states allow for the inclusion of energy storage in integrated resource and transmission planning processes; grid operators and utilities undertake these planning processes to ensure that the grid infrastructure has sufficient capacity and grid operators are able to meet future power demands. For example:

- The New Mexico Public Utility Commission's integrated resource planning rules require investor-owned utilities to evaluate all feasible energy resources as part of their resource planning process. When the Commission's integrated resource planning rules were originally implemented, energy storage was not commercially feasible;

[52]Interconnection rules include the technical procedures for allowing generation and other resources to connect to the grid.

however, the state commission recently amended these rules to include energy storage as a resource in planning.

- The Oregon Public Utility Commission directed Portland General Electric to address energy storage in its future integrated resource plans.
- Washington's Utilities and Transportation Commission directs utilities to demonstrate that, when considering a new resource acquisition, their analysis should include an evaluation of the costs and benefits of a storage alternative. The Commission also directs utilities procuring resources to issue requests for proposals that are technology neutral, allowing energy storage to bid.

Several states are also incorporating storage into broader energy planning efforts, including conducting research to identify the benefits of and opportunities for storage in the state. For example:

- North Carolina passed legislation directing the North Carolina Policy Collaboratory, at the University of North Carolina, to conduct a study on energy storage to address how and if storage may benefit consumers, the feasibility of storage in the state, and policy recommendations.
- Massachusetts has also undertaken a number of efforts including launching the Energy Storage Initiative, an initiative administered by the Massachusetts Department of Energy Resources and the Massachusetts Clean Energy Center to facilitate the deployment of storage and provide environmental and ratepayer benefits. As part of this initiative the 2016 State of Charge report was released and, among other things, identified barriers to energy storage adoption in the state and made recommendations to increase deployment of storage, setting a target of 600 MW of energy storage capacity by 2025.

Financial Incentives and Funding. Several states offer financial incentives including tax credits, tax exemptions, and rebate programs that encourage the deployment of residential, commercial and industrial energy storage systems by offsetting costs. For example:

- California's Self Generation Incentive Program—designed to help reduce emissions, demand, and customer electricity costs—provides rebates to support existing, new, and emerging distributed energy resources installed on the customer's side of the utility meter. This program is open to many different technologies, but according to the California Public Utilities Commission, the largest share of funding is allotted for energy storage projects.[53]

- In 2017, Maryland established a state tax credit for a percentage of certain installed costs of energy storage systems on residential and commercial property.
- Legislation has also been proposed in New York that would create a state tax credit for residential energy storage systems equal to 25 percent of costs up to $7,000.

A number of states offer funding for energy storage pilot and demonstration projects. For example:

- Massachusetts launched a $20 million grant program to pilot energy storage use cases to increase deployment of storage.
- The Washington Clean Energy Fund supports demonstration projects, including projects at utilities working with the Pacific Northwest National Laboratory to support understanding approaches to integrate and optimize storage control systems and development of a framework for evaluating the technical and financial benefits of storage.

In addition to the efforts described above, we found that several states have proposed or undertaken a range of other efforts that may encourage the deployment of energy storage or address market barriers. For example, the Arizona Corporation Commission required two electric utilities to develop residential battery storage programs in order to lower customers' energy use during peak demand. In addition, Maryland's Public Service Commission initiated a grid modernization rulemaking that,

[53]Qualifying technologies include wind turbines, waste heat to power technologies, pressure reduction turbines, internal combustion engines, microturbines, gas turbines, fuel cells, and advanced energy storage systems. According to the California Public Utilities Commission, California's Self-Generation Incentive Program will reserve 80 percent of these incentives for energy storage projects and 20 percent of its incentives for generation projects. While evaluation of this program has shown it is effective in reducing demand and customer bills, it has not reduced greenhouse gas emissions. Evaluators believe that this is the result of rate designs that are misaligned with peak marginal emissions hours, which prevent customers from receiving signals that would lead to reductions.

among other things, will define residential energy storage, determine a classification for storage in the Commission's rules, and create criteria to evaluate storage investments. Similarly, state legislation directs Oregon's Public Utility Commission to create a framework for utilities to use when conducting storage evaluations. Moreover, the California Public Utility Commission has approved rules that increase the ways for energy storage systems to obtain revenue for multiple uses, or grid services, for example, from frequency regulation, capacity, or other services.

Agency Comments

We provided a draft of this report to DOE, FERC, and IRS for review and comment. In its comments, reproduced in appendix II, FERC generally agreed with our findings. DOE and FERC provided technical comments which we incorporated as appropriate. IRS did not provide written or technical comments.

We are sending copies of this report to the appropriate congressional committees, the Secretary of Energy, the Chairman of FERC, the Commissioner of IRS, and other interested parties. In addition, the report is available at no charge on the GAO website at http://www.gao.gov.

