Worthington BESS

Hazard Mitigation Analysis

Outdoor Ground Mounted Battery Energy Storage System

Canadian Solar Solbank 3.0

190 Ridge Road, Worthington, MA (BWC Wades Stream, LLC)

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Revision Draft RevB

April 16, 2026

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EXECUTIVE SUMMARY

Fire and Risk Alliance, LLC, (FRA) performed a hazard mitigation analysis (HMA) for the battery energy storage system (BESS) proposed for installation at the Worthington BESS site located at 190 Ridge Road, Worthington, MA (Worthington BESS). The HMA was performed in accordance with the 2020 Edition of NFPA 855 which is referenced by 527 CMR (Massachusetts Comprehensive Fire Safety Code) pursuant the 2021 Edition of NFPA 1. The Worthington BESS is anticipated to include two SolBank 3.0 (SB3) cabinets manufactured by e-STORAGE of Canadian Solar and will have an approximate capacity of 2.4 megawatts (MW)/9.6 megawatt hours (MWh). This HMA report is intended to be used as a tool for a fire code official (FCO) or an authority having jurisdiction (AHJ) to assist in their review of the Worthington BESS.

will meet/ shall meet

Based on a review of the SB3 and the IFP drawing package dated 12/23/2025 (the drawing set), the SB3 installation at the Worthington BESS site design can meet the NFPA 855 installation level requirements for an outdoor, NWI style BESS when it is installed in accordance with the manufacturer's instructions, its listing, the approved drawings, and NFPA 855. However, as the final site design is developed, several items were identified in this analysis that still need modification/confirmation to ensure compliance. These include:

- Approved signage must be provided at the site per NFPA 855 §4.3.5.
- Increase minimum unobstructed fire apparatus access roadway width from 16 ft to 20 ft.
- Obtain FCO approval for having no fire protection water supply at the site per NFPA 855 §4.13.

The HMA demonstrates the Worthington BESS meets all the HMA performance criteria for approval outlined in NFPA 855 §4.1.4.3, as follows:

- Fires will be contained to a single SB3 as demonstrated through UL 9540A unit level testing and should a fully developed fire event occur, site level emergency response procedures (such as exposure protection) could be utilized during a fire event, based on real time fire conditions and observations (i.e., wind direction/speed, fire intensity, proximity of flames to adjacent cabinets), to minimize the potential for fire to spread to adjacent cabinets.
- Suitable deflagration protection is provided for the SB3 cabinet via the NFPA 69 CCR explosion control system.
- Fires will be detected in time to allow personnel to safely evacuate via the fire alarm system and internal sensors of the SB3.
- Toxic and highly toxic gases will not be released during normal charging, discharging, and operation of the SB3 given the listed lithium-ion cells utilized in the SB3 are hermetically sealed and do not vent during charging, discharging or normal operation.
- Toxic and highly toxic gases released during fires and other fault conditions will not reach concentrations in excess of IDLH levels within a building or an adjacent means of egress given the nearest building is approximately 500 ft away.
- Flammable gases will not be released during charging, discharging and normal operation of the SB3 given the listed lithium-ion cells utilized in the SB3 are hermetically sealed and do not vent during charging, discharging or normal operation.

In summary, based on the UL 9540A testing and a review of the drawing set, the Worthington BESS meets the Hazard Mitigation Analysis approval criteria presented in NFPA 855. In addition, as the site design is still under development, it is assumed that all the code required items, as listed above, will be addressed prior to commercial operational of the facility.

This executive summary is an abbreviated list of findings. Refer to the main report for details of the analysis.

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1. INTRODUCTION

Fire and Risk Alliance, LLC, (FRA) performed a hazard mitigation analysis (HMA) for the battery energy storage system (BESS) proposed for installation at the Worthington BESS site located at 190 Ridge Road, Worthington, MA (Worthington BESS). The HMA was performed in accordance with the 2020 Edition of NFPA 855 which is referenced by 527 CMR (Massachusetts Comprehensive Fire Safety Code) pursuant the 2021 Edition of NFPA 1. The Worthington BESS is anticipated to include two SolBank 3.0 (SB3) cabinets manufactured by e-STORAGE of Canadian Solar and will have an approximate capacity of 2.4 megawatts (MW)/9.6 megawatt hours (MWh). This HMA report has been prepared by FRA and summarizes our analysis. It is intended to be used as a tool for a fire code official (FCO) or an authority having jurisdiction (AHJ) to assist in their review of the Worthington BESS.

1.1 Purpose and Scope

NFPA 855 §4.1.4.2 requires an HMA to evaluate the consequences associated with the following failure modes, and others deemed necessary by the FCO. Note, only single failure modes must be considered in this analysis:

1. Thermal runaway condition in a single module, array, or unit.
2. Failure of an energy storage management system.
3. Failure of a required ventilation or exhaust system.
4. Failure of a required smoke detection, fire detection, fire suppression, or gas detection system.

After analyzing these single failure modes and analyzing their potential consequences per NFPA 855 §4.1.4.3, the AHJ is authorized to approve the HMA provided that it demonstrates all of the following:

1. Fires will be contained within unoccupied ESS rooms for the minimum duration of the fire resistance rating specified in NFPA 855 §4.3.6.
2. Suitable deflagration protection is provided where required.
3. ESS cabinets in occupied work centers allow occupants to safely evacuate in fire conditions.
4. Toxic and highly toxic gases released during normal charging, discharging, and operation will not exceed the permissible exposure limit (PEL) in the area where the ESS is contained.
5. Toxic and highly toxic gases released during fires and other fault conditions will not reach concentrations in excess of immediately dangerous to life or health (IDLH) level in the building or adjacent means of egress routes during the time deemed necessary to evacuate from that area.
6. Flammable gases released during charging, discharging, and normal operation will not exceed 25 percent of the lower flammability limit (LFL).

To perform this evaluation for the Worthington BESS, the framework of FRA's HMA is as follows:

- **Review the SB3 and UL 9540A Test Data**: FRA reviewed the SB3, its construction, design, fire safety features, listings, and UL 9540A fire test data (see Sections 2.0 and 3.0).
- **Review Site Specifications:** FRA reviewed the proposed Worthington BESS site layout including the areas surrounding the BESS yard (see Section 4.0).

- **Prescriptive Code Compliance Review:** The proposed site layout and BESS plans were reviewed for compliance with NFPA 855 requirements. Where gaps were identified in the BESS site design, recommendations are provided (see Sections 5.0 and 6.0).
- **Hazard Mitigation Analysis:** The HMA evaluates the BESS failure modes as required by NFPA 855. The consequence-based analysis considers product level and site level barriers to prevent failure or reduce the consequences of a failure scenario. Based on the provided barriers, the consequences of a failure event are analyzed. NFPA 855 outlines acceptance criteria for which the FCO or AHJ is authorized to approve the HMA provided the consequences of the analysis meet or exceed the criteria (see Section 7.0).
- **Recommendations:** Recommendations are provided throughout the report where gaps exist between the site design and code requirements and where the consequences of failure modes exceed the approval criteria (see Section 8.0).

1.2 Codes, Standards, and Test Methods

The following code and standards are applicable to this analysis:

- Massachusetts Comprehensive Fire Safety Code, based on the 2021 Edition of NFPA 1, *Fire Code* (527 CMR).
- NFPA 855, *Standard for the Installation of Stationary Energy Storage Systems* – 2020 Edition (NFPA 855).

The following standards and test methods are also relevant to this analysis:

- NFPA 68, Standard on Explosion Protection by Deflagration Venting – 2018 Edition (NFPA 68).
- NFPA 69, Standard for Explosion Control Systems - 2019 Edition (NFPA 69).
- UL 1973, Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications – 2018 Edition (UL 1973).
- UL 9540, Standard for Safety of Energy Storage Systems and Equipment - 2016 Edition (UL 9540).
- UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems - 2018 (UL 9540A).

1.3 Reference Materials

In addition to the standards and test methods listed above, the following reference materials were reviewed as part of this analysis:

- IFP drawing package dated 12/23/2025 (the drawing set).
- UL 1973 Certificate #CU7230247601, Hithium Model LFP71173207, dated 01/11/2023.
- UL 1973 Certificate #CU724059830001, CSI Models SolBank-R-418-2h-H and SolBank-R-418-4h-H, dated 07/18/2024.
- UL 9540 Certificate #CU724062740001, CSI Model SolBank-S-5016-2h-NA, dated 07/18/2024.
- UL9540A Cell Test Report #CN23F118001, Hithium Model LFP71173207, TÜV Rheinland (Shenzhen), dated 12/06/2023.

- UL9540A Module Test Report #CN248UKE001, CSI Models SolBank-P-104.5-2h-H and SolBank-P-104.5-4h-H, TÜV Rheinland (Shanghai), dated 06/28/2024.
- UL9540A Unit Test Report #CN24M32L001, CSI Models SolBank-R-418-2h-H and SolBank-R-418-4h-H, TÜV Rheinland (Shanghai), dated 06/28/2024.
- NFPA 69 System Evaluation Report #CN24SBF7001, CSI Models SolBank-S-5016-2h-NA and SolBank-S-5016-4h-NA, TÜV Rheinland (Shanghai), dated 08/09/2024.
- SolBank 3.0 BESS HMA, ESRG, V2, dated 12/19/2021
- SolBank 3.0 Datasheet, CSI Models SolBank-S-5016-2h-NA and SolBank-S-5016-4h-NA
- SolBank 3.0 Installation Manual, V1.3, e-STORAGE of Canadian Solar, 2024.
- SolBank 3.0 Commissioning Manual, V1.0, e-STORAGE of Canadian Solar, 2024.
- SolBank 3.0 User Manual, V1.5, e-STORAGE of Canadian Solar, 2024.
- SolBank 3.0 Safety Manual, V1.1, e-STORAGE of Canadian Solar, 2024.
- SolBank 3.0 Maintenance Manual, V1.3, e-STORAGE of Canadian Solar, 2024.
- SolBank 3.0 Decommissioning Manual, V1.0, e-STORAGE of Canadian Solar, 2024.
- SolBank 3.0 Fire Safety System and BMS Overview, e-STORAGE of Canadian Solar, September 2023.

2. SB3 DESCRIPTION

The SB3 is a fully integrated BESS consisting of battery modules, power electronics, control systems, battery management system (BMS), thermal management system (TMS), fire detection and notification system, and explosion prevention system all pre-assembled within a single, non-occupiable cabinet. It is meant for outdoor installations, mounted to the ground. Below is a brief description of the SB3, its components, design listing, and fire safety features. For a more detailed discussion of the SB3 components, their location, functionality, and purpose, refer to the SB3 installation manual.

