Attachment A

REPORT

SAN DIEGO COUNTY BESS BEST PRACTICES

Policy Recommendations for Battery Energy Storage Systems Projects

PREPARED FOR

San Diego County

Jensen Hughes Project #: 1WNF24016
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Revision Record Summary

Revision	Revision Summary
0	Initial use
1	Revisions based on San Diego County Comments

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1.0 Introduction

Following the fire at the Gateway Energy Storage Facility in Otay Mesa, California, the County of San Diego has tasked Jensen Hughes with developing and documenting guidelines and best practices for regulating stationary energy storage systems (BESS) facilities. Given the rapidly evolving technology and the development of codes, standards, and guidelines from various organizations or authorities having jurisdictions (AHJs) in the United States, the development of this document is intended to provide an overview of the current codes and standards regulating BESS facilities applicable to the San Diego County and to provide input on best practices for developing and implementing permitting policies involving BESS facilities.

The information in this document includes the professional opinion of Jensen Hughes' staff, unique consideration was done on each topic, however users of this document must perform their own due diligence before enacting or utilizing any of the recommendations or opinions presented in this report.

1.1 CODES AND STANDARDS

The following codes and standards were utilized in the preparation of this document. These resources represent the current state of the art in terms of standards and regulations as applicable to San Diego County.

+ 2022 Edition of the California Building Code (CBC), with July 2024 Supplement.
+ 2022 Edition of the California Fire Code (CFC), with July 2024 Supplement.
+ 2022 Edition of the California Electrical Code (CEC) – NFPA 70, National Electrical Code with California Amendments.
+ 2023 Edition of the San Diego County Consolidated Fire Code (CoFC).
+ 2024 Edition of the International Fire Code (IFC)*
+ 2024 Edition of the International Building Code (IBC).
+ 2023 Edition of National Fire Protection Association (NFPA) 855, Standard for the Installation of Stationary Energy Storage Systems.
+ 2023 Edition of NFPA 68, Standard on Explosion Protection by Deflagration Venting.
+ 2019 Edition of NFPA 69, Standard on Explosion Prevention Systems.
+ 2022 Edition of NFPA 72, National Fire Alarm and Signaling Code.
+ 2024 Edition of NFPA 1660, Standard for Emergency, Continuity, and Crisis Management: Preparedness, Response, and Recovery.
+ UL 9540, Edition 3 (June 2023), Energy Storage Systems and Equipment.
+ UL 9540A, Edition 4 (November 2019), Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems.
+ UL 1973 Batteries for Use in Stationary and Motive Auxiliary Power Applications.

+ UL 1741 Inverters, Converters, Controllers, and Interconnection System Equipment for Use with Distributed Energy Resources.

*This report provides some commentary on changes that will likely be incorporated into the 2025 CFC (effective January 1, 2026), which will be in the 2024 edition of the IFC.

1.2 PURPOSE

The intent of this document is to guide the County of San Diego in the review and permitting process of BESS. Specifically, this document aims to provide guidance in meeting the CFC Section 1.1.2, which states:

"The purpose of this code is to establish the minimum requirements consistent with nationally recognized good practices to safeguard the public health, safety, and general welfare from the hazards of fire, explosion, or dangerous conditions in new and existing buildings, structures, and premises, and to provide safety and assistance to firefighters and emergency responders during emergency operations."

As BESS hazards have seemingly outpaced the code development process, there may be additional requirements beyond those found in the currently adopted edition of the CFC that are needed to meet the intent of CFC Section 1.1.2.

1.3 SCOPE

The scope of this document is defined by the following elements:

1. The document provides guidance and recommendations on the application and interpretation of the CFC Section 1.1.2 as it relates to Lead Acid, Lithium-Ion, Nickel, and Sodium Nickel Chloride Batteries used in Energy storage systems. These are the top battery technologies used for energy storage systems, as listed in Table 1.3 of NFPA 855. It is noted that while CFC Section 1207 and NFPA 855 cover many types of energy storage systems, such as capacitor BESS and flywheel ESS, these technologies function differently and present different hazards from battery BESS and are not covered explicitly in this document.

2. There are constant advancements in energy storage systems, leading to new types of batteries being researched and produced. This document specifically addresses the types of batteries that are found in CFC Table 1207.1.1 and NFPA 855 Table 1.3. These concepts and recommendations may be applicable to other battery types; however, they are not specifically within the scope. Additionally, due to the vast implementation of lithium-ion batteries and the issues associated, there is a significant focus on lithium-ion battery chemistries.

3. The guidance and recommendations included in this document focus on the primary goal of the CFC Section 1.1.2, which is the health and safety of the general public, firefighters, and emergency responders. Recommendations focusing on property protection and business continuity are provided only on a limited basis.

4. This document does not fully address aspects of BESS installations that are typically covered by the CEC. However, there are aspects of the electrical installation, such as listing requirements, that are intrinsically involved in fire safety, and these are addressed by this report.

5. This document only applies to residential BESS that exceed the maximum stored energy in CFC Section 1207.11.4. Installations that do not exceed the maximum stored energy are addressed by the California Residential Code or by CFC Section 1207.11 for Group R-3 or R-4 occupancies.

1.4 DEFINITIONS

Given the terminology used in codes, standards, and technical documents when referring to associated systems, components, and facilities, the following terms have been selected for consistency purposes in this document. Table 1-1 below provides the list of terms and the corresponding definitions.

Table 1-1: BESS terminology and definitions used throughout this document

Term	*Definition*
Authority Having Jurisdiction (AHJ)	An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, installation, or procedure.
Battery	One or more cells connected together electrically in series, parallel, or both, to provide the required operating voltage and current levels.
Battery Management System (BMS)	A system that monitors, controls, and optimizes the performance of an individual or multiple battery modules.
Cell	The basic electrochemical unit, characterized by an anode and a cathode, used to receive, store, and deliver electrical energy.
Energy Storage Management System (ESMS)	A system that monitors, controls, and optimizes the performance and safety of an energy storage system.
Energy Storage System (ESS)	One or more devices, assembled together, capable of converting and storing chemical energy to electrical energy and vice versa for future use.
Energy Storage System Cabinet	An enclosure containing components of the energy storage system where personnel cannot enter other than reaching in to access components for maintenance.
Fire Area	A fire area is the aggregate floor area enclosed and bounded by fire walls, fire barriers, exterior walls, or horizontal assemblies of a building. Areas of the building not provided with surrounding walls shall be included in the fire area if such areas are included within the horizontal projection of the roof or floor above.
Dedicated-Use Building	A building used for energy storage, or energy storage in conjunction with energy generation, electrical grid-related operations, or communications utility equipment.
Energy Storage System Walk-In Unit	A structure containing energy storage systems that includes doors that provide walk-in access for personnel to maintain, test, and service the equipment and is typically used in outdoor and mobile energy storage system applications. Some jurisdictions define this as anything more than needing to reach an arm in.
Stationary Energy Storage System	An energy storage system that is permanently installed as fixed equipment.

Term	Definition
Fire and Explosion Testing	Testing of a representative energy storage system that evaluates the fire and explosion hazards produced by a propagating thermal runaway. Fire and explosion testing is used by NFPA 855. CFC and IFC use the term "Large-scale fire test"
Hazard Mitigation Analysis (HMA)	An evaluation of potential energy storage system failure modes and the safety-related consequences attributed to the failures.
Large-Scale Fire Test	Currently defined as testing of a representative energy storage system in accordance with UL 9540A. The testing shall be conducted or witnessed and reported by an approved testing laboratory and show that a fire involving one BESS will not propagate to an adjacent ESS, and where installed within buildings, enclosed areas, and walk-in units will be contained within the room, enclosed area, or walk-in unit for a duration equal to the fire-resistance rating of the room separation. Large-scale fire test is used by the CFC and IFC. NFPA 855[1] uses the term "fire and explosion testing."
Maximum Stored Energy	The quantity of energy storage permitted in a fire area prior to the area being considered a high hazard occupancy. The CFC refers to this term as "Maximum Allowable Quantities".
Module	A subassembly that is a component of a BESS that consists of a group of cells or electrochemical capacitors connected together either in a series and/or parallel configuration (sometimes referred to as a block) with or without protective devices and monitoring circuitry.
Occupied Work Center	Rooms or areas occupied by personnel not directly involved with maintenance, service, and testing of the BESS.
Off-Gassing	The event in which the cell case vents due to a rise in internal pressure of the cell.
Periodic Special Inspection	Special Inspection by the special inspector who is intermittently present where the work has been or is being performed and at the completion of the work.
Qualified Person	One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training to recognize and avoid the hazards involved.
Special Inspector	A qualified person employed or retained by an approved agency and approved by the building official as having the competence necessary to inspect a particular type of construction requiring special inspection.

[1] NFPA 855 2026 edition will require a separate large scale fire test (LSFT) in addition to UL 9540A testing. The objective of LSFT is to evaluate the thermal exposure from a developed fire within a battery energy storage system unit, including non-battery components, to determine propagation/ignition risk to adjacent units or exposures.

Term	Definition
Thermal Runaway	Self-heating of an electrochemical system in an uncontrollable fashion
Thermal Runaway Protection	Method to manage charging and discharging during normal operation of the ESS to maintain batteries and capacitors within their safe operating parameters.
Unit	A frame, rack, or enclosure that consists of a functional BESS, which includes components and subassemblies such as cells, modules, battery management systems, ventilation devices, and other ancillary equipment.

1.5 BATTERY TECHNOLOGIES

This section of the report provides background information on the types of batteries within the scope of this document. This includes selected technologies covered by IFC Table 1207.1.3. NFPA 855 Annex B.5 provides additional information on commercially available battery technologies.

1.5.1 Lead-Acid

Lead-acid batteries have a long history of use across many applications, such as in telecommunications centers and in automobiles. In general, lead-acid batteries are comprised of a lead dioxide cathode, a metallic lead anode, and a sulfuric acid electrolyte.

There are two basic categories of lead-acid batteries:

- Vented lead-acid (VLA). The contents of the batteries are open to the atmosphere through a vent assembly.
- Valve-regulated lead-acid (VRLA). These batteries are sealed with a valve that opens and closes to release pressure.

Lead-acid batteries release some hydrogen gas during normal charging, which is managed by the code required ventilation system. Thermal runaway has been observed in VRLA batteries when charging gases do not recombine, which can cause fires. However, these events are noted to be less severe than lithium-ion batteries, and successful developments have been made to reduce the likelihood of these events [1].

Both VLA and VRLA utilize a diluted sulfuric acid electrolyte. VLA batteries are suspended in the electrolyte solution, and thus, the spill potential is greater than with VRLA. If there is an electrolyte spill, there is not a flammability concern, but sulfuric acid is still corrosive and should be handled with caution.

The Fire Protection Research Foundation (FPRF) sponsored a report that was published by Texas A&M University to review incidents and fire tests associated with lead-acid batteries. The incident portion of the study noted a total of 14 deaths and 12 injuries (incidents resulting in minor injuries are expected to be underreported, however) within the 40-year time frame of 1979 to 2019. Thirteen of the fourteen deaths found in the study were due to a single incident within a mine. Additionally, the report noted that VLA batteries were not prone to thermal runaway and in general, that lead-acid batteries pose a much lower fire risk than lithium-ion batteries [2].

1.5.2 Lithium-Ion

Lithium-ion is one of the most widely used technologies for rechargeable batteries as lithium-ion has a relatively high energy density, high efficiency, and long life cycle compared to other rechargeable chemistries.

A lithium-ion battery is characterized as a battery that moves positive lithium-ions into electronically conducting solids to store energy. Within the classification of lithium-ion, there are variations that are typically classified by cathode technology, including the common lithium iron phosphate (LFP), nickel manganese cobalt (NMC), nickel manganese oxide (NMO), and nickel cobalt aluminum oxide (NCA). Each cathode type has advantages, for example, NCA and NMC have higher energy density while LFP is typically lower cost (due to the absence of cobalt) and has better thermal stability. In some cases, NMC and NMO are paired with a titanium anode rather than a carbon anode and this is referred to as LTO. LTO has a lower cell voltage than the other chemistries, but also offers an increased temperature to thermal runaway, which is better for safety. LFP safety advantages over other chemistries include lower temperatures during thermal runaway which slows propagation, and the ratio of flammable to non-flammable gas concentrations tends to be lower in LFP cells compared to others [3]. LFP cells are generally accepted to be safer, which can be demonstrated in Factory Mutual (FM) Global Data Sheet 5-33, where outdoor BESS enclosures utilizing LFP cells can be separated by 5 feet, while NMC systems are required to be separated by 8 or 13 feet depending on enclosure rating. It should be noted that while some types of lithium-ion batteries may be viewed as safer than others, all can undergo thermal runaway that is difficult to control and should be protected as such.

Lithium-ion batteries do not release flammable or toxic gases during normal charge and discharge situations. Lithium-ion batteries also do not present a credible electrolyte spill hazard as electrolyte is sealed and not present in large quantities in a single cell. However, lithium-ion batteries release flammable and toxic gases during thermal runaway and combustion scenarios. Lithium-ion batteries do not contain lithium metal (which is water-reactive) and are therefore not water-reactive.

1.5.3 Nickel Batteries

Nickel batteries can be classified into the following three categories:

+ Nickel-Cadmium (Ni-Cd): Nickel hydroxide anode and cadmium cathode with potassium hydroxide electrolyte.
+ Nickel-Zinc (Ni-Zn): Similar to nickel-cadmium, but with a zinc cathode.
+ Nickel-metal hydride (Ni-MH): Nickel hydroxide anode and a metal hydride cathode with potassium hydroxide electrolyte.

As with lead-acid batteries, Ni-Cd and Ni-Zn batteries can release some hydrogen gas during normal charging and discharging, which should be managed with the code required ventilation of the room or area. An explosion control system is also needed for management of the gases produced under abnormal situations.

Similar to lead-acid, Ni-Cd and Ni-Zn batteries can be flooded (similar to VLA) or starved electrolytes (similar to VRLA). Therefore, any flooded nickel battery would bring the same concerns with electrolyte spills and the corrosive nature of the electrolyte. Nickel-metal hydride batteries are starved electrolyte type and therefore do not have this issue.

1.5.4 Sodium Nickel Chloride (High Temperature Batteries)

Sodium nickel chloride batteries are considered high-temperature batteries and operate only at elevated temperatures (500°F to 662°F). High-temperature batteries are hermetically sealed with the active components in a molten state, which allows for conductivity. Sodium nickel chloride utilizes a sodium cathode, various types of anodes, and beta-alumina (which is a solid ceramic) as an electrolyte.

High-temperature batteries have long expected lifetimes, need minimal maintenance, and are less sensitive to external temperature variability than other battery types.

1.6 LOCATION CLASSIFICATIONS

This section summarizes the location classifications that are found in the IFC, CFC, and NFPA 855. The term location primarily refers to classifying the BESS facility as indoor or outdoor. For indoor facilities, it also refers to the use of the building in which they are located. The following sections describe the classifications.

1.6.1 Indoor Installations

Indoor installations are classified by dedicated-use buildings and nondedicated-use buildings. Outdoor walk-in units that exceed 53 feet by 8 feet by 9.5 feet (not including bolt-ion HVAC and related equipment) are also considered indoor installations.

Dedicated-use buildings are buildings that meet the following requirements:

+ The building is used only for ESS, electrical energy generation, or other electrical grid-related operations.
+ Occupants in rooms and areas containing BESS are limited to personnel that operate, maintain, service, test and repair the BESS and other energy systems
+ No other occupancy types are permitted in the building.
+ Administrative and support personnel are permitted in areas within the building that do not contain ESS, with the following conditions:
    - The areas do not occupy more than 10% of the building area of the story that they are located.
    - A means of egress is provided from the incidental use areas to the public way such that occupants do not have to traverse through areas containing ESS
    - The areas are separated from areas containing BESS by minimum 2-hour fire barriers and 2-hour horizontal assemblies

If a building does not meet the requirements above, it is considered an indoor, nondedicated-use building. Dedicated use buildings are not subject to maximum stored energy limits (or maximum allowable quantities) and, therefore, do not require an HMA as a basis to increase the maximum stored energy (interpretation from NFPA 855 9.4.1.1 2023 Ed). In addition, requirements for fire suppression systems in remote locations (see definition of remote location below with outdoor installations) and for transmission of alarm signals from smoke and fire detection systems are permitted to be waived for dedicated use buildings. Additional discussion will be provided on these omissions in later sections of this report.

1.6.2 Outdoor Installations

Outdoor installations are classified as remote or near exposures. Additionally, special types of outdoor installations include open parking garages and rooftop installations. Remote outdoor locations are located more than 100 feet from exposures, including the following:

+ Buildings
+ Lot lines that can be built upon

- Public ways
- Stored combustible materials
- Hazardous materials
- High-piled stock
- Other items may be considered exposure hazards, except for other BESS units and electrical grid infrastructure. Electrical grid infrastructure may include substations and power lines.

Where an outdoor installation does not meet the definition of remote, it is near exposures.

Outdoor, walk-in units are, in most cases, subject to the same requirements as indoor installations. When outdoor, walk-in units exceed 53 feet by 8 feet by 9.5 feet high (not including bolt-ion HVAC and related equipment), they are required to comply with all requirements for buildings.

1.6.3 Special Installations

Special installation types include rooftop installations and open parking garage installations.

1.6.4 BESS Location Classification Summary

Table 1-2 summarizes the location classifications and provides the corresponding code/standard sections.

Table 1-2: Summary of BESS location classifications with corresponding code/standard references

Description	*Classification and Reference*
BESS enclosure is in a building with uses or occupancies other than BESS-related, or access to BESS areas other than by maintenance personnel or with separate administrative and support areas that occupy more than 10% of building story area with no 2-hour fire rated separation or no direct means of egress to public way.	Indoor, Non-Dedicated-Use Building + NFPA 855 Section 9.3.1.2 + IFC and CFC Section 1207.7.2
BESS is in a dedicated use building. See definition requirements in Section 1.6.1 above.	Indoor, Dedicated Use Building + NFPA 855 Section 9.3.1.1 + IFC and CFC Section 1207.7.1
BESS enclosure is located outdoors more than 100 ft away from buildings, lot lines, public ways, stored combustible materials, hazardous materials, high-piled stock, and other exposure hazards not associated with electrical grid infrastructure.	Outdoor, Remote + NFPA 855 Section 9.3.2(1) + IFC and CFC Section 1207.8.1

Description	Classification and Reference
BESS enclosure is located outdoors less than 100 ft away from buildings, lot lines, public ways, stored combustible materials, hazardous materials, high-piled stock, and other exposure hazards not associated with electrical grid infrastructure. The BESS is in an enclosure that is not more than the maximum outdoor enclosure dimensions of 53 ft × 8 ft × 9.5 ft, not including bolt-on HVAC and related equipment.	Outdoor, Near Exposure + NFPA 855 Section 9.3.2(2) + IFC and CFC Section 1207.8.2

2.0 Best Practices for New Installations

The following subsections provide recommendations for best practices for new BESS installations. These recommendations include clarifications or expansions on applications of existing fire code requirements, requirements that are present in newer fire codes and standards (2024 IFC / NFPA 855), and other recommendations that are not addressed in codes or standards that were reviewed.

Table 2-1. Summary of Recommendations

Topic (Section)	Section	Summary
Listings and Certifications	2.1	+ BESS installations should comply with UL 9540, UL 1973 for battery systems and UL 1741 for power conversion systems. + Listings should be completed by an OSHA-recognized NRTL. + Alternative compliance, such as field certifications, may be used for custom systems; they are generally not equivalent to lab-issued listings and should be well-documented for compliance.
Large-Scale Fire Testing	2.2	+ Fire testing is mandated under CFC for specific conditions, including capacity increase or separation reduction. NFPA 855 provides standards and additional guidance (e.g., UL 9540A).
Hazard Mitigation Analysis (HMA)	2.3	+ HMA required under CFC for specific conditions, capacities exceeding limits, technologies not in CFC Table 1207.1, or multiple BESS with interaction potential. + Project-specific inputs for the HMA, such as fire protection and life safety conditions tailored for site-specific factors.
Site Requirements	2.4	+ Fire apparatus access, water supply, and hydrant requirements specified in accordance with CFC and CoFC. Spacing in accordance with CFC is needed to minimize fire propagation; distance recommendations vary based on site risk level and the HMA.

Topic (Section)	Section	Summary
Detection and Alarm	2.6	+ Smoke or radiant energy detection, gas detection, and BMS integration are recommended for early risk identification and should be evaluated based on site-specific installation.
Exhaust Ventilation	2.7	+ Required for technologies with flammable gas emissions during normal operation. Systems must comply with CFC requirements for explosion prevention.
Explosion Protection	2.8	+ Passive and active measures in accordance with NFPA 68 and NFPA 69 to prevent and mitigate explosion hazards. Specific standards depend on indoor/outdoor application and lithium-ion properties.
Fire Suppression	2.9	+ Recommended water-based systems for lithium-ion BESS. Optional for remote installations or based on HMA; large-scale testing is required for suppression systems' effectiveness validation.
Seismic Design	2.10	+ ASCE 7-16 standards for structure and equipment resilience; specifics required for structural stability, clearance, and anchoring
Fire Safety and Evacuation Plan	2.11	+ Require fire safety and evacuation plans for installations where personnel are regularly present. These plans ensure occupant safety and provide guidance to emergency responders.
Emergency Planning and Training	2.12	+ Require an Emergency Response Plan (ERP) and training for facility personnel and emergency responders. Plans should include site access, equipment locations, and potential hazards for responders.
Dispersion Analysis (Plume Modeling)	2.13	+ Toxic plume modeling, especially near sensitive sites, to guide evacuation routes and ensure IDLH standards. It is not regulatory but aids public safety response.
Environmental Control	2.14	+ IP ratings to prevent moisture ingress required testing to verify suitability for outdoor use in specific weather conditions.
Heating and Cooling Systems	2.15	+ Systems to maintain BESS within thermal limits, with contingencies for failure modes. Designs must consider ambient effects and component oversizing.
Fire-Fighting Water Runoff Collection	2.16	+ Runoff toxicity considerations are advised but not yet regulated. Local context and environmental impact assessed case-by-case
Additional Considerations	2.17	+ Continuous evaluation of new technologies, compliance with NFPA 855, and third-party testing for suppression and explosion protection.

2.1 LISTINGS AND CERTIFICATIONS

2.1.1 UL 9540

The CFC requires that BESS are listed in accordance with UL 9540, with exceptions for some lead-acid and nickel-cadmium battery systems. The current edition of the CFC references the second edition of UL 9540, which was released in February 2020. Notably, the first edition of UL 9540 did not include requirements for large-scale fire testing or specific safety standards for critical safety systems. However, the third edition of UL 9540, which was released in June of 2023, is now in effect at the time of this report's preparation.

UL 9540 is a system-level listing, meaning that it covers the BESS components, such as batteries, enclosure, battery management system (BMS), and the power conversion system (PCS), if applicable.

Where new BESS installations are required to be listed in accordance with UL 9540, they should be listed to either Edition 2 or Edition 3.

2.1.2 UL 1973

UL 1973 is a safety standard that applies specifically to the battery system component of a BESS. UL 9540 requires that the battery system used in a BESS must comply with the requirements of UL 1973.

Lithium-ion batteries covered under the scope of this report are required to be provided with a thermal runaway protection system. Typically, this protection is achieved by the BMS, which is evaluated as part of the UL 1973 listing or the UL 9540 system-level listing.

The BMS or any other thermal runaway protection system should be verified as being evaluated as part of a UL 1973 or UL 9540 listing.

2.1.3 UL 1741

UL 1741 is a key safety standard applicable to the PCS in the BESS. This standard ensures that inverters and other energy conversion equipment meet the required safety and performance criteria when interacting with the electrical grid or local loads.

For BESS installations, UL 1741 certification is required for any PCS that facilitates the energy conversion process. When a BESS is listed under UL 9540 and includes a PCS or uses a separate PCS, the PCS must also comply with UL 1741.

News BESS installations should ensure that the PCS complies with UL 1741 when listed under UL 9540 or listed separately.