If you or your staff members have any questions about this report, please contact me at (202) 512-3841 or ruscof@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff members who made major contributions to this report are listed in appendix III.

Frank Rusco
Director, Natural Resources and Environment

Appendix I: State Policies and Other Efforts Encouraging Deployment of Energy Storage

Through interviews with stakeholders and our review of documents, we identified examples of policies and other efforts that have encouraged the deployment of energy storage or aim to address market barriers, including the establishment of mandates and targets for storage adoption, the revision of interconnection rules and planning requirements, financial incentives, and funding. Table 1 describes examples of a range of state policies and other efforts that may encourage the deployment of energy storage.

Table 1: Examples of State Policies and Other Efforts Encouraging Deployment of Energy Storage

Policy or Effort	State	Status	Description
Mandates and Targets	Arizona	P	The Arizona Corporation Commission has proposed a target of 3,000 megawatts (MW) of deployed energy storage capacity by 2030. Eligible technologies would include the following categories: electrochemical, mechanical, thermal, and gravitational. The target would encourage a variety of sizes, ownership structures, and technologies, to be deployed in a prudent and responsible manner.
	California	✓	The California Public Utility Commission adopted an energy storage mandate requiring investor-owned utilities to collectively procure 1,325 MW of storage by 2020.
	Massachusetts	✓	The Massachusetts Department of Energy Resources adopted a 200 megawatt-hour storage target for electric distribution companies to collectively meet by January 2020.
	Nevada	✓	The Public Utility Commission must determine whether it is in the public interest to establish biennial targets for the procurement of energy storage by utilities.
	New York	✓	The Public Service Commission directed investor-owned utilities to have at least two energy storage projects deployed and operating at no fewer than two distribution substations or feeders by the end of 2018.
		✓	The Public Service Commission must establish an energy storage program and set a storage installation target for 2030. In January 2018, the Governor of New York announced an energy storage goal of 1.5 GW by 2025.
	Oregon	✓	Oregon is in the process of implementing a requirement for certain utilities serving more than 25,000 retail customers to procure energy storage systems with at least 5 megawatt hours of energy storage capacity by January 1, 2020.
	Vermont	P	House Bill 501 would direct the Department of Public Service to develop a policy recommendation and targets for storage capacity.
Changes to Interconnection rules	Arizona	P	The Arizona Corporation Commission proposed draft interconnection rules that include requirements for energy storage systems, and Commission officials told us that stakeholders are debating the scope and nature of those requirements.
	Colorado	P	The Colorado Public Utility Commission will consider adding energy storage in an upcoming rulemaking proceeding on interconnection rules.
	Hawaii	✓	Hawaii's Public Utility Commission made changes to interconnection standards and energy policies to provide for the interconnection of energy storage to the grid.

Policy or Effort	State	Status	Description
	Nevada	P	The Nevada Public Utility Commission opened an investigatory docket to explore energy storage technologies and interconnection issues.
Planning	Massachusetts	✓	The Massachusetts Department of Energy Resources and the Massachusetts Clean Energy Center launched the Energy Storage Initiative to facilitate the deployment of storage and provide environmental and ratepayer benefits.
	New Mexico	✓	The Public Utility Commission amended Integrated Resource Planning rules to include energy storage as a resource for utility planning purposes.
	North Carolina	✓	North Carolina directed a study on energy storage to address how and if storage may benefit consumers, the feasibility of storage in the state and policy recommendations.
	Oregon	✓	Oregon's Public Utility Commission directed Portland General Electric to address energy storage in future integrated resource plans.
	Washington	✓	The Washington Utilities and Transportation Commission's policy statement directs utilities to demonstrate when considering a new resource acquisition, that their analysis of options includes a storage alternative.
Financial Incentives	California	✓	The Self-Generation Incentive Program provides rebates for energy storage systems.
	Florida	✓	A partial property tax exemption was adopted for solar, wind, or geothermal storage devices.
	Hawaii	P	Senate Bill 665 would create a state tax credit for energy storage systems.
	Maryland	✓	A state tax credit was established for a percentage of certain installed costs of energy storage systems on residential and commercial property.
	Massachusetts	P	House Bill 2600 would allow municipalities to exempt storage systems from property tax, adopt a sales tax exemption for storage systems and direct establishment of a rebate for Massachusetts-based companies installing and manufacturing storage systems.
	Nevada	✓	The Nevada Public Utility Commission is required to establish, as part of an existing solar incentive program, incentives for the installation of energy storage systems.
	New York	P	Assembly Bill 6235 would create a state tax credit for residential energy storage systems equal to 25% of cost (up to $7,000).
	South Carolina	P	Senate Bill 44 would adopt an 80% tax exemption for distributed energy resources, including energy storage
Funding	Massachusetts	✓	The Department of Energy Resources announced a $20 million grant program under which it supported 26 energy storage projects totaling 32 MW of storage.
	New Jersey	✓	The New Jersey Clean Energy Program provides grants for energy storage projects integrated with behind-the-meter renewable energy projects at non-residential customer sites.
	New York	✓	The Public Service Commission approved a 10-year, $5.322 billion Clean Energy Fund, including a portfolio focused on addressing barriers for energy storage.
		✓	New York State Energy Research and Development Authority made available $15.5 million to support certain energy storage demonstration projects.