2.1 Cell

The cell is the smallest anatomy of the battery assembly. The SB3 utilizes a lithium iron phosphate (LFP) prismatic cell, as shown in Figure 1. The cells are Model LFP71173207 manufactured by Xiamen Hithium Energy Storage Technology Co. Ltd. (Hithium) and are UL 1973 compliant. Each cell has a nominal capacity of 314 amp-hour (Ah), a nominal voltage of 3.2 volts (V), and is prismatic in geometry. The cell has overall dimensions of 6.9 in (175 mm) × 8.2 in (207 mm) × 2.8 in (72 mm). This cell is manufactured for use in the SB3 and is intended to be part of the module assembly. Passive safety features include material reliability and manufacturing process. Known hazards of the cell during normal operation consist of either electrical, thermal, or mechanical failures which could result in gas release, flaming electrical fluid, electrical shorting, thermal heating, and/or thermal runaway.

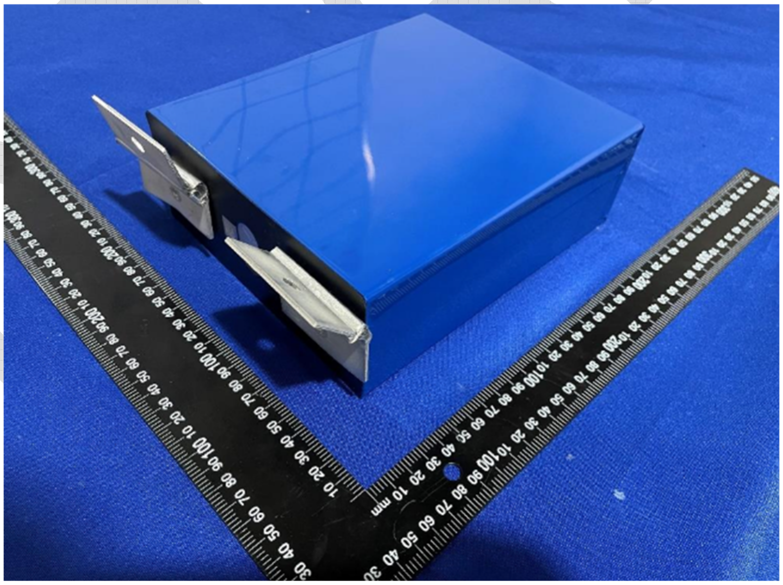

Figure 1: SB3 Cell

2.2 Module (Pack)

The battery module, also known as the pack, is the second smallest level of the BESS anatomy. The SB3 module is Model SolBank-P-104.5-4h-H manufactured by CSI Energy Storage Co., Ltd. (CSI), which is liquid-cooled with a metal enclosure. The module has a 1P104S cell configuration which comprises 104 LFP71173207 cells in series, as shown in Figure 2. The module has a nominal capacity of 314 Ah, a nominal voltage of 332.8 V, and a nominal energy capacity of 104.5 kWh. Each module has overall dimensions of 7.2 ft (2,180 mm) × 2.6 ft (790 mm) × 0.8 ft (248 mm).

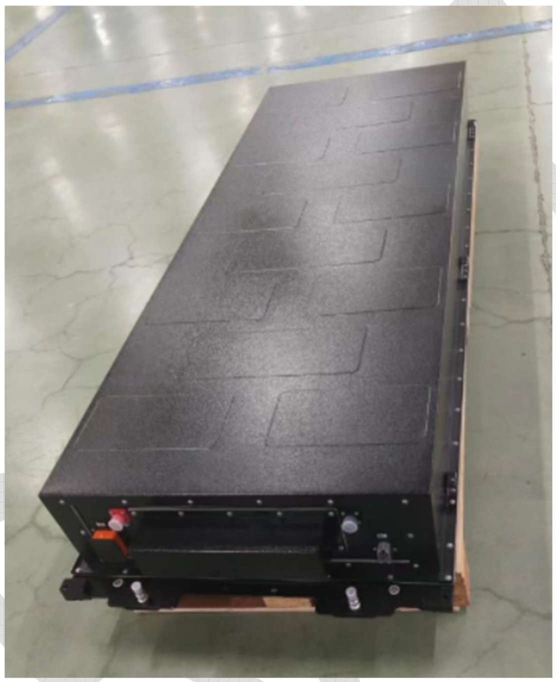

Figure 2: SB3 Module

This module is manufactured for use in the SB3 and is intended to be part of the unit-level assembly. The module assembly supports safe operation through its material insulation and internal cooling. Aerogel spacers are installed between each cell to insulate each cell from one another. Passive safety features include material reliability and manufactured assembly process. The module itself does not have any active emergency functions for disconnection from the charging source or discharging stored potential energy.

2.3 Unit (Rack)

The battery unit, also known as the rack, is the third level of BESS anatomy. Each unit holds 4 modules and a BMS box, as shown in Figure 3. The unit is Model SolBank-R-418-4h-H manufactured by CSI with a nominal capacity of 314 Ah, a nominal voltage of 1,331.2 V, and a nominal energy capacity of 418 kWh. The unit is manufactured for use in the SB3 and is intended to be part of the cabinet-level assembly.

Figure 3: SB3 Unit

2.4 Cabinet

The cabinet is the final and largest level of the BESS. The SB3 cabinet is a rigid metal (steel) enclosure designed to house the batteries, associated controllers, and appurtenances. The cabinet supports the safe operation of the BESS through its exterior rigid housing structure that helps to protect the batteries from mechanical damage and weather conditions. It is 2438 mm (8.0 ft) wide, 2896 mm (9.5 ft) tall, and 6058 mm (19.9 ft) long and is intended for ground-mounted, outdoor installations, with an IP-55 rating. The SB3 is equipped with 12 battery racks, as shown in Figure 4.

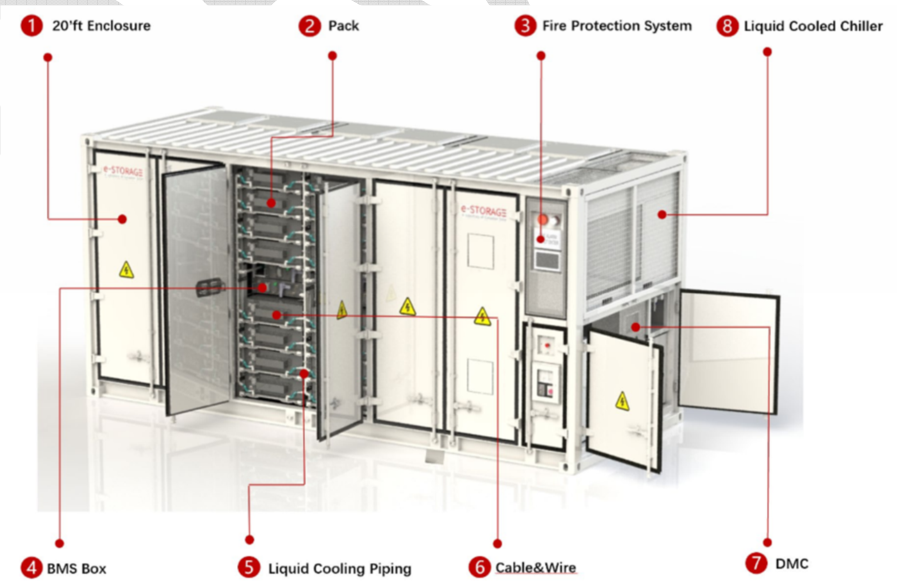

Figure 4: SB3 Cabinet

As described above, each unit contains 4 modules, and each module contains 104 LFP cells. In total, the SB3 has 4,992 cells with an energy capacity of 4,800 kWh and weighs approximately 43,000 kg (94,799 lbs.). Additional features of the SB3 cabinet include 12 rack-mounted BMS, a liquid cooling and heating system, and the integration of all power electronics, controls, and safety features required to support the DC side of the BESS.

2.5 Thermal Management System

Each SB3 is equipped with a TMS which utilizes a liquid cooling and heating system to maintain optimum cell temperature, between 20°C and 35°C. A temperature-regulated ethylene glycol solution is distributed throughout the cabinet using a piping system that connects the battery modules to the chiller in the HVAC cabinet of the BESS, as seen in Figure 5.

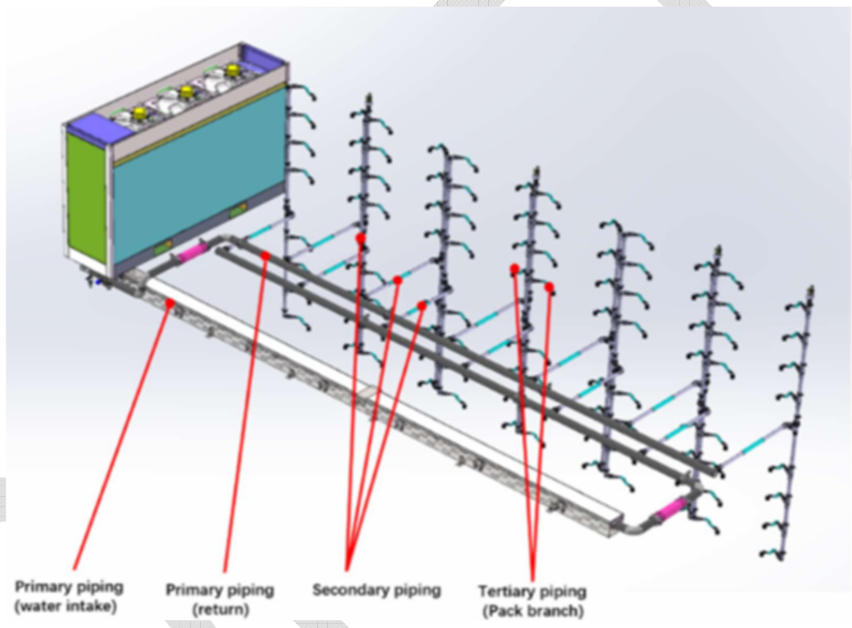

Figure 5: SB3 TMS

After passing through each device and absorbing or releasing heat, the refrigerant flows back into the HVAC cabinet where it is cooled, if necessary. The cabinet is continuously monitored for temperature and liquid chiller operation and will send alerts if either critical levels are reached or if loss of communication from the system occurs.

2.6 Battery Management System

Each SB3 is equipped with a dedicated BMS for each battery unit, with a total of 12 rack-mounted BMS per cabinet. The BMS is an electronic system that can identify possible risks to the battery system by monitoring battery cell performance, temperature, voltage, and current, and state-of-charge (SOC) in real-time. It is used to monitor and maintain the health and capacity of a battery to ensure optimal battery functionality and safety.

