Union of Concerned Scientists

POLICY BRIEF

Federal Support for Electricity Storage Solutions

State Perspectives on Research, Development, and Demonstration

HIGHLIGHTS

On March 8, 2018, the Union of Concerned Scientists convened 21 experts, from 13 states, on Capitol Hill to identify the most important breakthroughs needed to scale up electricity storage as well as ways the federal government can support innovation in this strategically important industry. This expert convening was sponsored by the Bipartisan House Advanced Energy Storage Caucus. This paper synthesizes the discussions, including recommendations for federal policymakers on how to best support electricity storage RD&D that drives innovation, lowers electricity prices, and increases the reliability of the US electric grid.

Energy storage has the potential to fundamentally transform the way we produce and use electricity, just as the refrigerator was a game-changer for food. However, the private sector is not making the needed investments in electricity storage research, development, and demonstration (RD&D) to achieve this transformation. Specific, strategic efforts are needed by the federal government to advance the technology and increase national energy security.

Our economic and national security are dependent on a continued abundance of electricity, which is also clean, affordable, and reliable. But the nation's electric grid is aging, and it is increasingly vulnerable to disruptions from extreme weather and cyberattacks. Our electricity infrastructure is inadequate to the task of managing short-term differences between supply and demand and integrating diverse energy resources—such as wind and solar—that increase electricity resilience and lower overall costs. Energy storage is the keystone technology for increased grid security—integrating new energy resources, serving as a replacement for aging infrastructure, and providing reliable backup power during outages.

The United States is losing its leadership on energy storage technology to other countries (Hart, Bonvillian, and Austin 2018). China is already cornering the markets for key components needed for battery manufacturing (Ayre 2017) and planning major demonstration projects over the next 10 years (CNESA 2017). How does the United States take a giant leap forward and regain its position as the global leader in this critical technology? Innovation. US policymakers must lead a cultural shift toward better valuing innovation—specifically, ensuring that the economic benefits of technological advances are realized here at home. With robust federal investments and wise policy, the United States can become a global leader in designing, developing, and manufacturing energy storage technologies into the next decade and beyond.

Megan Rising/UCS

Energy storage experts from across the country meet with UCS staff to discuss the role of the federal government in supporting energy storage.

BOX 1.

Convening Participants

Twenty-one experts from 13 states participated in the expert convening on March 8, 2018:

Bill Acker (New York)—executive director, New York Battery and Energy Storage Technology Consortium (NY-BEST); former vice president of technology, Plug Power, Inc.

Abbas Akhil (New Mexico)—Renewable Energy Ventures, LLC; former principle member of technical staff, Energy Storage Program, Sandia National Laboratories; founder, Utility Battery Group (now the Energy Storage Association)

Howard Branz (Colorado)—Branz Technology Partners; former program director, ARPA-E; former group leader, National Renewable Energy Laboratory

George Crabtree (Illinois)—director, Joint Center for Energy Storage Research (JCESR), Argonne National Laboratory

Dean Edwards (Idaho)—professor of chemical and materials science engineering, University of Idaho

David Hart (Virginia)—director, Center for Science, Technology, and Innovation, George Mason University; senior fellow, Information Technology and Innovation Foundation (ITIF)

Todd Haynes (Idaho)—renewable energy project manager, POWER Engineers; former mechanical engineer, Idaho National Laboratory

Gwen Holdmann (Alaska)—executive director, Alaska Center for Energy and Power, University of Alaska–Fairbanks; director, Office of Intellectual Property and Commercialization, University of Alaska–Fairbanks

Craig Irwin (New York)—managing director, senior research analyst for cleantech, Roth Capital Partners

Haresh Kamath (California)—program manager, energy storage, Electric Power Research Institute

Clay Koplin (Alaska)—CEO, Cordova Electric Cooperative, Inc.; mayor, Cordova, Alaska

Adrienne Little (California)—engineer, Project Malta, Google X; former fellow, ARPA-E

Jeffery Marqusee (Virginia)—chief scientist, Noblis; former executive director, Strategic Environmental Research and Development Program (SERDP), Department of Defense; former director, Environmental Security Technology Certification Program, Department of Defense

Matthew Mench (Tennessee)—head, Department of Mechanical, Aerospace and Biomedical Engineering, University of Tennessee–Knoxville; joint faculty, Oak Ridge National Laboratory

Rich Powell (Washington, DC)—executive director, ClearPath Foundation

Donald Sadoway (Massachusetts)—John F. Elliott Professor of materials chemistry, Massachusetts Institute of Technology

