Mitigating Fire Risks
in Battery Energy Storage Systems: Best Practices and Emerging Technologies

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Lucian Gavriliuc, P.E., serves as E3's Executive Director of Energy Storage, where he offers technical advisory services to developers, lenders, investors, and other stakeholders in the energy storage industry. A recurring question he receives concerns the safety of energy storage facilities. In this article, Lucian provides an overview of the fire safety incidents in the U.S. energy storage sector.

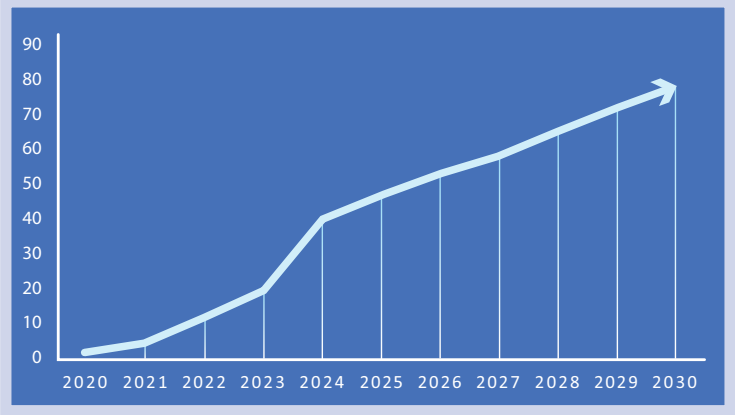
INTRODUCTION

Battery Energy Storage Systems (BESS) play a pivotal role in the transition to a cleaner energy supply. BESS systems are designed to store excess energy generated by renewable sources, such as wind and solar, and release it when demand exceeds supply. However, the rapid growth of BESS, while promising for the energy landscape, brings with it a heightened risk of fires and other safety concerns.

THE RAPID GROWTH OF BESS IN THE UNITED STATES

In 2020, the Battery Energy Storage Systems (BESS) market was still in its early stages. The US Energy Information Administration (EIA) reported that the total installed capacity was about 1.65 GWh, distributed across approximately seven sites. The number of sites is based on the location's capacity of 100 to 500 MWh. By the end of 2024, according to the Electric Power Research Institute (EPRI), this capacity had skyrocketed to approximately 40 GWh, spread across an estimated 186 sites. As of 2025, the market has seen a further increase, with around 192 sites in operation.

Figure 1: ESTIMATED BESS CAPACITY GROWTH IN THE UNITED STATES

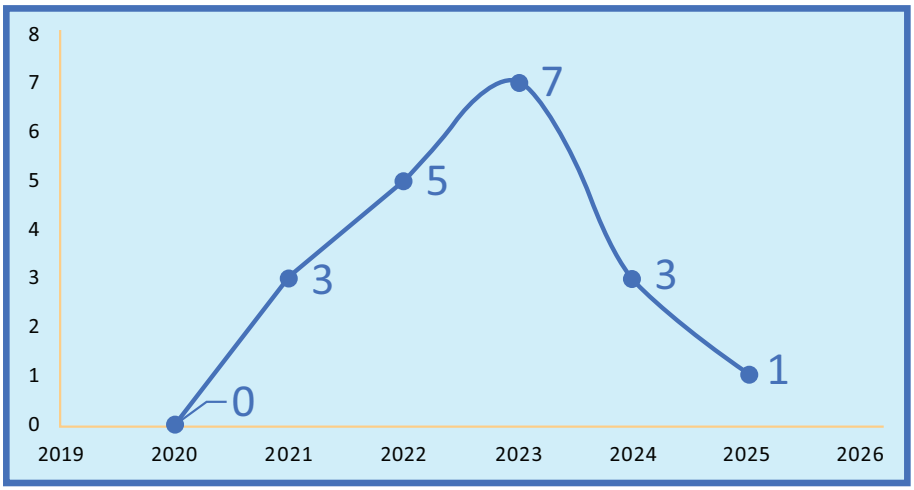


The growth of the BESS industry between 2020 and 2025 has been nothing short of remarkable, with a Compounded Annual Growth Rate (CAGR) of 88%. However, this explosive growth is expected to taper off in the coming years. The CAGR from 2025 to 2030 is projected to slow to about 10%, as the market matures. By the end of 2030, EPRI projects the total BESS installed capacity is expected to reach approximately 78 GWh.

UNDERSTANDING BESS FIRE RISK

While BESS technologies continue to evolve, they are not without risks. Between 2020 and 2025 in the United States, 19 BESS sites were affected by fires, according to EPRI. These incidents occurred mainly between 2021 and 2025, with no fires reported in 2020. When comparing the number of fires to the total number of BESS sites, it appears that nearly 10% of sites have been affected. However, when we consider the installed capacity, the fire incidents account for just over 1% of the total capacity.

