July 16, 2018

TO: Members, Subcommittee on Energy

FROM: Committee Majority and Minority Staff

RE: Hearing entitled "Powering America: The Role of Energy Storage in the Nation's Electricity System."

I. INTRODUCTION

The Subcommittee on Energy will hold a hearing on Wednesday, July 18, 2018, at 9:00 a.m. in 2322 Rayburn House Office Building. The hearing is entitled "Powering America: The Role of Energy Storage in the Nation's Electricity System." This hearing will examine the growth of large-scale energy storage in the United States, the unique reliability attributes energy storage provides for the electric grid, and the use and impacts of energy storage within wholesale electricity markets.

II. WITNESSES

- **Zachary Kuznar**, Director, CHP Microgrid and Energy Storage Development, Duke Energy;
- **Keith E. Casey**, Ph.D., Vice President, Market and Infrastructure Development, California Independent System Operator;
- **Kiran Kumaraswamy**, Director, Market Applications, Fluence;
- **Mark Frigo,** Vice President, Head of Energy Storage, North America, E.ON; and,
- **Kushal Patel,** Partner, Energy and Environmental Economics, Inc.

III. BACKGROUND

Energy storage resources have the ability to inject energy into the electric grid and receive energy from it. There are many different types of energy storage resources, including electrical, thermal, mechanical, and electrochemical technologies. According to the Energy Information Administration (EIA), for the United States, hydroelectric pumped storage, a mechanical technology, accounts for the greatest share of large-scale[1] energy storage power capacity. However, large-scale energy storage capacity additions since 2003 have been almost exclusively electrochemical—also known as battery storage—and most U.S. installations use

[1] The Energy Information Administration defines "large-scale" or "utility-scale" as systems that are connected to the grid and have a nameplate power capacity greater than 1 MW.
https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage.pdf

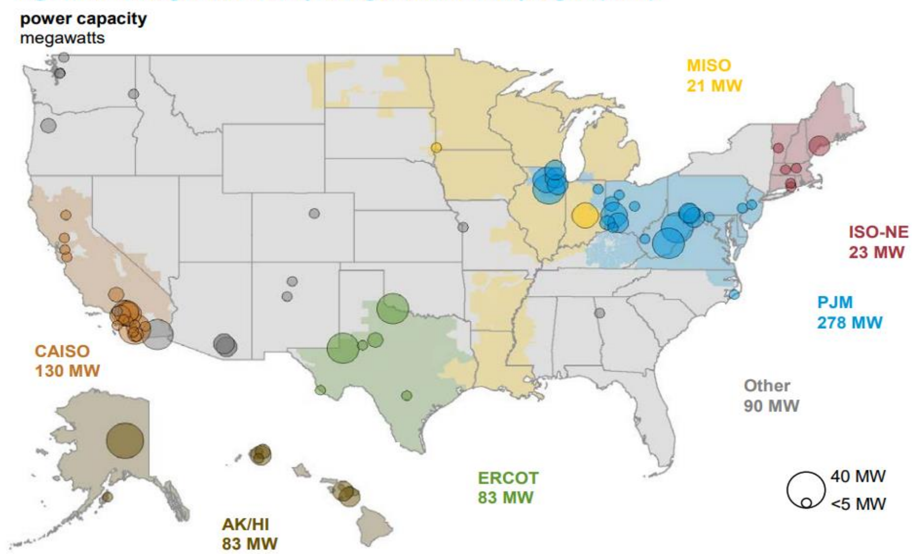
lithium-ion batteries. Currently, over 80 percent of the United States' large-scale battery storage capacity is provided by batteries based on lithium-ion.[2]

There are two categories of batteries – solid state and flow batteries. Solid state batteries have solid electrodes and electrolytes, where flow batteries operate with two chemical compounds dissolved in liquid. According to the Edison Electric Institute (EEI), electric utilities and companies primarily use lithium-ion and some lead-acid batteries because of their availability, price, and durability. Solid-state batteries, which include lithium-ion and zinc, typically last five to fifteen years, and flow batteries typically last fifteen to twenty years.[3]

