



Department of Energy  
Washington, DC 20585

April 5, 2018

MEMORANDUM TO THE DEPARTMENT OF ENERGY  
ELECTRICITY ADVISORY COMMITTEE

FROM: Bruce Walker, Assistant Secretary  
Office of Electricity Delivery and Energy Reliability

SUBJECT: DOE Response Electricity Advisory Committee Recommendations  
2016 Storage Plan Assessment Recommendations

A handwritten signature in black ink, appearing to be "BW", written over the printed name and title of the sender.

I want to thank all members of the Department of Energy's Electricity Advisory Committee for their thoughtful recommendations on the efforts within the Office of Electricity Delivery and Energy Reliability to advance energy storage technology for grid-scale applications.

The purpose of this memo and its attachments is to provide you with our response to your recommendations. We agree with the majority of the Committee's suggestions and provide an update on our current and planned efforts that are relevant to them. Otherwise, we provide comments where we are limited in our ability to pursue certain recommendations or where we believe that they are beyond the scope of the program.

I look forward to continued discussions on the path of our energy storage program and am committed to ensuring a strong and fruitful working relationship between the Committee and this office.

Thank you.



## **DOE Response to the Electricity Advisory Committee Recommendations: September 2016 Storage Plan Assessment Recommendations**

The Electricity Advisory Committee's (EAC) Biannual Storage Plan Assessment issued in September 2016 offered a set of fifteen recommendations to enhance the development and deployment of energy storage technologies, policies, and programs to help ensure an effective, resilient, electric power system. We understand that the EAC's recommendations are provided pursuant to requirements set forth in Section 641 ("Energy Storage Competitiveness") of the Energy Independence and Security Act of 2007 (EISA), which requires the development and review of the Department's energy storage strategy.

The Office of Electricity Delivery and Energy Reliability (OE) greatly appreciates the efforts of the EAC in reviewing the activities of this office related to research and development of grid-scale energy storage technology and values the insights offered by the EAC members. OE has reviewed the fifteen recommendations of the EAC report and has organized responses under the three areas: (A) General Assessments and Recommendations, (B) Technology Development, and (C) Economics and Markets.

### **A. General Assessments and Recommendations**

#### ***Recommendation Area 1: Visibility***

***EAC:*** *There is very limited visibility of and public relations around the Department's high-quality energy storage-related RD&D program (which includes efforts on the parts of OE, EERE, ARPA-E, and SC) to entities working in the electricity industry.*

**OE:** Sharing information on our research accomplishments is vitally critical to the success of our program, and it is broadly accepted that energy storage technology within the United States provides capabilities that can enhance the efficiency, flexibility, reliability, and resilience of the electric grid. While it is important for the general public to understand the promise of energy storage systems, our outreach efforts are primarily focused on the research community, industry professionals, policy makers, and regulators that are ultimately responsible for making decisions to advance and apply the technology to improve grid performance.

The Energy Storage Systems R&D Program (ESS Program) within the Office of Electricity Delivery and Energy Reliability (OE) receives considerable coverage in the industry press, including Energy Storage News, GreenTech Media, and other trade news outlets and actively disseminates information on technological advances and applications through various reports and other media. The ESS Program's research accomplishments are regularly featured in news reports issued by the Energy Storage Association and the National Alliance for Advanced

Technology Batteries (NAATBatt). In addition, the ESS Program website provides news and updates which are viewed by over 13,000 subscribers. The ESS Program website may be found at: <https://energy.gov/oe/activities/technology-development/energy-storage>

The program also maintains a publicly available archive of projects at [www.sandia.gov/ess](http://www.sandia.gov/ess) with published papers, patents, reports, standards and protocol documents, including:

- ESS Program Review Presentations, 2001 through 2016.
- Proceedings of the Biennial Electrical Energy Storage Applications and Technology (EESAT) Conference, 2000 through 2017.
- Presentations associated with the ESS Safety Forum, held during February 22-24, 2017.
- Presentations associated with the Energy Storage and Grid Integration Regional Workshop, held during August 23, 2016.
- A listing of peer-reviewed journal publications and conference proceedings, as well as articles that are openly accessible.
- An archive of patents and patent applications.
- Technical Reports produced by national laboratories, including Sandia National Laboratory (Sandia), Pacific Northwest National Laboratory (PNNL) and Oak Ridge National Laboratory (ORNL).
- DOE Performance Protocols.

Additional reports and presentations are also available at the ESS Program's website mentioned earlier.

