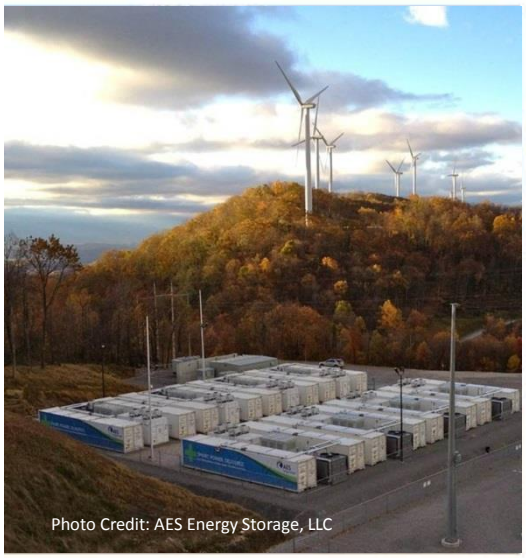
EAC
ELECTRICITY ADVISORY COMMITTEE

2016 Storage Plan Assessment
Recommendations for the U.S. Department of Energy

A Report by:

The Electricity Advisory Committee
September 2016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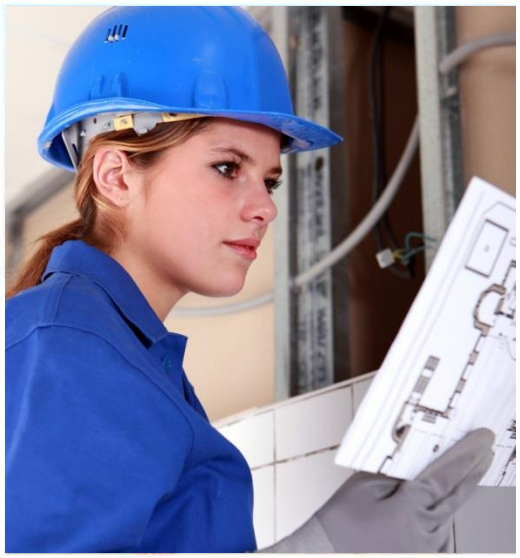

Electricity Advisory Committee

Electricity Advisory Committee Mission

The mission of the Electricity Advisory Committee is to provide advice to the U.S. Department of Energy in implementing the Energy Policy Act of 2005, executing the Energy Independence and Security Act of 2007, and modernizing the nation's electricity delivery infrastructure.

Electricity Advisory Committee Goals

The goals of the Electricity Advisory Committee are to provide advice on:

- Electricity policy issues pertaining to the U.S. Department of Energy;
- Recommendations concerning U.S. Department of Energy electricity programs and initiatives;
- Issues related to current and future capacity of the electricity delivery system (generation, transmission, and distribution—regionally and nationally);
- Coordination between the U.S. Department of Energy, state, and regional officials and the private sector on matters affecting electricity supply, demand, and reliability; and
- Coordination between federal, state, and utility industry authorities that are required to cope with supply disruptions or other emergencies related to electricity generation, transmission, and distribution.

Energy Independence and Security Act of 2007

The Energy Storage Technologies Subcommittee of the Electricity Advisory Committee was established in March 2008 in response to Title VI, Section 641(e) of the Energy Independence and Security Act of 2007 (EISA).

This report fulfills requirements of EISA Title VI, Section 641(e)(4) and (e)(5).

Section 641(e)(4) stipulates that “No later than one year after the date of enactment of the EISA and every five years thereafter, the Council [i.e., the Energy Storage Technologies Subcommittee, through the Electricity Advisory Committee], in conjunction with the Secretary, shall develop a five-year plan 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.”

EISA Section 641(e)(5) states that “the Council shall (A) assess, every two years, the performance of the Department in meeting the goals of the plans developed under paragraph (4); and (B) make specific recommendations to the Secretary on programs or activities that should be established or terminated to meet those goals.”

2016 Storage Plan Assessment

September 2016

More Information about the EAC is Available at:
http://energy.gov/oe/services/electricity-advisory-committee-eac

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Letter from the Chair

September 2016

On behalf of the members of the Electricity Advisory Committee (EAC), I am pleased to provide the U.S. Department of Energy (DOE) with this report, "2016 Storage Plan Assessment." This report summarizes a review of DOE's energy storage program strategies and activities, and includes recommendations that the Electricity Advisory Committee (EAC) offers for the DOE's consideration as it continues to develop and implement its energy storage program, as authorized by the Energy Independence and Security Act of 2007.