2.1.4 Nationally Recognized Testing Laboratory (NRTL)

The CFC defines "listed" as "*Equipment, materials, products, or services included in a list published by an organization acceptable to the fire code official*." The 2023 NFPA 855 expands this definition to include that the listed organization must "*maintains periodic inspection of the production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose."*

The CEC includes an informational note that the Occupational Safety and Health Administration (OSHA) recognizes qualified electrical testing laboratories for electrical equipment that requires a listing. These laboratories are commonly referred to as NRTLs. These NRTLs are subject to regular audits to maintain the integrity of their operations and must remain fully independent from the organizations whose products they list.

In addition to a laboratory being recognized by OSHA, the product should be certified at a recognized testing site, and the NRTL must list UL 9540 as a recognized testing standard. The current list of NRTLs, along with their recognized testing sites and standards, is available on OSHA's website.

The product listings should be conducted or witnessed by an NRTL that is recognized for the applicable standard and at a recognized testing site.

2.1.5 Alternative Compliance Options

In cases where a BESS cannot obtain a UL 9540 listing at the laboratory, such as for highly customized systems or installations requiring specific on-site modification, field certifications may be considered. However, it is important to note that field certifications are generally not regarded as equivalent to lab-issued listings. These evaluations are conducted at the installation site to verify compliance with safety standards.

While some AHJs may accept field certifications as a path to compliance, opinions differ on their appropriateness for safety-critical systems like BESS. Field certifications can be useful for systems that undergo site-specific modifications, but they may lack the consistency and rigor of factory listings, which are subject to strict testing and oversight.

An alternative compliance pathway may also be acceptable when a system-level UL 9540 listing is not feasible. In such cases, compliance can be demonstrated through a combination of UL 1741 for the PCS or inverter and UL 1973 for the battery system. This combination of listings can ensure that core safety requirements for energy conversion and battery protection are met, even without a full UL 9540 listing. It is critical to review this approach with the AHJ to confirm its acceptability for the specific installation.

For projects where field certifications are used, it is recommended to verify that the system components, including the batteries, the BMS, and PCS, have been tested against the applicable UL standards (e.g., UL 1973, UL 1741) by an NRTL. Documentation should be provided to confirm the integrity of the field evaluation and compliance with UL 9540 requirements.

2.2 LARGE-SCALE FIRE TESTING

Large-Scale Fire Testing (LSFT) is an essential process for assessing the fire risks and explosion hazards associated with BESS. The goal of LSFT is to generate data that characterize the fire performance of BESS's underdeveloped fire conditions. The test evaluates how a fire originating from battery cells propagates to additional cells, as well as the risk it poses to adjacent units or equipment. Intentional ignition of vent gases, a critical aspect of the LSFT, is used to assess the hazards of flammable gases released during thermal runaway. This informs fire protection strategies and helps in the design of mitigation systems.

The test is designed to capture the peak thermal stress from a BESS failure scenario, providing insights into various foreseeable failure conditions. By replicating the final installation configuration, including fire protection systems, LSFT helps determine the propagation risks and guides safety measures for BESS installations.

It is important to note that current standards allow UL 9540A testing to be considered LSFT. New regulations are currently being drafted that would shape the objective of LSFT as described here.

2.2.1 Current Requirements

In general, LSFT is required in scenarios where the safety and fire performance of BESS must be thoroughly evaluated, particularly in large-scale or commercial applications. It is typically mandated by fire and building codes, safety regulations, and industry standards to ensure that these systems do not pose significant fire risks to nearby structures, equipment, or people.

A large-scale fire test is required by the CFC in the following circumstances:

1. To increase the capacity of a BESS (>50 kWh) or reduce the separation (three feet) of a BESS group (CFC Section 1207.5.1).
2. To exceed the maximum stored energy (maximum allowable quantity in accordance with CFC Table 1207.5).
3. To determine design criteria for automatic sprinkler protection or alternative fire-extinguishing systems (CFC Section 1207.5.5). *This is covered in greater detail in Section 2.9 of this report.*
4. To reduce separation of BESS outdoors and in open parking garages from any means of egress (CFC Section 1207.5.8).
5. To waive explosion control requirements when flammable gases are not liberated from the BESS during testing (CFC Section 1207.6.3). *This is covered in greater detail in Section 2.8 of this report.*
6. To reduce clearance to exposures from 10 feet to 3 feet when testing demonstrates that a fire within a weatherproof enclosure over the BESS will not ignite combustible materials outside the BESS (CFC Section 1207.8.3 and 1207.9.3).
7. To reduce separation distances for exterior wall-mounted BESS from other BESS and from doors, windows, operable openings, and HVAC inlets (CFC Section 1207.8.4).
8. To omit fire suppression from walk-in units and BESS other than walk-in units that are not on levels open to the sky in open parking garages (CFC Section 1207.9.4).

CFC requires that large-scale fire testing is conducted on a representative BESS in accordance with UL 9540A. When a UL 9540A test is required, the testing must be conducted or witnessed and reported by an approved testing laboratory (e.g., NRTL or ISO 17025 accredited). The test report must be provided to the AHJ in accordance with CFC Section 104.8.2. In accordance with CFC Section 104.8.2, the test report must analyze the fire safety properties of the design and recommend necessary changes, and the fire code official can require the test report to bear the stamp of a registered design professional. NFPA 855 Section 9.1.5.2.2 further states that the test report must be accompanied by a supplemental report prepared by a registered design professional with expertise in fire protection engineering that provides an interpretation of the data in relation to the installation requirements. The NFPA 855 requirement for a supplemental report assists the AHJ in determining the acceptability of any exceptions

It is recommended that San Diego County utilize CFC Section 104.8.2 as needed to require a report prepared by a licensed fire protection engineer to accompany UL 9540A test data to support any modification to CFC language based on large-scale fire testing.

The requirement that large-scale fire testing is performed on a representative BESS is important to ensure that test results are utilized appropriately. NFPA 855 Section A.9.1.5.1.3 states the following:

Changes in an installation configuration, including the internal architecture of modules and units, that don't match the parameters tested, such as size and separation, cell type, or energy density, should not be accepted unless it can be shown that the configuration provides equivalent results. For example, scaling such as height, depth, and spacing need to conform to the configuration of the test. Changes also might include multiple levels of units on top of each other, located on a mezzanine floor above, or back-to-back units. These configurations might not have been evaluated in the test.

It is recommended that the report prepared by a licensed fire protection engineer (see above) address any deviations of the final installation from the tested assembly. Any deviation should be qualified in the report as providing equivalent or more conservative results than the testing arrangement. If the report determines that any deviation cannot be justified, the test results should not be accepted as a means to deviate from CFC requirements.

In most cases for lithium-ion systems, UL 9540A test data will need to be provided at a minimum at the cell, module, and unit level. The performance criteria at the cell level test require that thermal runaway cannot be induced in the cell, and both the cell and module level criteria include that the cell vent gas is not flammable. Since there are currently no known lithium-ion cells where thermal runaway cannot be induced and where vent gas is not flammable, all lithium-ion systems would require a unit-level test.

UL 9540A test reports should be provided for all stages of testing that were required. For example, if unit level testing is required, then cell and module level test reports should also be provided.

Further information is provided on UL 9540A testing in Appendix A of this report.

2.2.2 UL 9540A Limitations

The hazards associated with BESS are widely acknowledged, but the stochastic nature of battery failures creates significant variability in both the types of failures (e.g., venting, flaring, burning, explosion, fireball) and their durations. Moreover, real-world incidents often involve failure modes that differ from those tested in standardized tests like UL 9540A, making it challenging to establish a well-defined design basis. These challenges, combined with a lack of statistically significant data, can complicate efforts to consistently define the hazards involved. UL 9540A testing is often the key to the regulatory framework for allowing larger installations, reduced separation distances, and for the design of suppression and explosion control systems. Therefore, it is important that limitations are understood and, ideally, addressed.

When there is a failure of a BESS unit, flaming combustion may or may not occur which leads to two distinct hazard conditions. When flaming combustion is present, there is a risk for rapid propagation and a large fire, which creates exposure hazards for adjacent BESS units, buildings, occupants, and other exposures. The lack of flaming combustion combined with confinement of flammable gases can create a deflagration hazard.

It has been observed that the UL 9540A testing process almost always ends at the unit level stage when the performance criteria are met. This would require that flaming outside the unit is not observed, and that target unit temperatures do not exceed the temperature of cell venting (among other requirements). The ability of a system to meet these criteria would indicate that a true "large-scale fire" is not actually being induced during the testing process. Even so, UL 9540A indicates that a unit level test is considered a "large-scale" fire test:

Unit-level testing corresponds with the testing anticipated by fire codes and energy storage system codes to evaluate the large-scale fire and fault condition performance of BESS units installed in a building, walk-in container, or similar structure.

Therefore, although UL 9540A is technically considered to meet the requirements of a large-scale fire test and, therefore, can, by code, be used to create exceptions, caution should be practiced in the interpretation of test results.

Additionally, the nature of UL 9540A leads to data with limited statistical significance. Except for a portion of the cell level test that is performed four times (determination of vent temperature and thermal runaway temperature), only a single test is required at each stage. Information that is gathered for use in explosion hazard mitigation, including gas volume and composition, are collected from a single test. There is also subjectivity involved in the selection of the location of initiating cells and modules and the length of time external heating is applied [4].

2.2.3 Possible Future Requirements

The industry and the technical committee of NFPA 855 have been working on closing the gap between real-world incident scenarios and UL 9540A. Appendix G.12 in the next edition of NFPA 855 will provide guidance on LSFT. The provided guidance is aimed at evaluating the fire and explosion hazards associated with BESS, focusing on steps for testing the propagation of thermal runaway, fire exposure, and the interaction of vented flammable gases under various conditions. Key items will include intentional ignition of vent gases, evaluating thermal exposure risk to adjacent units, and fire impact on critical safety systems and communications.

The test setup should mirror the intended installed configuration of the BESS. Systems for fire protection and thermal runaway mitigation may be active in target enclosures, but they are required to be disabled in the enclosure of origin where only passive features are emphasized by the test.

While detailed prescriptive requirements are not available yet, any LSFT data, in addition to UL 9540A test reports, is seen as valuable and should be provided to the AHJ. LSFT is an important element in assessing the adequacy of passive mitigation measures such as separation distances.

2.2.4 Separation Distances

Proper separation of BESS units is an effective method of reducing the overall fire size and event time. UL 9540A assesses BESS separation distances in both the unit and installation level tests. However, installation level tests were rarely completed in the past if the performance criteria of the unit level test were met.

Units are required by the CFC to be separated by 3 feet between each group with a maximum stored energy of 50 kWh per group. In many indoor installations, a unit may be considered a single battery rack, and UL 9540A testing will be used to demonstrate that a reduced separation between racks is acceptable. The report required in Section 2.2.1 should evaluate whether the installation is in accordance with test data, including that any back-to-back, stacking of units, etc. found in the proposed installation was addressed as part of the testing.

It is recommended that the report required in Section 2.2.1 assess the proposed installation conditions compared with test data where separation distances are reduced. This assessment should include consideration for orientation of units including stacking or back-to-back units.

Determining spacing for outdoor BESS cabinets can be difficult as many systems do not perform a test with a fully involved fire within a cabinet. In many cases, cabinet BESS testing will consist of "unit level" testing solely on the racks that will be found within the cabinet. This test data is then used to justify the spacing of racks within the cabinet enclosure to the distance tested, with no data made available for the distance between the cabinets holding these "units". UL 9540A testing already has limitations as a large-scale fire test (as covered above) and does not require that vent gases are ignited, and fire is induced. In fact, UL 9540A only considers a single failure mode, whereas a real-world incident could be triggered by something different. This type of testing is also not representative of the installed conditions, which may impact the ability of a fire to propagate (for example, creating confinement in a cabinet could lead to increased heat transfer to adjacent units rather than to surrounding air). For this reason, best practice would require spacing for these systems based on testing showing that combustion of one cabinet does not result in propagation to adjacent cabinets. This requirement would provide a greater level of confidence that an outdoor BESS event will be contained to a single unit.

While some manufacturers are already voluntarily performing tests to assess the spacing of cabinets, future standards, and regulations are expected to make it mandatory (as discussed in Section 2.2.3). In the meantime, other processes should be in place to determine the spacing of units where testing is lacking, and additional mitigation methods, such as fire barriers or planning for manual firefighting, should be considered for each installation. Factory Mutual Insurance Company (FM) has performed several fire tests on lithium-ion battery arrangements. Factory Mutual Data Sheet (FMDS) 5-33 provides the recommendation that containers with NMC cells are separated by at least 13 feet and those with LFP are separated by at least 5 feet when test data showing propagation cannot occur is not provided. Additionally, codes require 10 feet spacing from BESS to adjacent exposures. This separation distance may be appropriate when lacking test data, but incident data has also shown that a fire can propagate across 10 feet if sufficient time is given. Fire modeling may also be performed to justify separation distance. Good engineering judgment is required when creating representative models of fire size without test data. In the best case, the fire size is modeled from FSFT data and for various wind conditions.

It is recommended that spacing for outdoor BESS in containers is based on fire testing, and propagation is assessed from container to container. If such testing is not performed, spacing should be evaluated through another method, and consideration for additional protection (such as fire barriers) should be part of the HMA.

2.3 HAZARD MITIGATION ANALYSIS (HMA)

The CFC currently requires an HMA to be performed under the following conditions (CFC Section 1207.1.6):

+ ESS technologies not identified in CFC Table 1207.1 are provided. See below for additional technologies that are now covered by IFC and NFPA 855.
+ More than one BESS technology is provided in a room or enclosed area where there is a potential for adverse interaction between technologies.

- NFPA 855 and IFC have the same requirement for a single fire area (i.e. fire barriers would be required to separate technologies with adverse interactions, or an HMA is required).

+ Where allowed as a basis for increasing maximum stored energy. See Section 2.3.1 of this report.

The IFC and NFPA 855 include the following additional conditions that warrant an HMA:

- Where required by the fire code official to address a potential hazard with a BESS installation that is not addressed by existing requirements (IFC Section 1207.1.6 and NFPA 855 Section 4.4.1)
- Where required for existing lithium-ion battery BESS systems that are not UL 9540 listed (NFPA 855 Section 4.4.1). See Section 3.3 of this report.
- Where required for outdoor lithium-ion battery BESS systems (NFPA 855 Section 4.4.1).
- NFPA 855 Section 9.5.2.1 states that an HMA is required for outdoor, open parking garages, rooftop, and mobile BESS installations that utilize lithium-ion batteries.

NFPA 855 and the IFC have also added requirements to address the following BESS technologies that are not covered by the CFC:

- Nickel-zinc batteries
- Sodium nickel chloride batteries
- Zinc manganese dioxide batteries (IFC only)

The CFC would technically require an HMA to be prepared for nickel-zinc, sodium nickel chloride, and zinc manganese dioxide batteries since they are not in CFC Table 1207.1.1. However, it is recommended that NFPA 855 or IFC requirements are followed in lieu of an HMA.

Where an HMA is required, it should be performed in accordance with the recommendations in the following subsections or other industry-accepted methods.

A hazard mitigation analysis is not a substitute for verification of the proper design of each individual safety system. Safety systems should be verified as meeting the applicable design requirements on their own. For example, the fire alarm system should be verified separately as meeting the requirements of NFPA 72.

2.3.1 Maximum Stored Energy (MSE)

The term MSE, as used for BESS, should not be equated to a maximum allowable quantity that is used to determine Group H occupancy requirements (the CFC refers to this term as “Maximum Allowable Quantities” or MAQ.). This distinction has been clarified in the 2024 edition of the IBC in Table 307.1.1, and BESS is included in the F-1 occupancy classification. MSEs for BESS are used as a threshold for requiring a HMA and large-scale fire testing.

The following MSE are provided by the CFC based on battery technology type:

- Flow batteries: 600 kWh (not specifically addressed by this report)
- Lead-acid, Ni-MH, Ni-Cd: unlimited
- Lithium-ion: 600 kWh
- Other battery technologies: 200 kWh
  - Recommended that NFPA 855 and 2024 IFC unlimited MSE is used for nickel-zinc.
  - Recommended that NFPA 855 and 2024 IFC 600 kWh MSE is used for sodium nickel chloride.

MSE for BESS are applicable to all installation location types except for the following:

+ Dedicated-use buildings (CFC Table 1207.7)
+ Remote outdoor installations (CFC Table 1207.8)

Therefore, an HMA is not required by the CFC for these types of installations unless a BESS technology not identified in CFC Table 1207.1 is provided or multiple BESS technologies are provided in an area where there is potential for adverse interaction between technologies. **However, since remote sites and dedicated use buildings may still have personnel on site, and dedicated use buildings may be located near exposures, it is recommended that an HMA is provided for all installations with lithium-ion BESS exceeding 600 kWh.**

2.3.2 Product Level Safety Analysis

Manufacturers or integrators of BESS that are listed in accordance with UL 9540 are required to provide a safety analysis, such as failure modes and effects analysis (FMEA). This safety analysis is intended to identify critical safety components of the system and consider interactions of components that provide a safety function. This safety analysis is performed as part of the evaluation of a system to UL 9540 and is reviewed by the qualified testing laboratory.

It is recommended that the product level safety analysis is provided to San Diego County during the review process for familiarity and understanding of the BESS. However, this analysis is already reviewed during the UL 9540 listing process and is provided for informational purposes.

2.3.3 Installation-Level HMA Process

As addressed in Report Section 2.3.2, UL 9540 listed BESS are required to have a product level safety analysis performed. This safety analysis is different from the HMA required by the CFC, IFC, and NFPA 855. The HMA being produced in accordance with the CFC for a UL 9540 listed BESS should address the required failure modes associated with installation-specific hazards and equipment.

The normative portions of NFPA 855, as well as the CFC and IFC, provide only basic requirements for failure modes and outcomes that are to be addressed by an HMA. NFPA 855 Appendix G and the EPRI document “ESIC Energy Storage Reference Fire Hazard Mitigation Analysis” provide significant guidance on the HMA process for a facility.

The HMA should consider the following (NFPA 855 Appendix G.3.3):

+ General inputs, including codes, standards, regulations, best practices and guides, design documents, and stakeholder inputs.
+ Project-specific inputs, including the following:
  - Energy capacity and power
  - Personnel/life presence:
    - Unattended/remote
    - Manned but unoccupied
    - Unoccupied but in populated areas

    - Occupied space
    - Ambulatory space
- Energy types and volatility
- Plant layout and geographic location
- Equipment availability/redundancy
- Availability of water supply
- Capability of first responders
- Storage configuration
- Historical loss information/lessons learned/fire reports
- Additional environmental considerations

Project specific inputs may drive the need to consider additional failure modes, different barriers, or different approval criteria beyond those that are required by the CFC, IFC, or NFPA 855. Examples that are applicable to San Diego County include the following:

+ Flame impingement due to wildfires.
+ Seismic events.
+ Potential for site to be located near highly populated areas or sensitive populations.

During discussions prior to preparation of an HMA (ideally) and/or during the review process (if not addressed prior), the authority should assess whether sufficient considerations for site-specific conditions are made.

The method utilized for the hazard mitigation analysis is required to be approved by the AHJ. The method selected should be assessed for its compatibility with the following aspects, at a minimum:

+ Method is understandable by the intended audience. For code-required installation level HMA's, the AHJ should be considered the intended audience.
+ Sufficient information is available for the method to be useful/accurate. Quantitative analysis requires failure and safety data that may not be available for emerging technologies.

For example, a bowtie analysis is commonly used as it is a qualitative analysis that can summarize the results of the HMA in diagrammatic nature that is relatively easy to understand. Bowtie analysis is an industry-accepted tool utilized in other industries [5]. Other methods should also be considered acceptable when provided with justification and it is recommended that the method is approved by the AHJ prior to preparing the HMA.

2.3.4 Failure Modes

A hazard mitigation analysis is required by the CFC Section 1207.1.4.1 to evaluate the following failure modes:

+ A thermal runaway condition in a single BESS rack, module, or unit.
+ Failure of any battery (energy) management system.
+ Failure of any required ventilation or exhaust system.

+ Voltage surges on the primary electric supply.
+ Short circuits on the load side of the BESS.
+ Failure of the smoke detection, fire detection, fire suppression, or gas detection system.
+ Required spill neutralization not being provided or failure of a required secondary containment system. *Note: This is not applicable to lithium-ion systems.*

These failure modes differ from NFPA 855 and IFC, which require only the following:

+ A thermal runaway or mechanical failure condition in a single BESS unit.
+ Failure of an energy storage management system or protection system that is not covered by the product listing FMEA.
+ Failure of a required protection system including, but not limited to, ventilation (HVAC), exhaust ventilation, smoke detection, fire detection, fire suppression, or gas detection.

As addressed in Report Section 2.3.3, additional failure modes may need to be included based on project specifics. Failure modes, in general, lead to propagating cell failure that causes off-gassing and, ultimately, either a fire or explosion hazard.

The CFC states that only single failure modes are considered. However, the failure of a single safety system (such as a suppression or explosion control system) during a thermal runaway event should be evaluated. The failure of multiple safety systems at the same time, or the loss of normal power to a safety system during a thermal runaway event would be considered a dual fault condition and is not required.

In addition to the minimum required failure modes above, it is important that the HMA incorporates all other credible failure mode scenarios. This shall require a deflagration hazard study and a heat vent capacity analysis.

2.3.5 Layers of Protection/Barriers

Layers of protection/barriers are components of the BESS or installation that prevent the failure from occurring, limit the extent of damage from failure, and help cope with any effects of the failure. The method used for the HMA will drive how these protection methods are presented and considered. Regardless of the method used, these layers of protection act as the bridge between the failure modes and meeting the approval criteria.

Where the author of the HMA finds that insufficient protection is provided to meet the analysis approval criteria, additional protection measures should be recommended.

2.3.6 Recommendations

The HMA may make recommendations for additional protection measures that were not proposed to be provided or are not required by the CFC in order to meet the analysis approval criteria. These recommendations are required to be installed, maintained, and tested in accordance with nationally recognized standards and specified design parameters (CFC Section 1207.1.4.3).

2.3.7 Analysis Approval

The CFC provides the following approval criteria for the HMA (CFC Section 1207.1.4.2). Each approval criteria have clarification for types of installations for which the criteria are applicable:

+ Fires will be contained within unoccupied BESS rooms or areas for the minimum duration of the fire-resistance-rated separations.

- Not applicable to outdoor installations. Applicable to dedicated use buildings where adjacent incidental uses are present. Applicable to all other indoor installations.

+ Fires in occupied work centers will be detected in time to allow occupants within the room or area to safely evacuate.

- Only applicable to occupied work centers.

+ 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.

- Applicable to indoor installations. Applicable to outdoor installations where a building occupants' path of egress to a public way may be affected.

+ Flammable gases released from BESS during charging, discharging, and normal operation will not exceed 25% of their lower flammability limit (LFL).

- Applicable to chemistries that release flammable gases under these situations. See CFC Table 1207.6 for chemistries requiring exhaust ventilation.

+ Flammable gases released from BESS during fire, overcharging, and other abnormal conditions will be controlled through the use of ventilation of the gases, preventing accumulation, or by deflagration venting

- Applicable to all installations.

+ The deflagration hazard analysis demonstrates that explosions can be prevented or mitigated.

2.3.8 Additional Considerations

Additional considerations for the site-specific HMA to address are found throughout the report and should be included as applicable for each site.

2.4 SITE REQUIREMENTS

It is recommended that a detailed site plan that includes the key considerations found in the following sections is provided for each BESS installation.

2.4.1 Fire Apparatus Access Roads

Fire apparatus access roads are required for all installations and must comply with CFC Section 503 and the SD County Consolidated Fire Code (CoFC). The fire apparatus access road is required to meet the following:

+ Road must extend within 150 feet of all portions of the facility including equipment (including BESS units) (CFC Section 503.1.1 and CoFC Section 503.1.1).