The BMS ensures early detection of pre-fault conditions and immediate direction of fault events. If a parameter exceeds pre-determined permissible values, the BMS will open the integrated DC contactors to automatically disconnect the affected string and send an alarm to the site's energy management system (EMS).

The BMS also interfaces with the fire alarm control panel (FACP) and can control the disconnection of the module(s) from the system in the event of abnormal conditions. When the FACP receives an alarm, such as combustible gas, heat, or smoke, this notification is routed to the EMS, which autonomously isolates the trouble battery cabinet.

The BMS function is intended to prevent the risk of thermal runaway by preventing the risks of overcharge, over-discharge, over-temperature, and overcurrent. It provides thermal runaway risk protection by safely disconnecting the batteries in case of fault conditions.

2.7 Electrical Fault Protection

In addition to BMS protections, electrical fault protection devices are provided for the SB3 and the power conversion system (PCS). The cabinet's DC junction box contains all primary DC busbars, fuses, surge protection devices, and power monitoring required to safely exchange power between the SB3 and the PCS. All SB3 electrical circuits are protected by overcurrent protection devices. Site-level electrical fault protection devices are provided by the UL 1741 listed inverter, including insulation monitoring devices for ground fault protection, medium voltage (MV) switchgear, DC switch disconnectors, and Type 2 protection for AC and DC overvoltage protection. The BESS MV switchgear typically includes protection and switching equipment to sufficiently protect both the BESS facility as well as the grid from faults: relays, meters, breakers (motorized or non-motorized), fuses, and other distribution gear.

2.8 Fire and Gas Detection System

The SB3 cabinet is provided with a fire and gas detection system that includes three photoelectric smoke detectors (two in the battery compartment and one in the electrical compartment), three heat detectors (two in the battery compartment and one in the electrical compartment), and two hydrogen gas detectors in the battery compartment, as shown in Figure 6. The fire and gas detection system is connected to a FACP. Any alarm or supervisory condition from the FACP is relayed to the site EMS.

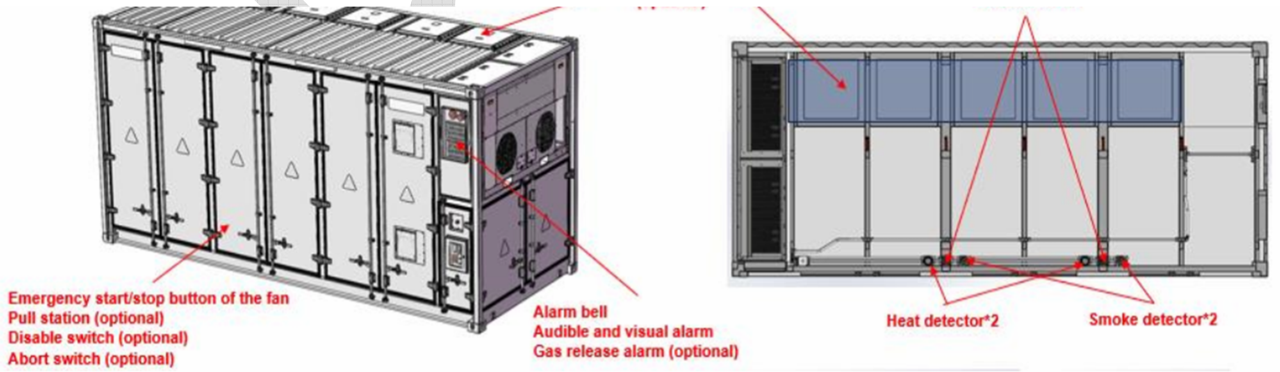

Figure 6: SB3 Fire and Gas Detection System

For local notification, an alarm bell and an audible/visible appliance are installed on the exterior of the SB3 cabinet. An emergency start/stop (E-stop) button is provided within each end of the cabinet, which will shut down the SB3 cabinet when pressed. Additional safety features are available optionally, including a pull station, disable switch, abort switch, and gas release alarm.

2.9 Fire Suppression System

The SB3 can come equipped with an optional aerosol suppression system or an optional dry sprinkler system. The SB3 cabinets at the Worthington BESS will not be equipped with the optional fire suppression system.

2.10 Explosion Control System

The SB3 cabinet is equipped with a combustible gas concentration reduction (CCR) system that consists of gas detection, an explosion-proof exhaust fan, and two air intake louvers that provide make-up air for the cabinet, as shown in Figure 7. This system utilizes two flammable gas detectors calibrated to hydrogen. Upon detection of 10% of the LFL, the explosion control system activates, ventilating the SB3 to maintain the gas concentration of the cabinet below 25% LFL. In addition, the BMS receives an alarm, the horn/strobe on the exterior of the cabinet activates, the BMS shuts down the battery system, and the HVAC system shuts down.

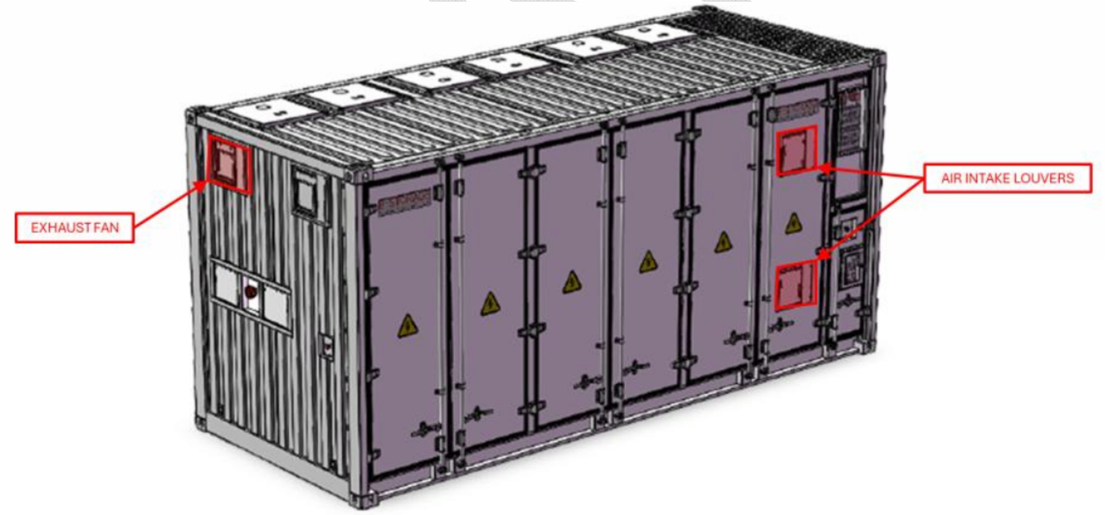

Figure 7: SB3 Explosion Control System

2.11 Site Controller and Monitoring

The SB3 is monitored and controlled by a site EMS or local plant controller (LPC) during normal operations. The EMS or LPC will communicate with an offsite fleet controller, SCADA operations center, or other third-party dispatch and monitoring entity to allow remote control and operations of the system. System status and alarms are communicated to the EMS and remote operations personnel. In the event of emergency conditions, the SB3 can be remotely shut down.

3. UL 9540A SUMMARY & ANALYSIS

UL 9540A provides a method to evaluate thermal runaway and fire propagation of a lithium-ion BESS at the cell level, module level, unit level, and installation level. The data generated from the test method can be used to determine the fire and explosion protection systems/features required for a BESS installation. This includes, but is not limited to, thermal runaway characteristics of the cell; cell thermal runaway gas composition; the fire propagation potential from cell to cell, module to module, and unit to unit; products of combustion; heat release rate; smoke release rate; and performance of fire protection systems.

Initially, cells are tested to determine if further testing is required. Module level testing is required if the following observations are recorded during cell level testing:

- Thermal runaway is induced in the cell; and,
- The cell vent gas is flammable in air when tested in accordance with ASTM E918.

Module level testing examines the module design, heat release rate, gas generation, external debris, and flying debris hazards. Unit level testing is required if the following observations are recorded during module level testing:

- Module design is unable to contain thermal runaway; and,
- Cell vent gas is flammable.

Unit level testing assesses the BESS design of the unit, heat release rate, gas generation and composition, deflagration and flying debris hazards, BESS and wall surface temperatures, heat flux at the target walls, and reignition. Installation level testing is required if the following observations are recorded during unit level testing:

- Flaming is observed outside the initiating BESS unit;
- Surface temperature of the modules in the adjacent BESS unit exceeds the temperature at which cell level gas venting occurred;
- Surface temperatures of wall surfaces increase more than 175ºF (97ºC) from ambient; and,
- Explosion hazards are observed.

Installation level testing assesses the effectiveness of fire protection systems installed as mitigation methods for the BESS in its intended installation configuration.

A summary of the cell, module, unit, and installation level test results for the SB3 are provided below.

3.1 UL 9540A Cell Level Testing

Cell-level testing was completed at TÜV Rheinland (Shenzhen) Co., Ltd. (TÜV) September through November 2023. TÜV is an OSHA-approved Nationally Recognized Testing Laboratory (NRTL) and offers the cTÜVus mark, which is equivalent to other NRTL marks such as UL, ETL or CSA. Testing was performed on five Model LFP71173207, 3.2 V, 314 Ah, LFP cells manufactured by Hithium and used in the SB3. Each cell was charged to 100% state of charge (SOC) prior to testing. Thermal runaway was initiated via an external film heater installed on each cell, as shown in Figure 8. The cell sample and heater were clamped by two steel plates together during the test to simulate the constraint in the BESS module to prevent excessive swelling during the test. The heater was programmed to increase the temperature of the cell's surface at a rate from 4°C-7°C per minute until the cell vented and went into thermal runaway. The cell was placed within a sealed enclosure and the products released during testing were collected and analyzed.

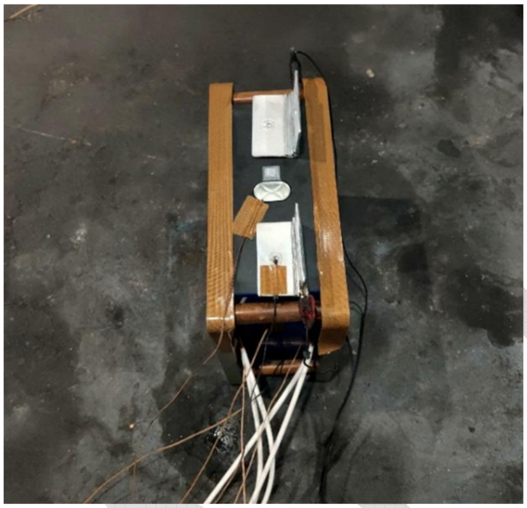

Figure 8: Cell Test Setup

3.1.1 Key Results & Takeaways

Key takeaways from the tests include:

- The average cell vent and thermal runaway temperature was determined to be 203.7°C (399°F) and 295.7°C (564°F), respectively, as listed Table 1.
- 130 liters of cell vent gases were released.
- The cell vent gas mixture is flammable and has an LFL of 8.1% at ambient temperature.
- The cell vent gases were predominantly (approximately 95%) Carbon Monoxide (CO), Carbon Dioxide (CO2), Hydrogen (H2), and Methane (CH4), as listed in Table 2.