### ***Recommendation Area 2: Accessibility of Research***

***EAC:*** Results and key takeaways of the Department's energy storage-related research are not easily accessible to regulators, utilities, and electricity consumers.

**OE:** To appropriately share the results of R&D efforts, the ESS Program has partnered with federal, state, and municipal organizations to analyze the use of energy storage systems, assess costs and benefits, and develop tools for utility customers and regulatory agencies for planning and implementing deployment of the technology. This approach provides an environment where energy storage deployment and service opportunities are recognized, appropriately valued, and implemented.

OE publishes comprehensive reports of research outcomes from R&D projects supported by the ESS Program and encourages the dissemination of research results through peer-reviewed journals. In addition, a significant number of fact sheets have been developed on individual projects and are available online. OE will continue to encourage the development of



communications materials for those projects where such fact sheets have not been produced.

In addition, ESS Program researchers take active roles in industry conferences and events including organizing panels, chairing sessions, and giving technical talks. During FY17, staff chaired or organized technical sessions at major industry conferences including Energy Storage North America, Solar Power International, InterSolar, Battcon, the Energy Storage Association Annual Meeting and NAATBatt.

### ***Recommendation Area 3: State Regulator and Storage-User Education***

***EAC:*** *There is great disparity in the information level of state regulators around storage technologies.*

***OE:*** With over 3,000 utilities operating in the country, sharing the results of R&D activities (as noted above) and supporting technical demonstrations are critical for validating the safety and performance of energy storage systems and providing a more detailed understanding of the benefits to grid operations. Current and proposed future efforts by the ESS Program to develop, validate, and evaluate energy storage technology for grid-scale applications will mitigate these challenges and enable more effective deployment.

Regulators and utility professionals are critically important stakeholder groups who need to understand the attributes and potential of grid-scale energy storage. The ESS Program has found that these organizations need technical assistance to guide field validations that achieve optimal results and enhance their knowledge base. Such assistance includes providing economic analysis, commissioning support, and technical evaluation for proposed demonstrations. Providing technical assistance assures that field validation efforts address the appropriate technical issues and inform the comprehensive reports that target wider industry stakeholders. Appendix 1 provides more information on the technical support provided to various states.

The ESS Program has also organized workshops for regulators in Western states. In these workshops, program staff reviewed each state's energy storage activities, shared DOE research, and discussed next steps for state needs (see Appendix 2 for more information on the workshops). In addition, the program sponsored the development of an introductory handbook for State Electric Utility Regulators, entitled *Evaluating Utility Procured Electric Energy Storage Resources: A Perspective for State Electric Utility Regulators*.<sup>1</sup>

These efforts have not only helped inform the efforts of public utility commissions regarding the attributes of energy storage, but they have helped their staff better understand the technical and institutional challenges facing greater adoption of grid-scale energy storage.

#### **Recommendation Area 4: Program Goals**

*EAC: The Department has produced many well regarded and highly respected studies of future energy systems, such as the Renewable Electricity Futures Study, which show the transformative role that energy storage can play. It has not, however, established a vision of this energy future in the public's eye.*

**OE:** An understanding of the potential future requirements of an advanced grid are essential for developing R&D strategies and informing the public and key stakeholders on the merits of technology. However, the Department recognizes that the pace and scope of energy system transformation is highly dependent upon the policies set forth by many separate jurisdictions and the availability of technology; therefore, multiple, co-existing futures are possible. The Department is careful not to formulate a single reference design or vision for an advanced grid, but rather focus on solving major issues that will lead to storage becoming a critical and vital element of the future power grid where it can provide tangible benefits in a timely manner.

As set forth in the 2013 DOE Grid Energy Storage strategy document,<sup>ii</sup> the ESS Program is focused on 4 primary goals:

- 1) Develop new, cost-competitive technologies,
- 2) Improve the safety and reliability of deployed systems,
- 3) Identify market barriers for effective storage deployments, and
- 4) Support industry assessment of storage technologies.

To achieve these goals, the program conducts a broad research effort that encompasses advanced materials research including the development of flow batteries, sodium batteries, alkaline batteries and flywheels. The program continues to support research on the development of next generation materials for power electronics, including wide bandgap semiconductor materials, soft magnetic materials, and high-voltage capacitors that are required for efficient power conversion. The program also supports basic and applied research to improve the safety and reliability of energy storage systems, development of tools for optimization, and operation of energy storage systems in the utility grid.

