2020 Biennial Energy Storage Review

Recommendations for the
U.S. Department of Energy

May 2020

EAC
ELECTRICITY ADVISORY COMMITTEE

2020 Biennial Energy Storage Review

Introduction

This report fulfills the requirements imposed on the Energy Storage (Technologies) Subcommittee (the Subcommittee) of the Electricity Advisory Committee (EAC) by the Energy Independence and Security Act (EISA) of 2007 related to assessing the Department of Energy's (DOE's) activities in energy storage technologies. Title VI, Section 641(e), of EISA requires the formation of a Council to serve in an advisory role to DOE, and the Subcommittee was formed in March 2008 to serve that function. Specifically, EISA Section 641(e)(4) states that every 5 years "the Council, in conjunction with the Secretary [of Energy], shall develop a 5-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 further 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." The *2020 Biennial Energy Storage Review* serves the purpose defined in EISA Section 641(e)(5) and presents the Subcommittee's and EAC's findings and recommendations for DOE.

Energy storage is critical to incorporate variable electricity resources in the country's electricity portfolio successfully. Variable electricity resources are growing substantially, as is illustrated consistently in the Energy Information Administration's *Annual Energy Outlook*. In addition, it is vital for the country to retain its leadership in this area so that it can retain electric energy independence and security.

DOE's energy-storage-related research, development, and deployment (RD&D) activities are conducted primarily by the Advanced Research Projects Agency–Energy (ARPA-E), Office of Energy Efficiency and Renewable Energy (EERE), Office of Electricity (OE), and Office of Science, Basic Energy Sciences (SC-BES). The program goals, as well as program activities, for each of these offices were included in a questionnaire sent to stakeholders, and which can be found in Appendix A.

We find that DOE's energy-storage-related RD&D activities are meeting DOE's goals. However, we provide recommendations for ways to improve these activities for better meeting the needs of third-party users of the RD&D outcomes.

Approach

For the purposes of this review, the EAC treats energy storage as any process (e.g., mechanical, chemical, or thermal) that is capable of absorbing energy, storing it for a period of time, and then releasing the stored energy.[1] The EAC and Subcommittee set about preparing the *2020 Biennial Energy Storage Review* by reviewing the full scope of DOE energy-storage-related RD&D activities and soliciting

[1] The EAC's June 2018 "A Review of Emerging Energy Storage Technologies" adopted this broad definition that focuses on capabilities instead of physical attributes and recommended to DOE that it do the same.

feedback from a broad range of stakeholders. Information for this assessment was gathered in the following three-step process.

1. Representatives from DOE offices that are engaged in substantive energy-storage-related RD&D activities provided a webinar-based briefing to the EAC on September 19, 2019. This briefing provided the EAC and Subcommittee with an overview of DOE's activities that are pertinent to this current assessment. A list of the offices and presenters that participated in this webinar is provided in Appendix B.
2. Three EAC members, who are listed in Appendix C, attended the DOE OE Energy Storage Peer Review 2020, which took place in Albuquerque, New Mexico, in September 2019. This peer review provided an opportunity for the members to understand the totality of OE's RD&D portfolio.
3. Questionnaires were emailed to a diverse set of stakeholders drawn from the national laboratories; nonprofit, consumer-advocacy, and research organizations; regulatory and legislative organizations; and industry trade associations. In addition to these stakeholder groups, feedback was solicited from members of the Subcommittee. This resulted in several additional completed questionnaires from these EAC members.

   A full list of questionnaire respondents and their affiliations is in Appendix D. All respondents were advised that their names and affiliations would be included in this review document but individual comments would not be attributed to any individuals or organizations.

Findings

Based on the information gathered from the DOE webinar, DOE OE Energy Storage Peer Review 2020, and questionnaire responses, the EAC identified the following four key findings.