Table 1: UL 9540A Cell Level Testing: Key Flammability Characteristics

Flammability Property	Value
Average cell surface temperature at gas venting	203.7°C
Average cell surface temperature at thermal runaway	295.7°C
Cell vent gas volume released	130 L
LFL, % volume in air at the ambient temperature	8.1%
LFL, % volume in air at the venting temperature	6.5%
Burning velocity (S_u)	0.779 m/s
Maximum pressure (P_{max})	0.78 MPa

Table 2: UL 9540A Cell Level Testing: Cell Vent Gas Composition (Excluding O_2 and N_2)

Gas Name	Chemical Structure	Measured %	Component LFL %
Carbon Monoxide	CO	16.202	10.9
Carbon Dioxide	CO_2	26.861	N/A
Hydrogen	H_2	49.875	4.0
Methane	CH_4	3.671	4.4
Ethylene	C_2H_4	1.389	2.4
Ethane	C_2H_6	0.548	2.4
Propene	C_3H_6	0.745	1.8
Propane	C_3H_8	0.18	1.7
-	n-C_4H_{10}	0.068	-
-	n-C_4H_8	0.22	-
-	n-C_5H_{12}	0.076	-
-	iso-C_5H_{12}	0.112	-
-	n-C_5H_{10}	0.053	-
Total	-	100	-

3.1.2 Performance Criteria

UL 9450A Section 7.7 outlines the performance criteria for the cell level test. If all these conditions are met, further tests (such as module, unit, or installation level tests) are not required. The acceptable performance criteria during the UL 9540A cell level test are as follows:

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

Given that the cell went into thermal runaway and vented flammable gases, UL 9540A module level testing was required.

3.2 UL 9540A Module Level Testing

Module level testing was completed at TÜV Rheinland (Shanghai) Co., Ltd. April through May 2024. Testing was performed on a 332.8 V, 314 Ah, Model SolBank-R-418-2h-H module manufactured by Hithium and used in the SB3, as shown in Figure 9. The module consisted of 104 Model LFP71173207, 3.2 V, 314 Ah, LFP cells manufactured by Hithium which were charged to 100% SOC prior to testing. During the test, the module was not connected to the BMS or TMS, i.e., they are not actively operating to prevent thermal runaway in a cell or to prohibit the propagation of thermal runaway from cell to cell. Thermal runaway was initiated via film strip heaters installed on both of the wide side surfaces of cell #40 within the module. This resulted in the simultaneous heating of three cells forcing multiple cells into thermal runaway at approximately the same time. The heaters were programmed to increase the cell surface temperature until the cells vented and went into thermal runaway. The module was placed under an instrumented hood and the products released during combustion were collected for analysis.

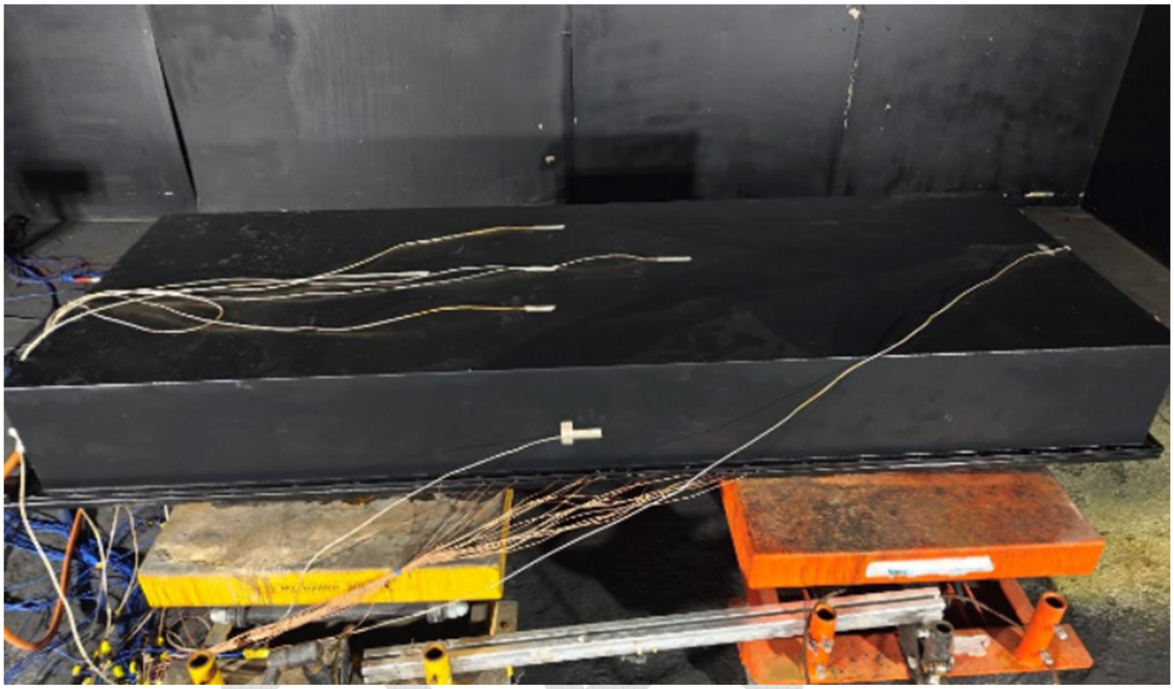

Figure 9: Module Test Setup

3.2.1 Key Results & Takeaways

This simultaneous heating of three cells forced multiple cells to go into thermal runaway that propagated from the initiating cells to two additional cells in the module. Key takeaways from the UL 9540A module level test include:

- Thermal runaway propagated from the three initiating cells to two additional cells in the module.
- No sparks, flying debris, or flaming was observed during the test.
- Products of combustion were collected, as listed in Table 3.
- Toxic gases sometimes associated with lithium-ion batteries, such as HF, HCl, and HCN, were not detected during the combustion of the module.

Table 3: UL 9540A Module Level Testing: Products of Combustion

Gas Name	Chemical Structure	Total Volume (L)	Detection Method
Carbon Monoxide	CO	157.10	FTIR
Carbon Dioxide	CO_2	388.98	FTIR
Methane	CH_4	85.54	FTIR

Gas Name	Chemical Structure	Total Volume (L)	Detection Method
Acetylene	C_2H_2	3.05	FTIR
Ethene	C_2H_4	56.26	FTIR
Ethane	C_2H_6	12.22	FTIR
Propylene	C_3H_6	29.24	FTIR
Propane	C_3H_8	20.11	FTIR
Hydrogen	H_2	262.16	Hydrogen Sensor
Total Hydrocarbons	(Propane Equivalent)	285.55	FID

3.2.2 Performance Criteria

UL 9540A Section 8.4 outlines the performance criteria for the module level test. If all these conditions are met, further testing (such as unit or installation level tests) is not required. The acceptable performance criteria during the UL 9450A module level test are as follows:

1. Thermal runaway is contained by module design; and
2. Cell vent gas is nonflammable as determined by the cell level test.

Given the cell vent gases are flammable (as summarized previously), UL 9540A unit level testing was required.

3.3 UL 9540A Unit Level Testing

The unit level fire test was completed at TÜV Rheinland (Shanghai) Co., Ltd. in May 2024. Below is a summary of the UL 9540A unit level fire test results as well as a description of the performance of key fire safety features and systems during the test. This discussion is a summary of the test setup, test data and results. For a full description of the test, please refer to TÜV's UL 9540A unit level test report.

3.3.1 Test Setup and Initiation

The SB3 test unit consisted of 4 battery modules, with a capacity of 418 kWh, tested at 100% SOC. During the test, the BMS and TMS were disabled, i.e., they were not actively operating to prevent thermal runaway in a cell or to prohibit the propagation of thermal runaway from cell-to-cell, or module-to-module. As such, the UL 9540A unit level fire test can be considered a worst-case scenario fire scenario, where the unit tested was at the highest energy density possible (100% SOC), and the BMS and TMS were disabled and, therefore, unable to actively respond to the thermal runaway condition.

The initiating battery module was chosen to be the second battery module from the bottom in the initiating unit (Unit 1), as shown in Figure 10. This location was deemed to be the worst case, given there are battery modules directly above it and below it. In addition, by initiating in the battery module second from the bottom, there are two battery modules installed directly above the initiation location. Within the battery module itself, three interior cells were simultaneously heated via two film heaters. The number of cells and the location were selected to provide the greatest thermal exposure to adjacent cells to ensure cell to cell propagation during the test. The objective of this initiation method is to simulate a mass failure of multiple cells in a localized area within the same battery module.

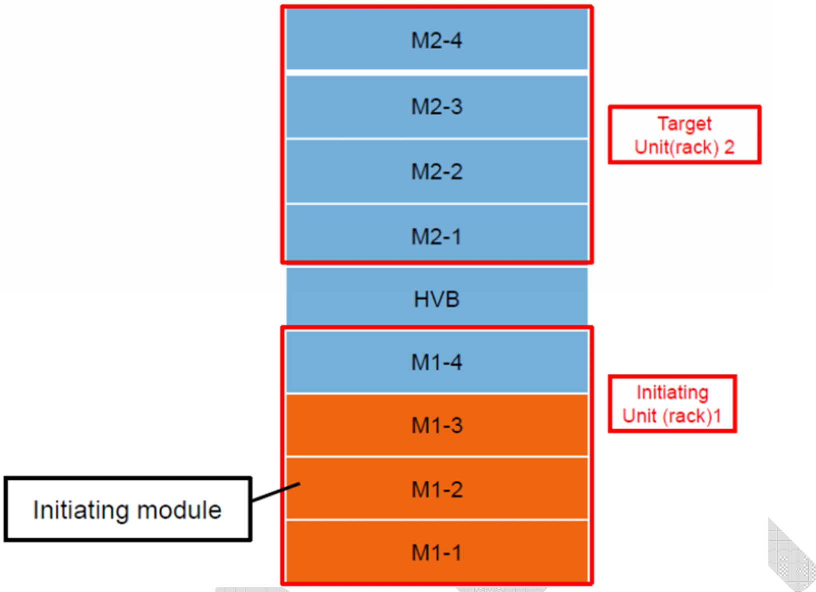

Figure 10: Initiating Module Location

Two additional target SB3 units were installed approximately 4.4 in (112 mm) to the side of the initiating unit, as shown in Figure 11. The two target SB3 units to the side simulate a multiple SB3 installation to determine if thermal runaway and/or fire will propagate from one SB3 cabinet to adjacent cabinets at separation distances of 4.4 in (112 mm). Additionally, the units were enclosed by three walls installed as close as 1.5 in (40 mm) from the initiating unit to demonstrate if fire could spread to a combustible surface during the test.

