EPRI

2024 White Paper

Insights from EPRI's Battery Energy Storage Systems (BESS) Failure Incident Database

Analysis of Failure Root Cause

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INTRODUCTION

The global installed capacity of utility-scale battery energy storage systems (BESS) has dramatically increased over the last five years. While recent fires afflicting some of these BESS have garnered significant media attention, the overall rate of incidents has sharply decreased,[1] as lessons learned from early failure incidents have been incorporated into new designs and best practices. Between 2018 and 2023, the global grid-scale BESS failure rate has dropped 97%. The battery industry continues to engage in R&D activities to improve prevention and mitigation measures, including development of a better understanding of the diverse causes of BESS failures.

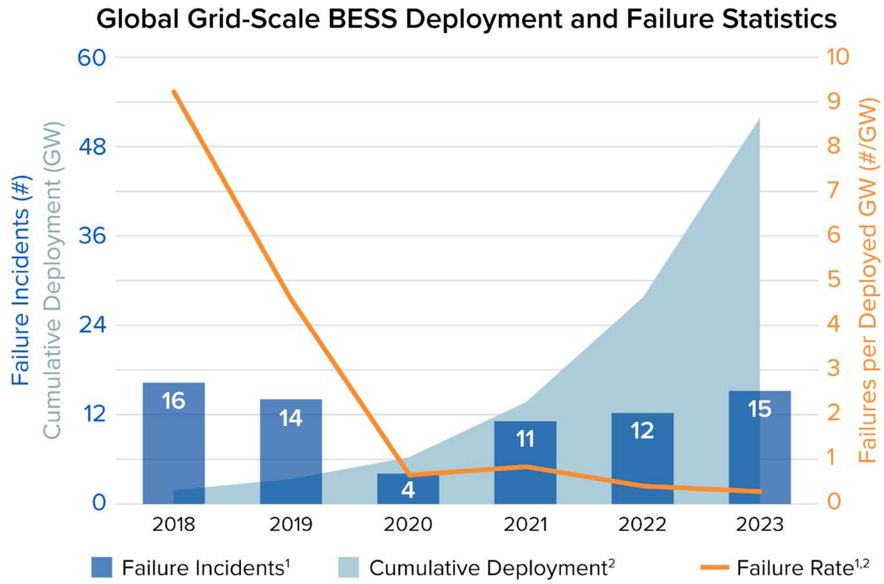


Figure 1. *Global Grid-Scale BESS Deployment and Failure Statistics*

Several entities compile information on battery fires that have occurred in various products (e.g., mobile, stationary, consumer product) categorized by differing battery technologies (e.g., lead acid, lithium ion). EPRI has produced the most comprehensive compilation of stationary BESS incidents, called the EPRI BESS Incident Database,[2] based on publicly accessible underlying data. Other notable databases include UL's Lithium-Ion Battery Incident Reporting[3] and EV FireSafe.[4]

1 *Technology Innovation Spotlight: Lithium Ion Battery Fires in the News.* EPRI, Palo Alto, CA: 2023. 3002028411.

2 BESS Failure Incident Database. This was formerly known as the BESS Failure Event Database. It has been renamed to the BESS Failure Incident Database to align with language used by the emergency response community. An 'incident' according to the Federal Emergency Management Agency (FEMA) is an occurrence, natural or man-made, that requires an emergency response to protect life or property, while an 'event' is a planned, non-emergency activity. The use of incident is prevalent, for example, in referring to the Incident Command, or Incident Command System used by public and private agencies to coordinate incident management operations, https://www.fema.gov/pdf/emergency/nrf/nrf-glossary.pdf.

3 Lithium-ion Battery Incident Reporting. UL Solutions. https://www.ul.com/insights/lithium-ion-battery-incident-reporting.

4 EV FireSafe Database. https://www.evfiresafe.com/.

The UL Lithium-Ion Battery Incident Reporting encompasses incidents caused by utility-scale, C&I, and residential BESS, as well as EVs, e-mobility, and consumer products. This database focuses exclusively on lithium ion technologies. EV FireSafe tracks EV and electric micro-mobility fires involving (though not necessarily *caused* by) the traction battery, and categorizes incidents by cause. Both the UL Lithium-Ion Battery Incident Reporting and EV FireSafe provide statistics and figures, but do not disclose details of individual failures or sources.

There is currently no public resource that categorizes BESS incidents by cause of failure. This information would provide industry-level insights on common and uncommon failure modes, and would help to prioritize needed mitigation technology R&D. This knowledge is particularly important because individual incident details and root cause information are not always easily accessible, but are crucial to improve safety and understand risk. Failure classification can help determine the role of different components of a BESS, from controls to battery cell/module, in contributing to an incident and in preventing future incidents. No current federal, state, or local jurisdiction requires incident reporting. Even in cases where detailed root cause investigations are conducted, legal barriers often prevent the results from being shared publicly. New York state encouraged Original Equipment Manufacturers (OEMs) to disclose root cause analyses (RCAs) after failure incidents, but stopped short of including a requirement for disclosure in their pending update[5] to the fire code.

This report is intended to address the failure mode analysis gap by developing a classification system that is practical for both technical and non-technical stakeholders. Once categorized in a standardized manner, the aggregated failure data was analyzed to better understand trends in how, why, and how infrequently BESS fail, and to provide recommendations for future safety improvements.

5 New York State Inter-Agency Fire Safety Working Group: Fire Code Recommendations. NYSERDA. Feb 6, 2024. https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Programs/Energy-Storage/Draft-New-York-State-Inter-Agency-Fire-Safety-Working-Group-Fire-Code-Recommendations.docx.

METHODOLOGY

This report relies on data from EPRI's BESS Failure Incident Database along with findings from incident reports and root case analyses and expert interviews conducted by the authors to build robust descriptions of each event. Each incident from the database is categorized through a biaxial framework to allow for analysis of two distinct failure facets. BESS failures were classified by a) the root cause of failure (design; manufacturing; integration, assembly & construction; or operation); and b) by the element of the BESS that experienced the failure (cell/module, controls, or balance of system). The study examines the proportion of failures sharing a root cause or responsible element, the relationship between root cause and the element experiencing failure, and the trends in failure type and rate over time. Results from this analysis will inform the industry's efforts to optimize safety research and product development.

The BESS Failure Incident Database

EPRI's BESS Failure Incident Database is the main source of data for this report. The database was initiated in 2021 following the series of lithium ion BESS fires in South Korea and the Surprise, AZ, incident in the US. The database gathers information on stationary BESS failure events for commercial and industrial (C&I) and utility-scale BESS. This database defines utility-scale BESS as a system that is interconnected to the grid, with no capacity limitations, while C&I systems could include behind-the-meter installations. Residential energy storage system failures are not tracked by this database and were not considered in this report.

