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PLANNING &
ZONING

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CASE NO. 130-AT-24

SUPPLEMENTAL MEMORANDUM #3
March 13, 2025

Petitioner: Zoning Administrator

Request: Amend the Champaign County Zoning Ordinance to add "Battery Energy Storage System" as a new principal use under the category "Industrial Uses: Electric Power Generating Facilities" and indicate that a Battery Energy Storage System may be authorized by a Special Use Permit in the AG-1 Agriculture, AG-2 Agriculture, B-1 Rural Trade Center, B-4 General Business, I-1 Light Industry and I-2 Heavy Industry Zoning Districts; add requirements and fees for "Battery Energy Storage Systems"; add any required definitions, and make certain other revisions to the Ordinance as detailed in the full legal description in Attachment I.

Location: Unincorporated Champaign County

Time Schedule for Development: As soon as possible

Prepared by: **John Hall**
Zoning Administrator

Charlie Campo
Senior Planner

REVISED AMENDMENT

Additional Revisions Based on Public Comments

See attachment A.

Separations to Principal Buildings Based on Air Quality Impacts of BESS Fire

The Draft amendment currently requires separations to existing dwellings based on those for PV SOLAR FARM and those separations were based largely on mitigating the noise from a PV SOLAR FARM. The current minimum separations are as follows:

- For any adjacent LOT less than 10 acres in area that is bordered (directly abutting and/or across the STREET) on no more than two sides by the TIER-2 BESS, the separation shall no less than 415 feet from the property line provided that no TIER-2 BESS equipment is closer than 100 feet to the perimeter fence and the total required separation shall be 515 feet and for any adjacent LOT that is bordered (directly abutting and/or across the STREET) on more than two sides by the TIER-2 BESS, the separation shall exceed 415 feet as deemed necessary by the BOARD.

- For any adjacent LOT that is more than 10 acres in area (not including the STREET RIGHT OF WAY), the minimum separation shall be no less than 430 feet from any existing DWELLING or existing PRINCIPAL BUILDING provided that no TIER-2 BESS equipment is closer than 100 feet to the perimeter fence and the total required separation shall be 530 feet.

Questions about safety concerns due to proximity to BESS fires from neighbors in Case 144-S-24 prompted staff to research more into best practice separations from BESS facilities. The research resulted in the following information:

- A better understanding of the potential down-wind impacts of a BESS failure incident can be achieved via “air plume simulation modeling”. A requirement for air modeling simulation was at one time recommended for inclusion in NFPA 855 if there are occupied buildings within ¼ mile of a BESS of more than 600kWh (a Tier 2 BESS) but ultimately not included due to outstanding uncertainties. Modeling must be done carefully so as not to overestimate the actual impact of fire events. There are many gaps that still exist in the science of air plume simulation modeling for BESS failure incidents. See Attachment B.

- `One paper recommended that best practice is to assume that a BESS failure incident can occur and plan accordingly. The same paper found that the particulate from a burning house is different from that from a lithium-ion BESS fire. The paper was based on a review of incidents between 2017 and 2021 and the paper acknowledges that design and fire protection will address risk as time passes. The authors recommend the following (see Attachment C):

  > “…to complete a plume dispersion study of the BESS and surrounding area, especially if there are occupied buildings within .25 mile.”

  The authors recommend that in the absence of a site-specific plume dispersion study that evacuation or shelter-in-place be implemented within a quarter mile of the BESS site.

Not mentioned in the paper is that an alternative to requiring a plume dispersion study if there are occupied buildings within .25 mile is simply to require a .25 mile separation to any existing principal building.

Ensuring there are no occupied buildings within .25 mile of a BESS site should help the relevant Fire Protection District in the event of a BESS incident.

- Air Quality and Water Quality reports from a recent large scale fire at a 30 MW BESS in Escondido CA that burned for 12 hours did not reveal any significant air or water quality impacts. See attachments D and E.

- No reports of air quality or water quality are available for a nearly two week long fire at the 250 MW BESS facility at Otay Mesa CA. A 600 feet safety barrier was used to keep people away from possible danger. See attachment F. The Otay Mesa BESS was not a containerized BESS but all the batteries were inside one large building.

- A similar single large BESS building was involved in a fire at the 300 MW Moss Landing Energy Storage Facility on January 16, 2025. However, that fire did not involve lithium-ion BESS. Monitoring by the EPA did not reveal any immediate risk to public health but expanded sampling of soil, water, and debris is underway. See attachment G. The Moss Landing fire prompted a local State Assembly member to propose a prohibition of BESS facilities of 200 MWH or greater within 3,200 feet of sensitive receptors. See attachment H.

ZBA members should determine if the current minimum required separation is adequate based on this new information

ATTACHMENTS

A Changes to Case 130-AT-24 Version 12/12/2024 based on Tenaska Comments

B *Lessons Learned from Air Plume Modeling of Battery Energy Storage System Failure Incidents*. EPRI, Palo Alto, CA. 2024

C *Hazards of lithium-ion battery energy storage systems (BESS), mitigation strategies, minimum requirements, and best practices*. Mylenbusch, Ian S., Kieran Claffey, and Benjamin Chu. Process Safety Progress 2023; 42:664-673

D Air Quality Report SDG& E Battery Fire, 571 Enterprise Street, Escondido CA. 2024

E Water Quality Report SDG& E Battery Fire, 571 Enterprise Street, Escondido CA. 2024

F *Battery Storage Fire in California Sparks Widespread Safety Concerns.* The Energy Mix. June 7, 2024

G *Incidents similar to Moss Landing battery fire are unlikely but stricter regulations proposed*. pv-magazine.com. January 28, 2025

H *Moss Landing fire leads to emergency regulations*. pv-magazine.com. February 7, 2025

I Legal advertisement

Changes to Case 130-AT-24 Version 12/12/2024 based on Tenaska Comments
(Note: Tenaska comments were provided in response to the 3/20/2024 Draft. Many other Tenaska comments were previously incorporated into the 12/12/2024 Draft.)

1. Revise Sec. 6.1.8D.(7) as follows (based on Tenaska comment #12):

(7) Cooling of a TIER-2 BESS shall not use groundwater other than for closed-loop ~~geothermal~~ cooling. The application shall include a description of the proposed cooling system of the TIER-2 BESS.

2. Revise Sec. 6.1.8R.(1)a.(a) as follows (a response to Tenaska comment #42):

(a) A general description of the project, the proposed BESS technology (type of BESS); the proposed BESS capacity at the point of interconnection; the maximum number and type of battery devices; the maximum area occupied by the BESS development; the expected lifetime of the battery devices; any planned capacity maintenance (augmentation); the proposed project features to respond to any BESS technology specific requirements of NFPA 855; and the potential equipment manufacturer(s). The maximum number and type of battery devices may be different at the time of application for a Zoning Use Permit based on the actual equipment manufacturer but the BESS technology and the proposed BESS capacity at the point of interconnection and the maximum area occupied by the BESS development should not exceed that approved in the Special Use Permit.

3. Revise Sec. 6.1.8R.(1)c.(c) as follows (a response to Tenaska comment #43):

(c) The general location of ~~all~~ below-ground wiring.

4. Delete Se. 6.1.8 R.(1)d. and incorporate the requirement into a new Sec. 6.1.8R.(3) as follows (a response to Tenaska comment #44):

(3) The Zoning Use Permit Application shall include the following:

a. Any updates or changes to the information that was submitted for the SPECIAL USE Permit but any changes must be consistent with the approved SPECIAL USE Permit.

b. Any information specifically required in Section 6.1.8 for a Zoning Use Permit Application.

c. Any other information necessary to document the authorized construction including an electrical diagram detailing the TIER-2 BATTERY ENERGY STORAGE SYSTEM layout, associated components, and electrical interconnection methods with all National Electrical Code compliant disconnects and overcurrent devices.

EPRI

2024 White Paper

Lessons Learned from Air Plume Modeling of Battery Energy Storage System Failure Incidents

TABLE OF CONTENTS

ABSTRACT

An improved understanding of the potential downwind impacts of a failure incident—such as thermal runaway-induced off-gassing or fire at a battery energy storage system (BESS) with subsequent gas and particle release to the atmosphere—enhances the ability to determine appropriate response to battery fires.

One approach to exploring the range of potential outcomes is air plume simulation modeling, which incorporates emissions, atmospheric dispersion, and transformation (for example, chemical reactions or physical changes such as deposition) of the chemicals present within a plume. This document provides an overview of various plume modeling tools that are available for such simulations, key model characteristics needed, important input metrics, guidelines for scenario building, and current knowledge gaps in the field. The goal is to educate BESS owners and operators, industry professionals, the emergency response community, and researchers as to current practices, drivers of plume evolution, information gaps, and future research needs.

INTRODUCTION

Battery energy storage system (BESS) failures have the possibility of evolving into thermal runaway, with associated cell rupture and off-gassing. This has the subsequent possibility of a fire ignition with a resulting combustion plume. Whether or not there is a flame, BESS failures emit gases and particles to the atmosphere, which can move downwind and potentially evolve through chemical reaction or physical processes (e.g., deposition to ground or other surfaces) as they are transported. This evolution may also be referred to as "fate and transport." Owners and operators must implement safety mitigation technologies and operational approaches to reduce risks of failures, as well as perform hazard assessment and community risk assessment evaluations to understand the range of potential on-site or downwind impacts. This includes simulation modeling of air plume evolution.[1,2]

While currently not required in most jurisdictions, reporting information on the potential toxic emissions from BESS fires and air modeling simulation results was suggested for inclusion in the next update of the National Fire Protection Agency 855 *Standard for the Installation of Stationary Energy Storage Systems* (current version 2023 Edition[3]) through the NFPA 855 Task Group 6 review of HF and other toxics production. Another suggestion to this working group was to recommend performing a plume dispersion study if there are occupied buildings with ¼ mile of a BESS >600 kWh. Neither was selected for final inclusion into the current 2023 version due to outstanding uncertainties, although this guideline is

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1 *Air Modeling Simulations of Battery Energy Storage System Fires*. EPRI, Palo Alto, CA: 2022. 3002021777.

2 *Near-Field Air Modeling Tools for Potential Hazardous Material Releases from Battery Energy Storage System Fires*. EPRI, Palo Alto, CA: 2020. 3002020094.

3 National Fire Protection Agency 855 Standard for the Installation of Stationary Energy Storage Systems, 2023. https://www.nfpa.org/codes-and-standards/8/5/5/nfpa-855.

recommended for use when possible by an electric power company.[4] Additionally, community impacts of potential BESS failures are increasingly becoming a focus of both public concern and the facility permitting process. Plume modeling can address these concerns by contributing to knowledge on:

- Potential site consequences and first responder exposures,
- Potential consequences at offsite locations,
- Site-specific emergency response planning (ERP), including personal protective equipment (PPE) recommendations and staging area locations,
- Range of efficacy of protective actions (e.g., shelter-in-place or evacuation),
- Environmental impacts,
- Possible setback distances,
- Facility planning and site selection processes, and
- Success of various BESS design and mitigation actions taken.

Off-gassing or combustion plume modeling allows for testing of potential impacts from a wide range of BESS designs, meteorology, locations, topography, nearby building structure, fire dynamics, suppression techniques and management approaches. The model results can also be used to determine the individual factors that most heavily influence the final ambient concentrations and exposures.

As part of the Battery Energy Storage Fire Prevention and Mitigation Phase 2 Supplemental Project,[5] a series of site-specific air quality modeling studies for simulated BESS fires have been performed. The goal was to improve understanding of the resulting potential spatial and temporal exposure, understand primary drivers of exposure, and provide feedback to the BESS facility design process.

This report summarizes the lessons learned from these modeling efforts of both the pre-combustion off-gassing (thermal runaway) and combustion phases of a BESS failure and provides suggestions that can be applied to future modeling efforts, regarding of the models or BESS designs used.

MODEL DESIGN OPTIONS

Modeling Tools

A variety of acceptable modeling tools are available that can be modified to address the needs of modeling BESS off-gassing and fire plumes, including Appendix W[6] tools. These include:

- AERMOD (*A*merican Meteorological Society and U.S. *E*nvironmental Protection Agency *R*egulatory *Mod*el) - a steady state Gaussian[7] plume model maintained by the U.S. EPA and commonly used for facility permit modeling. AERMOD does not account for dense gas effects that can occur during electrolyte off-gassing or at lower states of charge.
- FDS (Fire Dynamics Simulator) - a computational fluid dynamics (CFD) model developed by the National Institute of Standards and Technology. The code solves the Navier-Stokes equations describing conservation of mass using large-eddy-simulation approach for turbulence and is widely used for low-speed flows and smoke and heat transport from fires. The code has been extensively validated for a variety of scenarios involving fire, smoke, and gas dispersion. The tool is intended for detailed modeling of fire and gas plumes in outdoor conditions.
- PHAST – Process Hazard Analysis Software is a proprietary commercial model that can be used to analyze accidental releases from their starting point to distant areas.
- SAFER/TRACE - TRACE was developed to evaluate impacts of toxic chemical spills. This model is a proprietary version of TRACE developed and maintained by Systematic Approach for Emergency Response (SAFER). It incorporates over 600 different compounds in its chemical library.

4 Mylenbusch, I.S., Claffey, K.J., and Chu, B.N (2023) Hazards of lithium-ion battery energy storage systems (BESS), mitigation strategies, minimum requirements, and best practices. Process Safety Progress, 42(4), 664-673. https://doi.org/10.1002/prs.12491.

5 *Battery Energy Storage Fire Prevention and Mitigation Phase II Supplemental Project Notice*. EPRI, Palo Alto, CA: 2021. 3002022509.

6 Appendix W is the U.S. EPA Guideline on Air Quality Models that provides recommended models and techniques for modeling of ambient concentrations of air pollutants. https://www.epa.gov/scram/2017-appendix-w-final-rule.

7 A Gaussian model is probabilistic and describes a three-dimensional concentration field generated by a point source under stationary meteorological and emission conditions.

- SCICHEM – a Lagrangian[8] model used for the simulation of atmospheric dispersion using puffs. It is the basis for the US federal government Hazard Prediction and Assessment Capability Joint Effects Model (HPAC/JEM) emergency release models. This tool allows for the potential atmospheric chemistry of emitted pollutants to be included, avoids artificial diffusion problems in Eulerian models, and accurately treats length scales as plumes evolve.

More information on the pros and cons of these tools can be found in an EPRI report.[9]

Model Characteristics

Characteristics of the potential atmospheric models should be considered before use with BESS fire plumes. Key characteristics are listed below. While not all desired scenarios may require all the below features, if a tool is missing a substantial number of these it may be inappropriate for modeling of BESS off-gassing or fire plumes. When the user has a sense of the scenarios of interest for evaluation, review of the below characteristics can help confirm an appropriate modeling tool choice.

Desired Variables

- Meteorology:
  - Wind speed and direction
  - Temperature
  - Humidity
  - Rainfall rates
  - Stability or turbulence profiles
- Chemical:
  - Chemical characteristics (e.g., concentration, density, thermodynamic properties)
  - Explosion parameters (e.g., estimates of heat release rate and total released heat)

Desired Capabilities

- Models gaseous and particulate matter (PM) plumes (e.g., combustion) and dense gas plumes (e.g., off-gassing plume)
- Models buoyant plumes (e.g., combustion or otherwise heated plume)
- Models explosions
- Models industrial applications
- Incorporates complex terrain, including nearly building structures
- Incorporates changes in meteorology parameters
- Outputs averaging times in seconds/minutes
- Fast setup and run time
- Reduced complexity

Computational Fluid Dynamics Models vs. Chemical/Dispersion Models

The SCICHEM model that EPRI has selected for use with BESS off-gassing and fire scenarios incorporates chemical transformation plus dispersion (i.e., movement throughout atmosphere), provides for high spatial and temporal resolution modeling, and allows simulations that extend multiple kilometers from the site to capture nearby community exposure. Additionally, SCICHEM can be used with the Building Profile Input Program for PRIME preprocessor to understand how the downwash caused by surrounding buildings may affect plume dispersion. CFD tools like FDS are useful to represent near field impacts from the horizontal flow around nearby buildings and structures, but their computational expense means the CFD modeling domain usually cannot be extended more than a fraction of a kilometer downwind.

MODEL INPUT SELECTIONS

This section discusses typical metrics used during the modeling of off-gassing or fire plumes. Ideally, information specific to the project and location of interest would be used for all input metrics. However, since the science of BESS failure management and plume modeling is a new field, not all information may be explicitly available. Assumptions based on engineering or scientific judgement will likely be required. Additionally, some modeling tools may have default values that can be used after evaluation and confirmation of relevance to the scenario of interest. The rapid evolution of this field suggests frequent review of the state-of-the-science in upcoming years will identify an increasing number of sources for documented input values.

It is important to document all assumptions on input values and other scenario characteristics to clearly communicate the level of uncertainty and conservatism of the results,

8 Lagrangian models follow air parcels as they move with the wind, allowing for calculation of transformations at each model time step.

9 *Air Modeling Simulations of Battery Energy Storage System Fires.* EPRI, Palo Alto, CA: 2022. 3002021777.

and to retain the ability to compare against other modeling efforts. Key information needs on BESS design and site locations that impact final concentration estimates include the following:

1. Total battery weight (kg) and storage capacity (kWh) for estimating heat release and pollutant emissions,
2. BESS dimensions for initial source size inputs,
3. Number of modules to which thermal runaway might propagate (aka propagation cycles) during an event,[10]
4. Presence/location of ventilation ports (e.g., vent piping, deflagration panels), understanding of ventilation type (e.g., active/passive, deflagration-based)
5. Heights and dimensions of all nearby structures that can block the winds as well as major topography (e.g., located in a valley), and landscape type (e.g., forested, agricultural)
6. Locations of nearest off-site human populations and sensitive groups,
7. Battery chemistry (T*his is helpful, but as the range of emissions for batteries of similar chemistry are large and overlap with those from other chemistries, this may not be the driving factor in the results*), and
8. Battery state-of-charge (SOC) (*Higher SOC values are more likely to result in flaming combustion, which lofts and dilutes the combustion plume and subsequent reduces near-surface concentrations as compared to low SOC cases. Low SOC cases are more likely to result in dense off-gassing plumes of volatilized electrolyte that hug the ground surface, look like white fog, and increase estimated concentrations as compared to high SOC scenarios*).
9. Emission rates
10. Heat release rates and temperatures of off-gas or combustion plume
11. Minimum wind speed

10 One responsible approach is to assume 3 thermal runaway propagations in one hour (one every 20 minutes) with approximately 5 °C of temperature rise per minute. This can be considered a maximum credible event for large BESS. Venting can occur at 120 °C, so a 100 °C temp rise from ambient to 120 °C in 20 minutes is credible. The source term could be reduced to one module if UL 9540A tests justify it and if the test can be trusted.

Emission Rates

Due to their important driving effect on downwind exposures, emission rates during combustion and off-gassing are a key set of assumptions used in plume modeling. While results from a number of laboratory burn tests for lithium ion battery modules are publicly available[11,12,13,14] a knowledge gap currently exists as to the emission rates from real-world incidents, including chemical and physical dynamic evolution of the emitted pollutants close to the source. Fire service or hazardous materials team statements to the public on real-world incidents often state no presence of toxic gases. However, the chemicals tested, instruments/tools used, and the location and timing of measurement are rarely disclosed. It is known that easily accessible tools for measuring some chemicals of interest are susceptible to confounding by other chemicals. Determining accurate, precise, and field-deployable methods that can be engaged quickly in the event of a real-world fire are critical to improved understanding of human exposure risks. Use of UL 9540A test results as a total emitted chemical mass can be a good starting point for determining the magnitude of the source term. However, these results can be uncertain because real-world incidents have proven that more modules can be affected in a real-world incident that what was observed during 9540A testing in the laboratory. A conservative approach for the pre-combustion (or off-gassing) case would be to assume thermal propagation between modules occurs twice within 60 minutes to provide 3 modules off-gassing without ignition.[15] Additionally, emission rates differentiated by battery chemistry are not a substantial driver of results at this point because the existing laboratory data demonstrates wide ranges of emission rates for each chemistry that substantially overlap. Additional emissions

11 *Lithium ion Battery Thermal Runaway Propagation and Emissions Analysis.* EPRI, Palo Alto, CA: 2021. 3002021644.

