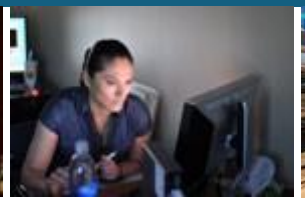
DOE OE Energy Storage Program at Sandia – FY20 Summary



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Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Where We Focus Our Energy

Materials

Advancing battery chemistries through development and commercialization

Safety & Reliability

Safety Science, Testing, Analysis, Standards, Protocols

Power Electronics

New Devices and Components, Modular Power Converters, Improve Control capability

Increase reliability

Analytics and Controls

Sizing, Optimization & Controls. Open Source Software Tools.

State Policy Analysis

Demonstration Projects

Support, Analysis, Implementation, Monitoring

Outreach

Regulatory Outreach & Education

DOE ESS Website

Global Energy Storage Database

University and Industry Collaborators

ACADEMIC

University of Alaska
University of Arkansas
Clemson University
CUNY The City University of New York
University of Houston
University of Kentucky
Michigan State University
NM State University
Northeastern University
The Ohio State University
South Dakota State University
SMU
University of California Irvine
University of Washington
Washington University in St. Louis
Texas – The University of Texas at Austin
The University of Tennessee Knoxville
Davidson
New Mexico Tech – Science • Engineering • Research University
SFCC – Santa Fe Community College
Stony Brook University
The University of Utah
University of Texas Arlington
UNC Charlotte

INDUSTRY

Anza Electric Cooperative, Inc. – A Touchstone Energy® Cooperative
Burlington Electric Department
Creare
EPRI – Electric Power Research Institute
epb
East – ecoult – Energy Storage Excellence
ESA – Energy Storage Association
EWEB
Green Mountain Power
Hawai'i Electric Light
GeneSiC Semiconductor
Strategen
WattJoule
Urban Electric Power
Helix Power
Los Alamos – where discoveries are made
PNM
UET UniEnergy Technologies
NAATBatt International
Mustang Prairie
NRECA – America's Electric Cooperatives

STATE PARTNERS

California Energy Commission
Connecticut Green Bank
NELHA
emnrd – New Mexico Energy, Minerals and Natural Resources Department
DOER – Massachusetts Department of Energy Resources

STANDARD BODIES

IEC
IEEE – Advancing Technology for Humanity
NFPA

FEDERAL PARTNERS

Bonneville Power Administration
NHTSA

INTERNATIONAL

Energy Market Authority – Smart Energy, Sustainable Future
nite – National Institute of Technology and Evaluation

MATERIALS THRUST

Innovating materials science and chemistry advances to enable safe, robust, cost-effective large format batteries for a more resilient, reliable, and flexible electrical grid.

FY20 Accomplishments

- With Urban Electric Power (UEP), developed a 350 Ah Zn-MnO_2 battery system (8-10% utilization of Zn, 20% utilization of MnO_2) w/ energy density of 125Wh/L; expected to be manufactured at $107-110/kWh (at scale).
- Utilized gel electrolytes to advance separator-free Zn-MnO_2 batteries (SNL + UEP) that breaks the "2V barrier" in Zn-batteries. Promises energy densities competitive w/ Li-ion, below $100/kWh.
- Advanced "low temperature" molten sodium batteries with increases of 10X in current density, 25X in usable capacity, and >10X in battery lifetime at 110°C, while identifying possible pathway to <$100/kWh.
- New collaboration with LANL on high voltage (3V) non-aqueous redox flow battery electrolytes based on low cost active materials.
- Demonstrated novel ion-exchange membranes for VRFBs showing 2X ionic conductivity and improved vanadium selectivity vs. commercial materials.
- Developed new anionic polymer separator with zincate blocking capability, resulting in 897% and 198% increase in Zn-Ni battery life at 20% and 50% zinc utilization, respectively.
- Demonstrated first example of a rechargeable alkaline Zn/CuO2 battery with energy densities near 260 Wh/L and ~100% coulombic efficiency.
- Initiated new ion exchange polymer modeling capability.
- Licensed 7 ion-exchange membrane patents to Xergy, Inc.