It contains incidents as far back as 2011 and continues to be updated with new incidents as they occur. The focus of the database is on occurrences that had a wider public health and safety risk or impact, rather than on operational failures where no additional risk to personnel or equipment was present or likely. EPRI defines *failure incident* as an occurrence which resulted in increased safety risk, *caused by* a BESS system or component failure rather than an exogenous cause of failure (e.g., wildfire impacting the BESS).

The database captures incidents occurring globally and cites information from publicly available sources, including media reports, published root cause analyses (RCA), and corporate press releases. Source documents are identified by active searching of global English-language media, and passive collection of reports through keyword flagging on internet websites and RSS feeds. Crowdsourced information that can be verified through publicly available documentation is also incorporated. EPRI has used academic publications, and collaborated with other organizations tracking failures, to ensure all publicly known stationary BESS events are captured. However, many incidents are not reported in news media, especially before 2018-19 when there was a renewed industry focus on safety. There is no guarantee that the database captures every relevant BESS failure incident, nor that all project data related to an incident is captured. Despite these caveats, this remains the most comprehensive stationary BESS failure database available.

Data Collection

At the time of writing, the database contained 81 incidents. Of these, 26 incidents had sufficient information to assign a root cause and to identify the element that experienced failure. Certain incidents had published root cause analysis reports that explicitly noted the cause of failure. The remaining incidents were classified based on engineering judgement by subject matter experts at EPRI, TWAICE, and Pacific Northwest National Laboratory (PNNL). The authors reviewed publicly available technical details and interviewed other industry experts involved in failure incident analysis. No proprietary information was discussed in these interviews nor used in the classification of the incidents.

Transparency on the cause of BESS failures continues to be limited. Battery OEMs and BESS integrators are often reluctant to disclose the cause of failure, and many investigation reports are not released to the public. In several instances, legal complications prevent site owners or manufacturers from divulging information about the nature of the failure. Aggregation and anonymization by a third-party can encourage disclosure of such information to support safety research advancement.

Classification of Failure Incidents

Incidents can result from a variety of causes, such as water intrusion, retrofitting errors, operating conditions, coolant leaks, temperature stress, quality control, component manufacturing defects and other factors. For meaningful analysis, these causes were grouped into classifications. Each failure incident with sufficient information was classified by root cause and by failed element. Definitions for each classification are provided below:

Root Cause:

- **Design**
  A failure due to planned architecture, layout, or functioning of the individual components or the energy storage system as a whole. Design failures include those due to a fundamental product flaw or lack of safeguards against reasonably foreseen misuse.
- **Manufacturing**
  A failure due to a defect in an element of an energy storage system introduced in the manufacturing process, including but not limited to, the introduction of foreign material into cells, forming to incorrect physical tolerances, or missing or misassembled parts.
- **Integration, Assembly & Construction**
  A failure due to poor integration, component incompatibility, incorrect installation of elements of an energy storage system or due to inadequate commissioning procedures.
- **Operation**
  A failure due to the charge, discharge, and rest behavior of the energy storage system exceeding the design tolerances of an element of an energy storage system or the system as a whole. Operational failures include, but are not limited to, incorrect sensing of voltage, current, temperature, and other set point values, or operation above designed temperature, C-rate, state of charge, or voltage limits of the energy storage system.

Failed Element:

- **Cell/Module**
  A failure originating in the lithium ion cell or battery module, the basic functional unit of the energy storage system. It consists of an assembly of electrodes, electrolyte, casing, terminal, and usually separators.[6]

6 IEC Glossary. https://www.electropedia.org/iev/iev.nsf/display?openform&ievref=482-01-01.

Cell failures usually begin with short circuits within the cell leading to eventual thermal runaway. They can originate from poor cell design, manufacturing defects, incorrect installation, or cell abuse.

- **Controls**
  A failure in the sensing, logic circuits, and communication systems. Control systems coordinate the operation of the ESS, including the battery management system (BMS), energy management system (EMS), plant controllers, and any subsystems. Controls failures include those due to control system incompatibility, incorrect installation of the control system, defects leading to errors in sensors or controls, or inappropriate operation limits.
- **Balance of System (BOS)**
  A failure in any of the elements of a BESS excluding the cells, modules, and controls. BOS typically comprises of, but is not limited to: busbars, cabling, enclosures, power conversion systems, transformers, fire suppression systems, HVAC, or liquid cooling systems.

An incident may have multiple failure elements or root causes; such incidents are assigned multiple classifications. The following example illustrates this classification methodology. The Elkhorn battery facility located at Moss Landing, CA, experienced a fire on September 20, 2022. The investigation report[7] was shared publicly by Tesla (the BESS manufacturer and integrator) and Pacific Gas & Electric (site owner). The investigation found that rainwater intrusion through the container caused electrical arcing within the system, leading to thermal runaway within one BESS unit on site. A water ingress point in the enclosure had been created when an umbrella valve had been dislodged during the improper installation of a vent shield. As a confounding factor, insulation loss alarms were not properly escalated to the operator. Two days after the initial insulation alarms were recorded, smoke and fire were reported to the fire department. Appropriate reporting of the insulation loss alarms could have prevented escalation of the initial failure into a fire that consumed the whole BESS unit. Therefore, the root cause was classified as both an integration, assembly & construction failure in the BOS and a design failure of the control system.

RESULTS

Results Overview

The following section contains insights from the 26 incidents that were classified. The distributions along the biaxial classification system are examined in detail. As described above, investigations into battery failures are often inconclusive, and there is a lack of transparency that further limits the sharing of lessons learned. The industry experts who provided additional information beyond public reports are based in the United States, so information on incidents in other parts of the world is more limited in this report.

7 Report: *Elkhorn Battery Energy Storage System Fire of September 20, 2022 - PGE Currents*. https://www.pgecurrents.com/articles/3833-report-elkhorn-battery-energy-storage-system-fire-september-20-2022.

