Assessment of Potential Impacts of Fires at BESS Facilities

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1 Executive Summary

Battery Energy Storage Systems (BESS) have become an essential component of modern energy infrastructure, supporting grid stability, renewable energy integration, and peak demand management. While concerns about fire hazards have been raised, historical data and scientific studies indicate that BESS remains a relatively safe technology with minimal environmental contamination risks. Furthermore, many reported fire incidents involved legacy systems that were designed, installed, and operational before the development and implementation of comprehensive national safety standards, such as NFPA 855 and UL 9540A.

This report provides an analysis of historical BESS fire incidents and, their causes, a review of the types of contaminants released, the extent of environmental impacts, and how advancements in safety regulations and technology have mitigated risks.

In none of the reviewed cases of environmental sampling related to the BESS fire events were contaminant concentrations found that would pose a public health concern or necessitate further remediation. This finding includes airborne contamination sampling conducted on-site, off-site, and within nearby communities, as well as relevant sampling of water from firefighting activities, automatic suppression system run-off, and groundwater testing in specific instances.

1.1 Historical Incidents: Context and Key Findings

A review of 35 documented large-scale BESS fire incidents in the United States (2012–2024) provides valuable insights into the evolution of ESS safety. These incidents occurred in 16 states, with California reporting the highest number (12). The following key trends emerged from the analysis:

- **Legacy System Involvement:** Many of these incidents involved early-generation BESS units that predate modern safety codes and lacked rigorous testing and integrated safety features.
- **Early Lifecycle Failures:** Nearly half (51%) of incidents reported the age of the system, with almost half of those incidents occurring within the first six months of operation, highlighting potential challenges during the commissioning and initial operational phases of BESS units.
- **Operational State at Time of Incident:** Among incidents where operational status was known, 69% of fires occurred during system use, while 17% took place during assembly, testing, or pre-commissioning.
- **Challenges in Root Cause Analysis:** Investigating BESS fires is complex due to the destruction of components at high temperatures. Available data suggests that failures primarily stemmed from system integration, construction, and assembly issues rather than fundamental battery chemistry concerns.
- **Advancements in Safety and Design:** Newer ESS units benefit from improved safety measures, such as advanced thermal management, suppression systems, and containment enclosures, significantly reducing the likelihood of large-scale incidents.

1.2 Case Studies of Notable BESS Fire Incidents

Several high-profile incidents illustrate the evolution of BESS safety and the limited environmental consequences of such fires. These incidents were also selected because they have published environmental impact assessments. Notable examples include:

- **Valley Center, CA (2022):** A small component-level BESS fire at a 560 MWh system. The fire was contained to a single module within a rack in one enclosure.

- **East Hampton, NY (2023):** A larger component-level fire at a 40 MWh system. The fire reportedly began as a result of a smoldering battery.

- **Surprise, AZ (2019):** A BESS enclosure fire and explosion in a 2 MWh system. Several firefighters were injured due to unexpected gas ignition and to date remains the sole incident in the US in which a person was injured.

- **Escondido, CA (2024):** A BESS enclosure fire at a 120 MWh system. The fire was limited to a single enclosure and had a duration of approximately 13 hours.

- **Lyme (Chaumont), NY (2023):** A BESS enclosure fire in a 15 MWh system. Four enclosures and two transformers were involved.

- **Melba, ID (2023):** A BESS enclosure fire that occurred in an 8 MWh system while in the pre-commissioning stage. The fire caused several battery stacks to be burned, and the fire had a duration of 3 days.

- **Warwick, NY (2023):** Two separate BESS fires occurred within 24 hours at a 36 MWh and a 17.9 MWh system. The BESS were allowed to consume themselves in a controlled manner, illustrating the shift in firefighting tactics from active suppression efforts to passive cooling of targets.

Table 1 summarizes the environmental sampling that was reported in the literature for each of the case studies selected. The documented record of environmental sampling performed for these events showed considerable variation in both the type of sampling conducted and the protocols employed, particularly concerning airborne contamination testing. Sampling was carried out by site personnel, HAZMAT first responders, and State and EPA personnel, often involving third-party consultants or testing laboratories.

Table 1: Summary of Environmental Sampling Performed at Case Study BESS Fires

Event #	Location	Date	Air	Soil	Water
1	Valley Center, CA	5-Apr-22	N/A	N/A	N/A
2	East Hampton, NY	31-May-23	X	X	X
3	Surprise, AZ	19-Apr-19	X	X	X
4	Escondido, CA	5-Sep-24	X		X
5	Lyme (Chaumont), NY	27-Jul-23	X	X	X
6	Melba, ID	2-Oct-23	X		
7	Warwick, NY	26-Jun-23	X	X	X

In addition to the case studies summarized above, a large indoor BESS fire occurred on January 16, 2025 involving a 1,000 MWh system at Moss Landing, CA. As of the drafting of this report, the investigation is ongoing and the environmental impact is being monitored closely.