These recommendations were developed through a systematic process undertaken in 2016 by the EAC. The members of the EAC represent a broad cross-section of experts in the electric power delivery arena, including representatives from industry, public interest groups, utilities, and state government. I want to especially thank Ramteen Sioshansi, Associate Professor of Integrated Systems Engineering and Associate Fellow of the Center for Automotive Research at Ohio State University, for his leadership in developing the report, as well as Merwin Brown, Co-Director of Electric Grid Research at the California Institute for Energy and Environment at the University of California, for his leadership as Chair of the EAC Energy Storage Subcommittee and to the other EAC members who served on the Subcommittee. Thanks also go to Patricia Hoffman, Assistant Secretary for Electricity Delivery and Energy Reliability, U.S. Department of Energy, Matthew Rosenbaum DOE Office of Electricity Delivery and Energy Reliability and Designated Federal Officer of the Electricity Advisory Committee, and to David Meyer, Senior Policy Advisor, DOE Office of Electricity Delivery and Energy Reliability.

The members of the EAC recognize the vital role that the DOE can play in modernizing the nation's electric grid. The EAC looks forward to continuing to support DOE as it develops and deploys energy storage technologies, policies, and programs to help ensure an effective, resilient, 21st century electric power system. This report fulfills the requirements in Section641(e)(4)(5) of the Energy Independence and Security Act of 2007.

Sincerely,

Susan Tierney, Chair
Electricity Advisory Committee

Executive Summary

Background and Context

This report fulfills three requirements of the Energy Independence and Security Act of 2007 (EISA). EISA Section 641(e)(4) directs the Council (i.e., the Energy Storage Technologies Subcommittee, through the Electricity Advisory Committee) to:

> Every five years…in conjunction with the Secretary…develop a five-year plan for…domestic energy storage industry for electric drive vehicles, stationary applications, and electricity transmission and distribution.

EISA Section 641(e)(5) further directs the Council to:

> Assess, every two years, the performance of the Department in meeting the goals of the plans developed under paragraph (4); and
>
> Make specific recommendations to the Secretary on programs or activities that should be established or terminated to meet those goals.

In 2012, the Electricity Advisory Committee (EAC) conducted its assessment of the Department of Energy's (the Department's) energy storage-related research, development, and deployment (RD&D) programs with a focus on the activities of the Office of Electricity Delivery and Energy Reliability (OE).[1] For its 2014 review, the EAC expanded its scope to include activities of OE, Office of Energy Efficiency and Renewable Energy (EERE), Advanced Research Projects Agency-Energy (ARPA-E), and Office of Science (SC). The EAC also examined coordination between the Department's energy storage-related efforts with those of other federal agencies (e.g., National Science Foundation and Department of Defense). This expanded scope was in line with the set of offices and agencies included in the Department's overall strategy as laid out in a December 2013 report entitled "Grid Energy Storage."[2]

The 2016 review maintains the same broad scope in its assessment. However, the 2016 review is structured to home in specifically on the recommendations that were derived from the assessment and that can inform the five-year plan. As such, the 2016 review omits background information on the Department's energy storage-related RD&D programs and goals. This background information was provided in the 2012 and 2014 reviews.[3]

[1] Electricity Advisory Committee, "2012 Storage Report: Progress and Prospects. Recommendations for the U.S. Department of Energy," October 2012. Available at: http://energy.gov/oe/downloads/eac-2012-storage-reportprogress-and-prospects-recommendations-department-energy.

[2] U.S. Department of Energy, "Grid Energy Storage," December 2013. Available at: http://energy.gov/oe/downloads/grid-energystorage-december-2013.

[3] The 2012 and 2014 reviews can be found on the U.S. Department of Energy Electricity Advisory Committee – Reports and Memos portal, available at: http://energy.gov/oe/services/electricity-advisory-committee-eac/electricity-advisory-committee-reports-and-memos. Additional information can be found on the Department's storage portal: http://energy.gov/oe/services/technology-development/energy-storage.

This omission is done for the sake of brevity and under the assumption that this background context is well known within the Department.

In addition to some recommendations on broadening and changing the Department's energy storage-related goals, this report also recommends some specific changes or additions to the Department's energy storage-related research portfolio. There are also recommendations on activities that can accelerate energy storage deployment and help with regulatory issues that energy storage faces.

Process

The 2016 review reflects the assessment of the EAC, the Energy Storage Technologies Subcommittee of the EAC, and, in particular, members of the Biennial Energy Storage Assessment Working Group (Working Group). These views are partially informed by 16 interviews conducted by the Working Group with representatives of companies, regulators, system operators, and researchers that are directly or tangentially involved in the energy storage industry. While it was impossible to interview every entity involved in the energy storage industry, the interviewees were selected to represent a broad range of organizations that are involved with the industry. The interviewees offered wide-ranging views on some topics, while other views were shared nearly unanimously. It should be reiterated and stressed, however, that this assessment reflects the views of the EAC, and not necessarily those of any interviewees. A categorized (by type of entity) list of interviewees and interviewee affiliations is given in Appendix A.