Note: this testing was performed as an indoor BESS. Therefore, not tested as specifically prescribed by NFPA 855. However, the testing arrangement can be considered conservative for an outdoor ground mounted BESS.

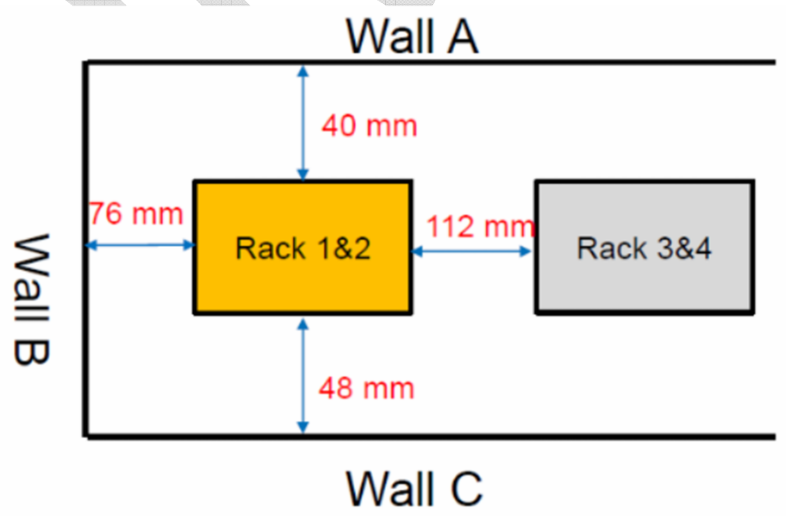

Figure 11: Instrumentation and Target SB3 Unit Setup (Top View)

3.3.2 Key Results & Takeaways

Table 4 provides a summary of key events from the UL 9540A unit level fire test of the SB3.

Table 4: UL 9540A Unit Level Testing: Timeline of Key Events

Locations (Cell #)	Event	Time
-	Test Start	15:45
40	Vent	16:40
40	Thermal Runaway	16:55
39	Thermal Runaway	17:04
41	Thermal Runaway	17:06
38	Thermal Runaway	17:09
42	Thermal Runaway	17:14

After the test, analysis of the data and a visual inspection of the initiating SB3 yielded the following observations:

- Over the duration of the test, five cells went into thermal runaway: the three that were forcibly heated and two additional cells. This demonstrated that cell to cell propagation had occurred during the test, as is required by UL 9540A.
- No other signs of distress were observed in the initiating battery module. Thermal runaway did not propagate beyond the three cells within the initiating module, nor did it spread to the module above or below it within the battery rack.
- Visible clues of fire damage were not observed to components (plastics, electronics, etc.) adjacent to the five failed cells. Based on this observation, it is likely that a sustained fire did not occur around the initiating battery module, even with the failure of five cells occurring.
- The battery modules within the target unit installed above and below were unaffected.
- Heat flux measurements were recorded throughout the UL 9540A unit level fire test on each wall and the target units to the side of the initiating unit. Since flames did not occur outside the initiating unit, predictably, these measurements were 0.0 kW/m^2 throughout the entire test.
- Explosion hazards, including but not limited to, observations of a deflagration, projectiles, flying debris, detonation, or other explosive discharge of gases were not observed during the test when a near simultaneous failure of up to five cells occurs within the same battery module.

These test results meet all five of UL 9540A's performance criteria for outdoor ground mounted BESS units. The unit level test demonstrated that the near simultaneous failure of five cells within the same battery unit did not lead to flaming combustion nor to a propagating thermal runaway event throughout the SB3 cabinet.

3.4 Large-Scale Fire Testing

This fire test information will be included once provided.

4. WORTHINGTON BESS SITE

The Worthington BESS is being proposed for installation in Worthington, MA. It is bounded by Ridge Road to the east, Buffington Hill Road to the north, and undeveloped land to the south/west as shown in Figure 12. As such, the Worthington BESS will be located in a rural area primarily surrounded by residential neighborhoods and undeveloped land with limited nearby commercial properties.

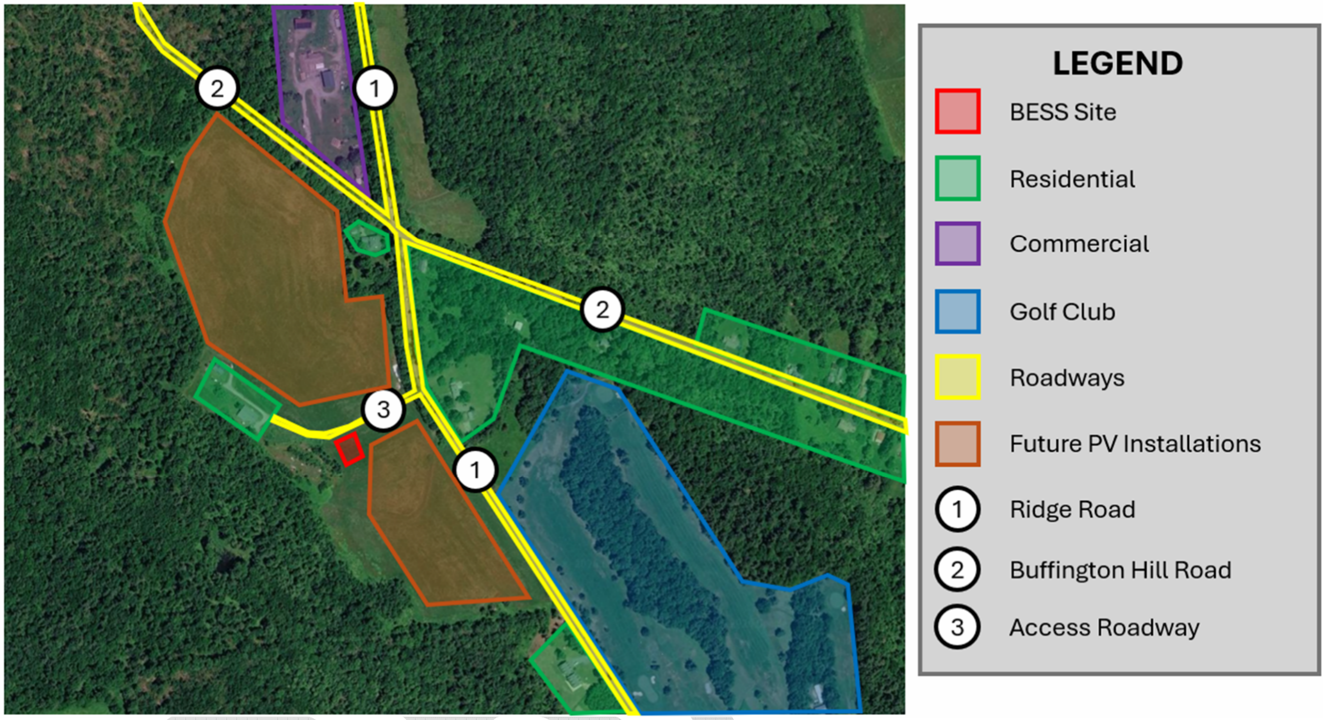

Figure 12: Aerial Map (Near View)

4.1 Site Level Fire Safety Features

Based on a review of the IFP drawing package dated 12/23/2025 (the drawing set) and discussion with BlueWave Energy, the Worthington BESS is anticipated to include two SB3 cabinets with an approximate capacity of 9.6 MWh, as shown in Figure 13. A fire apparatus access roadway will be constructed to connect the BESS yard to Ridge Road. This roadway also provides access to one on-site residence.

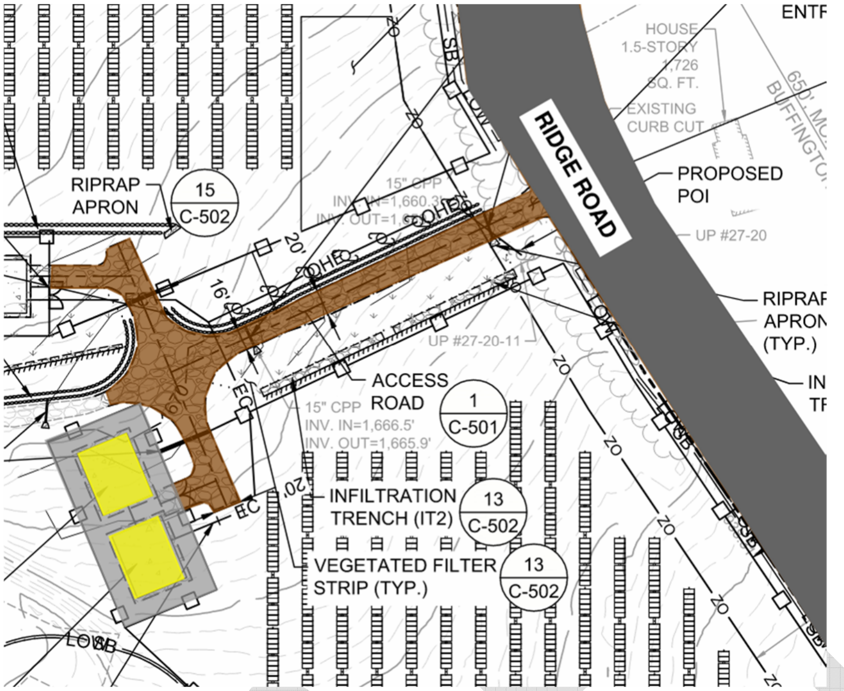

Figure 13: Site Plan (BESS Pads Highlighted)

As shown in the drawing set and the SB3 product documentation, the Worthington BESS will have a number of site-level fire safety systems and features as described in the following sections.

4.1.1 BESS Monitoring and Emergency Notification

It is anticipated that the Worthington BESS will be remotely monitored. If an abnormal signal is received, the O&M management organization and the responsible service personnel (O&M service personnel) would be notified in such a case. However, additional details of the BESS monitoring and emergency notification are forthcoming as the design progresses.

4.1.2 Periodic Maintenance

It is anticipated that the Worthington BESS will be periodically inspected and serviced by trained O&M service personnel.

4.1.3 BESS Security

An 8-ft tall fixed knot farm fence will be installed around the perimeter of the BESS yard at the Worthington BESS to prohibit access to the SB3 cabinets. Also, the secured area around the BESS yard will include one 20-ft wide double swing access gate on the yard's east side.