Bob Savinell (Ohio)—George S. Dively Professor of engineering, Case Western Reserve University; former director, Yeager Center for Electrochemical Sciences

Mark Swihart (New York)—executive director, New York State Center of Excellence in Materials Informatics, University at Buffalo

Sadrul Ula (California)—managing director, Winston Chung Global Energy Center, University of California–Riverside

Russ Weed (Washington State)—vice president, business development and marketing, UniEnergy Technologies; former vice president, business development for GE Security, General Electric

Tom Zawodzinski (Tennessee)—governor's chair in electrical energy storage, University of Tennessee–Knoxville; joint appointment, Oak Ridge National Laboratory

Convening participants recommend that policymakers should:

- Develop standardized technology metrics to evaluate effectiveness, spur advances, and increase investor confidence
- Adopt a diverse RD&D portfolio of energy storage technologies
- Pursue high-risk/high-reward research in areas where the private sector is not investing
- Keep the talent pipeline full by expanding partnerships with universities
- Work more closely with industry by expanding public-private partnerships
- Pursue more demonstration projects in the field, using states and communities as laboratories of innovation
- Create a federal energy storage roadmap and increase coordination among programs and agencies

UniEnergy Technologies/Creative Commons (Wikimedia Commons)

A 1 MW vanadium flow battery installed in Pullman, Washington. Advanced energy storage will play a key role in the modernization of our nation's electricity grid. Energy storage enables the integration of renewables, improves the grid's operating capabilities, enhances reliability, and provides backup power during emergencies.

Applications and Benefits of Electricity Storage

Advances in energy storage will make the US electricity system more reliable, more affordable, cleaner, and more secure. Specifically:

- Storage benefits **homes, businesses, military bases, and other critical infrastructure** by reducing power outages, providing reliable backup power during and after **extreme weather events**. It also helps protect US electricity infrastructure in the event of **terrorist attacks and cyberattacks**.
- Electricity storage can help **reduce electricity bills** for consumers (Milford et al. 2018), especially where electricity prices are high.
- Storage can benefit **utilities and grid operators** by providing more flexible control of the electric grid and by improving power quality and availability, reducing operating expenses, and allowing them to defer investments in new transmission lines.
- Storage can facilitate **high levels of wind, solar,** and other low-carbon energy technologies onto the electric grid, which is essential for **addressing climate change**.
- Storage can help integrate the **distributed energy resources** and support **microgrids** that are important for **islanded and remote communities**, areas that have limited access to electricity and often rely heavily on expensive diesel generators.
- Electricity storage can play a big role improving **air and water quality** in communities affected by pollution from aging fossil fuel–fired power plants, as a clean and healthy replacement alternative for meeting peak electricity demand.
- Non-stationary applications for energy storage, including reciprocal charging with electric vehicles, have the potential to **revolutionize transportation** and the electric grid.
- Advances in electricity storage will grow our economy and position the United States to lead in the **rapidly growing global market** for this technology.

Research Priorities for Electricity Storage Breakthroughs

Several obstacles are preventing the necessary advances in energy storage, leaving many of the benefits underutilized or unattainable. The federal government can play a critical role in helping to overcome technical and market barriers to wide-scale deployment of energy storage by focusing on the most important research priorities:

IMPROVE SYSTEMS INTEGRATION

Research on the integration of storage into the electricity system is a high priority, for large grids, smaller rural utilities,

distributed energy resources, and microgrids. Necessary advances in systems integration include improving power electronics, software, and other distribution automation technologies; these in turn will improve grid control and reliability, support reciprocal charging between electric vehicles and the grid, facilitate high levels of renewable energy, and increase the resilience of the grid in the face of extreme weather and cyberattacks. Remote communities in particular stand to benefit from cost and reliability improvements in systems integration, since reliable electricity often necessitates the integration of several different energy resources.

DEVELOP LONG-DURATION STORAGE

The length of time a battery is able to supply power needs to be extended from four hours with current lithium-ion batteries to eight hours and beyond—a capability critical for increased grid flexibility and reliability and overall national energy security. Long-duration storage has virtually unlimited applications; however, breakthroughs will require a strong focus on new battery chemistries and materials science (ARPA-E 2017). Promising technology options are available right now, but they lack the funding from industry to be proven at scale. Industry leaders see economical, long-duration storage as achievable within 10 years—with a strong federal commitment to technological innovation.