12 *Summary of Prior Electrochemical Battery Fire Emission Characterization Studies*. EPRI, Palo Alto, CA: 2020. 3002018741.

13 Premnath, V., Wang, Y, Wright, N., Khalek, I., and Uribe S. 2022. Detailed characterization of particle emissions from battery fires. Aerosol Sci. Tech. 56 (4) 337-354. https://doi.org/10.1080/02786826.2021.2018399.

14 Quant, M., Willstrand, O., Mallin, T., and Hynynen, J. 2023. Ecotoxicity evaluation of fire-extinguishing water from large-scale battery and battery electric vehicle fire tests. Environ. Sci. Technol. 57 (12) 4821-4830. https://doi.org/10.1021/acs.est.2c08581.

15 For example, if the first 50 KWH module is in thermal runaway, assume that the second and third modules can go into TR without ignition within the first 60 mins, to yield a source term or battery size of 150 KWH.

data will need to be collected in the future to further clarify these effects.

Wind Conditions

The highest modeled concentrations in BESS off-gassing and fire scenarios occur during calm wind conditions; the concentrations become disproportionally higher as zero wind speed is approached. Based on EPRI wind speed sensitivity testing, assuming a minimum wind speed of at least 0.5 m/s substantially reduces these disproportionate concentrations and is more physically relevant given the difficulty of defining wind conditions representative of an hourly timestep if measurements are not available.

There are two regulatory approaches that can inform wind condition selection: the U.S. EPA Risk Management Program (RMP) under Section 112 (r) versus U.S. EPA National Ambient Air Quality Standard (NAAQS) approach, both under the Clean Air Act Amendments. RMP requires facilities that use extremely hazardous substances[16] to develop a Risk Management Plan, which must be revised and resubmitted to EPA every five years. The NAAQS set required limits on ambient concentrations for pollutants that are common in outdoor air, considered harmful to public health and the environment, and that come from numerous and diverse sources (i.e., CO, $PM_{2.5}$, PM_{10}, NO_2, Pb, O_3, and SO_2). The two approaches are compared below for their wind speed, atmospheric stability and effective plume rise guidance.

1. **Wind speed and stability:**
   - The NAAQS approach uses all meteorological data on speed and direction without edits, leading to high concentrations for cases with zero wind speed and stable atmosphere (Pasquill stability class F). This is very conservative.
   - The RMP approach uses only the prevailing wind direction, wind speed of 1.5 m/s, and stable atmosphere (Pasquill stability class F).[17] This is less conservative.
2. **Effective plume rise:**
   - The NAAQS approach uses vertical velocity and temperature at the source to calculate effective plume rise. This is negligible for thermal runaway and generally small for low heat release assumptions.
   - The RMP approach assumes effective release height of 30 ft and 150 ft, effectively assuming negligible heat release. For large fires, this may be overly conservative.

EPRI's modeling efforts to date have used minimum wind speeds of 1.5 m/s to simulate calm conditions, and included an RMP-style scenario in the event its lower plume rise leads to higher surface concentrations. Additionally, multiple years of actual nearby meteorological data are used to determine the most appropriate nearby surface and upper air winds over diurnal cycles.

HUMAN HEALTH CRITERIA AND GUIDELINES

A variety of health criteria options are available for comparison against modeled concentrations, but the most used are the Immediately Dangerous to Life and Health (IDLH)[18] and one or more levels of the Acute Exposure Guideline Level (AEGL).[19] Similar exposure times for different criteria may result in a range of different acceptable concentrations. Table 1 and an EPRI report[20] provide further information. The most relevant criteria to use depends on for whom the exposure may occur. First responders and on-site personnel exposures likely occur nearest to the source and should be compared to IDLH criteria. IDLH reflects a concentration limit for time frames beyond which would result in irreversible and long-lasting adverse health effects, death, or prevent escape from such an environment. Any exposures to the surrounding population would occur downwind after dilution and can be compared to U.S. EPA Acute Exposure Guideline Levels (AEGLs) or similar criteria. AEGL-1 values reflect the lowest concentration at which a member of

16 U.S. Environmental Protection Agency Risk Management Program Rule August 22, 2023. https://www.epa.gov/rmp/list-regulated-substances-under-risk-management-program-rmp-program.

17 The Code of Federal Regulations for Chemical Accident Prevention Provisions 40 CFR 68.229(b) states *"For the worst-case release analysis, 1.5 meters per second wind speed and F atmospheric stability class must be assumed, unless the stationary source owner or operator can demonstrate that local meteorological data applicable to the stationary source show a higher minimum wind speed or less stable atmosphere at all times during the previous three years."*

18 The National Institute for Occupational Safety and Health (NIOSH). Immediately Dangerous to Life or Health (IDLH) Values. May 10, 2019. https://www.cdc.gov/niosh/idlh/default.html.

19 U.S. Environmental Protection Agency Acute Exposure Guideline Levels for Airborne Chemicals. March 21, 2024. https://www.epa.gov/aegl.

20 *Approaches for Evaluating Potential Human Health Consequences of Utility-Scale Lithium ion Battery Failures*. EPRI, Palo Alto, CA: 2021. 3002021634.

the general population, including susceptible individuals, would experience discomfort and irritation. However, at the AEGL-1 concentration the effects are not disabling, are temporary, and are reversible upon cessation of exposure. At AEGL-2, the effects may be irreversible or disabling. One potential emitted chemical of concern is hydrogen fluoride (HF). HF permissible exposure limits range several-fold depending on the guideline and exposure timeline selected. Table 2 lists a few relevant values. All criteria selected, and the reasons why, should be documented.

Table 1. *Summary of Common Health-Protective Air Exposure Limits for Public and Worker Protection.*

Public Protection

ISSUING BODY	LIMIT OR GUIDELINE	USE	POPULATION COVERED	EXPOSURE PERIOD	NOTES/DETAILS
Environmental Protection Agency (EPA)	**Acute Exposure Guideline Level (AEGL)**	Rare exposure to airborne chemicals	General public, including sensitive individuals	10-min. 30-min, 60-min, 4-hour, 8-hr	AEGL-1: transient, non-disabling effects; AEGL-2: irreversible or disabling; AEGL-3: life-threatening
American Industrial Hygiene Association (AIHA)	**Emergency Response Planning Guidelines (ERPGs)**	Single exposure to airborne chemicals; use when AEGLs are not available	General public, excluding sensitive individuals	1-hr	ERPG-1: transient, non-disabling effects; ERPG-2: irreversible or disabling; ERPG-3: life-threatening

Worker Protection

ISSUING BODY	LIMIT OR GUIDELINE	NOTES/DETAILS
American Conference of Government Industrial Hygienists (ACGIH)	**Threshold Limit Values (TLVs)**	Time-Weighted Average (TWA) – time-weighted-average concentrations for 8-hr workday (40 hr/week). Allow repeated exposure with no adverse effects.
		Short-Term Exposure Limit (SATEL) – 15-min TWA concentrations for 8-hr workday (40 hr/week). Allow up to four exposures/day with no adverse effects if TLV-TWA not exceeded.
		Ceiling (C) - concentration not to be exceeded under any circumstances
National Institutes of Occupational Safety and Health (NIOSH)	**Recommended Exposure Limits (RELs)**	8-hr or 10-hr TWA or ceiling concentration
Occupational Safety and Health Administration (OSHA)	**Permissible Exposure Limits (PELs)**	Generally equivalent to ACGIH TLVs. Enforceable.

Table 2. *A Selection of Permissible Exposure Limits for HF. This does not cover the full range of values for all guidelines.*

HEALTH CRITERIA GUIDELINE	PERMISSIBLE LIMIT FOR HF (PPM)
Emergency Response Planning Guidelines (ERPG-2[21]) over 1 hour	20
Acute Exposure Guideline Levels (AEGL-2) over 1 hour	24
Immediately Dangerous to Life or Health (ILDH) over 30 minutes	30
Acute Exposure Guideline Levels (AEGL-2) over 10 minutes	95
Acute Exposure Guideline Levels (AEGL-1) over 1 hour	1
Acute Exposure Guideline Levels (AEGL-1) over 10 minutes	1

21 American Industrial Hygiene Association. Essential Guidelines for Emergency Response. August 23, 2022. https://www.aiha.org/blog/essential-guidelines-for-emergency-response.

EXTENT OF CONSERVATISM

A key area requiring clarification is the extent of conservatism that is most appropriate for the selection of input values (such as the emission rates) and scenario design in any given analysis. A range of options exist that may depend on the desire to understand certain conditions, a requirement based on a permitting or other regulatory authority, and research advances in BESS fire dynamics and modeling. While many are interested in the colloquially termed "worst case scenario," that is a nebulous term, especially when most necessary input values have wide possible ranges and unclear probability distributions across those ranges. More useful paradigms that can each be simulated for a given site may include "realistic and probable," "realistic and improbable," "conservative and probable," and "conservative and improbable." A "worst case scenario" would be expected to be more unlikely than "conservative and improbable."

Stacking multiple conservative assumptions, even if not "worst case," can result in unrealistically conservative results. One way to address this is to look at large range of meteorological conditions over a year and look at the statistical frequency or probability distribution of the results. Including tables of modeling results based on time of day and wind speed can be helpful to documenting the percentile frequency of results. A plume that would be an issue during 100% of the hours in a year if thermal runaway occurs is much more notable than if it would pose issues during only 1% of the hours.

Most researchers and practitioners in the field agree that conservative assumptions that would overestimate the impacts of a potential event should be used as part of the scenario building. However, there remain many knowledge gaps that influence those assumptions and the appropriate level of conservatism.[22] One prior risk analysis suggested that BESS failures could only occur once every 10 to 100 years;[23] another suggested 1% of all BESS containers on average could experience a failure in one of its battery cells.[24] Another approach using calculations of fire events divided by the number of operating years of facilities on the U.S. electrical grid estimated 1 event per 500+ facility years.[25] Safeguards such as battery management systems, redundant HVAC (Heating, Ventilation, and Cooling) units with failure alarms, and fire suppression systems can further reduce the odds of a battery module going into thermal runaway following failure; DNV GL estimate this several years ago as dropping to once in every 100,000 to 1,000,000 years (DNV GL, 2019). Current estimates based on the real-world amount of 67 GW and 150 GWh of lithium ion BESS deployed globally at the end of 2023,[26] and 85 failure incidents by that time,[27] results in 1 incident per 1.76 GWh deployed. This is an ***order of magnitude less frequent*** than 1% incident and 1 in 10 million 18650-type cell predictions. Thus, the odds of any gas release from the proposed battery container are already very low and continually getting lower. If thermal runaway occurs in a battery module, additional mitigations through the battery management system controls or thermal barriers between modules reduce the odds of the thermal runaway spreading to half of a rack of modules. If it does, it is still unlikely to release the upper limit emissions estimates. Additionally, not all thermal runaway events will lead to combustion,[28] and thus the odds of a fire are even lower than those of a thermal runaway. When combustion does occur, it is unlikely to occur with the maximum emission rates and is further unlikely to occur at the worst possible time (calm winds and a stable nighttime boundary layer). Thus, use of these types of scenarios and inputs are over-protective simulations that almost certainly would overestimate the actual impact of an extremely unlikely fire event at the stationary energy storage system.

22 *Approaches for Evaluating Potential Human Health Consequences of Utility-Scale Lithium ion Battery Failures*. EPRI, Palo Alto, CA: 2021. 3002021634.

23 DNV GL, 2019: Quantitative Risk Analysis for Battery Energy Storage Sites. DNV GL Energy Insights, Chalfont, PA.

24 National Fire Protection Association (NFPA). 2020. "Beyond EVs: Stranded energy is a concern across all energy storage technologies." https://www.nfpa.org/News-and-Research/Publications-and-media/NFPA-Journal/2020/January-February-2020/Features/EV-Stranded-Energy/ESS.

25 Jensen Hughes, 2023. Personal communication.

26 Energy Storage News. June 15, 2023. https://www.energy-storage.news/global-bess-deployments-to-exceed-400gw-annually-by-2030-says-rystad-energy/.

27 EPRI Battery Energy Storage System Incident Database. 2024. https://storagewiki.epri.com/index.php/BESS_Failure_Event_Database.

28 *Difference Between Thermal Runaway and Fire Ignition of a Lithium Ion Battery*. EPRI, Palo Alto, CA: 2022. 3002025283.

SCENARIOS CONSIDERED

Selection of the BESS, location, and fire scenarios to be modeled will depend on the primary question being asked and potential human receptors of interest. Options to consider are listed below.

1. The scenarios may address multiple phases of battery fire events:
   - **Pre-Combustion (Off-gassing) Phase:**
     - Has the highest total gas release rate
     - Lasts seconds to minutes, or hours if a fire does not initiate
     - Density of the gases must be accounted for
     - Important to consider as 1) an increasingly common fire management approach is to keep the system in a pre-combustion stage while cooling, and 2) NFPA-69 Standard on Explosion Prevention Systems[29] compliant mechanical exhaust systems are designed to vent offgas before ignition
   - **Combustion Phase:**
     - Initial ignition can be explosive
     - Lasts hours
     - The combustion removes a large amount of the gases released
     - Dense gas effects can be neglected, but the buoyancy of the hot smoke needs to be accounted for
   - **Suppression Phase**
     - Chemical agents may be used by firefighters to stop the combustion, but the heat release continues
     - The emitted gases are lower than the pre-combustion phase but are not removed by combustion
     - Exposure of firefighters near the source becomes a consideration
     - Dense gas and buoyancy effects may both be needed
     - Water mist through rainfall or applied spray can substantially reduce concentrations of gases and particles through entrainment and dissolution

29 National Fire Protection Agency 69 Standard on Explosion Prevention Systems. 2024. https://www.nfpa.org/product/nfpa-69-standard/p0069code.

2. Concentrations should be calculated at 2 m and 1 m above ground level height at a minimum, as these bound typical human breathing heights. Concentrations at breathing heights can be lower than surface concentrations for dense gas thermal runaway events. Vertical profiles of the plume with additional points can be helpful in understanding exposure to people in closely sited multi-story buildings.
3. First responders may be more interested in the maximum distance away from the site at which concentrations can exceed health criteria than the exact concentration maps. This is easier to communicate, to use for decision-making, and to enforce for any evacuation and shelter-in-place orders implemented by the fire service managing the response.
4. Depending on emissions assumptions, HCl may be a larger health concern than HF for the combustion case. While the relevant health criteria (IDLH, AEGL) for HCl are higher than for HF, the larger emissions of HCl often lead to more exceedances of the health criteria. Any conditions resulting in concentrations protective of human health for HCl and HF is likely protective for all other pollutants of interest.

ADDITIONAL INSIGHTS

It could be helpful to have a simple meteorological station installed at the BESS facility. These can cost less than $1,000 and can be located at the height of the expected release point of a ventilation plume. The resulting wind speed and direction data can be used for proactive simulation modeling or during the response activities for an actual event. Most facilities currently must rely on city-wide meteorological stations, which can be located quite far in distance from the BESS and do not account for localized effects such as building structures.

Monitoring of the emitted pollutants from battery off-gassing or a fire is another alternative. Portable monitoring devices (aka "gas detectors") for HF and HCl do exist in the range of several hundred dollars, but it is unclear if their lower detection limits or chemical specificity would be appropriate for a BESS incident. More complex monitoring devices such as open path spectrometers are substantially more expensive and require more power. With either type of device, equipment calibration and training on use would need to be determined.

KNOWLEDGE GAPS

Despite the increasing attention on air plume modeling of potential BESS failures, many knowledge gaps still exist that require future research and development. Critical review and assessment of options for emissions testing (both the experimental design and the instrumentation measuring the emissions) is the primary need. This capacity will improve understanding of fate and transport as the plume is emitted and evolves in the atmosphere. This topic is important as there is the capability of reaction and deposition of chemicals that are emitted from the battery in the enclosure itself or very near the source before the plume is fully evolved and migrates downstream. This issue will continue to be discussed in broad public forums as part of the development of the post-2023 edition of the NFPA 855 standard, as well as EPRI's forthcoming portfolio.

New ambient atmospheric concentration monitoring instruments can be quickly, easily and cheaply deployed during an actual failure event. Unmanned aerial vehicles (UAV) or drones have been outfitted with thermal cameras to image failure events; observe the evolution of thermal runaway and containment; and target water suppression activities in real-world BESS failure events. Another option to consider is the use of radar measurements of smoke plumes to measure plume rise.

UAVs have independently been outfitted with air quality monitoring equipment for greenhouse gases, NAAQS criteria pollutants (i.e., CO, $PM_{2.5}$, PM_{10}, NO_2, Pb, O_3, and SO_2), and hazardous pollutants. Combining these features into a single UAV system would allow for monitoring in and around off-gassing or combustion plumes in real-time, and the results could be fed into emissions and model evaluation studies, emergency response protocol development, and post-failure assessments. Determining what entity would best own and operate these devices would need to be determined in the future. Inclusion of a wider range of emitted chemicals (e.g., PM of specific composition, fire suppressant chemicals, and other organics) into modeling would provide broader insight into potential downwind consequences. It is also suspected that scaling emissions measured from module-level burn testing to a full unit fire introduces additional uncertainties which are not well-characterized. Use of UAV or other ambient monitoring during large-scale burn testing or real-world fires would help to resolve these concerns. Note that the commonly required Underwriters Laboratory (UL) 9540A[30] testing for BESS thermal runaway and flammability is not designed to measure emissions of toxics, and the necessary information cannot be gleaned from those test reports. Researchers are investigating chemical emission profiles, and their dynamics, from battery fires with a variety of analytical techniques and burn conditions.[31] However, these are generally based on module-only burns that must be scaled, with an unclear amount of associated uncertainty. Published studies also use a wide variety of methods which are not usually directly comparable.[32]

Detailed chemical evolution, phase changes, and deposition of gases and particulate matter released from BESS fires should be included in future plume modeling research. SCICHEM was chosen as EPRI's primary model partly because it can simulate these effects. For example, recent updates have included deposition effects[33] and suggest that simulated rain or water suppression (i.e., wet deposition) rates of as low as 3 mm/hr can reduce HF concentrations by an order of magnitude near the source and reduce HF transport downwind. This could be further explored by modeling water suppression scenarios and evaluating the potential counteracting effects of pollutant removal via wet deposition and the reduction of plume dispersion due to reduction in heat release and buoyant plume rise. Another recent update discusses the atmospheric chemistry of some key battery fire pollutants (e.g., fluorinated compounds, organic carbonates), which suggest significant chemical and deposition loss rates in typical ambient air conditions and makes recommendations for including this chemistry in air quality models.[34]

30 Underwriters Laboratory UL 9540A Test Method. https://www.ul.com/services/ul-9540a-test-method

31 *Lithium ion Battery Thermal Runaway Propagation and Emissions Analysis*. EPRI, Palo Alto, CA: 2021. 3002021644.

32 *Summary of Prior Electrochemical Battery Fire Emission Characterization Studies*. EPRI, Palo Alto, CA: 2020. 3002018741.

33 *Investigating Battery Fire Smoke Plume Dispersion: Effects of Deposition*. EPRI, Palo Alto, CA: 2022. 3002024677.

34 *Initial Addition of Chemical Evolution to Battery Fire Modeling Tools.* EPRI, Palo Alto, CA: 2021. 3002023295.

Finally, model intercomparisons are needed to understand if and how the designs and operations of each will result in varying ambient concentration results for similar scenarios and inputs. EPRI has recently completed a direct comparison between the FDS model and the SCICHEM tools.[35]

APPENDIX: EPRI'S EMISSION CALCULATION FOR RECENT BESS FIRE PLUME MODELING SCENARIOS

In EPRI's recent modeling, two calculations are performed. The first is for the total gas emitted, for which density effects need to be accounted. An emission factor of 0.1-0.7 L/Wh is used, which is multiplied by the size of the battery in Wh. The second calculation is for HF emitted. That is based on an emission factor of 0.4-1.5 g HF emitted/kg battery, which is then multiplied by the size of the battery in kg. In both cases all the gas and HF are assumed to be released in one hour. Thus, the HF emissions only depend on (a) the mass of the battery in thermal runaway, (b) the emission factor (g HF/kg battery) used, and (c) the assumption of how long the HF is released over.