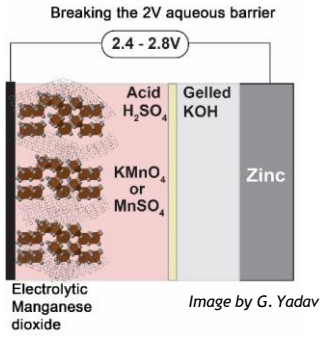


Image by G. Yadav

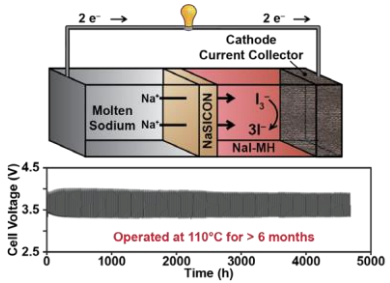


Image by M. Gross

Image by C. Fujimoto

- Published 9 Journal papers or book chapters; Submitted 10 additional papers and 3 book chapters, Edited 1 book.
- 4 Issued/Published U.S. Patents, 5 U.S. Patent Applications, 2 SNL Technical Advances.
- 10 Invited Talks, 20 Technical Presentations
- Earned *2 Best Poster Awards*
- Organized 4 Conferences, Workshops, or Symposia
- 1 New project accepted at CINT

SODIUM BATTERIES ZINC BATTERIES FLOW BATTERIES MEMBRANES

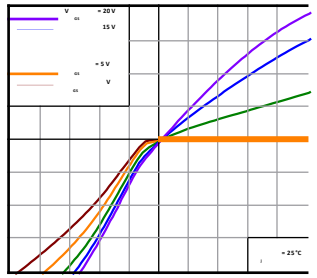
POWER ELECTRONICS THRUST

Using wide bandgap semiconductor devices, advanced topologies, and controls to significantly reduce installed cost and footprint, improve control capability, and increase reliability of next generation energy storage systems

FY20 Accomplishments

- R&D100 Award- Green Tech Gold Recognition, Developed world's first commercially available monolithically integrated 1.2 kV SiC-based power device
- 2 technical advances – One with SMU and other with NMSU & UEP
- 6 journal papers: IEEE Journal of Emerging & Selected Topics in Power Electronics, Nature Scientific Reports
- 6 Conference papers: WiPDA-Asia, IEEE ECCE, IAS Annual Meeting
- Plenary talk at IEEE ECCE, 2 invited talks
- 5 technical presentations: ACS National Meeting & Expo, IEEE Electronic Materials Conference, International Conference on Nitride Semiconductors, IEEE Photonics Conference, CLEO
- 1 - technical webinar in *2020 Tribal Energy Webinar Series: Tribal Energy Project Technologies Options*
- *APEX Lab - New laboratory capability dedicated to the development of advanced hardware topologies and intelligent control strategies for utility-scale energy storage applications*

High-frequency, 1.2 kV SiC-based monolithic switch
R&D100 2019 Green Tech Gold Award Winner



HW development highlights

- Developed 97% efficient, compact(48W/in^3) GaN modular power converter system
- Doubled the Fe4N composite magnetic core efficiency with frequency range of 10kHz-100kHz
- Developed a 20kW GaN-based inverter with a power density of 0.95 ft3/kW

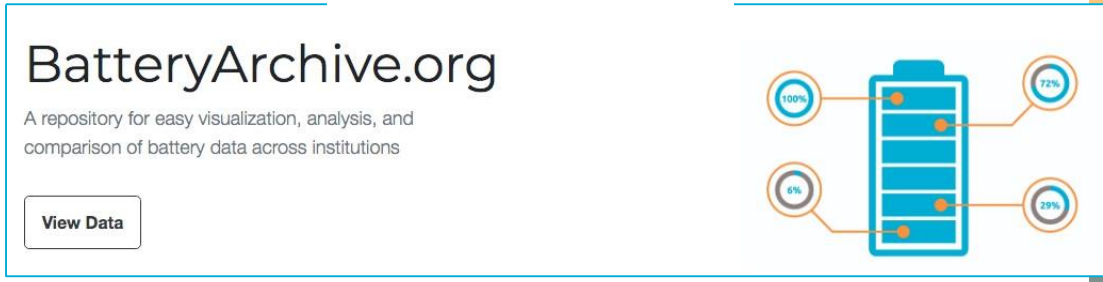
SAFETY & RELIABILITY THRUST

Improve the safety and reliability of grid scale energy storage systems by furthering the understanding of how battery failure occurs and propagates, the mechanisms of battery failure and degradation, and ensuring battery safety and reliability data is available to a wide variety of stakeholders

FY20 Accomplishments

- 5 journal papers: JECS, IEEE Power and Energy Magazine, Proceedings of the Combustion Institute
- 6 Conference papers: ECS Fall and Spring Meeting, GRC Batteries Conference
- 7 invited talks: Battery Safety Summit, Battery Safety Council, Fall MRS Meeting, Case Wester Reserve University Public Safety Forum, Energy Storage Systems & Reliability Forum
- BEST: New battery energy storage test lab (BEST) dedicated to bridging the gap between cell level assemblies and grid scale energy storage devices.
- New collaboration with ORNL on developing battery thermal runaway risk database