Collaborative efforts with the electric industry, including through program reviews, represent activities for receiving feedback and determining the requirements needed to fulfill the program's goals. This coordinated approach emphasizes broad-based research that advances new technologies that can meet the industry's cost and performance requirements. The approach provides the greatest opportunity for the successful integration of storage into the U.S. grid infrastructure while bolstering U.S. based manufacturing of storage technologies and systems.

The performance and lifetime of storage systems for grid-scale purposes (e.g., requiring



thousands of duty cycles) must be quantified and disseminated throughout the industry. Over the past couple of years, the Department has initiated several efforts to better understand long-term performance and reliability of emerging energy storage systems. These efforts have occurred at both national and international levels in conjunction with national laboratories and industry.

In 2016, the ESS Program held a reliability workshop with stakeholders from utilities, technology developers, federal agencies, and academia resulting in a strategy to address reliability. The following objectives were articulated:

1. To conduct research and development targeting the identification and mitigation of degradation and failure mechanisms, as well as accelerated life testing,
2. To develop standard testing protocols and conduct independent testing of prototypic storage devices under accepted utility use cases, and
3. To track, document, and make available information on the performance of installed storage systems.

In addition, the ESS Program's stated cost and performance goals for energy storage are to achieve:

- A total, installed system cost of \$150/kWh by 2022 (for a flow battery)
- And, by 2028:
  - A total, installed system cost of \$100/kWh,
  - The ability to accommodate 2 long-duration cycles (with deep discharge for each cycle) per day,
  - An output duration of 6 hours per cycle, and
  - A lifetime of 10,000 cycles (about 20 years).

### ***Recommendation Area 5: Pilot and Demonstration Projects***

*EAC: Pilot and demonstration energy storage projects are praised as being very helpful.*

**OE:** The Department is working with industry and government partners in many energy storage projects across the country to enable an enhanced understanding of the useful application of storage technology. Providing technical assistance for field validations helps to achieve optimal results which can then be shared to enhance our knowledge base. Such assistance includes providing economic analysis, commissioning support, and technical evaluation for proposed demonstrations.

Although significant strides have been made over the past decade, the adoption of grid-scale energy storage today is still largely limited by the cost of energy storage systems (which

depends largely on the price of electricity in a given region), a lack of industrial confidence in the safety and reliability of these systems, and an incomplete understanding by industry and regulators as to the services and benefits storage can provide given the myriad applications possible.

The ESS Program shares the results of these projects through several mechanisms. For example, a webinar series, available to a wide range of stakeholders in the electric utility industry, is provided through the Energy Storage Technology Advancement Partnership (ESTAP). These webinars have covered topics ranging from providing lessons learned from demonstrations, the commissioning and operation of energy storage systems, and the financial considerations of energy storage projects. Recent webinars included discussions on utility class demonstration projects at Green Mountain Power and Sterling Municipal Light Department, as well as a behind-the-meter project, the McKnight Lane Redevelopment project.<sup>iii</sup> As shown in Appendix 2, 19 webinars were provided with a total attendance of almost 3,300 attendees during FY17.

Along with regular ESTAP webinars, program staff and utility demonstration partners continue to participate in a range of events to help industry with engineering and deployment challenges, as well as with state energy agencies and regulators on the benefits of energy storage for the electricity infrastructure and markets. As mentioned above, Appendix 2 provides additional details on the FY17 webinars, recent events, and presentations.

The ESS Program has also provided technical assistance in field demonstrations to Sterling Municipal Light (Massachusetts), the Natural Energy Laboratory of Hawaii Authority (Hawaii), the Eugene Water and Electric Board (Oregon), and the City of St. Mary's (Alaska). In addition, various demonstration projects funded through efforts undertaken through the DOE Grid Modernization Laboratory Consortium (GMLC) have enabled the program to compare the operation, control, performance and financial return of energy storage systems in various locations within the United States, each presenting unique operational and financial challenges. Representative projects include those undertaken with Green Mountain Power (Vermont), the Electrical Power Board of Chattanooga (Tennessee), Portland Gas and Electrical (Oregon), and Los Alamos County (New Mexico).

The program's approach for demonstration projects includes extensive cooperation with the Independent System Operators (ISOs), Regional Transmission Organizations (RTOs), utilities, and other stakeholders involved or affected by each installation. The result of these partnerships includes lessons learned associated with project siting and sizing that can then be leveraged for designing future energy storage projects. These lessons learned are covered in webinars and conferences to broadly disseminate this valuable information.



