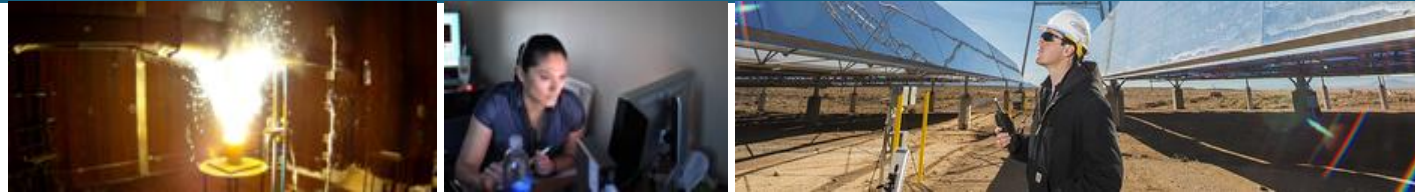


DOE OE Energy Storage Program at Sandia – FY21 Summary



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Sandia – Grid Energy Storage Program



Battery Materials Research

- Advancing battery chemistries through development and commercialization

Safety & Reliability

- Safety Science, Cell and Module Reliability, Failure Analysis, Standards, Protocols

Power Electronics

- Modular Power Converters, Circuit Architectures to Improve Safety and Reliability, New Devices and Components

Analytics and Controls

- Energy Storage Sizing, Optimization & Controls; Open Source Software Tools

Demonstration Projects

- Support, Analysis, Implementation, Monitoring

Policy & Outreach

- State Policy & Regulatory Outreach, Education, Global Energy Storage Database, DOE ESS Website

Cross disciplinary research effort with staff from a number of departments at Sandia

- Over 50 Sandia research staff, 48 individual projects

26 collaborative projects with universities

Collaborative projects a number of utilities and companies, collaboration with National Institute of Technology and Evaluation (Japan), and a new CRADA with PNM

At FY21 Peer Review

- 26 oral presentations
- 49 poster presentations

Battery Materials



Low Temperature Sodium Batteries

- Na-NaI battery materials, low cost solid ion conductors, operating at $\sim 100^\circ\text{C}$. Team includes Sandia and Univ of Kentucky

Alkaline Zinc Batteries

- Comprehensive team advancing rechargeable alkaline Zinc batteries: Sandia, CUNY Energy Institute, Stony Brook Univ, Northeastern Univ, NMSU, Urban Electric Power, LLNL

Non-Aqueous Flow Battery Materials

- Primarily focused on the development of non-aqueous electrolytes. New project on mediated Li-S flow batteries. Collaborative work includes Sandia, LANL, UNM, University of Rochester, UNM, Davidson College, UNC Charlotte

Membranes and Electrode Materials

- Polymeric membranes: Sandia, Xergy, Univ of Colorado, and commercial partners
- Printed electrodes: Sandia and LLNL

Continued advancements in developing low cost, battery energy storage technologies.

- Zinc batteries demonstrated a new high voltage ($> 2.5\text{V}$) dual electrolyte battery concept.
- Demonstrated novel Zn/CuO_x batteries. TCF awarded to enable advanced TRL and scale-up.
- Sodium Battery Materials team developed new NaSICON synthetic strategy that produces 2X improvement in ionic conductivity and easier fabrication.
- Na-batteries demonstrated >8 months cycling in high voltage (3.6V) low temperature (110°C).
- Continued progress in commercial validation of membrane technology.

Organized and hosted the DOE workshop “BIG” Energy Storage: Priorities and Pathways to Long-Duration Energy Storage” on March 9-10, 2021. The workshop had more than 1500 registrants.

- Initiated research in long duration energy storage

7 projects at Sandia, 1 LANL, 1 LLNL, 8 University, 1 Company



New Devices and Components

- Integrating new magnetics, high temperature capacitors and WBG devices in novel power converter architectures. Team: Sandia, UC Irvine, SMU

Modular Power Converters

- High gain DC-DC converters, MVDC converters, Plug-and-Play Battery Energy Storage System. Team: Sandia, Ohio State, UT Austin, Georgia Tech, Univ Alaska, Missouri S&T

Circuit Architectures to Improve Safety and Reliability

- Predicting Reliability, Improving Safety and Resiliency in Grid Connected BESS. Team: Sandia, Univ Houston, NMSU

Significant progress across all areas:

- Demonstrated energy redistribution for thermal runaway using prototype advanced power converters and control. Patent application filed.
- Correlated semiconductor and magnetic materials to the impact of device degradation on the power conversion system
- Demonstrated doubled efficiency in Fe_4N composite magnetic cores at temperatures up to 150C. Prototypes.
- “AC Cube” w/ 1 kWh internal storage, 120 VAC 1 kW validated
- Commercialized 3300V/50A SiC-based monolithic switch for insertion into power circuits (GeneSiC)
- Fabricated a 100kW stackable 3-phase grid-tied inverter using bottom-cooled GaN devices (InnoCit)

Best Paper Award for “A High-Voltage Cascaded Solid-State DC Circuit Breaker Using Normally-On SiC JFETs” at IEEE ECCE-Asia

8 projects at Sandia, 8 University, 2 Companies

Safety and Reliability



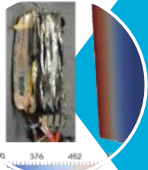
Battery Reliability

Yuliya Preger, Armando Fresquez,
Reed Wittman, Alex Bates,
Venkat Subramanian (UT Austin)



Battery Abuse Testing

Josh Lamb, Loraine Torres-Castro, Alex Bates,
Michael Hargather (NM Tech)