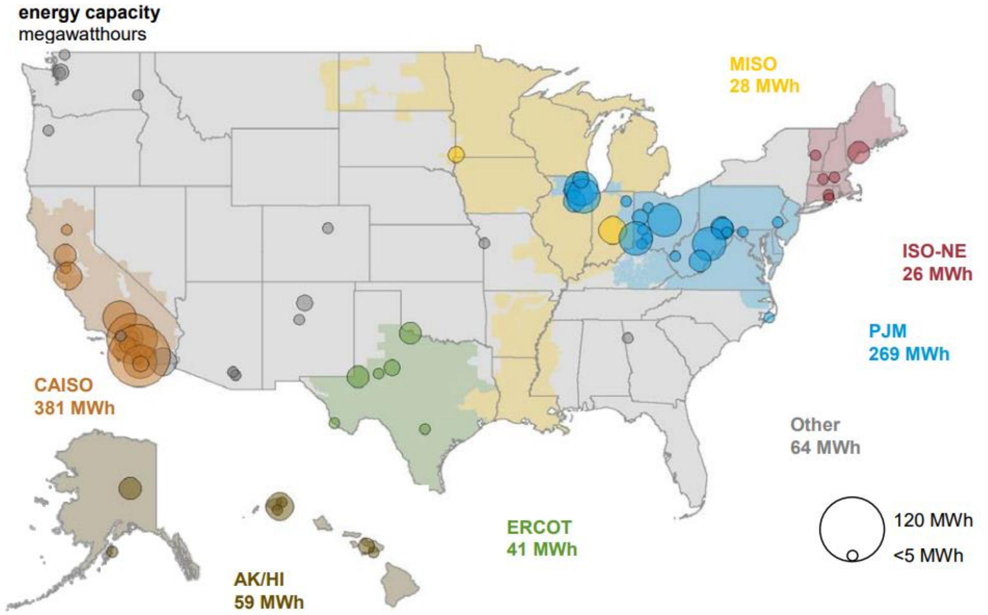
Batteries are characterized by two metrics – power capacity and energy capacity. Power capacity is the maximum instantaneous amount of power that can be produced on a continuous basis and is measured in megawatts (MW). Energy capacity is the total amount of energy that can be stored or discharged by the battery and is measured in megawatt hours (MWh).[4]

According to a recent report by the EIA, by the end of 2017, the United States had 708 MW of large-scale battery capacity in operation, representing 867 MWh of energy capacity.[5] As of 2017, the first large-scale battery storage installation in the United States still in operation entered into service in 2003. According to EIA, installed power capacity has nearly doubled every two years since 2011.[6] The EIA maps below show 2017 battery storage installations in the U.S., in terms of power capacity, and energy capacity, respectively.

Figure 2. U.S. Large-Scale Battery Storage Installations by Region (2017)



[2] Energy Information Administration, U.S. Dept. of Energy, *U.S. Battery Storage Market Trends*, (May 2018). https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage.pdf
[3] Edison Electric Institute, *Harnessing the Potential of Energy Storage – Storage Technologies, Services, and Policy Recommendations*, (May 2017). http://www.eei.org/issuesandpolicy/generation/Documents/EEI_HarnessingStorage_Final.pdf
[4] Energy Information Administration, U.S. Dept. of Energy, *The Design and Application of Utility-Scale Battery Storage Varies by Region*, (Feb. 28, 2018). https://www.eia.gov/todayinenergy/detail.php?id=35132#
[5] Energy Information Administration, U.S. Dept. of Energy, *U.S. Battery Storage Market Trends*, (May 2018). https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage.pdf
[6] *Id.*



Notes: Energy capacity data for large-scale battery storage installed in 2017 are based on preliminary estimates.
Sources: U.S. Energy Information Administration, Form EIA-860M, *Preliminary Monthly Electric Generator Inventory*; U.S. Energy Information Administration, Form EIA-860, *Annual Electric Generator Report*.