LOWER CAPITAL COSTS

While capital costs for some storage technologies have been declining in recent years, high costs still often impede greater storage deployment. To bring down costs, RD&D investments are needed in chemistry and materials science, including the supply chain of energy storage technologies, where volatile global commodity prices and competition for minerals and materials are major obstacles. Cost reductions in power electronics are also important for better systems integration. Discovering and refining ways to reuse and recycle batteries will also significantly lower costs. Non-electrochemical battery technologies are also worthy of increased RD&D focus because they omit the need for exotic materials and expensive manufacturing processes, which greatly reduces costs.

> ***Federal government support for energy storage technologies can help overcome barriers to commercial deployment.***

DETERMINE VALUE OF STORAGE SERVICES

The flip side of reducing capital costs is recognizing and capturing the wide range of value streams and services that energy storage can provide. Benefits from reducing air pollution and from improving grid reliability, resilience, and efficiency are not fully monetized and rewarded in the market. Electric utilities are regulated by public utility commissions (PUCs), which have historically viewed the electric grid as consisting of two asset classes—generation and distribution/load—into which energy storage does not easily fit. Therefore, PUCs have struggled to assign value to these projects, hampering the ability of developers and storage owners to fully capitalize on the very real technological and economic benefits that storage provides. Focusing federal research on cost-benefit analysis, business models, and improving tools that quantify and stack multiple value streams will help utilities and their large commercial customers make a rational assessment and valuation of energy storage options, increasing large-scale commercial investment in the technology.

IMPROVE STORAGE DURABILITY

One key way to lower costs is by developing storage technologies with longer lifetimes and greater durability. Battery degradation is a persistent issue affecting the energy management and grid reliability services that electricity storage provides. New battery chemistries and improved membranes are key to addressing durability; electrochemical flow batteries show promise, as does thermal storage. Science-based durability metrics are also needed, to document progress and increase investor confidence.

Federal Government RD&D on Energy Storage

Innovative energy technologies, such as energy storage, face significant barriers to commercial deployment that can only be overcome through federal government support. The venture capital community has limited ability to invest in storage technologies due to the time it takes to yield sufficient return on their investments. The utility industry is risk-adverse and slow to adopt new technologies, spending less than 0.5 percent of revenues on R&D, much less than other industries. By comparison, the pharmaceutical industry spends about 10 percent (Costello 2016). Electricity markets and regulations fragmented across 50 states create additional barriers and prevents private investment in demonstrations, inhibiting advances that come from learning by doing.

Participants in the March expert convening agreed that federal energy storage RD&D across the government is

BOX 2.

Support for Energy Storage in Congress

The Bipartisan House Advanced Energy Storage Caucus can be a powerful forum in Congress for educating lawmakers about the wide range of applications and benefits of electricity storage technologies for our national security, as well as illuminating the critical research questions and challenges facing the industry. The caucus can also serve as an incubator for wise policy that helps the United States stay on the cutting edge of electricity storage technology and increase our global economic competitiveness.

Megan Rising/UCS

Cochairs of the Bipartisan House Advanced Energy Storage Caucus, Representatives Mark Takano, D-CA (speaking), and Chris Collins, R-NY (far right), discuss energy storage technologies at the March 8 convening.

underfunded relative to the strategic importance of innovation in this technology. Federal RD&D at all stages of the innovation ecosystem is needed to advance energy storage.

Most federal investments in storage RD&D are made through the Department of Energy (DOE), but the participants also discussed the important work happening at other agencies, most prominently at the Department of Defense (DOD). Here is a look at some important federal programs that need more support:

ENERGY STORAGE RD&D AT THE DEPARTMENT OF ENERGY

- The **Basic Energy Sciences** program within the DOE's Office of Science supports early-stage basic research for new technologies, including materials science and electrochemistry related to energy storage (Crabtree 2017). Basic Energy Sciences manages four Energy Frontier Research Centers as well as two of the DOE's five Energy Innovation Hubs, including the **Joint Center for Energy Storage Research (JCESR)** at Argonne National Laboratory. JCESR's early-stage basic research helps expand functionality, improve durability, and improve the performance of electricity storage.
- The **Office of Electricity Delivery (OE)** within the DOE's Office of Energy leads the DOE's efforts on grid modernization and resilience in energy infrastructure, including smart grid, microgrid, and energy storage R&D. The OE also supports technology adoption at the intersection of technology, policy, and markets. The **Energy Storage Program** partners with industry, utilities, and state energy organizations to advance multiple storage technologies, improve performance, and reduce costs. This program focuses on research questions ranging from the applied early stage, to pre-commercialization and demonstration projects.
- The **Office of Energy Efficiency and Renewable Energy (EERE)** within the DOE's Office of Energy funds applied research in various clean energy technologies. The lion's share of its funding for storage goes to the Vehicles Technologies Program, but the office funds some important cross-programmatic initiatives in electricity storage systems integration, including a recent solicitation for solar and storage integration (Pyper 2018) as well as its ongoing and broader **Grid Integration Initiative**.
- The **Advanced Research Projects Agency—Energy (ARPA-E)** pioneers transformational energy projects that represent high-risk but potentially game-changing technologies and provides effective technology-to-market advice to the best performers. For storage, ARPA-E takes this transformational approach to new chemistries, controller technologies, long-duration components, and cost reduction. Between 2009 and 2014 ARPA-E invested 10 to 15 percent of its funding in electricity storage projects (NASEM 2017). The agency recently announced the creation of the Duration Addition to electricitY Storage program (DAYS) for projects devoted to long-duration storage (ARPA-E 2018).

