

EEESDP 17

ELECTRICAL ENERGY STORAGE DEMONSTRATION PROJECTS 2017

SANDIA NATIONAL LABORATORIES ES DEMONSTRATION PROJECTS YEARBOOK



**Sandia
National
Laboratories**

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ABOUT THE EESDP YEARBOOK

The Electrical Energy Storage Demonstrations Projects (EESDP) Journal is a collection of selected summaries about current areas being explored by the U.S. Department of Energy (DOE) and Sandia National Laboratories' scientists, engineers, technologists and industry partners involved in the research and development and deployment (RD&D) of electrical energy storage materials, devices, equipment, systems and facilities through purposed demonstration projects.

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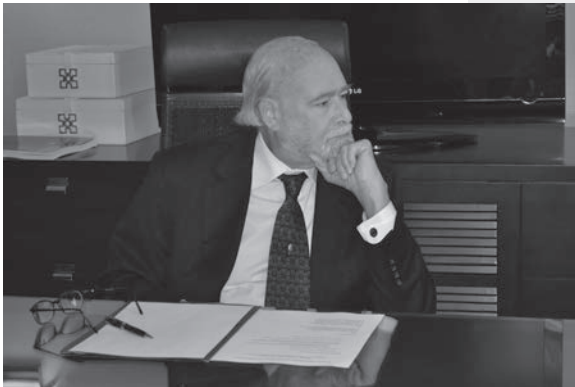
ACKNOWLEDGEMENT

We wish to express appreciation and gratitude to the U.S. Department of Energy's Office of Electricity Delivery and Energy Reliability and Dr. Imre Gyuk, Energy Storage Program Manager, for the vision, support, and encouragement to collaborate with industry, utilities, and academia to achieve the work of the demonstrations program.

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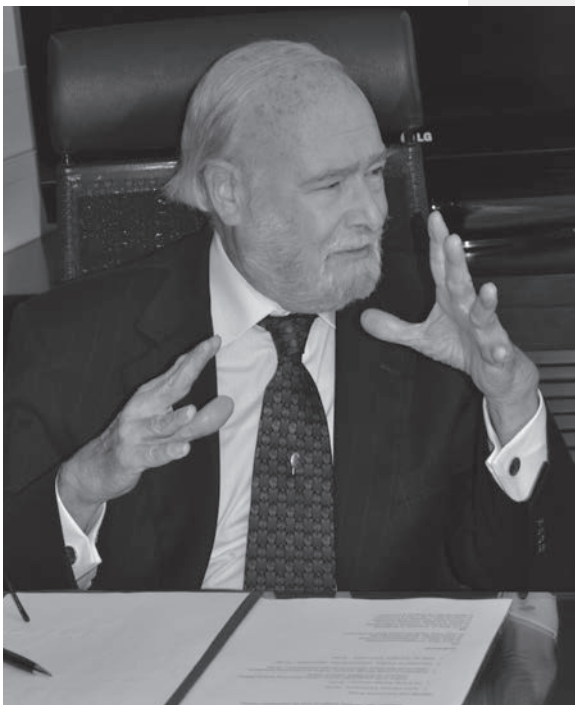
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DEMONSTRATION PROJECTS: VISION AND PRACTICAL APPLICATIONS



DR. IMRE GYUK

Energy Storage Program Manager,
Office of Electricity Delivery and
Energy Reliability



The Office of Electricity Delivery and Energy Reliability recognizes that our Nation's sustained economic prosperity, quality of life, and global competitiveness depend on access to an abundance of secure, reliable, and affordable energy resources. We leverage effective partnerships, solid research, and best practices to address the changing dynamics and market uncertainty through a mix of technology and policy solutions.