- Road must have an unobstructed with of at least 24 feet (CoFC Section 503.2.1(a)).
- Road must have an unobstructed vertical clearance of at least 13.5 feet (CFC Section 503.2.1 and CoFC Section 503.2.1(c)).
- Dead-ends in excess of 150 feet in length must be provided with an approved turn around (CFC Section 503.2.5 and CoFC Section 503.2.5).
- Road must be designed and maintained to support the loads of the fire apparatus and to provide all-weather driving capabilities (CFC Section 503.2.3 and see additional requirements CoFC Section 503.2.3)
- It is also recommended that the following considerations are made specifically for sites containing BESS:
- Location of road with respect to BESS enclosures or other equipment that may make access difficult or impossible during an incident.
- Consideration of prevailing wind direction on transportation of smoke and toxic gases that may make access to the site difficult or unsafe during an incident.

The fire code official also has the authority to make additional requirements where necessary to enhance fire or rescue operation or to meet public safety objectives of the jurisdiction (CFC Section 503.2.2). CoFC Section 503.1.1 provides an exception which allows for modifications or exemptions to fire apparatus access roads for solar photovoltaic power generation facilities. BESS may be provided at these facilities, and similar exceptions may also be warranted for remote BESS facilities. Where providing a fire apparatus access road in accordance with this section is exceedingly difficult, the applicant should contact the fire code official early in the design process to determine alternative solutions. If alternative solutions impact the fire department's response, these impacts should be addressed in the HMA and emergency response plan as necessary.

2.4.2 Water Supply

Water supply for BESS installation is not specifically addressed by CFC Section 1207. However, CFC Section 507 requires that “premises on which facilities, buildings or portions of buildings” are constructed, and an approved water supply is provided. Additionally, a water supply is required for all BESS facilities by NFPA 855 Section 9.6.3. Therefore, it is recommended that an approved water supply is provided for all BESS installations, including outdoor installations, unless otherwise approved on a case-by-case basis. NFPA 855 Section 9.5.2.5 indicates that fire suppression and water supply can be waived by the AHJ for remote locations.

The water supply is required to consist of reservoirs, pressure tanks, elevated tanks, water mains, or other fixed systems capable of providing the required fire flow (CFC Section 507.2). CoFC Section 507.2 indicates that the required fire flow is to be determined in accordance with CFC Appendix B or the Insurance Service Office “Guide for Determination of Required Fire Flow”. Appendix B and the guide are both geared toward fire flow requirements for buildings and should be used for indoor BESS installations. However, for sites that do not have any buildings, guidance for required fire flow is limited. It is recommended that the minimum fire flow requirement for buildings, which is 1,500 GPM in accordance with CFC Table B105.1(2), is provided for outdoor installations near exposures.

For sites that are equipped with a water supply with a limited quantity (such as a tank), exposure protection (if needed) by means other than water should be considered. It has been observed that BESS fires can extend for much longer than the durations required by CFC Table B105.1(2), and therefore, it is reasonable to assume that a water supply with limited quantity will be depleted while there is still an active fire when durations from the CFC are utilized. FMDS 5-33 provides further guidance on water supply duration.

For BESS installations in remote locations that do not have an existing permanent water supply, it may be acceptable to omit the requirement for a water supply. This strategy typically involves allowing the BESS unit to burn completely, provided that protective measures, such as adequate separation from other units, fire-resistant construction, and cooling mechanisms, are in place to prevent fire spread to adjacent units, buildings, and vegetation.

+ For installations with limited site spacing where the distance between BESS units and other exposure hazards is less than 10 feet, full-scale fire data should be provided to demonstrate that fire will not propagate to adjacent units.
+ Sites with combustible vegetation nearby pose a higher risk of wildfire, which should be considered in both the HMA and Emergency Response Plan (ERP).

Where an installation is proposed not to be provided with a water supply, the HMA should not include fire service response involving water-based suppression as a mitigation strategy. Additionally, the emergency response plan should provide guidance for any necessary fire service response without the use of water-based suppression. In cases where proper containment measures, such as those demonstrated in large-scale fire testing, show that fires can be effectively limited to the unit of origin, this may further justify the omission. However, it should be noted that this approach is only acceptable based on the site and system design and approval from local authorities.

2.4.3 Fire Hydrants

Where a portion of the facility (including outdoor BESS units) is more than 400 feet from a fire hydrant, on-site fire hydrants are required to be provided when requested by the fire code official (CFC Section 507.5.1). Additional fire hydrants may also be required based on the fire flow and spacing of existing fire hydrants in accordance with CFC Appendix C. When measuring distances to public fire hydrants, proposed fencing for the BESS facility should be considered if it will affect the ability to pull hoses to BESS locations. Additional private fire hydrants should be installed in accordance with the CFC when needed to meet these requirements.

2.4.4 Fire Department Connections

Fire department connections (FDCs) are required to be provided for buildings containing BESS that are provided with sprinkler systems. Fire department connections may also be used for BESS containers with an internal suppression system that is not connected to a permanent water supply (see Section 2.9 for more information). Where required, fire department connections must be installed in accordance with the standard applicable to the system they are designed for and CFC Section 912:

+ NFPA 13 for sprinkler systems in buildings
+ NFPA 24 is recommended for remote FDCs connected to BESS containers

2.4.5 BESS Buildings Distances from Lot Lines

Minimum distances from lot lines for buildings containing BESS should be determined by the greatest distance of the following as applicable:

+ CBC required distances based on exterior wall ratings and openings based on the occupancy classification.

- Dedicated use BESS buildings are considered Group F-1 occupancies

- ESS areas within non-dedicated use buildings should be considered F-1 occupancies (based on the IBC).

+ Distances based on the location of deflagration vents on exterior walls:

- 50 feet from lot lines for vents that are designed to release from exterior walls or roofs as required by CFC Section 911.2.

- 20 feet from lot lines for vents that remain attached to the building as required by CFC Section 911.2.

- Greater than the hazard zone as determined by NFPA 68 analysis. (See Section 2.8.4 of this report)

+ Distances based on the location of outlets venting flammable gases for exhaust ventilation systems and NFPA 69 explosion prevention systems.

+ Distances based on recommendations from site-level HMA or equipment manufacturer.

2.4.6 Outdoor BESS Distances from Lot Lines

Minimum distances from lot lines for outdoor BESS installations should be determined by the greatest distance of the following as applicable:

+ 10 feet as required by CFC Section 1207.8.3 unless reduced to 3 feet if a 1-hour free-standing fire barrier suitable for exterior use and extending 5 feet above and 5 feet beyond the physical boundary of the BESS installation is provided.

+ Distances based on the location of deflagration vents on exterior walls:

- 50 feet from lot lines for vents that are designed to release from exterior walls or roofs as required by CFC Section 911.2.

- 20 feet from lot lines for vents that remain attached to the building as required by CFC Section 911.2.

- Greater than the hazard zone as determined by NFPA 68 analysis. (See Section 2.8.4 of this report).

+ Distances based on the location of outlets venting flammable gases for exhaust ventilation systems and NFPA 69 explosion prevention systems.

+ Distances based on recommendations from site-level HMA or equipment manufacturers.

2.5 FIRE-RESISTANCE RATED CONSTRUCTION

Fire-resistance rated construction is utilized in BESS facilities in the following cases:

+ Two-hour fire barriers and horizontal assemblies are required to be provided to separate rooms and areas containing ESS in buildings from other areas (CFC Section 1207.7.4).

+ To reduce separation distances to exposures for outdoor installations. Separation distances can be reduced from 10 feet to 3 feet when a one-hour fire-resistance rated free-standing fire-barrier is provided that extends 5 feet above and 5 feet beyond the physical boundary of the ESS installation.

- As recommended by an HMA or when provided to slow or prevent propagation between ESS units.
- Provided as part of the construction of a container. This fire-resistance rating is not required but may be evaluated as a barrier to propagation as part of the HMA. Since many BESS are designed and constructed in other countries, the fire-resistance rating may be determined by a different standard than is required by the CBC (for example, an ISO standard rather than an ASTM standard).

Where fire-resistance rated construction is required or recommended by an HMA, it should be provided in accordance with the CBC:

- CBC Section 703: Fire-resistance Ratings and Fire Tests. Fire-resistance ratings are required to be determined by test methods (ASTM E119 or UL 263), analytical methods, or alternative methods.
- CBC Section 707: Fire Barriers. Fire barriers are required to be constructed in accordance with this section. This section includes requirements for continuity and protection of openings, penetrations, joints, and voids.
- CBC Section 711: Floor and Roof Assemblies. Where floor and roof assemblies are required to be rated, they must be constructed in accordance with this section.

2.6 DETECTION AND ALARM

2.6.1 Battery Management System

CFC Section 1207.3.1 requires an approved BMS to be installed to monitor and balance cell voltages, currents, and temperatures within manufacturer specifications. If potentially hazardous conditions such as overvoltage, undervoltage, shorts, or abnormal temperatures are detected, the BMS will automatically disconnect electrical connections or place the BESS into a safe mode. The BMS helps prevent the escalation of failures by monitoring that the system operates within safe limits and automatically takes corrective action when necessary.

2.6.2 Smoke and Fire Detection

CFC Section 1207.5.4 and NFPA 855 Section 9.6.1 require that approved automatic smoke detection systems or radiant energy-sensing fire detection systems (as compliant with CFC Section 907.2 and NFPA 72) must be installed in any rooms, indoor areas, or walk-in units containing BESS. However, for outdoor installations, whether near exposures or remote, fire detection systems may be required based on a Hazard Mitigation Analysis (HMA) to determine site-specific fire and explosion risks. If an outdoor BESS installation is in close proximity to other structures, buildings, or equipment (near exposure), detection systems are typically required due to increased fire spread risks. The fire detection requirement may be waived or adjusted based on the low risk posed by the remote or isolated location.

Radiant energy-sensing fire detection systems detect fires based on the detection of radiant energy emitted by flames. These systems typically consist of photodetectors that are sensitive to specific wavelengths of infrared (IR), visible, or ultraviolet (UV) radiation emitted by flames. Sensor arrays allow detectors to locate the angular position of the fire within the field of view. Radiant energy-sensing fire detection systems provide an advantage in covering large areas and distances, making them suitable for outdoor BESS installations such as open parking garages or rooftop installations.

According to NFPA 855 Section 4.8.3, smoke and fire detection systems protecting a BESS with lithium-ion batteries shall be required to provide a secondary power supply in accordance with NFPA 72 capable of 24 hours in standby and 2 hours in alarm. The HMA or deflagration evaluation study in conjunction with UL 9540A or fire and explosion test data is generally used to support the requirement for additional power supply backup above and beyond NFPA 72 requirements. This requirement applies to lithium-ion technologies because testing and actual events have shown that events can be several hours in duration. The additional backup will allow first responders to monitor situational conditions for longer periods of time.

2.6.3 Gas Detection

Gas detections are used to monitor the buildup of flammable gases such as hydrogen and activate ventilation systems when gas levels exceed safe limits. The detectors are typically set to trigger ventilation when the concentration reaches 10-25 percent of the LFL. particularly during thermal runaway or failure events. This is important both during normal charging and charging operations for some BESS, such as in lead-acid BESS, and during abnormal conditions or failure events in other BESS, such as lithium-ion BESS.

According to CFC Section 1207.6.1.2.4 and NFPA 855 Section 9.6.5.1.5.4, where gas detection is used to activate exhaust ventilation systems (in Section 2.7 of this report), a continuous and approved gas detection system must be installed in rooms, walk-in units, enclosures, walk-in containers, and cabinets containing BESS that comply with the requirements of these sections, including activation of ventilation, operation, standby power, and system alerts.

According to NFPA 855 Section 9.6.5.6.7, where gas detection is used for the purpose of explosion prevention (in Section 2.8 of this report), and based on an NFPA 69 deflagration study, the system must be installed in rooms, walk-in units, enclosures, walk-in containers, and cabinets containing BESS that complies with the requirements of these sections, including activation of ventilation, operation, standby power, and system alerts.

For lithium-ion BESS, a smoke detection system can be supplemented by a listed or approved off-gas detection system. Off-gas detection can increase the effectiveness of the smoke detection system for providing early response to an off-normal condition. Gas detection technology can also provide additional information on conditions inside the BESS enclosure.

2.6.4 Early Detection Devices

Early detection devices include those that monitor temperatures and off-gas at the cell, rack, or module level. These devices are intended to detect cell failures earlier than smoke or traditional gas detectors and are interlocked with the battery management system via relays. This may allow a BMS to electrically isolate the failed cell, module or rack, preventing the initial cause (i.e. short circuit) from causing cascading thermal runaway. However, these systems cannot prevent initial thermal runaway from occurring and will have no effect on thermal runaway that is caused by thermal abuse, physical damage, or manufacturing defects. Additionally, thermal runaway may still propagate throughout the system even once the system is electrically isolated due to the pressure and heat that is produced by the already failing cells.

While these systems can provide value in earlier detection, the implementation may be cost-prohibitive for the value-added, and therefore, it is not recommended that they are required for all systems.

Early detection devices may also be used to activate a direct injection battery rack coolant system (refer to Report Section 2.9.6) to provide suppression/cooling at the module level.

Early detection via the BMS and local temperature monitoring is currently being researched and may provide benefits, if it can be integrated into the general protection scheme.

2.6.5 Alarm and Notification

CFC Section 1207.5.4 requires that alarm signals from fire and smoke detection systems must be transmitted to a central station, a proprietary station, or a remote station service in compliance with NFPA 72. Alternatively, alarms may be sent to a constantly attended location, allowing the system to notify responders immediately when a fire or hazardous condition is detected.

In accordance with CFC Section 1207.5.4.1, where required by the fire code official, visible annunciation must be provided on the exterior of BESS cabinets or in other approved locations to indicate when potentially hazardous conditions exist within the BESS. The location and information provided should be covered by the emergency operations plan and evaluated as part of the HMA.

2.7 EXHAUST VENTILATION

Exhaust ventilation provided in accordance with CFC Section 1207.6.1 and the California Mechanical Code is required for technologies that release flammable gases during normal operation (see Section 1.5 for more information). Exhaust ventilation requirements found in CFC Section 1207.6.1 do not apply to lithium-ion batteries and should not be confused with an NFPA 69 explosion prevention system (see Report Section 2.8.5), although the concepts may require similar components.

2.8 EXPLOSION PROTECTION

The CFC requires that explosion control is provided for rooms, areas, and walk-in units that contain electrochemical BESS technologies. This requirement applies to all technologies covered by CFC Section 1207 and NFPA 855, with exceptions made in the following circumstances:

+ UL 9540A testing demonstrates that flammable gases are not liberated from the cells or modules.
+ Documentation is provided that demonstrates that the BESS technology does not have the potential to release flammable gas concentrations in excess of 25% of the LFL anywhere in the room, area, walk-in unit, or structure an explosion prevention system is not required.
+ When lead-acid and nickel-cadmium batteries are used at facilities under the exclusive control of communications utilities that comply with NFPA 76 and operate at less than 50 VAC and 60 VDC.
+ Lead-acid and nickel-cadmium batteries that are used for DC power for control of substations and control or safe shutdown of generating stations under the exclusive control of the electrical utility located outdoors or in dedicated use buildings (Only stated in NFPA 855).
+ Lead-acid battery systems in UPS listed and labeled in accordance with the application used for standby power applications and housed in a single cabinet in a single fire area in buildings or walk-in units (Only stated in NFPA 855).
+ Lead-acid and nickel-cadmium batteries listed in accordance with UL 1973 (Only stated in NFPA 855).

It should be noted that the first two exceptions are rarely met, if ever, for lithium-ion batteries, and scrutiny should be applied when reviewing projects utilizing these exceptions.

The CFC can be interpreted to indicate that BESS cabinets, which are commonly utilized for outdoor installations, do not need to be provided with an explosion protection system as it is not a room, area, or walk-in unit. However, NFPA 855 and some jurisdictions (such as APS Appendix W and the New York State Working Group), have clarified that explosion prevention systems are required for cabinet-style BESS.

Explosion protection shall be provided for BESS cabinets in the form of an explosion prevention system (e.g., NFPA 69) and/or deflagration venting (e.g., NFPA 68). The HMA shall demonstrate which explosion protection approach is most suitable for the installation. This will likely require testing or modeling. The technical basis report for the explosion protection measures shall be provided to the AHJ for review and approval.

Where required, explosion protection systems are required to comply with CFC Section 911, which allows for an NFPA 68 or NFPA 69 system.

These two types of explosion protection options for ESS, NFPA 68 deflagration venting and NFPA 69 exhaust ventilation, are based on a design basis determined from UL 9540A test data. This data can provide a baseline for the analysis, but generally needs to be extrapolated and supplemented with literature data to develop a sufficiently conservative hazard scenario for the BESS installation.

2.8.1 Deflagration Venting

Deflagration venting is a passive protection measure that is designed to minimize damage by maintaining the enclosure's structural integrity. This is achieved by utilizing deflagration vent panels that activate at a pressure lower than the strength of the enclosure. The basis for the empirical models prescribed by NFPA 68 for calculating deflagration vent area are from experiments that are primarily relevant to the process safety industry and not BESS. For example, the experiments involved enclosure designs that do not resemble modern BESS enclosures with large battery racks. Typically, the hazards in these experiments involve a single flammable gas, unlike the mixture of flammable and non-flammable gases observed during a Li-Ion cell thermal runaway. In addition, the prescriptive methodology does not consider the dispersion of battery gas in the enclosure, and the resulting vent areas are based on homogeneous stoichiometric gas clouds. Computational Fluid Dynamics (CFD) models such as FLACS [6] can address the dispersion of battery gas along with explosion analysis. However, these models also lack a validation dataset directly applicable to BESS applications. Finally, this methodology requires deflagration to activate the panels, leading to battery gas accumulation if ignition does not occur.

2.8.2 Explosion Prevention

An explosion prevention system for BESS is typically composed of a mechanical exhaust system, which is activated upon detection of flammable gas to reduce the concentration of the flammable battery gas below 25% of the LFL. This is an active system that requires detailed design analysis, the use of reliable components, and regular maintenance. It is also referred to as Combustible Gas Reduction System (CGRS). All components involved in the detection and ventilation of combustible gas are considered part of a safety critical system. CFD analysis testing may be necessary to capture the densities of different failure scenarios on the system design (e.g., failure location with respect to detection delays and flow momentum effectiveness).

The success of this approach depends on each aspect of the sequence of events operating as per design. If equipment maintenance is neglected, components may fail and lead to the exhaust ventilation system not activating during a failure event. Backup power is also a requirement for ensuring system availability during a failure event, but the duration can be difficult to define due to the stochastic nature of the failure. Designing an NFPA 69 system requires the release rate of battery gas, which is the most significant design input needed to size the exhaust fans. However, there is no standardized methodology to calculate this parameter, and it is not directly provided in the UL 9540A test report. A typical approach to determine this parameter is to perform an engineering analysis of UL 9540A test data and supplement it with literature data, if necessary. For most systems, the data available lacks statistical significance, and practitioners need to be cognizant of deficiencies in test methodologies to ensure the design basis is sufficiently conservative. NFPA 69 requires that the system design be reviewed by a qualified person acceptable to the facility's AHJ.

It is recommended to review the technical basis report, maintenance plan, and flow test data that validate that the system functions as designed.

2.8.3 General Application

In general, using deflagration venting as passive explosion protection in addition to an active system has multiple benefits due to the nature of the battery failure event, which involves a rapid release of flammable gases. Exhaust ventilation normally depends on the detection of battery gas, but the accumulation of gas could cause a deflagration before the system fully activates. In addition, even with an active exhaust ventilation system, a thermal runaway event in a BESS can still result in a localized high concentration of flammable gas in certain zones that may be difficult to ventilate such as dead spots or stagnation areas. The above highlighted issues are further aggravated by rapid innovations in the BESS industry which is witnessing a rapid increase in the energy density of individual cells. This higher energy density can lead to a greater volume of flammable gas being released into the enclosure over a short period of time during a failure event. This makes it difficult to keep the global gas concentration below 25% of the LFL within containerized systems, particularly prior to exhaust fan activation. For indoor applications, this challenge is usually not significant because of the larger free air volume which provides dilution. This in turn results in a slower increase of combustible concentration and provides longer reaction times. Thus, having a passive system (i.e. deflagration vent panels) to address the residual explosion hazard is beneficial by providing additional protection for a container.

It is recommended that BESS located within buildings are provided with an active explosion protection system, and optionally in combination with deflagration vents.

Buildings may be best protected with an active explosion prevention system (e.g., NFPA 69). This is due to the fact that most indoor applications have large volumes of dilution air. In this case, it will take some time for combustible gas concentrations to become flammable. This will allow time for the removal of such gases and the reduction of combustible gas concentrations. Special attention must be given to areas (or pockets) where flammable gas could accumulate in higher concentrations. Should the deflagration study and HMA indicate that concentrations above 25% of the LFL could form quickly (e.g., in small modular buildings), a passive explosion protection system in the form of deflagration vents may also be required.

As with any life safety system, proper design, reliability of components, and maintenance are key to success for any explosion protection system. General best practices for any explosion protection system are as follows:

+ The protection design demonstrates that deflagrations will not propagate to interconnected or adjacent cabinets, enclosures, or rooms (NFPA 855 Section 9.6.5.6.9).
+ The system will be survivable up to the point at which fire occurs. For example, detection systems should be capable of operating in an environment that would be expected during thermal runaway conditions.
+ The system will operate as intended regardless of the location of the initial failure, including consideration for compartmentalization within the enclosure (e.g. hot and cold aisles) as applicable.

- Environmental effects on the longevity of components should be addressed in the selection. For example, corrosion may be a point of concern for deflagration vents, louvers, and fans in San Diego County, particularly in locations that are closer to the ocean.
- Environmental effects on the ability of components to operate should be considered in the selection. Where components are located outside of the enclosure or building, their ability to operate in the range temperatures and other climatic conditions should be assessed. Additionally, in areas of the County subject to freezing temperatures and snow, the need to remove ice and snow from components should be addressed in the design and maintenance of systems.

2.8.4 NFPA 68

NFPA 68 is one of the two prescriptive options for compliance with CFC Section 911 for ESSs and addresses Deflagration Venting as discussed in Report Section 2.8.1 above. NFPA 68 designs consist of deflagration vents which are used to relieve the pressure wave created by a deflagration event. This relief protects the structure housing the BESS and prevents hazardous ejections of components of the BESS or enclosure.

NFPA 68 has an option for performance-based design in Chapter 5, which is not addressed in detail in this report. However, the performance-based design should be reviewed and indicate that the intent of the prescriptive design requirements is met.

It is recommended that when a deflagration venting system is provided in accordance with NFPA 68, it is accompanied by a report prepared by a registered fire protection engineer outlining the information found in these sections and compliance with NFPA 68.

2.8.4.1 Acceptability of Method

Deflagration venting may be considered acceptable when the fireball size and blast wave threats to nearby buildings or people are assessed and found to be acceptable. The fireball dimensions are required to be evaluated in accordance with NFPA 68 Section 7.6 and should be accounted for in the distances from exposures, means of egress, and lot lines. When the distances cannot be met, a deflector may be designed in accordance with NFPA 68 Section 6.6.2.

The ability to provide sufficient vent area should be assessed. High proportions of hydrogen in the vent gas may lead to vent areas that are larger than the area that is available for vents.

2.8.4.2 Strength of Enclosure

A key component of an NFPA 68 design is consideration of the room or enclosure strength and is required by CFC Section 911.2 Item 1 and NFPA 68 Section 6.3. CFC Section 911.2 Item 1 requires that the enclosure strength can withstand an internal pressure of 100 pounds per square foot (psf). NFPA 68 requires that the enclosure strength that is used to calculate the reduced pressure of a vented deflagration is based on the strength of the enclosure. Where deformation of the structure is acceptable, the ultimate strength of the enclosure may be used. When deformation cannot be tolerated, the yield strength is used. The weakest structural element must be identified when assessing the strength of the enclosure.