1. Overall, the goals of the program are appropriate, and the activities are beneficial to the interests of a wide set of stakeholders vis-à-vis energy storage. DOE's current RD&D portfolio has a strong emphasis on electrochemical and flow batteries. There are no major areas of the existing RD&D portfolio that should be removed or de-emphasized. However, a key grand challenge that DOE must address through its RD&D activities is the development of viable technologies for long-duration and seasonal energy storage. More resources and greater emphasis should be devoted to these areas.
2. Overall, DOE is effective in handling the development of technologies that are low and high on the technology readiness level (TRL) scale. A lingering challenge is getting mid-TRL technologies through the phase that precedes profitable deployment (i.e., the "valley of death"), assuming that technologies are assessed to have merit.
3. Some stakeholders, particularly those with limited resources to devote to their own customized modeling, or those in regions of the country that have seen limited deployments of these technologies, find modeling exercises and tools that can be used for valuation of energy storage very helpful. Such information could inform their own investment decisions as well as engage key stakeholders and regulators of the value of energy storage in a variety of different applications.
4. A major benefit of the Energy Storage Grand Challenge is to develop a DOE-wide strategy for addressing the RD&D needs of energy storage. EAC believes that the Energy Storage Grand Challenge will help address some of these issues and coordinate activities among the program

offices within DOE. The additional funding requested in the fiscal year (FY) 2020 budget will help address the challenges mentioned, particularly those listed under finding number 1.

Recommendations

Based on their findings, the EAC and Subcommittee provide the following recommendations for DOE's energy-storage-related RD&D activities. The recommendations are ranked with highest priorities first.

1. The EAC supports DOE efforts to develop and implement the Energy Storage Grand Challenge. A key strength of the Energy Storage Grand Challenge is its cross-cutting approach to coordinating energy-storage-related RD&D activities across DOE offices. This model may be beneficial for coordinating activities between DOE and other pertinent federal agencies. DOE should expand the coordination efforts under the Energy Storage Grand Challenge to include RD&D, as well as education and other activities that it collaborates on with other agencies.
2. Additional resources and emphasis should be directed toward some of DOE's energy-storage-related activities, such as dissemination of RD&D products and outcomes to relevant stakeholders, and greater engagement of state-level and industry entities.
3. The current RD&D portfolio's strong emphasis on electrochemical and flow batteries should remain, but DOE should expand its RD&D portfolio to include technologies that can serve economically viable long-duration and seasonal energy storage roles. There is an increasingly important need for long-duration and seasonal energy storage as state-level policies set more aggressive decarbonization or renewable-integration targets. For this reason, EAC supports the additional funding requested in the FY 2020 budget, as that funding will help address this issue. In particular, DOE should analyze existing, updated technologies that can provide near-immediate benefits for the grid's long-duration energy-storage needs. One such technology is advanced pumped hydroelectric storage facilities that can be built immediately to utility scale. These facilities offer performance characteristics that can offset variable electricity resources. In addition, they can provide long-term, economic solutions and very long useful lifecycles.
4. DOE should pursue technology RD&D, and input from key stakeholders, in a manner that is tailored to the maturity (e.g., TRL) of the technology in question. Development of energy-storage technologies and getting over the proverbial valley of death are critical for bringing DOE's RD&D advances to market.
    - DOE should pursue, in a "full-bore" manner, RD&D of low-TRL technologies that appear to have some technical and economic viability.
    - For mid-TRL technologies, DOE should seek input from stakeholders who are hoping to develop and deploy the technologies, assuming that the technology is assessed to have merit. Doing so helps identify the critical gaps that RD&D can help address for commercializing these technologies.
    - For high-TRL technologies, DOE should seek input from stakeholders that are skeptical of the technologies. This would help understand what technical and economic barriers remain to wide adoption of such technologies.
5. DOE should continue to expand the dissemination of its work on tools that can be used for modeling the value and performance of different applications and energy-storage technologies, in different energy-system contexts. For example, energy storage often is cited as a technology that can facilitate very high penetrations of variable renewable energy. However, this use of energy storage depends on the system context and the availability of other low-carbon technology options.