THE CURRENT TRENDS DRIVING ELECTRICITY SYSTEM CHANGES ARE

- A changing mix of types and characteristics of electric generation
- Aging infrastructure
- The emergence of interconnected electricity, information and control systems
- Growing supply- and demand-side opportunities for customers to participate in electricity systems
- Growing demands for a more resilient and reliable grid

KEY CHARACTERISTICS OF A MODERNIZED GRID

- Reliable – Not prone to outage or disruption
- Resilient – Smaller scale and shorter duration of disruptions if/when they occur
- Secure – Able to survive physical or cyber attack
- Affordable – Delivered at an economically-competitive cost
- Sustainable – Enabling cost-effective utilization of advanced generation resources
- Flexible – Ability to respond to the variability and uncertainty of conditions at various timescales

AS THE ELECTRICITY INDUSTRY CONTINUES TO CHANGE AND GROW, MY VISION IS TO SEE

- Added storage at generation to ease issues of supply intermittently or load ramping
- Strategically located storage across the transmission and distribution lines to improve reliability, efficiency, ramping, and resilience, and
- Storage at Load to support distributed resources and add redundancy to improve resilience

DEMONSTRATION PROJECTS APPROACH

Development, deployment, and operation of energy storage through controlled testing of prototype commercial storage technologies is critical for industry acceptance.

KEYS FOR INDUSTRY ACCEPTANCE:

- Identify applications
- Provide cost-benefit analysis
- Offer use case analysis
- Deliver technical assistance
- Establish control architecture
- Capture real-world successes

PROGRAM ACCOMPLISHMENTS:

- Ten R&D 100 Awards, 169 peer reviewed publications, and 70 patents
- Fourteen commercial technology licenses
- Established industry-wide Energy Storage Safety Working Group
- Established Global Energy Storage Database

ON THE HORIZON

- R&D prototyping new aqueous soluble organic flow battery chemistries for 2X reduction in cost
- Expand Safety Forum to include national and international community for adoption of codes and standards
- Expand regional workshops to engage utility regulatory commissions
- Expand technical assistance to states on demonstrations with 8MW+ of energy storage assets



DAN BORNEO

Principal Investigator
ESS Demonstration Projects
Sandia National Laboratories

“We leverage effective partnerships, solid research, and best practices to address the changing dynamics and market uncertainty through a mix of technology and policy solutions.”

—Dr. Imre Gyuk

FY 2017 ES DEMONSTRATION PROJECTS

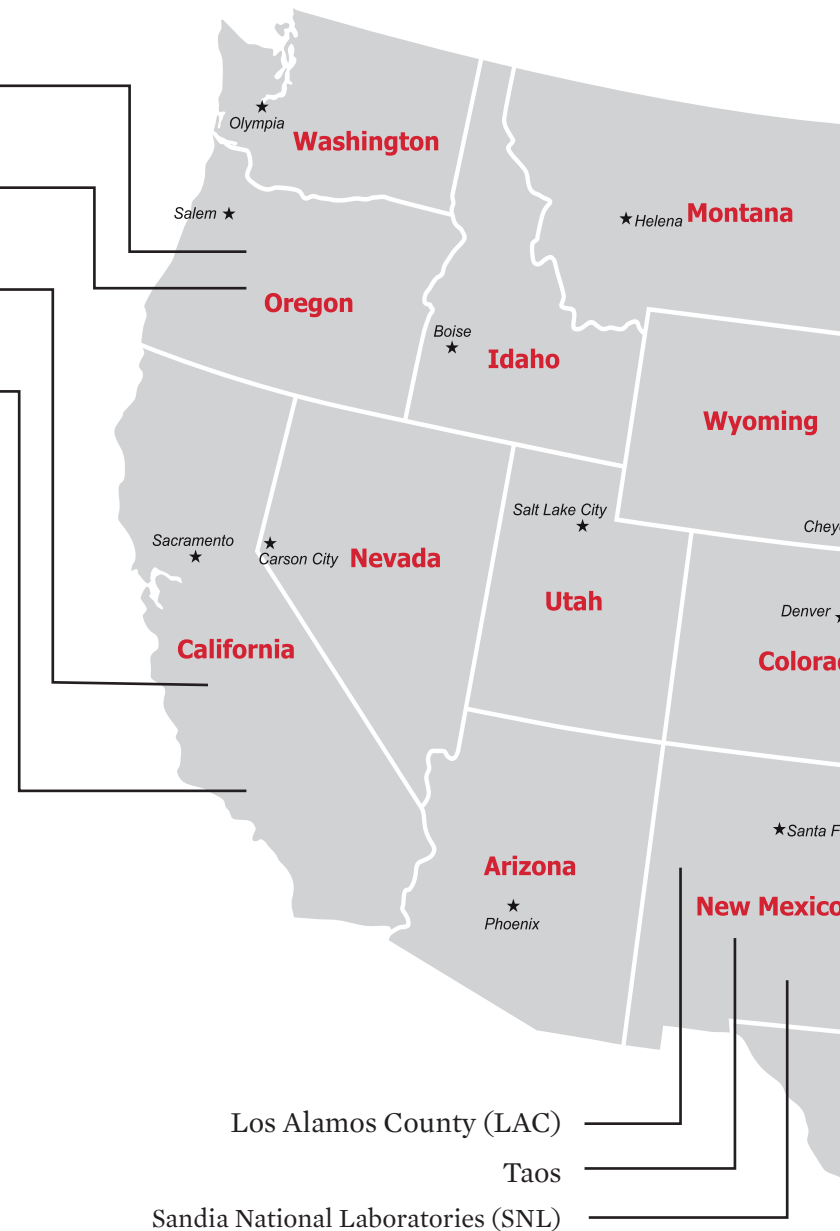
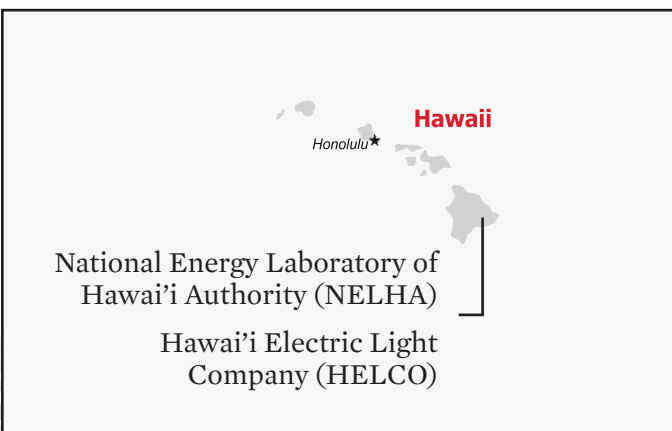