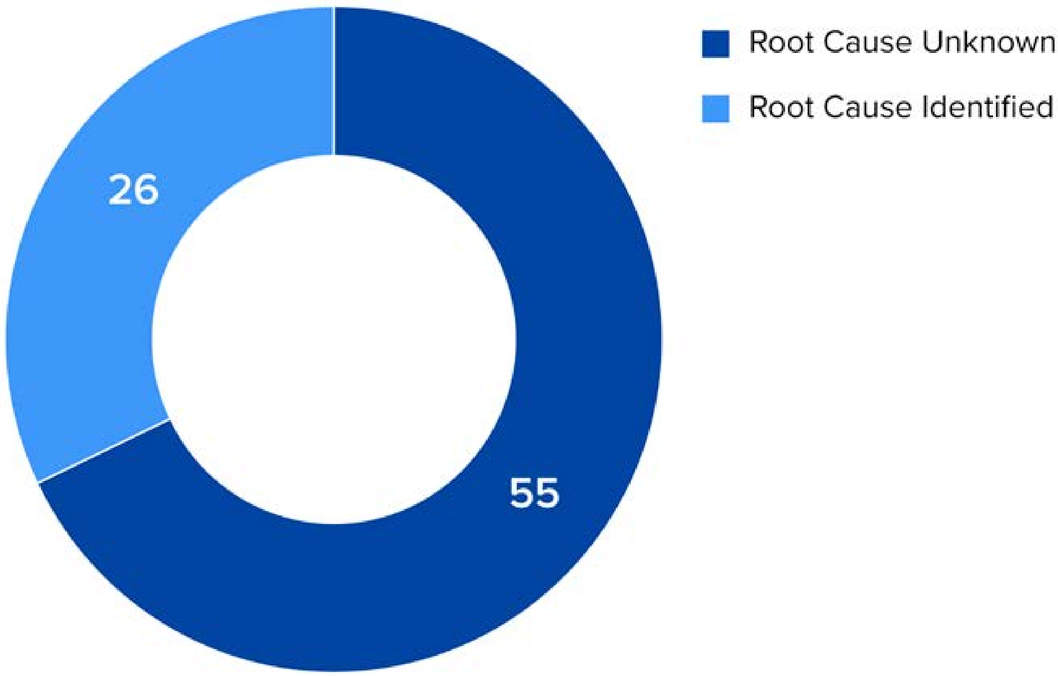


Figure 2. *Fraction of BESS Failures with Identified Cause*

Of the 9 incidents recorded in the BESS Failure Incident Database between 2011 and 2017, none were able to be classified, while 36% of incidents between 2018 and the present had root causes identified. The availability of root cause information starting in 2018 is an indication of both energy storage industry maturity as well as collective action and scrutiny on lithium ion BESS safety.

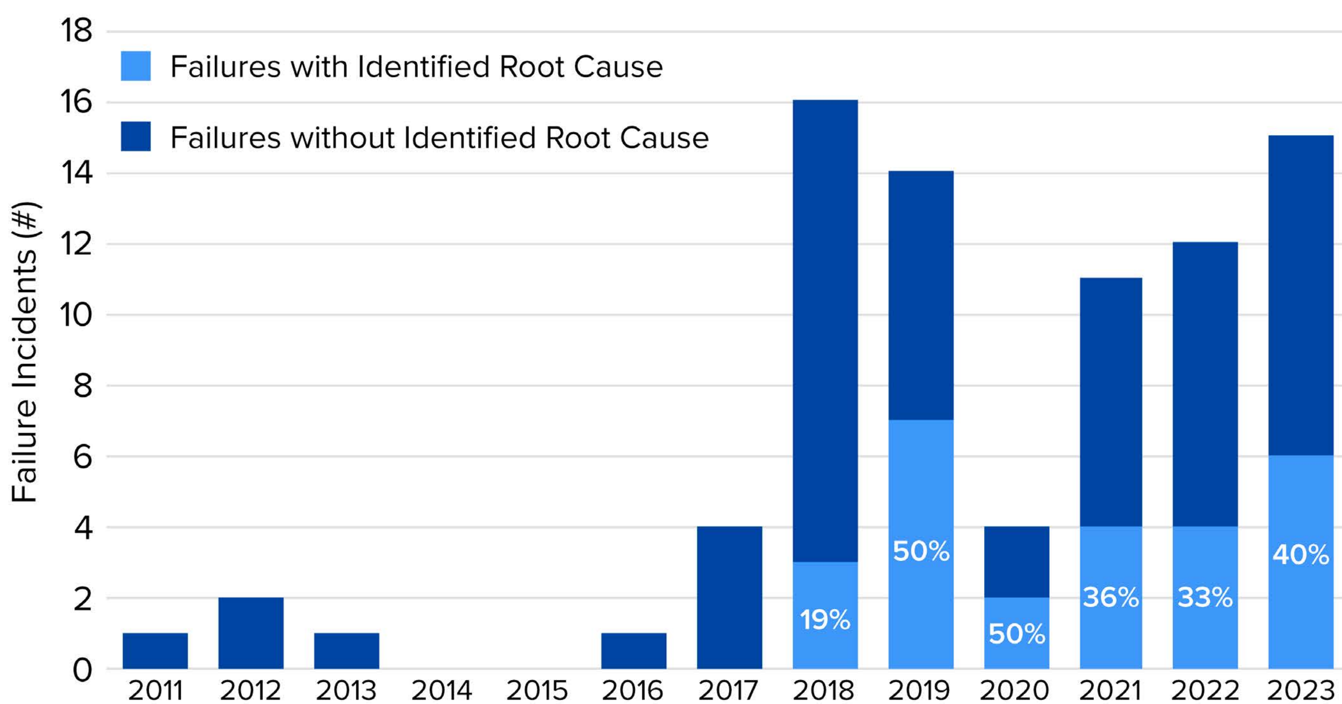


Figure 3. *BESS Failures with Identified Root Cause Over Time*

Between 2017 and 2018, the lithium ion BESS deployments increased by ~1 GW, more than doubling total global deployment, and signaling the advent of the commercial BESS industry.[8] The period between 2017-2019 also experienced a spike in BESS failure incidents. Of the 30 incidents in the database between 2018 and 2019, 27 occurred in South Korea. The Korean government had provided strong economic incentives for BESS, especially paired with solar PV generation. The number of installed BESS in South Korea rose from 30 in 2013 to 947 in 2018. The rapid deployment was not accompanied by robust safety standards and regulations, which contributed to the failures.[9] After the first spate of fires, the South Korean government investigated the incidents, and provided summarized findings for the failures in aggregate. Subsequent academic papers provided more detailed root cause analyses for individual incidents.[10]

In the United States, a fire and explosion at a BESS facility in Surprise, AZ in 2019 injured four firefighters. Following the incident, multiple root cause investigation reports were released publicly, and safety became a priority issue for the energy storage industry in the US. In the subsequent years, root cause investigations have occasionally been made public to support industry learnings. However, the number of unclassified incidents in the preceding figures are a clear indication of the continued challenges around failure data access and transparency.