If the emission factor for the total gas is changed, say from 0.4 L/Wh to 0.25 L/Wh, that reduces the total gas and changes the density effects. It does not change the HF calculation, just raises the percentage of the total gas that is HF. It could instead be assumed that a constant percentage of the gas is HF, but most scientific studies don't report their results that way, instead using mass (kg) or energy content (Wh) of the battery as the normalizing factor. If HF measurements from the 9540A testing that correspond to the lower gas release seen in the test are available, that could be used as an alternative emission factor.

35 *Comparing the Fire Dynamics Simulator and SCICHEM Plume Models for Battery Fires*. EPRI. Palo Alto, CA: 2024. 3002030364.

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ORIGINAL ARTICLE

PROCESS SAFETY PROGRESS

Hazards of lithium-ion battery energy storage systems (BESS), mitigation strategies, minimum requirements, and best practices

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Abstract

In the last few years, the energy industry has seen an exponential increase in the quantity of lithium-ion (LI) utility-scale battery energy storage systems (BESS). Standards, codes, and test methods have been developed that address battery safety and are constantly improving as the industry gains more knowledge about BESS. These standards address the minimum requirements for shipping, installation, commissioning, and operation of the battery. In addition to minimum standards, there are recommended practices that enhance the safety of utility-scale energy storage installations. This paper reviews the recommended practices that, through knowledge and experience with BESS, are being adopted by electric utilities. The focus is on fire, explosion, and toxic emission hazards of thermal runaway events of the battery and their mitigation. The paper also addresses utility considerations of minimum requirements dictated by codes, standards, and expectations of authorities having jurisdiction (AHJs) and insurance companies. This paper is intended to increase the technical acumen of environmental health and safety personnel and to provide practical information to utilities and developers installing LI BESS.

KEYWORDS
batteries, BESS, lithium-ion

1 | INTRODUCTION TO LITHIUM-ION BATTERY ENERGY STORAGE SYSTEMS

The term "battery energy storage system" (BESS) typically refers to an energy storage system that uses batteries to store and distribute energy as electricity. The storage capacity of these systems ranges from a few kilowatt-hours (kWh) to a few hundred megawatt-hours (MWh). Charging energy sources for the BESS include renewables, grid power, or diesel generators, and uses for the stored power include commercial, industrial, and utility applications. In many cases, components such as the inverter, safety systems, and controls are an integrated part of the BESS. A key component of the BESS is its software integration. Software algorithms calculate the optimal times for power generation, storage, and distribution, and control the BESS equipment accordingly. Most BESSs are designed to operate without personnel on site.

The cost benefits of a BESS installation are realized through increased power system reliability, operational efficiency, or integration with renewable power. For power system reliability, a BESS can provide emergency backup power, black start capabilities, and frequency and voltage regulation. Operational efficiency improvements from a BESS include load management, energy-time shifting, peak shaving, and deferral of transmission and distribution assets. Intermittent renewable energy sources coupled with a BESS allow for on-grid, off-grid, or hybrid consumers to receive continuous power as well as to reap any additional benefits associated with decarbonized energy.

Compared with traditional battery chemistries such as lead-acid and alkaline, lithium is the key element of choice today for many

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energy storage applications because of its high energy density, long lifespan, fast charging ability, and suitability for storing renewable energy. It is no surprise, then, that most BESS projects use a lithium-based chemistry. Batteries containing lithium are referred to as lithium-ion batteries (LIBs) because they use an intercalated lithium compound for their cathode material. Various lithium-based compounds produce different cathode chemistries and, thus, different types of LIBs with a range of performances.

Portable electronics have traditionally set the market for LIBs, but the transportation industry now commands about 80% of the market share. Currently, consumer electronics have less than 20% of the LIB market share, but the Electric Power Research Institute (EPRI) predicts that by 2024, the LIB market share for BESS projects will surpass that of consumer electronics. In the context of the LI BESS market, nickel manganese cobalt oxide (NMC) chemistry comprises about 30%, with 60% being lithium iron phosphate (LFP) and 10% being nickel cobalt aluminum oxide (NCA). Stationary storage installations mostly favor LFP chemistry.

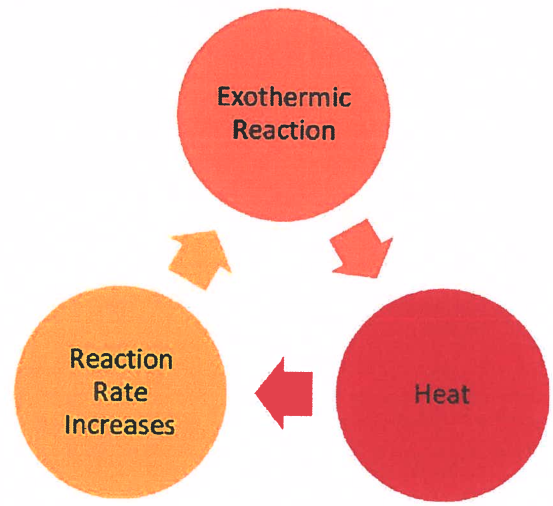

FIGURE 1 Thermal runaway.

2 | THERMAL RUNAWAY

Thermal runaway occurs when self-sustaining exothermic chemical reactions occur uncontrollably above a threshold temperature, usually resulting in any combination of fire, gas, and explosions. For a battery, when a cell reaches a certain temperature, the chemical compounds begin to degrade, releasing heat and gases in the process. The decomposition reaction and the ensuing—directly proportional—self-heating rate increase exponentially with temperature. The rate of heat generation is much higher than the rate at which it can be removed. This heat increases the temperature of the reaction which, in turn, produces more heat. As a result, the reaction proceeds to a "runaway" state, or "point of no return," in which the reaction cannot be stopped until the thermal and electrochemical energy has been completely consumed. Figure 1 shows how reaction elements combine in a cyclical nature to form a thermal runaway reaction.

A thermal runaway is different from a fire. In a fire, heat, oxygen, and fuel are needed to sustain the fire. Removing one element can extinguish the fire. In a thermal runaway, an external oxygen supply is not needed to sustain the exothermic chemical reactions, and the fuel and heat sources causing the reactions cannot be removed. Thermal runaway and fire from thermal runaway are separate, as Figure 2 depicts.

Once thermal runaway has been initiated, it can generate toxic, flammable, and explosive gases within the cell enclosure, which is typically a pouch cell, prismatic can, or cylindrical cell. Once a certain pressure is reached, the enclosure bursts and gases are released. This can resemble a flame thrower, especially with nickel-based chemistry. Many prismatic cells have a vent designed to prevent explosions from over pressurization, but even when a vent exists, the gases can ignite. LFP has a less energetic flame compared to NMC but can produce as much hydrogen as NMC batteries. There is often an initial fire at the cell level, as plastics and flammable liquid electrolyte are burned. The flames appear to stop, but the thermal runaway chemical reactions keep occurring and the battery keeps smoldering, releasing more and more gas. The main explosive gas of concern is hydrogen. The main toxic gas of concern is hydrogen fluoride (HF). Table 1 lists possible gaseous and particulate emissions of a LIB event. It does not contain all possible emissions, nor does it imply that all of these substances will be emitted; it is simply a guideline.

Electrical, thermal, mechanical, or any combination of these energy sources can provide enough activation energy to initiate thermal runaway in a cell. They can originate internally or externally; example causes include short-circuits, overheating, or punctures. Thermal runaway at the cell level can cause thermal propagation from cell to cell, within a module, between modules, between racks, and externally between storage containers.

2.1 | Probability of BESS events

A widely shared viewpoint is that 1 in ten million 18650 lithium-ion cells is likely to fail because of internal faults[1] causing a thermal runaway event. A typical 18650 cell battery has 10 Wh capacity, which means a 100 MWh of BESS could contain 10 million cells. [Correction added on 6th July 2023, after first online publication: "10,018,650 LI cells" has been changed to "ten million 18650 lithium-ion cells" in the first line immediately below heading "2.1 Probability of BESS events" paragraph. Also, a comma has been deleted from the number 18,650 in the 3rd line of same paragraph.] The sheer number of cells that are required to make up a BESS container makes an event inevitable. However, this common assumption may not be true. We have not found the original study where this "one in ten million" figure was measured. It is likely that this assertion has never been verified. There are many references to this figure in the literature, suggesting that this could be considered a reasonable failure rate, but none of them links back to an original quality control study in an actual battery plant. Manufacturers practicing Six Sigma have a target failure rate of 3.4 failures per million parts. One in 10 million seemed like a plausible figure for the battery industry, but the real figure is still unknown. A quality control study needs to be performed and results need to be published before this

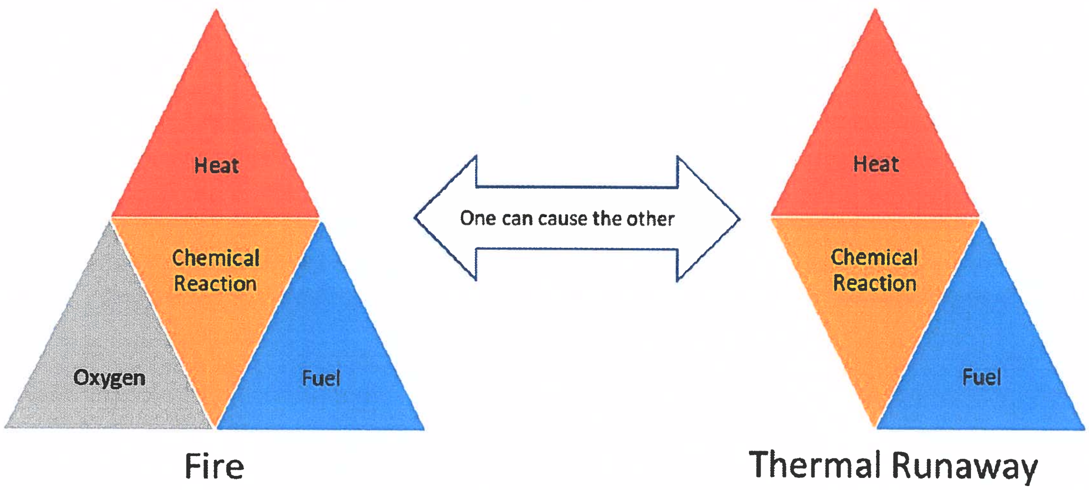

FIGURE 2 Fire versus thermal runaway.

TABLE 1 Possible emissions and particulates at the source of a lithium-ion battery event.

1	Possible gas emissions at source
	Carbon monoxide (CO), hydrogen fluoride (HF), hydrogen cyanide (HCN), hydrogen chloride (HCl), formaldehyde (CH_2O), nitrogen monoxide (NO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon dioxide (CO_2), hydrogen sulfide (H_2S), phosphorus pentafluoride (PF_5), phosphoryl fluoride (POF_3), fluorine (F_2), carbonyl fluoride (COF_2), etc.
2	Possible flammable and explosive gases at source
	Hydrogen (H_2), methane (CH_4), ethane (C_2H_6), ethylene (C_2H_4), benzene (C_6H_6), toluene ($C_6H_5CH_3$), propylene (C_3H_6), acetylene (C_2H_2), methanol (CH_3OH), propane (C_3H_8), and various alkyl-carbonates
3	Possible particulate emissions at source
	Soot, soot with metallic species (e.g., Al, Ni, Co, Mn)

figure can be considered true. EPRI (2022) has a publicly available BESS Failure Event Database with details of BESS events from around the world since 2017.[2] An approximation of BESS event probability can be made based on the installed capacity and number of BESS events. From 2017 through 2021, it is estimated that 56 GWh of LIBs have been deployed globally, with an estimated 40 MWh of LIBs being involved in an event (limited to one container). This translates into an event probability of 0.000714 (1/1400). This is an approximation based on capacity and has inherent inaccuracy due to lack of reporting. A more thorough analysis is warranted to calculate the event probability than is presented here. As the LI BESS market matures, it is expected that the probability will decrease with improvements in manufacturing and experience in commissioning. It is a best practice to assume that an event can occur and to plan accordingly.

2.2 | Historical BESS thermal runaway events

As of the date of the publication of this paper, there are 50 events in the EPRI BESS Failure Event Database. Below are a few notable observations from the database.

- Failure events occurred at sites from 0.5 to 730 MWh of storage capacity.
- Twenty-one events occurred within a year of operation.
- Events were not limited to whether the battery was charging, discharging, or inactive.
- In most cases, the difficulty of determining the root cause of the event was evident.
- First-responder engagement with extensive fire and gas release was the norm, but reported casualties were very rare.
- For stations near public or residential areas, impacts to the public typically involved "shelter-in-place", evacuation orders, and road closure.
- Two events documented fatalities.

3 | SYSTEM DESIGN CONSIDERATIONS

3.1 | Deflagration versus conflagration

Thermal runaway and LI fires can cause deflagration (vapor cloud) explosions. The explosions tend to have subsonic pressures, unlike a detonation explosion that travels at supersonic speeds. When an LIB container explodes, it can be considered a large-scale, short-duration, subsonic deflagration. However, just because the explosion does not achieve detonation at supersonic speeds does not mean the force of the explosion cannot cause severe damage. Explosions from LIBs have resulted in fatalities,[3] injuries,[4] and equipment damage.[5] Deflagration can also be an energetic venting of a cell, which resembles a flame thrower venting a concentrated jet of fire. The cell-level deflagration is dramatic but not as serious as when one entire container suffers a deflagration event. Conflagration, in the context of BESS sites, is defined as fire spreading from one container to adjacent containers, resulting in a larger scale fire at the site. Deflagrations may cause conflagrations. The BESS industry should be vigilant to prevent conflagration and to always minimize events to one container (or one battery bank if the system is located indoors). When events can be minimized to one container, smoke release is also minimized. Fire spreading to an adjacent container is rare, but it can happen.

3.2 | Spacing

The main concern with tight BESS spacing is flame impingement on an adjacent BESS and propagating thermal runaway. Having the ability to drive a vehicle between the containers is desirable in order to have access to systems; a spacing of approximately 9 ft between BESSs is typical for vehicle access. A road wider than 9 ft is typical between rows of containers. In urban areas, some systems have been planned as close as 6 ft because land is at a premium. There are, however, more important considerations when it comes to spacing. The insurance industry would like to see a spacing of 25 ft between containers as a metric for maximum foreseeable loss. This spacing requirement is conservative compared to hydrogen equipment. Guidance from NFPA 55 and NFPA 2 specifies separation distances from 10 to 16 ft for hydrogen storage.[6] Hydrogen is the main off-gas for battery events, consisting of approximately 50% of the vapor cloud, with volatile electrolyte making up the majority of the remainder.

Explosion from adjacent BESS is also a consideration. The energy from a BESS explosion can shock an adjacent BESS. Vibration or shock can put a LI cell into thermal runaway. For example, crashing and shocking an electric vehicle (EV) battery at 40 m per hour (mph) can initiate thermal runaway. This type of failure has not been experienced in large BESS, but even though the risk of conflagration is low, the risk is not zero, especially if most of the energy from the explosion is directed sideways, as opposed to vertically. The energy from the Liverpool BESS explosion was able to eject debris as far away as 72 ft from the container.[5] NFPA 855 states that in locations near exposures, ESS located outdoors shall be separated by a minimum of 10 ft from buildings. This is considered too close for large utility systems, especially BESSs that exceed 600 kWh in capacity. It is preferred to have these large BESSs at least 100 ft away from any occupied space when considering fire and explosion risk. NFPA 855 defines a remote location to be 100 ft from buildings and other exposures. This 100 ft distance does not include the minimum approach distance in the event of toxic gases.

It is best practice to have the weakest point of the container on the roof so that most of the energy from an explosion is directed upward away from people or equipment. This best practice needs to be evaluated on a case-by-case basis. For example, urban areas with people in high buildings or areas prone to heavy snow loads on rooftops may prevent energy from being dispersed upward. The risk of conflagration is greater from flame throw-over/impingement compared to an explosion, but both risks exist. For large utility-scale BESSs, the pressure from the blast for different chemistries and container sizes generally becomes moderate for equipment at a spacing of 15 ft. At 6 ft, the energy can be high enough to blow off panels on adjacent BESSs and expose adjacent BESS modules to high temperatures. We cannot give specific recommendations on spacing for BESS to minimize conflagration because the optimal spacing depends on the system chemistry, the total energy capacity of the system, and the geometry of the containers. Every project is different. It is recommended to examine spacing early in the planning process, keeping in mind that the greater the spacing between containers, the less the risk of conflagration. When containers are placed end to end, as with many new designs, it is a best practice to keep battery racks in each container as far as possible from battery racks in the adjacent container. Flame throw-over and subsequent conflagration can become a greater problem in high wind conditions. Fire departments can spray water on adjacent BESS to keep them cool, but this solution introduces additional risks because water can short-circuit batteries and cause a fire where none previously existed. In this instance, extra space between containers is helpful because it decreases the risk of thermal runaway propagation between containers when a "no water strategy" is used.

3.3 | Facility siting

The siting of a facility needs careful consideration from an environmental and safety perspective. Some siting considerations for a BESS project are proximities to occupied buildings, waterways, and protected ecosystems; prevailing wind direction and speeds; availability of land for adequate spacing; availability of piped water; community engagement; grid location and congestion; and energy justice and equity in siting and economic valuations. It is difficult to find the perfect site to accommodate all these parameters, but it is important to incorporate safety from the very beginning of a project. There are certain general rules that can be followed such as providing at least 100 ft from the BESS to perimeter fencing to mitigate explosion debris risk to first responders, placing the BESS away from occupied buildings as much as possible, and creating room for a first responder station uphill and upwind of the BESS.

3.4 | BESS augmentation

LIBs lose both power and energy capacity during their normal life cycle. Generally, when the energy capacity is below 70% of the original battery capacity, the BESS can be deemed ready for recycling. Over time, the system may require augmentation with new batteries to address the loss in capacity for the required application. Some BESS container systems allow space within a container for future battery augmentation. This approach is problematic because there is extra empty volume within the confines of the container where hydrogen could accumulate during an event. It is a best practice not to leave open space in a container for augmentation. Instead, the initial system design can provide space for additional separate battery containers dedicated to future augmentation plans. This also has the advantage of keeping old and new batteries separate, which should allow for improvements to the overall system degradation.

3.5 | Toxic/flammable gases and particulates

The gases and particulates that evolve during a BESS event are sufficiently toxic to kill or permanently harm people if the persons were located inside the container. This is true of any fire that contains large amounts of plastic and chemicals. No one should ever enter a BESS container not only because of the explosion risk but also because of the risk of exposure to lethal emissions. There is also a risk of asphyxiation in a confined space.[7] Studies have been conducted to determine the distance above which the contaminants of concern become dispersed enough to be benign to people or animals. The safety and health implications of these gases and particulates are not exclusive to BESS because EVs use the same types of LIBs as utility BESS. There is much interest from researchers, first responders, LIB manufacturers, utilities, and the general public in this area. UL 9540A testing does a satisfactory job at identifying the combustible gases that develop, such as hydrogen, methane, ethane, and other hydrocarbon gases. The toxic gases and particulates of concern from a LI BESS are CO, HF, HCN, HCL and soot (PM2.5/1). Gases such as NO, SO_2, NO_2, formaldehyde, and others can also be present and potentially pose a problem. CO detection is standard in a firefighter four-gas detector. If high levels of CO are detected, the vicinity must be evacuated. If first responders remain, a self-contained breathing apparatus, or SCBA, must be worn. CO gas can be the surrogate for the probable presence of other contaminants of concern and is a useful tool for first responders. Metallic species have the potential to be absorbed onto carbon soot. For first responders close to the fire, it is possible that soot with carcinogenic metal species could reside in personal protective equipment (PPE). This is also an issue for firefighters dealing with EV LI fires, and the hazard needs to be addressed either by discarding firefighter PPE or by removing the battery soot by a known process. The particulate from a burning house is different from that from a LI fire.