Eugene Water and Electric Board (EWEB)

PGE

California Energy Commission (CEC)

Poway



INTERNATIONAL PROJECTS AND PARTNERS:

Singapore

Australia (ECOULT)





GRID

MODERNIZATION

LABORATORY CONSORTIUM

The U.S. Department of Energy (DOE) has built on its Grid Modernization Initiative – an ongoing effort that reflects their commitment to improving the resiliency, reliability, and security of the nation’s electricity delivery system. During his visit to a utility control center in Miami, FL today, Energy Secretary Ernest Moniz announced the release of DOE’s comprehensive new Grid Modernization Multi-Year Program Plan, a blueprint for modernizing the grid.

The Secretary also announced the award of up to \$220 million over three years, subject to congressional appropriations, to DOE’s National Labs and partners to support critical research and development in advanced storage systems, clean energy integration, standards and test procedures, and a number of other key grid modernization areas. Additional programs, initiatives, and funding opportunity announcements related to the Grid Modernization Initiative will be announced in the coming days.

“Modernizing the U.S. electrical grid is essential to reducing carbon emissions, creating safeguards against attacks on our infrastructure, and keeping the lights on,” said Secretary Moniz. “Our Quadrennial Energy Review and Quadrennial Technology Review identified needs and opportunities to invest in the grid. This public-private partnership between our National Laboratories, industry, academia, and state and local government agencies will help us further strengthen our ongoing efforts to improve our electrical infrastructure so that it is prepared to respond to the nation’s energy needs for decades to come.”

The Grid Modernization Initiative represents a comprehensive DOE effort to help shape

the future of our nation’s grid and solve the challenges of integrating conventional and renewable sources with energy storage and smart buildings, while ensuring that the grid is resilient and secure to withstand growing cyber security and climate challenges. Today’s announcements fall under the Grid Modernization Initiative’s framework.

- The Grid Modernization Multi-Year Program was developed by DOE in close collaboration with a wide range of key external partners. The program lays out a blueprint for the Department’s research,

This public-private partnership between our National Laboratories, industry, academia, and state and local government agencies will help us further strengthen our ongoing efforts to improve our electrical infrastructure

development, and demonstration agenda to enable a modernized grid, building on concepts and recommendations from DOE’s recently released Quadrennial Energy Review and Quadrennial Technology Review.