Root Causes of Incidents

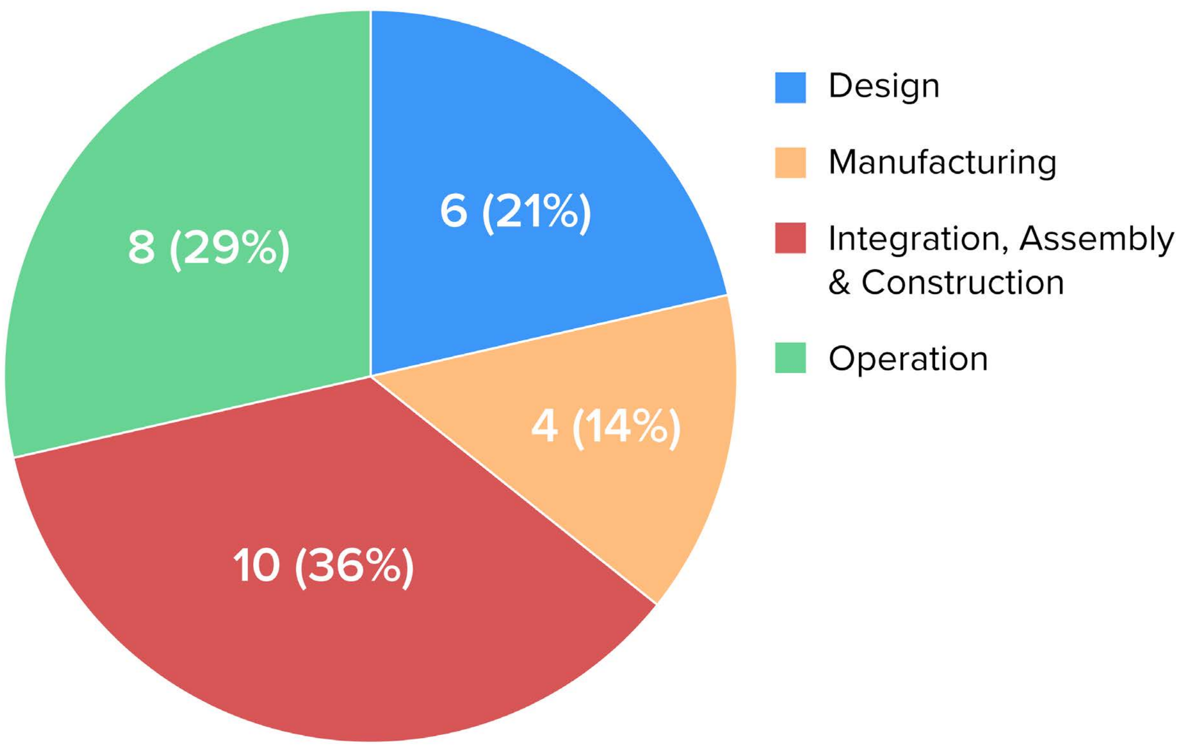


Figure 4. *Breakdown of BESS Failures by Root Cause*

8 WoodMackenzie Energy Storage Database. Accessed Apr 17, 2024.

9 Im, D-H and J-B Chung. Social construction of fire accidents in battery energy storage systems in Korea. *Journal of Energy Styorage,* Volume 71, 1 November 2023, 108192. https://doi.org/10.1016/j.est.2023.108192.

10 Na, Y-U and J-W Jeon. Unraveling the Characteristics of ESS Fires in South Korea: An In-Depth Analysis of ESS Fire Investigation Outcomes, *Fire,* 6(10), 389, 2023. https://doi.org/10.3390/fire6100389.

Figure 4 shows the root cause classification for the 26 incidents considered in the analysis. Note that two incidents were classified with dual root causes (Design as well as Integration, Assembly & Construction), and the discrepancy in total incidents is due to this double-counting. There is no clear phase across the product lifecycle that is particularly susceptible to failure, with all phases contributing to several failures. EPRI has also gathered information on failure incidents during manufacturing, transportation, and recycling of batteries, which can be found in the 'Other' table in the database.[11] These incidents were not considered for this analysis.

Integration, Assembly & Construction was the most common root cause of failure in this analysis. Figure 5 highlights the number of failures in the database that happen early in the project lifecycle. Referring back to Figure 1, deployment has increased significantly in recent years, and there are relatively few older BESS that are operational. This may be why there are not many recorded failure incidents of aged systems so far. It remains to be seen if this trend will be sustained as systems being installed today age over time. Regardless, the majority (72%) of failures where the system age is known happen during construction, commissioning, or within the first two years of operation. Integration, Assembly & Construction is a critical phase in BESS risk mitigation. This root cause is examined further in subsequent sections of this report.

