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SAFETY AND RELIABILITY FOR GRID-SCALE BESS

From technical evidence to grid confidence

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THE QUESTION HAS CHANGED



Early-stage R&D

Can it work?

Proof-of-concept
Lab-scale performance
Controlled testing



Safety & Reliability

Can it operate safely, reliably, and predictably under real conditions?

Real-world duty cycles and stress testing
Predictable degradation across the lifecycle
Validate failure modes and mitigation strategies

FROM SAFE-BY-DESIGN TO EVIDENCE-BY-DESIGN



Safe-by-Design

Asks: What are the hazards, risks, acceptable limits, and mitigations required?

Evidence-by-Design

Asks: What specific data, tests, and models support safety and reliability decisions?

✓ Risk must be understood to be managed

✓ Evidence turns uncertainty into guidance

✓ Evaluation begins before costly redesigns



IDENTIFY
HAZARDS



ANALYZE
PROBABILITY
AND
SEVERITY



APPLY
ENGINEER
CONTROLS



VALIDATE
TESTS AND
MODELS

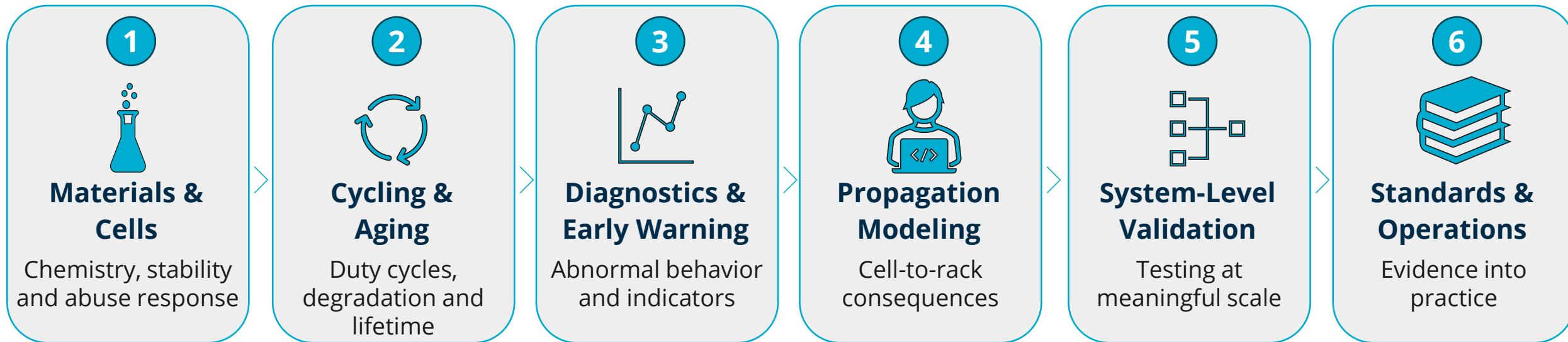


INFORM
RISK-
INFORMED
DECISIONS

THE EVIDENCE CHAIN FOR BESS SAFETY & RELIABILITY



Confidence comes from connecting evidence across scales, from cell chemistry to system operation



Connected evidence across scales is the organizing principle for today's session

MAKING SAFETY BEHAVIOR MEASURABLE



High-consequence events can be measured, modeled, and used to improve safety margins and mitigation strategies.



Quantify heat release, gas generation venting, and combustion behavior through controlled experiments.



Connect cell-level failure triggers to module, rack, and system-level response.



Integrate empirical data physics-based simulations to predict system behavior.



Translate results into actionable mitigation strategies, safety standards, and response guidance.



Figure: 25kWh Large Scale Destructive Battery Test

TECHNICAL GOAL

From Failure Observation to Predictive Understanding

TECHNICAL IMPACT

kWh-scale burn tests, and inverse simulations generate data on energy release behavior that informs safety standards, design practices, and protection guidance.

RELIABILITY DATA FOR REAL OPERATING DECISIONS



Reliability is a Lifecycle Question

Reliability is not a snapshot of day-one performance; it is a measure of how systems age under real grid operations.



Grid Stress Profiles: Real duty cycles stress batteries differently than standard laboratory test conditions.



Dynamic Margins: Aging fundamentally changes performance, lifetime, and safety margins over time.



Shared Knowledge: Standardized data (e.g., BatteryArchive.org) supports state-of-health models and product evaluation.