Fire Sciences and Modelling

John Hewson, Randy Shurtz, Andrew Kurzawski,
Alex Headley (Univ of Memphis)



Outreach, codes, and standards

David Schoenwald, David Rosewater, Tu Nguyen,
Chris Searles



System Design Impacts & Security

David Rosewater, Valerio De Angelis, Rodrigo Trevizan,
Wei-Jen Lee (UT Arlington), Vittal Rao (Texas Tech)

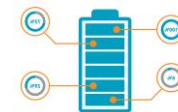
Steady progress in advancing safety and reliability

- Organized the Energy Storage Systems Safety & Reliability Forum on April 20-21, 2021.
- Initiated research on safety of Solid-State Batteries and Aqueous Batteries
- Completed a comprehensive long term cycling of 18650 cells. JECS papers among the top 5 downloaded papers in 2021
- Released the thermodynamic web calculator – an easy tool for estimating the heat production during battery failure
- Launched BatteryArchive.org, the first public repository for easy visualization and comparison of battery degradation data across institutions.
- Developed and released open-sourced the Battery Lifecycle (BLC) Framework software.
- Developed a special issue of MRS Bulletin (May 2021) on New Developments in Battery Safety for Large Scale Systems

13 projects at Sandia, 3 University, 1 International



BATTERY
LIFECYCLE
FRAMEWORK





Energy Storage Sizing, Optimization & Controls, Open Source Software Tools

- Open Source Tools for Storage Analytics and Valuation of Energy Storage
- Technology-specific modelling and optimization
- Modeling for energy storage enabled transmission, distribution grids and asset deferrals
- Analytics/evaluation of ESS in tribal utilities and Native American Communities
- Energy storage control to improve transient stability in low inertia grids, system identification and monitoring
- Grid Resilience Enabled by Energy Storage
- Energy Storage Economics, Policy and Regulatory Analysis for Project Finance
- Team: Sandia, Michigan State, Univ of Utah, South Dakota State Univ, Clemson Univ, Univ of Notre Dame, Montana Tech, Quanta Technology, Mustang Prairie, PNM

FY21 Accomplishments

- Released a new version of QuEST with Technology Selection Tool, QuEST Equity and QuEST Performance applications
- Organized two energy storage finance summits, bringing together leaders from finance with energy storage developers and government officials (with Mustang Prairie, K&L Gates)
- Strengthened collaboration with Quanta Technology to improve distribution expansion planning for energy storage, including the development of a probabilistic integrated resource planning tool.
- Developed python tools for modeling energy storage system performance in extreme climates (hot or cold) (with Army Lab)
- Developed an optimization framework for evaluating energy storage as a virtual transmission asset.
- Developed energy storage models to the open source Power System Toolbox (MATLAB) and released as open source model
- Built a modular UL-compliant energy storage system that can accommodate Lead-Acid, Li-ion, and alkaline batteries.
- Developed the first version of an Open-source ES/DER controller for LDES/Power batteries.
- Performed analysis for a number of demonstration projects.

7 projects at Sandia, 1 CRADA, 3 Companies

FY21 Highlights

MOU with California Energy Commission to support LDES

Completed Phase 1 of Rural Energy Storage Deployment Program (RESDP) with NRECA in Poudre Valley, CO, Fort Bragg, NC, and RoseAcre Farms in NC. Systems for three projects have been ordered and are awaiting delivery.

Completed commissioning of a 2.5 MW 1 hr BESS with Alliant Energy in Decorah, Iowa and a 2 MW 1 hr BESS at Anza Rural Electric Co-op.

Contracts Placed with AVEC (Alaska Village Electric Corp) to provide a 1 Mw 15 min BESS; Albuquerque Public Schools for a 725 kW 4 hr BESS at a socially disadvantaged school; Electric Power Board (EPB), Chattanooga, TN to install a 1.25 MW 2hr BESS to replace the Vanadium Flow Battery; Green Mountain Power, VT, to install a 3 MW 4hr BESS

Selected to lead the Project Development and Deployment for the DOE Social Equity for Energy Storage program.

Entered into an MOU with the California Energy Commission (CEC). Sandia will assist CEC in a range of activities including technical evaluation of projects and performance validation of commissioned projects.

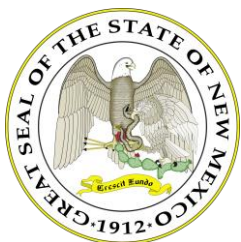
Provided safety and operations best practices training to first responders and Volunteer Fire Departments at Decorah, IA and the Red Feather Lakes & Crystal Lakes, CO (with PNNL)

FY21 Highlights

Hosted educational webinars for state commissions and regulators about energy storage issues including technologies, economics, and policy topics specific to the state's interests:

- Iowa State's Electric Power Research Center and the Organization of MISO States
- New Mexico Public Regulation Commission (NM PRC)
- New Jersey Board of Public Utilities (NJBPU)
- New England Consortium of Public Utility Commissions (NECPUC)
- Wisconsin Public Service Commission (PSC)

Continued development of the Global Energy Storage Database (GESDB) with analytical content, improved user interface, and enhanced features



FY21 Summary of Accomplishments



Acknowledgements



Peer Review Organization Team

- Howard Passell, Will McNamara, Marisa Montes, Sam Roberts-Baca, Sharon Ruiz, David Sokoloff

Partner Laboratories

- Oak Ridge National Laboratory
- Pacific Northwest National Laboratory

Other Collaborating Partners

- Universities, utilities, companies, state and regional entities

Department of Energy

- DOE Office of Electricity and Dr. Imre Gyuk, Director of the Energy Storage Program