Timing of Report

This report is intended to meet the requirements of EISA Section 641(e)(5) (the two-year requirement) and those of EISA Section 641(e)(4) (the five-year requirement). Per the statutory requirements of EISA, the two-year requirement must be met this year in 2016, whereas the five-year requirement could be met with a separate report next year in 2017.

The EAC has opted to meet both requirements this year with this single report for two reasons. First, the interviews that were conducted, and which formed the basis of many of the recommendations in this report, contained time-sensitive information. The EAC and the Working Group felt that it would be a disservice to the Department, the interviewees, and the energy storage industry to “wait” on the recommendations received in and derived from the interviews. Second, the Department may have new leadership beginning in early 2017. The EAC and the Working Group believe it would be beneficial for Department leadership to have this report available now to provide suggestions on further developing the Department's high-quality energy storage-related RD&D programs.

Format of Findings, Assessment, and Recommendations

Our assessment resulted in 15 recommendation areas, which are organized into the following three broad thematic categories:

A. General Assessments and Recommendations,
B. Technology Development, and
C. Economics and Markets.

Each recommendation area is discussed in greater detail in the following section and includes the following:

Comments: A summary of the feedback and comments that were received from interviewees or EAC members, which provide framing context behind the recommendation area; in many cases this framing context is informed by responses from interviewees, but in other cases it is based on views of Working Group and EAC members.

Recommendations: Specific recommendations for the Department that are derived from the comments and feedback received.

At a high level, the 15 recommendation areas can be summarized into the following 10 points:

1. Improve visibility and publicity of the Department's high-quality energy storage–-related RD&D: The most commonly raised issue in the interviews centered on **visibility and publicity** of the Department's energy storage-related RD&D activities. With few exceptions, the interviewees had limited or no knowledge of the Department's efforts.
2. Make RD&D publicly available through industry conferences and open-access journal publications: Small regulatory agencies or utilities may have limited resources to learn about energy storage. Many of these entities do not have budgets for paid access to peer-reviewed academic publications. Researchers funded by the Department should be strongly encouraged and financially supported to make their **research available through industry conferences and open-access journal publications**. Similar requirements should be placed on recipients of Department funding for **pilot and demonstration projects—information gained** from such projects should be **disseminated to the industry** at public workshops. The Department should also prepare and publicize short "fact sheets" that summarize findings and key takeaways of storage-related RD&D.
3. Address the need for energy storage operational and planning models: The second-most commonly raised issue in the interviews centered on the need for **energy storage operational and planning models**. Existing tools provided by industry are extremely lacking in their ability to model energy storage. Modeling priorities should be **interactions between distribution and transmission systems** and the **operational uncertainties that energy storage faces**. A number of national laboratory studies have made use of good modeling methodologies. **Primers explaining how software tools can be used for storage modeling** based on these studies are highly desirable.
4. Commission studies to understand market-design and regulatory impediments to capturing energy-storage value: Energy storage faces numerous **economic issues** related to **market and regulatory design**. It is difficult for energy storage to get paid for the full range of services that it can be provide. At the same time, the electricity industry is undergoing massive changes with a move toward greater use of non-dispatchable, variable and uncertain generation and distributed resources. This provides the Department a unique opportunity to **study the fundamental design of electricity markets**. The Department should commission studies to define and assess energy storage value with real data from utility systems. The aim should be developing **methodical techniques to determine energy storage value**. At the same time, the Department should move beyond assessing energy storage to understanding why this value is not being realized. The Department should actively engage with the Federal Energy Regulatory Commission (FERC) and state regulatory agencies to **ensure that market designs and regulatory practice better capture energy storage value**.

5. Educate state regulators and utilities on energy storage technology and uses: There is great **disparity in the information level of state regulators around energy storage**. This information disparity is exacerbated by some agencies having small staffs and limited resources. Utility interviews revealed similar informational disparities. The Department should have a strong presence at fora, such as **NARUC**, **to educate state regulators on energy storage**. This should be supplemented with **workshops or tutorials** with educational materials for both **regulators *and* utilities**, so both entities hear the same message about energy storage technology and uses.
6. Broaden and add energy storage-related goals to the Department's existing list: The Department should develop and actively promote a **grand vision of an energy system of the future** and show how **energy storage can play a transformative role** in it. The Department should also consider adding **appropriate and achievable cost-effectiveness goals for energy storage**, following the example set by the Department's solar programs. Some of the goals, as stated, focus too much on specific use cases. These goals should be reworded to place more emphasis on making energy storage accessible to the electricity industry and its consumers as opposed to risking "pigeonholing" energy storage's role within the industry.
7. Provide additional funding and resources for energy storage RD&D: The Department, and by implication the Federal government, should consider devoting **more funding and resources to the energy storage program**, given the **transformational role** that the technology can play in the so-called **"Grid 2.0."** Overall, the Department is focused on important issues. However, it needs to be able to fund more projects and expand its research portfolio in line with the other recommendations.
8. Encourage better coordination of energy storage RD&D between OE and EERE: The Department's energy storage-related research activities are generally well praised. The Department should continue to maintain the "**DOE Global Energy Storage Database**," supplementing it with **energy storage-related market-design information**. The Department should retain a focus on **technology research**, with the goal of helping to **build and maintain a strong energy storage-manufacturing industry in the United States**. The Department should continue to focus on a **wide range of device sizes** between small distributed energy storage to bulk long-duration storage. The Department should conduct a systematic review of its energy storage-related RD&D and encourage **greater cooperation and coordination between OE and EERE**.
9. Make experts available as a source of informed and unbiased information on energy-storage safety: Department experts should be made available to and actively seek out reporters to **objectively inform concerns surrounding the safety** of energy storage technologies, for instance from media reporting about batteries catching fire.
10. Provide short-term seed funding for energy-storage development and deployment: The Department should make **short-term seed funding** available to help fund the development and deployment of storage projects. Such "bridge loans" could help energy-storage deployments secure longer-term funding as potential financiers learn about the new technology, eventually making the deployment self-sufficient.