3.6 | Plume dispersion

It is recommended to complete a plume dispersion study of the BESS and surrounding area, especially if there are occupied buildings nearby (within 0.25 m). Expertise in BESS plume dispersion is limited, but it is anticipated that this will change with more deployments. Important factors include site topography, the presence of buildings, wind speed and direction, and the battery's state of charge and chemistry. Low wind and low state of charge conditions tend to form the worst case for the presence of toxic HF. In the absence of a site-specific plume dispersion study, operators are using the advice from Hazmat incidents: evacuate or shelter-in-place within a quarter-mile radius of the BESS site. Each case must be judged on its own merit, and it is possible that an evacuation order is required if the wind is blowing the plume directly at nearby buildings. The Federal Emergency Management Agency (FEMA) guidance for chemical hazard shelter-in-place is to close off all outdoor airways by turning off any air conditioners, furnaces, fans, or fireplace dampers.[8] A conservative approach is recommended when dealing with the potential for toxic gases. The main contaminant of concern in a plume dispersion study is HF due to its low IDLH (immediately dangerous to life and health) concentration of 30 parts per million (ppm) and AEGL-2 (acute exposure guideline level) concentration of 95 ppm over 10 min. HF can pose a serious toxic threat, especially for large LIBs in confined environments.[9] There are different approaches to air quality management and plume dispersion studies. A time-history type of analysis is useful for determining HF levels during a fire, and a static study is useful for determining the extreme limits that are possible. An important aspect of BESS plume dispersion studies is correctly determining the initial release rate from the BESS. Release rates are generally higher for NMC batteries compared to LFP.

3.7 | "Water strategy" versus "no water strategy"

Water is the best method to cool a battery that has gone into thermal runaway. Copious amounts of water provide enough thermal mass to remove the excess heat generated. However, there is an inherent problem with water: water is electrically conductive and can short-circuit batteries, leading to high currents that rapidly heat current collectors and battery electrodes. This heating can cause a thermal runaway and fire in a battery in which none previously existed. Conversely, the risk of not using water to cool the battery could pose a more severe threat. When safety personnel apply the "no water strategy," they are trying to prevent setting more of the battery on fire. However, it is important to assess the risks when a "no water strategy" is adopted. Location can be the determining factor in choosing a "water" versus "no water strategy". If a BESS is in a remote location, a better option may be to adopt a "no-water strategy", whereas a "water strategy" may be more appropriate in populated locations. NFPA 855 allows for alternative fire suppression systems to water if the authority having jurisdiction (AHJ) agrees. A "no water strategy" is specific to the container that is having the event. For example, one could have a "no water strategy" for the battery container that is on fire, yet still use water to intermittently cool adjacent balance of plant equipment, such as transformers and inverters. It is worth noting that DC voltage in the presence of water and dissimilar metals can cause electrolysis and could create hydrogen in a flooded container. This risk is considered low. Experience has shown that immersion of LIBs in salt water is an effective method to deal with stranded energy in LIBs; this is usually performed in an open salt bath where evolved gases can safely dissipate. When a "no-water strategy" is used and free burning of LIBs occurs, the plume tends to be more buoyant and hence less toxic than a plume from thermal runaway without ignition.

Since each strategy can potentially improve or exacerbate the event, thermal runaway situations need to be dealt with individually and explained clearly in the emergency response plan.

3.8 | Fire protection systems

The requirements of NFPA 855 are recommended for utilities for fire protection systems. The international fire code may be the standard adopted by a state and may be less stringent than NFPA 855. It is anticipated that NFPA 855 will eventually be adopted by all states for stationary BESS because it is a standard that specifically addresses the intricacies of energy storage. One design consideration for fire protection systems is to make sure that the solution to a problem does not initiate a new problem. The LIB industry is not a new industry, but putting these batteries together in large containers is relatively new and knowing all the risks is difficult. Fire protection systems must be thoroughly evaluated and tested. As with any industry, as time passes, it is anticipated that design and fire protection systems will address the risk. It is recommended to have redundancy incorporated into detection whereby two different types of detection are required to activate the suppression system: for example, both smoke and heat detection required before directed nozzle water injection is activated. AHJs are requesting to immediately vent once hydrogen is detected, to prevent explosions.

3.9 | Stranded energy and reignition

Determining when an event is completely over can be difficult. Reignition of LIBs after an EV fire occurred 5 days[10] after an initial fire.[11] An LIB that has burned can still hold stranded energy, which cannot be easily discharged. If the battery had a high state of charge (SOC) when the initial fire happened, it may still have electrochemical energy stored within the battery. The battery will tend toward its lowest energy state. The battery will de-energize through whatever means it can, once given the chance. A burnt battery can begin smoldering again, initiating a second thermal runaway and reignition.

One scenario that could cause smoldering is the creation of pyrophoric lithium metal dust. If there is any lithium metal plating at the anode, a punctured cell case could expose small particles of lithium metal dust to water vapor existing in the air. Small particles of lithium metal have a high surface area relative to their size and spontaneously ignite in air if the air is not completely dry. It is worth noting that there has been little research into reignition, and the mechanisms of reignition are not fully understood. There have been many instances of reignition in waste disposal and recycling of LIBs. To prevent reignition, some municipalities in Europe are submersing burning EVs into saltwater baths. This appears to be an effective way of discharging the batteries, but it results in complete loss of the vehicle. Southern Company has been able to discharge LIB modules in this manner. If saltwater baths are used, then another problem presents itself: the proper disposal of wastewater. It may be a best practice not to remove burnt batteries from the site for at least a week to mitigate the chances of reignition, or to have a planned process to submerge burnt modules in saltwater. Leaving the batteries in place may be the best option. Recycling companies are willing to take burnt batteries for recycling once they are deemed safe to remove from site. The entire fire department does not need to be present for a week, but monitoring for at least a week at 2-h intervals is recommended.

3.10 | Degradation and safety

Understanding battery degradation is important from both a planning and safety perspective. All LIBs degrade over time, but the mechanisms of degradation and the rate of degradation vary depending upon usage and environmental conditions (temperature, C-rate, and depth of discharge). The main degradation mechanism of concern from a safety standpoint is lithium metal plating and the subsequent dendrite formation. Having a robust battery management system with adequate data acquisition is recommended in order to monitor data point outliers that may indicate a problem. These systems can use machine learning and digital twins to predict degradation and possibly prevent future BESS events. There are companies working in this new area of research, and EPRI and SLAC National Accelerator Laboratory[12] are also conducting research in this area. Utility BESS degradation is becoming a greater challenge than initially thought, especially at the larger scales. If underperforming modules can be identified early, future BESS failure events may be prevented. Degradation near the end of life may pose a safety hazard that has not yet been fully quantified. Old batteries have a higher probability of having greater dendrite density than newer batteries. Understanding degradation is an important area of research for batteries that may be used below 70% state of health. This is particularly important in the context of safety for second-use EV batteries in potential BESS applications. Degradation and safety for aging batteries will be an important research field in the coming years.

3.11 | Decommissioning

It is anticipated that by 2030 there will be 1000 GWh of global energy storage installations. There will be significant BESS capacity that requires decommissioning toward the end of this decade. Communities are interested in knowing what will happen to the BESS at the end of life and this needs consideration during the planning phase of the project. Recycling companies are beginning to consider the BESS recycling market as well as EV LIB recycling; companies such as Ascend Elements, Li-Cycle, and Redwood Materials are developing innovative hydrometallurgy techniques that recover most of the lithium and as much as 95% of the metals contained in BESS. Today, the costs to recycle are high, but it is anticipated that costs will decrease significantly when recycling of EVs becomes common place. It may even be possible to receive payment for recycling battery contents. Recycling is the preferred method of dealing with the batteries during decommissioning because it prevents toxic battery materials from being placed in landfills, and it could reduce the overall costs of decommissioning. The battery black mass can be reused to produce more battery materials and will help create a circular economy for energy storage. The same safety measures that are taken during commissioning need to be considered for decommissioning because the system is vulnerable to damage while being disassembled and transported for recycling.

4 | MINIMUM REQUIREMENTS

In this paper, "minimum requirements" refers to the normative text in a standard whereby terms such as "shall" and "must" are used. Many of the standards included below have addendum sections with recommended practices that may not be considered "minimum requirements."

Numerous safety standards pertain to the production, transportation, and usage of energy storage systems. Table 2 lists some of the battery energy storage safety standards by cell, module, rack/string/cabinet, and system level.

Many of these standards reference one another, and many of these are still under development. IFC or NFPA standards become law when they are adopted into the state or local fire code.

Two important standards are NFPA 855 and UL9540, with UL9540A test protocol considered as crucial for safety.

The increase in the number of ESSs prompted the NFPA Standards Council to create standards pertaining specifically to ESS.

TABLE 2 Applicable lithium-ion energy storage safety standards by battery system level.

Level	Safety standards
Cell	UL 1642, UL 1973IEC 62,619, IEC 62133 UN 38.3
Module	UL 1642, UL 1973, UL 1974 IEC 62619 UN 38.3
Battery rack/string	UL 1973 NFPA 70E IEC 61508 (BMS), IEC 62040-1, IEC 61000-6-2, 4, 5, and 7 FCC 47 CFR Part 15 Subpart B Class A EN 55011 CBC/IBC and IEEE 693 UN 38.3 NFPA 75, NFPA 76, NFPA 110/111
Battery energy storage system	UL9540, UL9540A, UL 1741SA (Inverter), UL 991 / UL 1998 NFPA 8552023, NFPA 70 AND 70E; NFPA 1, NFPA 68, NFPA 69, NFPA 550, NFPA 551, NFPA 791 ICC IFC 2021 Ch 12 UN 38.3 IEC 60529, IEC 60950-1, IEC 64040-1, IEC 61000-6-2,4, and 5, IEC 60529, IEC 62933 IEEE C-2 (National Electrical Safety Code), IEEE 693, IEEE P2962, IEEE 519, IEEE 1547, IEEE 1679.1, IEEE 1815, IEEE P2686, IEEE 1584, IEEE 1547 (Connectivity) IEEE 1635/ASHRAE 21; ASHRAE 62.1CBC/IBC and IEEE 693 FCC 47 CFR Part 15 Subpart B Class A EN 55011 NECA 416 DNVGL-RP-0043 2021 FM Global 533 ANSI/ISA-60079-0 NEMA ESS 1 CSA 62109-3, CSA/ANSI C22.2340.23

Thus, the initial draft of *NFPA 855 Standard for the Installation of Stationary Energy Storage Systems* was released to the public in 2017. NFPA 855 pertains not only to BESSs but also to general electrochemical energy storage systems as well as fuel cell energy storage and flywheel energy storage systems. Its guidance includes emergency response, hazard mitigation analyses, interconnections, commissioning, operations and maintenance, and decommissioning. It references and requires various other ESS standards. NFPA 855 focuses on fire and explosion risk for BESS. It is anticipated that future versions of NFPA 855 will include more details on toxic emissions for abnormal conditions and events.

Underwriters Laboratories (UL) standards and certifications are also an important part of BESS safety. Because UL-listed products are rigorously tested and monitored under nationally recognized standards, they carry to their end-user a higher level of confidence over non-listed products regarding safety. UL 9540 is a safety standard for an ESS as well as for the equipment intended for connection to a local utility grid or standalone application. Key issues addressed include functional safety, grid connectivity, fire detection and suppression, and environmental performance. UL 9540 is referenced frequently by NFPA 855.

Though it is not a standard, UL 9540A is a test method for evaluating thermal runaway in an ESS. Thermal runaway propagation testing is evaluated at the cell, module, unit, and installation level. Critical data obtained includes gas composition, heat and gas release rates, deflagration hazards, reignition hazards, and effectiveness of fire protection systems. There are ESS technologies that do not suffer from thermal runaway. The test method in UL 9540A can be used to perform an extreme test on the technology to gauge system performance in the event of a fire. It can give the user an extra sense of security with regard to fire and explosion risk for new ESS technology. Many utilities will require that the BESS is UL 9540-listed, that a UL9540A test has been conducted, and that the UL 9540A results can be shared.

BESSs should first and foremost follow applicable standards to maximize protection from harm to individuals and minimize the likelihood of a failure event. Additionally, these standards may also provide value for insurance coverage purposes, project permissions, and evaluation of how a battery manufacturer or system integrator approaches safety.

5 | OVERALL SYSTEM RECOMMENDATIONS AND BEST PRACTICES

As BESS technology develops and matures, utilities are gaining operating experience with existing storage installations. As such, the knowledge of best practices and system recommendations is growing. Some of these best practices and recommendations are as follows:

5.1 | Battery chemistry selection

There are many choices of cathode chemistry for LIBs, but the two most common choices for BESSs are NMC/NCA and LFP. NMC is more common than NCA, which means the typical choice for large-scale BESSs is between LFP and NMC. Nickel adds the benefit of a higher specific energy but reduced stability. Cobalt increases the stability of the cathode but has increased toxicity. Manganese adds the benefit of low internal resistance but has low specific energy. NMC batteries have greater energy density compared to LFP and are typically used for EV applications where weight is more of a consideration than stationary storage. For LFP, there is less competition from the EV sector and more available supply compared to NMC. This may change as more car manufacturers may favor and adopt LFP for light, shorter-range vehicles over nickel-based chemistry. LFP has some inherent advantages over nickel-based cathodes. LFP batteries use an iron phosphate cathode and are generally regarded as more stable than NMC batteries. Industry experience has shown LFP batteries exhibit better thermal stability and are more abuse-tolerant than NMC batteries. Cobalt is not required to make LFP chemistry work. This means LFP batteries are less toxic than NMC batteries when disposed in a landfill. NMC batteries are recycled for their nickel and cobalt and are less expensive to recycle than LFP; however, there are human rights issues associated with the sourcing of some cobalt used in NMC batteries, which does not seem to be a concern for LFP. Cobalt cannot avoid ethical sourcing issues (child labor, corruption, and worker safety).

LFP batteries do not undergo crystalline phase change in the same way NMC batteries do, which means they are inherently more stable. LFP batteries can undergo thermal runaway, but it initiates at a higher temperature than NMC chemistry. LFP batteries tend not to off-gas O_2 to support combustion below approximately 450°C. This is opposed to NMC batteries where off-gas of O_2 happens in the 150°C–250°C range. It is more difficult to put an LFP battery into thermal runaway compared to NMC. LFP has a wider operating temperature range, which requires less cooling and parasitic power. LFP performs better in large-scale fire testing and develops significantly less plume gas in a cell-venting event compared to NMC. This has the overall effect of generating fewer toxic gases in a cell deflagration. LFP will generate similar amounts of hydrogen gas as NMC when thermal runaway has been initiated. LFP is generally considered a safer chemistry than NMC, but that statement needs to be qualified. It is harder to initiate thermal runaway with LFP compared to NMC, but if thermal runaway has occurred, LFP is as dangerous as NMC in a vapor cloud explosion.

LFP batteries have significantly longer cycle life and much better resistance to degradation than NMC batteries. LFP can be used to a lower depth of discharge compared to NMC, meaning more of the cell capacity is utilized (i.e., deeper cycling is possible). The absence of cobalt or nickel means lower initial cost and less price volatility. The cost of an LFP BESS is typically lower than that of NMC on a $/kWh basis. It is quite possible that nickel-based chemistries will eventually be replaced by LFP and partially by sodium-ion batteries. Sodium-ion batteries are not yet commercially available in BESSs but are expected to make an introduction due to lower costs than LIBs. Sodium-ion batteries are prone to thermal runaway in the same manner as LIBs because they use similar electrolytes. Solid-state LIBs do not use flammable electrolytes and may be used in BESSs in the 2030s after they are adopted by EV manufacturers.

5.2 | Water management

A major design focus of BESS is fire mitigation and cooling. It is important to recognize that LIB fires may last substantially longer than structure fires or even other types of industrial fires. As such, fire-water may need to be applied to these systems for considerably longer durations.[13] Two important factors should be considered: water supply and drainage.

If the BESS is located near large sources of fire-water, permanent plumbing or fire department connections must be included in the design. If water is not readily available, storage tanks may be required. Whether used to spray directly onto the cells undergoing thermal runaway, to flood the container, or to spray adjacent containers for cooling, the quantity of water used will be significant.

As mentioned earlier, LIBs are comprised of many chemicals, and their combustion byproducts often include hazardous compounds. Any water used to fight BESS fires should be contained to eliminate the possibility of groundwater contamination as well as to minimize environmental damage and cleanup costs.[14] Electrocution poses another hazard if first responders stand in fire-water pool.

5.3 | Hazard mitigation analysis

Per NFPA 855, a BESS must have a hazard mitigation analysis (HMA) performed if the stored energy exceeds 600 kWh for outdoor installations, installations in an open parking garage, rooftop installations, or on mobile equipment.[15] The HMA must consider all potential failure modes and the consequences of those failures as they relate to safety and be performed by subject matter experts in fire protection, fire prevention, and explosion prevention, using applicable process safety management (PSM) methodologies.[15] Additionally, the International Fire Code requires that HMAs for utility BESS demonstrate the following[16]:

- Fires will be contained within unoccupied ESS rooms or areas for the minimum duration of the fire-resistance-rated separations.
- Fires in occupied work centers will be detected in time to allow occupants within the room or area to safely evacuate.
- Toxic and highly toxic gases released during fires will not reach concentrations in excess of the IDLH level in the building or adjacent means of egress routes during the time deemed necessary to evacuate occupants from any affected area.
- Flammable gases released from ESS during charging, discharging, and normal operation will not exceed 25% of their lower flammability limit (LFL).
- Flammable gases released from ESS during fire, overcharging, and other abnormal conditions will be controlled through the use of ventilation of the gases, preventing accumulation, or by deflagration venting.

Since the purpose of the HMA is to document the hazards and safeguards of the BESS, NFPA recommends that it be treated as a living document, like a process hazard analysis (PHA) for a PSM-covered process. Similar to PSM-covered processes, the HMA should be maintained and revalidated for the life of the BESS to ensure that adequate safeguards are provided against hazards and to aid in managing changes to the BESS. Proposed changes to the BESS should also follow a management of change (MOC) authorization process that refers to the HMA. Insurance companies recommend tracking these changes over the life of the BESS and evaluating their impacts in an HMA revalidation process performed at regular intervals.

5.4 | Community engagement

Another best practice is to engage with the local community early and gain buy-in where BESSs are being planned. Each BESS will have its own risks, as distribution BESSs will tend to be located among populated areas and transmission BESSs in remote locations. Close engagement with community leaders and the AHJ early in a project will provide for a better run project with less costly changes; the project will gain overall benefit from cooperation between the community, law enforcement, first responders, and the general public.

5.5 | First responder training

Because the odds of a LI BESS entering thermal runaway are far from zero, utilities should plan for *when* they have an incident, not *if*. Therefore, first responder training is recommended for all BESSs greater than residential or EV battery (approx. >150 kWh) size. First responders should not be encountering a BESS site for the very first time when an event is occurring. Most BESS events take place during the early stages of the project and during commissioning. An initial walk-through of the BESS site should be conducted with first responders before the commercial operation date, and a second walk-through training session should be conducted once the site is operational. First responder groups may have turnover or limited availability; it is therefore recommended to offer recurrent training on an annual basis, at a minimum. Both the fire department and law enforcement should be involved in first responder training. Law enforcement may be responsible for enforcing a shelter-in-place order and may be needed to direct traffic away from an event. An incident commander (IC) should be appointed to make decisions regarding site entry and evacuation of downwind areas. The IC will be the on-site authority making decisions, but a utility representative or "qualified person" should provide guidance based upon diagnostic information from the BESS. This type of synergy is required to mitigate risks to the public once an event has occurred and is more likely to work well if there has been sufficient contact between utility and/or developer and the local fire department.

All first responders should operate from outside of the BESS fencing unless a life safety emergency clearly requires entry. Smoke plumes from thermal runaway events may contain toxic fumes. Depending on the location of the BESS and its proximity to occupied structures, the IC may decide to evacuate occupied structures downwind or advise residents to take shelter in a place with windows and doors closed, pets inside, and so on.