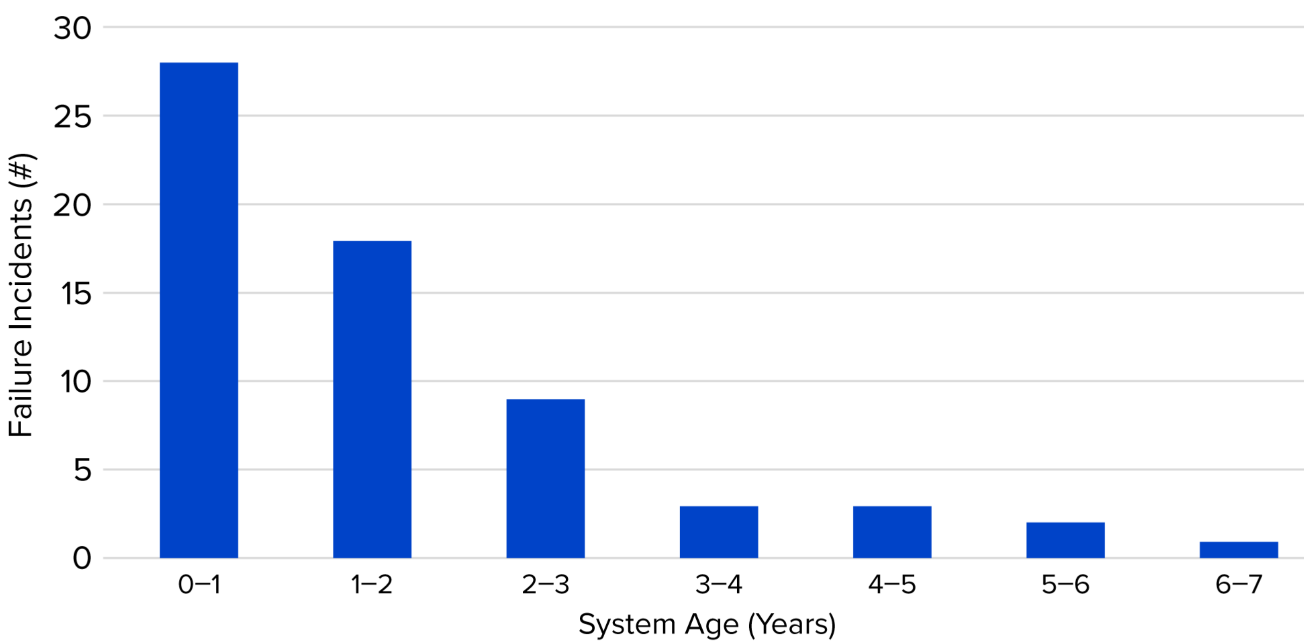


Figure 5. *BESS Age at Failure, where known*

11 BESS Failure Event Database.

Manufacturing as a root cause has the fewest failures attributed to it. This is most likely due to the difficulty in definitively identifying a manufacturing defect as a root cause with the loss of physical evidence after a fire or explosion. Earlier failures from 2018-2020 in particular may have involved cell or module manufacturing defects as a contributing factor. Several product recalls from major EV manufacturers during those years cited manufacturing issues by battery OEMs.[12,13] Some residential ESS products were also recalled during the same timeframe.[14] It is important to note that recalls do not definitively point to manufacturing issues, but indicate the probable failure cause. In recent years, more robust product standards such as Underwriters Laboratory (UL) 1973 (Standard for Batteries for Use in Light Electrical Rail Applications and Stationary Applications) and UL 1642 (Standard for Lithium Batteries) have improved the quality of manufactured batteries. Product certifications include quarterly and annual audits of factories to review quality control procedures, part inspection standards, and more. A recent report from Clean Energy Associates (CEA) summarizes findings from BESS factory quality audits. Of the identified issues in cell and module manufacturing, the majority were classified as minor issues, meaning they were not expected to impact safety in the short or long term.[15]

Failed Element

The distribution of failure sources across BESS elements (i.e. components) provides an insightful view of the vulnerabilities within the system.

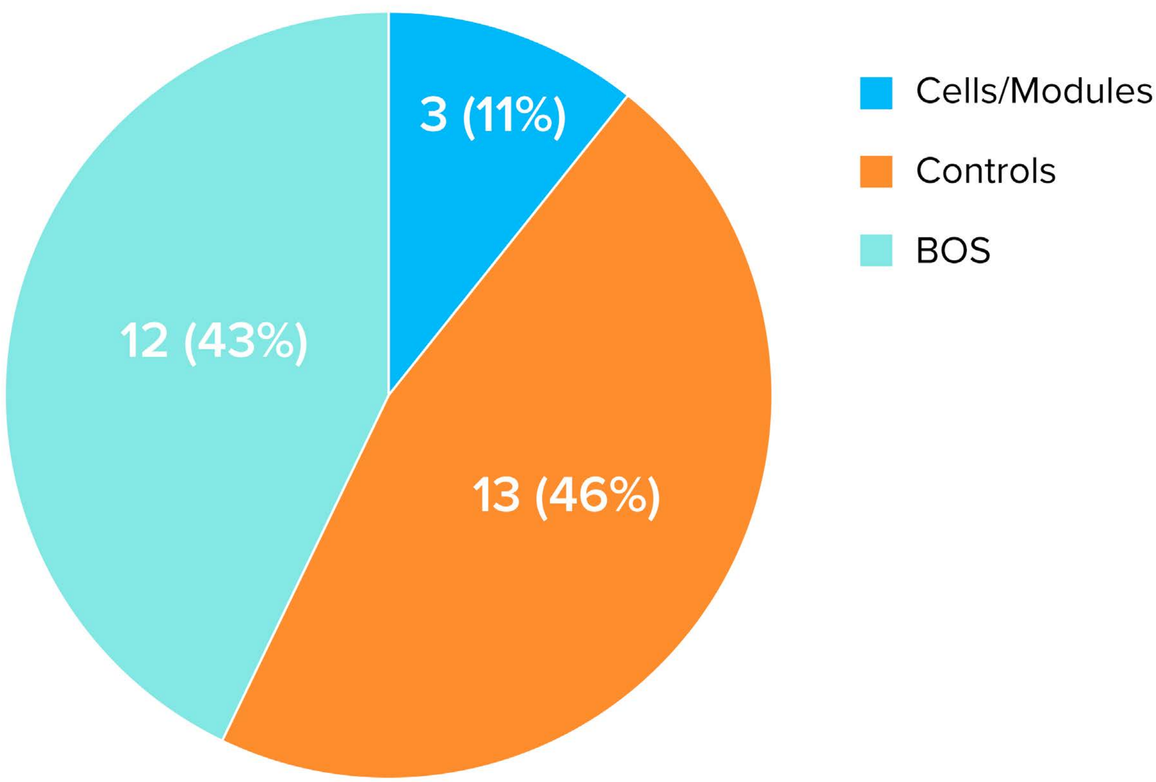


Figure 6. *Breakdown of BESS Failures by Failed Element*

12 Gitlin, J. Multiple recalls spark Fed investigation of LG's electric car batteries. *Ars Technica*, 2022. https://arstechnica.com/cars/2022/04/multiple-recalls-spark-fed-investigation-of-lgs-electric-car-batteries/.

13 De Chant, T. GM recalls every Chevy Bolt ever made, blames LG for faulty batteries. *Ars Technica*, 2021. https://arstechnica.com/cars/2021/08/gm-recalls-every-chevy-bolt-ever-made-blames-lg-for-faulty-batteries/.

14 United States Consumer Product Safety Commission. LG Energy Solution Michigan Recalls Home Energy Storage Batteries Due to Fire Hazard.

15 BESS Quality Report. February 2024. Clean Energy Associates Insights.

The BOS and controls account for the vast majority of failed components. The prevalence of BOS failures is corroborated by the recent CEA report cited above, which found that nearly 50% of quality assurance items were in the BOS. Only 3 incidents, or 11% of classified incidents, are attributed directly to the cells. However, it should be noted that many of the failures classified as controls were related to operational issues aimed at restricting cell state of charge (SOC), voltage and current, due to cell limitations. These were classified as controls failure rather than cell/module since the failures could have been prevented if more limited operational windows were maintained.

Biaxial Analysis

The following analysis looks at the combination of root cause and failed elements across the 26 incidents considered.