Findings: Assessment and Recommendations

A. GENERAL ASSESSMENTS AND RECOMMENDATIONS

Recommendation Area 1: Visibility

Comments: 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. This view was expressed by the vast majority of interviewees representing different segments of the energy storage industry. Moreover, the Department should work to ensure that its activities are covered in the press and not "crowded out" by others engaged in energy storage-related work. For instance, if the Rocky Mountain Institute does the same work on energy storage, it tends to be covered extensively in the trade press. Finally, a comprehensive summary of the Department's entire energy storage-related RD&D portfolio would be helpful.

Recommendations:

1.1. The Department should make a concerted effort to advertise its high-quality energy storage-related RD&D efforts through outlets such as (but not limited to) Energy Storage News, Clean Horizon Report, and GreenTech Media.

1.2. The Department should prepare a single summary document that lists its entire portfolio of energy storage-related RD&D. This document should detail funds and resources devoted to each RD&D program. This document and all of the Department's energy storage-related RD&D products should be archived and made available to the public for free on the Department's website.

Recommendation Area 2: Accessibility of Research

Comments: Results and key takeaways of the Department's energy storage-related research are not easily accessible to regulators, utilities, and electricity consumers. Small regulators may have small staffs. Moreover, these regulatory agencies are typically charged with regulating other industries besides electricity. Similarly, a small utility or rural cooperative may only have one or two engineers on staff. These groups will not have the time or resources to read and digest a 100-page technical report on energy storage. Moreover, many of these entities do not have budgets for paid access to peer-reviewed journal articles.

Recommendations:

2.1. National laboratory and other Department-supported researchers should have a strong presence at industry conferences such as (but not limited to) the Energy Storage Association Conference. Such conferences should be used for disseminating their research findings to regulators and utilities. The Department should provide funding for researchers to attend such conferences.

2.2. National laboratory and other Department-supported researchers should be encouraged to publish their research in journals that are open access or have options for paid open access. In the latter case, funding should be provided for researchers to publish their work in this manner.

2.3. The Department should produce short (e.g., three-page or shorter) "fact sheets" that summarize the findings and key takeaways of energy storage-related RD&D projects. These fact sheets should be actively promoted in-person at conferences, through the types of channels discussed in Recommendation Area 1 (Visibility), and on the Department's website.

Recommendation Area 3: State Regulator and Storage-User Education

Comments: There is great disparity in the information level of state regulators around storage technologies. Some are taking an active role in promoting the technology because of perceived risk aversion of potential adopters or other issues hampering storage development and deployment in their states. Others are taking a more relaxed approach and waiting until a utility proposes an energy storage development before learning more about the technology. The former group feels relatively well educated about energy storage whereas the latter is relatively uninformed. This is exacerbated by the fact that some state regulatory commissions have small staffs with limited budgets and many industries (in addition to electricity) to monitor and regulate (see Recommendation Area 2, Accessibility of Research).

At the same time, there is disparity in the extent to which utilities are informed about and engaging with energy storage. Some are at the forefront (either because of regulatory mandates or by their own choice), while others are outright skeptical of energy storage. Energy storage vendors and developers report that when selling a product the process is highly consultative and that the salesperson must often act as an educator. This can be problematic if the salesperson is not seen as being independent or unbiased.

Some of the educational materials produced by the Department are noted as being comprehensive but not practical. For instance, the energy storage handbook[4] is useful for understanding different battery electrochemistries. However, this is not as valuable to a utility planning around an overloaded distribution circuit as knowing what can actually be done with a battery.

Recommendations:

3.1. Have a strong Department presence at fora, such as NARUC, to educate state regulators on energy storage, with particular focus on states that are not at the forefront of advancing energy storage technology.