### **Recommendation Area 6: Funding and Resources**

*EAC: Across the board, there is industry recognition that the Department is providing a useful service through its energy storage-related RD&D programs. It is becoming increasingly difficult for utilities to recover research-related costs and they cannot undertake major research programs.*

**OE:** The Department agrees that additional R&D spending within the electric utility industry with support by government funds would help utilities and regulators examine and test technologies that might provide useful benefits. Given funding availability, the ESS program will continue to work closely with technology developers, utilities and regulators to advance energy storage technology and deliver research and technical support that maintains America's global competitiveness in this emerging field. The scope and pace of grid modernization must be done in a practical manner and in a way that meets expectations driven by policy objectives and customer expectations, while maintaining affordability.

### **Recommendation Area 7: Program Coordination**

*EAC: The Department's energy storage-related RD&D programs are historically spread out between OE and EERE. ARPA-E is also increasingly involved in energy storage-related RD&D. Moreover, some specific technology programs (e.g. wind, solar) are increasingly interested in and funding energy storage-related RD&D.*

**OE:** The Department works to develop a cross-cutting portfolio of R&D projects through collaboration among the various offices, including OE, the Basic Energy Sciences (BES) program and the Office of Energy Efficiency and Renewable Energy (EERE). The Department will continue to encourage more effective collaboration across the programs. Efforts like the Grid Modernization Initiative and the supporting activities of the GMLC ensure that projects are not duplicative and funding is leveraged to its maximum potential. For example, a recent study on the impact of frequency regulation duty cycles on the expected lifetime of Li-Ion battery technologies was supported by both the OE ESS Program and the EERE Vehicles Technology Program. This provided both programs with information on how Li-Ion technologies developed for the electric vehicle industry will perform as grid service providers and how that would impact their overall performance.

The GMLC was established under the leadership of OE and EERE to develop a strategic partnership between DOE and the national laboratories, bringing together leading experts, technologies, and resources to collaborate on the goal of modernizing the nation's grid. The benefits of the GMLC include more efficient use of resources, shared networks, improved learning and preservation of knowledge, enhanced lab coordination and collaboration, and regional perspective and relationships with local stakeholders and industry.



## **B. Technology Development**

### ***Recommendation Area 8: Technology Focus***

*EAC: There are wide-ranging views on which specific technologies the Department should focus its attention.*

**OE:** The primary focus of the ESS Program continues to be on the development of cost-effective energy storage technologies for stationary applications in the utility grid. As mentioned above (see Recommendation 4), the program conducts a broad research effort that encompasses a focus on various chemistries, materials, and systems to improve such parameters as life-time cost, roundtrip efficiency, energy and power density, cycle life, and capacity fade. The program also continues to support research on the development of next-generation materials for power electronics, including wide bandgap semiconductor materials, magnetic materials, and capacitors that are required for efficient power conversion. In addition, the program supports basic and applied research to improve the safety and reliability of energy storage systems, as well as the development of analytical tools to assess optimal applications in the electric grid.

### ***Recommendation Area 9: Safety***

*EAC: People see reports in the popular media about lithium-ion batteries catching fire or similar stories about safety issues with energy storage technologies. Such reporting makes consumers nervous about the technology.*

**OE:** The safety of energy storage systems is a critical issue for increased acceptance of the technology by the electric utility industry. Utility-scale demonstrations and efforts in advancing safety protocols and standards enable industry to overcome their concerns regarding the safety and reliability of energy storage technologies and help speed adoption across the electricity infrastructure. Efforts to support a scientifically derived knowledge base with respect to the development of new protocols, codes, and standards for safety and reliability will improve the current understanding and predictability of grid-scale energy storage.

The ESS Program has a comprehensive R&D and outreach program on energy storage safety. This activity is publicly available on the ESS Program's website at <http://www.sandia.gov/energystoragesafety/> and [www.sandia.gov/ess](http://www.sandia.gov/ess). The genesis of the activity occurred in developing the ESS Program strategy (see the *2013 DOE Grid Energy Storage* strategy document) in which "Validated Reliability and Safety" was identified as one of four R&D focus areas.

To address this strategy, the program organized a two-day workshop on energy storage system

safety in Albuquerque, New Mexico, in February 2014. The workshop attracted over 100 participants from relevant stakeholders, including storage system manufacturers, engineering and construction companies, investor owned utilities, municipal utilities and rural co-operatives, first responders, test and standards organizations like United Laboratories (UL), North American Electric Reliability Corporation (NERC), and researchers from national laboratories and universities.