A. Applications and Attributes of Large-Scale Batteries

Large-scale energy storage has many applications and provides unique attributes that can improve the reliability and resiliency of the U.S. electric grid. Energy storage provides an array of services, including managing peak load, essential reliability services (voltage and frequency control), reserve capacity, and black start capability. In the United States, 88 percent of large-scale battery storage power capacity provides frequency regulation, which helps the electric system quickly balance frequency when unexpected differences in electricity supply and demand occur.[7]

i. Managing Peak Load or Peak Shaving

Energy storage can help manage peak load, often called peak smoothing or peak shaving. Generation is generally dispatched in order of cost (or bid) to meet load. When load is at its peak, more expensive units generally are used to meet the increased demand, and the overall cost increases. As the amount of power needed to serve load constantly changes, electric system operators must schedule or "dispatch" production by the generators to meet changing demands. Peak load is often met with generation resources that are able to start quickly but run for limited times, often called "peaker plants." When energy storage is incorporated, these systems can dispatch quickly and can hold several hours of energy that is generated during off-peak hours at a

[7] Energy Information Administration, U.S. Dept. of Energy, *U.S. Battery Storage Market Trends*, (May 2018). https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage.pdf

lower cost, and then be deployed during costlier high-demand periods, also known as "energy time shifting."[8]

ii. Essential Reliability Services – Frequency Regulation and Voltage Control

Energy storage can also provide two essential reliability services – frequency regulation and voltage support. According to EEI, for the United States, electric system frequency regulation is the moment-to-moment response to frequency deviations from the standard 60 Hertz (Hz), and control is necessary to prevent a cascading failure of the electric system. Energy storage can play a key role in correcting for unintended fluctuations in output from generators that can cause frequency deviations.[9]

Another essential reliability service that energy storage can provide is voltage support. According to EEI, voltage support is necessary to maintain proper operation of equipment, prevent damage to connected generators from overheating, facilitate energy transfers, and reduce transmission loss. Energy storage can improve voltage support by providing or absorbing reactive power and by helping to maintain specific voltage level on the electric grid.[10]

iii. Reserve Capacity and Black Start Capabilities

Energy storage helps contribute to electric grid reliability through reserve capacity. Reliability requirements instruct electric companies to keep certain amounts of available generation capacity, or "reserves," which can be accessed quickly in case of disruption or unexpected variations in the demand of electricity. When utilized, energy storage can be dispatched quickly to help meet peak demand, thus making it easier to comply with reserve requirements.[11]

The electricity industry must constantly plan and be prepared for disruptions to the supply of electricity. When power outages occur, electric utilities and companies can use black-start resources to restore service quickly. "Black start" is the process of bringing a power plant back online without help from the transmission network, and is an essential service needed to restore power after an outage. Energy storage can assist a power plant in coming back online, in part due to its fast response capabilities.[12]

B. Energy Storage Costs

According to the Electric Power Research Institute (EPRI), several large-scale lithium-ion battery projects have entered the market in recent years, with the increase in large-scale

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[8] Edison Electric Institute, *Harnessing the Potential of Energy Storage – Storage Technologies, Services, and Policy Recommendations*, (May 2017).
http://www.eei.org/issuesandpolicy/generation/Documents/EEI_HarnessingStorage_Final.pdf
[9] Edison Electric Institute, *Harnessing the Potential of Energy Storage – Storage Technologies, Services, and Policy Recommendations*, (May 2017).
http://www.eei.org/issuesandpolicy/generation/Documents/EEI_HarnessingStorage_Final.pdf
[10] *Id.*
[11] *Id.*
[12] *Id.*

projects being driven by rapidly falling costs on both the supply and demand side.[13] According to EEI, although the costs of some energy storage devices are declining, high costs are still a challenge to wider deployment of energy storage.[14]

Beyond capital costs, battery storage prices can be financed through power purchase agreements (PPAs). PPA projects are owned and operated by entities that supply electricity to a customer, often an electric utility, at a fixed price per unit of electricity delivered. As EIA notes, PPA prices are often heavily influenced by each project's specifications, contract terms, and other project-specific factors – these differ from capital costs and are not necessarily reflective of total capital costs of the electricity system.[15]