If a water strategy is chosen, firefighters should spray water from outside the fence to cool adjacent equipment and, if possible, to suppress the plume from the burning container. There may also be means to spray water inside the containers via an external fire department connection. Do not open the battery container doors during a potential thermal runaway event, as an explosion could ensue. Recent incidents have resulted in injuries to firefighters who entered utility BESS containers. Lastly, do not disconnect auxiliary power supply to the battery containers unless explicitly requested to do so for specific containers. Disconnecting power from containers may inadvertently cause thermal runaway in non-affected containers or the loss of remote monitoring and communication.

5.6 | First responder stations

Another best practice is to provide a first responder station outside the BESS perimeter. The station shall be so equipped to allow first responders to diagnose the emergency without entering the BESS enclosure. Equipment inside the first responder station should include emergency stop pushbuttons and disconnects, alarm notification panel, copies of the emergency response plan and emergency action plan, electrical single-line drawings showing disconnects, and other diagnostic information, Access to the first responder station should be restricted or protected to minimize vandalism and unauthorized system interruptions. If multiple BESSs are located in a localized region, all efforts should be made to standardize the configuration of the first responder stations as well as the alarm tones and strobe colors. This standardization helps to ensure consistency in response from first responders.

5.7 | Pre-startup safety review

Prior to initial operation of the BESS, the system should undergo a pre-startup safety review (PSSR). The goal of the PSSR is to verify that all system safeguards given credit in the HMA have been installed correctly and tested before system startup. The PSSR should verify that all BESS safety-critical systems, such as hydrogen detectors, smoke detectors, ventilation systems, alarms and interlocks, communications, fire suppression, beacons, and horns, are in proper working order and have been tested. The PSSR should also include a physical walkdown of the BESS, verifying proper area classification, required signage, and that the system is constructed in accordance with the specifications.[17]

6 | CONCLUSION

In summary, BESS technology will continue to evolve and with it our understanding of the hazards. With technology changes, applicable codes and standards will also develop, as well as the minimum requirements imposed by AHJs and insurance companies. Utilities looking to transition to distributed energy systems including BESSs must understand the hazards of each BESS technology, ensure the design addresses those hazards, and that changes to the BESS over the life cycle continue to address the hazards. There are many technical challenges associated with BESSs, but by applying best practices and recommendations, system operation and maintenance can be successful.

AUTHOR CONTRIBUTIONS

Ian Mylenbusch: Writing – original draft (lead); writing – review and editing (lead). **Kieran Claffey:** Writing – original draft (equal); writing – review and editing (equal). **Benjamin Chu:** Writing – original draft (equal); writing – review and editing (equal).

DATA AVAILABILITY STATEMENT

Portions of the data that support the findings of this paper may be available from the Electric Power Research Institute (EPRI). Restrictions apply to the availability of this data. Other data is available through the reference links.

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Air Quality Report

This report has been compiled utilizing data provided by San Diego County HAZMAT/ San Diego City Fire Rescue HAZMAT and Haley & Aldrich, Inc.

The information obtained from these sources has been carefully analyzed and incorporated to ensure the accuracy and reliability of the findings.

SDG&E Battery Fire
571 Enterprise Street
Start 9/5/2024 12:09
Repopulate 9/7/2024 12:00

Air quality monitored by San Diego County HAZMAT

- Three types of monitoring units
- First reading taken at 14:30 on 9/5/2024
- Final reading taken at 18:32 on 9/6/2024

Air monitoring equipment (SD HAZMAT)

1. EAGLE 2 CGI
Last calibrated on 8/30/2024 and was "zeroed" prior to use on incident.
Standard 4 gas monitor which measures:
Lower Explosive Limit -**LEL**
Oxygen -**O2**
Hydrogen Sulfide-**H2S**
Carbon Monoxide-**CO**

2. RedWave XplorIR
Self-Calibrates at device startup.
Identifies over 5,500 gases at low part per million (ppm) concentrations

3. MultiRAE Pro
Last calibrated on 8/30/2024 and "zeroed" prior to use on the incident.
Monitors both chemical threats and gamma radiation and is the only multi-threat monitor with parts per billion

Gases monitored

1. **PH3 (Phosphine)**
2. **Cl2 (Chlorine)**
3. **H2S (Hydrogen Sulfide)**
4. **CO2 (Carbon Dioxide)**
5. **HCN (Hydrogen Cyanide)**
6. **CO (Carbon Monoxide)**
7. **HF (Hydrofluoric Acid)**

Hazmat Exposure Terms

1. TWA (Time-Weighted Average)

- **Definition**: TWA refers to the average exposure to a hazardous substance (usually airborne) over a standard workday, typically 8 hours, and a 40-hour workweek.
- **Purpose**: It is used to assess the cumulative exposure a person may experience and is compared against permissible limits to ensure safety over long-term exposure.

2. STEL (Short-Term Exposure Limit)

- **Definition**: STEL is the maximum concentration to which a person can be exposed to a chemical substance for a short period, typically **15 minutes**, without suffering adverse effects like irritation, chronic or irreversible tissue damage, or narcosis.
- **Purpose**: It helps control exposure to hazardous substances during short bursts of high exposure within a workday.

3. PEL (Permissible Exposure Limit)

- **Definition**: PEL is the maximum amount or concentration of a substance that a person can be exposed to under OSHA (Occupational Safety and Health Administration) regulations over an 8-hour work shift (TWA) or a 40-hour workweek.
- **Purpose**: These are legally enforceable limits to protect workers from the harmful effects of hazardous chemicals and substances in the workplace.

4. REL (Recommended Exposure Limit)

- **Definition**: REL is a recommended exposure limit set by NIOSH (National Institute for Occupational Safety and Health) that suggests maximum allowable concentrations for exposure to substances over a workday or workweek.
- **Purpose**: These limits are non-enforceable but serve as guidelines for employers and regulators to ensure worker safety. They are typically more stringent than PELs.

5. IDLH (Immediately Dangerous to Life or Health)

- **Definition:** the maximum concentration of a chemical in the air to which a person can be exposed for **30 minutes** without suffering life-threatening health effects or death.
- **Purpose:** Determines when workers need to wear protective equipment, such as respirators, and **when emergency evacuation is necessary**. It is critical for ensuring worker safety in hazardous environments.

Summary:

- **TWA** refers to the average exposure over time.
- **STEL** refers to the limit for short-term exposures.
- **PEL** is a legally enforceable limit by OSHA.
- **REL** is a recommended limit by NIOSH (often more conservative than PEL).
- **IDLH** refers to the maximum level of a toxic substance in the air that a person can be exposed to for 30 minutes without experiencing life-threatening effects or being unable to escape.

OSHA and NIOSH exposure limits

1. **Phosphine (PH_3):**
    - **OSHA PEL: 0.3 ppm (TWA)**
    - **NIOSH REL: 0.3 ppm (TWA) / 1 ppm (STEL)**
    - **IDLH 50 ppm**

2. **Chlorine (Cl_2):**
    - **OSHA PEL: 1 ppm (TWA) 3 ppm (STEL)**
    - **NIOSH REL: 0.5 ppm (TWA) / 1 ppm (STEL)**
    - **IDLH 10 ppm**

3. **Hydrogen Sulfide (H_2S):**
    - **OSHA PEL: 20 ppm (TWA) / 50 ppm (STEL)**
    - **NIOSH REL: 10 ppm (TWA) / 15 ppm (STEL)**
    - **IDLH 100 PPM**

4. **Carbon Dioxide (CO_2):**
    - **OSHA PEL: 5,000 ppm**
    - **NIOSH REL: 5,000 ppm (TWA) / 30,000 ppm (STEL)**
    - **IDLH 40,000 ppm**

5. **Hydrogen Cyanide (HCN):**
    - **OSHA PEL: 10 ppm (TWA)**
    - **NIOSH REL: 4.7 ppm (not to be exceeded)**
    - **IDLH 50 ppm**

6. **Carbon Monoxide (CO):**
    - **OSHA PEL: 50 ppm (TWA)**
    - **NIOSH REL: 35 ppm (TWA) / 200 ppm (STEL)**
    - **IDLH 1,200 ppm**

7. **Hydrofluoric Acid (HF):**
    - **OSHA PEL: 3 ppm (TWA) 6 ppm (STEL)**
    - **NIOSH REL: 3 ppm (TWA) 6 ppm (STEL)**
    - **IDLH 30 ppm**

SD County Hazmat Readings in Parts Per Million (PPM)

Location	Distance from Incident (ft)	Time	PH3	CL2	H2S	CO2	HCN	CO
Main Gate	315	14:30	0	0	0	0	0	0
Venture and Simpson	784	14:35	0	0	0	0	0	0
State St (All	1447	14:36	0	0	0	0	0	0
Enterprise and Auto Park	776	18:15	0	0	0	0	0.5	0
Enterprise Gate	262	18:16	0	0	0	18	2	0
Venture and Simpson	784	18:21	0	0	0	0	0.5	0
Venture and State	1108	18:22	0	0	0	0	0.5	0
Market and Auto Park	2227	18:25	0	0	0	0	0	0
Vinewood and Industrial	2280	18:27	0	0	0	0	0.5	0
Andreasen and Simpson	2522	18:29	0	0	0	0	0.5	0
1287 Simpson	3943	18:32	0	0	0	0	0.5	0

****Above readings are the peak (highest detected) readings during the entire incident*****

**** CO2 sensors are calibrated to account for typical atmospheric CO2 levels, which generally range between 400-420ppm. This ensures that variations above normal levels are easily detectable*****

****Negative reading on Fluoride paper at all locations. Non detect for Hydrofluoric Acid (HF) at all sites*****

**** All readings taken <u>were well below acceptable exposure limits</u> and considered expected readings during a routine structure fire*****

Air quality monitored by SDG&E

- Via 3rd party contractor; Haley & Aldrich, INC.
- Two types of monitoring units
- First reading taken at 20:30 on 9/5/2024
- Final reading taken at 21:36 on9/6/2024

Air monitoring equipment

1. RAE Systems MultiRAE with P2P
   Calibrated on 9/5/2024.
   Multi-threat chemical detector and gas monitor

2. TSI 7575-x Indoor air quality monitor utilizing the TSI 982 Sensor probe
   Monitor calibrated on 8/29/2024.
   Probe calibrated on 3/11/2024.
   Used to monitor indoor air quality

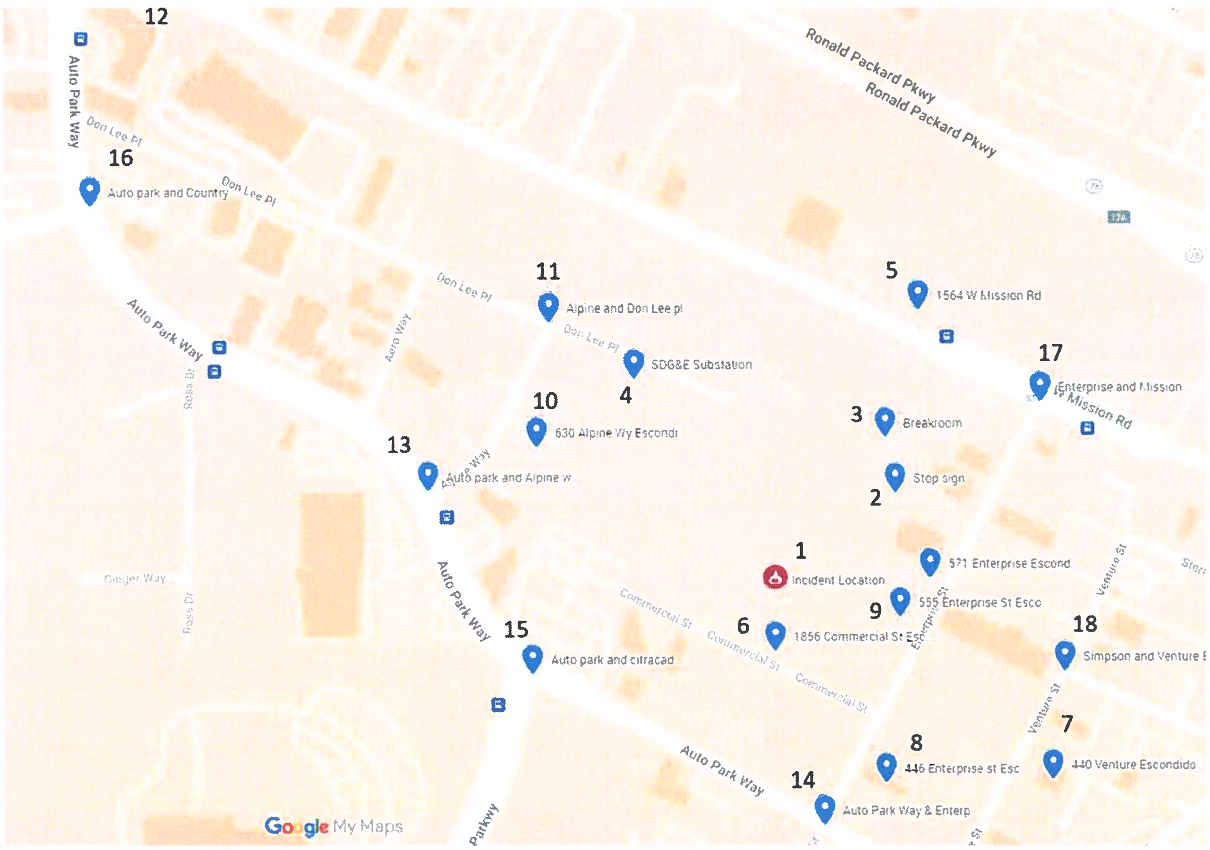
Gases Monitored

- **LEL (Lower Explosive Limit)**
- **HCN (Hydrogen Cyanide)**
- **CO (Carbon Monoxide)**
- **H2S (Hydrogen Sulfide)**
- **O2 (Oxygen)**

***** Only Carbon Monoxide (CO) levels were detected and had readings above 0 but remained <u>well below acceptable exposure limits</u>. Elevated CO readings are expected result during a structure fire*****

*****Carbon monoxide (CO) levels may be detected in the environment due to various sources of incomplete combustion, including vehicle emissions*****

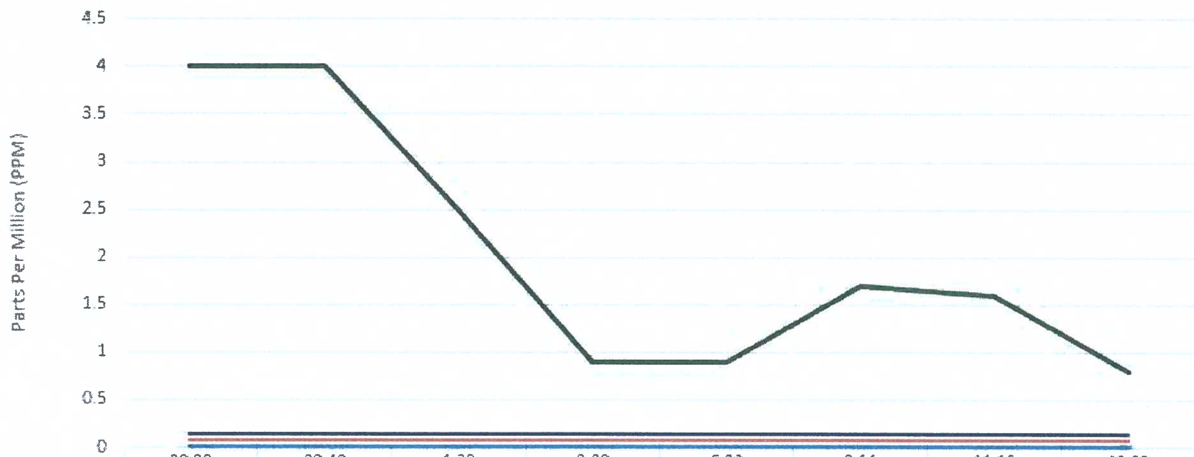
Haley & Aldrich, INC (SDG&E) Monitoring locations denoted in blue



Monitoring Locations

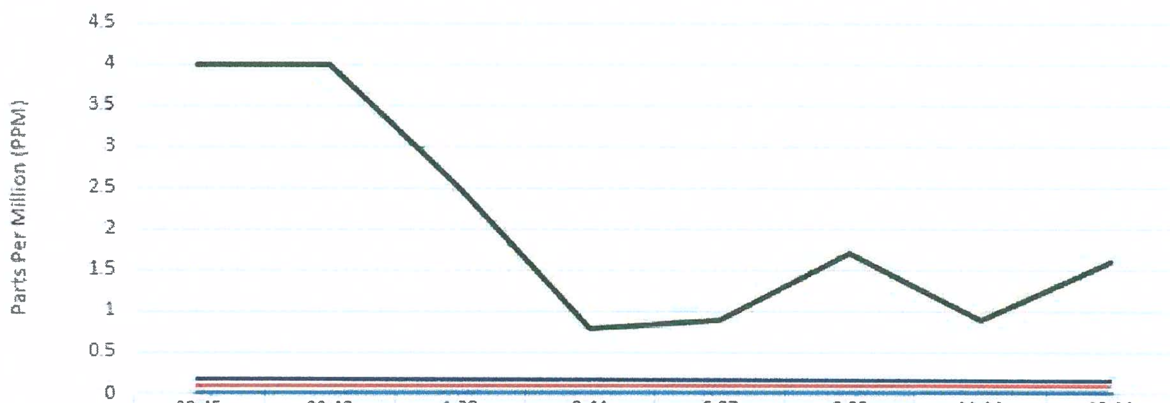
1. **Incident location**: 571 Enterprise St South side of property
2. 571 Enterprise St: Stop sign in equipment yard
3. 571 Enterprise St: Breakroom
4. 571 Enterprise St: Substation
5. 1564 Mission Rd
6. 1856 Commercial St
7. 440 Venture
8. 446 Enterprise St
9. 555 Enterprise St
10. 630 Alpine Wy
11. Alpine Wy and Don Lee
12. Auto Park and Mission Rd
13. Auto Park and Alpine Wy
14. Auto Park and Enterprise
15. Auto Park and Citracado
16. Auto Park and Country Club Dr
17. Enterprise St and Mission Rd
18. Simpson Wy and Ventrure St

1. Air monitoring at SDG&E site location



	20:30 9/5/2024	22:42 9/5/2024	1:32 9/6/2024	3:39 9/6/2024	6:32 9/6/2024	9:14 9/6/2024	11:10 9/6/2024	13:09 9/6/2024
LEL (%)	0	0	0	0	0	0	0	0
HCN	0	0	0	0	0	0	0	0
CO	4	4	2.5	0.9	0.9	1.7	1.6	0.8
H2S	0	0	0	0	0	0	0	0

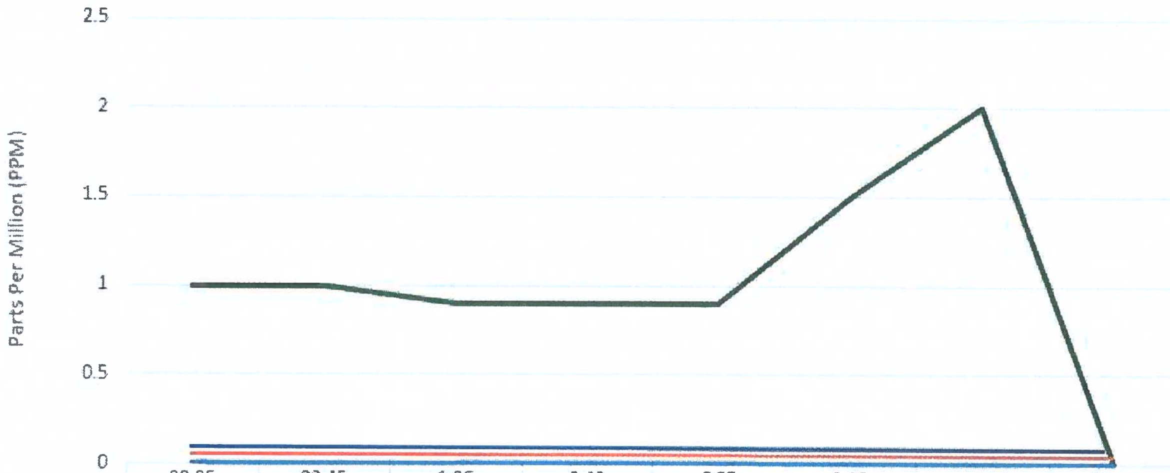
2. Air monitoring at Stop Sign NE corner of Equipment Storage yard



