



Exceptional service in the national interest

Safety and Reliability of Energy Storage Systems

Overview of Efforts at the National Labs

Loraine Torres-Castro, Ph.D.

Battery Safety Lead, Sandia National Laboratories

August 6, 2024

2024 OE Peer Review



Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and 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.

SAND2024-099070

Safety and Reliability are Interconnected



Safety (Vigilant Guardian)



Prevent accidents by eliminating, reducing, or controlling hazards

Hazard – a system state or set of conditions that could lead to an accident

Safety and Reliability are Interconnected



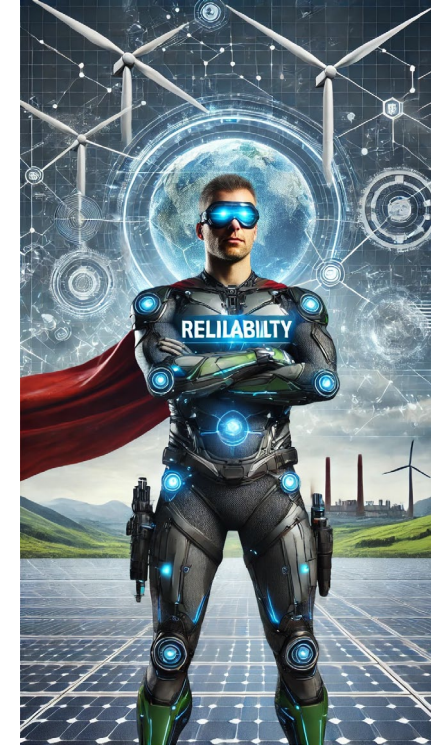
Safety (Vigilant Guardian)



Prevent accidents by eliminating, reducing, or controlling hazards

Hazard – a system state or set of conditions that could lead to an accident

Reliability (Steadfast Partner)



Prevent loss of service by eliminating, reducing, or controlling risk

Risk – a combination of the probability of a failure with its severity

Safety and Reliability are Interconnected



Safety & Reliability



Safe energy storage systems are more reliable

&

Reliable energy storage systems reduce the risk of failures

Increased Media Attention on Energy Storage Systems Safety, But...



Bloomberg

Hyperdrive

Explosions Threatening Lithium-Ion's Edge in a Battery Race

By [Brian Eckhouse](#) and [Mark Chediak](#)

April 23, 2019, 4:58 PM MDT Updated on April 24, 2019, 8:24 AM MDT

- ▶ Battery exploded at plant in Arizona; two others were shut
- ▶ Arizona utility regulator calls for 'thorough investigation'

LISTEN TO ARTICLE

▶ 4:52

SHARE THIS ARTICLE

Share

Tweet

in Post

Email

Another lithium-ion battery has exploded, this time at an energy-storage complex in the U.S.

At least 21 fires had already occurred at battery projects in South Korea, according to BloombergNEF. But this latest one, erupting on Friday at a facility owned by a Pinnacle West Capital Corp. utility in Surprise, Arizona, marked the first time it has happened in America since batteries took off globally.

<https://www.bloomberg.com/news/articles/2019-04-23/explosions-are-threatening-lithium-ion-s-edge-in-a-battery-race>

Greentech Media

APS and Fluence Investigating Explosion at Arizona Energy Storage Facility

The stakes are high for the energy storage sector after an explosion with an unknown cause left several firefighters injured.

KARL-ERIK STROMSTA | APRIL 22, 2019



Earlier this year APS announced plans to build 850 megawatts of battery storage by 2025.

Fluence has dispatched a team of experts to help utility Arizona Public Service determine what caused an explosion at one of its grid-scale battery facilities. The explosion on Friday reportedly left four firefighters injured, including three who were sent to a burn center.

Firefighters responded to a call on April 19 after smoke was seen rising from APS' McMicken Energy Storage facility, one of two identical 2-megawatt/2-megawatt-hour grid-scale batteries the utility installed in 2017 in Phoenix's growing West Valley region.