The output of the workshop was used to develop the *2014 DOE OE Energy Storage Safety Strategic Plan*.<sup>iv</sup> This strategy document has served as a guide for developing a comprehensive research and outreach effort to organize stakeholders concerned in energy storage safety through the formation of topical working groups. Over the past three years these groups have hosted public webinars and formed task forces to develop ESS safety training material.

In February 2017, the Department organized the first annual ESS Safety Forum in Santa Fe, New Mexico. This two-day meeting led to the creation of a *DOE OE Energy Storage Systems Safety Roadmap*,<sup>v</sup> an ESS Safety website ([www.sandia.gov/energystoragesafety](http://www.sandia.gov/energystoragesafety)) with monthly codes and standards reports, and a bimonthly newsletter (available at [www.sandia.gov/energystoragesafety/news](http://www.sandia.gov/energystoragesafety/news)) that has reached over 500 subscribers.

There is also an online data repository to support the broad-based research effort toward the advancement of energy storage safety.<sup>vi</sup> The ESS Program remains engaged with National Fire Protection Association, the Electric Power Research Institute, the Institute of Electrical and Electronics Engineers, and many other organizations from a comprehensive list of stakeholder groups (see [www.sandia.gov/energystoragesafety/external-resources](http://www.sandia.gov/energystoragesafety/external-resources)).

### ***Recommendation Area 10: Energy Storage Database***

*EAC: There was generally much praise for the DOE Global Energy Storage Database. It was particularly noted that it is wonderful that this resource is free to use.*

**OE:** The ESS Program is updating the DOE Global Energy Storage Database.<sup>vii</sup> The goal is to make the database a comprehensive resource for up-to-date project information on grid-connected energy storage projects. Currently, the database has information on over 1600 projects and site has received 2 million page-views in FY17. The site is undergoing revisions which includes a new vetting process to improve the reliability of project details. Further development plans include legislation tracking that relate to utility-scale energy storage to highlight opportunities and address potential policy barriers.

### ***Recommendation Area 11: Operational and Planning Modeling***

*EAC: Many interviewees noted severe limitations in being able to model energy storage for*



*operational and longer-term planning purposes. Simply put, existing private-sector tools are extremely lacking in their ability to model energy storage.*

**OE:** The ESS Program has supported the development of tools for engineering analysis and planning of energy storage systems for utilities, utility customers, third-party merchants, and system operators. The Department actively encourages and supports the wide availability of software products for open-access license-free use. The tools and analysis methodologies developed under the ESS Program are supported by the national laboratories and universities and have been used by other federal and commercial agencies to evaluate energy storage deployments. It is worth noting, however, that the ability to model a mixed set of distributed energy resources, including energy storage, is under development by the private sector, universities and the national laboratories for both operational and planning purposes.

Examples of planning tools developed with sponsorship from the ESS program include:

- The Battery Storage Evaluation Tool (BSET)<sup>viii</sup> which simulates the use of an energy storage system to meet multiple objectives and can determine the optimal dispatch such that total economic benefits are maximized. The tool simulates one year of battery storage operations to evaluate the services to the power grid, including energy arbitrage, balancing service, capacity value, distribution system equipment deferral, and outage mitigation. Application of BSET has been used to determine the added resiliency benefits of energy storage within microgrids at U.S. Army bases in California and has been licensed, royalty-free, to more than 10 nonfederal entities.<sup>ix, x</sup>
- The Optimal Sizing Tool for Battery Storage<sup>xi</sup> determines the benefit of placing a storage system behind the meter, including providing an optimal size with respect to energy and power characteristics.
- The Energy Storage Select (ES-Select) decision support tool<sup>xii</sup> enables users to improve the understanding of different electrical energy storage technologies and their feasibility for intended applications in a simple, visually comparative form.

The ESS program is continuing to support the development of a suite of advanced optimization, analysis and modeling tools with improved functionality and data analytics. Much work has been undertaken at Pacific Northwest National Laboratory to develop valuation methodologies and tools, as well as models for evaluating the performance of battery systems under specific applications and operating modes. In addition, Sandia National Laboratories is developing a software tool kit for utilities and potential investors to perform cost/benefit analyses of various storage technologies, including examining locational value, sizing, and potential revenue opportunities. A beta version of the tool kit was demonstrated in December 2017, and a full version the first release of this open source tool set will be released available in June 2018. The software toolset will evaluate energy storage as it operates with other distributed resources, essentially analyzing the operation of energy storage for microgrid and behind-the-meter

applications.