3.2. Convene workshops, tutorials, or webinars with educational materials for regulators, utilities, and end users that are free to attend. This is to ensure that these entities receive the same messages about energy storage. Ensure that the educational materials are focused on potential real-world uses of storage and what technologies have actually been demonstrated to be appropriate for different use cases, as opposed to detailed technology characteristics. Record and archive these educational events and provide free access to the recordings through the Department's website.

Recommendation Area 4: Program Goals

Comments: The Department has produced many well regarded and highly respected studies of future energy systems, such as the Renewable Electricity Futures Study,[5] 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. President Kennedy stirred the nation's imagination by establishing the goal of landing a man on the moon within a

[4] Akhil, A., Huff, G., Currier. A., Kaun. B., Rastler, D., Chen, S., Cotter, A., Bradshaw, D., and Guantlett, W., "DOE/EPRI Electricity Storage Handbook in Collaboration with NRECA," Akhil, A.; Huff, G.; Currier. A.; Kaun. B.; Rastler, D.; Chen, S.; Cotter, A.; Bradshaw, D.; Guantlett, W.; Albuquerque, NM and Livermore, CA: Sandia National Laboratories, February 2015 (revised). Available at: http://www.sandia.gov/ess/publications/SAND2015-1002.pdf.

[5] Hand, M.M., Baldwin, S., DeMeo, E., Reilly, J.M., Mai, T., Arent, D., Porro, G., Meshek, M., and Sandor, D. eds., "Renewable Electricity Futures Study," Hand, M.M.; Baldwin, S.; DeMeo, E.; Reilly, J.M.; Mai, T.; Arent, D.; Porro, G.; Meshek, M.; Sandor, D. eds. NREL/TP-6A20-52409. Golden, CO: National Renewable Energy Laboratory, 2012. Available at: http://www.nrel.gov/analysis/re_futures/.

decade. So too can the Department create enthusiasm with regulators, public officials, utilities, and the public by establishing a highly visible, dramatic, and achievable vision for the development of an advanced energy system that meets the Federal goals of reducing emissions of greenhouse gases and identifies the important role that energy storage can play. The Department should take leadership in promoting this vision to regulators, public officials, utilities, and the general public.

At the same time, cost effectiveness is not an explicit goal, whereas this is front and center in the solar program. Moreover, many of the energy storage goals focus too much on specific use cases, as opposed to more broad statements on how energy storage should be more accessible to the electricity industry and consumers. This runs the risk of "pigeonholing" energy storage's role within the electricity industry.

Recommendations:

4.1. Develop and actively promote a grand vision of an energy system of the future to members of Congress, state public utility commissioners, energy media, and most importantly, the general public. This vision should maintain the established standards of reliability on the grid, show how energy storage can play a transformative role, and also address the Federal goals surrounding climate change.

4.2. Add appropriate and achievable cost effectiveness goals for energy storage, following the example set by the Department's solar program.

4.3. Change the current energy storage program goals to be less use and/or case specific. The following gives an example of how the current goals could be changed with this in mind:

Goal #1 (current text): Energy storage should be developed and demonstrated as a broadly deployable asset for improving the efficiency, resilience, and reliability of electric power systems and electricity service to customers.

Goal #1 (suggested revision): Energy storage should be developed and demonstrated as a broadly deployable asset ~~for improving the efficiency, resilience, and reliability of electric power systems and electricity service to customers~~.

Goal #2 (current, retain existing text): Energy storage should be available and demonstrated to industry and regulators as an effective option to resolve issues of grid efficiency, resiliency, and reliability.

Goal #2 (current, retain existing text): Energy storage should be a well-accepted contributor to the realization of smart-grid benefits—specifically enabling confident deployment of electric transportation and optimal utilization of demand-side assets.

Recommendation Area 5: Pilot and Demonstration Projects

Comments: Pilot and demonstration energy storage projects are praised as being very helpful. A great deal of "practical" information is learned through these and more can be learned from further projects of this type. For instance, "how will a device respond to 30 signals per hour?" "Can a device respond to a signal within half a second?" "Can a device discharge to the grid for 10 consecutive minutes?" "Can a device really provide the multiple services that modeling studies suggest?" "How long will a device last?"

The industry needs results from an independent third party to get energy storage to be a "bankable" product. Otherwise, utilities and others may be reluctant to deploy an unknown and uncertain technology, such as energy storage. Moreover, demonstration projects have spurred independent system operators (ISOs), regional transmission organizations (RTOs), utilities, and other entities into looking at energy storage as a viable alternative to generation, transmission, and distribution.

At the same time, the Department is limited in the detail that it can report on these projects. It often comes down to making a bullet-point statement. Many of these projects are in California and New York, and industry players in the middle of United States cannot directly learn from these. These issues are especially important as some utilities compare energy storage and its unknowns and risks to well known traditional technologies (e.g., a generation, transmission, or distribution upgrade) and opt for the latter (even if energy storage is a more prudent solution). Moreover, some utilities report that they do not believe modeling studies that claim storage can provide multiple stacked services (see Recommendation Area 3, State Regulator and Storage-User Education).