Conclusion

The EAC finds DOE's goals for its energy-storage activities to be appropriate. Moreover, DOE is making excellent progress toward meeting its goals. Both the Energy Storage Grand Challenge and the proposed FY 2020 budget are clear and concrete tools that DOE already is deploying to achieve these goals. The recommendations provided in this review are intended to build further on these successes and achieve better alignment between energy-storage-related RD&D and the needs of key stakeholders and third-party users.

Appendix A: Stakeholder Questionnaire

Department of Energy Electricity Advisory Committee

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The Electricity Advisory Committee (EAC) is a federal advisory committee, made up of experts from across the electric power industry, which provides direct guidance to the U.S. Secretary of Energy. Pursuant to statutory language contained in Section 641 e(5) of the Energy Independence and Security Act of 2007, every 2 years the EAC reviews the performance of the energy storage research, development, and deployment (RD&D) activities of the Department of Energy (DOE) in meeting its goals. DOE's current RD&D activities relating to energy storage are conducted primarily across four offices: the Advanced Research Projects Agency–Energy (ARPA-E), the Office of Science, Basic Energy Sciences (SC-BES), the Office of Energy Efficiency and Renewable Energy (EERE), and the Office of Electricity (OE). The EAC will use responses to this questionnaire to develop recommendations for DOE leadership on how RD&D programs and activities could be adjusted or improved. In responding to this questionnaire, your name and affiliation will be listed in the Appendix of the final white paper that is presented to DOE leadership. However, no specific response, comment, or feedback will be attributed to any individual.

Part I: Background

Q1. Summarize your organization's background, priorities, and interests in energy storage research, development, deployment, or policy.

Part II: Program Goals

Each program office within DOE has the following set of program goals.

- Office of Electricity (OE)
  1. Developing new materials and chemistries to be used for battery storage
  2. Increasing industry acceptance for storage technologies
  3. Increasing the duration and capacity for energy storage
  4. Decreasing costs associated with energy storage
- Office of Science, Basic Energy Sciences (SC-BES)
  1. Conduct basic and fundamental research to establish the science base for early-stage applied energy storage research
  2. Provide broad characterization and synthesis capabilities at SC-BES user facilities that are relevant to the energy storage research community
- Office of Energy Efficiency and Renewable Energy (EERE)
  1. Flexibility in generation
  2. Flexibility in demand
  3. Bidirectional storage
  4. Effective, affordable transportation
- Advanced Research Projects Agency–Energy (ARPA-E)
  1. DAYS: Levelized cost of storage of $0.05/kWh cycle without siting constraints

Q2. Are these goals appropriate? Explain.

Q3. Do the goals help your organization meet its own goals? Explain.

Q4. What other goals should DOE or individual program offices within DOE consider pursuing? Explain.

Part III: Program Activities

The program offices within DOE are focusing their energy storage RD&D in the following areas.

- Office of Electricity (OE)
  - Cost-Competitive Materials
    1. Advanced Flow Battery Development
    2. Sodium-Based Batteries
    3. Zn-MnO_2 Batteries
  - Validated Safety and Reliability
    1. Safety-Related Stakeholder Engagement
    2. Grid Storage Reliability
  - Regulatory and Storage Analytics
    1. Energy Storage Technology Advancement Partnership with State Regulatory Community
    2. Southeastern Energy Storage Seminar and Workshop
    3. Ad Hoc State Assistance
  - Industry Acceptance
    1. Pilot and Demonstration Projects
- Office of Science, Basic Energy Sciences (SC-BES)
  - Transformative Science for Next-Generation Batteries, Including Phenomenological Understanding to Underpin Technology Advances for:
    1. Air-Breathing Aqueous Sulfur Flow Batteries
    2. Non-Aqueous Redox Flow Batteries
    3. Controlled Porous Membranes for Better Batteries
  - Characterization, Computing, and Analysis to Discover Novel Materials
- Office of Energy Efficiency and Renewable Energy (EERE)
  - Solar
    1. Thermal energy storage coupled with advanced power cycles in concentrating solar power plants
    2. System models and prototypes for coupling distributed solar with building loads and energy storage
  - Water
    1. Increasing flexibility of hydroelectric and pumped hydroelectric storage
    2. Studying performance and capabilities of new and existing pumped hydroelectric storage
  - Geothermal
    1. Ground source heating and cooling applications
  - Buildings
    1. Enhancing thermal energy storage capabilities of building materials
    2. Controllable building loads
  - Advanced Manufacturing
    1. Combined heat and power and chemical and thermal energy storage in manufacturing facilities
  - Vehicles