4.1.4 Fire Department Access

The Worthington District Fire Department is the closest fire department to the Worthington BESS and is approximately 1 mile away from the BESS installation. The closest access road to the Worthington BESS is Ridge

Road which connects to the fire apparatus access roadway as shown in Figure 13 above. The fire apparatus access roadway has the following design features:

- Extends to within 150 ft of each SB3 cabinet contained in the BESS yard.
- Minimum unobstructed width of 16 ft with suitable turning radius/angles of approach/departure and an unobstructed vertical clearance.
- Constructed of 6-in. depth gravel to provide all-weather driving capabilities.
- No dead ends exceeding 150 ft. in length.
- It is anticipated that the grade of the fire apparatus access roadway will not exceed 10%.

4.1.5 Emergency Water

No on-site water will be provided for firefighting purposes.

Note, based on the UL 9540A unit level fire testing, manual fire suppression (hose lines) is not required to suppress a SB3 fire.

4.1.6 Fire Alarm and Notification System

The SB3 cabinet is provided with fire and gas detection. The fire and gas detection system includes three photoelectric smoke detectors (two in the battery compartment and one in the electrical compartment), three heat detectors (two in the battery compartment and one in the electrical compartment), and two hydrogen gas detectors in the battery compartment. The fire and gas detection system is connected to a FACP. For local notification, an alarm bell and an audible/visible appliance are installed on the exterior of the SB3 cabinet. Additional safety features are available optionally, including a pull station, disable switch, abort switch, and gas release alarm.

As the site design is still under development, fire alarm design drawings have not been provided. It is anticipated that the fire alarm system will be monitored locally by a FACP. It is anticipated that the FACP will be monitored 24/7 by a remote monitoring station. Should a fire or other thermal event occur at the Worthington BESS that triggers an alarm at the FACP, the remote monitoring station would receive that alarm signal and could then notify the site contact and the fire department.

4.1.7 Fire Suppression System

No external nor internal fire suppression system will be provided on or in the SB3 cabinets.

4.1.8 Emergency Stop

An emergency start/stop (E-stop) button is provided at each end of the SB3 cabinet, which will shut down the SB3 cabinet when pressed. This E-Stop can be used for maintenance purposes or during an emergency to isolate the SB3 cabinets from connected energy sources. Note, a site-wide E-Stop should never be initiated without first coordinating with the site and the Utility.

4.2 Permanent BESS or Electrical Grid Exposures

The Worthington BESS and its associated equipment are intended to operate year-round, 24 hours a day, 365 days a year. It is anticipated that each SB3 cabinet will be installed on a concrete pad surrounded by gravel. As the design for the BESS yard is progressed, the clearance distances to permanent electrical exposures associated with the Worthington BESS and/or electrical grid will be confirmed.

4.3 Permanent Public Exposure Hazards

All permanently installed public exposures (lot lines, public ways, buildings, stored combustible materials, hazardous materials, high-piled stock, and exposure hazards not associated with electrical grid infrastructure) are greater than 10 ft from the closest SB3 cabinet. As described in the drawing set and aerial map, clearance distances to public exposures are summarized in Figure 14 and Table 5.

Figure 14: Aerial Map (Far View)

Table 5: Distance to Permanent Public Exposures

Exposure	Approximate Distance
Nearest Property Line Boundary	400 ft.
Nearest Roadway (Ridge Road)	400 ft.
Closest Residence	500 ft.

Exposure	Approximate Distance
Other Nearby Residences	800 ft.
Hilltown Community Health Center	3,300 ft.
Corners Grocery	3,600 ft.
RH Conwell Elementary School	1 mile
First Congregational Church Worthington	1 mile

5. SITE DESIGN CODE ANALYSIS

527 CMR (Massachusetts Comprehensive Fire Safety Code) adopts/amends the 2021 Edition of NFPA 1. As amended by 527 CMR, NFPA 1 Chapter 52 (Energy Storage Systems) references the 2020 Edition of NFPA 855. Accordingly, the code analysis herein is conducted in accordance with NFPA 855 (2020).

Compliance with NFPA 855 is required when a lithium-ion BESS installation has an energy capacity greater than 20 kWh (NFPA 855 Table 1.3). Since the Worthington BESS is anticipated to have an energy capacity of approximately 9.6 MWh, NFPA 855 requirements apply. Below is a review of the Worthington BESS site design for compliance with NFPA 855. Note, this code analysis applies only to site design elements of the Worthington BESS pertaining to fire and life safety. Other aspects of the site design, including the electrical or structural design, are outside the scope of this review. As this is a site design review, elements related to the installation itself are also outside the scope of this analysis. It is assumed that the BESS and its associated equipment, including all fire protection systems, will be installed, commissioned, inspected, tested, and maintained as required by the manufacturer(s), NFPA 855, and/or other applicable codes and standards.

5.1 Outdoor BESS Classifications

The Worthington BESS is anticipated to include two SB3 cabinets (subject to change as the design progresses). The SB3 is a NWI style BESS that is unoccupiable, with all internal components accessible via exterior doors. NFPA 855 defines this type of BESS as an Energy Storage System Cabinet, which is an enclosure containing components of the ESS where personnel cannot enter the enclosure other than reaching in to access components for maintenance purposes. For outdoor BESS installations, NFPA 855 provides code requirements based on the proximity and location of the BESS equipment from adjacent exposures (NFPA 855 §4.4.3.1). The two relevant outdoor installation classifications are as follows:

- **Remote locations** – BESS located more than 100 ft from buildings, lot lines that can be built upon, public ways, stored combustible materials, hazardous materials, high-piled stock, and other exposure hazards not associated with electrical grid infrastructure.
- **Locations near exposures** – BESS locations that do not comply with remote outdoor location requirements.

Based on the drawing set, there is greater than a 100 ft separation distance between the SB3 cabinets and the nearest exposures not associated with the electrical grid infrastructure. As such, the Worthington BESS is classified as a remote, outdoor BESS for this analysis. Table 6 summarizes code requirements pertaining to a remote, outdoor lithium-ion BESS installation, which are discussed in detail within the following sections. Other NFPA 855 requirements that apply to all facilities, BESS or otherwise, include fire apparatus access roads (NFPA 855 §4.4.3.8).

Table 6: NFPA 855 Outdoor BESS Installation Requirements

Requirement	Remote Exposures	NFPA 855 Reference
All ESS Installations	Yes	§4.1-4.3
Maximum Size	Yes	§4.4.3.2
Clearance to Exposures	N/A	§4.4.3.3
Means of Egress Separation	N/A	§4.4.3.4
Vegetation Control	Yes	§4.4.3.6
Size and Separation	No	§4.6
Maximum Stored Energy	No	§4.8
Smoke and Fire Detection	Yes	§4.10
Fire Control and Suppression	Yes	§4.11
Fire Protection Water Supply	Yes	§4.13
Technology Specific Protection – Lithium-Ion Batteries		
Thermal Runaway	Yes	§9.3
Explosion Control	Yes	§4.12
Other NFPA 855 Requirements – All Facilities		
Fire Department Access Roads	Yes	§4.4.3.8

5.2 All ESS Installations

NFPA 855 §4.1 through §4.3 apply to all ESS installations: indoor, outdoor, stationary, and mobile. Only the fire and life safety general installation requirements applicable to the site design of a remote, outdoor, NWI style BESS installation are summarized in the following sections. Requirements unrelated to fire and life safety (such as electrical or structural) or pertaining to other types of BESS installations (such as indoor) are not discussed. These include electrical installations (NFPA 855 §4.3.1), seismic and structural design (NFPA 855 §4.3.3), design loads (NFPA 855 §4.3.4), egress (NFPA 855 §4.3.10), open rack installations (NFPA 855 §4.3.11), fire-resistance rated separations/barriers (NFPA 855 §4.3.6), and occupied work centers (NFPA 855 §4.7).

5.2.1 Combustible Storage

NFPA 855 §4.1.6 does not permit combustible materials to be stored in ESS rooms, cabinets, enclosures, areas, or walk-in units. In addition, combustible materials cannot be stored within 3 ft of the ESS. The SB3 is a NWI style BESS that is unoccupiable with all internal components accessible via exterior doors. It does not have free open space within the cabinet to store additional combustible materials. Based on a review of the drawing set, no combustible materials will be stored within 3 ft of the SB3 cabinets. As such, the Worthington BESS site design complies with NFPA 855 combustible storage requirements.

5.2.2 Equipment

NFPA 855 §4.2.1 requires ESS to be listed in accordance with UL 9540. The SB3 is listed to UL 9540. As such, the Worthington BESS site design complies with NFPA 855 equipment listing requirements.

5.2.3 Environment

NFPA 855 §4.2.6 requires the temperature, humidity, and other environment conditions in which the ESS is located to be maintained in accordance with the listing and the manufacturer's specifications. The SB3 is provided with a TMS that maintains suitable environmental conditions for the ESS, as described in Section 2.5. As such, the Worthington BESS site design complies with NFPA 855 environment requirements.

5.2.4 Energy Storage Management System (ESMS)

NFPA 855 §4.2.9 requires ESS to be provided with an ESMS or a BMS. The SB3 is provided with a BMS that monitors battery cell temperatures, voltages, currents, and dry contact switching in real-time, as described in Section 2.6. As such, the Worthington BESS complies with NFPA 855 ESMS requirements.

5.2.5 Toxic and Highly Toxic Gases

NFPA 855 §4.1.1 does not permit ESS to release toxic and highly toxic gas during normal charging, discharging, and use. The SB3 uses listed lithium-ion cells that do not vent toxic or highly toxic gases, or any gases, during charging, discharging, or normal use conditions. As such, the Worthington BESS site design complies with NFPA 855 toxic and highly toxic gas requirements.

5.2.6 Enclosures

NFPA 855 §4.4.3.7 requires enclosures to be noncombustible and weatherproof. The SB3 is a noncombustible cabinet with an IP66 rating. As such, the Worthington BESS site design complies with NFPA 855 enclosures requirements.

5.2.7 Signage

NFPA 855 §4.3.5 requires approved signage to be provided in the following locations:

1. On the front of doors to rooms or areas containing ESS or in approved locations near entrances to ESS rooms.
2. On the front of doors to outdoor occupiable ESS.
3. In approved locations on outdoor ESS that are not enclosed in occupiable containers or otherwise enclosed.

The signage required must be in compliance with ANSI Z535 and include the following information:

1. "Energy Storage Systems" with symbol of lightning bolt in a triangle.
2. Type of technology associated with the ESS.
3. Special hazards associated as identified in Chapters 9 through 15.
4. Type of suppression system installed in the area of the ESS.