Some entities also noted that the size and location (e.g., next to a wind farm) of some projects seem forced and that nothing is learned as a result of these choices.

Recommendations:

5.1. Convene a conference or event (or make use of an existing one) that groups pilot or demonstration energy storage projects funded in the same category and disseminates lessons learned from them. Make participation by a member of the team that develops and operates a pilot or demonstration project part of the obligation of having such a project funded. Use this as a mechanism to educate skeptical utilities and others about the *actual demonstrated* benefits of energy storage. This will allow these entities to better compare energy storage to alternatives. Ensure that the use of energy storage for multiple services is emphasized. Record and archive the educational event and provide free access to the materials via the Department's website.

5.2. Work to have more regional diversity in energy storage projects that are funded.

5.3. Get input from ISOs, RTOs, utilities, and other stakeholders in sizing and siting a demonstration energy storage project to maximize benefits and lessons learned.

Recommendation Area 6: Funding and Resources

Comments: 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. As such, the Department is filling an important gap. Energy storage is also viewed as being an increasingly important technology for the so-called "Grid 2.0." There is broad consensus that the Department is focusing on the right issues (although some additional emphases, listed in the other recommendation areas, are noted).

That being said, many interviewees feel that energy storage is underfunded, especially in light of its growing and important role in the future. Some compared the Department's energy storage-related funding (~$21 million in fiscal year 2016) to the solar program's (~$242 million enacted budget in fiscal year 2016) and noted a large disparity despite energy storage's importance. Some also noted that the limited resources for energy storage-related RD&D contributes to the various offices within the Department involved in energy storage not coordinating their programs well.

Recommendation:

6.1. More funding and resources should be devoted to energy storage–related RD&D, so the Department can continue to fill an important gap in light of utility cost and regulatory models. These should be focused toward having energy storage technologies and cost structures ready for Grid 2.0. OE, EERE, and ARPA-E are noted as focusing on important issues, but need to be able to fund more

projects and expand their research portfolios in line with the other recommendation areas.

Recommendation Area 7: Program Coordination

Comments: 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.

There is a sense that there is some overlap between these programs (especially between OE and EERE) and also overlap in assessing distributed energy storage (DES) as an energy storage technology and other distribution assets in other programs. Interviewees also noted that differences in working styles between OE and EERE may serve as an impediment to better coordination. There is also the sense that OE is primarily focused on energy storage technology, EERE on studying the combination and synergies between energy storage and renewables, and that there is not a concerted effort toward broader and more comprehensive analyses.

Recommendations:

7.1. Conduct a systematic study of what energy storage-related RD&D is being conducted by different programs and identify overlaps or areas that could be better coordinated. Production of the summary document recommended in Recommendation Area 1 (Visibility) could facilitate this.

7.2. Encourage better coordination of the storage programs within OE and EERE. Some interviewees feel that insufficient funding and resources contributes to the low levels of coordination.

7.3. Ensure that there is sufficient emphasis placed on broader and more comprehensive analyses of energy storage beyond technology and integration of renewable energy.

B. TECHNOLOGY DEVELOPMENT

Recommendation Area 8: Technology Focus

Comments: There are wide-ranging views on which specific technologies the Department should focus its attention. Many interviewees feel that lithium-ion batteries and similar technologies are well developed and being researched by industry and manufacturers. Thus, they do not warrant the Department's focus. Some interviewees noted that other countries are becoming dominant in storage research and manufacturing, and that the Department should work to encourage these activities in the United States. It was noted that much energy storage-technology research is occurring in Taiwan, Japan, and Korea, as evidenced by research publications in major journals.

In terms of technologies, thermal, power-to-gas, and virtual energy storage (i.e., demand response) were noted as needing more emphasis. Further work on inverters and reducing balance-of-system costs were also suggested. Additionally, considering ice and chilled water for air conditioning as a storage technology, and water heating and water pumping controls as a storage technology was suggested.

Interviewees suggested that the Department should focus on a broad range of device sizes. Comments range between “more emphasis on distributed as opposed to bulk storage,” “more emphasis on two- to three-hour storage,” and “more emphasis on long-duration storage.” In terms of long-duration storage, it was noted that there is no good recent analysis on the availability and deployability of pumped hydroelectric and compressed-air energy storage in the near-future. These two technologies were highlighted, as they are the two most promising bulk-scale technologies in the immediate future.

Some interviewees noted that electrochemical storage research has historically been largely driven by mobile applications. Only after these technologies were developed with that use in mind did industry later engineer and design systems for stationary use.

Recommendations:

8.1. Retain a focus on energy storage-technology research in the United States, with the goal of helping to build and maintain a strong energy storage-manufacturing industry in the United States. This research should focus on fundamental chemistry and material science research, as opposed to, for instance, improving lithium-ion technology, which manufacturers will continue doing.