2.8.4.3 Gas Properties

The deflagration venting design should be based on the gas composition reported in the UL 9540A cell-level report. This test level occurs in a controlled environment and captures the vent gases more accurately than the module, unit, and installation level tests. In addition, cell-level testing occurs in a low oxygen environment which limits combustion and allows flammable gases to accumulate. The fundamental burn velocity and maximum explosion pressure should also be used from the cell-level report. Furthermore, the design analysis should assume stochiometric and well mixed conditions. A partial volume deflagration approach may also be acceptable, if it can be demonstrated with additional test data and engineering analysis that the expected gas release volume is limited (e.g., a finite number of cells undergo thermal runaway).

2.8.4.4 Release of Vents

The deflagration vents must be designed (including the manufacturer's tolerance) to release at a lower pressure than the intended reduced pressure for a vented deflagration. The vent must also be designed to withstand the expected wind loads required by the CBC. The CFC requires that vents are provided only in exterior walls or roofs unless a specially designed shaft is provided for venting to the exterior of the building.

2.8.5 NFPA 69

NPFA 69 is the second of the prescriptive options for compliance with CFC Section 911 and addresses Explosion Prevention as discussed in Report Section 2.8.2. Since the CFC does not reference a specific edition of NFPA 69, references in this report will refer to the 2019 Edition (edition in effect at time of CFC release). Specifically, for ESS, a combustible gas concentration reduction system (CGCRS) can be provided which is found in Chapter 8 of NFPA 69. NFPA 69 was not written specifically for BESS and the requirements are generic. The basic requirements of an NFPA 69 system as applicable to a BESS are as follows:

+ Combustible gas concentration is maintained at 25% of the LFL (as determined by UL 9540A test data)*. This limit is based on the total concentration of gases within the enclosure, not localized concentrations. The system remains on to ensure that the gas concentration does not increase.
+ CGCRS is activated by a gas detection system which activates at 10% of the LFL or less.
+ The gas detection system and the CGCRS are provided with a minimum of two hours of standby power. For lithium-ion systems, the gas detection system must be provided with 24 hours of standby power and two hours in alarm (or more, as required by HMA).
  - Standby power should not be provided by the BESS that is being protected.
+ Outlets from the protected enclosure must be located so that flammable gases are not drawn back into the building or enclosure through

*Concentration can be limited to 60% of the LFL when Safety Instrumented Systems (SIS) listed for explosion prevention or when safety integrity level 2 (SIL-2) components are used in accordance with NFPA 69 Section 15.5.1.1 (NFPA 69 Section 8.3.1).

It is recommended that when an explosion prevention system is provided in accordance with NFPA 69, it is accompanied by a report prepared by a registered fire protection engineer outlining the information found in these sections and compliance with NFPA 69.

2.8.5.1 Design Methodologies

A CGCRS should be designed and/or verified based on one of the following methods:

1. Full-scale testing of the system.
2. Computer-based CFD modeling.
3. Hand calculation methods or simple computational methods such as CONTAM.

The CFC does not directly state a method that is required to be used. However, NFPA 855 requires that deflagration mitigation measures that are designed into BESS cabinets are evaluated as part of fire and explosion testing. Therefore, it would be considered best practice, although not currently required by the CFC, for a BESS cabinet with an NFPA 69 system to be evaluated by full-scale testing of the system.

Ideally, full-scale testing would be performed for any installation as this will most closely represent the situation that the system is operating under. When full-scale testing is used, a test plan should be developed prior to testing to determine the appropriate scenarios to be tested.

Where full-scale testing is performed, the test plan, actual procedures used, and all-relevant data collected should be summarized in a report for review by the AHJ. This report should indicate enough information to assess that sufficient testing was performed to determine reasonable worst-case test scenarios and to summarize the outcomes. Additionally, the test report should indicate sufficient information on the test layout so that the final installation can determined to be representative of what was tested.

Where full-scale testing is not performed, computer-based CFD modeling can be performed. A CFD model has a better ability to assess effects such as the locations of the gas detectors, the location of the gas release, the location of exhaust fans and return air grilles, and density of gas on system performance than hand calculations. CFD modeling should account for any fixed objects in the enclosure including battery racks, ductwork, and other equipment. The model should also account for the effects of HVAC systems which may influence detection times. The gas release rate and release velocity are two key parameters required for understanding the dispersion characteristics and sizing the exhaust fan for NFPA 69 analysis. Assumptions and limitations shall be provided in selecting these parameters as they are not directly provided by the UL 9540A test data running which may influence detection times.

In some situations, a simpler design methodology may be sufficient. This includes situations where there is sufficient justification in the analysis report that the gases within the space will be well mixed. Where this is the case, one of the following methods may be utilized:

+ Hand calculations: A volume-in, volume-out approach using a steady-state gas release. A gas release rate in CFM is determined based on extrapolating UL 9540A data and fans are sized to exhaust the same or greater rate.
+ Computer model: A gas release curve can be used to model the rate of gas released (extrapolated from UL 9540A results), and detection time can be simulated to model time where exhaust fans begin running. The model can track the overall the concentrations within the room over time but does not directly assess effects of locations of detectors, locations of fans, and locations of gas release.

Hand calculations and simple computer models are typically not appropriate for enclosures with limited free air volume and high degrees of obstructions. Where hand calculations or computer modeling are used, the designer should provide justification with the analysis that the method selected is appropriate for the installation.

2.8.5.2 Gas Detection System

When the CGCRS is activated by a gas detection system within the enclosure containing the ESS, the following apply to the gas detection system (NFPA 855 A.9.6.5.6.6):

+ Gas detectors should be listed to an appropriate standard such as UL 2075 or FM 6325.
+ Detected gas should be a gas that will be generated in high enough quantities during a thermal runaway event. Hydrogen is a common gas, although other gases may also be appropriate. Selection can be aided by studying the cell gas composition from UL 9540A testing. Detectors should also be able to sense an appropriate range of concentrations (at a minimum 10% of the LFL to 100% of the LFL).
+ Response time should be considered when selecting a gas detector. This includes factors such as the location/number of detectors which increases distances gas must travel, length of sampling tubes, analysis time, etc. Early detection is key and therefore response time should be as low as feasible and cost effective. NFPA 855 indicates a range of 1-3 minutes.
+ Both HVAC ON and OFF scenarios should be considered to quantify the dispersion of the gas within an enclosure before detection. This can vary significantly depending on the installation. Since installations require ventilation to cool batteries, it is possible to place gas detectors in ducts in some scenarios for smaller installations where gas will be drawn into ductwork quickly. In outdoor, containerized systems, the method of cooling will need to be considered, along with how this affects free air volumes and airflows within a container.
+ The ability of a sensor to misread or fail from cross-contamination should be considered. The gases that are produced during a fire or thermal runaway situation should be considered as well as gases that may be present in the ambient environment.
+ The required maintenance including calibration, bump testing, and sample tube cleaning should be considered and communicated to end users. It may be more desirable and cost effective to select a detector that requires less frequent maintenance. This may also contribute to a reduced reliability if maintenance is not performed as often as required.

The gas detector and layout should be selected based off data from UL 9540A testing and any findings from the design analysis in Report Section 2.8.5.1.

The gas detection system should be monitored by the fire alarm control panel located within the building or site, which is monitored by a central, proprietary, or remote station in accordance with NFPA 72. NFPA 855 requires that a trouble signal is transmitted upon failure of the gas detection system and an alarm signal is transmitted when the flammable gas concentration exceeds 10%. The HMA should consider the failure of the gas detection system as a failure mode and any recommendations made in the HMA should be accounted for in the design.

2.8.5.3 Residual Explosion Hazard

NFPA 69 systems are required to maintain the average concentration of flammable gases in the enclosure below 25% of the LFL. This prevents a deflagration involving the full volume of the enclosure. However, there may still be localized concentrations that exceed 25% of the LFL and in some cases, that exceed 100% of the LFL. Hence, the NFPA 69 approach reduces the likelihood of a deflagration but does not fully eliminate it. It should be noted, however, that the residual explosion hazard would likely result in a less severe incident. If the

HMA finds that there is a credible residual explosion hazard, this should be addressed in accordance with NFPA 68.

Clean agent suppression systems shall be carefully evaluated in the NFPA 69 design. Clean agents may have a higher density than air and could temporarily disable the NFPA 69 system. This is due to the clean agent blanketing the volume with a heavy layer, which could be difficult to exhaust, thus, delaying the removal of flammable gases.

2.8.5.4 Manual Venting

Although not currently required, it is recommended that the ability to manually activate the CGCRS is provided at a remote location.

2.8.6 Alternative Methods

Explosion control is required by CFC Section 1207.6.3 to comply with CFC Section 911, which allows for explosion control in accordance with NFPA 68 or 69 (see previous sections for further information). However, as stated in NFPA 855 Section A.9.6.5.6.3, it is recognized that some cabinets are designed with low internal volume that makes the application of NFPA 68 or 69 difficult. NFPA 855 includes the option to provide an engineered system that meets the following requirements to be installed in lieu of an NFPA 68 or NFPA 69 system:

+ The design ensures that no hazardous pressure waves, debris, shrapnel, or enclosure pieces are ejected.
+ The design is validated by installation level fire and explosion testing and an engineering evaluation complying with NFPA 855 Section 9.1.5. This engineering evaluation would require to be provided by a registered design professional with expertise in fire protection engineering.

The 2024 Edition of the IFC has also added an exception to Section 1207.6.3 which is similar to the exception in NFPA 855. However, the exception in NFPA 855 is much clearer that the design must be validated as part of an installation level UL 9540A test and that test results must be accompanied by a report prepared by a registered design professional.

It is recommended that alternative methods of explosion control are allowed for BESS cabinets when provided in accordance with NFPA 855 Section 9.6.5.6.4.

2.9 FIRE SUPPRESSION

CFC requires fire suppression for rooms, areas, and walk-in units in accordance with Section 1207.5.5. Where suppression is required, the CFC allows the following types of systems:

1. An automatic sprinkler system designed and installed in accordance with NFPA 13 with a minimum density of 0.3 gpm/ft^2 over the fire area or 2,500 square feet, whichever is smaller.
2. An automatic sprinkler system designed and installed in accordance with NFPA 13 with a sprinkler hazard classification based on large-scale fire testing.
3. Alternative fire suppression systems designed and installed in accordance with CFC Section 904, their respective standard, and based on large-scale fire testing. The includes the following types of systems:
    a. Carbon Dioxide Extinguishing Systems (NFPA 12)

b. Fixed water spray (NFPA 15)

c. Water mist (NFPA 750)

d. Clean agent fire extinguishing systems (NFPA 2001)

e. Aerosol fire extinguishing systems (NFPA 2010)

Where a sprinkler system is provided, CFC Section 1207.5.5 requires a density of 0.30 gpm/sq. ft. over the fire area, or 2,500 sq. ft., whichever is less. However, NFPA 855 Section 4.9.2 requires that groups of BESS that exceed 50 kWh must use a density based on large-scale fire testing (typically UL 9540A, Installation Test Method 1). In many cases, BESS tested in accordance with UL 9540A will only be tested through the unit level test and therefore will not have an installation level test to assess sprinkler density.

Refer to Report Section 2.2 and Appendix A of this report for more information on UL 9540A testing and testing of alternative suppression systems.

Water based suppression systems is usually the preferred choice for BESS applications, unless specific data exists that clearly demonstrates that alternative methods will be effective for the application (e.g., some BESS utilize clean agent injection systems that are part of their UL 9540A testing and UL 9540 listing).

Dedicated-use buildings that are located more than 100 feet from exposures are permitted to omit fire suppression systems when approved by the fire code official (CFC Table 1207.7 Note C and NFPA 855 Section 9.5.1.1.1). NFPA 855 Section 4.9.1.5 further requires that in order to omit suppression, large-scale fire testing must document that a BESS fire does not compromise the means of egress and does not present an exposure hazard to items other than electrical grid infrastructure. This is allowed as the risk to occupants and other buildings or exposures is already very limited in remote locations. Omission of fire suppression systems should be considered in both the HMA and ERP.

2.9.1 Fire Suppression for Lithium-Ion BESS – When Optional

Fire suppression is not required for remote outdoor systems, other than in walk-in units and as needed to meet performance criteria in UL 9540A testing. Although suppression can be provided voluntarily, it may be of limited benefit in many circumstances. Outdoor, containerized installations may not pose a risk to a building structure or occupants to the same degree as for indoor facilities. For lithium-ion systems, alternative suppression agents have not been observed to be effective in stopping thermal runaway in most cases. Some types of suppression agents may further damage batteries that would otherwise not have been affected – including water-based suppression. In most cases, outdoor, containerized BESS will be pre-engineered with or without a suppression system, leaving limited flexibility once a certain BESS unit is selected for a site.

The main benefit of fire suppression for outdoor, non-walk-in units, is the protection of exposures and prevention of propagation to adjacent containers. This benefit may be weighed with the difficulty and cost of installation, risk of accidental discharge or leaks causing damage, and potential environmental effects associated with suppression agents or contaminated water runoff. It may also be more desirable to allow a fire to burn through the initiating unit to minimize the amount of stranded energy. The fire would also combust flammable gases which could otherwise accumulate and potentially elevate the deflagration hazard. Prevention of propagation to adjacent units may also be achievable by manual firefighting (also emergency response planning and standard operating procedures), increased spacing of enclosures, or by installation of fire barriers.

Where there are separate enclosures provided for equipment other than batteries, alternative fire suppression agents such as clean agents or inert gases designed for a Class C fire hazard may be provided.

Some BESS units are pre-engineered with an internal dry-pipe sprinkler-like system that is not connected to a permanent water supply. Typically, these units are provided with exterior points for a hose connection like a fire department connection (FDC). Use of the system would require a first responder to approach a container with an active fire and/or a lingering deflagration hazard, which is not advisable. When these types of systems are used, it is recommended that FDC connections are piped further away from the units to allow for remote connection. It should be demonstrated with an analysis that the FDC is in fact in a lower risk area (e.g., expecting acceptable heat flux, no flying debris, etc.). If multiple units are on the site with closed sprinklers, a single FDC pipe can feed all units. If the units use open sprinklers, a clearly identified individual FDC should be provided for each unit so that non-involved units are not flooded. Flooding of units will cause a total loss and should be used as a last resort to prevent propagation to adjacent containers. If an FDC is not provided at a safe distance from containers it is recommended that the suppression system is not considered in any emergency planning or HMA.

See the following section for further commentary on the effectiveness of suppression systems for lithium-ion batteries.

It is recommended that optional fire suppression for lithium-ion BESS is evaluated on a case-by-case basis when there is concern for adjacent exposures identified. Alternative measures such as manual firefighting, increased spacing of units, or installation of fire barriers may be more desirable than a suppression system. If used, fire suppression systems should be evaluated by large-scale fire testing.

2.9.2 Fire Suppression for Lithium-Ion BESS – When Required

Suppression of lithium-ion battery fires is difficult as once thermal runaway is initiated within a cell, it cannot be stopped, and the primary goal becomes prevention of propagation to adjacent cells, modules, and units. When selecting a suppression agent, consideration must be given to both the effectiveness of slowing or stopping thermal runaway propagation by cooling and whether the agent itself could induce further thermal runaway or interact poorly with other systems such as explosion prevention. Suppression of fires should also be weighed with consideration for an increased explosion hazard. Suppression of a fire without prevention of thermal runaway propagation can cause a buildup of flammable gases in an enclosure that may have otherwise been consumed in a fire. NFPA 855 Appendix G.6 provides additional insight into suppression methods for lithium-ion batteries.

Water-based suppression is currently considered the industry accepted solution and can be accomplished by an automatic sprinkler system, water spray, or water mist system. Water has the advantage of having a high specific heat capacity (high ability to absorb heat) and having a functionally unlimited supply in most scenarios. A misconception is that lithium-ion batteries are water-reactive as lithium metal is water-reactive, but lithium-ion batteries do not contain lithium metal and will not react with water. However, water can also induce further thermal runaway by creating short circuits, particularly in systems that are not well shielded. Water is still recommended as it can help cool the compartment, other exposures, and it may also help reduce airborne pollutants. Water-based suppression should also be evaluated in combination with ventilation. Indoor BESS could experience excessive heat during a prolonged thermal runaway. It is important to provide adequate compartment cooling via ventilation to assure that the sprinkler system stays intact.

Clean agent, carbon dioxide, aerosol, and other alternative suppression agents may initially extinguish flames and inert the compartment, but in many cases they do not prevent thermal runaway propagation. There is limited research to support the hypothesis that at very high concentrations, thermal runaway propagation can sometimes be prevented by the clean agent Novec 1230 [7]. However, at Class C (electrical fire) concentrations, thermal runaway propagation was not prevented. Additionally, lithium-ion fires have been observed to re-ignite after suppression, sometimes multiple times over the span of hours or days. Alternative suppression agents will not be available for suppression of any reignition. In any case, UL 9540A installation level testing is required to utilize any alternative suppression system and should demonstrate that the agent can prevent thermal runaway propagation in addition to providing suppression of flames.

If large-scale testing were to demonstrate that an alternative fire suppression method is effective in preventing propagation of thermal runaway, consideration should still be given to the possibility of reignition (after the agent is depleted) and for interaction with other systems such as explosion prevention systems. See Report Section 2.9.3 for further commentary.

It is recommended that required suppression systems for lithium-ion batteries are water-based and designed based on large-scale, installation level testing.

2.9.3 Consideration of Suppression Effects on Deflagration Hazard for Lithium-Ion Batteries

Lithium-ion batteries generate flammable gases during thermal runaway, and it is possible for thermal runaway propagation to occur without flaming combustion in a BESS. When flammable gases are released and are not combusted, they can begin to collect in an enclosure, which may cause a deflagration hazard.

Clean agent, CO_2, and aerosol systems may initially extinguish a fire, but will not typically stop thermal runaway propagation. These systems are usually designed to shut down any openings or ventilation to the enclosure upon detection to create a hold time for the suppression agent within the space. During this hold time, flammable gases may still be generated by the propagating thermal runaway, increasing to the explosion hazard.

Alternative suppression agents may also have an unexpected effect on the gas layer development and exhaust systems. At a minimum, these effects need to be accounted for in any explosion prevention system design.

Where there are separate enclosures provided for equipment other than batteries, alternative fire suppression agents such as clean agents or inert gases designed for a Class C fire hazard may be provided to help prevent propagation to battery enclosures.

2.9.4 General Fire Suppression for Other Non-Water-Reactive BESS

Suppression systems for any battery chemistry, including sprinkler systems, should be designed based on large-scale fire testing, where available. See Appendix Section A.5 for more information on UL 9540A testing for suppression systems.

Smaller energy capacity BESS may be protected with an automatic sprinkler system in accordance with NFPA 855:

+ Automatic fire sprinkler systems for ESS units (groups) with a maximum stored energy of 50 kWh, as described in NFPA 855 Section 9.4.2.1, shall be designed using a minimum density of 0.3 gpm/ft^2 (12.2

mm/min) based over the area of the room or 2,500 ft^2 design area, whichever is smaller, unless a lower density is approved based upon fire and explosion testing in accordance with NFPA 855 Section 9.1.5

Any system provided in lieu of an automatic sprinkler system as described above is required by the CFC to be designed based on large-scale fire testing. Any exception to this should be made as an alternative materials, design, and methods of construction and equipment and should be requested in accordance with CFC Section 104.10. It is also suggested that any substantiating report or test for an alternative materials, design, and methods of construction is subject to a peer review process as needed (see Report Section 2.17.2).

2.9.5 General Fire Suppression for Water-Reactive BESS

Where systems utilize water-reactive components (such as lithium metal batteries), and suppression is required, alternative fire suppression systems are required in accordance with CFC Section 1207.5.5.1. This alternative fire suppression system should be designed based on large-scale testing for the specific system as is required by the CFC. Where large-scale testing is not available, alternative materials, design, and methods of construction and equipment should be requested and evaluated in accordance with CFC Section 104.10. It is also suggested that any substantiating report or test for an alternative materials, design, and methods of construction is subject to the independent design review process as needed (see Report Section 2.17.2).

2.9.6 Direct Injection Battery Rack Coolant System

Clean agent direct injection battery rack coolant systems are not currently addressed specifically by the CFC. Targeted module level fire suppression by means of water or clean agents may help prevent thermal runaway propagation by providing cooling on a more localized scale than fire suppression provided at the room or enclosure level. At this time, it is not recommended that module level fire suppression be used as an alternative to suppression provided for the entire room or enclosure.

It is recommended that this optional system is tested through large-scale fire testing in accordance with UL 9540A and is designed to meet the requirements of UL 9540 Annex G.

Where additional fire suppression is provided at the module level, room or enclosure-level suppression as required by CFC Section 1207.5.5 must still be provided for indoor installations and walk-in units.

2.10 SEISMIC DESIGN

The battery system listing in accordance with UL 9540 requires that the equipment of a BESS that contains the energy storage mechanism and is intended for installation where they will be subject to seismic activity shall be evaluated and if necessary, tested in accordance with their seismic ratings and installations instructions. The installation instructions shall indicate the limitations of the particular seismic rating of the equipment. Standards that provide guidance on seismic evaluation such as IEEE 693, IEC 60980, the seismic testing in GR-63-CORE, or similar, shall be used for this evaluation.

In addition to the battery system, the enclosure or building must be analyzed for seismic loading. In accordance with the ASCE 7-16, Ch. 11 definitions: a “building” is “any structure whose intended use includes shelter of human occupants,” a “nonbuilding structure” is “A structure, other than a building, constructed of a type included in Chapter 15 [of ASCE 7-16] and within the limits of Section 15.1.1.,” and a “nonbuilding structure similar to a building” is “A nonbuilding structure that is designed and constructed in a manner similar to buildings, responds to strong ground motion in a fashion similar to buildings, and has a basic lateral and vertical seismic force-resisting system conforming to one of the types indicated in Tables 12.2-1 or 15.4-1 [of ASCE 7-16].

Seismic design reports can be complex. It may be necessary for a civil or structural engineer to review and approve the seismic design for the specific installation location. Appendix E provides considerations that can be used for guidance during the review.

2.11 FIRE SAFETY AND EVACUATION PLAN

The CFC does not currently have a requirement for a fire safety and evacuation plan, which was added to the 2024 IFC Section 404. In general, fire evacuation plans provide information on egress routes, procedures for employees who must remain to operate critical equipment, and means of notification. Fire safety plans include information for reporting an emergency, site, and floor plans with egress routes, assembly points, and information on locations of fire hydrants, fire department access roads, and other fire safety-related features. Fire safety and evacuation plans are required to be reviewed and updated annually (or more frequently as necessary) and required to be made available to employees and the fire code official.

Fire safety and evacuation plans are intended for the safety of building occupants and differ from emergency operations and response plans, which provide more detailed procedures for employees and the fire service to respond to an event. **Therefore, it is recommended that fire safety and evacuation plans are provided for all installations of any size that are regularly occupied.**

2.12 EMERGENCY PLANNING AND TRAINING

2.12.1 Emergency Operations Plan

The CFC does not currently have a requirement for a site-specific emergency response plan or emergency operations plan. An emergency operations plan is required by NFPA 855 for all installations exceeding the MSE as outlined in Section 2.3.1 of this report. The emergency operations plan is required to address procedures to be performed by facility personnel in response to an emergency and to include drills and training.

It is recommended that an emergency operations plan is provided for all installations requiring an HMA. The emergency operations plan should be provided in accordance with NFPA 855 Section 4.3.2.1.

2.12.2 Emergency Response Plan

In addition to the emergency operations plan, an emergency response plan should also be prepared for procedures to address the foreseeable hazards associated with on-site emergencies. California State Senate Bill 38, which was approved in October of 2023, requires that all BESS facilities including those owned by utilities prepare an emergency response and emergency action plan. The emergency response and action plan are required to do the following:

+ Establish response procedures for an equipment malfunction or failure
+ Include procedures that provide for the safety of surrounding residents, neighboring properties, emergency responders, and the environment.
+ Establish notification and communication procedures between the BESS facility and local emergency management agencies.

Additionally, the plan is not required to, but may do the following:

- Consider responses to potential offsite impacts, such as poor air quality, threats to municipal water supplies, water runoff, and threats to natural waterways.
- Include procedures for the local emergency response agency to establish shelter-in-place orders and road closure notifications when appropriate.