Figure 2: BESS FIRES RECORDED IN US: 2020 - 2025



The leading battery chemistries are Lithium nickel manganese cobalt oxides (NMC) and Lithium iron phosphate (LFP). EPRI is keeping a database of the fires, including information such as battery technology, battery suppliers, and integrators. According to this database, the majority of these fires occurred in Lithium Nickel Manganese Cobalt Oxide (NMC) batteries, with eight out of 19 sites using this chemistry. Only two of the fires were linked to Lithium Iron Phosphate (LFP) batteries.

Table 1: FIRE INCIDENTS BY TECHNOLOGY

Technology	Number of Fire Incidents
• LG Chem	8
• Powin	3
• GE	1
• SimpliPhi Power [1]	1
• Sinexel [1]	1

1. Technology: LFP, 2 Source EPRI

While the circumstances of the fires has varied, the common thread in these incidents is that once a battery enters thermal runaway, it becomes nearly impossible to stop the fire.

THE THREAT OF THERMAL RUNAWAY

Thermal runaway is the most significant risk in BESS fire incidents. It is a chain reaction where the battery cell overheats, releasing flammable gases, which can cause nearby cells to overheat and release gases as well. This chain reaction leads to a situation where traditional firefighting methods become ineffective.

Let's do a comparison of two distinct technologies. In Figure 3a, a battery energy storage container may be observed. In Figure 3b, the process of a gas turbine may be observed.

Figure 3a: BATTERY ENERGY STORAGE

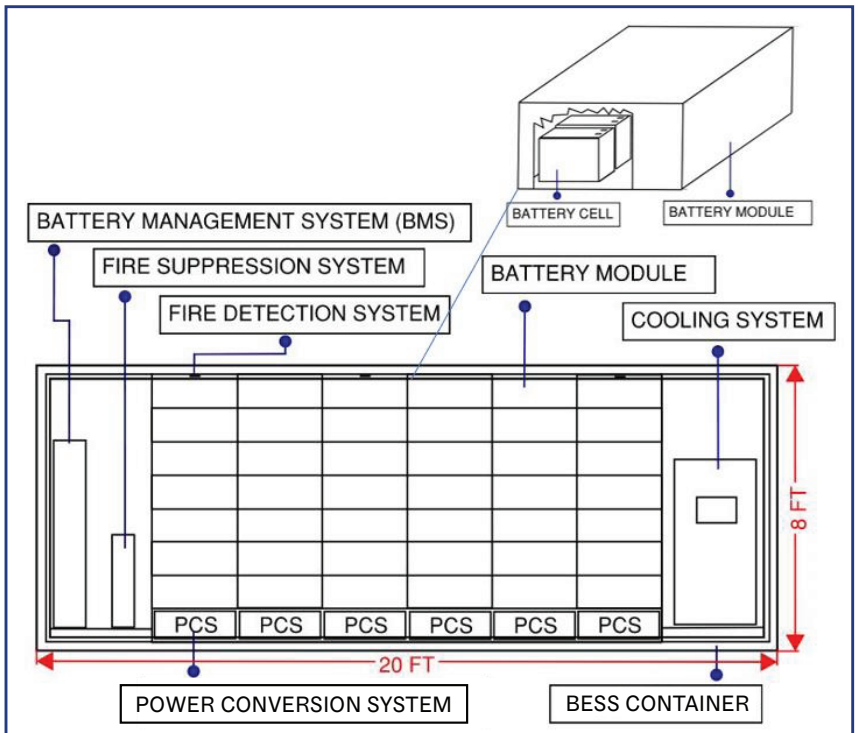
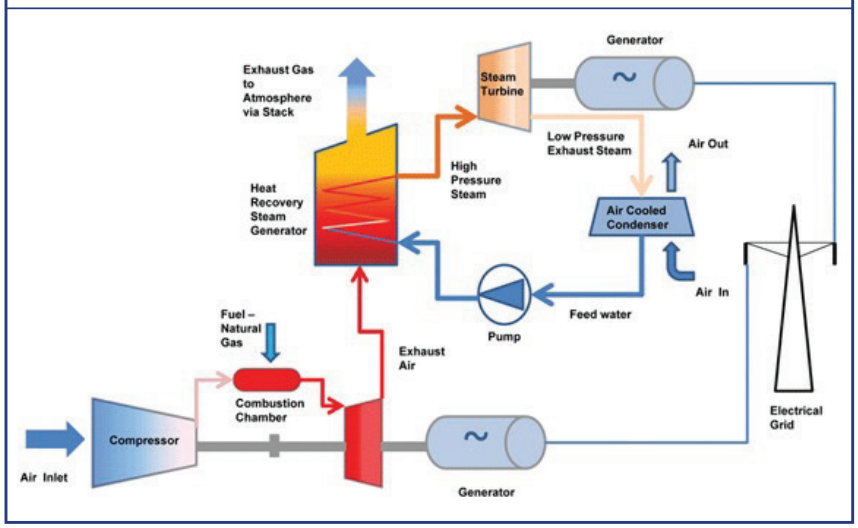


Figure 3b: GAS TURBINE PROCESS



In comparison to other industrial processes, such as gas turbines, BESS offers no immediate "emergency stop" option to mitigate risk. In a gas turbine, operators can push an emergency stop button to cut off the fuel supply.