- The up to \$220 million in research and development funding falls under the Grid Modernization Laboratory Consortium. The consortium involves 14 DOE National Laboratories and dozens of industry, academia, and state and local government agency partners across the country. These funds are being awarded in response to a challenge to the National Laboratories to establish a comprehensive grid-related research and development effort to address a range of emerging challenges and opportunities in the nation’s power grid.

Sterling

MUNICIPAL LIGHT DEPARTMENT



Sterling Municipal Light Department's groundbreaking energy storage system project is the result of a collaboration among municipal, state, federal, industry, philanthropy, and nonprofit partners.

The 2-megawatt, 3.9 megawatt-hour battery storage system, installed at the Sterling Municipal Light Department (SMLD) Chocksett Road Substation, is expected to save the town's ratepayers at least \$400,000 per year by decreasing costs associated with capacity and transmission charges from the regional power services supplier, ISO New England. Sterling will be able to lower its demand for grid services from the ISO by discharging the battery system during times of regional peak demand. The project demonstrates a strong investment strategy for municipal energy storage: With the help of grants, this \$2.7 million project is expected to pay for itself in just over two years.

"Sterling's energy storage system is proving that energy storage works...So far, the system has produced cost savings of \$350,000 in the first nine [9] months of operation, putting it on track to meet or beat the predicted \$400,000 per year in cost savings....even without [considering] grants, it would pay itself off in under seven years." - Sean Hamilton, General Manager, Sterling Municipal Light Department





Sterling's energy storage system is proving that energy storage works, and it can save a town substantial money. So far, the system has enabled savings in excess of \$350,000 in nine months – these savings will directly benefit Sterling's ratepayers.

In addition to the economic benefits, the system can “island” from the grid during a power outage and provide at least 12 days of backup power to the town’s police station and emergency dispatch center, a critical facility providing first responder services. Because Sterling’s battery system is connected to a 2.4 MW solar array, the solar can charge the batteries when grid power is not available, providing an even longer period of energy assurance.

Dr. Imre Gyuk, Energy Storage Program Manager for the U.S. Department of Energy Office of Electricity Delivery and Energy Reliability, said of the project, “There are monetized and unmonetized benefits. Resiliency is a benefit that is more difficult to monetize, but it is equally important.”

The project received a \$1.46 million Community Clean Energy Resiliency Initiative grant from the Massachusetts Department of Energy Resources, under Commissioner Judith Judson, with additional financial and technical assistance from the U.S. DOE Office of Electricity under the leadership of Dr. Imre Gyuk, and Sandia National Laboratories under the direction of Dan Borneo. Additional technical support was provided by the Clean Energy States Alliance through its Energy Storage Technology Advancement Partnership (ESTAP), and by Clean Energy Group’s Resilient Power Project through a generous grant from Boston-based Barr Foundation.

“Success is never about a single player; it’s about the team,” said Sean Hamilton, referring to the unique collaboration that occurred to implement this project.

“Energy storage is the critical piece of the puzzle to ensuring a clean, green, cost-efficient and reliable energy source,” said Mariella Puerto, co-director for Climate at Barr Foundation. “What is happening in Sterling is giving us a glimpse of the future; and this future is not that far off, if we get the right policies in place.”

“Sterling is in the spotlight because its municipal utility can use the battery system to control rising power costs,” said Clean Energy Group Project Director Todd Olinsky-Paul. “This benefits the town, but the project also provides

What is happening in Sterling is giving us a glimpse of the future; and this future is not that far off, if we get the right policies in place.

environmental benefits for the entire New England region. By using batteries to curb electricity demand spikes, the need to call on expensive gas-fired peaker plants is reduced, and the region’s air quality is improved. And when more municipal utilities install batteries, the grid will become more efficient and more resilient.”

The Sterling project has been the recipient of many awards and accolades, including the No. 1 ranking for Utility Energy Storage Annual Watts Per Customer for 2017 in the Smart Electric Power Association’s top ten ranking of U.S. electric utilities, and a 2017 Grid Edge award from Greentech Media. The SMLD project has also garnered international attention with delegations from Europe and Asia visiting the installation.