Data turns experience into reusable knowledge

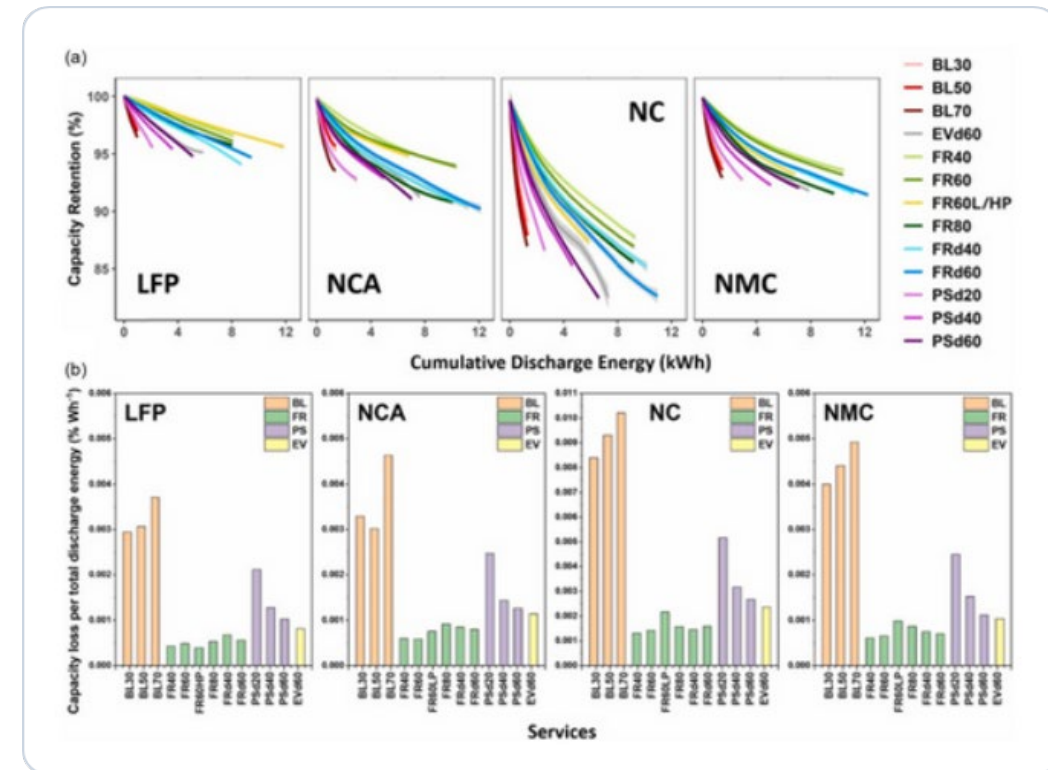


Figure: Comparative Analysis of Capacity Retention Across Chemistries and Conditions

CONNECTING SCIENCE, SCALE, AND SAFETY & RELIABILITY PRACTICE



National labs connect fundamental behavior and field-relevant testing to real-world practice.



Cell & Module Testing



Destructive Testing



Grid-Relevant Cycling



Diagnostic & Warning

**EVIDENCE FOR
SAFETY &
RELIABILITY**



Modeling and Simulation



Shared Data Repository



Standards & Codes

SNL | PNNL | ORNL



Worker Safety Standards

Predictive arc flash models informed NFPA 70E, now adopted in OEM training and utility operations to protect field personnel.

Codes & Standards Translation

Laboratory research outputs help inform how systems are designed, installed, operated, and evaluated.

Public Safety Recognition

2026 NFPA Foundation Medal awarded for research on lithium-ion incident impacts, improving first responder preparedness.

TODAY'S SESSION: A CONNECTED SAFETY & RELIABILITY STORY



Jaime Kolln

PNNL

Operating technical perspective on system-level reliability, interoperability, and confidence in operation.

Daiwon Choi

PNNL

Li-ion reliability testing: analyzing performance and degradation under grid-relevant duty cycles.

Hsin Wang

ORNL

Thermal runaway early warning: detecting over-temperature via acoustic emission before hazards escalate.

Mike Meehan

SNL

Predicting consequences: a modeling perspective on thermal runaway propagation through module and rack scales.

Yuliya Preger

SNL

Re-evaluating standard metrics for Battery aging reporting.

UNDERSTAND | TEST | DETECT | MODEL | VALIDATE | INFORM PRACTICE

Testing + Data + Diagnostics + Modeling + Standards → Confidence Grounded in Evidence

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