SAFETY COLLABORATIVE



Tools

- Launched BatteryArchive.org – open source data archive for cell and performance data
- A. Kurzawski, "LIM1TR: Lithium-Ion Mitigation for 1-D Thermal Runaway." Open Source model
- R. C. Shurtz. "Thermodynamic Reaction Heat Calculator for Layered Metal Oxide Cathodes in Organic Electrolytes" (2020) https://www.sandia.gov/ess-ssl/thermodynamic-web-calculator/

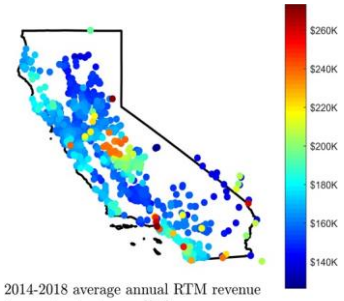
ANALYTICS THRUST

Reduce barriers to widespread adoption by developing analytical tools for optimal sizing, placement, and valuation of energy storage systems; developing new control algorithms to unlock the value of energy storage; and supporting the demonstration team with project analysis.

FY20 Accomplishments

- 2 technical advances: Packetized Delivery of Energy
- 3 Iournal papers: IEEE ACCESS; IET Generation, Transmission, and Distribution
- 3 Book chapters: DOE Energy Storage Handbook
- 9 Conference papers: IEEE PES GM, SPEEDAM 2020, IEEE T&D, American Control Conference
- 23 - technical presentations: IEEE PES GM, SPEEDAM 2020, 2020 IEEE T&D, 2020 IEEE Innovative Smart Grid Technologies (ISGT), Energy Storage Finance Summit, American Control Conference, State PUCs, FERC
- 1 Best Paper Session Award: IEEE PES GM
- New laboratory capability dedicated to evaluating cyber vulnerabilities of battery management systems
- Continued updates to QuESt Software suite. Developed algorithms for microgrid partitioning to size energy storage and improve grid resilience
- Started new IEEE Standards on Battery Management System (BMS) and Energy Storage Management System IEEE standard activities

Quest



2014-2018 average annual RTM revenue from solar + storage ($K)

- PNM CRADA – develop expansion planning tools to meet carbon/renewable targets
- QuESt updates – extreme climate system models; API; improved documentation; production cost modeling

INDUSTRY ACCEPTANCE THRUST

Collaborating with industry to proliferate energy storage system through research, development, demonstration and educational outreach

FY20 Accomplishments

- **3 conference papers -** IMECE, IEEE PES GM, IEEE SPEEDAM
- **1 invited talk -** G&T Communicator Conference
- **3 Technical presentations -** TechAdvantage 2020, IEEE PES GM, Second Southeast Energy Storage Symposium on Policy and Regulation
- **11 Technical webinars**

ESTP: Enhanced capability of Energy Storage Test Pad to evaluate communication latency impact through physical miles of fiber optic and wireless.
ESCAL: Improved capability for data access and system monitoring of demonstration projects around the country.

Projects in 34% of States in FY20

International Projects:
- Singapore -EMA

POLICY & OUTREACH THRUST

Sandia partners with other Labs & external partners to provide educational workshops to regulators.

AN EXPANDING FOCUS AREA

- Energy storage policy analysis
- Expansion of the GESDB to include policy content
- Educational workshops conducted for state regulators

Policy & Outreach Initiatives	FY20 Accomplishments
Educational Workshops for State Regulators	Workshops held in 6 states/ regions 20 + workshops held (multiple sessions held in some of the 6 states).
State Policy Summaries	13 state summaries (AZ, CA, CO, HI, IL, MD, MA, NJ, NM, NV, OR, PA & TX)
Federal Issue Briefs	2—ES As A Transmission Asset & ES and Resource Adequacy
External presentations to national groups	McNamara—4 (NARUC, NASEO, EMNRD, IEEE) Passell—2 (EMNRD & PNM Advisory Board)
White Papers	2—completed but not yet published (Interconnection Standards and ES Ownership Models).