The Senate Bill requires that the plans are developed in coordination with the local agencies and that the owner or operator submits the plans to the county and city where the facility is located.

In addition to the requirements and additional suggestions from Seante Bill 38, the emergency response plan should be provided in accordance with NFPA 1660 Chapters 17 through 23, and include measures for the following, at a minimum:

- Mitigation
- Preparedness
- Response
- Recovery

It may also be beneficial that a shorter version of the emergency response plan or a technical worksheet is provided on site for ease of use during response, including the following information:

- Emergency contact information for the fire mitigation personnel required by CFC Section 1207.1.6.1.
- Site overview map including facility access points, simplified equipment layout, fire hydrant, and FDC locations, and muster locations for on-site personnel.
- Key information and cautions for first responder to understand upon arrival.
- Summary of the hazard mitigation systems on site, including fire suppression systems, detection systems, etc.

It is recommended that an emergency response plan is provided for all installations requiring an HMA.

2.12.3 Training

As emergencies can occur during the installation process, personnel responsible for the installation of the BESS should be trained in the emergency response and operations plans prior to the BESS arriving to the site. Personnel that are responsible for the operation, maintenance, repair, servicing and response of the BESS should be trained in the emergency response and operations plans prior to operation of the BESS. Emergency responders should be offered initial training on the emergency response plan prior to the operation of the BESS.

Refresher training should be provided to the appropriate BESS facility personnel annually. Emergency responders should be notified of the training dates and locations so they may attend as needed.

It is recommended that training on the emergency operations and emergency response plan is provided as outlined in this section.

2.13 DISPERSION ANALYSIS (PLUME MODELING)

Prior incidents such as the Surprise, AZ APS BESS have shown the potential for toxic gas emissions to be released during failure events. In addition, fires involving lithium-ion batteries can produce HF in significant quantities, and this causes concern due to the toxic potency of this gas. To assess the hazard for public receptors, in many cases a dispersion analysis is required by authorities to define setback distances or evacuation zones in the event of a BESS fire.

Public commentary in San Diego County has demonstrated a concern regarding the exposure of residents to toxic gases that may be released during a BESS failure. This is an ongoing research area, but significant health hazards have not been observed in the U.S. for BESS failures and current understanding is limited. A conservative approach to public health has led to evacuation procedures that may be unjustified. The evacuation of businesses, homes, and other nearby occupancies is taxing on the local community and a dispersion analysis may assist in reducing the disruption of the public.

Dispersion modeling can be provided during the project planning process to help determine appropriate evacuation distances and approach distances for first responders. Dispersion analysis is not currently required by the CFC for BESS, however, HMA approval is contingent upon evacuation routes being maintained below IDLH levels. This concern is most applicable to buildings, however, in certain populated areas or locations in close proximity to sensitive populations a dispersion analysis may be required by an authority to address this concern. In addition, non-regulatory standards may set a dispersion modeling requirement. APS safety standards for energy storage, contained in APS Appendix W, requires modeling to be performed to determine risk to responding firefighters, seller representatives, and others who may be in the vicinity or occupying nearby buildings.

Although dispersion modeling may be useful in providing rough information for emergency response planning, there are limitations to the modeling. It is important to appropriately define the input (e.g. source term), boundary conditions (atmospheric and wind conditions), and applicable thresholds for the toxic gases considered in the analysis. A guidance document on air plume modeling for BESS failure incidents stated that "…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 a knowledge gap currently exists as to the emission rates from real world incidents, including chemical and physical dynamic evaluation of the emitted pollutants close to the source" [8]. Hence, there are variables that affect the outcomes of models which currently lack firm basis in the event literature. Model performance is subject to the input data used and thus typically conservative assumptions are used despite real-world events rarely leading to high levels of toxics being observed.

It is recommended that dispersion modeling be provided as part of the design process in order to create guidance for the emergency response plan especially for the sites that are in the vicinity of vulnerable populations. However, dispersion modeling is not recommended to be used as a determination for project approval. Some guidance for best practices for dispersion modeling of BESS fires is provided in Appendix B.

2.14 ENVIRONMENTAL CONTROL

Historically, containerized units, which are commonly used for outdoor BESS, were made up of components placed within standard shipping containers (ex., 40' long by 8' wide by 8.5' height). However, it has been recognized that water and dust ingress may contribute to short-circuit failures of BESS [9]. Condensation may be amplified in mountainous and coastal areas.

It can be difficult to obtain a high IP rating for air-cooled containerized systems as the container will inherently need to have more openings to allow for the required airflow needed to maintain the batteries within operating temperature ranges.

ESS that are intended to be installed where exposed to moisture are required to be marked with the environmental rating of the enclosure (UL 9540 Section 45.17). The environmental rating is to be in accordance with IEC 60529, UL 50E, or C22.2 No. 94.2. As part of the UL 9540 listing, the BESS must be tested in accordance with the moisture rating they are listed for and then subjected to electrical insulation tests and examined for signs of water that could result in hazardous conditions. It must also be indicated in the installation instructions when BESS are intended to only be installed indoors or in environments where they will not be exposed to moisture (UL 9540 Section 46.13).

It is recommended that all BESS that are proposed to be installed outdoors are verified as being listed for outdoor installation and for exposure to moisture. Additionally, it is recommended that the IP rating is evaluated as part of the site-specific HMA to ensure that the rating is sufficient for the anticipated exposure. Where it is expected that hose streams may be applied to prevent fire propagation between BESS units, the HMA or emergency response plan should evaluate the environmental rating of the enclosure for recommendations on manual firefighting response.

2.15 HEATING AND COOLING SYSTEMS

Significant care should be taken to ensure that batteries will be maintained within their operating temperature range, which is provided by the manufacturer. When the thermal management system fails, the BESS should be designed to shut down in a safe manner. The design of the thermal management system should be verified to have considered the following at a minimum (based on APS Appendix W):

+ An oversizing factor and justification for the selection of the oversizing factor that accounts for total system size and augmentation, as well as the impacts of additional heat from degradation over time due to increased impedance.
+ Data pertaining to the heat generation of battery cells.
+ The number of cells in the system, and the total heat load at rated power.
+ An analysis of the BESS duty cycle translated to C-rate over time for the battery cells and an estimation of the maximum duration of time cells will be at that nameplate C-rate.
+ The thermal mass of the battery cells and constituent components shall be considered in the heat and mass balance calculation.
+ The rejection rate of heat from the walls and ceiling.
+ The impact of heat gain from the environment, including sunshine and ambient conditions.
+ Even distribution of heating and cooling within the system such that the deviation between cell temperatures is maintained within the manufacturer’s specifications.

Condensation can occur on enclosures when the outside temperatures are cooler than the temperatures maintained within the enclosure. This condensation could potentially lead to water droplets forming that may cause short circuits within the system.

2.16 FIRE-FIGHTING WATER RUNOFF COLLECTION

Lithium-ion battery fires may release a variety of toxic chemicals, including hydrogen fluoride (HF), carbon monoxide (CO), volatile organic compounds (VOCs), and heavy metals like lithium, cobalt, and nickel [10]**.** The fire water used to extinguish the fire can become contaminated with these substances. However, incident data and research on this topic is still not well understood.

There has been at least one industry example (Neuhardenberg/Germany, 2021) where the responding fire department measured elevated levels of pollutants in the runoff and implemented mitigation measures (e.g., runoff water collection, decontamination station for personnel and equipment). It shall be noted that the exact measurement data is unknown.

On the contrary, the BESS fire incident in Escondido, CA (2024) did not indicate elevated levels of pollutants in the runoff [11].

Recent research by Quant et, al. (2023) performed an “Ecotoxicity Evaluation of Fire-Extinguishing Water from Large-Scale Battery and Battery Electric Vehicle Fire Tests”. In this work, extinguishing water from three vehicles and one battery pack fire test were analyzed for pollutants. Additionally, the acute toxicity of the collected extinguishing water on three aquatic species was determined. The vehicles used in the fire tests were both conventional petrol-fueled and battery electric. For all the tests, the analysis of the extinguishing water showed toxicity toward the tested aquatic species. This may indicate that the runoff from a battery fire contains pollutants, but that pollutants at a similar level are expected for a conventional combustion engine vehicle fire.

Hence, fire-fighting water runoff collection is a controversial topic. If in doubt, it is best to implement mitigation measures. It is recommended to address the possibility of environmental contamination in the facility siting process of a planned installation (e.g., take into account exposure to people, farmlands, wetlands, and wildlife).

2.17 ADDITIONAL CONSIDERATIONS

2.17.1 Compliance with NFPA 855

NFPA 855 has been considered the leading standard for the installation of stationary BESS. Some jurisdictions, such as Kern County, require compliance with both CFC and NFPA 855. Additionally, the International Code Council (ICC) proposed changes for the 2027 Edition of the IFC to delete most of Section 1207 and instead refer to NFPA 855. If approved, Section 1207 will simply refer the user to other chapters of the fire code for the installation of systems that are required by NFPA 855 (for example, fire suppression systems required by NFPA 855 will be installed in accordance with Chapter 9 of the IFC). The implementation of NFPA 855 ensures that the most up-to-date and agreed-upon practices for BESS installations are being utilized.

2.17.2 Independent Design Review

Where deemed necessary by the AHJ, it is recommended to utilize third parties for the review of new installations. This is due to the complex nature of requirements surrounding protection for ESS, permitting documents such as UL 9540/9540A data, HMAs, FMEAs, and explosion control system design documents. This may require resources that may not be readily available by the AHJ. This is why NFPA 855 also requires that test reports be accompanied by a supplemental report prepared by a registered design professional with expertise in fire protection engineering, for example.

A request for qualifications should be solicited to firms to establish qualified reviewers that can be utilized.

2.17.3 Emerging Protection Technologies

There is a constant stream of new protection technologies that come to market, particularly those geared at suppression and thermal runaway propagation prevention for lithium-ion battery technologies. These technologies are often marketed to AHJ's and system manufacturers as the solution to the ongoing challenges presented by these batteries. As new technologies emerge, it is important that they are assessed and tested by third parties to ensure the accuracy of any claims. Products that have not been performed third party testing should not be used in place of code required protection. Additionally, the use of any new technology should be assessed for negative interactions with other components of the BESS before use as an optional system.

2.17.4 Commissioning – Integrated Testing

CBC Section 901.6.2 requires that where two or more fire protection or life safety systems are interconnected, the intended response of subordinate fire protection and life safety systems are to be verified when required testing of the initiating system is conducted. Additionally, CFC Section 1207.2.1 requires that integrated testing for all fire and life safety systems is included in the commissioning plan and process. A test plan outlining the testing requirements and procedures that includes the sequence of operations for all systems that includes all applicable initiating devices and output functions can be included as part of the BESS design.

The test plan should be developed based on project information such as the commissioning plan, the operation and maintenance plan, the emergency response plan, and the HMA. All equipment and components of the BESS should be commissioned and tested in accordance with applicable codes, standards, and manufacturer requirements.

2.17.5 Periodic Special Inspections

Periodic special inspections are not currently required by the CFC for BESS installations but are required for other types of construction in accordance with CBC Chapter 17. As discussed in Appendix C, the New York State Working Group recommended that periodic special inspections are conducted for BESS facilities. The working group provided the following guidelines for special inspections:

+ The Fire Code should specify a scope of inspection criteria. The criteria should include verification of emergency response contacts, system layouts, signage, and other critical components relevant to BESS safety.
+ The frequency of inspections should be established to correspond with specific needs and risks of the installation.
+ The inspections are conducted by specialized, third-party experts.

The working group did not provide further guidance on the execution of the requirements above, however, if special inspections are enforced, the following additional recommendations are made:

- Inspection criteria should include the specific requirements recommended by the working group (in above list). Other critical components could be those that are identified in the HMA or in the product level safety analysis (See Section 2.3 of this report).
- The frequency established can be based on the intervals established in the operation and maintenance plan required by CFC Section 1207.2.2. The operation and maintenance plan is required to be provided to the ESS owner prior to operation and the frequency of testing can be reviewed at that time.
- Special inspector qualifications can be reviewed by the County of San Diego prior to the start of inspections in accordance with CBC Section 1704.2.1. These qualifications should demonstrate understanding of the specific hazards associated with BESS, in addition to other qualifications such as an engineering license or other certifications. As special inspections are not currently required in most jurisdictions for BESS, specific experience in inspection of BESS installations may be an unrealistic requirement.
- A test plan should be developed by the special inspection agency and approved by the County of San Diego prior to the start of inspections. The test plan should be developed based on project information such as the commissioning plan, the operation and maintenance plan, the emergency response plan, and the HMA.

3.0 Best Practices for Assessment and Retrofit of Existing Installations

This section of the report is intended to provide guidance on reasonable assessments and improvements that could be made to existing BESS installations. The recommendations provided in the previous section should also apply to existing installations but may be prohibitive to apply.

Depending on when a facility was built, the requirements in place at the time of construction could vary widely. NFPA 855 Annex F provides an overview of the historical development of codes related to stationary BESS. The 2018 Edition of the IFC was the first major update to the fire code addressing BESS after the addition of new chemistries in 2006 and 2009. The major changes made in the 2018 Edition of the IFC were captured in the July 2018 supplement to the 2016 Edition of the CFC.

The update to the 2018 Edition of the IFC (and therefore, the 2018 supplement for the 2016 Edition of the CFC) moved requirements to Chapter 12, where they are found today, and included many new requirements, including but not limited to, the following:

- Construction documents
- Hazard mitigation analysis, HMA
- Stationary battery arrays (limiting the size and spacing of each array)
- Maximum Stored Energy (Maximum allowable quantities)
- Fire-extinguishing and detection systems
- Specific battery type requirements (primarily related to signage, spill control, and ventilation)
- References to fire and explosion testing as exceptions to requirements, but UL 9540A was not referenced.
- Prepackaged and pre-engineered systems are required to be listed in accordance with UL 9540

Additional changes were made to the 2021 IFC, which included the following:

- Special installation types (roof, open parking garage, differentiation of remote outdoor installations, dedicated use)
- Large-scale fire test language is introduced and references UL 9540A
- UL 9540 listing is no longer stated as only for prepackaged and pre-engineered systems
- Deflagration protection is required

Based on the development of requirements above, it can be concluded that existing installations would, in many cases, be considered deficient when compared to systems that are being designed and installed today. Beyond requirements that are captured in code language, improvements have also been made in battery technologies that have enhanced safety, such as shifts in battery chemistries and improvements in battery management systems. It could be expected that as earlier systems continue to age, failures may continue to occur, but ideally, newer systems will continually experience better performance and less significant failures.

An HMA (See Section 3.3 of this report) shall be prepared and provided to the AHJ for review and approval where existing installations that utilize lithium-ion BESS are not UL 9540 listed.

3.1 REPAIRS, RETROFITS, AND REPLACEMENTS - CODE REQUIREMENTS

Where repairs are required to a BESS, they must be performed by qualified personnel (CFC Section 1207.6.3). Repairs are not subject to the same requirements as retrofits when identical parts are used. When identical parts are not used, repairs are considered a retrofit, see below.

Retrofits require the following (CFC Section 1207.3.7):

- A construction permit.
- New batteries, modules, and similar BESS components must be listed. (See Section 2.1 of this report).
- BMS and other monitoring systems must be connected and installed in accordance with the manufacturer's instructions.
- The overall installation must continue to comply with UL 9540 listing requirements.
- Systems must be commissioned in accordance with CFC Section 1207.2.1.
- Retrofits must be documented in the services records log.

Where BESS are replaced, they are considered BESS and must comply with current code requirements. The BESS being replaced must be decommissioned in accordance with CFC Section 1207.2.3. NFPA 855 also clarifies that retrofitting that utilizes a different BESS technology or chemistry is considered a replacement.

3.2 LISTINGS

As stated in Section 2.1 of this report, utilizing equipment that is listed in accordance with UL 1642, UL 1973, UL 9540, and UL 1741 is important to ensure the safety of the electrical components of a system. Systems that were approved in California prior to the adoption of the July 2018 supplement were not required by the fire code to have a UL 1973 or UL 9540 listing. Additionally, systems that were listed in accordance with the first edition of UL 9540 may not have been tested in accordance with UL 9540A.

It is recommended that an HMA is performed for existing BESS systems, particularly those that do not have a UL 9540 listing.

3.3 HAZARD MITIGATION ANALYSIS

As stated in above in Section 3.2, a HMA is recommended for any existing systems that do not have a UL 9540 listing. The HMA should be provided in accordance with the recommendations made in Section 2.3 of this report.

The HMA should also focus on identifying safety features that are required by current codes but may not be present in the installation due to when it was installed. Examples of areas that have had significant development in recent years include the following:

+ Deflagration protection: The potential for a deflagration hazard should be assessed, and if found, recommendations for deflagration protection should be made.
+ Inadequacy of fire suppression system: Recent events and further research have shown that suppression agents other than those that are water-based may not provide adequate fire protection. The fire suppression system should be evaluated, and a water-based suppression system should be provided if recommended by the HMA. The HMA should also consider whether the existing suppression system has adverse effects on any existing or recommended deflagration protection system and make recommendations for modifications accordingly.
+ Detection system alarm transmission: The requirement for alarm signals from smoke or fire detection systems to be transmitted to a central, proprietary, or remote station service in accordance with NFPA 72 was not introduced into the fire code until the July 2021 supplement to the 2019 Edition of the CFC. Therefore, the HMA should evaluate whether this service is provided and make recommendations accordingly.
+ Separation of outdoor BESS from exposures: The requirement for separation of outdoor BESS from exposures was increased from 5 feet to 10 feet in the July 2021 supplement to the 2019 CFC. Therefore, the HMA should consider if the current separation from exposures is adequate and make recommendations as needed.
+ Thermal runaway protection: Thermal runaway protection (e.g., BMS) was not required for lithium-ion BESS until the July 2021 supplement to the 2019 Edition of the CFC. Although it may be difficult to retrofit thermal runaway protection to existing battery systems, the HMA should address any increased hazard that may be found in systems that do not have thermal runaway protection.

Additionally, since the system may not have a UL 9540 listing, a product-level FMEA may not be available. When this is the case, the HMA should consider potential failure modes, including those that would typically be covered by the product-level FMEA.

3.4 EMERGENCY PLANNING, TRAINING, AND DECOMMISSIONING

It is recommended that emergency planning and training procedures are developed for existing facilities. It is recommended that annual site familiarization visits be held for the local fire department as part of regular maintenance activities. See Section 2.12 of this report for details.

Furthermore, a decommissioning plan that covers the removal of the system from service and from the facility in which it is located shall be prepared by the owner or designated agent in accordance with CFC Section 1207.2.3 and NFPA 855 Chapter 8.

4.0 Conclusion

The intent of this document is to provide guidance to the County of San Diego in best practices for regulating battery energy storage facilities. The information in this document includes the professional opinion of Jensen Hughes' staff, unique consideration was done on each topic, however users of this document must perform their own due diligence before enacting or utilizing any of the recommendations or opinions presented in this report. This document provides an overview of the current codes in place regulating BESS facilities and provides input on best practices for future permitting policies involving lithium-ion battery energy storage systems in San Diego County.

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Appendices Table of Contents

Appendix A UL 9540A Testing

UL 9540A testing is required in many circumstances for BESS installations and, in most cases, for a BESS product to receive a UL 9540 listing. This appendix is intended to assist the user in understanding the UL 9540A test, its applications, and its limitations. This appendix is not inclusive of all testing procedures and is only intended to assist in the overall understanding of the test.

A.1 GENERAL REQUIREMENTS

To be considered valid, UL 9540A testing must be performed by an approved laboratory on a representative BESS. The test documents should present enough information on the BESS components that were tested for an individual reviewer to understand if the BESS is representative of the installation.

UL 9540A testing is performed at various "levels", which are shown below in Figure A-1. Each level has performance criteria, which are used to assess if testing needs to continue to the next level. This performance criteria are not considered a pass/fail but simply indicates if testing needs to continue.

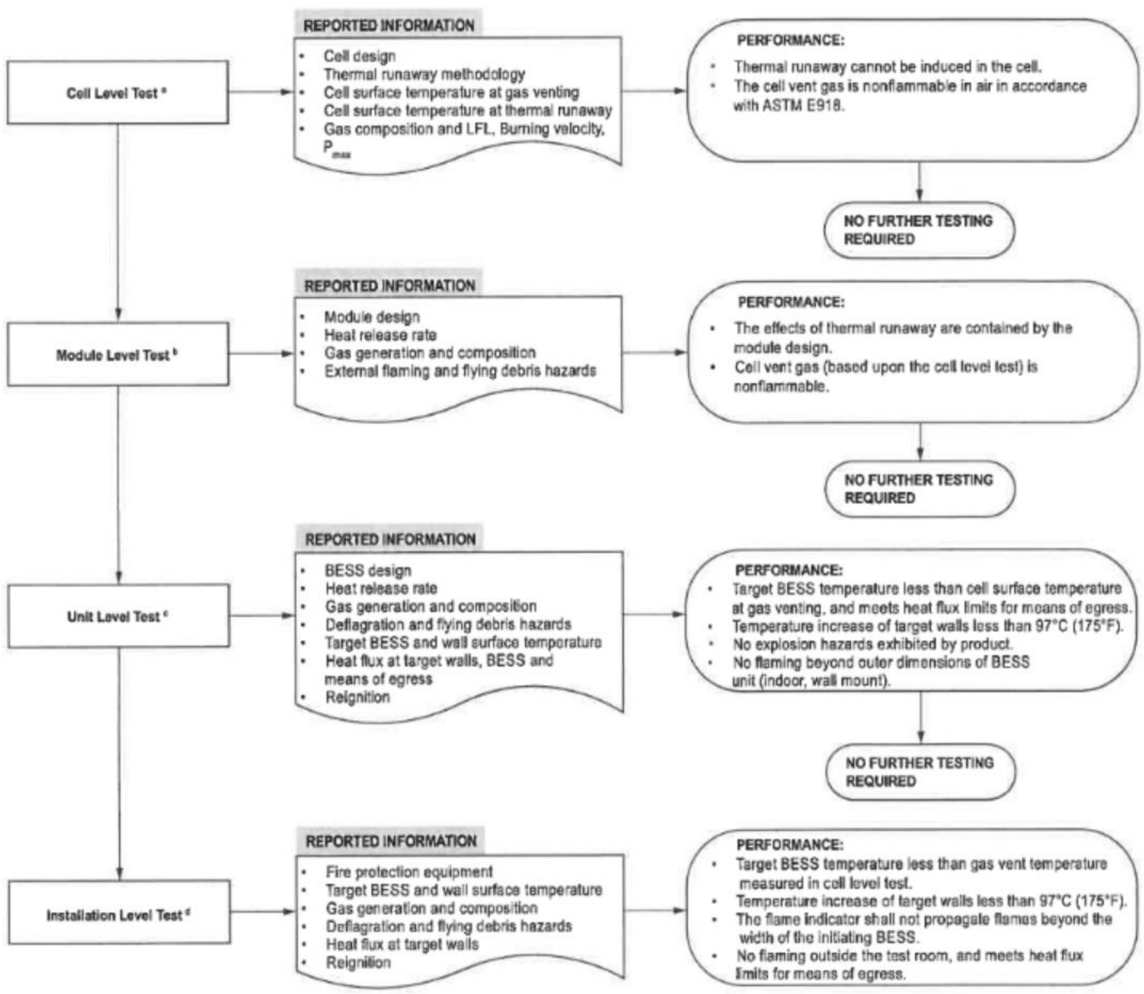

Figure A-1. UL 9540A (2019), Figure 1.1: Schematic of Test Sequence.

A.2 CELL LEVEL TEST

The cell level test is utilized to assess the cell design, including the ability to induce thermal runaway, and to study the cell vent gas composition. Cells are conditioned through a minimum of two charge and discharge cycles prior to testing. Cells that are tested are charged to 100% and then stabilized for one to 8 hours. Initially, the cell is tested by external heating. If external heating does not induce thermal runaway, mechanical means or electrical stresses (overcharging, over discharging, external short-circuiting) are required to be tested. The temperature at which a cell vents due to internal pressure rise and the temperature at the onset of thermal runaway are required to be documented and presented in the cell level report. Where thermal runaway is induced, the test is required to be repeated for 3 additional cells with the same method and the recorded temperatures are averaged for use in further test levels.