	20:45 9/5/2024	22:48 9/5/2024	1:38 9/6/2024	3:44 9/6/2024	6:37 9/6/2024	9:25 9/6/2024	11:14 9/6/2024	13:14 9/6/2024
LEL (%)	0	0	0	0	0	0	0	0
HCN	0	0	0	0	0	0	0	0
CO	4	4	2.5	0.8	0.9	1.7	0.9	1.6
H2S	0	0	0	0	0	0	0	0

****Urban CO levels are typically higher than in rural areas due to vehicle emissions and industrial processes. Although average concentrations are low (0.5 to 5 ppm), they can increase near heavy traffic or industrial sites, especially during rush hours. The concentrations shown on the graphs remained significantly below harmful thresholds and do not pose any significant health risks ****

3. Air monitoring at SDG&E Breakroom



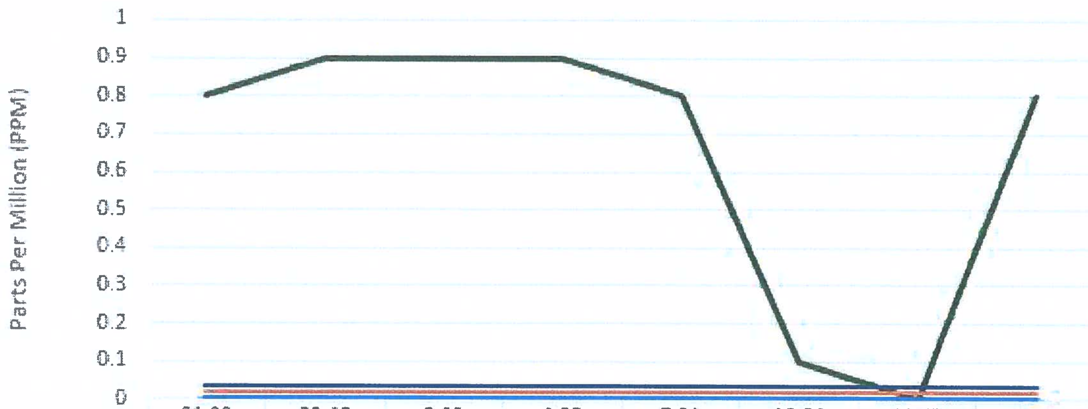
	20:35 9/5/2024	22:45 9/5/2024	1:36 9/6/2024	3:42 9/6/2024	6:35 9/6/2024	9:18 9/6/2024	11:12 9/6/2024	13:05 9/6/2024
LEL(%)	0	0	0	0	0	0	0	0
HCN	0	0	0	0	0	0	0	0
CO	1	1	0.9	0.9	0.9	1.5	2	0
H2S	0	0	0	0	0	0	0	0

4. Air Monitoring at North SDG&E substation

	20:47 9/5/2024	22:52 9/5/2024	1:43 9/6/2024	3:49 9/6/2024	7:16 9/6/2024	9:26 9/6/2024	11:17 9/6/2024	13:22 9/6/2024
LEL (%)	0	0	0	0	0	0	0	0
HCN	0	0	0	0	0	0	0	0
CO	1	1	2.5	0.9	0.9	0.9	0.8	3
H2S	0	0	0	0	0	0	0	0

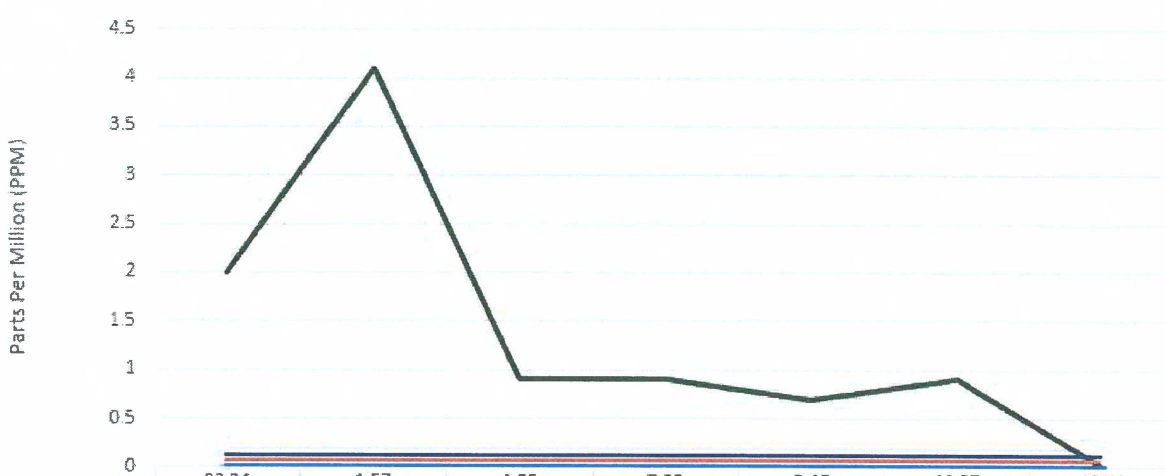
****Urban CO levels are typically higher than in rural areas due to vehicle emissions and industrial processes. Although average concentrations are low (0.5 to 5 ppm), they can increase near heavy traffic or industrial sites, especially during rush hours. The concentrations shown on the graphs remained significantly below harmful thresholds and do not pose any significant health risks ****

5. Air monitoring at 1564 Mission Rd



	21:29 9/5/2024	23:40 9/5/2024	2:03 9/6/2024	4:03 9/6/2024	7:31 9/6/2024	10:04 9/6/2024	11:45 9/6/2024	13:53 9/6/2024
LEL (%)	0	0	0	0	0	0	0	0
HCN	0	0	0	0	0	0	0	0
CO	0.8	0.9	0.9	0.9	0.8	0.1	0	0.8
H2S	0	0	0	0	0	0	0	0

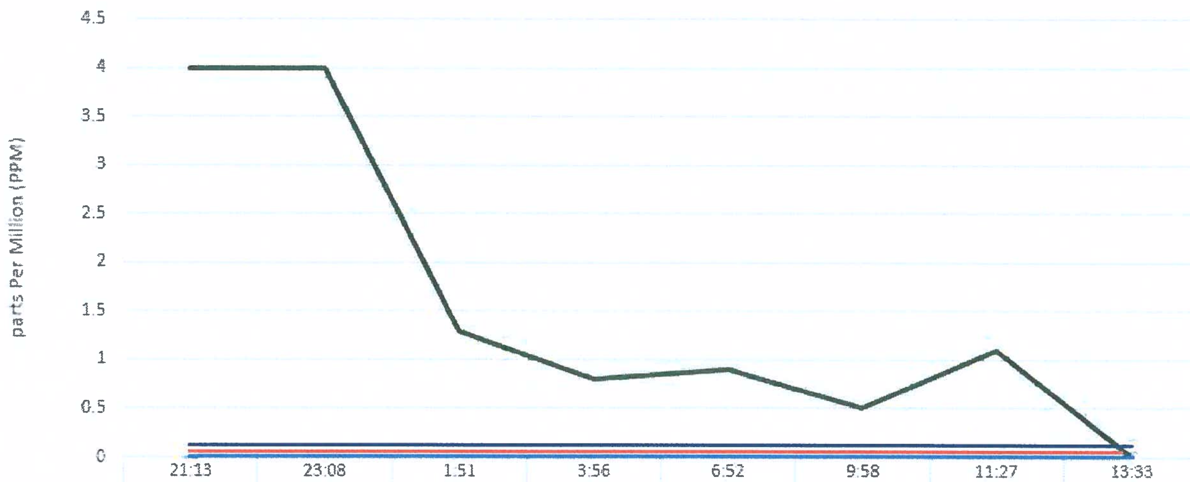
6. Air monitoring at 1856 Commercial St



	23:34 9/5/2024	1:57 9/6/2024	4:00 9/6/2024	7:23 9/6/2024	9:46 9/6/2024	11:37 9/6/2024	13:46 9/6/2024
LEL(%)	0	0	0	0	0	0	0
HCN	0	0	0	0	0	0	0
CO (PPM)	2	4.1	0.9	0.9	0.7	0.9	0
H2S	0	0	0	0	0	0	0

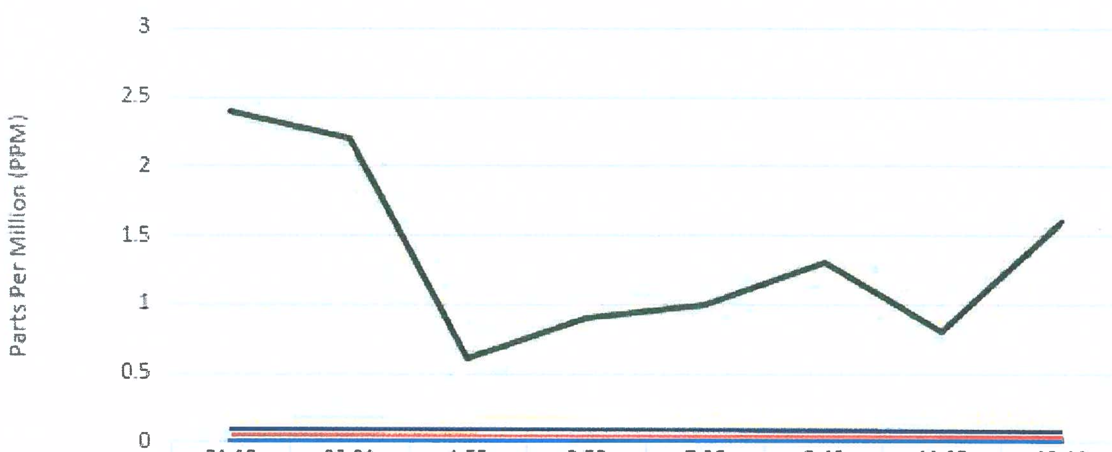
****Urban CO levels are typically higher than in rural areas due to vehicle emissions and industrial processes. Although average concentrations are low (0.5 to 5 ppm), they can increase near heavy traffic or industrial sites, especially during rush hours. The concentrations shown on the graphs remained significantly below harmful thresholds and do not pose any significant health risks ****

7. Air monitoring at 440 Venture Rd



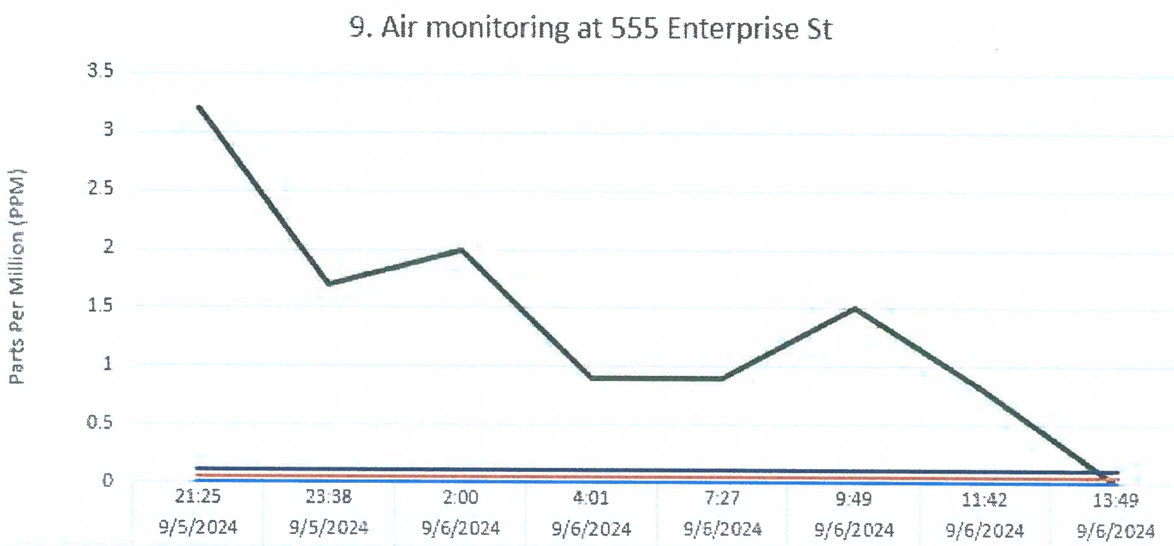
	21:13 9/5/2024	23:08 9/5/2024	1:51 9/6/2024	3:56 9/6/2024	6:52 9/6/2024	9:58 9/6/2024	11:27 9/6/2024	13:33 9/6/2024
LEL (%)	0	0	0	0	0	0	0	0
HCN	0	0	0	0	0	0	0	0
CO	4	4	1.3	0.8	0.9	0.5	1.1	0
H2S	0	0	0	0	0	0	0	0

8. Air monitoring at 446 Enterprise

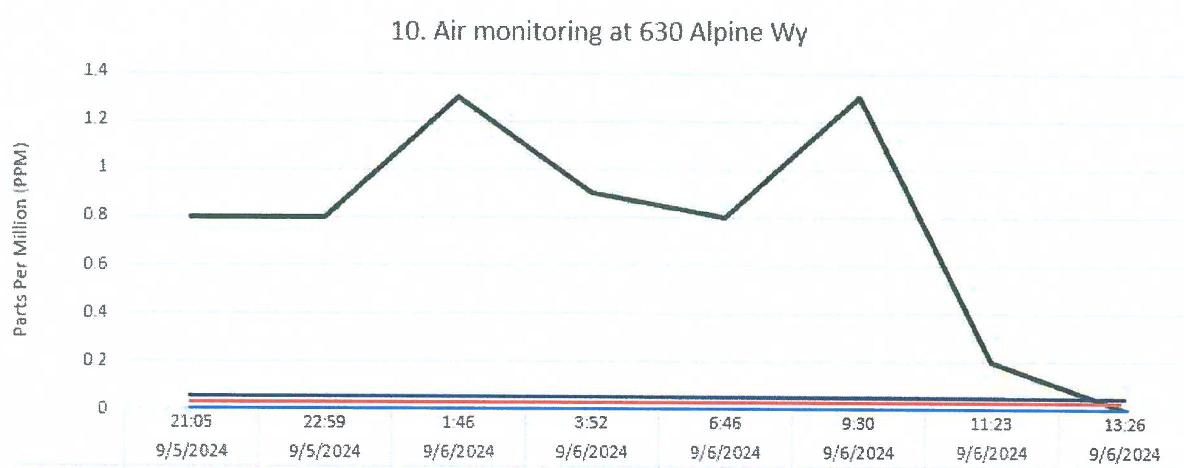


	21:18 9/5/2024	23:31 9/5/2024	1:55 9/6/2024	3:59 9/6/2024	7:26 9/6/2024	9:42 9/6/2024	11:35 9/6/2024	13:44 9/6/2024
LEL (%)	0	0	0	0	0	0	0	0
HCN	0	0	0	0	0	0	0	0
CO (PPM)	2.4	2.2	0.6	0.9	1	1.3	0.8	1.6
H2S	0	0	0	0	0	0	0	0

****Urban CO levels are typically higher than in rural areas due to vehicle emissions and industrial processes. Although average concentrations are low (0.5 to 5 ppm), they can increase near heavy traffic or industrial sites, especially during rush hours. The concentrations shown on the graphs remained significantly below harmful thresholds and do not pose any significant health risks ****



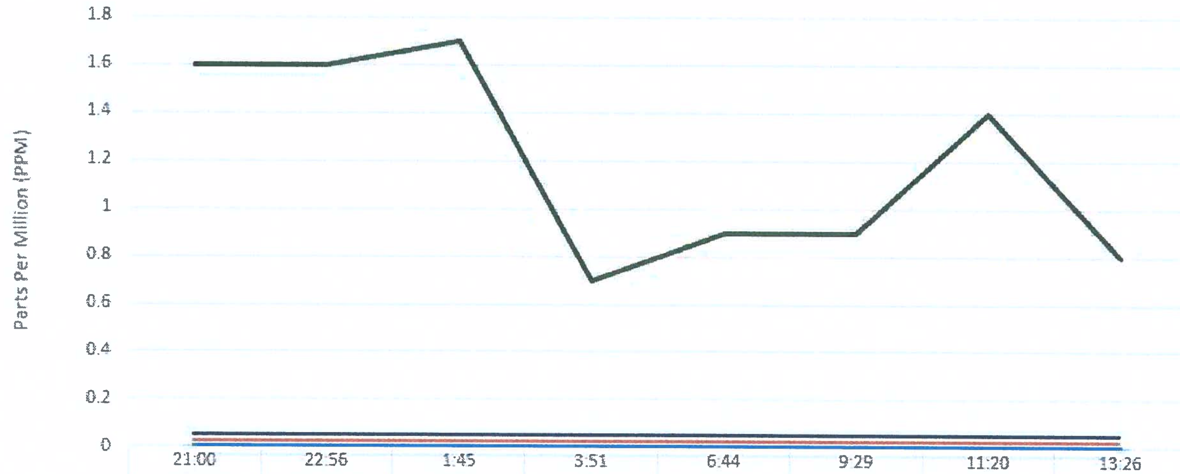
	21:25 9/5/2024	23:38 9/5/2024	2:00 9/6/2024	4:01 9/6/2024	7:27 9/6/2024	9:49 9/6/2024	11:42 9/6/2024	13:49 9/6/2024
LEL (%)	0	0	0	0	0	0	0	0
HCN	0	0	0	0	0	0	0	0
CO	3.2	1.7	2	0.9	0.9	1.5	0.8	0
H2S	0	0	0	0	0	0	0	0



	21:05 9/5/2024	22:59 9/5/2024	1:46 9/6/2024	3:52 9/6/2024	6:46 9/6/2024	9:30 9/6/2024	11:23 9/6/2024	13:26 9/6/2024
LEL (%)	0	0	0	0	0	0	0	0
HCN	0	0	0	0	0	0	0	0
CO	0.8	0.8	1.3	0.9	0.8	1.3	0.2	0
H2S	0	0	0	0	0	0	0	0

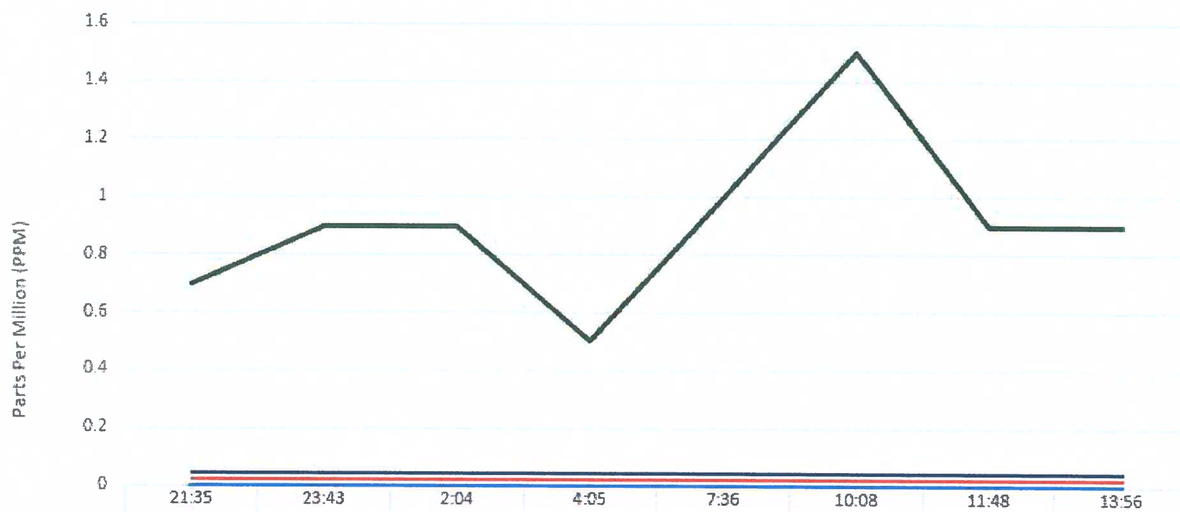
****Urban CO levels are typically higher than in rural areas due to vehicle emissions and industrial processes. Although average concentrations are low (0.5 to 5 ppm), they can increase near heavy traffic or industrial sites, especially during rush hours. The concentrations shown on the graphs remained significantly below harmful thresholds and do not pose any significant health risks ****