ENERGY STORAGE RD&D AT THE DEPARTMENT OF DEFENSE

The DOD has a long and successful history of partnership with industry and academia in advancing the technologies it needs. Today, energy storage is a critical need in a wide variety of military applications, thereby making the DOD a natural

US Navy/Mass Communication Specialist 2nd Class Clifford L. H. Davis

Energy storage has a wide variety of military applications and is an important RD&D priority for the Department of Defense.

first adopter and customer. The DOD's work significantly contributes to addressing most of the important storage research priorities and is managed through the Office of the Secretary, at the **Operational Energy Management Capability Investment Fund (OECIF)** and the **Environmental Security Technology Certification Program (ESTCP)** and has offices within the branches of service. Over the next five to 10 years, the military is expecting a wave of multi-megawatt storage deployments at dozens of locations. The DOD is therefore a natural testbed for new energy storage technologies, helping to advance our understanding of the technology while bringing down costs of future projects.

Recommendations for Advancing Electricity Storage RD&D

ADOPT A DIVERSE RD&D PORTFOLIO

Electricity storage RD&D programs at federal agencies should fund a diverse portfolio of technologies, applications, geographies, institutions, project timelines, and scale. Specifically, they should:

- Focus on a diversity of project time frames, for example, five- to 10-year and more than 20-year efforts, thus increasing the chances of research breakthroughs in both the near and long term.
- Target different stages of the innovation cycle, ranging from early- and later-stage research to demonstration projects that help promising technologies and applications overcome the "valley of death" as they move toward commercialization.
- Include technologies with diverse applications and cross-cutting subsystems and components, which increase opportunities for commercialization.
- Pursue a diversity of partnerships with a variety of public/private institutions, including universities, businesses, state and local governments, national labs, and nongovernmental organizations.
- Pursue RD&D in a diversity of locations, thereby advancing dynamic proof of concepts applicable to a wide range of markets and consumers, while providing economic development opportunities in different states and communities.
- Create more Energy Innovation Hubs that are smaller and more diverse in areas of specialization, ranging from high-risk/high-reward approaches to long-term applied RD&D in areas such as lithium-sulfur, lithium-oxygen, flow batteries, and other battery chemistries.

> ***Electricity storage RD&D programs at federal agencies should fund a diverse portfolio of technologies, applications, geographies, and scale.***

PURSUE HIGH-RISK/HIGH-REWARD RESEARCH

The private sector is especially unwilling to invest capital in high-risk but potentially game-changing technology, underscoring the need for more federal investment in this area if the United States is to regain its global leadership role in this strategically critical technology. The DOE's Office of Science understands innovative basic research with transformative potential, while ARPA-E understands disruptive innovation in these technologies' applications.

- Increase funding for ARPA-E. The National Academy of Sciences report that recommended ARPA-E's creation recommended that its funding be stabilized at $1 billion per year within four years of its inception (NAS 2007). However, in FY2018, ARPA-E was funded at only $353 million.
- Bolster ARPA-E's successful model of transformational energy storage development with even more emphasis on radical innovation.

US Department of Energy

Funded partially by the Department of Energy, AREVA's solar team and Sandia's molten salt technology experts have developed an innovative approach to energy storage.

- Expand ARPA-E's successful Innovative Development in Energy-Related Applied Science (IDEAS) program focused on early-stage applied research.
- Increase opportunities for promising ARPA-E projects to graduate to additional funding, or "plus-ups."
- Increase funding for Basic Energy Sciences at the DOE's Office of Science, which focuses on basic science advances at the pre-competitive phase that can have big payoff in transformative battery technology.
- Focus on power electronics, innovative electrochemistry, and materials science—innovations like new material chemistries, as they move toward "proof of concept."

KEEP THE TALENT PIPELINE FULL

Partnerships with universities and colleges need to be expanded to explore innovative ideas in energy storage, as well as provide longer-term grants.