8.2. Continue to focus on a wide range of device sizes between small DES to bulk long-duration energy storage.

8.3. Ensure that energy storage-technology research has an adequate focus on stationary applications.

8.4. Increase emphasis on research on thermal (both hot and cold), power-to-gas, and virtual energy storage technologies, as well as inverter and balance-of-system cost reductions.

8.5. Commission comprehensive studies of the availability and deployability of large amounts of pumped hydroelectric and compressed-air energy storage in the near future. If such studies suggest that these technologies are not broadly deployable, refocus technology research elsewhere to fill this gap.

Recommendation Area 9: Safety

Comments: 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.

Recommendation:

9.1. Make Department experts available to (and actively seek out) reporters to provide unbiased and complete information about energy storage safety. The information provided by Department experts should be made available for free on the Department's website.

Recommendation Area 10: Energy Storage Database

Comments: 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.

Recommendations:

10.1. Supplement the current database with information about storage-related market-design information. This could either be a separate category, or included in the “Policy” section of the database.

Recommendation Area 11: Operational and Planning Modeling

Comments: 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. This was the most commonly raised issue (other than those discussed in Recommendation Area 1, Visibility) in the interviews and was the highest priority for many of the interviewees.

The industry needs help in evaluating, capturing, and increasing the value of energy storage. This includes models, analytics, sizing, and dispatch to allow the end user to "do more" with energy storage. An important part of this is having a common platform for analysis and sizing of a potential energy storage deployment and for dispatch and operations. Several interviewees noted that national laboratories do good modeling in their analyses and reports of energy storage. However, these models need to be made available to industry and potential technology adopters. In addition, the national laboratories have provided help with assessing storage value for demonstration projects. This needs to be generalized for other potential users.

Another issue that was raised is the need for models to study the interaction of DES with other distribution resources and the seams between the distribution and transmission systems. Such tools do not exist for energy storage providers and users because these types of analyses have not historically been done. A final issue is that many of the models are focused on the engineering aspects of energy storage but have no connection to project financing.

Recommendations:

11.1. Develop a common platform for dispatch/operations and planning/sizing of potential energy storage projects. This platform can be structured like the Solar Advisor Model. Continue work such as that of Sandia National Laboratory on energy storage modeling—its work is preliminary but on the right track. Ensure that the platform developed is able to convert the engineering and operational modeling into project finance and return information.

11.2. Develop capabilities to model DES with other distribution resources and the interactions between transmission and distribution systems.

11.3. Develop primers that explain how software tools can be used for energy storage valuation, based on national laboratory studies. For instance, the National Renewable Energy Laboratory has used PLEXOS to model storage and Sandia National Laboratory has developed cost-value equations. Utilities and other potential energy storage investors cannot justify multimillion-dollar projects without being able to replicate cost/benefit analyses on their own.

11.4. Develop a simple software tool for an electricity user, such as a homeowner, to evaluate a hybrid energy system consisting of distributed generation, DES, and other distributed resources.

11.5. All of the products listed in this Recommendation Area should be made available for free via the Department's website.

C. ECONOMICS AND MARKETS

Recommendation Area 12: Value of Energy Storage

Comments: 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. The Department has done a reasonably good job of discussing this issue. Nevertheless, determining the value of energy storage, particularly DES, is challenging because this value is likely to be very time- and location-dependent. It is not clear how prices can or should capture these differences. Absent such prices, the value of these services must be calculated or computed in a more direct manner. In fact, determining the economic value of different types and locations of energy storage for grid operations is an essential first step for developing effective regulatory practices and market structures. This is especially vital for DES because it can provide many valuable services that are currently unpriced.

It can be difficult in practice to reach consensus on how to calculate the value of energy storage, especially in light of differences in the realized values of energy storage to utilities and other stakeholders (e.g., IPPs, customers, or independent storage owners). The IRP process, which drives much transmission and distribution investment, typically focuses on the bulk power system. Thus, it does not capture the true value of DES. Energy storage may also need a unique asset classification, allowing it to replace rules that are traditionally applied to load, generation, transmission, distribution, and other types of "single-role" assets.

These issues of value are particularly challenging for the Department because they are currently determined largely by FERC orders and state regulatory processes. The FERC has done a good job (but work still remains) at the wholesale level. Considerably more work needs to be completed at the retail level, and recent opportunities to work with the state regulatory community have been lost. The Department has been timid in making recommendations to or working with the FERC to get energy storage compensated correctly for the services that it can provide, in terms of reducing the costs of electricity generation, transmission, distribution, and consumption. The Department has the fundamental knowledge about grid operations that will be crucial for establishing an effective agreement among all participants about how the value of energy storage should be determined.