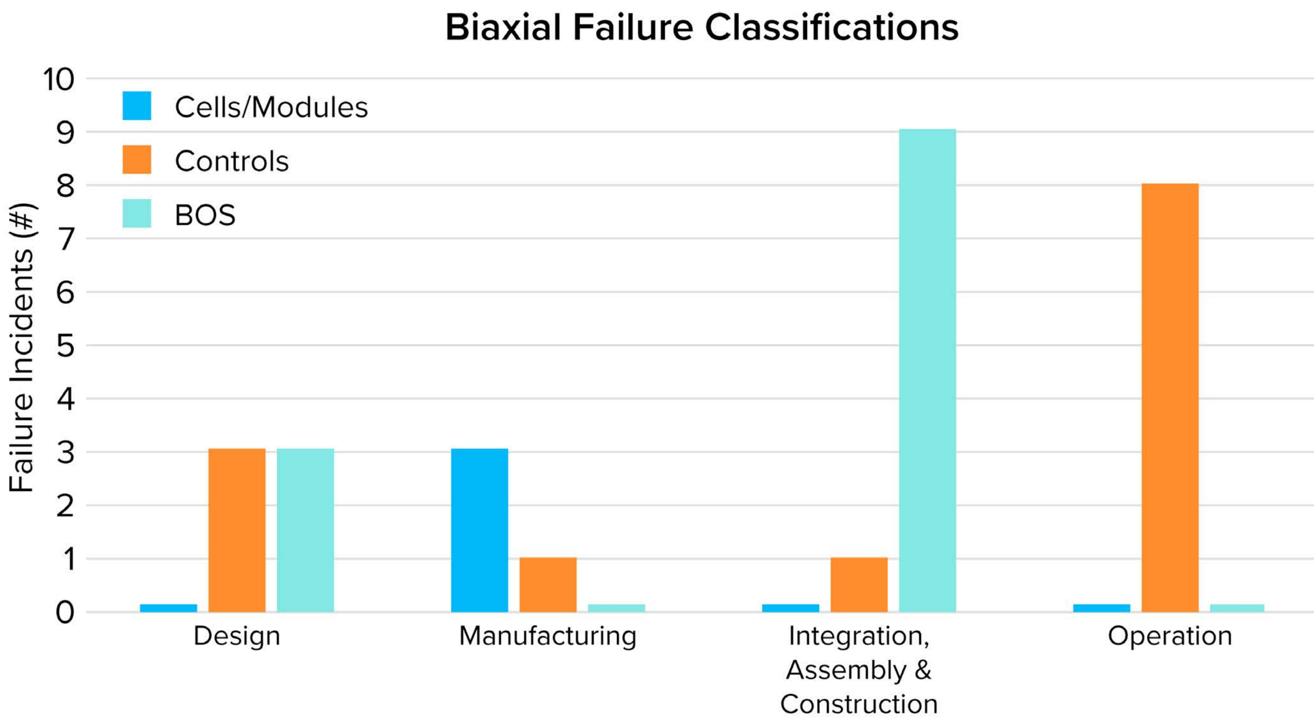


Figure 7. *Relationship between Root Cause and Failed Element*

1. ***Integration, Assembly & Construction and BOS***
   Integration is the most common root cause of BESS failures, and the vast majority of incidents with this classification involved BOS components. These components included DC and AC wiring, HVAC subsystems, and safety elements such as the fire suppression system. Lithium ion BESS contain components from multiple suppliers, which are not necessarily designed to work together. Integration is a critical part of the deployment and installation process to ensure all interfaces are compatible and functional. A 2021 incident in Australia at the Victoria Big Battery facility is an example of BOS failure due to assembly quality issues. During commissioning, a leak in the coolant system led to a fire that spread across two BESS units.[16]

2. ***Operation and Controls***
   Operation is the second most common root cause, and in all cases, the operation failure occurred in the controls system. Seven of these incidents occurred in 2018-2019 in South Korea, reflecting the early challenges in determining appropriate BESS operation limits for parameters such as voltage and SOC.

16 *Lessons Learned from Past Failures Around the World, Session 6: Responding to a Safety Event.* EPRI, Palo Alto, CA: 2023. https://www.sandia.gov/app/uploads/sites/163/2023/06/2023ESSRF_Session6.2_Srinivasan_Lakshmi.pdf.