The cell vent gas is also required to be collected and sampled. The cell is placed in a pressure vessel (typically 82 L) at atmospheric pressure and less than 1% oxygen by volume. The vent gas composition is determined and reported on the cell level test. A synthetically replicated gas mixture is then used to find the lower flammability limit of the mixture at ambient and cell vent temperatures, to determine the gas burning velocity, and to determine the P_{max}. *Note: These values are necessary for the design of deflagration venting systems.*

The performance criteria for the cell-level test are as follows:

- Thermal runaway cannot be induced in the cell; and
- The cell vent gas does not represent a flammability hazard when mixed with any volume of air, at ambient and cell vent temperatures

Where cells do not meet the performance criteria above, module-level testing is required.

A.3 MODULE LEVEL TEST

The module-level test assesses the ability to resist propagation at a small scale and to collect data on heat release rate, gas generation and composition, and flaming and flying debris hazards. Similar to the cell level test, modules are conditioned through two cycles, then recharged and allowed to rest before performing testing. Any controls, such as a BMS, are required to be disconnected or disabled prior to module-level testing.

The module-level test requires one or more cells to be forced into thermal runaway (using the same method as the cell-level test) such that cell-to-cell propagation is achieved within the module. The location of initiating cells is required to present the greatest thermal exposure to adjacent cells including consideration of maximum heat transfer, restricted cooling or ventilation, etc. The heat release rate and the vent gas composition are recorded throughout the test.

The performance criteria for the module-level test are as follows:

- Thermal runaway is contained by module design.
- Cell vent gas is nonflammable as determined by the cell level test.

Where modules do not meet the performance criteria above, unit level testing is required.

A.4 UNIT LEVEL TEST

Note: UL 9540A definition of a unit is "a frame, rack, or enclosure that consists of a functional BESS which includes components and subassemblies such as cells, modules, battery management systems, ventilation devices, and other ancillary equipment".

The unit-level test is conducted with the BESS unit as described in the manufacturer's instructions and is used to evaluate propagation between units, separation distances from walls, and to assess explosion hazards. The following configurations can be tested for non-residential BESS:

+ Indoor floor-mounted non-residential use BESS
+ Outdoor ground-mounted non-residential use BESS
+ Indoor wall-mounted non-residential use BESS
+ Outdoor wall-mounted non-residential use BESS
+ Rooftop and open parking garage non-residential use BESS

Tests that are conducted for indoor floor-mounted BESS are considered representative of outdoor ground mounted installations.

The unit level test layout depends on the type of installation, but in general consists of placing BESS units at the spacing representative of the intended installation (including spacing to walls). The initiating unit is required to contain components representative of the installation, including any combustible components that interconnect the initiating and target units. Target units include the outer cabinet, racking, module enclosure, and components that retain cells but do not need to contain cells. Integral fire suppression systems can be included with the testing and are considered required if they are utilized. The BMS is also disabled for unit level testing.

Measurements taken during the test are dependent on the type of installation. For an indoor, floor-mounted BESS, the following measurements are taken:

+ Chemical and convective heat release rate vs. time
+ Wall surface temperature and target BESS temperatures
+ Ceiling or soffit surface temperature to target walls
+ Incident heat flux on target wall surfaces and target BESS
+ Incident heat flux on target ceiling or soffit surfaces
+ Gas generation and composition data
+ Peak smoke release rate and total smoke release
+ Time of activation of integral fire protection (if applicable)
+ Observation of any of the following:
    - Flaming outside the initiating enclosure and maximum flame extension
    - Flying debris or explosive discharge of gases

- Re-ignition from thermal runaway
- Sparks, electrical arcs, or electrical events
- Damage to the initiating unit, target unit, and adjacent walls, ceilings, or soffits.

Some measurements may not be applicable for systems that are intended to be installed solely outdoors, on rooftops, or in open parking garages.

The performance criteria for the unit level test for an indoor floor-mounted BESS are as follows:

+ Flaming outside the initiating BESS unit is not observed.
+ Surface temperatures of modules within the target BESS units do not exceed the temperature at which cell venting occurs, as was determined in cell level testing.
+ When intended to be installed in combustible construction, the surface temperature rise measurements on wall surfaces do not exceed 175°F.
+ Explosion hazards are not observed, including deflagration, detonation, or accumulation within flammability limits that can cause a deflagration of battery vent gases.
+ Heat flux in the center of the accessible means of egress does not exceed 1.3 kW/m^2.

Performance criteria for outdoor ground mounted installations are similar, except for the following differences:

+ Flaming is permitted outside of the unit. Separation distances to exposures are determined by the greatest flame extension observed.
+ Surface temperature rise of wall surfaces is also limited to 175°F for installations near exposures.

See UL 9540A for performance criteria for other types of installations. Where the performance criteria are not met, installation level testing is required, which will assess the effectiveness of fire protection systems.

A.5 INSTALLATION LEVEL TEST

The installation level test is intended to assess the effectiveness of fire and explosion mitigation methods. The test setup is similar to a unit-level test, except suppression systems are provided, and a representative cable tray is added above the units. There are two installation level test methods:

+ Test method 1: "Effectiveness of sprinklers". The explosion mitigation system is installed in accordance with the manufacturer's specifications and four sprinklers are installed at 10 feet spacing in the center of the test room. The sprinklers K-factor, temperature rating, and density all use standardized values unless specific values are indicated in the manufacturer's instructions. The same measurements and performance criteria are used as the unit level test, except that the initiating unit is observed for 24 hours to verify that there is no reignition, and the flame spread among a representative cable tray is assessed.
+ Test method 2: "Effectiveness of fire protection plan". Evaluates fire and explosion mitigation methods other than sprinkler systems. Test method 2 setup and test procedures are identical to test method 1, except that the room is fitted with the manufacturer's specified fire protection and explosion mitigation equipment rather than with sprinklers.

Appendix B Dispersion Modeling Recommendations

When batteries fail, they have the potential to release flammable as well as toxic gases. The flammability hazard is addressed by explosion prevention system requirements. However, toxic gases may remain an issue and can affect people located near the site. This appendix is intended to provide guidance on modeling that may be performed to assess exposure risks from toxic gases.

Dispersion or plume modeling can be performed to assist in emergency response planning for evaluation of first responder risk and for evacuation recommendations. However, there are still information gaps and research needs which require to make assumptions which affect the validity of the model. Even as information and research develop, actual failure conditions will always vary in some way compared to the assumed conditions and therefore modeling is recommended to be used in guidance, not as an assumption of any exact outcome that may occur.

This Appendix is based specifically on lithium-ion batteries, but general principles may be applied to other battery types.

B.1 TOXICITY LIMITS OF BATTERY OFF-GAS CHEMICALS

B.1.1 Available Guidelines

There are various sources of thresholds for human health effects due to toxic gases. Guidelines are in some cases provided in three tiers that can generally be summarized as follows [12]:

1. Temporary, non-disabling
2. Disabling (escape impairment)
3. Life-threatening

There are many sources for exposure guidelines, and some may not provide guidelines for the chemical of interest. Guidelines are also provided in some cases for specific purposes, such as public or workplace safety, which may cause differences in threshold values. The following table provides a summary of various exposure limit guidelines [12] [8], which are presented in order of preference for public exposure criteria.

Table B-1. Summary of Exposure Limit Guidelines

Issuing Body	Limit or Guideline	Intended Use	Exposure Period	Notes
Environmental Protection Agency (EPA)	Acute Exposure Guideline Level (AEGL) [13]	General Public, including sensitive individuals (infants, children, elderly, those with asthma, and other illnesses). Once in a lifetime or rare exposure to airborne chemicals	10 minutes, 30 minutes, 60 minutes, 4 hours, and 8 hours	+ Level 1: Notable discomfort, irritation, or certain asymptomatic non-sensory effects. Effects and not disabling and are reversible. + Level 2: Irreversible or long-lasting adverse health effects, impaired ability to escape. + Level 3: Life-threatening or deadly + Preferable for public exposure evaluation since sensitive individuals are included. + At time of access, there are 188 final values and 72 interim values in the database.
American Industrial Hygiene Association (AIHA)	Emergency Response Planning Guidelines (ERPGs) [14]	General public, not including sensitive individuals. Single exposure.	1 hour	+ Level 1: Mild, transient adverse health effects. + Level 2: Irreversible or long-lasting adverse health effects, impaired ability to escape. + Level 3: Life-threatening.
Department of Energy (DOE)	Temporary Emergency Exposure Limits (TEELs) [15]	General Public, including sensitive individuals (infants, children, elderly, those with asthma, and other illnesses).	1 hour	+ Level 1: Notable discomfort, irritation, or certain asymptomatic non-sensory effects. Effects and not disabling and are reversible. + Level 2: Irreversible or long-lasting adverse health effects, impaired ability to escape. + Level 3: Life-threatening or deadly + TEELs are intended to be used when AEGLs and ERPGs are not available for chemicals. + TEELs are produced using existing published exposure limits and toxicity data.

National Institute of Occupational Safety and Health (NIOSH)	Immediately Dangerous to Life and Health (IDLH) [16]	Workplace exposure limit for decision making for respirator use	N/A	+ Above the IDLH, only supplied air respirators should be used while purifying respirators may be used below the level. + Only includes one exposure level is intended to provide workers ability to escape from environment without permanent health damage or severe eye or respiratory tract irritation that impairs ability to escape.

The DOE also publishes a Protective Action Criteria for Chemicals (PACs), which combines AEGLs, ERPGs, and TEELs for a 1-hour exposure in the order of preference shown above (i.e. if an AEGL value is not provided but ERPG value is, the PAC will be an ERPG value).

B.1.2 Toxins of Concern

Lithium-ion batteries emit a wide range of toxic gases dependent on a variety of factors including chemistry, cell form, SOC, etc. A review of numerous studies found that the main toxic compounds released from lithium-ion batteries include CO, HCl, HCN, NO, SO_2, HF, fluorinated carbonates, POF_3, COF_2, acrolein, and formaldehyde [17]. HF is often considered a conservative toxin for modeling for lithium-ion BESS and can exist as both liquid and gas, depending on the temperature and pressure. HF condenses into a liquid at approximately 68°F under normal atmospheric conditions. The temperatures during a battery failure event are significantly higher than 68°F resulting in the release of HF as a gas. The permissible limits for HF from various guidelines (as described above in Table B-1) are listed in Table B-2 below. These concentration limits correspond to the limits beyond which a person would suffer irreversible and long-lasting adverse health effects.

Table B-2. HF Permissible Limits

*Guideline**	*HF Permissible Limit (in ppm)*
Emergency Response Planning Guidelines, ERPG-2 (one-hour)	20
Acute Exposure Guideline Levels, AEGL-2 (1-Hr)	24
Immediately Dangerous to Life or Health, IDLH (30 min)	30
Acute Exposure Guideline Levels, AEGL-2 (30 min)	34

* The permissible limits are based on average concentration exposure levels over a time duration indicated in parentheses.

The presence of fluorinated slats as a primary component of electrolyte justifies modeling HF. However, the toxin selected should be based on an analysis of the battery type and the other parameters that are being modeled in each scenario.

For reference, thresholds for AEGL-1 10 min. exposure duration were assessed for each chemical which could be emitted from a lithium-ion battery [18] and are reproduced in Table B-3. These thresholds are shown for a comparison between substances and the 10-minute AEGL-1 may not always be the appropriate threshold for modeling efforts.

Table B-3. AEGL-1 thresholds (no effect level) for toxic gases which may be emitted from lithium-ion batteries [18]

Substance	10 min. AEGL-1	Notes
HF	1.0 ppm	Common gas released due to electrolyte salt decomposition
HCl	1.8 ppm	Cell packaging material may contain polymers with Cl
HBr	1.0 ppm	Some electrolyte compositions contain Br
SO_2	0.2 ppm	Electrolyte salts and additives may contain S
NO_x (NO_2)	0.5 ppm	Polymer packaging or electrolyte salts and additives may contain N
Ammonia (NH_3)	30 ppm	Polymer packaging or electrolyte salts and additives may contain N
Formaldehyde (CH_2O)	0.9 ppm	Decomposition of organic carbonate electrolyte

B.2 GAS SOURCE

The source of toxic gas is the most important component for dispersion modeling. A lot of specific information is required related to the source while performing the dispersion analysis. The information required includes but is not limited to:

- Release gas
- Release location
- Release rate (g/s)
- Release temperature
- Release velocity
- Release direction

None of this information is provided in the UL 9540A test reports resulting in significant assumptions for these inputs. In addition, the values reported in literature may be limited to laboratory scale measurements and a consideration shall be given on key assumptions and limitations while extrapolating those to a site level failure analysis.

B.3 ATMOSPHERIC WIND CONDITIONS

Wind conditions are critical to dispersion because they affect how toxic releases will spread and impact downwind areas. High wind speeds typically enhance the dispersion of pollutants, reducing concentrations near the source. Conversely, low wind speeds can lead to poor dispersion, causing higher pollutant concentrations in the immediate vicinity of the source. In addition to wind speed, stability classes to quantify atmospheric conditions are required for dispersion modeling. EPA provides guidance on these topics and can be used if the local data on wind conditions is either not available or not reliable. Atmospheric stability classes are based on local meteorological data and are used to represent the dispersion characteristics of the atmosphere. The six main atmospheric stability classes are:

+ **A**: Highly unstable or convective
+ **B**: Moderately unstable
+ **C**: Slightly unstable
+ **D**: Neutral
+ **E**: Moderately stable
+ **F**: Extremely stable

Meteorological conditions for the worst-case scenario are defined in the EPA as atmospheric stability class F (stable atmosphere) and wind speed of 1.5 meters per second (3.4 miles per hour). If, however, one can demonstrate that the minimum wind speed at the site (measured at 10 meters) has been higher than 1.5 meters per second, or that the maximum atmosphere stability has always been less stable than class F, one may use those conditions for the worst-case analysis. To demonstrate higher minimum wind speeds or less stable atmospheric conditions, one will need to document local meteorological data for the previous applicable to the site.

B.4 MODELING SOFTWARES

There are a variety of tools available that are generally acceptable for industry use in modeling toxic off-gassing in BESS failure events:

+ AERMOD (American Meteorological Society and US EPA Regulatory Model): Used by the EPA for facility permitting. However, the program does not account for dense gas effects which may occur during failures at lower states of charge. Provided by EPA: **https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models**
+ Fire Dynamics Simulator (FDS): FDS is typically used for modeling of fire and gas plumes in both indoor and outdoor conditions. FDS may be useful for near field assessments but is very computationally taxing and may not be the best selection for long-range modeling. Provided by National Institute of Standards and Technology (NIST): **https://pages.nist.gov/fds-smv/**
+ Process Hazard Analysis Software (PHAST): A proprietary model offered by DNV which can analyze accidental releases: **https://www.dnv.com/software/services/plant/consequence-analysis-phast/** *
+ SAFER/TRACE: A proprietary model that was developed to evaluate toxic chemical spills. **https://www.indsci.com/en/safer-one** *
+ SCICHEM: This model is used by the US federal government for emergency release models. **https://github.com/epri-dev/SCICHEM/releases** *

* These models are allowed by APS Appendix W.

B.5 OUTCOMES

Dispersion modeling can be a used for emergency planning and site design but are also not representative of every failure scenario. For example, dispersion analysis performed will require assumptions can be used to be made about atmospheric understand specific bounding scenarios, such as a failure in a low-wind conditions with non-flaming combustion. This may provide an idea of an appropriate evacuation radius if conditions are similar. APS Appendix W utilizes plume modeling as part of the establishment of minimum approach distances (MAD), alongside a risk analysis of other hazards such as fires and a gas release explosions. It is recommended that likely will a similar process is followed where dispersion modeling is used to inform but does not be the same as the conditions that the failure occurs underprovide direct requirements for facility locations or for emergency evacuation zones.

Appendix C Lithium-Ion BESS Code Review

A review of organizations and local jurisdictions that provide additional requirements for lithium-ion BESS beyond the IFC/CFC/NFPA 855 was performed and a summary of these additional requirements is provided in this Appendix. These requirements are often tailored specifically to the organization or jurisdiction's needs and may not be necessary in San Diego County. Where found to be appropriate, recommendations based on these jurisdictions' requirements were incorporated into the main body of this document.

C.1 UNIFIED FACILITIES CRITERIA

The United Facilities Criteria (UFC) are the minimum standards for Department of Defense (DoD) facilities. Overall, the UFC criteria are more restrictive than other jurisdictions that were researched. The risk tolerance for DoD facilities is typically lower than what is acceptable for fire codes, as property protection and mission continuity are also necessary (as stated in UFC 3-600-01 Section 1-1). Therefore, some of these increased requirements may not be necessary as a requirement for public or first responder safety.

UFC 3-520-01 (current edition – October 6, 2015, with Change 2, April 12, 2021) is the standard for Interior Electrical Systems. UFC 3-520-01 prohibits the use of any lithium-based battery chemistry for stationary applications in occupied structures. Unless an exception is provided, lithium-ion and other lithium-based batteries are only permitted in unoccupied structures. UFC 3-600-01 (current edition – August 8, 2016, with Change 6, May 6, 2021) is the standard for Fire Protection Engineering for facilities and references NFPA 855 (current edition at time of project) as the primary standard for lithium-ion BESS. Additional requirements beyond those in NFPA 855 for unoccupied lithium BESS are found in UFC 3-600-01 Section 4-8 and are summarized in Table C-1.

TableC-1. UFC Criteria Comparison for Unoccupied Structures

UFC Requirement (Section)	*CFC/NFPA 855 requirement (Section)*	*Notes*
Lithium BESS are only permitted in structures dedicated to the BESS operation. The structure may not be used for any purpose other than the batteries and approved switching. (4-8.1)	The CFC, IFC, and NFPA 855 all allow for lithium-ion BESS in occupied or unoccupied structures. Protection requirements vary based on the type of installation and are most restrictive for BESS in buildings with other occupancies. (Various sections)	The UFC only allows BESS-Li in occupied structures when a specific exception is granted and when the facility is owned by the DoD.
The structure must be located 100 feet or more from occupied structures and identified outdoor use areas. A perimeter fence must be provided 100 feet or more from the unoccupied BESS structure. Other electrical utility equipment may be located within the perimeter fence. (4-8.1.1)	Outdoor installations located 100 feet or more from buildings, lot lines, public ways, stored combustible materials, hazardous materials, high piled stock, and other exposure hazards are considered remote (CFC 1207.8.1 and NFPA 855 Section 9.3.2). Dedicated use buildings that are located 100 feet or more from exposures are also granted certain exceptions (Various sections). Installations must be secured against unauthorized entry (CFC Section 1207.4.9 and NFPA 855 Section 4.7.6).	The UFC requires that the unoccupied structure is in a location 100 feet or more from other structures. These 100 feet would be included within a perimeter fence that is 100 feet or more from the BESS structure. The CFC and NFPA 855 consider outdoor installations that are greater than 100 feet from exposures to be “remote” and have reduced requirements from installations that are not remote. Remotely located dedicated-use buildings may also waive some requirements (such as fire suppression) when agreed upon by the AHJ. In summary, the UFC only allows for installations that would be considered remote by the CFC/NFPA 855.

UFC Requirement (Section)	*CFC/NFPA 855 requirement (Section)*	*Notes*
A minimum of two doors must be provided into the structure, spaced a minimum of the long distance of the structure or 75% of the diagonal of the structure apart. The doors must swing in the direction of egress. (4-8.1.2)	Means of egress is required to be in accordance with the local building code and required egress doors must swing in the direction of travel and have panic hardware (NFPA 855 Section 4.7.8 and CFC Section 1010.2.9.2). The CFC and NFPA 855 do not specifically discuss multiple egress doors.	The UFC, NPFA 855, and CFC all require that doors must swing in the direction of egress. The UFC does not specifically state that doors must be provided with panic hardware, but the CFC and NFPA 855 include this requirement.
The structure and doors to the structure must be provided with ANSI compliant signage (4-8.1.5).	The CFC contains signage requirements in Section 1207.4.8 and NFPA 855 in Section 4.7.4.2. The CFC also refers to the California Electrical Code (CEC), which references ANSI for signage in an informational note.	Functionally the CFC, UFC, and NFPA 855 very similar signage requirements, including requiring ANSI compliant signage.

Any BESS other than a remote, unoccupied structure as above must be owned and operated by the DoD and approved as an exception to UFC 3-520-01. Where an exception is approved, the installation must meet the requirements of NPFA 855 and the additional requirements summarized in Table C-2.

Table C-2. UFC Criteria Comparison for Occupied Structures

UFC Requirement (Section)	*CFC/NFPA 855 requirement*	*Notes*
Rooms must have one exterior wall (4-8.1.1)	No specific requirement to locate along an exterior wall.	The CFC and NFPA 855 do not specifically restrict an installation to an exterior wall. However, it may be more feasible to meet some requirements when installations are located on an exterior wall (such as provisions for explosion protection).
Rooms must not contain more than 600 kWh of stored energy (4-8.2.2)	Maximum stored energy is limited to 600 kWh (NFPA 855 Table 9.4.1 and CFC Table 1207.5). However, this can be exceeded with an HMA and fire testing.	The UFC does not contain a provision for exceeding 600 kWh for installations in occupied structures, while NFPA 855 and the CFC will allow for this with an HMA and fire testing process.

UFC Requirement (Section)	CFC/NFPA 855 requirement	Notes
Roof and walls must have a minimum fire resistance rating of 3 hours (4-8.2.3) Floor construction must be 4-inch concrete when in contact with earth. Floors to vacant spaces or other stories must have approved structure strength for imposed loads with a minimum fire-resistance of 3 hours (4-8.2.3.1) Walls must be of reinforced concrete or concrete masonry unit (CMU), or equivalent impact resistance (wallboard construction prohibited). (4-8.2.3.2)	Rooms and areas containing BESS must be separated from other areas of the buildings with fire barriers and horizontal assemblies with 2-hour fire resistance ratings (NFPA 855 Section 9.6.4 and CFC Section 1207.7.4).	The UFC has an increased requirement for a 3-hour fire-resistance rating. Additionally, the UFC also requires that construction of these rated assemblies uses concrete, rather than allowing for more frangible construction, such as wallboards.
BESS cabinets or racks must be separated by 3 feet or by masonry units that extend from floor to ceiling (or roof or deck) and 6 inches beyond racks or cabinets. For cabinets that meet UL 9540A *(note: assumed to mean meeting performance criteria of unit level testing),* separation can also be by a single layer of 5/8" Type X gypsum board on both sides of noncombustible studs with fire stopped penetrations. (4-8.2.4)	BESS must be segregated into groups not exceeding 50 kWh and must be separated by a minimum of 3 feet Capacities can be increased and separation can be reduced based on UL 9540A testing. (NFPA 855 Section 9.4.2 and CFC Section 1207.5.1).	Both the UFC and NFPA 855/CFC require that units are separated by 3 feet as a basic requirement. However, while NFPA 855/CFC would allow for a reduced separation based solely on test data, the UFC always requires some additional barrier to slow or prevent propagation.

