Risk Reduction in Grid-scale Battery Siting and Deployment

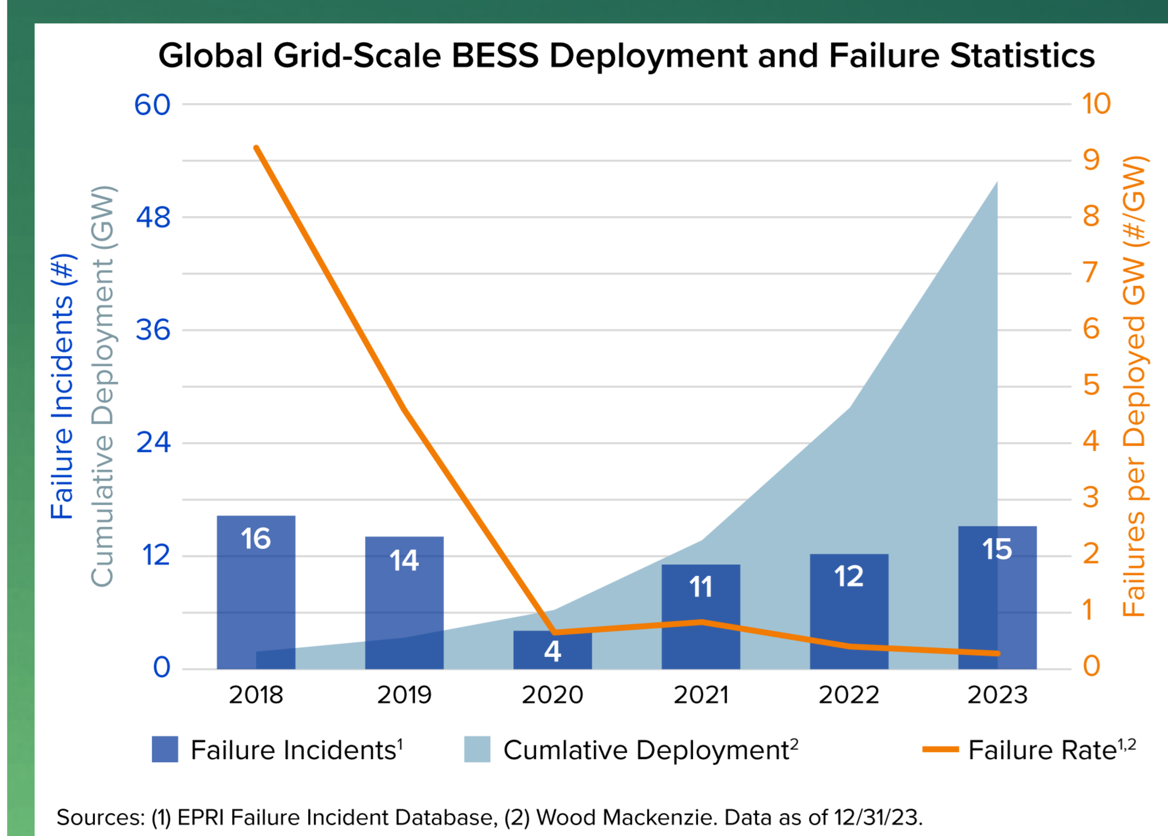
How can we quantify risk?

Risk is a combination of the **frequency**, or likelihood, of a failure happening and the **severity** of the failure. Risk reduction involves reducing **both** components of risk, through identifying common points of failure and effective **mitigation** strategies.

$$Risk = \sum_{i=1}^{n} f_i \times S_i \quad \text{where} \quad \begin{array}{l} f_i = frequency\ of\ failure\ i \\ S_i = severity\ of\ failure\ i \end{array}$$

How can we reduce risk in energy storage?

The **frequency** of safety-related failures in grid-scale battery energy storage systems (BESS) has decreased significantly in the last few years. There has been a **97% reduction** in global failures between 2018-2023[1]. This trend continues for 2024.