C. <u>Energy Storage in Wholesale Electricity Markets</u>

For the United States, about 90 percent of large-scale battery storage is installed in regions covered by five of the seven organized regional transmission organizations (RTOs) and independent system operators (ISOs). These regions account for 53 percent of total U.S. large-scale power capacity and have the largest shares of storage capacity relative to their shares of total installed capacity.[16]

RTOs/ISOs are independent, federally-regulated non-profit organizations that ensure reliability and optimize supply and demand bids for wholesale electric power. RTOs/ISOs are by design, technology neutral, and must ensure their market rules do not unfairly preclude any resource from participating, as enforced by the Federal Energy Regulatory Commission (FERC). According to EIA, about two-thirds of large-scale (utility) battery storage power capacity installed in 2016 in the United States is located in two electricity markets, the California Independent System Operator (CAISO), which covers most of California, and the PJM Interconnection, which covers all or parts of 13 eastern states and the District of Columbia.[17]

The PJM Interconnection currently has the most utility-scale battery storage capacity with nearly 40 percent of power capacity, and 31 percent of energy capacity. In 2012, the PJM Interconnection created a new frequency regulation market product for fast-responding resources, and the conditions were favorable for battery storage.[18] In 2017, the CAISO territory, had 18 percent of existing U.S. large-scale battery storage power capacity and 44 percent of existing battery storage energy capacity. According to EIA, large-scale installations in California

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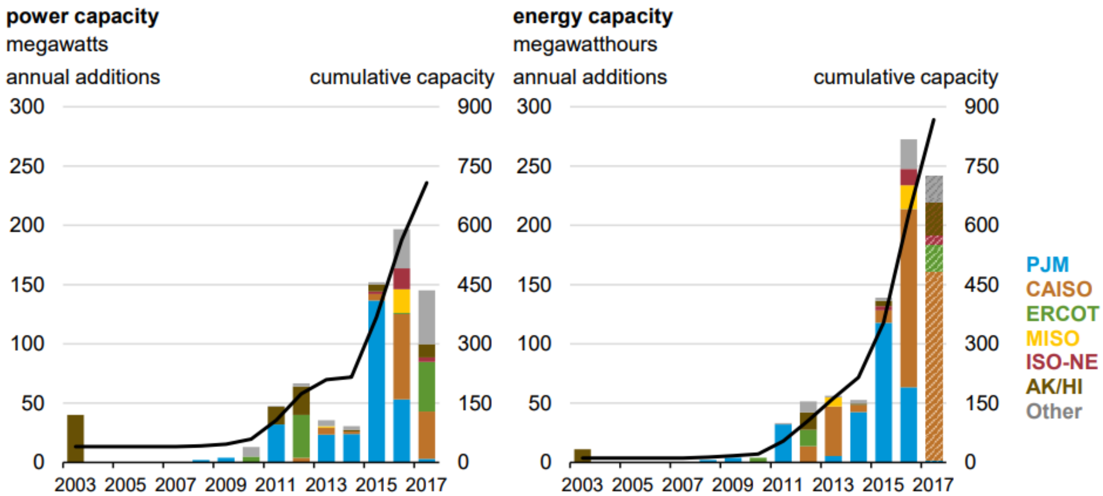
[13] Electric Power Research Institute, *Quick Insights: Evolution in the Lithium Ion Battery Industry*, (Mar. 29, 2017). https://www.epri.com/#/pages/product/000000003002010978/?lang=en
[14] Edison Electric Institute, Harnessing the Potential of Energy Storage – Storage Technologies, Services, and Policy Recommendations, (May 2017). http://www.eei.org/issuesandpolicy/generation/Documents/EEI_HarnessingStorage_Final.pdf
[15] Energy Information Administration, U.S. Dept. of Energy, *U.S. Battery Storage Market Trends*, (May 2018). https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage.pdf
[16] *Id.*
[17] Energy Information Administration, U.S. Dept. of Energy, *The Design and Application of Utility-Scale Battery Storage Varies by Region*, (Feb. 28, 2018). https://www.eia.gov/todayinenergy/detail.php?id=35132#
[18] Energy Information Administration, U.S. Dept. of Energy, *U.S. Battery Storage Market Trends*, (May 2018). https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage.pdf

tend to provide energy-oriented services, thus serving a wider array of applications, beyond only frequency regulation.