The variety of methodologies used to assess and optimize the application of energy storage systems can be found within a comprehensive review paper, entitled *Energy Management and Optimization Methods for Grid Energy Storage Systems*.<sup>xiii</sup>

## **C. Economics and Markets**

### ***Recommendation Area 12: Value of Energy Storage***

**EAC:** *It is well recognized by the Department and others that there are major economic issues that hamper the growth of energy storage capacity. It is difficult for an energy storage owner to get paid for the full range of services that it can provide.*

**OE:** The ESS Program has supported research on the value of energy storage for various applications, including the development of models and tools (see the OE response under Recommendation Area 11: Operational and Planning Modeling), as well as conducting several valuation studies performed for a wide variety of stakeholders (see the OE response under Recommendation Area 15: Valuation Studies). These efforts have identified and assessed a large range of value streams for a variety of applications and owners.

It is well understood that the value of an energy storage device is highly location-specific and dependent upon the price of electricity, as well as market and regulatory policies. A detailed review of energy storage benefits, including drivers and challenges for storage applications is found in *Energy Storage for the Electric Grid: Benefits and Market Potential Assessment Guide*.<sup>xiv</sup> The program will continue to work with utilities, technology vendors and officials within federal, state and local governments to disseminate its work on developing models and tools to evaluate and plan for the optimal application of energy storage technology. The program will also continue to pursue research to develop new potential value streams for energy storage. An example is wide area damping control to improve small signal stability in large power grids.<sup>xv</sup> This research was recognized with an R&D100 Award in 2017.

The program has also issued a report, *Market and Policy Barriers to Energy Storage Deployment*<sup>xvi</sup> which identifies, discusses, and categorizes five barriers to energy storage adoption:

- Regulatory issues at the federal and state levels
- Market issues that affect non-ISO/RTO and ISO/RTO markets
- Utility and developer business model issues
- Cross-cutting issues (limited knowledge of energy storage technologies and limited/lack of modeling capabilities)



- Technology issues that affect the multitude of energy storage technologies

The study includes a discussion of possible solutions to address these barriers and a review of initiatives around the country at the federal, regional, and state levels that are addressing some of these issues.

### ***Recommendation Area 13: Augmenting Current Market Designs***

*EAC: The potential for using new capabilities on distribution systems to improve the performance of the grid and lower system costs is recognized in the industry. Nevertheless, a major challenge for designing electricity markets is to allow new entities, such as demand aggregators, to participate effectively in the market.*

**OE:** The ESS Program does not participate in efforts to design markets to promote or utilize energy storage technologies. Rather, the program is concerned with providing technical and economic performance data and addressing barriers to enable the widespread deployment of the technology, including for their participation in markets.

It is recognized that resource participation in the organized wholesale electric markets is currently governed by participation models consisting of market rules. There are some electricity markets that currently allow energy storage technology participation, including frequency and even capacity markets. In addition, there is currently an effort being undertaken by the Federal Energy Regulatory Commission to examine potential participation strategies that would more fully utilize the benefits of energy storage technology. The ESS Program will be working with FERC in this effort.

### ***Recommendation Area 14: Project Financing***

*EAC: Financing an energy storage deployment can be complicated because financiers are risk-averse toward a relatively new technology. Providing short-term (two- or three-year) loans could help secure longer-term funding as financiers learn about the new technology, eventually making an energy storage deployment financially self-sufficient.*

**OE:** The extent of funding, and the manner in which it is applied, is dependent upon Congressionally-mandated budget language. The Department will continue to support the deployment of energy storage systems through a range of demonstration projects across the country.

### ***Recommendation Area 15: Valuation Studies***

*EAC: Interviewees praised the range of energy storage-valuation studies produced by the*

Department and the national laboratories. It was suggested that one additional area of study—valuation of behind-the-meter energy storage to end customers and business models for utilities or customers to deploy these—would be useful.

**OE:** The ESS Program has sponsored a variety of energy storage valuation studies, particularly to assess the value of energy storage for utilities and regional operators. These studies determined the value proposition of energy storage systems for various types of utilities and regional coordinators. They include:

- The California Independent System Operator (CAISO) - *Opportunities for Energy Storage in CAISO: Day-ahead and Real-time Market Arbitrage* <sup>xxvii</sup>
- PJM - *Potential Revenue for Electrical Energy Storage in PJM* <sup>xxviii</sup>
- The Electric Reliability Council of Texas (ERCOT) - *Potential Revenue from Electrical Energy Storage in the Electricity Reliability Council of Texas* <sup>xxix</sup> and *Potential Revenue from Electrical Energy Storage in ERCOT: The Impact of Location and Recent Trends* <sup>xxx</sup>
- Midcontinent Independent System Operator (MISO) - *Maximizing Revenue from Electrical Energy Storage in MISO Energy & Frequency Regulation Markets* <sup>xxxi</sup>
- Independent System Operator of New England (ISO NE) - *The Value Proposition for Energy Storage at the Sterling Municipal Light Department* <sup>xxxii</sup>
- Hawaii Electric Company - *The Benefits of Grid-scale Storage on Oahu* <sup>xxxiii</sup>
- Maui Electric Company - *Maui Energy Storage Study* <sup>xxxiv</sup>
- Nevada Energy - *NV Energy Electricity Storage Valuation* <sup>xxxv</sup>
- Southern Company - *Southern Company Energy Storage Study: A Study for the DOE Energy Storage Systems Program* <sup>xxxvi</sup>
- Puget Sound Energy – *Assessment of Energy Storage in the Puget Sound Energy System, Volume 1: Financial Feasibility Analysis* <sup>xxxvii</sup> and *Assessment of Energy Storage in the Puget Sound Energy System, Volume 2: Energy Storage Evaluation Tool* <sup>xxxviii</sup>
- Portland General Electric – *An Economic Assessment of Portland General Electric’s Salem Smart Power Center Energy Storage System* <sup>xxxix</sup>
- Green Mountain Power – *Green Mountain Power (GMP): Significant Revenues from Energy Storage* <sup>xxx</sup>

In addition to the modeling tools and approaches mentioned above, the program has conducted customer-based, behind-the-meter valuation studies. <sup>xxxxi xxxxii</sup>

In order to disseminate the lesson-learned from these valuation efforts, the ESS Program has provided extensive technical assistance and guidance to support valuation of storage in multiple markets and worked with many states in advancing energy storage deployments, including providing support to California, Massachusetts, Oregon and Washington in the formulation of energy storage sourcing procedures.



## Appendix 1 – Technology Assistance

The table provides examples where the ESS program has provided technical assistance.

Jurisdiction	Project Description
<b>Alaska</b>	The program is working with the Alaska Center for Energy and Power and Cordova Electric to conduct a study analyzing the potential benefits of energy storage combined with local hydropower.
<b>California</b>	The program is assisting the California Energy Commission to better understand how to apply storage as a way to balance energy demand with water availability. In addition, it is providing technical assistance to the California Public Utility Commission as they oversee the installation of 1.8 GW of energy storage throughout the state.
<b>Hawaii</b>	The program has partnered with the Natural Energy Lab of Hawaiian Authority and the Hawaiian Electric Light Companies to complete a 100 kW/4-hour flow battery project. In this project, the program is providing technical analysis and evaluation to determine the applicability and value of utilizing a flow battery in an island environment.
<b>Massachusetts</b>	The program has worked closely with the Department of Energy Resources and Clean Energy Center. Specific project-level technical support has been provided to four of the larger projects funded under the state’s Community Clean Energy Resilience Initiative, including a 2 MW/3.9 MWh energy storage and solar microgrid project with Sterling Municipal Light Department that was completed in December 2016. The Sterling system will provide backup power for first responders and demand response tradeable in transmission-level markets.
<b>New Mexico</b>	The program is supporting continued analysis of the operational flexibility of a 1 MW/6 MWh sodium-sulfur battery system installed at the Los Alamos Department of Public Utilities.
<b>New York</b>	The program has provided technical support to the New York State Energy Research and Development Authority on the application of a 1 MW flywheel system that will recycle braking energy on subway systems to assist propulsion.