According to local press reports, the firefighters were inspecting the facility's lithium-ion batteries when they were hit with an explosion. Several of the firefighters received chemical burns, the local fire department told the *Arizona Republic*.

<https://www.greentechmedia.com/articles/read/aps-and-fluence-investigating-explosion-at-arizona-energy-storage-facility>

Korea Times

Frequent fire raising concerns over safety of solar energy



A fire engulfs an energy storage system at a cement plant in Jecheon, North Chungcheong Province, Monday. / Courtesy of North Chungcheong Province Fire Service Headquarters

By Nam Hyun-woo

A series of fires in energy storage systems (ESSs) has been raising safety concerns, according to industry analysts, Tuesday.

With ESSs essential for optimizing energy efficiency, further accidents may compromise the feasibility of renewable power and hamper the government's bid to expand the use of cleaner energies.

According to the Ministry of Trade, Industry and Energy, it recommended individuals, companies and other organizations to stop using 584 uninspected ESSs across the country.

https://www.koreatimes.co.kr/www/tech/2024/07/129_260560.html

...Battery Fires Are Not New



2006
Sony/Dell Laptops



2010
UPS Cargo Plane



2011
DOT/NHTSA Facility



2013
Boeing Dreamliner



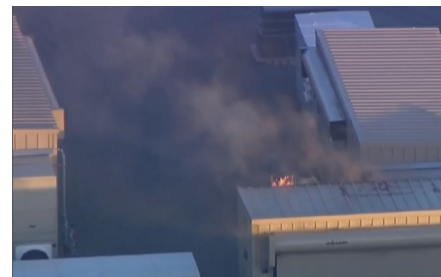
2019
ESS Arizona



2022
Electric Vehicle (Tesla)



2023
Battery Storage Facility



2024
Manufacturing Facility



Each incident has provided valuable lessons, leading to advancements in battery technology, improved safety standards, and better risk management practices.

Stored Energy Carries Inherent Risk



Potential Energy



Stored Energy Carries Inherent Risk



How to reduce the risk of energy storage systems?

Safe by Design

Key Questions

- What are the hazards?
- What are the risks?
- What is the level of acceptable risk?
- What are the mitigation strategies for those risks?

Safety must be addressed at the cell, battery and system level to ensure the safety and reliability of the energy storage system.

Comprehensive Overview of ESS Safety and Reliability



Materials R&D



Thermal stability
Gas evolution
Degradation

Cell and Module Testing



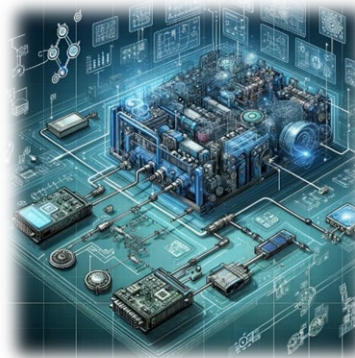
Aging
Diagnostics
Abuse testing
Thermal propagation

Simulations and Modeling



Multi-scale models
Fire dynamic simulations
Predictive simulations

System Level Design and Analysis



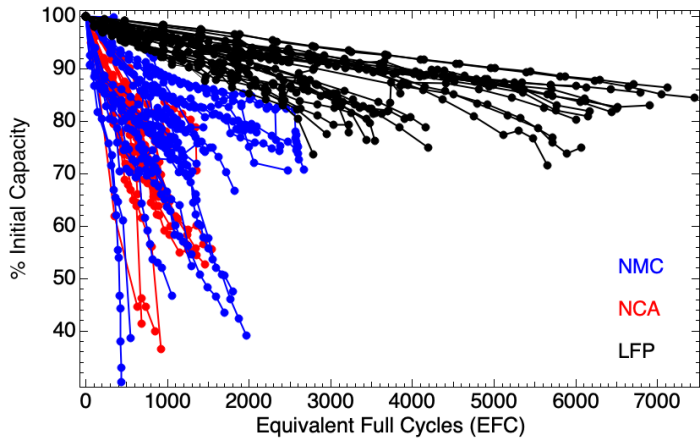
Hazard analysis methods
Predictive maintenance
Power electronics