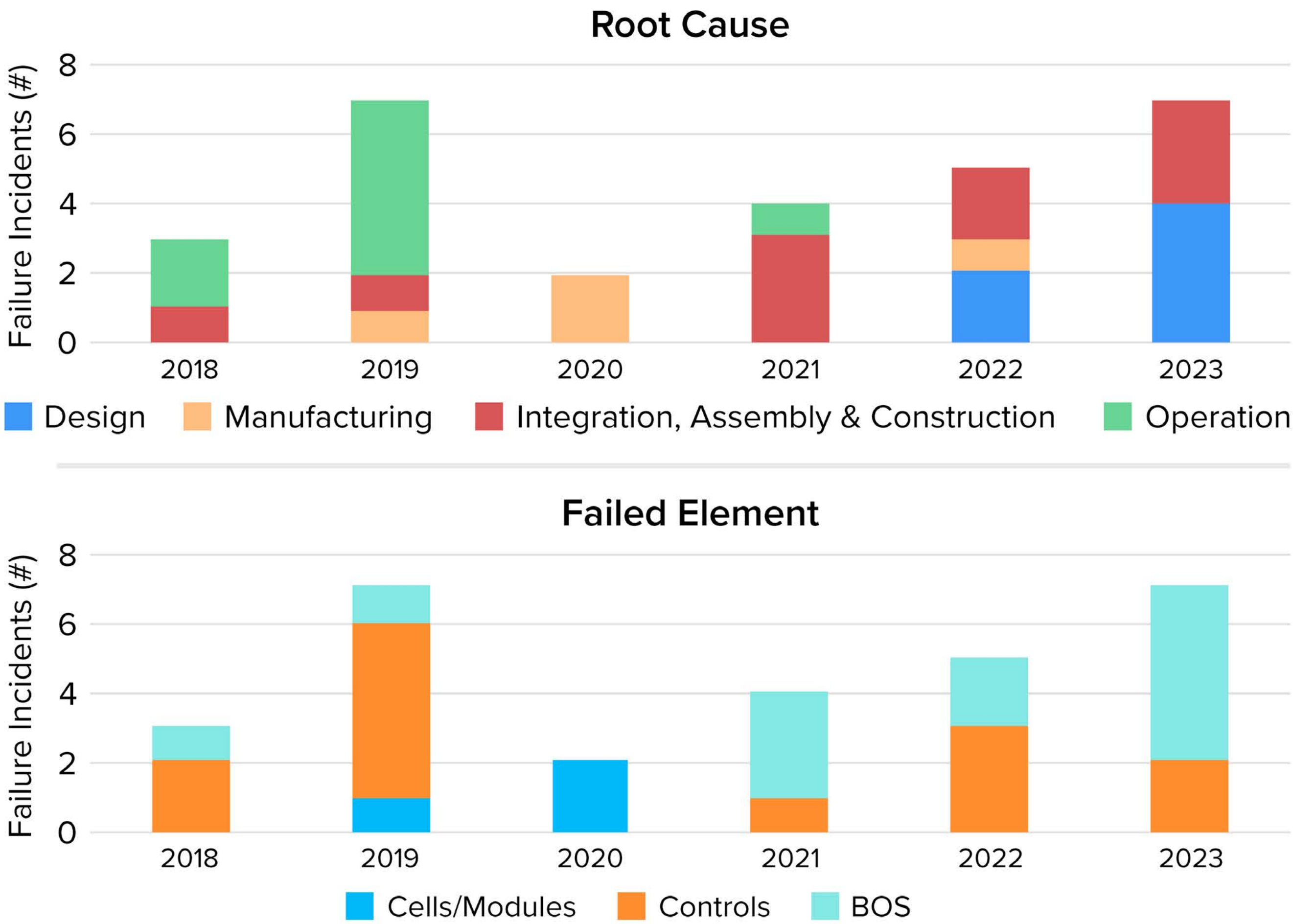


Figure 8. *Root Cause and Failed Element Trends Over Time*

Considering root cause trends over time, the bulk of operational failures occurred in 2018-2019 when a significant number of BESS installed in South Korea experienced fires. Many of these were classified as operational failures since the SOC just before incidents was higher than recommended limits. Investigation of the failures revealed that a significant fraction of those failures occurred when the SOC was above 90%.[17] It is possible that these failures could also be attributed to manufacturing or design issues with the cell, but there was not sufficient evidence to make that determination with confidence.

Integration-related failures have become more common. The vast majority of these failures are related to poor build quality in the BOS, whether it is AC or DC wiring, coolant systems, or safety systems such as water suppression piping. The CEA report corroborates these findings: 26% of inspected BESS units had defects in the fire suppression system, while 18% had thermal management system defects.[18] Both subsystems are critical for BESS safety. It is important to note that some of these failures occurred during the commissioning phase, when monitoring and communications were not online, thus allowing leaks or isolation failures to cascade into large-scale fires. Site-specific hazard assessments, monitoring, and procedures during commissioning are recommended to avoid failures. EPRI published an updated commissioning guide[19] in 2023 through the Energy Storage Integration Council (ESIC) that captures recommendations and lessons learned to improve safety.

While the core battery technology has been in commercial development since the 1990s, fully integrated BESS products arrived much later to market. BOS subsystems like cooling, and especially safety components are not yet

17 Na, Y-U and J-W Jeon. Unraveling the Characteristics of ESS Fires in South Korea: An In-Depth Analysis of ESS Fire Investigation Outcomes, *Fire,* 6(10), 389, 2023. https://doi.org/10.3390/fire6100389.

18 BESS Quality Report. February 2024. Clean Energy Associates Insights.

19 *ESIC Energy Storage Commissioning Guide*. EPRI, Palo Alto, CA: 2023. 3002013972.

mature. BESS products have rapidly evolved from walk-in containers assembled on-site to module, pre-integrated systems. There is a diversity of products, architectures, thermal management approaches etc., leading to integration challenges and the potential for incompatible interfaces or unexpected interactions between components.

As deployment increases, many more individuals and organizations are working on BESS for the first time. New products without long operational histories are entering the market. A lack of experience and training in integration and assembly could have contributed to the assembly and construction-related failures in the recent years. Designs may have flaws, or may not account for all operating and ambient conditions. For example, three of the four design-related failures in 2023 occurred due to same BOS design flaw in a BESS product. The enclosure design for systems in New York and Idaho allowed water intrusion into the battery compartment, leading to loss of isolation and thermal runaway. Global storage deployment is expected to grow exponentially, and many new entrants to the industry are expected. Sufficient training for manufacturers and integrators/developers and more extensive product quality control systems are needed to prevent integration, assembly, and construction failures going forward.

Mitigations and Recommendations

Reducing the risks associated with lithium ion BESS is a complex task. Safety must be embedded at every scale of a project, from material selection at the cell level to public health impacts at the community level. As illustrated by this analysis, safety must also to be considered at every phase of the project lifecycle, from design to operation to decommissioning. For an overview of related lithium ion BESS safety resources, including state-of-the-science documentation of safety technology and hazard assessments, visit EPRI's Storage Wiki Safety Page.[20]

The recommendations in this section focus on addressing the gaps identified in this report. These are not intended to be exhaustive. Preventative and mitigative measures against thermal runaway can take many forms, included components design/engineering, monitoring, procedural, and site-level analyses. A comprehensive view of risk mitigation options can be found in the ESIC Energy Storage Reference Hazard Mitigation Analysis.[21]

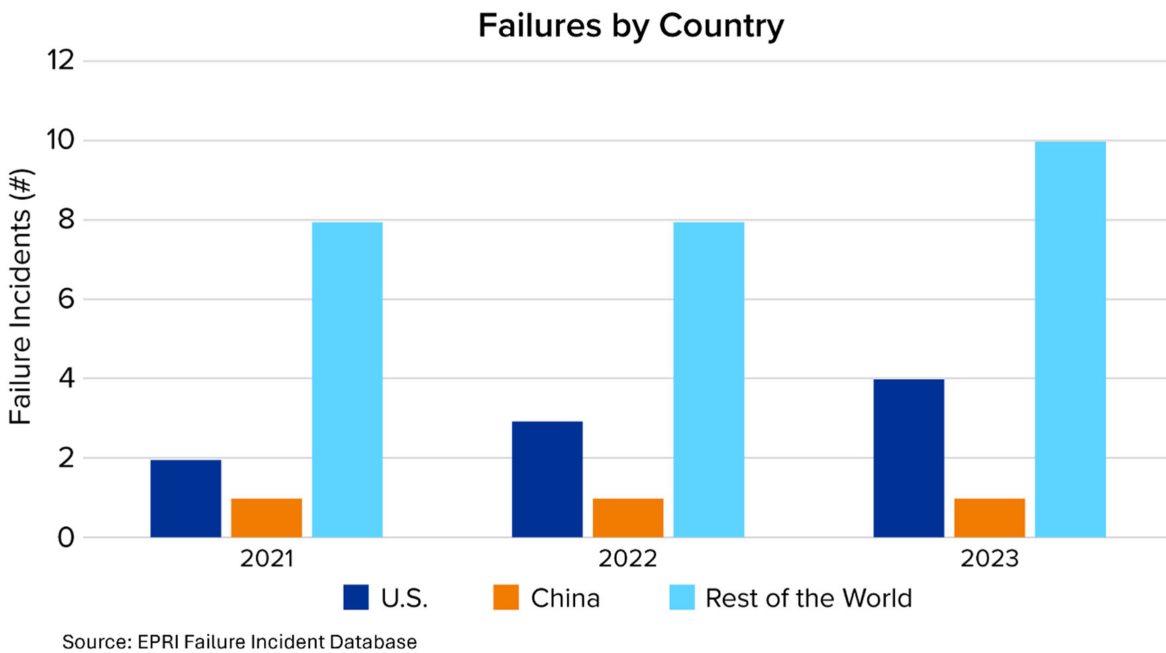
Table 1. *Mitigations and Recommendations for Each Root Cause*

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.