Iowa State/MISO	Maryland PSC	New Mexico PRC	Nevada PUC	Utah Governor's Office	New England Conference of PUCs (NECPUC)
Aug-Nov 2020	March 2020	2019/2020 and	January 2020	July-Aug 2020	"in the works"

POLICY & OUTREACH THRUST

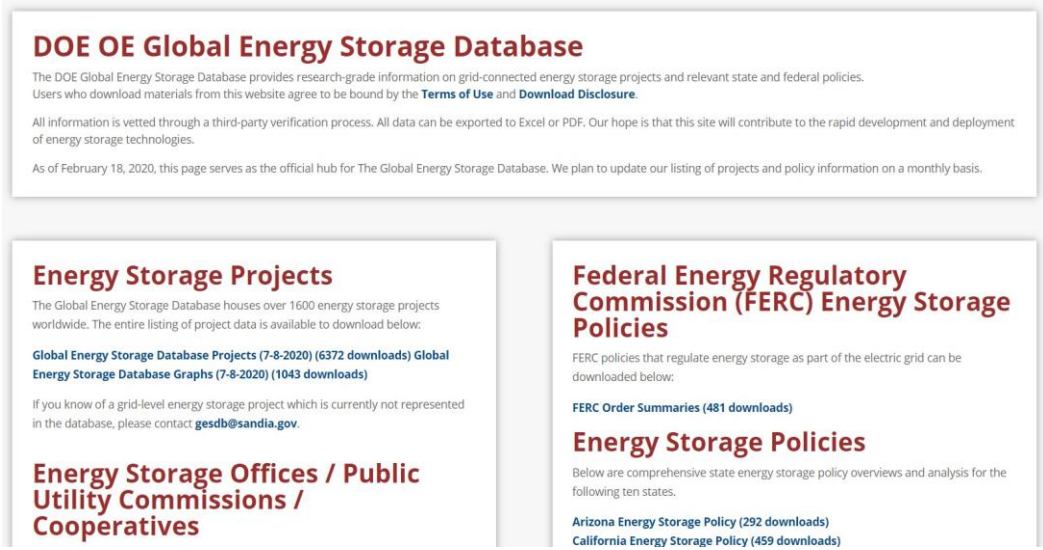
Policy content is publicly available on the GESDB, and through targeted distributions.

Energy Storage Policy Analysis

- Use of new technologies to track legislative and regulatory activity specific to energy storage (PowerSuite)
- Independent analysis of policy trends and assessment of regulatory barriers to energy storage.

Expansion of the Global Energy Storage Database (GESDB)

- Creation of a new Policy Section
- Stand-alone state profiles
- Issue Briefs on key policy issues



FY20 Accomplishments by the Numbers

31
Journal Articles
17 published
14 under peer review

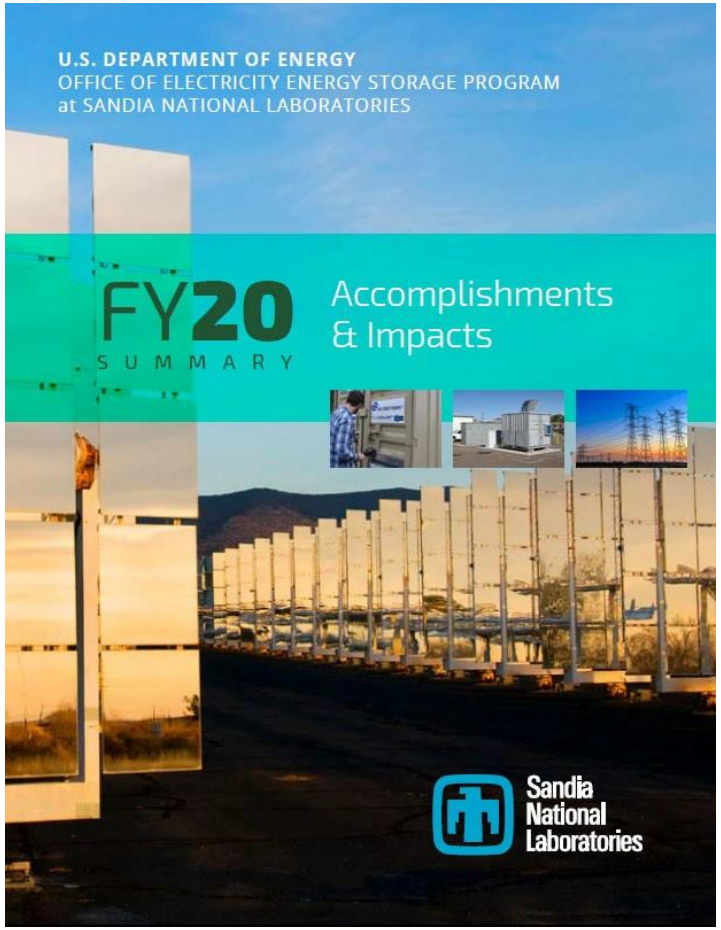
11
Conference Proceedings
7 Technical Reports

10
Patents
3 granted
7 Applications filed

34
Invited Talks

35
Technical Presentations

28
Seminars and Webinars
CESA, IEEE, and prominent universities



Acknowledgements

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Partner Laboratories

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Pacific Northwest National Laboratory

Other Collaborating Partners

Universities, utilities, companies, state and regional entities

Department of Energy

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