Policy or Effort	State	Status	Description
	Washington	✓	A Clean Energy Fund was created to expand clean energy projects and technologies, including energy storage. The fund includes about $112 million for clean energy projects from 2013 through 2019.
Other	Arizona	✓	The Arizona Corporation Commission ordered two electric utilities to develop residential battery storage programs and a program to facilitate energy storage technologies to help customers lower their energy use during peak demand.
	California	✓	Local governments must make documents and forms for advanced storage permitting public and accessible online beginning in September 2018.
		✓	The California Public Utility Commission has approved rules that increase the ways for energy storage systems to obtain revenue for multiple uses or grid services, for example, from frequency regulation, capacity or spinning reserve services.
	Connecticut	✓	The state's energy plan includes promoting the development of microgrids and energy storage technologies.
	Maryland	P	The Public Service Commission initiated a grid modernization rulemaking to include: defining residential energy storage, how it is classified in the rules, and criteria for evaluation of storage as a grid investment.
	New York	✓	The Public Service Commission approved a plan to (1) establish compensation values for battery storage systems when combined with eligible forms of distributed energy resources and (2) requires utilities to work with the state to integrate storage into the electric grid.
		P	Senate Bill 1225 would create a self-directed program for promoting, among other things, renewable energy, microgrids, fuel fells, and energy storage technologies.
	Oregon	✓	Public Utility Commission staff are directed to develop a framework for utilities to use in conducting storage evaluations.
	Pennsylvania	P	House Bill 1412 would authorize all distribution companies to propose energy storage and microgrid pilot programs.
	Washington	✓	The Utilities and Transportation Commission released an energy storage policy statement citing energy storage as a key technology for utilities to comply with the state's energy policy and that investor owned utilities should be working to pursue cost effective energy storage opportunities.

Legend:
✓ = established
P = proposed/under investigation as of May 16, 2018.

Source: GAO analysis of documents and studies. | GAO-18-402

Note: We reviewed documents and studies identifying and describing state policies and other efforts including reports from stakeholder and industry groups; and state government documents, reports, policies, and legislation. Given our methodology, we identified examples that illustrate the range of state policies and other efforts that may encourage the deployment of energy storage or address market barriers but the table does not represent a comprehensive list of state policies and efforts.

Appendix II: Comments from the Federal Energy Regulatory Commission

FEDERAL ENERGY REGULATORY COMMISSION
WASHINGTON, DC 20426

May 14, 2018

OFFICE OF THE CHAIRMAN

Mr. Frank Rusco
Director, Natural Resources and Environment
United States Government Accountability Office
441 G Street, NW
Washington, DC 20548

Dear Mr. Rusco:

Thank you for the opportunity to provide comments on behalf of the Federal Energy Regulatory Commission with respect to the Government Accountability Office's draft report entitled, "Energy Storage: Information on Challenges to Deployment for Electricity Grid Operations and Efforts to Address Them."

As you highlighted, the Commission has taken steps to address market barriers to energy storage, most recently through issuance of a final action on Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators. In addition, in April 2018, the Commission finalized action on its January 2017 proposals with respect to interconnection reforms referenced in your draft report. This final action, Order No. 845, will be published in the Federal Register soon. Order No. 845 adopts reforms designed to improve certainty for interconnection customers, promote informed interconnection decisions and enhance the interconnection process. While Order No. 845 is technology neutral and could benefit resources of all kinds, there are some reforms that electric storage facilities may find particularly relevant. These include reforms to potentially reduce interconnection costs, help expedite the interconnection process, allow new interconnecting projects to leverage existing assets, and allow a resource requesting interconnection to incorporate technology advancements without losing queue position. Notably, the Commission added storage to the definition of generating facilities to reduce a potential barrier to the interconnection of electric storage resources. GAO's examination of such issues is a timely contribution to this area of the Commission's work. I generally agree with the findings of the draft report, and I appreciate your attention to these matters.

Sincerely,

Kevin J. McIntyre
Chairman

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

Frank Rusco, (202) 512-3841 or ruscof@gao.gov.

Staff Acknowledgments

In addition to the contact named above, Karla Springer (Assistant Director), Antoinette Capaccio, Janice Ceperich (Analyst-in-Charge), Philip Farah, Kristen Farole, Paul Kazemersky, and Daniel Kojetin made key contributions to this report. Also contributing to this report were Tara Congdon, R. Scott Fletcher, Cindy Gilbert, and Dan C. Royer.

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