Outreach, Codes, and Standards

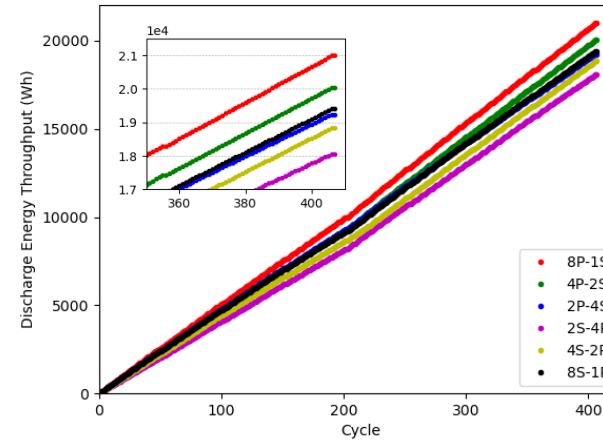


ES safety working group
IEE BMS standard
EPRI ESS data guidelines

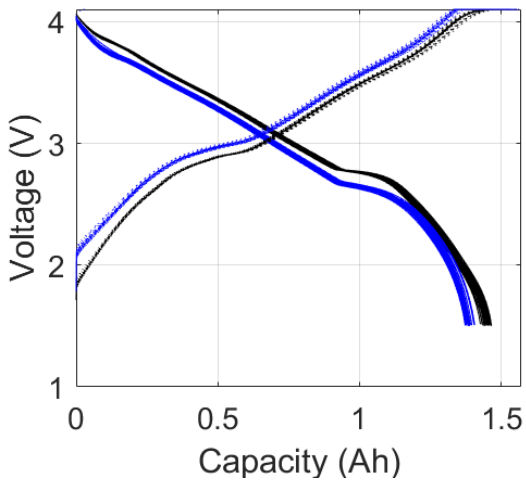
Addressing Reliability Gaps Through R&D at National Labs



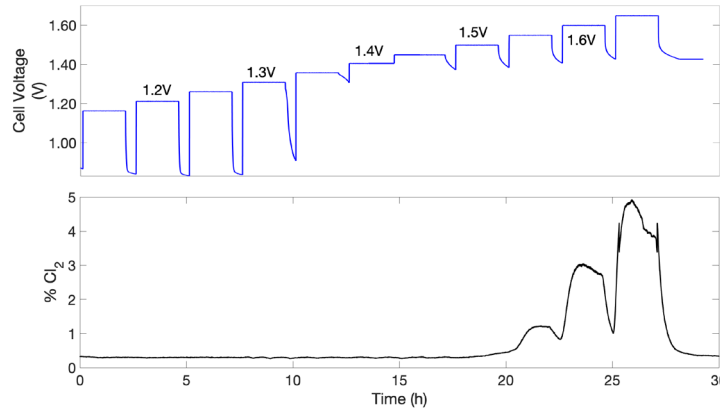
Li-ion cell degradation beyond 80% capacity