UFC Requirement (Section)	*CFC/NFPA 855 requirement*	*Notes*
Doors must meet the same requirements as stated in Table. Additionally, doors must be provided with panic hardware and be 3-hour fire rated. (4-8.2.5)	Doors must meet the same requirements as stated in Table. Doors into 2-hour fire barriers are required to be provided with a 1½ hour fire resistance rating (CBC Table 716.1(2)).	The UFC requires a door to be provided with a greater level of fire resistance than NFPA 855/CFC.
Sprinkler protection for the room must provide a minimum density of 0.6 gpm/sq. ft. over the room with a 500-gpm hose stream allowance for a 2-hour duration. (4-8.2.9)	Sprinkler protection required by NFPA 855, and the CFC is discussed at length in the body of this report. However, the basic requirement would be for a 0.3 gpm/sq. ft. density.	The UFC sprinkler protection criteria are likely to be greater than what is required by NFPA 855/CFC (dependent on testing).
Pipes, conduits, and duct systems not used for the BESS room cannot pass through the room. (4-8.2.11)	Not specifically addressed. Any penetration through the fire-rated assembly is required to be protected.	The UFC specifically restricts any utilities that do not serve the BESS space from passing through it. This is not specifically commented on in NFPA 855/CFC, but any penetrations into the room would need to be protected.
Occupancy classification of the room is Group H-3 (4-8.2.13)	NFPA 855 and CFC do not provide occupancy classifications.	The UFC requires BESS rooms to be considered H-3 occupancies. NFPA 855/CFC do not provide occupancy classifications. However, the CBC classifies dedicated use buildings as Group F-1 and the IBC (2024 Edition) now clarifies that all BESS spaces are considered Group F-1. The IBC recognizes that the IFC provides more specific requirements for ESS than Group H requirements would.
A battery management system must be approved and meet manufacturer's specifications. The BMS must transmit signals to an approved location if hazardous conditions are detected. (4-8.2.14)	A BMS is not specifically required but is often used to meet thermal runaway protection requirements (NFPA 855 Section 9.6.5.5.2 and CFC Table 1207.6 Note e). There is no specific requirement to transmit signals to an approved location.	A BMS is essentially required by the UFC and NFPA 855/CFC since it is used to meet the thermal runaway protection requirement. However, only the UFC specifically requires that signals are transmitted to an approved location.

C.2 FM DATA SHEETS

FM or Factory Mutual Insurance Company (formerly referred to as FM Global) is a leading property loss insurance. FM is a mutual insurance company and is owned by its policyholders, so there is an incentive for policyholders to continually improve their property protection. Therefore, FM recommendations may be more restrictive than is necessary to meet the intent of providing life safety including stating as such in their technical reports. However, often research conducted by FM is incorporated into NFPA standards and local codes, including research into sprinkler protection for lithium-ion BESS fires.

FM provides data sheets for public use that can be used to help reduce the chance of property loss due to fire or other circumstances and failures. Specifically, FM data sheet (FMDS) 5-33 applies to lithium-ion BESS. Requirements/recommendations found in FMDS 5-33 that are equivalent to those found in NFPA 855 or the IFC/CFC are not included in this summary.

C.2.1 Location Preference

FM provides the following preferences for location:

1. In an enclosure outside and away from critical buildings or equipment.
2. In a dedicated building containing only BESS and support equipment.
3. In a dedicated exterior cutoff room that is accessible for manual firefighting.
4. In a dedicated interior corner cutoff room with at least two exterior walls accessible for manual firefighting.
5. In a dedicated interior cutoff room with at least one exterior wall that is accessible for manual firefighting.

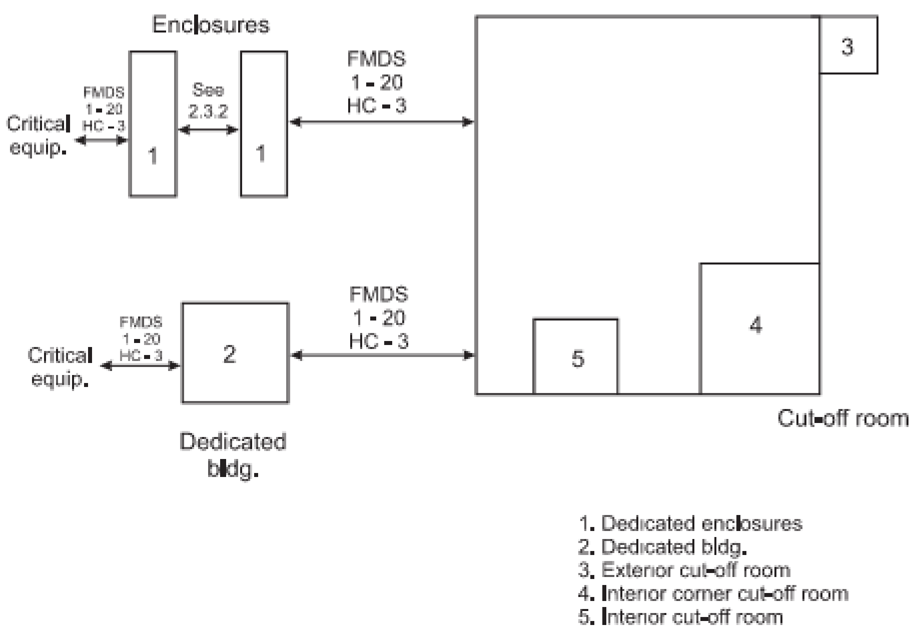

Figure C-1. FMDS 5-33 Fig. 2.3.1 Locations by Preference

C.2.2 Outdoor Requirements

A comparison of more stringent requirements found in FMDS 5-33 for indoor installations compared with NFPA 855/CFC is provided in Table C-3.

Table C-3. FMDS 5-33 Criteria Comparison for Outdoor Installations

FMDS 5-33 Requirement (Section)	*CFC/NFPA 855 requirement (Section)*	*Notes*
Separations between outdoor containers on sides with access panels, doors, or deflagration vents: + LFP: 5 feet + NMC: 13 feet, unless wall construction is at least 1 hour (ASTM E119), then reduce to 8 feet. (2.3.2.2 and 2.3.2.3) On sides with solid walls with no openings: + Separation distances on sides with no openings based on installation testing demonstrating that thermal runaway cannot propagate between containers, or above if testing is not available. (2.3.2.4)	BESS must be segregated into groups not exceeding 50 kWh and must be separated by a minimum of 3 feet Capacities can be increased and separation can be reduced based on UL 9540A testing. (NFPA 855 Section 9.4.2 and CFC Section 1207.5.1). Testing to determine distances between outdoor containers is not explicitly stated as required by NFPA 855 or the CFC.	FMDS requires a minimum separation for walls with openings, doors, etc. based on cell chemistry that cannot be reduced by fire testing. On other sides, distances can be reduced in a similar manner to NFPA 855/CFC. However, NFPA 855/CFC do not specifically indicate that installation-level testing must be performed for the containers, which may lead to acceptance of testing at smaller scales to reduce separation distances.
If any penetrations are present, separation should be extended, or the penetrations protected (2.3.2.4.1).	No explicit requirement to increase separation or protect openings for outdoor enclosures in NFPA 855 or CFC.	None.
Where explosion vents or other penetrations are provided, ensure they are arranged and directed away from surrounding equipment and buildings (2.3.2.4.2).	Deflagration vents must be designed to be setback from lot lines and directed such that there are no injuries to people on the property or public way (CFC Section 911.2).	None.

FMDS 5-33 Requirement (Section)	*CFC/NFPA 855 requirement (Section)*	*Notes*
Minimum separation from BESS enclosures to buildings or critical site utilities in accordance with FMDS 1-20 using hazard category 3 for the exposing building occupancy (2.3.2.5). Separation distances range from 5 to 50 feet (FMDS 1-20 Table 2).	ESS located outdoors must be separated by 10 feet from buildings, unless exceptions are met which allow reduction to 3 feet (CFC Section 1207.8.3 and NFPA 855 Section 9.5.2.6)	FMDS 5-33 refers to FMDS 1-20 *Protection Against Exterior Fire Exposure.* The separation distance from BESS units to buildings is highly dependent on the building's exterior wall construction. However, use of FMDS 1-20 may result in the need for greater exterior wall ratings or separation distances than required by NFPA 855/CFC.

C.2.3 Indoor Requirements

A comparison of more stringent requirements found in FMDS 5-33 for indoor installations compared with NFPA 855/CFC is provided in Table C-4.

TableC-4. FMDS 5-33 Criteria Comparison for Indoor Installations

FMDS 5-33 Requirement (Section)	*CFC/NFPA 855 requirement (Section)*	*Notes*
Provide damage-limiting construction in accordance with FMDS 1-44 (2.3.3.3.1 and 2.3.4.5.1). *Note: This is the FM guideline for design and construction of buildings or rooms where a deflagration hazard exists. Requirements include pressure-resistant construction and vents.*	Rooms and areas containing BESS are required to be provided with explosion protection (CFC Section 1207.6.3 and NFPA 855 Section 9.6.5.6). Explosion protection is provided by NFPA 68 or NFPA 69.	All standards recognize the deflagration hazard posed by lithium-ion BESS. However, FM refers to damage limiting construction which has minimum requirements for the pressure resistance of enclosures and requires vents. This approach is similar in concept to NFPA 68.
Air circulation must be provided at 1 cfm/sq. ft. (2.3.3.5 and 2.3.4.4). FM approved hydrogen detectors are required to alarm at 10% of LEL and ramp ventilation rate to 2.5 cfm/sq. ft. (2.5.5).	Constant air circulation is not required for lithium-ion batteries.	FM requirement is somewhat similar to exhaust ventilation requirements from NFPA 855/CFC for technologies that produce flammable gases under normal operating conditions. The increased ventilation rate may function similarly to an NFPA 69 combustible gas concentration reduction system, albeit with different design criteria.

FMDS 5-33 Requirement (Section)	CFC/NFPA 855 requirement (Section)	Notes
Single row or back-to-back racks must have solid, noncombustible fire barriers between racks in non-dedicated-use buildings. (2.3.4.1) Separation between non-accessible sides of adjacent racks determined on installation level-testing or assume thermal runaway will propagate (2.3.5.3). Indoor BESS racks must have 6-foot separation from the accessible face to noncombustible exposures, and adjacent BESS racks (2.3.5.1). Indoor BESS racks must have 9-foot separation from combustibles and combustible construction elements (2.3.5.2).	BESS must be segregated into groups not exceeding 50 kWh and must be separated by a minimum of 3 feet (including 3 feet from walls). Capacities can be increased and separation can be reduced based on UL 9540A testing. (NFPA 855 Section 9.4.2 and CFC Section 1207.5.1).	FM provides more detailed and stringent requirements for separation of BESS racks from each other and from walls. As with outdoor installations, separation distances between accessible faces cannot be decreased by fire testing. Also, in non-dedicated-use buildings, adjacent racks must have barriers installed between them to slow fire propagation.
Sprinkler protection is required to be provided at 0.30 gpm/ft^2 over the room area, with a 250-gpm allowance for hose streams. (2.4.1) Room must be designed to address drainage of water released (2.4.2).	Automatic sprinkler systems must have a minimum design density of 0.3 gpm/ft^2 (CFC Section 1207.5.5 and NFPA 855 Section 4.9.2.1). NFPA 855 limits this protection criteria to ESS up to 50 kWh. CFC and NFPA 855 only require 2,500 sq. ft. design area or room area, whichever is less. No specific requirements for water drainage.	FM states the following: “Testing of a 125 kWh LIB-ESS utilizing lithium nickel oxide/lithium manganese oxide (LNO/LMO) batteries demonstrated that the fire growth ultimately exceeded the 2500 ft^2 design area. Therefore, the sprinkler design should be designed for the room area.”

FMDS 5-33 Requirement (Section)	CFC/NFPA 855 requirement (Section)	Notes
The duration of water supply is based on the estimated duration of the fire event, based on 45 minutes times the number of racks in a fire area. A fire area is considered to be a row of racks where the separation distances for indoor racks (see above) is not met (2.4.2).	Water supply duration is not explicitly stated by NFPA 855/CFC. Water supply duration could be based on an extra hazard occupancy based on NFPA 13, which would require 1.5-2 hours of water supply duration (NFPA 13 Table 19.2.3.1.2)	Lithium-ion BESS fire events have been observed to continue for extended periods of time, and FM global recognizes that this time period is correlated to the number of racks that could reasonably be expected to become involved.

C.2.4 Equipment and Processes

FMDS requires the following to be provided for equipment and processes:

+ Short circuit and protection coordination study for existing circuit breakers when the BESS adds power to the existing electrical system
+ Provide a disconnect at each rack. Additionally, provide a remote and local disconnect for the BESS space.
+ Provide a high temperature alarm, routed to a continuously attended location, for each room, building or enclosure with BESS.
+ Grounded systems must be provided with ground fault protection. Ungrounded systems must be provided with ground fault monitoring with an alarming function.
+ Overcurrent, overvoltage, and under-voltage protection must be provided.
+ The BMS is required to have the following functions:

- High cell temperature trip (cell level): Isolates the module or rack when a cell temperature exceeding limits is detected.
- Thermal runaway trip (cell level): Trips the entire system when a thermal runaway condition is detected in a cell.
- Rack switch fail-to-trip: Identifies any failure from the pack switch to trip once a trip command is initiated.
- Inverter/charger fail-to-trip: Isolates the BESS if the inverter/charger fails to trip or if communication is disrupted.

+ An online condition monitoring system must be provided for the parameters found in FMDS 5-33 Section 2.5.3.2.1. The system must be able to transmit data to a constantly attended location or personnel, generate alarms when unusual conditions are detected, analyze monitored parameters and create a summary of battery condition, prevent unauthorized changes to parameter limits, and have self-diagnostic capabilities. The following parameters must be monitored at the module or cell level.
+ Early intervention thermal runaway protection is required by either high cell temperature monitoring or off-gas monitoring.

- Power conversion equipment must be provided with overcurrent protection and surge arrestors on the AC side. Transformer electrical protection must be provided in accordance with FMDS 5-4 or 5-20.

C.3 ARIZONA PUBLIC SERVICE

Arizona Public Service (APS) is an electric utility that serves central Arizona. APS Appendix W contains safety requirements applicable to the design, construction, and installation of BESS. APS Appendix W requirements in many cases exceed those required by local jurisdictions in Arizona.

C.3.1 Types of Facilities

APS allows only outdoor non-occupiable units for BESS components. APS defines non-occupiable units as “A BESS contained within prefabricated enclosures containing components of the system, but without ability for personnel to enter the enclosures (other than to reach in for access to components for maintenance purposes).”

Occupiable spaces may be built for other uses such as control rooms or bathrooms.

C.3.2 Enclosure Requirements

APS Appendix W requires the following for the BESS enclosure:

- The enclosure and any insulation must be fire-rated using UL 263 (4th Edition) and/or ASTM E119 (2020) or equivalent materials. Fire rating is required to be at least the minimum of a fire event according to UL 9540A test results or 1 hour, whichever is greater.
- Prefabricated BESS enclosures must meet minimum outdoor enclosure rating as specified in NEMA 3R in accordance with ANSI/IEC 60529:2004, or an IP 54 rating.

C.3.3 General Facility Design and Layout

APS facilities are required to meet the following general requirements for facility design and layout:

- Must be enclosed by a wall or fence.
- Consideration for external fires impinging on BESS units must be included in the design.
- Each facility must have a first responder station (FRS). The first responder station has information such as site plans, indication of major equipment status, and information on fire and explosion protection systems and alarms.

C.3.4 Separation Requirements

APS Appendix W lists the following requirements for separation:

- Fire-resistant barriers installed within enclosures, between racks or modules, unless demonstrated as unnecessary by UL 9540A testing.
- Enclosures separated from each other and from other equipment and structures by a distance determined through UL 9540A testing and as approved in a sealed letter from a fire protection engineer.

C.3.5 Explosion Control

Explosion control must be provided in accordance with NFPA 68, NFPA 69, or both. The following preference is given:

1. Provide both NFPA 68 and NFPA 69 system.
2. Provide only an NFPA 69 system.
3. Provide only an NFPA 68 system.

CFD modeling is required to be conducted in accordance with NFPA 68 or 69 as applicable, utilizing data from UL 9540A tests. The CFD model must include case runs for the following scenarios and be made available to the developer of the HMA:

- Thermal runaway event from the total number of cells that reached thermal runaway in UL 9540A module or unit level testing (whichever is greater).
- Thermal runaway event producing gas cloud of 25% of the LFL.
- Thermal runaway event producing gas cloud of 100% of the LFL.
- Thermal runaway event producing gas cloud just before the upper flammability limit (UFL).

The CFD modeling must also simulate enough ignition points to identify the "worst-case" ignition point for modeling and utilize this point in the modeling. The model must also consider and address the potential for small, trapped gas spaces.

An NFPA 68 evaluation must utilize either the full volume or partial volume method.

The activation of a powered NFPA 69 ventilation system must be controlled by a system listed for explosion or fire control purposes.

Hazard zones that are determined as part of explosion control modeling efforts must be incorporated into the HMA.

C.3.6 Fire and Explosion Detection, Alarm, Control, and Suppression/Protection

The fire and explosion detection, alarming, control, and suppression system must be UL 864 listed where commercially available.

A gas detection system must be provided and meet the following requirements:

- Gas detected must be based on UL 9540A data for the explosive gas(es) most likely to be detected under fault conditions and located appropriately for the expected gas and flows.
- The system must trigger visual and audible alarms that are distinct from fire alarms. The alarms must also be sent to the FRS and be supervised.
- The detector must be able to continue operating under non-flaming thermal runaway conditions and be capable of determining if the environment in the enclosure is below the flammability limit of the explosive gases.

- A smoke and/or heat detection system for the unit must be designed, installed, inspected, tested, and maintained in accordance with NFPA 72. Automatic visual and audible alarms that are triggered by the smoke, heat, or fire detection system must be provided on the exterior of the enclosures and designed, installed, inspected, tested, and maintained in accordance with NFPA 72.
- Appendix W does not recommend suppression within enclosures unless tested in accordance with UL 9540A. Where testing is not performed for a suppression system, it is recommended that water is only used as a defensive tool to manage risk to adjacent exposures. If water-based systems are provided, they must be installed in accordance with NFPA standards.
- Finally, Appendix W states that “dry-type” (i.e. clean agent) fire suppression systems designed, installed, inspected, and tested to the applicable NFPA standard or in accordance with manufacturer’s recommendations may be installed for suppression on non-battery fires. If this system is provided it may not interfere with the explosion control system.

C.3.7 Plume Analysis

A plume analysis is required for the installation to assess the flammability and toxicity risks of the battery failure plume. The results of the plume analysis modeling are used in the development of the HMA.

The following scenarios are required to be considered:

- Flaming or non-flaming. Flaming scenarios should consider flammability and toxic gas generation from other components in the enclosure where information is available.
- A single rack failure.
- A full propagation event of the entire enclosure.
- Multiple enclosures if the UL 9540A tests show propagation between containers or it is reasonably expected based on other studies and analysis performed.

The plume analysis may be performed using SCICHEM, Phast, or SAFER/TRACE.

C.3.8 Hazard Mitigation Analysis

An HMA is required for each facility and must include the following:

- Minimum approach distances (MAD) which is the distance that a qualified person may approach the hazard without proper PPE. MAD are based on the modeling required, FMEA, FRA, etc. that considers fire events, deflagration events, and venting/thermal runaway events.
- A FMEA in accordance with IEC 60812 that focuses on safety including probable and bounding design basis accidents.
- Summary of the required explosion control and plume modeling.
- Fire Risk Assessment (FRA) in accordance with NFPA 551. The FRA must identify a 5 kW/m^2 boundary and assess heat transfer to adjacent exposures.
- Identification of critical design elements and any corrections.

C.3.9 Emergency Response Planning and Training

An emergency response plan (ERP) must be prepared prior to batteries arriving on the site and maintained on site throughout the operation of the facility in the FRS. The emergency response plan ensures a well-coordinated response by designating an Emergency Event Management Coordinator and by requiring continuous training to onsite personnel. Training is required to be in accordance with the Homeland Security Exercise and Evaluation Program and include the responding fire department. Classroom training must also include FEMA IS-100/200 training and the Emergency Event Management Coordinator is required to take the FEMA IS-300/400 training.

ERP's are required to utilize information from the HMA and use terminology that first responders are familiar with. A Tactical Worksheet, which is intended to provide the most important information in a short (maximum 3 page) format is also required to be provided. ERPs and the Tactical Worksheets must be reviewed and updated annually with copies made available to the AHJ within 30 days of modification.

Training on the FRS and ERP must be conducted with the AHJ and first responders prior to batteries arriving on site and updated training must be offered to first responders at least annually. A video must also be provided to the responding fire department for distribution within the department.

The ERP must also provide a plan for mitigating hazards due to stranded energy and provide procedures for safe removal and discharge.

C.4 LOCAL JURISDICTIONS

C.4.1 Phoenix Fire Code

The Phoenix Fire Code (PFC) is based on the 2018 IFC but has been heavily modified. PFC requires that all systems exceeding 3 kWh receive a construction and operation permit. The CFC, IFC, and NFPA 855 all have separate provisions for Group R-3 and R-4 occupancies while the PFC requires that BESS in Group R-3 and R-4 occupancies comply with all requirements.

This section will focus on PFC modifications that are more stringent or are in addition to those found in NFPA 855/CFC. Differences based on the PFC being based on an earlier edition of the IFC than the current CFC are not addressed.

Table C-5 Phoenix Fire Code Comparison

PFC Requirement (Section)	CFC/NFPA 855 requirement (Section)	Notes
Permits must be obtained for the construction and operation of stationary ESS with a capacity of more than 3 kWh. (1206.2)	CFC requires permits for all ESS exceeding threshold quantities in Table 1207.1.1, which are typically greater than 3 kWh. NFPA 855 does not specifically require permits as an installation standard, however Table 1.3 lists the threshold quantities for compliance with NFPA 855.	The PFC has a lower threshold for requiring permits than the CFC. However, Section 1206 of the PFC applies to BESS exceeding quantities in Table 1206.2, which is similar to how NFPA 855/CFC function.
HMA can be requested by the fire code (1206.2.3).	The CFC does not contain a specific allowance for the fire code official to request an HMA. NFPA 855 includes the ability for the AHJ to require an HMA to address a potential hazard with an installation that is not addressed by existing requirements (NFPA 855 Section 4.4.1)	The PFC gives the fire code official the authority to request an HMA that would not otherwise be required (i.e. for increasing maximum stored energy (maximum allowable quantities). NFPA 855 also has this provision with the qualification that a hazard is not addressed by the base requirements. Therefore, the PFC and NFPA 855 give the fire code official more authority to require an HMA than the CFC does.
Failure of temperature control is an additional fault condition required to be addressed by the HMA (1206.2.3.1 Item 8). The fire code official may also deem other failure modes as necessary to be evaluated.	The CFC does not specifically include failure of temperature control as a required fault condition. NFPA 855 is also not specific, although failure of a protection system not covered by the product listing FMEA may cover this (NFPA 855 Section 4.4.2.1).	The PFC includes an additional specific requirement for failure of temperature control to be assessed by the HMA, which is not specifically included in NFPA 855/CFC. Failure of temperature control may already be addressed in a product listing FMEA.
Analysis approval for HMA requires that flammable gases released from ESS during charging, discharging, normal operation will not exceed 10% of the LFL. (1207.1.4.2 Item 4).	NFPA 855 does not contain a similar analysis approval criterion. CFC requires the same approval criterion, but with a threshold of 10% of LFL (CFC Section 1207.1.4.2).	None.
Exhaust ventilation is required for lithium-ion batteries (Table 1206.2.10).	Exhaust ventilation is not required for lithium-ion batteries by the CFC or for NFPA 855.	Exhaust ventilation is typically used for battery technologies that release flammable gases under normal operations, which is not the case for lithium-ion batteries.