5. Emergency contact information.

A permanent plaque denoting the location of all electric power source disconnecting means on or in the premises shall be installed at each service equipment location and at the location(s) of the system disconnect(s) for all energy sources capable of being interconnected. The Worthington BESS is capable of being installed in accordance with these requirements; however, signage will be evaluated once additional site design details are provided to confirm compliance.

5.2.8 Impact Protection

NFPA 855 §4.3.7 requires ESS to be located or protected to prevent physical damage, including impact by a motor vehicle. Based on a review of the drawing set, vehicle impact protection is not being provided at the Worthington BESS. However, the Worthington BESS is a secure, remote installation that does not have personnel on site each day. In addition, there is no motor vehicle traffic moving through the site other than the occasional maintenance vehicle (i.e., there are no public roads/ways on the site) and access to one on-site residence. Therefore, vehicle impact protection is not necessary for the Worthington BESS. As such, the Worthington BESS site design complies with NFPA 855 impact protection requirements.

5.2.9 Security of Installation

NFPA 855 §4.3.8 requires rooms, areas, and walk-in units in which electrochemical ESS are located to be secured against unauthorized entry and safeguarded in an approved manner. Security barriers, fences, landscaping, and other enclosures shall not inhibit the required air flow to or exhaust from the electrochemical ESS and its components. As described in Section 4.1.3, a gated, 8-ft tall fixed knot farm fence will be installed around the perimeter of the BESS yard to prohibit access to the SB3 cabinets. This fencing shall not, however, prohibit the required air flow to the cabinets. As such, the Worthington BESS site design complies with NFPA 855 security of installation requirements.

5.2.10 Access Roads

NFPA 855 §4.4.3.8 requires fire department access roads to be provided to outdoor ESS installations in accordance with the local fire code. NFPA 1 Chapter 18 requires fire apparatus roads to be provided in accordance with §18.2.3 for every facility, building, or portion of a building hereafter constructed or relocated. At a minimum, the fire apparatus access roads must meet the following:

- Extend to within 150 ft of all portions of the facility and all portions of the exterior walls of the first story of the building as measured by an approved route around the exterior of the building or facility (§18.2.3.2.2).
- Have an unobstructed width of not less than 20 ft and an unobstructed vertical clearance of not less than 13 ft 6 inches (§18.2.3.5.1.1 and §18.2.3.5.1.2).
- Be designed and maintained to support the imposed loads of fire apparatus and shall be surfaced so as to provide all-weather driving capabilities (§18.2.3.5.2).
- Have a turning radius, angles of approach and departure that are approved by the FCO (§18.2.3.5.3).
- Minimum inside turning radius of 25 ft. (§18.2.3.5.3.1 as amended by 527 CMR).
- Dead-end fire apparatus access roads in excess of 150 ft in length shall be provided with an approved area for turning around fire apparatus (§18.2.3.5.4).

- The grade of the fire apparatus access road shall not exceed 10% unless approved by the FCO (§18.2.3.5.6.1 as amended by 527 CMR).

Based on the review of the drawing set, the 6-in. depth crushed stone access roadway at the Worthington BESS is within 150 ft of all areas of the BESS facility, there are no dead ends exceeding 150 ft, and the access roads within the BESS facility are anticipated to be less than 10% in grade. However, the minimum unobstructed roadway width must be increased from 16 ft to 20 ft or obtain AHJ approval.

5.3 Outdoor ESS Installations

5.3.1 Size and Separation

NFPA 855 §4.6 requires near exposures, outdoor BESS to be segregated into groups not exceeding 50 kWh with each group to be separated by minimum 3 ft from other groups. However, these requirements do not pertain to the Worthington BESS as it is classified as a remote, outdoor BESS.

5.3.2 Maximum Stored Energy

NFPA 855 §4.8 requires near exposures, outdoor BESS to meet the maximum allowable quantities threshold of 600 kWh. However, this requirement does not pertain to the Worthington BESS as it is classified as a remote, outdoor BESS.

5.3.3 Maximum Size

NFPA 855 §4.4.3.2 does not permit outdoor ESS cabinets to exceed 53 ft × 8.5 ft × 9.5 ft, not including HVAC and other equipment. The SB3 is a NWI style cabinet with dimensions 19.9 ft × 8.0 ft × 9.5 ft, which is smaller than the maximum permitted size for outdoor cabinets per NFPA 855. As such, the Worthington BESS site design complies with the NFPA 855 maximum size requirements.

5.3.4 Clearance to Exposures

NFPA 855 §4.4.3.3 requires ESS located outdoors to be separated by a minimum of 10 ft (3048 mm) from the following exposures: lot lines, public ways, buildings, stored combustible materials, hazardous materials, high-piled stock, and other exposure hazards. Note, the *other exposure hazards* applies to other exposure hazards not associated with the electrical grid infrastructure. Based on a review of the drawing set, no exposure is within 10 ft of the nearest SB3. As such, the Worthington BESS site design complies with the clearance to exposures requirements.

5.3.5 Means of Egress Separation

NFPA 855 §4.4.3.4 requires ESS located outdoors to be separated from any accessible means of egress as required by the FCO to ensure safe egress under fire conditions, but not less than 10 ft. The FCO is authorized to approve a reduced separation distance to 3 ft where large-scale fire testing complying with NFPA 855 §4.1.5 is conducted and demonstrates that a fire involving the ESS will not adversely impact occupant egress. Based on a review of the drawing set, the Worthington BESS site design complies with the means of egress separation requirement.

5.3.6 Vegetation Control

NFPA 855 §4.4.3.6 requires areas within 10 ft on each side of outdoor ESS to be cleared of combustible vegetation and other growth. It is anticipated that each SB3 cabinet will be installed on a concrete pad surrounded by gravel. This design would provide at least 10 ft on each side of all SB3 cabinets free of combustible vegetation. As such, the Worthington BESS site design complies with the vegetation control requirements.

5.3.7 Smoke and Automatic Fire Detection

NFPA 855 §4.10 requires areas containing ESS located within buildings or structures to be provided with a smoke detection or radiant energy sensing system in accordance with NFPA 72. The SB3 is a NWI style BESS that is unoccupiable, with all internal components accessible via exterior doors. It is not being installed inside a room, indoor areas, or walk-in units. Therefore, the SB3 installation at the Worthington BESS does not require smoke and automatic fire detection. As such, the Worthington BESS site design complies with the smoke and automatic fire detection requirements.

However, the SB3 is equipped with a smoke and heat detection system. In addition, the SB3 is equipped with an audible/visual notification appliance located on the exterior of the cabinet. It is anticipated that any alarm state communicated from a SB3 BMS would be seen at the full site network's EMS as described in Section 2.6. Although this system is not required by NFPA 855, FRA recommends that any fire alarm system be designed, commissioned, and installed in accordance with NFPA 72.

5.3.8 Fire Suppression System

NFPA 855 §4.11 requires an automatic fire suppression system to be installed in rooms and areas within buildings and walk-in units containing ESS. The SB3 is a NWI style BESS that is unoccupiable with all internal components accessible via exterior doors. It is not being installed inside a room or within a building. Therefore, the SB3 installation at the Worthington BESS does not require fire suppression systems. As such, the Worthington BESS site design complies with fire suppression system requirements.

5.3.9 Water Supply

NFPA 855 §4.13 requires sites where non-mechanical ESS are installed to be provided with a permanent source of water for fire protection. Where no permanent and reliable water supply exists for firefighting purposes, the requirements of NFPA 1142, *Standard on Water Supplies for Suburban and Rural Firefighting*, apply. As discussed in Section 4.1 above, no on-site water will be provided for firefighting purposes which will require FCO approval. However, when agreeable with the ESS owner and approved by the AHJ, a permanent water supply for firefighting purposes can be omitted [NFPA 855 Table 4.4.3 Footnote D]. The Worthington BESS is capable of being installed in accordance with these requirements; however, the AHJ must approved the omission of a permanent firefighting water supply.

Note, typical BESS firefighting response procedures do not require or recommend offensive firefighting tactics to manually suppress a BESS fire. In addition, UL 9540A unit level fire testing (see Section 3.3) demonstrated that a fire will not spread from module to module within the SB3 cabinet or to adjacent SB3 cabinets. This result was without a fire suppression system installed inside the SB3 cabinet and without manual fire suppression via hose lines.

5.4 Technology Specific Protection – Lithium-Ion Batteries

NFPA 855 requires electrochemical ESS to comply with the thermal runaway requirements of NFPA 855 §9.3 and the explosion control requirements of NFPA 855 §4.12. Note, lithium-ion batteries do not need to meet the exhaust ventilation requirements of NFPA 855 §4.9, the spill control and neutralization requirements NFPA 855 §4.14 and §4.15, or the safety cap requirements NFPA 855 §9.4.

5.4.1 Explosion Control

NFPA 855 Table 9.2 requires lithium-ion ESS installed within a room, building, ESS cabinet, ESS walk-in unit, or otherwise unoccupiable enclosure to be provided with one of the following per §4.12:

(1) Explosion prevention systems designed, installed, operated, maintained, and tested in accordance with NFPA 69; or

(2) Deflagration venting installed and maintained in accordance with NFPA 68.

The SB3 is equipped with a CCR system that is designed per NFPA 69 to maintain the flammable gas concentration inside the SB3 cabinet below 25% of the LFL, thereby minimizing the deflagration potential. To detect flammable gases, two combustible gas detectors are installed at the top interior of each cabinet and are activated when the concentration of hydrogen at the detector location reaches 10% of the LFL. Once activated, the FACP receives an alarm signal, which activates the alarm bell, exhaust fan, and intake air louvers.

TÜV performed a review of the explosion control system and associated fluid dynamics (CFD) simulations for the SB3 and determined the system complies with NFPA 69. This NFPA 69 evaluation report is not endorsed by a registered design professional. A detailed compliance review of these systems was not part of this scope of work. Based on the TÜV CFD modeling, the SB3 installation at the Worthington BESS can meet the NFPA 855 explosion control requirements. FRA recommends that the NFPA 69 compliance evaluation be signed and sealed by a registered design professional.

5.4.2 Thermal Runaway Protection

NFPA 855 §9.3 requires thermal runaway protection for lithium-ion BESS. This protection can be provided with a listed device or other approved method to prevent, detect, and minimize the impact of thermal runaway. The thermal runaway protection is permitted to be part of the BMS that has been evaluated with the battery as part of the evaluation to UL 1973 or UL 9540. The SB3 is equipped with a BMS that was tested and verified to UL 9540. As such, the Worthington BESS site design complies with NFPA 855 thermal runaway requirements.