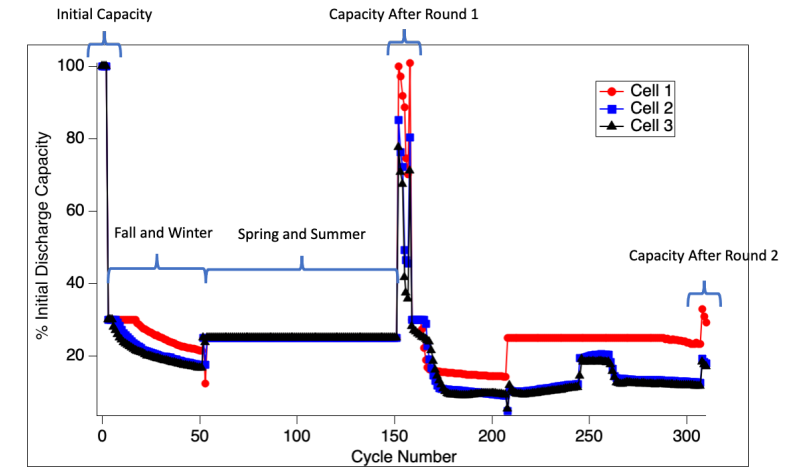
Li-ion impact of module configuration



Na-ion cell degradation

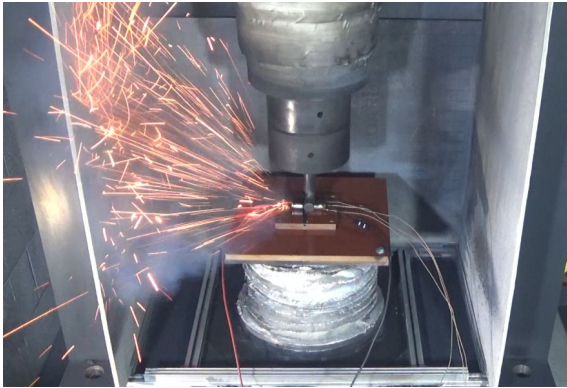


Redox flow cell gas evolution

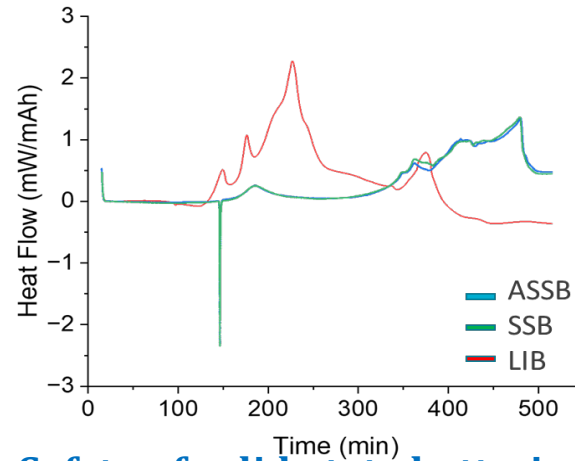


Zn-MnO₂ cell impact of duty cycle/temperature

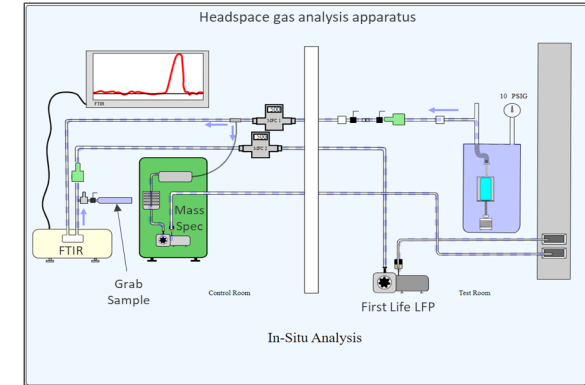
Addressing Safety Gaps Through R&D at National Labs



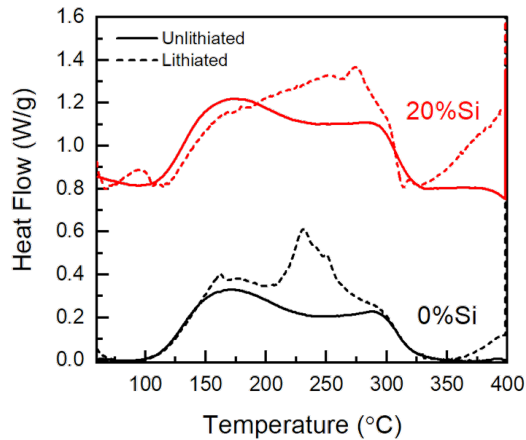
Multi-scale approach to delineate the safety of sodium-ion batteries