Energy


STORAGE TEST PAD



In August of 2017, the Energy Storage Demonstration team partnered with UniEnergy Technologies(UET) to install a 1MWH/250kW vanadium redox flow battery at the Energy Storage Test Pad at Sandia National Labs. The system utilizes two 20-foot shipping containers filled with vanadium electrolyte that serves as both the catholyte and anolyte. The containers are connected to two EPC Power Corporation Inverters/Control Units.

The Vanadium Redox Flow Battery (VRFB) is a unique electrochemical device that stores electrical energy in liquid electrolytes, instead of in solid electrodes as many other batteries do. The VRFB releases the stored energy according to various demands needed at each site, at levels up to multi-MW and MWhs. The new-generation electrolyte – semi-exclusively licensed by UET and improved upon since UET’s founding in 2012 – doubles the energy density of traditional vanadium sulfate electrolytes and greatly improves the operating temperature range, among other benefits, while retaining the inherent safety and excellent charge-discharge reversibility of vanadium-based flow batteries. Zero electrolyte degradation enables virtually unlimited cycle-life, and access to 100% of the State-Of-Charge (SOC), resulting in maximum operational flexibility for the full range of power and energy applications, all at a low level cost and high system reliability.

The system will be used for a variety of purposes including testing SNL/PNNL energy storage protocols, the degradation of the system when exposed to various real life micro-grid situations, cyber security, and energy management controls.

A person wearing a blue protective suit, an orange hard hat, and a clear face shield is working on a complex electrical system. The system consists of a large metal cabinet with a green printed circuit board (PCB) inside, which is densely packed with various colored wires (red, orange, purple, black) and components. The person is holding a yellow tool or component. The background shows a laboratory or industrial setting with various cables and equipment.

The system will be used for a variety of purposes including testing SNL/PNNL energy storage protocols, the degradation of the system when exposed to various real life micro-grid situations, cyber security, and energy management controls.
—Cole Benson

Chattanooga

ELECTRIC POWER BOARD



(left to right) Rep. Chuck Fleischmann, Dr. Thomas Zacharia, Director of Oak Ridge National Laboratory, David Wade, President of EPB, Senator Bob Corker, Joe Ferguson, EPB Board of Directors Chairman, Dr. Imre Gyuk, Department of Energy, Jim Coppinger, Mayor of Hamilton County, TN, U.S. Representative Diane Black, Babu Chalamala, Sandia National Laboratories, Senator Lamar Alexander

The Chattanooga Electric Power Board (EPB) has energized a 100kW/400kWh Vanadium Redox Flow Battery as part of a national research effort to explore the best use of cutting edge technologies that could be implemented across the United States to modernize the power grid.

“Because Chattanooga’s power distribution infrastructure combines a community-wide fiber optics network with more than 1,200 automated power management devices to form one of the most advanced smart grids in the country, we are well-positioned to serve as a living laboratory for testing new technologies and developing best practices that will help other utilities modernize their infrastructure,” said EPB Board of Directors Chairman Joe Ferguson. “EPB thanks its partners for joining with us in an effort to better serve our local customers while conducting research that will benefit people across the United States.”

EPB’s project constitutes a partnership with the U.S. Department of Energy (DOE), Oak Ridge National Laboratory, Sandia National Laboratories, and Pacific Northwest National Laboratory as part of the DOE’s Grid Modernization Lab Consortium (GMLC) program. The goal of the GMLC is to develop and test new technologies that can enhance the flexibility and resiliency of the national power grid. The battery system for the EPB project is provided by UniEnergy Technologies (UET), a U.S. manufacturer.

“This new battery system is a good example of how basic energy research at our national laboratories can bring together businesses and utilities to develop and deploy new energy,” said U.S. Senator Lamar Alexander. “I applaud Chattanooga’s Electric Power Board, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, Sandia National Laboratories and UniEnergy Technologies for working to solve an urgent problem facing this country – how to make sure we can store the energy we produce and use it when we need it. Researchers at our national laboratories will now be able to study how this battery system performs in the real world and make this technology even better – modernizing our nation’s electricity grid to make it more reliable and responsive to customers.”

“It will come as no surprise to our community that Chattanooga and EPB are continuing to play an important

role in the modernization of our country's power grid," said U.S. Senator Bob Corker. "Through this partnership, we will be able to better understand energy storage and test new technologies in an effort to bring resilient and affordable electricity to Americans. An extensive and reliable grid is critical for a 21st century economy, and I thank EPB, Oak Ridge National Laboratory and their partners for their work to improve our nation's infrastructure."