Figure 3. U.S. Large-Scale Battery Storage Capacity by Region (2003–2017)



Notes: Energy capacity data for large-scale battery storage installed in 2017 are based on preliminary estimates. Energy capacity additions do not include 26 MW of since-retired batteries since energy capacity is not reported for retired generators.
Sources: U.S. Energy Information Administration, Form EIA-860M, *Preliminary Monthly Electric Generator Inventory*; U.S. Energy Information Administration, Form EIA-860, *Annual Electric Generator Report*.

i. FERC Order 841

On February 15, 2018, FERC unanimously issued Order No. 841,[19] which amended the Commission's regulations under the Federal Power Act (FPA) to remove barriers to the participation of electric storage resources in the capacity, energy, and ancillary services markets operated by RTOs/ISOs. Pursuant to this rule, FERC found that, "existing RTO/ISO market rules are unjust and unreasonable in light of barriers that they present to the participation of electric storage resources in the RTO/ISO markets, thereby reducing competition and failing to ensure just and reasonable rates."[20]

Based on this determination, the Commission required each RTO/ISO to revise its tariff provisions to establish market rules that, recognizing the physical and operational characteristics of electric storage resources, facilitate their participation in the markets. Specifically, the Commission stated that:

> For each RTO/ISO, the tariff provisions for the participation model for electric storage resources must (1) ensure that a resource using the participation model for electric storage resources is eligible to provide all capacity, energy, ancillary services that it is technically capable of providing in the RTO/ISO markets; (2) ensure that a resource using the participation model for electric storage resources can be dispatched and can set wholesale market clearing price as both a wholesale seller and wholesale buyer consistent with

[19] *See* FERC Order No. 841, Docket Nos. RM16-23-000, AD16-20-000, 83 Fed. Reg. 44 (March 6, 2018) (to be codified at 18 CFR pt. 35). https://www.gpo.gov/fdsys/pkg/FR-2018-03-06/pdf/2018-03708.pdf
[20] *Id.*

existing market rules that govern when a resource can set wholesale price; (3) account for the physical and operational characteristics of electric storage resources through bidding parameters or other means; and, (4) establish a minimum size requirement for participation in the RTO/ISO markets that does not exceed 100 kW. Additionally, each RTO/ISO must specify that the sale of electric energy from the RTO/ISO markets to an electric storage resource that the resource then resells back to those markets must be at the wholesale locational marginal price (LMP).[21]

The final rule will take effect 90 days after publication in the Federal Register. RTOs and ISOs will have 270 days after the publication date to submit compliance filings, with an additional 365 days from that date to fully implement the new tariff provisions.

IV. ISSUES

The following issues may be examined at the hearing:

- Application of large-scale energy storage in the United States electric grid;
- Operational attributes of large-scale energy storage and its benefits for consumers;
- Potential barriers to entry and competitiveness of large-scale energy storage in wholesale electricity markets, including FERC Order No. 841; and,
- Major developments in large-scale energy storage through advanced technologies.

V. STAFF CONTACTS

If you have any questions regarding this hearing, please contact Annelise Rickert, Wyatt Ellertson or Mary Martin of the Majority Committee staff at (202) 225-2927, and Rick Kessler of the Minority Committee staff at (202) 225-3641.

[21] *See* FERC Order No. 841, Docket Nos. RM16-23-000, AD16-20-000, 83 Fed. Reg. 44 (March 6, 2018) (to be codified at 18 CFR pt. 35). https://www.gpo.gov/fdsys/pkg/FR-2018-03-06/pdf/2018-03708.pdf