<p><b>Oregon</b></p>	<p>The program has provided support to the Eugene Water and Electric Board to install two 100 kW/200 kWh energy storage systems that provide resiliency and emergency backup to core operations facilities. The program is also assisting Portland General Electric (PGE) in evaluating the economic potential of its Salem Smart Power Center and is designing control strategies to help PGE realize these values in real-time. In addition, efforts with the Oregon Public Utility Commission has led to legislative action and guidelines for proposed energy storage systems.</p>
<p><b>Tennessee</b></p>	<p>The program is supporting the installation of a 100 kW/4-hour vanadium flow battery combined with solar photovoltaics in a microgrid with the Electric Power Board in Chattanooga.</p>
<p><b>Vermont</b></p>	<p>The program has partnered with Green Mountain Power to support installation of a 4 MW/3.4 MWh lithium-ion/lead acid storage system to be used with a 2.5 MW photovoltaic system. The targeted applications are for emergency shelter back up, renewable firming, frequency regulation, and demand reduction. GMP calculates the value of storage at \$300,000 - \$500,000 /MW/year for peak demand shaving, plus revenue from frequency regulation, and anticipates a 5-10 year payback. In addition, the program is currently providing technical analysis support to the Burlington Electric Department on the potential of energy storage additions to the Burlington Airport’s electrical distribution system to provide resiliency to their power grid.</p>
<p><b>Washington</b></p>	<p>The program has evaluated the technical performance and economic potential of four energy storage systems at three utilities (Snohomish Public Utility District, Puget Sound Energy, and Avista Utilities) with power and energy capacities of 7 MW/15 MWh, respectively. This program has included an extensive multi-year energy storage testing effort that has yielded a patent application focused on improving the ability of operators to predict energy storage performance based on changes in power, state of charge, state of health, and temperature. A preliminary finding of this work is that utilities can generate much more value, as much as 50-60% more for certain applications, with an enhanced operational knowledge of the energy storage system. Assistance requested by the Washington Utilities and Transportation Commission resulted in a draft policy statement that incorporates energy storage analysis in integrated resource planning.</p>



## Appendix 2 – Workshops, Webinars, and External Events

Regional Workshops with regulatory representatives are listed below:

- Energy Storage Workshop for Northwest PUCs, Richland, Washington, held on July 22-23, 2015. This workshop was attended by PUC commissioners and staff from Washington, Oregon, Idaho and Montana.
- Southwest Public Utility Regulatory Energy Storage Workshop, Albuquerque, New Mexico, held on May 3, 2016: This one-day workshop had with forty participants from Arizona, New Mexico, Utah, Colorado and Hawaii PUCs and State Energy Agencies. Presentations from this workshop are available at:  
<http://www.sandia.gov/ess/publication/conference-archives/southwestern-public-utilities-commission-sw-puc-energy-storage-workshop/>
- An energy storage workshop was held for commissions in several western states on November 8, 2017 in Salt Lake City. The presentations made at this workshop are available at:  
[https://events.pnnl.gov/Default.aspx?topic=US DOE Energy Storage Regulatory Commission Seminar](https://events.pnnl.gov/Default.aspx?topic=US%20DOE%20Energy%20Storage%20Regulatory%20Commission%20Seminar)

Below is a listing of the FY17 webinars along with a listing of attendance. Archived webinars and presentations are available at: <https://www.cesa.org/projects/energy-storage-technology-advancement-partnership/>.

	Webinar Title	Event Date	Attendance
1	McKnight Lane Project Updates	9/27/17	
2	Identifying Potential Markets for Commercial Behind-the-Meter Battery Storage	9/19/17	
3	SolarResilient: A New Tool for Resilient Solar+Storage Design	8/3/2017	183
4	Solar Risk: How Energy Storage Can Preserve Solar Savings in California Affordable Housing	6/15/2017	117
5	ESyst: Optimizing Energy Storage Savings with Geli's New Online Tool	5/24/2017	197
6	Is Energy Storage Right for Our Community-Based Solar Project? A Solar+Storage 101 Webinar	5/12/2017	46
7	The Value Proposition for Energy Storage at the Sterling Municipal Light Department	4/27/17	284
8	Tools for Building More Resilient Communities with Solar+Storage	4/6/2017	131
9	NYC's Policy Target and Roadmap for Resilient Solar+Storage	4/4/2017	115
10	Solar+Storage Industry Perspectives: JLM Energy	3/22/2017	151
11	Comparing the Abilities of Energy Storage, PV, and Other Distributed Energy Resources to Provide Grid Services	3/13/17	354
12	Developing an Energy Storage Project: A Technical Perspective	3/8/2017	310
13	American Samoa's Solar+Storage Microgrid	2/16/2017	182
14	GTM Energy Storage Market Updates	1/27/17	320
15	McKnight Lane: A Rural Low-Income Resilient Solar+Storage Housing Project	12/14/2016	266
16	Energy Storage for Public Health	11/2/2016	114
17	Mass Energy Storage Study and Legislation	10/27/16	237
18	Sterling Microgrid Project	10/25/2016	260
19	Resilient Power Retrofit: How a Minnesota Nature Center Became a Solar+Storage Community Shelter	10/19/2016	80



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- <sup>vii</sup> DOE Global Energy Storage Database, See: <http://www.energystorageexchange.org/>.
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