AN EPRI PERSPECTIVE



Lithium Ion Battery Energy Storage Fire Safety Measures

Lithium ion battery energy storage systems (BESS) have been operated successfully, efficiently, and safely for many years. BESS safety design starts at the most basic level, with the cell (3002028522), and expands outward to encompass every part of the system. At every stage, dedicated site-specific hazard assessments inform design, commissioning, testing, operation, maintenance, and decommissioning. There is a growing body of battery codes, standards, and regulations (3002028521) that captures leading practices, and is continually updated. EPRI works with industry stakeholders, utilities, battery manufacturers, system developers, first responder associations, and others (such as the National Fire Protection Association, NFPA) to address battery fire incidents. Through these efforts, the industry has developed failure mitigation systems, test methods, emergency response procedures and more to reduce the likelihood and impact of fire incidents. **As a result of these industry efforts, the rate of battery storage failures has declined even as the amount of storage deployed has expanded significantly (3002030360).**

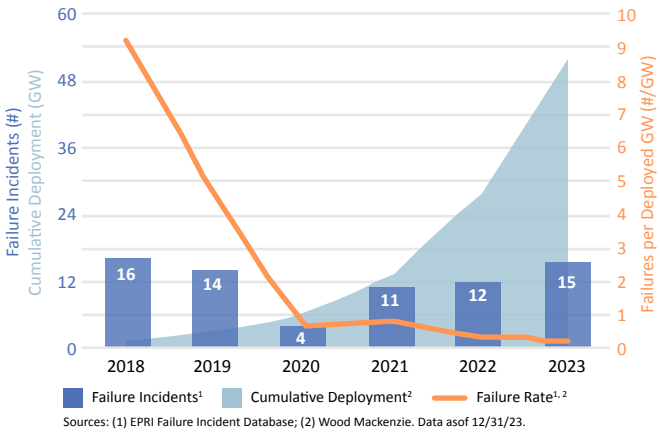


Figure 1. *Global grid-scale BESS deployment and failure statistics*

However rare they may be, EPRI takes every battery failure very seriously. A new entry is immediately added to the online EPRI BESS Failure Incident Database, to communicate confirmed incident information and to track incident trends. This unique resource receives hundreds of visits a week from interested parties in over 50 countries. EPRI works with stakeholders to understand and document the cause of the failure, along with any lessons learned to avoid future incidents (300202639). BESS developers and owners are encouraged to go beyond meeting existing codes and standards to incorporate state-of-the-science technology and protocols.

EPRI's recent analysis indicates that most BESS failures can be traced to system integration issues rather than the batteries themselves. **There are simple design and operational approaches (see Table 1) that can lead to a significant increase in safety.**

While design and equipment updates may have feasibility challenges, EPRI strongly recommends routine updates to emergency response plans and annual training and safety drills with facility staff and first responders. EPRI's research shows that failures occur most frequently during the early years of a project, especially during installation and commissioning (see Figure 2). **A well-trained workforce is an essential part of a safe BESS ecosystem.** EPRI publishes and speaks publicly on work to make it accessible. Much of this research is available through our Storage Safety website.

Table 1. *Mitigations and recommendations for root causes of BESS failure*

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

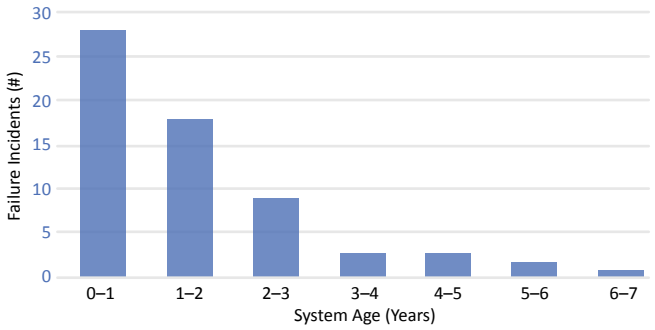


Figure 2. *Age of BESS during failure for BESS installed 2011–2024*

These learnings and improvements were accomplished despite there being little to no reporting by BESS owners and operators of root causes or effects of BESS fires. A lack of required transparency has impeded efforts to reduce failure incidences. EPRI BESS fire records are the most robust in existence but is incomplete. EPRI has worked diligently to acquire the information available, and the industry has made progress reporting incidents and response procedures (https://eprijournal.com/an-untold-success-story/).

There is an increased focus on potential human exposure to combustion or off-gassing plumes and water runoff during fires. Real-world incidents have almost always reported no harmful exposures, but also do not report the pollutants or sampling protocols used. Toxic gas emissions from battery fires are not measured during product testing, as are flammable gases.

Better information on emitted chemicals as compared to common fires (e.g., residential) would improve modeling of public health and environmental impacts (3002030586) and help develop appropriate incident responses. **The industry needs more research and public data to fully address the impact of a BESS failure.**

That said, it's important to keep these incidents in perspective. Battery fires garner a great deal more media attention (3002028411) than comparable fires with other causes. In fact, media alerts are a major source of EPRI's initial failure database entries. The absence of adequate information about the causes and effects of battery fires often leads authorities to take worst-case scenario measures. These actions, taken out of an abundance of caution in the absence of data, may create unnecessary fear and inconvenience.

All the above concerns can be addressed through increased education, and by ensuring first responders, utilities, government officials, and the general public have access to information about the true risks and effects of battery fires. **EPRI's research portfolio (3002028531) provides the scientific understanding, training, and education needed to improve battery safety.**

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