1.3 Regulatory and Scientific Assessments on Environmental Impact

- **ISO Standard 26367-1** provides a framework for assessing the environmental impact of fires.
- **EPA Risk Management Program** provides guidance on how to conduct off-site consequence analyses under the EPA's Clean Air Act and provides guidance both on establishing the worst-case scenarios for evaluation and data on a variety of toxic substances.
- **EPRI Guidance Documents**: The Electric Power Research Institute (EPRI) has published guidance on the available plume models that may be used for evaluating the potential airborne contamination from BESS fires and these guidance documents provide a modeling framework for performing air modeling simulations of BESS fires.
- **Community Risk Assessment Studies**: Studies performed by various engineering consultants model the spread of acid gases (HF and sometimes HCN and HCl) and conclude that acid gas emissions generally do not reach levels of concern beyond the immediate fire site. This conclusion is supported by limited large-scale BESS fire testing.

1.4 Environmental Impact Assessment

The environmental consequences of BESS fires have been a subject of increasing scrutiny. However, data from real-world incidents, experimental studies, and environmental monitoring efforts indicate that BESS fires have a minimal long-term environmental impact compared to other large industrial and structural fires.

1.4.1 Airborne Emissions from BESS Fires

A key concern in BESS fire events is the release of toxic gases, but studies indicate that emissions are largely confined to the immediate vicinity of the fire, with rapid dissipation and concentration reduction in open-air scenarios. It has also been shown that fires involving BESS share many similarities with conventional fires, particularly those involving plastics, in terms of combustion byproducts. This is because the materials that make up lithium-ion batteries—such as polymer-based separators, electrolytes, and enclosures—contain hydrocarbons and other organic compounds that produce similar combustion emissions when the materials are exposed to high temperatures. Key findings on airborne contaminants include:

- **Common Gases Released:** BESS fires primarily emit CO, CO_2, and volatile organic compounds (VOCs), and may emit other trace gases such as HF, HCN, or others depending on the battery chemistry and overall materials of construction of the BESS unit.

- **Limited Off-Site Impact:** Air sampling from past incidents has found that contaminant concentrations beyond the immediate fire scene do not pose a public health risk. For example, monitoring at the Escondido, CA and NY incidents showed no detectable hazardous concentrations in nearby communities and initial shelter in place and evacuation orders were generally lifted shortly after the measurements were taken.

- **Flammability and Gas Dispersion:** The rapid dispersion of gases in outdoor BESS fires limits the potential for widespread toxic exposure. Studies show that the local concentration of gases rarely reaches flammability limits in well-ventilated environments and toxic gases are rapidly diluted.

1.4.2 Soil and Water Contamination

Concerns about soil and water contamination primarily arise from firefighting suppression efforts, particularly when large volumes of water are used. However, available data from real-world incidents and testing does not support the notion of widespread contamination risks. Key findings include:

- **Firefighting Water Runoff:** The consensus best practice for response to a BESS fire is to allow the BESS to consume itself and provide cooling water to targets if needed. Unless there is direct suppression water applied to the BESS on fire, any cooling water applied will be similar to rain and no potential contaminants will be included in any runoff. While lithium-ion battery fires produce chemical byproducts, studies show that their solubility in water is low, limiting the potential for groundwater contamination if direct suppression efforts are performed. Additionally, standard stormwater management practices help prevent runoff from reaching natural water sources in the event that the fire department determines that suppression efforts are required.

- **Environmental Sampling Results:** In past BESS fire incidents where environmental sampling was conducted, water and soil samples did not reveal hazardous contamination levels requiring remediation.

1.5 Firefighting Strategies and Risk Mitigation

Lessons learned from BESS fire events have impacted the firefighting tactics and safety features for newer BESS installations and provided increased awareness of safety and environmental considerations.

1.5.1 Key Firefighting Considerations

The evolution of BESS firefighting strategies has led to a shift in approach, particularly in cases where deep-seated battery fires occur within enclosed containers. Fire suppression tactics now emphasize containment and cooling of targets rather than active suppression efforts, therefore reducing potential environmental impacts, particularly those associated with soil and water contamination.

- **Controlled Burn Approach:** Many fire departments now adopt a strategy of letting a burning BESS container consume itself rather than applying excessive amounts of water. This minimizes the potential runoff and reduces potential exposures to soil and water.

- **Regulatory Compliance:** Adherence to updated standards such as NFPA 855 and UL 9540A ensures that newer BESS installations include fire safety features designed to limit fire initiation and propagation, therefore reducing potential environmental impacts in the event of a fire.

1.5.2 ESS Safety and Environmental Considerations

While BESS fire incidents have raised safety concerns, it is important to contextualize these events within the broader landscape of industrial and energy-related hazards. Many documented BESS fires involved early-generation systems that predate modern safety standards. The implementation of robust national codes and advancements in ESS design have significantly improved fire safety and reduced risks.

Crucially, environmental monitoring data from real-world BESS fire incidents does not support claims of widespread contamination. Airborne emissions are short-lived and localized, soil and water contamination risks are minimal, and existing firefighting strategies further mitigate potential environmental harm.

As the BESS industry continues to evolve, adherence to best practices in system integration, commissioning, and fire protection will further enhance safety and environmental sustainability. With continuous ongoing research and advancements in technology, ESS remains a reliable and safe energy storage option.