PFC Requirement (Section)	*CFC/NFPA 855 requirement (Section)*	*Notes*
Energy management systems must transmit an alarm signal to an approved location and an approved annunciator panel if hazardous conditions are detected (1206.10.3). An approved annunciator panel is required to be provided to indicate hazardous conditions detected by the energy management system and must be located in an approved location (1206.2.10.3.1).	The CFC does not contain a requirement for signal transmission from emergency management systems. NFPA 855 contains a provision that the AHJ can require visible annunciation on the cabinet exterior or at an approved location (NFPA 855 Section 9.2.3.3).	The visible annunciation is intended to provide emergency responders with information about potentially hazardous conditions. NFPA 855 does not specifically state that an annunciator panel must be used, as PFC does.
Alarm and supervisory signals from all fire protection and life safety systems must be transmitted to an approved station and to the annunciator panel (1026.2.11)	The CFC only specifically requires that alarm signals from detection systems are submitted to an approved station (CFC Section 1207.5.4). NFPA 855 contains various provisions requiring signals to be transmitted and systems to be supervised including exhaust ventilation systems and gas detection systems.	The PFC has a blanket requirement that all alarm and supervisory signals are transmitted to an approved station, while the CFC and NFPA 855 have more limited requirements.
Automatic sprinkler systems must have a minimum design density of 0.6 gpm/ft^2 (1206.2.11.1.1)	Automatic sprinkler systems must have a minimum design density of 0.3 gpm/ft^2 (CFC Section 1207.5.5 and NFPA 855 Section 4.9.2.1). NFPA 855 limits this protection criteria to ESS up to 50 kWh.	PFC, NFPA 855, and CFC all include provisions for other protection based on fire testing. However, PFC has an increased requirement for the basic requirement for sprinkler density.
Exhaust ventilation systems must be provided with 6 hours of standby power and be provided with clearly identified manual controls (1206.2.11.3.3 and 106.2.11.3.4)	The CFC requires 2 hours of standby power and does not include a requirement for manual controls (CFC Section 1207.6.1.2). NFPA 855 does not contain a requirement for standby power or manual control, except for gas detection systems used to activate the system must have 2 hours of standby power (NFPA 855 Section 9.6.5.1.5.4).	None.

PFC Requirement (Section)	*CFC/NFPA 855 requirement (Section)*	*Notes*
Explosion control systems must comply with NFPA 68 and NFPA 69 (1206.2.11.6)	Explosion control systems must comply with either NFPA 68 or NFPA 69 (CFC Section 911 and NFPA 855 Section 9.6.5.6.3). NFPA 855 also allows for some exceptions for cabinets with alternative engineered systems.	None.
An approved means to safely release stored energy during an emergency situation must be provided (1206.2.11.7)	The CFC and NFPA 855 do not have any related requirement.	None.

C.4.2 Kern County Fire Code

Kern County modifies the 2022 CFC and also provides an application guide for BESS. Kern County adopts NFPA 855 (2020 Edition) for BESS that are regulated by Section 1207. The Kern County application guide also includes the following requirements/clarifications:

+ ESS Walk-in Unit: If more than arms can enter the enclosure, an outdoor BESS is walk-in unit.
+ Construction documents: Additional requirement for a site plan with the layout diagram of enclosures including size, distance between units, and distance to exposures. The plans must also show fire apparatus access and water supply.
+ HMA: HMA of fire risk analysis (FRA) prepared by an FPE is required for all installations.
+ Emergency Action Plan: An emergency action plan is required for all installations both during construction and operation after approval.
+ Contractor’s Licenses: C-16 licenses are required for automatic sprinkler systems and water supplies and C-10 licenses are required for fire alarm systems and gas detection systems.
+ Gas Detection Systems: Gas detection systems are required to comply with NFPA 72.
+ References are made to NFPA 855, 2023 Edition. This may indicate that Kern County is enforcing compliance with this edition rather than the 2020 Edition, which is adopted by the Municipal Code.

C.4.3 New York State

Following a series of fires at three BESS locations across New York State, an interagency fire safety working group (WG) was formed to address safety concerns around lithium-ion BESS. The objective of the WG was to investigate recent fires, inspect current installations, identify gaps in codes and industry best practices, and develop recommendations for revisions and enhancements to the Fire Code of New York State (FCNYS). The FCNYS is based on the 2018 Edition of the International Fire Code, which was created prior to the incorporation of many of the requirements found in the more recent editions of the Fire Code and NFPA 855. However, New

York state adopted the draft language from the 2021 IFC in 2020. Therefore, much of the language in the FCNYS is similar to the 2022 CFC, since they are based on the same edition of the IFC.

The WG released a list of recommendations in February of 2024, which was shared with organizations including the New York City Fire Department (FDNY), NFPA, ICC, and UL. Public comments were received and incorporated into the Fire Code Recommendations Report, which was released in July of 2024. The WG recommendations were developed to apply only to lithium-ion BESS exceeding 600 kWh with a focus on outdoor, dedicated use buildings, and other grid-scale BESS systems. While the WG recommendations may not fit all sites, the recommendations are some of the most recent updates to the 2021 Edition of the IFC that have been able to be reviewed and provided with public feedback. The following paragraphs describe the WG recommendations and a general summary of public feedback.

Table C-6 New York State Working Group Fire Code Recommendations Comparison

New York State Working Group Recommendation	*CFC/NFPA 855 requirement (Section)*	*Notes*
Reference 2023 Edition of NFPA 855 in the next edition of FCNYS.	N/A	No public comments.
Require industry-funded independent peer reviews for all projects: + Local AHJs can lack resources or expertise in reviewing critical documents such as the HMA, FMEA, and UL 9540A reports. Peer reviews can assist AHJs in their review and understanding of permit applications. + FCNYS contains language that authorizes local AHJs to require BESS developers pay for an independent peer review, however, it is rarely utilized and this recommendation would make it mandatory.	No requirements.	Public commentary was mostly supportive of required peer reviews; however, issues were addressed such as costs, scope and deliverables, qualifications of peer reviewers, and the peer review process as causes for concern. The WG stood by the original recommendation even after concerns from public commenters.

New York State Working Group Recommendation	CFC/NFPA 855 requirement (Section)	Notes
Require explosion control for BESS cabinets in addition to rooms, areas, and walk-in units. Additionally, provide design requirements or language for what constitutes a passable system: + The current FCNYS does not include specific design requirements for explosion control systems. + Recommended that NFPA 68 and NFPA 69 are referenced in the updated fire code and that that flexibility is included for other solutions outside of NFPA 68 and 69 systems. + Address the lack of a requirement to provide substantiating documentation for the explosion prevention system. This includes computational fluid dynamics (CFD) analysis, sizing calculations, and testing.	CFC states that explosion control is required for “rooms, areas, and walk-in units” which may be interpreted that cabinets are not included (CFC Section 1207.6.3). NFPA 855 specifically includes cabinets in explosion control requirements (NFPA 855 Section 9.6.5.6.3). Both CFC and NFPA 855 reference NFPA 68 and NFPA 69 (CFC Section 911 and NFPA 855 Section 9.6.5.6.3). CFC and NFPA 855 do not specifically require substantiating documentation.	Public commentary was overall supportive of the proposed additions. The WG also clarified that the HMA may not be sufficient for validation of explosion control systems.

New York State Working Group Recommendation	*CFC/NFPA 855 requirement (Section)*	*Notes*
Require that qualified personnel are available for dispatch within 15 minutes and able to arrive on scene within 4 hours to provide support to local emergency responders. + 2024 IFC requires fire mitigation personnel to dispatch within 15 minutes. The WG added the requirement that they are able to arrive on site within 4 hours. + Recommended that the personnel successfully completed ICS-100, ICS-200 and IS-700B which are offered by the Federal Emergency Management Agency (FEMA). + Recommended that the Fire Code requires a qualified person knowledgeable about the project and associated hazard be immediately available by phone.	NFPA 855 and the CFC require an authorized service personnel is dispatched when a fire or other event damages the ESS and ignition or reignition is possible (NFPA 855 Section 9.6.6.1 and CFC Section 1207.1.6). Hazard support personnel are also required when requested by the AHJ (NFPA 855 Section 9.6.6.2).	Public feedback stated that this recommendation was impractical, but WG reiterates that requirement is found in the 2024 IFC and 2023 NFPA 855, with only the addition of the 4-hour arrival on site. Local community groups preferred that lithium-ion battery experts are imbedded into county or state emergency response and hazmat infrastructure, and the WG suggested that a hazmat cost recovery system could offset the cost of integrating these experts. The WG suggested the use of a certification program similar to FDNY B28.
Extend signage location requirements beyond BESS to include perimeter fences or security barriers and include a site map. + Signage should contain 24-hour emergency contact information and hazard warnings. + Signage or maps should identify isolation distances response personnel should maintain from BESS during an emergency. + Signage should be provided for grid-interactive BESS operating in parallel with other power generating sources. + Signage should be provided indicating explosion hazard zones.	CFC and NFPA 855 do not require signage to be posted on perimeter fences or to include a site map.	Public commentary was positive towards this recommendation and included a requirement that deflagration panels be directed towards the sky to minimize injuries to first responders. Additional recommendations include establishing a distance from the project fence line or the closest roadway for the signage and mandating that signage indicate when it was last updated.

New York State Working Group Recommendation	CFC/NFPA 855 requirement (Section)	Notes
Require that BMS data incorporates high resolution sensor data, including voltage, state of charge, and temperature measurement of each cell or series-connected cell group. This data would be monitored by a 24/7 staffed network operations center (NOC) and failure notifications should be immediately communicated to the site owner/operator. + This requirement could also fulfill the recommendation that a qualified person be available for immediate phone consultation in the Fire Mitigation Personnel recommendation.	The CFC does not have specific requirements for BMS data or a requirement for monitoring of BMS data. NFPA 855 also does not have these requirements. NFPA 855 has some information on monitoring of energy management systems by central stations (NFPA 855 Section A.4.3.2.1.4(3))	Public commentary was generally supportive, although additional costs associated with an NOC was noted as problematic. Some public support indicated that the requirement for an NOC made Hazard/Fire Mitigation Personnel unnecessary, but the WG suggested that the recommendations are complementary and having on site assistance is important.
Add a requirement for video surveillance systems to allow for continuous monitoring and post-event analysis. + This update is not incorporated into NFPA 855 or the 2024 IFC. + Access to footage should be available to emergency responders during an incident in addition to being provided for post-event investigation.	No requirement.	Public commentary was positive but highlighted cybersecurity issues for sites located at utility substations. The WG suggested that a modification to the recommendation is made to include that the footage is available to first responders as required by the AHJ, so that utilities may operate under their own relevant regulations. The WG also recommended that the requirement for video storage is capped at 72-168 hours unless a fire occurs due to the high costs of storing video data. It was also suggested that video surveillance is monitored by the NOC.

New York State Working Group Recommendation	CFC/NFPA 855 requirement (Section)	Notes
Removal of the exemption for Fire Code requirements for BESS projects owned or operated by electrical utilities. + This update aligns with the proposed language in Section 1201.1 in the IFC.	CFC contains an exemption for electrical utilities. NFPA 855 does not address applicability in this way since it is a standard, not a code.	Public commentary was supportive, except for utility companies. The WG continued to recommend removal of the exception, in alignment with the 2024 IFC.
Add a requirement for an emergency response plan (ERP) and annual local first responder training. + Recommended that an emergency response plan that is written specifically for first responders is provided for every facility and that annual site-specific training is provided to local fire departments. + The WG highlights the difference from fires safety plans (such as Fire Code Section 403 and NFPA 855 Section 4.3.2.1) which are created for emergency operations for personnel.	The CFC and NFPA 855 do not require ERPs and the CFC does not address first responder training. NFPA 855 requires emergency operations plans and training for personnel, but not for first responders (NFPA 855 Section 4.3). NFPA 855 has guidance for emergency responder protocols in Appendix G.11.2.	Public commentary was very supportive except for concerns for fire department bandwidth for trainings and to provide feedback on the emergency response plan. The WG modified the recommendation to state that the owner or operator must make effort to include the local fire department in preparation of the ERP and annual trainings but does not penalize sites where the local fire department does not participate.
Add a requirement for monitoring of fire detection systems by a central monitoring station that meets the requirements of NFPA 72, as required by 2024 IFC.	CFC and NFPA 855 contain this requirement (CFC Section 1207.5.4 and NFPA 855 Section 4.8.1)	Public commentors may have misunderstood this requirement for a network operations center (NOC) monitoring of a BMS. The central station monitoring requirement applies to the fire alarm signals from the BESS installation (such as smoke detectors).

New York State Working Group Recommendation	CFC/NFPA 855 requirement (Section)	Notes
Add a requirement for industry-funded special inspections. + The recommended inspections would be required on a regular basis, with the frequency dependent on the specific needs and risks of each site.	No requirement.	The WG believed that public commentors misunderstood the use of the term “special inspections” and clarified that the recommendation is analogous to the special inspection requirements in Chapter 17.
Remove current perceived exemptions for BESS cabinets by including “cabinets” in all Fire Code requirements that pertain to rooms, areas, or walk-in units, except for fire suppression requirements. + The use of “rooms, area, and walk-in units” for requirements for outdoor units appears to exclude non-enterable units from requirements. + The recommendation applies to the following requirements: large-scale fire test, security of installations, maximum allowable quantities, and fire detection.	CFC still contains perceived exceptions. NFPA 855 has removed most of these perceived exceptions.	- Public commentary was supportive and noted that most AHJs have been interpreting the Fire Code this way for a few years. -

Additional topics that were considered but ultimately not included in the recommendations are as follows:

+ Root Cause Analysis. The WG found that the Fire Code may not be the appropriate means to require a root cause analysis.
+ Water Supply. The WG recognized that a universal requirement for water supply would likely be inappropriate since water is often not appropriate for extinguishing fire, but rather for containment. The water supply needs will vary among systems.
+ Transformers Containing Highly Flammable Materials. The WG noted that propagation from a BESS fire to non-dry-type transformers may exacerbate a BESS failure, but the Fire Code is also not clear if transformers are included as an exposure requiring clearance. The WG suggested that there is further discussion around this requirement, or that existing relevant standards are used to address potential issues.
+ Fire Stops, Barriers, or Fire Breaks. The WG originally made a recommendation to fire stop BESS enclosure penetrations to prevent propagation, however public commentary indicated that this requirement is redundant from UL 9540A testing and creates an onerous burden on the industry.

Appendix D Insights from EPRI's BESS Failure Incident Database (2024 Whitepaper)

Electric Power Research Institute (EPRI) began the Failure Incident Database in 2021 following the previously mentioned fires in South Korea and the Surprise, Arizona incident. The database is based on publicly available information for BESS failure events at stationary BESS facilities, including commercial, industrial, and utility-scale BESS. EPRI defines commercial and industrial scale to include "behind-the-meter" installations, while utility-scale installations are directly interconnected with the grid. Although the database was started in 2021, it includes data on incidents as far back as 2011 and is updated regularly. The database also considers a failure event as an event that had an impact or risk to public health and safety and as an occurrence that was caused by a system component rather than an outside failure cause (for example, wildfire). The database may not be inclusive of all events, but it is also the most comprehensive database available.

The white paper *Incidents from EPRI's BESS Failure Incident Database* was released in May of 2024 and the database had 81 incidents at the time of preparation, 26 of which had sufficient information to assign a root cause and to identify the element that experienced failure. The white paper also highlights the difficulty of determining the cause of failures due to the reluctance of original equipment manufacturers (OEMs) and integrators to disclose the cause of failure publicly. However, for the incidents where the root cause could be identified, it was classified into one of the following four categories:

+ Design: Failure of planned architecture, layout, or functioning of the individual components or the BESS. This includes fundamental product flaws or lack of safeguards.
+ Manufacturing: A failure due to a defect in an element of the BESS introduced in the manufacturing process.
+ Integration, Assembly, and Construction: A failure due to poor integration, incompatibility of components, incorrect installation, or inadequate commissioning.
+ Operation: A failure due to operating conditions exceeding the design tolerances.

The failures were also classified by the failed element into the following categories:

+ Cell/module: A failure originating in a cell or module. These failures usually begin with short circuits within a cell that lead to thermal runaway.
+ Controls: A failure in the sensing, logic circuits, and communication systems. Control systems include the BMS, EMS, plant controllers, and subsystems.
+ Balance of system (BOS): A failure of other elements outside of cells, modules, and controls. Typically, this includes busbars, cabling, enclosures, inverters, transformers, suppression systems, HVAC, and liquid cooling systems.

Figure D-1 shows a breakdown of the root causes of incidents where known. A single incident could be classified under multiple root causes or failed elements.

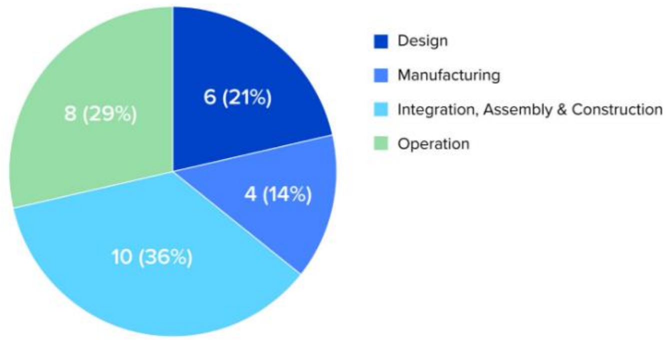

Figure D-1. Root Causes of BESS Incidents [19]

The least common root cause is manufacturing, which may be due to the difficulty of identifying a manufacturing defect as a root cause and may also be attributed to UL Standards 1973 and 1642 (see Report Section 2.1). The most common root cause of integration, assembly, and construction. There are many failures that occurred in the first two years of installation, but there are also many newer systems compared to aged systems. This trend may change over time as the systems recently installed begin to age.

The report also performed a biaxial analysis which paired root causes with failed elements. Integration, assembly, and construction most commonly were associated with a failure in the balance of the system. This indicates that assurance that the BOS components and the battery system are compatible and that both are assembled correctly is a key to preventing failures.

The other common biaxial connection was between operations and controls. The vast majority of these failures occurred between 2018 and 2019 in South Korea and are believed to be due to operational limits for SOC, voltage, etc., not being well understood yet.

Table D-1 Root Causes of BESS Incidents

Root Cause	*Failed Element*	*Mitigations and Recommendations*
Design	Controls, BOS	+ Compliance with relevant codes and standards (UL, NFPA). The latest revisions have incorporated lessons learned from past failures. + Site-specific hazard assessments to consider all risks and failures. + Robust sensing and monitoring for early alerts of design failures.
Integration/ Assembly/ Construction	BOS, Controls	+ Workforce training and quality checks during energy storage commissioning and installation. + System-level failure analysis, especially for components interfaces.
Manufacturing	Cell/Module, Controls	+ Increased manufacturing quality controls. + Supplier quality verification. + Robust system specifications. + Factory acceptance testing.
Operation	Controls	+ Battery monitoring and analytics to augment BMS operation, generating trends and predictive analyses to identify potential failures early

Appendix E Considerations for the Review and Approval of Seismic Analyses

E.1.1 For the Building or Nonbuilding Structure Containing the BESS

1. Verify that all seismic inputs are in accordance with Section 1603.1.5 of the 2021 Edition of the IBC and 2022 Edition of the CBC are indicated within the design documents and are appropriate for the subject BESS site.
    a. Risk category.
    b. Seismic importance factor, I_e.
    c. Mapped spectral response acceleration parameters, S_S and S_1.
    d. Site class.
    e. Design spectral response acceleration parameters, S_{DS} and S_{D1}.
    f. Seismic design category.
    g. Basic seismic force-resisting system(s).
    h. Design base shear(s).
    i. Seismic response coefficient(s), C_S.
    j. Response modification coefficient(s), R.
    k. Analysis procedure used.
2. If the Structural Engineer of Record (SEOR) selects a Risk Category classification of the subject BESS site that is less than Risk Category IV (see Table 1604.5 of 2021 Edition of the IBC and 2022 Edition of the CBC), then ensure that sufficient justification of this lesser risk categorization is provided in the design documentation.
3. In accordance with Section 11.4.8 of ASCE 7-16, verify that the geotechnical engineer has provided a site response analysis (for Site Class F sites) or ground motion hazard analysis (for the following instances) the site unless exempted.
    a. Seismically isolated structures and structures with damping systems on sites with S_1 greater than or equal to 0.6.
    b. Structures on Site Class E sites with S_s greater than or equal to 1.0.
    c. Structures on Site Class D and E sites with S_1 greater than or equal to 0.2.
4. In accordance with Section 11.8 of ASCE 7-16:
    a. Ensure that the site is not located where a known potential exists for an active fault to cause rupture of the ground surface at the structure if the subject BESS structure is Seismic Design Category E or F.
    b. Ensure that the geotechnical engineer at the site has generated a geotechnical investigation report if the subject BESS structure is Seismic Design Category C, D, E, or F.
5. If the structure is seismically designed using a response coefficient *R* that exceeds three (ASCE 7-16 Tables 12.2-1 or 15.4-2), then verify that the SEOR has justified the higher *R* value by ensuring that proper

detailing of connections, reinforcement, section sizes, etc. are used within the structure. Use the details provided in the AISC Seismic Design Manual as needed.

6. Verify that all special inspection practices for construction materials that are required in accordance with Ch. 17 of 2021 Edition of the IBC and 2022 Edition of the CBC are indicated within the design drawings and/or specifications.
7. Verify that references to the associated International Code Council (ICC) Evaluation Service Reports (ESRs) for each make and model of anchorage used at the site are indicated within the design drawings and specifications.
    a. Ensure that, for anchorage components whose structural capacities (as listed in the associated ICC-ESR) vary between sustained loads (such as dead loads) and seismic loads, and between cracked and uncracked conditions of the concrete into which the anchors are to be installed, that the correct capacities are used. Since almost all concrete members are prone to cracking (except prestressed members and slabs), it is recommended that “cracked concrete” values are picked when manufacturer’s design tables are used for capacity determination rather than testing or explicit formulation from Chapter 17 of ACI 318-19.
    b. Note that design tables for anchors only provide single anchor capacities and potential reduction factors for many different cases, however, special attention shall be given when a group of anchors are designed for multi-directional loading. Reduction factors due to member thickness, concrete edge distance and anchor spacing for corner anchors (if laid in a grid pattern) can be challenging.
8. Verify that deflections / drifts of the structures have been calculated (using the appropriate deflection amplification factors, C_d, in accordance with Ch. 12 of ASCE 7-16) and that there is sufficient clearance between adjacent structures to prevent impact between the structures during a seismic event.
9. Verify that appropriate redundancy factors, ρ, in accordance with Section 12.3.4 of ASCE 7-16, are incorporated into the analysis of structural components as required.
10. Verify that appropriate overstrength factors, Ω_0, in accordance with Section 12.4.3 of ASCE 7-16, are incorporated into the analysis of structural components as required.

E.1.2 For the BESS Units and their Supporting Systems, Supporting Components, Racks, etc.

1. Verify that all seismic inputs in accordance with Ch. 13 of ASCE 7-16 are indicated within the design documents and are appropriate for the subject BESS site and for each analyzed component.
    a. Component amplification factor, a_p.
    b. Component importance factor, I_p.
    c. Component operating weight, W_p.
    d. Component response modification coefficient(s), R_p.
    e. Height in structure of point of attachment of component with respect to the base, z.
    f. Average roof height of structure with respect to the base, h.
    g. Analysis procedure used.
2. Verify that BESS modules and units that are required to function during and/or after a seismic event, plus any required electrical or mechanical supporting systems and components (pumps, fans, ductwork, coolant

lines and their connections, fire protection systems and their connections, electrical wires and conduit and their connections, etc.), are seismically qualified.

a. (This is in addition to seismic qualification of the BESS units' supporting racks, containers, building or nonbuilding structures, etc.)

b. Seismic qualification of the BESS modules or units can be done via one or both of the following methods:

i. Seismic testing in accordance with ICC AC156, "Acceptance Criteria for Seismic Certification by Shake-Table Testing of Nonstructural Components."

ii. Finite element analysis using seismic loads generated in accordance with ASCE 7-16, Ch. 13.

3. Verify that supporting systems (coolant lines and their connections, fire protection systems and their connections, electrical wires and conduit and their connections, etc.) that span between two separate structures or anchored components have been evaluated to have sufficient flexibility to account for differential deflections / drifts between the two structures and components.

4. Verify that supporting racks for BESS units, and their anchorage to the enveloping structure or floor, have been evaluated for seismic loads in accordance with ASCE 7-16, Ch. 13.

5. Verify that either…

a. Deflections / drifts of the supporting racks for the BESS units have been calculated and that there is sufficient clearance between adjacent racks to prevent impact between the racks during a seismic event.

Or…

b. Adjacent racks are connected structurally so as to prevent impact between racks during a seismic event.