In the case of a battery cell, there is no such "e-stop" to stop the flow of lithium ions once thermal runaway occurs.
So what must be done?

MANAGING TEMPERATURE: A CRITICAL COMPONENT OF SAFETY

The answer is to manage the temperature of the cells and build the battery modules and BESS containers of fire-resistant materials. Battery Management Systems (BMS) play a vital role in regulating the temperature by controlling the rates at which batteries are charged and discharged to ensure the temperature stays within safe operating limits.

Cooling systems are also integral to maintaining safe temperatures. Early NMC systems, like those used at Moss Landing, utilized air cooling, where fans circulated air over the battery modules. With newer systems, for example, LFP batteries, battery modules are liquid-cooled, with chillers and pumps making up the cooling system, thereby keeping temperatures in check more effectively.

PROPER MAINTENANCE: A KEY TO SAFETY

It is crucial that BESS sites are maintained regularly to ensure continued safety. The notion of "set it and forget it" is dangerous when it comes to such critical infrastructure. Regular performance tests and maintenance checks are essential to ensure that temperature management systems, such as cooling systems and the BMS, are functioning optimally.

KEY SAFETY CONSIDERATIONS FOR BESS

1. **Battery Management System (BMS):** The BMS must have access to comprehensive data on each battery cell. Some manufacturers are now incorporating Artificial Intelligence (AI) to help identify poorly performing cells before they become a fire risk.
2. **Fire-Resistant Materials:** The use of fire-resistant materials in the construction of battery modules and BESS containers can help mitigate fire risks.
3. **Fire Detection and Suppression Systems:** Implementing advanced fire detection and suppression systems is essential to contain any fire before it escalates.
4. **BESS Layout Design:** Proper layout design is crucial for minimizing fire risks. Adherence to standards like NFPA 855 for indoor installations is necessary.

LESSONS LEARNED FROM BESS FIRE INCIDENTS

The fires of the past few years have provided valuable lessons for the industry:

1. **Early Detection Beats Suppression Every Time:** Fires such as the one at Valley Center in 2023, where sprinklers contained the fire in 45 minutes, contrast with the Moss Landing incident in 2025, where fires continued for days. It's nearly impossible to stop a thermal runaway once it starts.
2. **Design Trumps Chemistry Alone:** Poor system design can exacerbate fire risks. For example, despite using LFP batteries, the Valley Center fire in 2023 occurred due to poor system layout.
3. **Gas Management Is Non-Negotiable:** The Boulder City incident in 2022 highlighted the risks posed by trapped gases. Proper gas management, including deflagration vents and gas sensors, is crucial.
4. **Suppression is a Fantasy Without Scale Control:** At Moss Landing, the sprinklers by spraying water, fed the hydrogen risks. There is no magic bullet to stop a big thermal runaway - water, chemicals, and gases are inefficient in stopping a fire when thousands of cells ignite.
5. **Human Error is a Silent Killer:** EPRI reports that 40% of failures can be attributed to commissioning or maintenance mistakes. Thorough training and rigorous quality assurance processes are essential to avoid errors. Standardize the human aspect.
6. **Scale Amplifies Stakes, Not Solutions:** The 400 MW loss at the Moss Landing fire in 2021 and the 300 MW loss in 2025 dwarfed the Queens 10 MW fire in 2022. The scale of the system requires proportional safety measures and buffers.
7. **Toxic Fallout is Underrated:** The fires at Queens in 2022 and Moss Landing in 2025 highlighted the significant air quality risks posed by BESS fires. Community air quality plans and proper protective gear for responders are essential. As the saying goes: It's not just the fire, it's also the cloud!

THE PATH FORWARD

As the BESS market continues to grow, fire risk management and safety considerations must remain a top priority. By learning from past incidents, improving system design, implementing advanced detection and suppression systems, and ensuring proper maintenance, the industry can mitigate fire risks and ensure a safer, more resilient energy future.

By recognizing the challenges BESS systems face and addressing them proactively, we can create a safer and more reliable energy storage infrastructure for the years ahead.

ABOUT THE AUTHOR

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