The rapid evolution of BESS safety codes and standards[2] has supported the reduction in global failures, requiring more stringent explosion protection, detailed site-specific hazard analyses, emergency response planning, and more. Industry leading practices in safety are continually improving in response to lessons learned from previous failures. Root cause investigations revealed that many of the incidents between 2018 and 2023 began with failures unrelated to the battery cell or module, which could have been prevented with increased engineering rigor in design and installation[1].

Reducing Frequency

Site-specific hazard assessments can prevent or reduce the likelihood of a failure. To **eliminate** system-level failures, **anti-propagation** measures at the cell and module level should be considered. R&D in this area is ongoing. Other recommendations for failure prevention are below:

Table 1. Mitigations and Recommendations for Each Root Cause

ROOT CAUSE	FAILED ELEMENT	MITIGATIONS AND RECOMMENDATIONS
Design	Controls, BOS	• Compliance with relevant codes and standards (UL, NFPA). Latest revisions have incorporated lessons learned from past failures. • Site-specific hazard assessments to consider all risks and failures. • Robust sensing and monitoring to provide early alert for design failures.
Integration/Assembly/ Construction	BOS, Controls	• Workforce training and quality checks during energy storage commissioning and installation. • System-level failure analysis, especially for interfaces between components.
Manufacturing	Cell/Module, Controls	• Increased manufacturing quality controls. • Supplier quality verification. • Robust system specifications. • Factory acceptance testing.
Operation	Controls	• Battery monitoring and analytics to augment BMS operation, generating trends and predictive analyses to identify potential failures early.

*BOS = Balance of System, including components like the enclosure, thermal management system and safety system[1].

Failures Beyond Thermal Runaway

There are other failure mechanisms and risks associated with Grid-scale BESS. The **insurance** industry, for example, considers extreme weather impacts such as hailstorms or flooding on projects, **water intrusion** to containers, impacts to nearby exposures and more when **quantifying** project risks. Regular **inspections** and maintenance are important **preventative** measures to avoid environmental damage to BESS.

Reducing Severity

Project Developers

- ✓ Use a quantitative risk assessment methodology for site safety planning[3]
- ✓ Commit to emergency response planning and training with local first responders[4]
- ✓ Leverage plume modeling to assess local impacts of failures[5]. Plan to collect model input data.
- ✓ Conduct site-specific Hazard Mitigation Assessment and implement recommendations[6]
- ✓ Use modeling and test such as heat flux analysis, explosion modeling[7], large-scale fire testing, and others to understand how failures may evolve. This can support siting, spacing, setbacks, and clearances during the project design phase.

Local Authorities

- ✓ Stay up-to-date with the evolution of BESS safety codes and standards[2]
- ✓ Know the energy storage failure rates, and learn from recent events to assess risks and impacts of new projects[1]

For more information, please contact:

Lakshmi Srinivasan, Pr. Team Lead. LSrinivasan@EPRI.com

Stephanie Shaw, Technical Executive. SShaw@EPRI.com

Electrical Power Research Institute

References

1. Srinivasan, L., Shaw, S., Billaut E. "Insights from EPRI's BESS Failure Incident Database: Analysis of Failure Root Cause." EPRI, 2024 (3002030360)
2. Srinivasan, L. "The Evolution of Battery Energy Storage Safety Codes and Standards." EPRI, 2023 (3002028521)
3. Shaw, S. "Battery Energy Storage Systems Failure Quantitative Risk Assessment Methodology." EPRI, 2024 (3002029662)
4. Shaw, S., Long, D. "Proactive Engagement First Responder Engagement for BESS Owners and Operators." EPRI, 2021 (3002021774)
5. Shaw, S. "Lessons Learned from Air Plume Modeling of BESS Failure Incidents." EPRI, 2024 (3002030586)
6. Simpson, M., et. al. "ESIC Energy Storage Reference Fire Hazard Mitigation Analysis." EPRI, 2021 (3002023089)
7. Long, D. "Battery Energy Storage Systems Explosion Hazards." EPRI, 2021 (3002022706)

Scan here to learn more[1]

SITING + PERMITTING

EPRI