Installed at the site of EPB's Solar Share community solar array in Chattanooga, the battery system is a pilot project to explore how large-scale energy storage can be integrated with smart grid automation to provide consistent output from highly variable power generation sources like solar as well as how these devices could be used as a "battery backup" to reduce the impact of outages. In addition, the advanced flow battery has the capacity to store bulk energy during off-peak hours when fewer customers are using it so that the power can be released to meet needs during times of higher power demand.

"This battery storage project is a great example of why I have worked so hard to build bridges between Chattanooga and Oak Ridge National Lab," said U.S. Representative Chuck Fleischmann. "Through this initiative, we have the opportunity to enhance our local power distribution infrastructure for the benefit of people in our hometown community while advancing the national effort to modernize the grid."

"This project is a wonderful example of what can happen when local and national entities work together," said U.S. Representative Diane Black. "As a result of thoughtful collaboration, this community is not only enhancing local power distribution infrastructure, but also contributing to the national effort to modernize and improve the reliability of the power grid. President Trump's Department of Energy is truly reaching out to partner with Tennessee to improve energy production."

EPB will use the battery system for a wide variety of applications including solar integration, voltage regulation, back-up power, advanced microgrid operations and energy management. Working closely with the national laboratories, EPB will hone the control strategies used to operate and maximize the value proposition for utilizing battery systems. The utility and the labs will also collaborate to quantify and analyze the different benefits from the project to EPB's customers.

"This installation combines cutting edge, long duration storage technology with an outstanding communication network," said Dr. Imre Gyuk, Director of Energy Storage Research in DOE's Office of Electricity. "Chattanooga will serve as an example of innovative electrical infrastructure for Tennessee and the Nation."

"Our partnership with EPB continues to create exciting opportunities to enhance the security and resilience of the electric grid," said Dr. Thomas Zacharia, Director of Oak Ridge National Laboratory. "This project is leveraging our shared strengths in sensing and measurement, advanced control concepts, and cybersecurity to explore the potential value of this emerging technology for the region and the nation."

The advanced vanadium flow battery technology utilized in the UET system was developed at Pacific Northwest National Laboratory, with the support of the DOE Office of Electricity. Sandia National Laboratories has assessed the technology's applications in the U.S. and globally. Starting in 2012, UET commercialized that technology into grid-scale containerized flow battery products, with 380 megawatt-hours of systems deployed, contracted, and awarded in 3 countries and 6 U.S. states. UET's technology features no degradation of power or energy, unrestricted cycles, and 20+ year life.

As a result of thoughtful collaboration, this community is not only enhancing local power distribution infrastructure, but also contributing to the national effort to modernize and improve the reliability of the power grid.

"Our community is proud to once again serve as a testing ground for advanced technology and infrastructure," said Hamilton County Mayor Jim Coppinger. "I hope other researchers and entrepreneurs will continue to think of the Chattanooga area as an ideal place to develop and launch new products and technologies."

"This project is the next step in EPB's continuing effort to serve our customers by providing world-class energy solutions as the electric industry undergoes rapid change," said David Wade, president and CEO of EPB. "As it becomes possible to deploy large-scale battery storage throughout our system, I envision a time when we can further reduce the number of customers impacted by outages. As our community becomes more dependent on solar power generation, we will be able to keep power flowing consistently when clouds cause solar generation to drop off suddenly. I can even foresee a future when it is possible for us to utilize energy storage to reduce the need to make massive investments in building or replacing power generation plants."

ABOUT ELECTRIC POWER BOARD

Established as an independent board of the City of Chattanooga in 1935, EPB is a municipally-owned utility that provides electric power and fiber optic communications services as a means of promoting economic development and enhancing quality of life across the local area.

SANDIA ES INDUSTRY ACCEPTANCE CAPABILITIES

OVERVIEW OF SANDIA'S ENERGY STORAGE PROGRAM

Modernization of the electricity infrastructure is critical for the economic vitality and the future of the country. Sandia's support for this grid modernization vision includes a broad research program in energy storage technologies and systems. The laboratories' work is focused on making energy storage safe, reliable, and cost effective through research and development (R&D) in new battery technology development, advancements in power electronics and power conversion systems, improving the safety and reliability of energy storage systems, and enabling the deployment of new energy storage technologies in the electric grid. Sandia's grid energy storage research is primarily supported by the U.S. Department of Energy's (DOE) Office of Electricity Delivery and Energy Reliability (OE) – Energy Storage Program.