20 Storage Safety. EPRI, Palo Alto, CA.
21 *ESIC Energy Storage Reference Fire Hazard Mitigation Analysis*. EPRI, Palo Alto, CA: 2021. 3002023089.

Looking Ahead

This analysis is the first look at BESS failure root causes in aggregate. For a significant fraction of the incidents, the root cause was unknown, highlighting challenges in transparency around BESS failures. Additionally, it is possible that there are BESS failures that have not been captured in the EPRI database. A comparison of deployments in energy capacity and reported failures in recent years by country points to a possible information gap. The number of failures is taken from the EPRI BESS Failure Incident Database, while installed capacity numbers are from Rho Motion Consulting.[22]



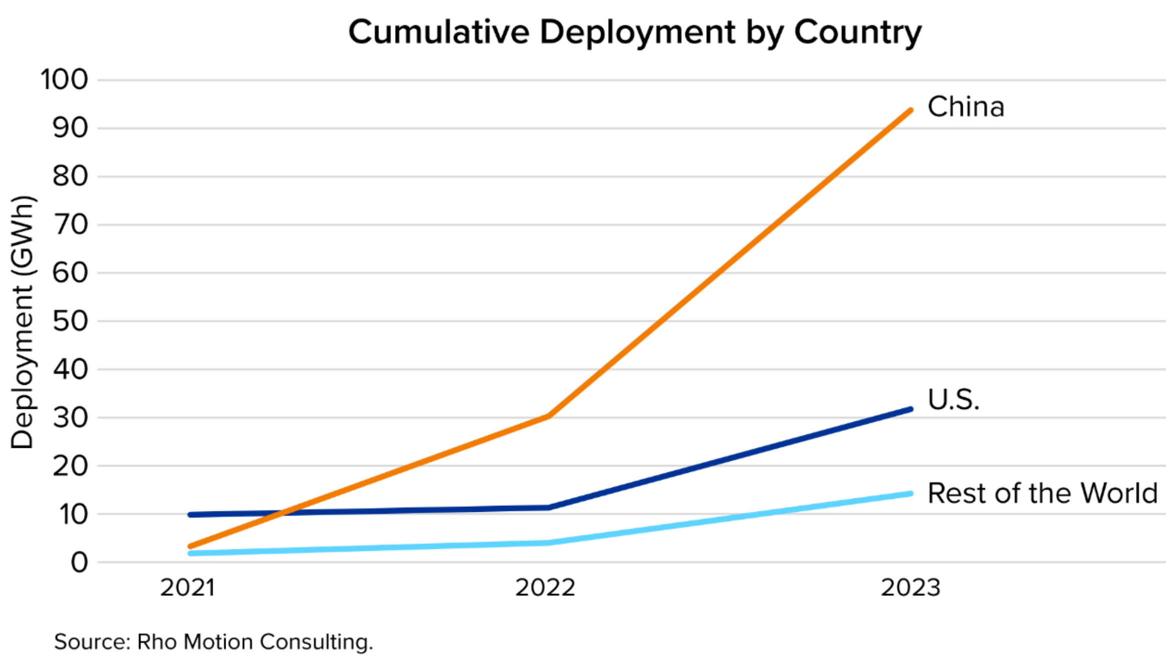


Figure 9. *Failures and Cumulative Deployment by Country*

22 Rho Motion Consulting. Battery Energy Stationary Storage Monthly Database.

EPRI and the other co-authors of this paper call for more transparency and data-sharing by the storage industry, especially of root cause investigations. With additional incident identification and classification, future work could build on this initial report to provide deeper insights on root causes and effectiveness of preventative measures.

EPRI continues to conduct research in BESS safety, and the current portfolio[23] includes projects on thermal runaway off-gas characterization, propagation mitigation technologies, characterizing risks of siting BESS near critical infrastructure, first responder training, and more. These activities are done in collaboration with a variety of industry stakeholders including electric power companies, OEMs, fire departments, and other research organizations. Ongoing regulatory development, voluntary industry efforts, and focused research initiatives will continue to support increased BESS safety.

CONCLUSION

Industry efforts to improve BESS safety during a period of rapid deployment expansion have led to a sharp decrease in the failure rate, but areas of needed improvement remain. This analysis demonstrated that all stages of the product lifecycle contribute significantly to BESS safety and must be rigorously engineered and diligently tested. Notably, the data challenges the widespread assumption that the lithium ion battery cell is the primary cause of failure. The BOS and controls were the leading causes of failure, with the cell having a relatively small number of failures attributed to it. Finally, this analysis is limited by the data that is publicly available. Of the known incidents, less than a third were assigned a cause of failure due to lack of sufficient information. Industry transparency on details of BESS failures will be essential to more comprehensive analysis, to ongoing safety research, and to future development that will ensure the continued safe operation of BESS facilities.

23 *Battery Energy Storage Fire Prevention and Mitigation Phase III*. EPRI, Palo Alto, CA: 2023. 3002028531.

DISCLAIMER OF WARRANTIES AND LIMITATION OF LIABILITIES

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Founded in 1972, EPRI is the world's preeminent independent, non-profit energy research and development organization, with offices around the world. EPRI's trusted experts collaborate with more than 450 companies in 45 countries, driving innovation to ensure the public has clean, safe, reliable, affordable, and equitable access to electricity across the globe. Together, we are shaping the future of energy.

About TWAICE

TWAICE provides predictive analytics software for companies working with batteries addressing key challenges throughout the entire lifecycle. Customers using TWAICE de-risk their battery business and outperform their peers by increasing battery performance and lifetime. Uniquely combining deep battery knowledge and artificial intelligence on a scalable analytics platform, TWAICE is committed to increasing the lifetime, efficiency, safety, and sustainability of the products that power the economy of tomorrow.

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