Recommendations:

12.1. Commission studies to define and mathematically assess DES value with real data from utility systems. Use these studies as a basis to come up with methodical techniques to assess DES value.

12.2. Move beyond assessing the value of energy storage to understand why this value is not being realized. For instance, what is the difficulty in developing and deploying DES for enhancing transmission and distribution infrastructure? Such studies may uncover regulatory issues.

12.3. The Department should engage and interact more with the FERC to get better clarity on its positions on regulatory barriers that it sees, as well as issues uncovered by the Department from the studies conducted in line with Recommendation 12.2.

12.4. Have similar engagements with state regulatory commissions, in concert with or building from educational workshops already scheduled (see Recommendation Area 3, State Regulator and Storage-User Education).

Recommendation Area 13: Augmenting Current Market Designs

Comments: With higher penetrations of variable renewable generation, wholesale electricity prices tend to be lower and are increasingly negative. At the same time, more reserve capacity is needed for ramping to maintain operating reliability. The overall effect is to undermine the financial viability of conventional generators.

Energy storage is among the solutions that can mitigate the adverse effects of integrating renewables by providing frequency regulation and mitigating the variability of renewable generation. For example, electric water heaters and municipal water pumping have been managed successfully to provide these services in the PJM Interconnection system. With these storage capabilities, the capacity factors of conventional generating units are also improved. DES has an additional advantage of flattening the daily profile of energy purchases from the grid. This reduces congestion on the grid at peak-load periods, providing a partial substitute for upgrading transmission capacity in load pockets and reducing the amount of conventional generating capacity needed for resource adequacy. These potential benefits of DES will be recognized if the value of energy storage for reducing system costs is measured correctly. Markets should be designed to reflect these values accurately.

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. This can be done badly or well (e.g., by revising energy prices to reflect real-time costs and demand charges determined by actual purchases during peak-load periods). There are already competing visions of how greater market participation by distributed resources should be accomplished. As such, the Department has an opportunity to help resolve these issues and avoid the type of mistakes that were made earlier in iterations of market restructuring and redesign (e.g., trying to accommodate point-to-point physical contracts for power flows).

Recommendations:

13.1. Commission studies to fundamentally revisit electricity markets from the bottom up. Many of the principles underlying today's electricity market designs were developed 30 or more years ago, when power systems were dominated by large, centralized, dispatchable generation. These market designs may not be appropriate for today's system architecture, which is increasingly moving toward small distributed generation, DES, and other distributed resources, and variable and uncertain supply. Such work may find that some market design principles in use today are appropriate whereas others should be fundamentally changed.

13.2. The Department should engage and interact with the FERC and state regulators to assist them in their endeavors to see any proposed market designs developed in line with Recommendation 13.1 adopted and implemented. Interaction with Congress may also be needed, to the extent that some of the market designs developed in line with Recommendation 13.1 may straddle between wholesale and retail markets.

Recommendation Area 14: Project Financing

Comments: 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.

Recommendation:

14.1. Provide short-term (two- or three-year) seed funding to help fund the development and deployment of energy storage projects.

Recommendation Area 15: Valuation Studies

Comments: 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. It was mentioned that such studies from an independent third party, such as the Department, could provide good “ammunition” for a potential energy storage deployer to work with regulators to get an energy storage project approved and to improve regulatory practice around energy storage projects.

Recommendation:

15.1. Commission more studies of the value of behind-the-meter energy storage to end customers and

business models for utilities or customers to deploy these. This should include surveys of existing valuation approaches used in the states and internationally to compare and contrast them.

Appendix A: List of Interviewees

Interviewee	Affiliation	Interview Date
Chris Campbell	Schneider Electric	February 25, 2016
Hector Pulgar	University of Tennessee, Knoxville	February 29, 2016
Curt Kirkeby	Avista	March 2, 2016
Stu Bressler and Scott Baker	PJM Interconnection	March 3, 2016
Babu Chalamala	Sandia National Laboratories	March 4, 2016
Paul Denholm	National Renewable Energy Laboratory	March 11, 2016
Kenneth Ragsdale	Electric Reliability Council of Texas	March 21, 2016
Mark Irwin	Southern California Edison	March 23, 2016
Andrew Cotter	National Rural Electric Cooperative Association	March 24, 2016
Carla Peterman	California Public Utilities Commission	April 11, 2016
Seyed Madaeni and Brian Zimmerly	SolarCity	May 18, 2016
Tim Ash and Kiran Kumaraswamy	AES Energy Storage	June 10, 2016
Janet Joseph, Ravi Tetambre, Jason Doling, Michael Worden, Leka Gjonaj, Matt Wallace	New York State Energy Research and Development and New York State Department of Public Service	June 13, 2016
Jay Emler	Kansas Corporation Commission	June 16, 2016
Beth Trumbold	Public Utilities Commission of Ohio	July 13, 2016
Todd Bianco	Rhode Island Public Utilities Commission	July 15, 2016