11. Air monitoring at Alpine Wy and Don Lee



	21:00 9/5/2024	22:56 9/5/2024	1:45 9/6/2024	3:51 9/6/2024	6:44 9/6/2024	9:29 9/6/2024	11:20 9/6/2024	13:26 9/6/2024
LEL (%)	0	0	0	0	0	0	0	0
HCN	0	0	0	0	0	0	0	0
CO	1.6	1.6	1.7	0.7	0.9	0.9	1.4	0.8
H2S	0	0	0	0	0	0	0	0

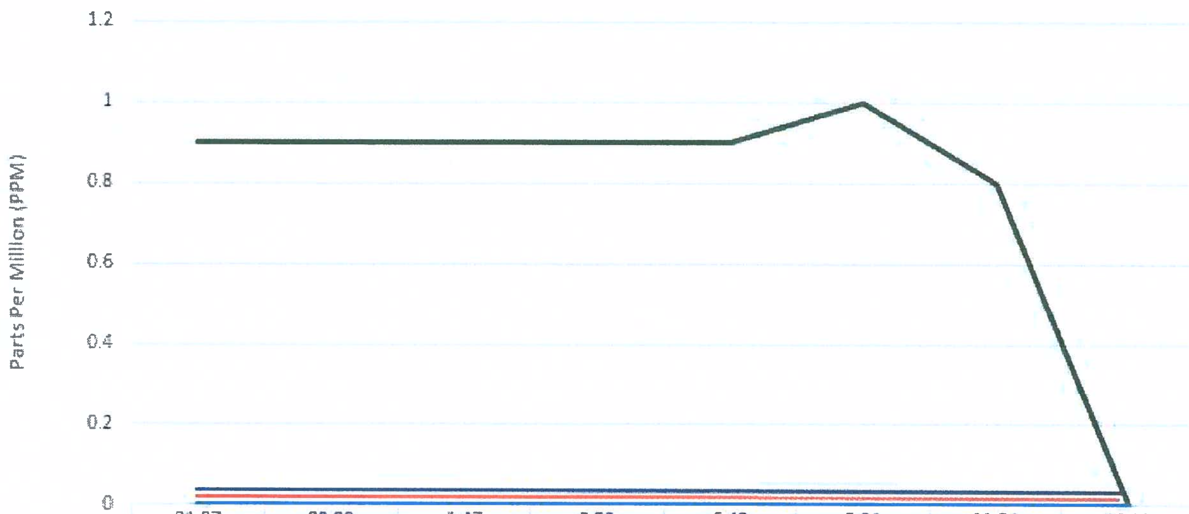
12. Air monitoring at Auto Park Way and Mission Rd



	21:35 9/5/2024	23:43 9/5/2024	2:04 9/6/2024	4:05 9/6/2024	7:36 9/6/2024	10:08 9/6/2024	11:48 9/6/2024	13:56 9/6/2024
LEL (%)	0	0	0	0	0	0	0	0
HCN	0	0	0	0	0	0	0	0
CO	0.7	0.9	0.9	0.5	1	1.5	0.9	0.9
H2S	0	0	0	0	0	0	0	0

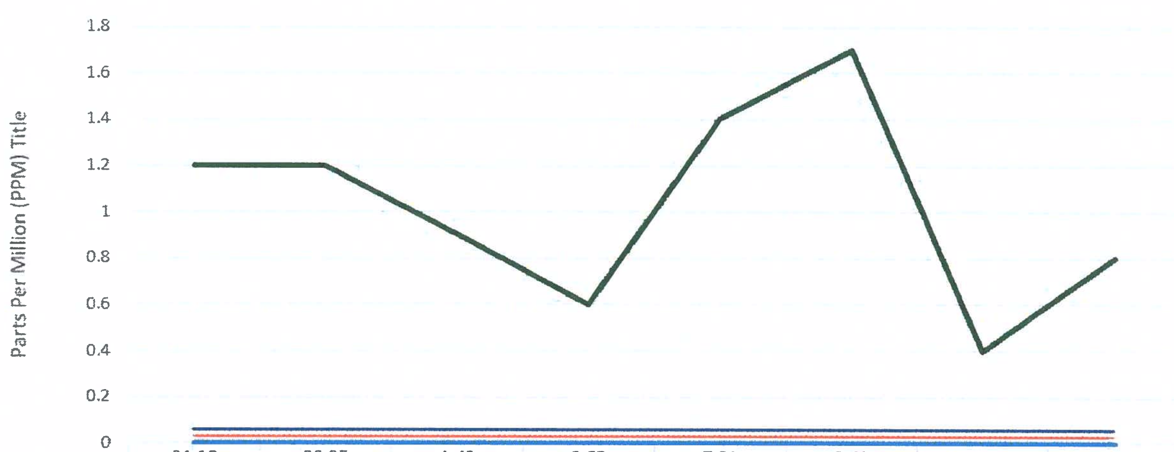
****Urban CO levels are typically higher than in rural areas due to vehicle emissions and industrial processes. Although average concentrations are low (0.5 to 5 ppm), they can increase near heavy traffic or industrial sites, especially during rush hours. The concentrations shown on the graphs remained significantly below harmful thresholds and do not pose any significant health risks ****

13. Air monitoring at Auto Park and Alpine Wy



	21:07 9/5/2024	23:00 9/5/2024	1:47 9/6/2024	3:52 9/6/2024	6:48 9/6/2024	9:34 9/6/2024	11:24 9/6/2024	13:27 9/6/2024
LEL (%)	0	0	0	0	0	0	0	0
HCN	0	0	0	0	0	0	0	0
CO	0.9	0.9	0.9	0.9	0.9	1	0.8	0
H2S	0	0	0	0	0	0	0	0

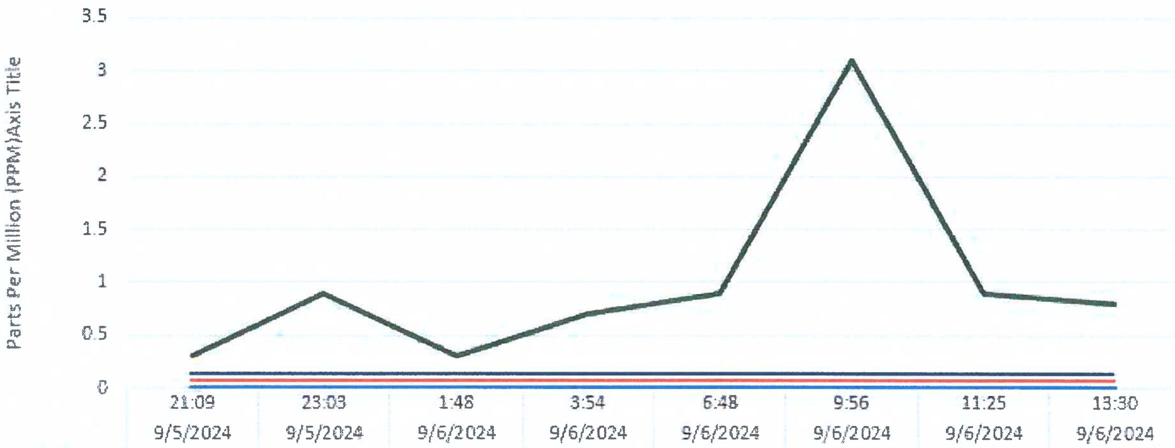
14. Air monitoring at Auto Park and Enterprise St



	21:10 9/5/2024	23:05 9/5/2024	1:49 9/6/2024	3:55 9/6/2024	7:21 9/6/2024	9:41 9/6/2024	11:34 9/6/2024	13:32 9/6/2024
LEL (%)	0	0	0	0	0	0	0	0
HCN	0	0	0	0	0	0	0	0
CO	1.2	1.2	0.9	0.6	1.4	1.7	0.4	0.8
H2S	0	0	0	0	0	0	0	0

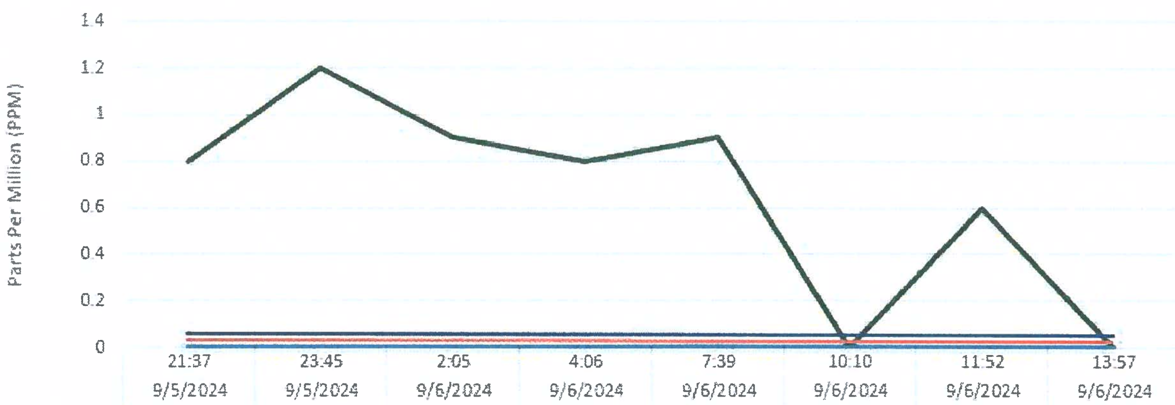
****Urban CO levels are typically higher than in rural areas due to vehicle emissions and industrial processes. Although average concentrations are low (0.5 to 5 ppm), they can increase near heavy traffic or industrial sites, especially during rush hours. The concentrations shown on the graphs remained significantly below harmful thresholds and do not pose any significant health risks ****

15. Air monitoring at Auto Park and Citracado



	21:09 9/5/2024	23:03 9/5/2024	1:48 9/6/2024	3:54 9/6/2024	6:48 9/6/2024	9:56 9/6/2024	11:25 9/6/2024	13:30 9/6/2024
LEL (%)	0	0	0	0	0	0	0	0
HCN	0	0	0	0	0	0	0	0
CO	0.3	0.9	0.3	0.7	0.9	3.1	0.9	0.8
H2S	0	0	0	0	0	0	0	0

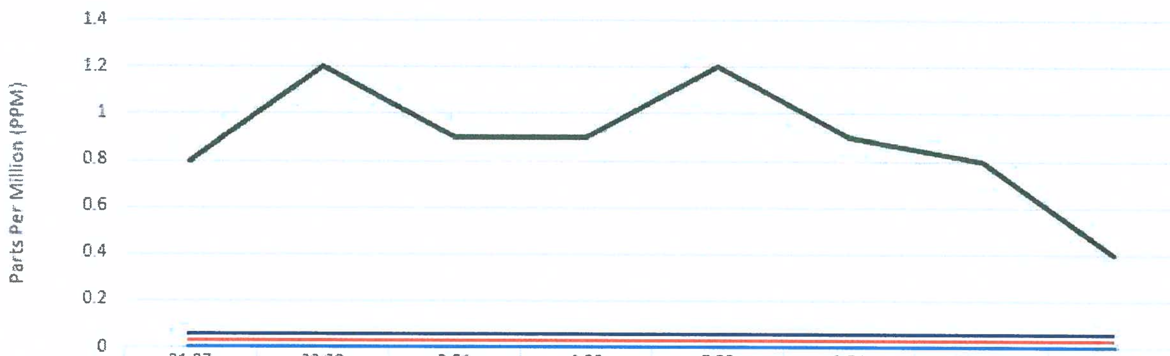
16. Air monitoring at Auto Park Way/Country Club Dr



	21:37 9/5/2024	23:45 9/5/2024	2:05 9/6/2024	4:06 9/6/2024	7:39 9/6/2024	10:10 9/6/2024	11:52 9/6/2024	13:57 9/6/2024
LEL (%)	0	0	0	0	0	0	0	0
HCN	0	0	0	0	0	0	0	0
CO	0.8	1.2	0.9	0.8	0.9	0	0.6	0
H2S	0	0	0	0	0	0	0	0

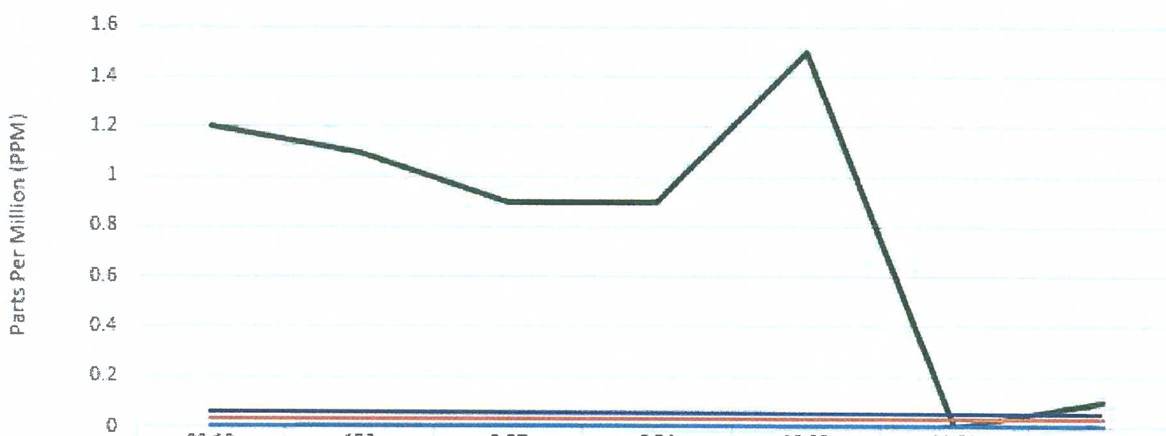
****Urban CO levels are typically higher than in rural areas due to vehicle emissions and industrial processes. Although average concentrations are low (0.5 to 5 ppm), they can increase near heavy traffic or industrial sites, especially during rush hours. The concentrations shown on the graphs remained significantly below harmful thresholds and do not pose any significant health risks ****

17. Air monitoring at Enterprise and Mission



	21:27 9/5/2024	23:39 9/5/2024	2:01 9/6/2024	4:02 9/6/2024	7:29 9/6/2024	9:51 9/6/2024	11:43 9/6/2024	13:50 9/6/2024
LEL (%)	0	0	0	0	0	0	0	0
HCN	0	0	0	0	0	0	0	0
CO	0.8	1.2	0.9	0.9	1.2	0.9	0.8	0.4
H2S	0	0	0	0	0	0	0	0

18. Air monitoring at Simpson and Venture



	23:10 9/5/2024	152 9/6/2024	3:57 9/6/2024	6:54 9/6/2024	10:00 9/6/2024	11:31 9/6/2024	13:36 9/6/2024
LEL (%)	0	0	0	0	0	0	0
HCN	0	0	0	0	0	0	0
CO	1.2	1.1	0.9	0.9	1.5	0	0.1
H2S	0	0	0	0	0	0	0

**Urban CO levels are typically higher than in rural areas due to vehicle emissions and industrial processes. Although average concentrations are low (0.5 to 5 ppm), they can increase near heavy traffic or industrial sites, especially during rush hours. The concentrations shown on the graphs remained significantly below harmful thresholds and do not pose any significant health risks **

Findings:

On September 5 at 12:09, units from the Escondido Fire Department responded to a fire at the SDG&E battery storage facility at 571 Enterprise Street. Upon arrival, crews found an active fire in a Lithium-Ion battery bank. Due to the specific hazards of such fires, a defensive strategy was employed, focusing on protecting adjacent structures containing additional batteries by applying water to those adjacent structures. Evacuations of the surrounding area began at approximately 13:00 on September 5 and remained in effect until September 7. San Diego County Hazmat arrived to conduct air monitoring from 14:30 to 18:30 at which time only normal products combustion of a structure fire were detected and at levels considered by NIOSH and OSHA to be well below exposure thresholds. Haley & Aldrich Inc., SDG&E's third-party contractor, began air quality monitoring later that evening and concluded on September 7. The fire was fully extinguished at 01:10 on September 6, with precautionary air monitoring continuing for an additional 12 hours into the afternoon of September 7. At no time during the incident did the levels of Oxygen deviate from 20.9 percent which is considered normal atmospheric level. Any decrease in the percentage of Oxygen would indicate that there was some unknown gas in the atmosphere that was not able to be detected by monitoring equipment. Fortunately, no such deviation was detected. The use of Fluoride reactive test strips was negative at all locations. Additionally, Hydrofluoric acid was not detected at any of the sampling locations.

Information Requests:

San Diego County HAZMAT/ San Diego City Fire Department HAZMAT
(619) 595-4633

San Diego Gas & Electric/ Haley & Aldrich INC
(877) 866-20266

Water Quality Report

This report was prepared using data obtained from runoff water analysis conducted by Eurofins Calscience, a laboratory accredited for environmental testing. The analysis was reviewed by personnel at the City of Escondido Hale Avenue Resource Recovery Facility (HARRF) laboratory to ensure the accuracy and integrity of the results.

SDG&E Battery Fire

571 Enterprise Street

Start 9/5/2024 12:09

Incident summary

On September 5 at 12:09, units from the Escondido Fire Department responded to structure fire at the SDG&E battery storage facility at 571 Enterprise Street. Upon arrival, crews found an active fire in a Lithium-Ion battery bank. Due to the specific hazards of such fires, a defensive strategy was employed, focusing on protecting adjacent structures containing additional batteries by applying water to those adjacent structures.

Sampling

- The samples were collected on **September 5, 2024 at 18:30 and again at 18:35** and were sent to a 3rd party laboratory for analysis
- The pH of the water sample was recorded at **7.47**, with a temperature of **26.8°C** at the time of testing.

Laboratory Analysis

- The analyses were performed by **Eurofins Calscience**, a laboratory with accreditation for environmental testing (EPA and SW846 protocols were followed).
- Samples were tested for various metals, including **barium, molybdenum, vanadium, copper, zinc, and cobalt**.

Results

- **Barium** concentration was found at **0.115 mg/L**, while the detected levels of **molybdenum**, **vanadium**, **copper**, **zinc**, and **cobalt** were all within acceptable ranges based on the applied methodologies.
- No detectable concentrations of other potentially harmful metals such as **cadmium**, **antimony**, **beryllium**, and **lead** were observed.

Quality Control

- The report indicates thorough quality control (QC) measures were applied, including spike recovery tests to ensure the accuracy and reliability of the results.
- For all tested metals, the recovery rates were within acceptable limits, confirming that the sampling and testing processes were effective.

Analysis

- **Water Quality**: The pH and metal concentrations suggest the water quality was within normal or acceptable ranges for most of the analyzed contaminants. The absence of toxic metals like **cadmium** and **lead** is a positive outcome.
- **Environmental Impact**: The low levels of metals like **barium**, **copper**, and **zinc** indicate that the runoff water does not pose significant environmental hazards.

pH and Temperature:

- **pH Level**: The pH of the water sample was recorded at **7.47**, which is neutral and within the acceptable range for general water quality standards (6.5 to 8.5 for drinking water). This suggests that the water was neither too acidic nor too alkaline.
- **Temperature**: The sample temperature was **26.8°C**, which is within a typical range for water at ambient temperatures. However, temperature could affect the solubility and mobility of metals, especially if the water is in a warmer environment.

Concentration of Detected Metals

- **Barium**:
    - Detected concentration: **0.115 mg/L**.
    - **Barium** is naturally occurring but can enter water through industrial discharge or from drilling operations. According to the **EPA's maximum contaminant level (MCL)** for barium in drinking water, the limit is **2 mg/L**. The detected level of **0.115 mg/L** is well below this threshold, indicating no significant risk from barium in this water sample.
- **Molybdenum**:
    - Detected concentration: **0.0075 mg/L**.
    - **Molybdenum** is an essential trace element, but elevated levels can be harmful to aquatic life. The detected concentration is relatively low and does not raise any immediate concerns. The **WHO** suggests a guideline of **0.07 mg/L** in drinking water, which makes this result favorable.
- **Vanadium**:
    - Detected concentration: **0.0051 mg/L**.
    - **Vanadium** is present in some natural water sources but can also come from industrial activities. There is no widely established regulatory limit for vanadium in drinking water, but concentrations below **0.01 mg/L** are generally considered safe. The level in the sample is well within this range.