1. Behind-the-meter storage and optimized charging station designs
2. Smart, fast, and wireless charging technologies

- Fuel Cells
  1. Hydrogen infrastructure, electrolyzer, and storage materials

- Advanced Research Projects Agency–Energy (ARPA-E)
  - Duration Addition to electricitY Storage (DAYS)
    1. Develop energy storage with 10–100 hours of duration
    2. Types of storage include: electrochemical, thermal, thermophotovoltaic, and geomechanical
  - Integration and Optimization of Novel Ion-Conducting Solids (IONICS)
    1. Create electrochemical cells using solid-ion conductors
    2. Applications include lithium-metal batteries, flow batteries, and alkaline exchange membrane fuel cells and electrolyzers
  - Renewable Energy to Fuels Through Utilization of Energy-Dense Liquids (REFUEL)
    1. Develop scalable technologies to convert electrical energy from renewable sources into energy-dense carbon-neutral liquid fuels and convert back to electricity or hydrogen

Q5. Do you think these programs are appropriate and helpful to meet the goals of DOE's program offices?

Q6. Does your organization benefit directly or indirectly from these efforts?

Q7. How would you rank the activities in order of importance or interest to your organization?

Q8. Are there areas that DOE is pursuing that it should not because they are not priorities or because they can be done better by others (e.g., industry or other agencies)? Explain.

Q9. Are there areas that DOE is not pursuing currently that they should focus on? Explain.

Part IV: Process

Q10. Are there other agencies (including the public and private sectors) with which DOE should coordinate its work? If so, specify which ones and which areas of DOE's work would benefit from better coordination.

Q11. Is DOE effective in its RD&D process? For example, should decision-making be more transparent and include more stakeholder input? Is DOE leveraging or engaging the right stakeholders at the right time?

Q12. Does DOE have the correct balance between different types of RD&D goals (e.g., basic science, theoretical exercises, and real-world applications). Explain and provide specific suggestions on process improvements.

Q13. Are there ways in which the goals and activities of DOE's program offices could be coordinated better between the offices? Explain.

Appendix B: Representatives and Offices Involved in September 2019 EAC Webinar of Storage RD&D Activities

Presenter	**Office**
Eric Hsieh	Office of Electricity
Scott Litzelman	Advanced Research Projects Agency—Energy
Alejandro Moreno	Office of Energy Efficiency and Renewable Energy
John S. Vetrano	Office of Science, Basic Energy Sciences

Appendix C: EAC Members at DOE OE Energy Storage Peer Review 2020

Name	**Affiliation**
Flora Flygt	American Transmission Company (Ret.)
Clay Koplin	Cordova Electric Cooperative
Ramteen Sioshansi	The Ohio State University

Appendix D: Questionnaire Respondents

Name	**Affiliation**
Chris Ayers*	North Carolina Utilities Commission Public Staff
Venkat Banunarayanan & Jan Ahlen	National Rural Electric Cooperative Association
Evelyn Butler	Solar Energy Industries Association
Babu Chalamala	Sandia National Laboratories
Armond Cohen*	Clean Air Task Force
Kimberly Denbow*	American Gas Association
Paul Denholm	National Renewable Energy Laboratory
Haresh Kamath	Electric Power Research Institute
Shaun Mann*	Tri-State Generation and Transmission
Jeff Morris*	Schneider Electric

Aaron Smallwood	Smart Electric Power Alliance
Rodney Sobin	National Association of State Energy Officials
Kelly Speakes-Backman	Energy Storage Association
Vincent Sprenkle	Pacific Northwest National Laboratory
Michael Starke	Oak Ridge National Laboratory
Kerry Worthington	National Association of Regulatory Utility Commissioners

* Indicates an EAC member