THE CHALLENGE

After the American Recovery Act provided DOE \$4.5 billion to modernize the electrical grid in 2009, energy storage became an integral part of solving this issue. Energy storage technologies can support the grid in several ways such as demand reduction, infrastructure improvements, reliability, frequency regulation, energy management, and backup power. In order for Energy Storage Systems (ESS) to become widely deployed, they should meet the following challenges:

- Be cost competitive with other alternatives
- Meet the regulatory requirements
- Have validated reliability and safety
- Be accepted by industry

CAPABILITIES

Sandia strives to help ESS meet these challenges by collaborating with developers, academia, utilities, energy storage providers, and others to understand and improve ESS. Sandia's expertise allows us to:

- Provide initial analysis and modeling of the grid to determine the appropriate applications for the ESS, the need for distributed energy resources (DER), and financial benefits of energy storage for the given markets
- Model ESS to determine size MW/MWh for optimum cost benefit
- Support project programming development that includes safety, scope, schedule, and budget
- Develop Requests for information (RFI) and Requests for Proposals (RFP)
- Review proposals and vet technologies
- Develop conceptual electrical plans for microgrids and power distribution systems
- Work with the project team to vet distributed resources and control methods
- Review contract documents to ensure requirement compliance
- Vet commissioning plans and testing protocols for both factory tests and field installations
- Provide technical support during construction and commissioning
- Conduct operational performance data review and analysis
- Provide analysis and develop optimization algorithms

CURRENT DEMONSTRATION PROJECTS

Sandia is currently involved with over 17 projects. Each project is at a varying level of completion and each is designed to address the DOE's key challenges. Featured projects include the following:

NATIONAL ENERGY LAB OF HAWAI'I AUTHORITY COLLABORATION

Sandia is currently providing the National Energy Lab of Hawai'i (NELHA) with technical consulting, system evaluation, and analysis services for its efforts to incorporate electrical energy storage. There are currently three projects in progress. Once completed, they will utilize 200, 3, and 30 MW of power respectively.



ENERGY MARKET AUTHORITY OF SINGAPORE CRADA

The Energy Market Authority (EMA), in partnership with Singapore Power and Sandia, is developing two projects to demonstrate ESS at two different substations. The goal of the work is to understand the benefits of energy storage in their market and the reliability of energy storage in their tropical environment.



CURRENT DEMONSTRATION PROJECTS *(continued)*

Sandia is currently involved with over 17 projects. Each project is at a varying level of completion and each is designed to address the DOE's key challenges. Featured projects include the following:



STERLING MUNICIPAL LIGHT DEPARTMENT ESS

Sandia contributed to the analysis, request for proposal, and deployment of a 2 MW, 3.9 MWh GSS[®] grid energy storage system for the Sterling Municipal Light Department. The system is the largest system of its kind installed in New England and the first utility scale project in Massachusetts. Using solar energy, the system can provide up to 12 days of clean backup power to nearby police stations and emergency dispatch centers in case of a grid outage.

HELIX POWER FLYWHEEL DEMONSTRATION

Along with NYSERDA, Sandia has partnered with Helix Power to provide technical support for the composite components of their flywheel technology. Helix Power hopes to successfully demonstrate their full scale 1 MW-90 second platform that will recycle braking energy from subway systems to be used as propulsion energy.



CORDOVA ELECTRIC COOPERATIVE ESS

With the Cordova Electric Cooperative (CEC), Sandia is providing in-depth analysis to develop an RFP for an ESS for the CEC's hydro-diesel islanded microgrid. The system will help balance the periods of low demand and high water availability with the periods of high demand and low water availability.