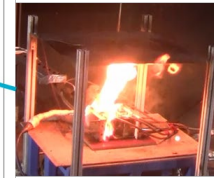
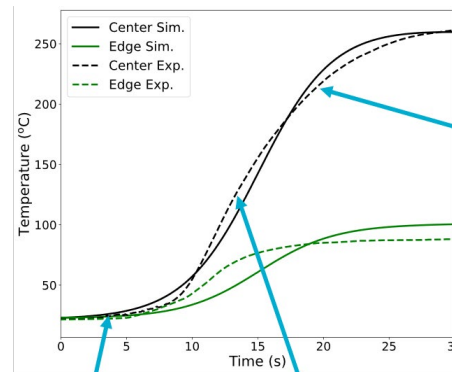
Safety of solid-state batteries from the ground-up



Off-gassing and safety analysis of aged cells



Safety implications of Variable Si content in Si/Graphite anodes



Venting Heat Flux with Inverse Simulations



Large-scale testing

Advancing Safe and Reliable ESS with SOA Facilities at National Labs

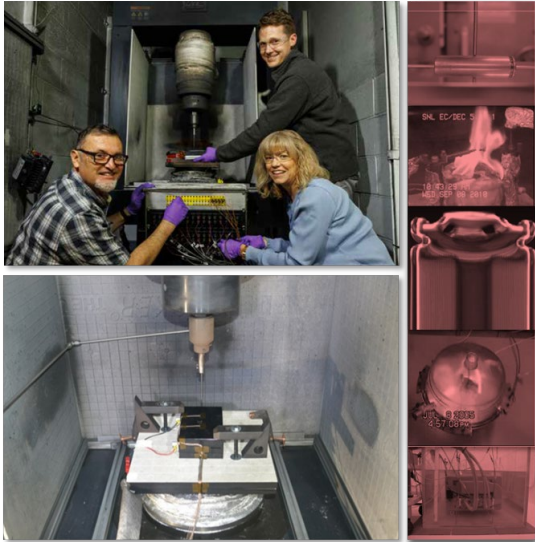


**Sandia
National
Laboratories**



**Pacific Northwest
NATIONAL LABORATORY**

DOE Core Capability for Destructive Battery Testing



5,000 Sq Ft Facility for Analysis within Spec



Remote Site for Large-Scale Destructive Testing

Grid Storage Launchpad



Safety and Reliability Efforts Through Community Engagement

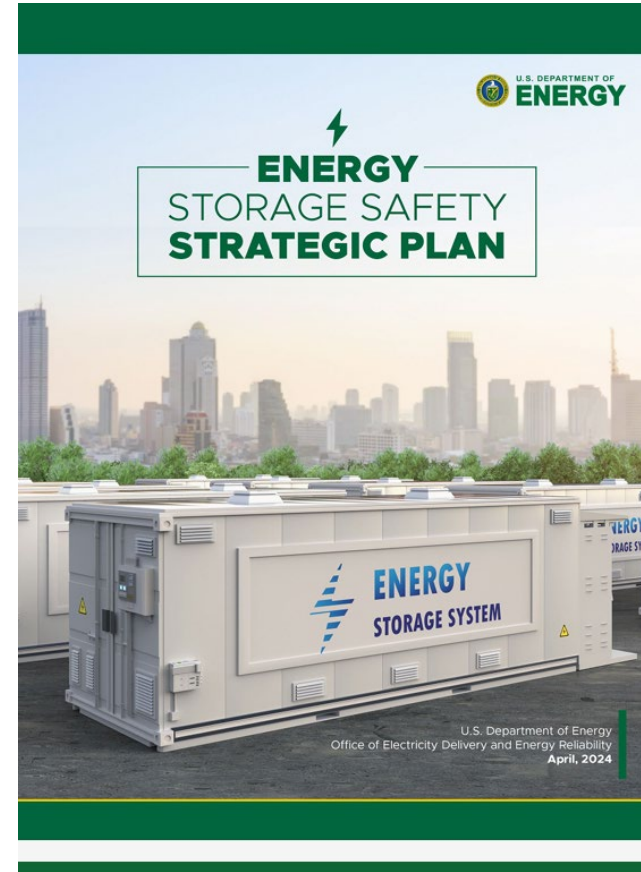


➤ Energy Storage Systems Safety and Reliability Forum

➤ Energy Storage Safety Strategic Plan



Save the date
April 15-18, 2025
San Juan, Puerto Rico



Full Report



Don't Miss the Posters!



Presentation	Presenter	Organization
Towards Deploying Anomaly Detection Algorithms in Battery Management Systems	Victoria O'Brien	Sandia National Laboratories
Toward rack-scale heat transfer in thermal runaway scenarios: Vent gases and air entrainment in idealized energy storage systems	Michael Meehan	Sandia National Laboratories
Li-ion Batteries Thermal Runaway Risk Grading and Prediction	Lianshan Lin	Oak Ridge National Laboratory
The Current Energy Storage Roadmap	Christopher Searles	CGS & Associates
Reliability Testing of Lead Acid Battery Modules for Peak Shaving Application	Nimat	Pacific Northwest National Laboratory