- Create a University Innovation Research Program at the DOE that provides seed grants to colleges and universities to explore innovative ideas in energy storage, with a focus on region-specific applications.
- Train the next generation of scientists and engineers in next-generation battery technologies. Create mentorship programs that pair experienced researchers at the nation's energy hubs and national labs with young innovators and students pursuing work in energy storage.
- Encourage collaborative research between university and industry teams, and create more on-ramps for young engineers and scientists into private sector R&D.

EXPAND PUBLIC-PRIVATE PARTNERSHIPS

More federal public-private partnerships are needed that are focused on innovation in electricity storage.

- Include "customers"—utilities and manufacturers—as well as universities, state governments, and large companies with dedicated R&D shops as well as small businesses and start-ups.
- Reduce user fees and make testbeds such as the National Renewable Energy Laboratory and Sandia National Laboratories more accessible to utilities, battery manufacturers, and entrepreneurs, allowing innovators to learn through testing and demonstration and discover new applications for electricity storage technologies.
- Increase funding for the Energy Storage program in the DOE's Office of Electricity Delivery, building on its successful track record partnering with the private sector and increasing emphasis on collaboration with utilities.

More federal public-private partnerships are needed that are focused on innovation in electricity storage.

- Support applications-centric programs that focus on near-term improvements in key research areas that are appealing to the private sector, such as the Office of Energy Efficiency and Renewable Energy's Grid Integration Initiative.
- Leverage federal analytical capacity and relationships with federal electricity market authorities, such as the Federal Energy Regulatory Commission, to highlight proven business models and help utilities make a rational assessment and valuation of energy storage options.

DEVELOP STANDARDIZED TESTING AND METRICS

Standardized and recognized methods for testing and measurement of batteries and other storage technologies are needed to create consumer and investor confidence and to foster real advances. Federal support for the development of national standards for electricity storage technologies will allow the best technologies to win out in the market, benefiting consumers and enabling both large and small manufacturers to compete on a level playing field. Standards should:

BOX 3.

Partnership Opportunities between ARPA-E and the Department of Defense

A partnership between ARPA-E and the DOD could provide a pathway for promising technologies to take the next step toward commercialization. The DOD has the testbed capacity, resources, experience, and demand to continue the development and demonstration of promising ARPA-E projects. Moreover, the DOD has the longer-term investment tolerance needed to see these projects through, as well as the capacity to scale up successful new technologies. Such a partnership would help move key advances in storage technology from the lab bench to the field, and then to market.

- Focus on safety. Local fire safety officials need stronger federal leadership in testing battery safety and providing model fire safety codes and training programs that effectively address energy storage.
- Focus on performance. Every potential buyer and financing entity will rely on consistent and predictable information about performance. An open, federally supported standard-setting process will increase transparency in the industry and allow verifiably superior technologies to advance.

PURSUE MORE DEMONSTRATION PROJECTS

The federal government should pursue more demonstration projects in the field, utilizing states and communities as laboratories of innovation.

- Prioritize demonstrations that provide key engineering and field data that will speed up deployment of energy storage.
- Pursue more energy storage demonstration projects through the DOD, which has a great deal of experience and is focused on performance in the field. The DOD can reap benefits of being an early adopter and is willing to pay for those benefits.
- Prioritize niche markets and utilize the states as laboratories of innovation. States such as Alaska with islanded grids and high costs can provide valuable opportunities for demonstra-tion projects from which the rest of the country can learn.
- Pursue an appropriate balance of larger, higher-cost demonstration projects (more than $10 million), where venture capitalists are not willing to invest, and smaller, lower-cost demonstrations that yield valuable information quickly and cheaply.
- Pursue demonstration projects in a variety of environments with different physical conditions and market constraints. Demos should answer questions of importance to a broad range of stakeholders—rural electric co-ops, large utilities, residential customers, industrial customers, the military—around the country.

CREATE AN ENERGY STORAGE RD&D ROADMAP

The DOE should collaborate with other federal agencies to develop a comprehensive Energy Storage RD&D Roadmap for the electric grid that lays out a long-term vision with targets and key milestones to track progress. The roadmap should:

- Identify key areas for future research across a portfolio of technologies and approaches, and adopt long-term cost, performance, and deployment targets for specific applications of electricity storage technologies.
- Increase coordination across federal programs and agencies. For example, the energy storage program at the Office of Electricity Delivery should increase coordination with ARPA-E's storage program to better identify synergies and build on promising work. Likewise, the DOD and DOE have some overlapping priorities on energy storage RD&D and should increase the coordination and collaboration across both agencies.

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