CURRENT DEMONSTRATION PROJECTS *(continued)*

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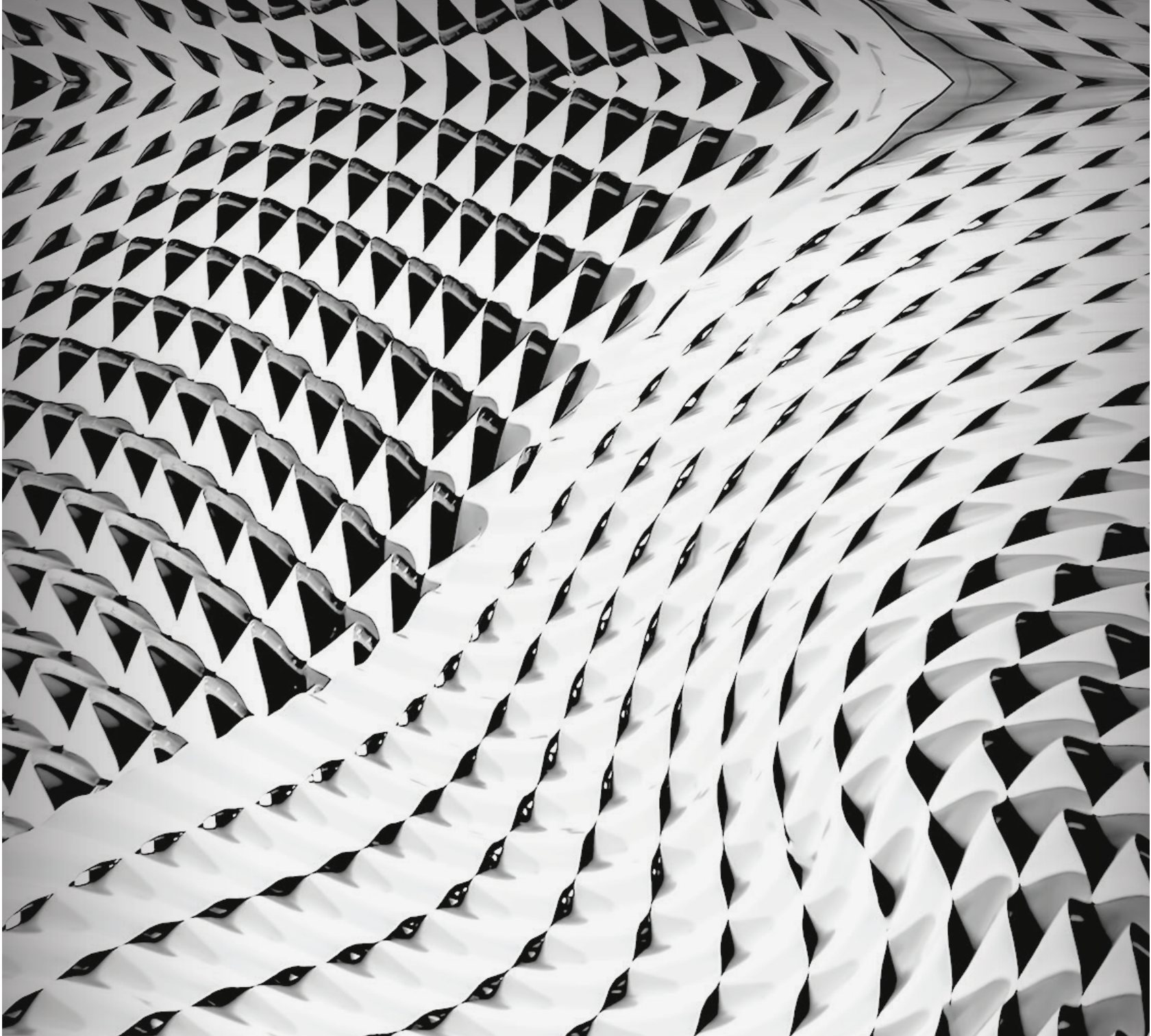
GREEN MOUNTAIN POWER ESS

Green Mountain Power, with support from DOE OE and Sandia, issued an RFP for an ESS to provide resilient backup power to a nearby school and emergency shelter. The resulting system provides 3 MW/3.4 MWh of battery storage and is integrated with 2.5 MW of photovoltaic power.



WEICAN: OPTIMIZATION OF GRID-TIED ENERGY STORAGE

Sandia partnered with Wind Energy Institute of Canada (WEICan) to utilize their Wind R&D Park along with expertise in technical and economical evaluation of ESS. Utilizing their 1 MW/2 MWh battery system, the goal of this project is to increase knowledge and improve service to the energy storage industry.



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