Development of Temperature Sensitive Paint for Energy Storage System (ESS) Safety	Chanaka Ihala Gameralalage	Oak Ridge National Laboratory
Quantifying Variability from Key Factors in Materials-Scale Battery Safety Testing	Nathan Johnson	Sandia National Laboratories
Battery Management System Standards	David Rosewater	Sandia National Laboratories
Understanding the Thermal Behavior and Safety of Silicon-Graphite Anodes	Bryan Wygant	Sandia National Laboratories
Long-Term Cycling and Analysis of 18650 Li-ion Cells Beyond 80% Capacity	Sahana Upadhyia	UW Madison
Safety Hazards Associated with Heat Transfer from Li-ion Battery Thermal Runaway Vent Gases	Ala' Eyad Qatramez	University of Memphis
Repeatability in Battery Abuse Testing: Sandia and NITE NLAB Collaboration	Andrew Kurzawski	Sandia National Laboratories

Center Stage: Presentations



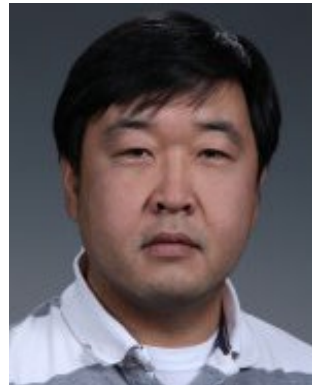
Time	Presentation	Presenter	Organization
1:40 – 1:55pm	Thermal Runaway Studies: Development of Coatings for Over-Temperature Warning and Database of Hazards Risk Ranking	Chanaka Ihala Gamaralalage	Oak Ridge National Laboratory
1:55 – 2:10pm	ESS Safety; IntelliVent Explosion Control Installation Updates	Matt Paiss	Pacific Northwest National Laboratory
2:10 – 2:25pm	Commercial Single Cell Testing Update under Grid Cycles	Daiwon Choi	Pacific Northwest National Laboratory
2:25 – 2:40pm	Toward Understanding the Role of Cell Venting in Module-to-Module Propagation	Mike Meehan	Sandia National Laboratories
2:40 – 2:55pm	Impact of Aging on the Safety of Lithium-ion Batteries	Yuliya Preger	Sandia National Laboratories



**Chanaka Ihala
Gaamaralalage**



Matt Paiss



Daiwon Choi



Mike Meehan



Yuliya Preger