- **Copper**:
    - Detected concentration: **0.0216 mg/L**.
    - The **EPA** action level for copper in drinking water is **1.3 mg/L**. The detected concentration of copper in the sample is far below this limit, indicating that the water is safe from copper-related toxicity.
- **Zinc**:
    - Detected concentration: **0.0767 mg/L**.
    - **Zinc** is essential for human health, but at higher concentrations, it can impart a metallic taste to water and cause health issues. The **EPA** has set a secondary maximum contaminant level (SMCL) of **5 mg/L** for zinc, primarily for aesthetic concerns. The concentration in this sample is well below this level, indicating no risk from zinc contamination.
- **Cobalt**:
    - Detected concentration: **0.0014 mg/L**.
    - **Cobalt** is another essential element but can be toxic at higher levels. There are no specific regulatory limits for cobalt in drinking water, but the detected amount in the sample is extremely low and does not pose any immediate health concerns.

Non-Detected Metals

- **Cadmium**, **antimony**, **beryllium**, **thallium**, **nickel**, **silver**, **arsenic**, **lead**, **selenium**, and **chromium** were **not detected** in the samples. This is a positive result as these metals are known for their potential toxicity and environmental persistence. The absence of these contaminants suggests that the water is not exposed to significant industrial pollution or corrosion from pipes that could introduce these metals.

Mercury Analysis

- **Mercury** was **not** detected in the samples, which is significant because mercury is highly toxic, especially in its methylated form. Even small amounts of mercury can have serious health and ecological impacts. The non-detect result (ND) indicates that the water is free from mercury contamination.

Comparative Toxicity and Environmental Impact

- The presence of trace amounts of metals like **zinc**, **copper**, and **barium** is typical in urban environments where water can come into contact with various materials and sediments. However, the levels detected in this sample do not indicate a significant environmental or health hazard.
- The absence of **toxic metals** such as **lead**, **cadmium**, and **mercury** further support that this water is unlikely to contribute to significant contamination of the environment.
- Laboratory personnel at the Hale Avenue Resource Recovery Facility (HARRF) laboratory were consulted regarding the results of the runoff water analysis and confirmed that there were no concerns with this water entering the environment.

Conclusion:

The analysis of the samples collected from the runoff water suggests that the water quality is within acceptable limits for most contaminants, especially when considering public health standards for drinking water. The low levels of metals detected, combined with the absence of more toxic elements like **lead** and **cadmium**, suggest that the water poses minimal risk both to human health and the environment.

Information Requests:

San Diego Gas & Electric/ Eurofins Calscience

(877) 866-20266

Battery Storage Fire in California Sparks Widespread Safety Concerns

June 7, 2024 Reading time: 3 minutes

Primary Author: Compiled by Christopher Bonasia

Manage consent

Chris Vanderstock/YouTube

18
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A nearly two-week-long fire at a battery energy storage facility in California highlighted the risks associated with emerging

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battery storage technologies that are central to the clean energy transition.

Fire crews took 24 hours to "get a handle on" the flare that erupted May 15 at the 250-megawatt Gateway Energy Storage Facility in Otay Mesa near San Diego, reports Fox 5 News. Two days later it reignited—and then smouldered for more than a week.

Surrounding businesses were evacuated and a 600-foot safety barrier was established to keep civilians away from possibly dangerous levels of hydrogen near the facility.

"The fire is what we call 'thermal runaway'—(meaning) the lithium-ion batteries are kind of ignited in their burning, so what we are doing right now is trying to contain the toxic fumes and the smoke, and the fire obviously," said Cal Fire Battalion Chief Patrick Walker, during the response to the second fire.

"But it's one of those processes that could be long-duration."

The facility's lithium-ion batteries are believed to be the source of the fire. They are prone to thermal runaway, a chain reaction that results in the battery producing heat more rapidly than it can dissipate. Internal battery temperatures can spike to around 400°C (752°F) in milliseconds, and the intense heat driving the fires make them extremely difficult to put out.

Fires like the one at Gateway have made people wary of battery energy storage facilities. Polling by Heatmap shows them to be

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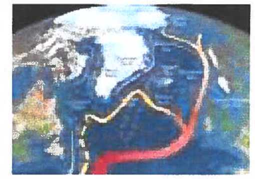
March 6, 2025



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the least popular form of carbon-free power. While fires at large energy storage facilities may be rare, Heatmap says respondents may have lumped them together with the relatively more common fires seen in lithium-ion-powered devices like scooters and e-bikes.

About an hour's drive north from Otay Mesa, residents of Eden Valley are fighting a battery storage project of up to 320 megawatts at the site of a former equestrian school, reports KPBS.

"I don't feel safe, and my kids don't feel safe either," Amanda Black, who lives next to the proposed site, told the regional news outlet.

But experts say battery energy storage will be crucial to the clean energy transition, especially to harness intermittent sources like wind and solar. California has been pushing the deployment of storage batteries for its transition to clean energy and is already a world leader in battery storage capacity.

in **Batteries & Storage**, **Cities & Communities**, **Health & Safety**, **Heat & Power**, **Media, Messaging, & Public Opinion**, **Subnational**, **United States**

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FIRE RISK AND SAFETY

Incidents similar to Moss Landing battery fire are unlikely but stricter regulations proposed

Battery safety has come a long way since the construction of the 300 MW first phase of Vistra Energy's Moss Landing Energy Storage Facility in California which caught fire on January 16. From the choice of chemistry, fire detection and supression mechanisms, to stricter codes and standards, the vast majority of today's large-scale battery energy storage systems (BESS) does not have much in common with the affected project deployed in a former turbine hall.

By **Marija Maisch**
Jan 28, 2025

Fire risk and safety | Grid-scale | Products & Services | Projects & Applications

Screenshot from a video posted on the official Facebook account of County of Monterey, California. | Image: County of Monterey, Facebook

Battery safety is a work in progress. But fires like the one that swept through the 300 MW first phase of Vistra Energy's Moss Landing Energy Storage Facility in California are unlikely. This is because the number of utility-scale energy storage installations in the U.S. housed indoors – as Moss Landing is – is lower than 1%.

The massive fire, which erupted at the facility on January 16 around 3 p.m., closed roads in the area and prompted evacuation of up to 1,500 local resident due to concerns over hazardous materials and potential chemical releases. The Monterey County Board of Supervisors unanimously declared a local state of emergency to address the various concerns.

No one was reported injured or killed and the air monitoring for hydrogen fluoride and particulate matter carried out by Environmental Protection Agency (EPA) showed no risk to public health throughout the incident. Expanded sampling of soil, water, debris and dust by state and county inspectors is underway. The first samples are being tested with the first results expected next week.

“We continue to gather information on the Moss Landing incident from our partners and stakeholders on the ground. Fire-related incidents at battery energy storage sites are rare, and investigations into historical incidents have not found health risks to neighbors or the surrounding community. The initial findings from the EPA testing at the Moss Landing site are consistent with this, having determined there to be no risk to public health,” Phil Sgro, American Clean Power (ACP) spokesperson, tells **ESS News**.

Indeed, since the first battery energy storage system (BESS) installations about 10 years ago, the Electric Power Research Institute (EPRI) BESS Failure Event Database has recorded roughly 85 events worldwide, ranging from minor to major. Over the past four years alone, there have been, on average, 10 such failure events annually, even as global battery deployments have increased 20-fold.

In the United States, six battery failure events occurred in 2022 and seven in 2023. To put that into perspective, according to the Wood Mackenzie Q1 2024 and 2023 Year in Review, roughly 7.9 GW of grid-scale energy storage was installed in the United States in 2023. This was reported to be a 98% increase over the total installed capacity in 2022. So, while the number of incidents roughly stayed constant, the number of installed units vastly increased, lowering the failure rate of these systems.

“Safety is the first and foremost priority of the industry and, after the incident is resolved and there is a thorough investigation, the industry will ensure the lessons learned are applied to prevent future incidents and inform safety standards and best practices,” said Sgro.

Project design

The industry has already learned a lot since the commissioning of Moss Landing Phase 1 in 2020. First of all, it underwent a shift in chemistry choice.

Phase 1 is equipped with nickel manganese cobalt (NMC)JH4 battery cells from LG Energy Solution. While this chemistry was used in early storage installations, the industry later moved to lithium iron phosphate (LFP) cells, which are present today in more than 80% of utility-scale storage projects. NMC undergo thermal runaway at a lower temperature and release more energy from decomposition i.e. LFP can withstand higher temperatures before catching fire.

Furthermore, the Moss Landing Phase 1 project consists of indoor battery racks mounted in the former turbine hall from the 1950s. Housing BESS projects in an enclosed space is rarely done today, partially because of the fear that any cascading failure could spread through the system in an uncontrolled manner.

“The fact the battery was housed in the old turbine hall may have made it more difficult to control. For external containerized BESS, many emergency response procedures focus on preventing the spread of fire to more containers, keeping surrounding ones cool, while the failed unit burns itself out,” Peter Bugryniec, research associate at the University of Sheffield, tells **ESS News**.

The high energy density in a confined space allows for heat and flames to spread rapidly, while outdoor, modular, containarized solutions are designed to isolate failures and avoid unit-to-unit propagation. Fortunately, according to ACP’s data, facilities that are located within retrofitted buildings that were not specifically engineered to house energy storage systems are an anomaly, representing less than 1% of existing projects.

Since Moss Landing Phase 1, safety standards have also evolved and became much more rigorous. In the U.S., the National Fire Protection Association (NFPA) 855 provides mandatory requirements for the design, installation, commissioning, operation, maintenance, and decommissioning of energy storage facilities.

It includes requirements for metrics such as maximum energy and spacing between units and lists several submissions that must be made to the regulating government entity, including 1) hazard mitigation analyses (HMA), 2) emergency response plans, 3) details of all safety systems, and more.

Furthermore, UL 9540 is the safety standard for energy storage equipment, including batteries, that is required under NFPA 855. NFPA 855 requires that batteries included in energy storage projects are listed to the safety specifications included in UL 9540 and undergo rigorous fire testing. This standard ensures that equipment incorporated into battery energy storage facilities are tested, certified, and safe for operation on the electric grid.

Nonetheless, following the Moss Landing incident, the California Public Utilities Commission (CPUC) has proposed further enhancement of battery energy storage safety. If approved, the proposal would, among other things: 1) implement Senate Bill (SB) 1383 to establish new standards for the maintenance and operation of battery energy storage facilities, and 2) increase oversight over emergency response action plans for battery energy storage facilities.

“If approved, the proposal will enhance the safety of battery energy storage facilities, which play a crucial role in California’s transition away from fossil fuels,” CPUC said on Monday, while its staff is conducting an investigation of the Moss Landing battery fire. The proposal will be tabled in the CPUC’s March 13 voting meeting.

Over the past several years, the deployment of BESS has grown significantly throughout California, growing from 500 MW in 2019 to over 13,300 MW statewide in 2024. Battery storage systems are one of the key technologies California relies on to enhance reliability and reduce dependency on polluting fossil fuel plants. For instance, in 2024, California’s solar-heavy electrical grid was able to keep the lights on during extreme heat waves in large part because of the rapid BESS deployment.

Meanwhile, in Texas, batteries played an essential part in keeping the lights on during extreme 2023 summer heat and freed up more than 3 GW of natural gas power plants during critical hours. According to Aurora Energy Research, during the January 2024 winter freeze, BESS units saved an estimated $750 million in day-ahead market costs by fulfilling essential ancillary services and meeting critical energy needs and reducing prices.

Written by

Marija Maisch

Marija has years of experience in a news agency environment and writing for print and online publications. She took over as the editor of pv magazine Australia in 2018 and helped establish its online presence over a two-year period.

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FIRE RISK AND SAFETY

Moss Landing fire leads to emergency regulations

Following the Moss Landing fire in Monterey County, local Californian counties are enacting urgency regulations for battery energy storage systems (BESS).

By **Tristan Rayner**
Feb 07, 2025

Fire risk and safety | Grid-scale

The Moss Landing power plant in 2007. CC BY-SA 3.0 via Wikipedia, photo taken by David Monniaux.

Less than a month after a BESS fire at the Moss Landing Energy Storage Facility in Monterey County, California, the Orange County Board of Supervisors enacted an 'urgency ordinance' to place a temporary moratorium permitting BESS facilities.

The fire at the Moss Landing Phase 1 project erupted at the 300 MW Phase I energy storage indoor facility on January 16 around 3 pm, causing evacuations of as many as 1,200 residents due to concerns over hazardous materials and potential chemical releases.

Few confirmed details about the fire have emerged since, but an update on February 5 from Monterey County, North County Fire Protection District, said the situation was stable. A spokesperson with the Monterey County Sheriff's Office told local reporters that 40% of the battery storage system had burned at the time, with later reports indicating nearly all of the 300 MW Phase 1 had burned.

Politicians, including California Governor Gavin Newsom, supported calls for an independent investigation into the fire at the Vistra Energy-owned facility. At the same time, the California Public Utilities Commission (CPUC) has proposed to 'enhance the safety of battery energy storage facilities'.

Adding to the events is environmental activist Erin Brockovich, who filed a lawsuit along with residents of Monterey County against Texas-based Vistra Energy and the utility Pacific Gas & Electric over the fire.

'Urgency ordinance'

In nearby Orange County, the local Board of Supervisors approved Vice Chair Katrina Foley's Urgency Ordinance Moratorium on Permitting of Large-Scale Battery Energy Storage System (BESS) facilities in unincorporated Orange County.

This temporarily halts permits for large-scale BESS facilities in unincorporated areas. Vice Chair Katrina Foley introduced the moratorium, citing concerns about lithium-ion battery fires and their unique challenges for firefighters.

The ordinance requires the Orange County Public Works Department to collaborate with the Orange County Fire Authority (OCFA) to produce a comprehensive report. This report, due ten days before the moratorium's expiration, must recommend measures to address hazardous conditions associated with BESS facilities.

Also making decisions was the city council of Morro Bay, located about 2 hours south of Moss Landing. According to The Tribune of San Luis Obispo, the Morro Bay council voted on Tuesday to impose a 45-day moratorium on either current projects or any new ones going ahead.

Along with local actions, state-level legislative responses are emerging. On January 23, 2025, State Assemblymember Dawn Addis, representing the Moss Landing district, introduced Assembly Bill 303 (Battery Energy Safety & Accountability Act). The bill proposes significant restrictions on BESS developments, including:

- Prohibiting BESS facilities of 200MWh or greater within 3,200 feet of sensitive receptors
- Restricting development on environmentally sensitive sites
- Repealing 2022 permitting reforms that had expedited state approvals for these facilities under California's climate change initiatives

The American Clean Power Association has expressed concerns about the bill's broad scope.

In addition, the California Public Utilities Commission (CPUC) has proposed further regulations for a March 13 voting meeting, which would, among other things: 1) implement Senate Bill (SB) 1383 to establish new standards for the maintenance and operation of battery energy storage facilities, and 2) increase oversight over emergency response action

"If approved, the proposal will enhance the safety of battery energy storage facilities, which play a crucial role in California's transition away from fossil fuels," said the CPUC.

Recent fires in nearby San Diego also saw action taken by the local County, which opted for new BESS standards in the wake of a first 17-day fire but later refused a call to ban battery storage projects, while requiring all battery storage site applications to include details of fire safety properties related to project design, operation, and use, drawn up by a fire protection engineer, among other measures.

Safety, unusual circumstances

As covered on **ESS News**, the Moss Landing facility is unusual for its indoor enclosure, with BESS projects rarely housed in an enclosed facility today.

Data suggests 2024 has seen a continuing fall in the rate of BESS safety incidents over the years. Just five significant events occurred in 2024, with three in the US, one in Japan, and one in Singapore. Compared to the exponential growth in large-scale batteries installed around the globe, rates of incident have fallen to their lowest point in nearly a decade.

Written by

Tristan Rayner

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LEGAL PUBLICATION: WEDNESDAY, MARCH 13, 2024 CASE: 130-AT-24

NOTICE OF PUBLIC HEARING IN REGARD TO AN AMENDMENT TO THE TEXT OF THE CHAMPAIGN COUNTY ZONING ORDINANCE

CASE 130-AT-24

The Champaign County Zoning Administrator, 1776 East Washington Street, Urbana, has filed a petition to amend the text of the Champaign County Zoning Ordinance. The petition is on file in the office of the Champaign County Department of Planning and Zoning, 1776 East Washington Street, Urbana, IL.

A public hearing will be held **Thursday, March 28, 2024 at 6:30 p.m.** prevailing time in the Shields-Carter Meeting Room, Brookens Administrative Center, 1776 East Washington Street, Urbana, IL, at which time and place the Champaign County Zoning Board of Appeals will consider a petition for the following:

Amend the Champaign County Zoning Ordinance as follows regarding Battery Energy Storage Systems (BESS):

1. Add the following definitions to Section 3.0 Definitions: BATTERY ENERGY STORAGE MANAGEMENT SYSTEM (BESMS), BATTERY ENERGY STORAGE SYSTEM (BESS), TIER-1 BATTERY ENERGY STORAGE SYSTEMS, TIER-2 BATTERY ENERGY STORAGE SYSTEMS.

2. Add new paragraph 4.2.1 C.8. to provide that a BATTERY ENERGY STORAGE SYSTEM may be authorized as a SPECIAL USE Permit in the AG-1 and AG-2 Agriculture Districts as a second PRINCIPAL USE on a LOT with another PRINCIPAL USE.

3. Amend Section 5.2 as follows:
   a. Add “BATTERY ENERGY STORAGE SYSTEM” to be allowed by Special Use Permit in the AG-1 Agriculture, AG-2 Agriculture, B-1 Rural Trade Center, B-4 General Business, I-1 Light Industry and I-2 Heavy Industry Zoning Districts.
   b. Add Footnotes 32 and 33 regarding TIER-1 and TIER-2 requirements.

4. Add new Section 6.1.8 TIER-2 BATTERY ENERGY STORAGE SYSTEMS to establish regulations including but not limited to:
   a. General standard conditions
   b. Minimum lot standards
   c. Minimum separations
   d. Standard conditions for design and installation
   e. Standard conditions to mitigate damage to farmland
   f. Standard conditions for use of public streets
   g. Standard conditions for coordination with local fire protection district
   h. Standard conditions for allowable noise level
   i. Standard conditions for endangered species consultation
   j. Standard conditions for historic and archaeological resources review
   k. Standard conditions for acceptable wildlife impacts
   l. Screening and fencing
   m. Standard condition for liability insurance

n. Operational standard conditions
o. Standard conditions for Decommissioning and Site Reclamation Plan
p. Complaint hotline
q. Standard conditions for expiration of Special Use Permit
r. Application requirements

5. Regarding BATTERY ENERGY STORAGE SYSTEMS fees, revise Section 9 as follows:
   a. Add new paragraph 9.3.1 K. to add application fees for a BATTERY ENERGY STORAGE SYSTEMS Zoning Use Permit.

   b. Add new subparagraph 9.3.3 B.(9) to add application fees for a BATTERY ENERGY STORAGE SYSTEMS SPECIAL USE permit.

All persons interested are invited to attend said hearing and be heard. The hearing may be continued and reconvened at a later time. Meeting materials can be found online about one week before the meeting at: http://www.co.champaign.il.us/CountyBoard/meetings_ZBA.php. If you would like to submit comments or questions before the meeting, please call the P&Z Department at 217-384-3708 or email zoningdept@co.champaign.il.us no later than 4:30 pm the day of the meeting.

Ryan Elwell, Chair
Champaign County Zoning Board of Appeals

TO BE PUBLISHED: WEDNESDAY, MARCH 13, 2024, ONLY

Send bill and one copy to: Champaign County Planning and Zoning Dept.
Brookens Administrative Center
1776 E. Washington Street
Urbana, IL 61802
Phone: 384-3708

Our News Gazette account number is 99225860.