5.5 Product Design Code Analysis Summary

Based on a review of the SB3 and the IFP drawing package dated 12/23/2025 (the drawing set), the SB3 installation at the Worthington BESS site design can meet the NFPA 855 installation level requirements for an outdoor, NWI style BESS when it is installed in accordance with the manufacturer's instructions, its listing, the approved drawings, and the NFPA 855. However, as the final site design is developed, several items were identified in this analysis that still need modification/confirmation to ensure compliance. These include:

- Approved signage must be provided at the site per NFPA 855 §4.3.5.
- Increase minimum unobstructed fire apparatus access roadway width from 16 ft to 20 ft or obtain AHJ approval per NFPA 855 §4.4.3.8.
- Obtain FCO approval for having no fire protection water supply at the site per NFPA 855 §4.13.

6. BESS PLANS & TRAINING

NFPA 855 requires several plans to be developed for a BESS site. Often times, these documents are developed during construction or after substantial completion of the facility, such that they include site specific details that would not be available prior (such as during the design phase of the project).

6.1 Commissioning, Operation, Decommissioning, and ITM

NFPA 855 requires commissioning, decommissioning, and inspection, testing, and maintenance (ITM) requirements for all BESS installations. It states that the operation, inspection, testing, and maintenance must follow the manufacturer's instructions.

A commissioning plan must be developed for the integration of the new BESS equipment into the electrical utility grid. The commissioning documentation is to capture the commissioning roles and responsibilities, list of equipment, conditions, BESS operation compliance, fire protection feature compliance, and operability (NFPA 855 Chapter 6). An operation and maintenance manual must be developed and provided to both the owner, or their authorized agent, and the BESS operator before the BESS is put into operation (NFPA 855 Chapter 7). A decommissioning plan must be developed to provide the organization, documentation requirements, contingencies, and methods and tools necessary to indicate how the safety systems, ESS, and components will be decommissioned and removed from the site (NFPA 855 Chapter 8). In addition, all fire protection systems must be designed, installed, commissioned, inspected, tested, and maintained as required by each respective NFPA standard.

6.2 Emergency Operations Plan

NFPA 855 §4.1.3.2.1 requires an emergency operations plan (EOP) to be readily available at a BESS site for use by facility operations and maintenance personnel. The EOP is a living document that should be updated when conditions change that affect the response considerations and procedures. At a minimum, the EOP shall include the following: procedures for safe operational shutdown, inspection testing and maintenance, BESS response procedures, fire response procedures, safety data sheets, emergency contact information, procedures for dealing with damaged equipment, and procedures for conducting drills [NFPA 855 §4.1.3.2.1.4].

6.3 Emergency Response Plan

An ERP is typically developed to be readily available at the Worthington BESS for use by facility operations and maintenance personnel. The ERP is a living document that should be updated when conditions change that would affect the response considerations and procedure changes. It should be written using terminology that the fire department and first responders are familiar with and should consider them as the primary reader. The BESS ERP, at a minimum, should include: contact information, a site overview, BESS details, site fire protection system details, site hazards, response tactics and recovery/post incident operations.

6.4 Emergency Response Training

NFPA 855 §4.1.3.1 requires the owner of the BESS or their authorized representative to engage in emergency planning and training of ESS facility operations and maintenance personnel and emergency responders so that they can effectively address foreseeable hazards associated with the on-site systems. Additionally, NFPA 855 §4.1.3.2.2 requires all personnel responsible for the operation, maintenance, repair, servicing, and response of the ESS to be trained in the procedures included in the EOP. In addition, annual refresher training must be provided, and records of the training must be retained.

6.5 Plans and Training Summary

Canadian Solar has developed commissioning, installation, user, maintenance manuals, safety and decommissioning manuals for the SB3 to provide guidance to anyone designing, installing, commissioning, operating, maintaining, servicing, decommissioning, or responding to an emergency involving an SB3. These manuals can be utilized by site owners/operators to develop their own site-specific documents. As the site is still in the design phase, more details related to these plans will be included once provided. It is anticipated that a commissioning plan, operations and maintenance manual, a decommissioning plan, EOP, or an ERP will be developed for the Worthington BESS to meet the NFPA 855 requirements. FRA recommends that all of these plans be finalized and approved prior to energizing the Worthington BESS and that all site personnel and emergency response personnel, who could be responsible for responding to a Worthington BESS emergency, be trained prior to energizing the Worthington BESS. In addition, refresher training should be provided as appropriate, typically annually, as required by NFPA 855.

7. HAZARD MITIGATION ANALYSIS

This HMA is being prepared following the guidance by NFPA 855. The HMA evaluates the fire safety features of the SB3, the findings of the UL 9540A cell, module, and unit level tests, and the site level fire safety features of the Worthington BESS.

Based on the product level and site level safety features, the fire and life safety consequences associated with typical BESS failure modes can be evaluated to determine the impact to site personnel, the general public, and adjacent exposures.

NFPA 855 §4.1.4.2 requires an HMA to evaluate the consequences associated with the following failure modes, and others deemed necessary by the FCO. Note, only single failure modes must be considered in this analysis:

1. Thermal runaway condition in a single module, array, or unit.
2. Failure of an energy storage management system.
3. Failure of a required ventilation or exhaust system.
4. Failure of a required smoke detection, fire detection, fire suppression, or gas detection system.

The consequences of each failure mode are evaluated in Sections 7.1 through 7.4 of this report.

7.1 Thermal Runaway Condition

7.1.1 Description

Thermal runaway is a condition in which a self-heating chemical reaction occurs within a battery cell. This occurs when the battery cell generates heat faster than the battery cell is able to dissipate heat. Thermal runaway can be caused by physical damage (e.g. puncture, crushing), electrical malfunctions (e.g. overcharging), exposure to elevated ambient temperatures (e.g. adjacent cells in thermal runaway with elevated temperatures), manufacturing defects, and other internal conditions which may develop inside of aging battery cells (e.g. dendrites).

Thermal runaway typically results in an overpressure event within the battery cell due to internal heat generation inside the casing causing battery gases to be ejected from the cell through the pressure relief valve. Depending on the conditions, thermal runaway may be limited to the initiating cell(s) or thermal runaway may propagate to adjacent cells. Thermal runaway propagation typically occurs through conductive and convective heating or physical damage of adjacent cells due to swelling of the initiating cell. Conductive heating is the primary mode of heat transfer to adjacent cells for a non-flaming event and convective heating is the primary mode of heat transfer to adjacent cells for a flaming event.

Based on cell level and module level testing, the SB3 cells generate toxic and flammable gases. Depending on the conditions of release, flammable gases released during a thermal runaway event may present an explosion or fire hazard. An explosion hazard exists when sufficient flammable gases are released in the absence of an ignition source and build up within the cabinet. A fire hazard exists when the flammable gases are released in the presence of an ignition source or self-ignite. It should be noted, the fire hazard and explosion hazard are not mutually exclusive, and both may exist at different time periods throughout a propagating thermal runaway event. In addition, toxic gases present a health exposure hazard to site personnel and first responders located in the vicinity of a BESS failure.

7.1.2 Barriers

Passive and active mitigation strategies are provided to prevent batteries from entering thermal runaway and cool adjacent batteries to prevent thermal runaway propagation. The following barriers are provided in the SB3:

- The cells and modules utilized in the SB3 are certified to UL 1973.
- The SB3 is equipped with a BMS which monitors cell health and shuts down power to modules/cabinets with cells operating outside of their operating conditions, as described in Section 2.6.
- The SB3 is equipped with a TMS which automatically activates to provide cooling and prevent batteries from overheating and escalating to a thermal runaway event, as described in Section 2.5. Additionally, the TMS cools adjacent batteries in a thermal runaway scenario to prevent thermal runaway propagation.
- The SB3 modules are equipped with passive barriers to minimize the likelihood of thermal runaway of spreading from cell to cell.
- The SB3 is equipped with a series of electrical fault protection devices, as described in Section 2.7.
- The SB3 will be regularly maintained to ensure it is operating within its specific parameters and to verify the batteries are in good working condition, as described in Section 4.1.2.

7.1.3 Consequences

The consequences of thermal runaway can vary widely depending on the gas release scenario and level of confinement; however, the primary consequences of thermal runaway can be grouped into the following hazard categories: fire and radiant heat, deflagrations and explosions, and toxic gases.

7.1.3.1 Fire & Radiant Heat Exposure Hazard

UL 9540A unit level testing did not result in a fire (i.e., flaming thermal runaway). During that test, five cells went into thermal runaway: the three that were forcibly heated and two additional cells. Thermal runaway did not propagate beyond the fifth cell, and no sustained fire event occurred. However, a large-scale fire test (LSFT) and/or fire modeling has not been performed to explicitly evaluate the potential for thermal runaway to propagate from one SB3 cabinet to adjacent SB3 cabinets or to determine the minimum approach distances (MAD) should a fully involved SB3 fire occur. In the absence of this data, FRA recommends that site level emergency response procedures be utilized during a fire event to minimize the potential for fire to spread to adjacent cabinets and exposures.

Note, typical BESS firefighting response procedures do not require or recommend offensive firefighting tactics to manually suppress a BESS fire. If manual firefighting tactics are used, water is considered the preferred agent for managing lithium-ion battery fires, suppressing nearby combustibles, cooling nearby exposures, and controlling smoke. Other fire suppression methods, such as gaseous agents (CO_2, Halon), dry chemical suppressants, or foams, are unlikely to be effective. As such, FRA recommends defensive firefighting tactics to be utilized during a fire event involving a SB3 cabinet, and first responders should be trained on these tactics.

Accordingly, FRA recommends that fire responders remain at an initial MAD of 100 ft during a battery emergency. Note, these aspects provide mitigation only in the case in which multiple failures occur, including all of the battery system barriers identified in Section 7.1.2.

7.1.3.2 Deflagration & Explosions Hazard

The SB3 has been tested to UL 9540A, as described in Section 3.0. These test results demonstrated that flammable gases are released from the cells during thermal runaway which can pose a deflagration hazard within the SB3. To mitigate the impact of this hazard, the SB3 is equipped with a CCR system as described in Section 2.10. The CCR system is activated upon receiving signals from the gas detection sensors within the cabinet. Upon gas detection of 10% of the LFL, the ventilation system activates, pulling in outside air and exhausting internal air, to reduce the concentrations of flammable gases to under 25% of the LFL. In addition, the activation of the CCR system would also trigger the sounding of local fire notification appliances installed on the exterior of the SB3. These appliances can alert local site personnel and/or first responders, should any be in the area, of the hazard. Per the EOP/ERP and the training of site personnel/first responders, all personnel would be prompted to evacuate the area immediately upon activation of a fire alarm notification appliance. By immediately evacuating to a designated safe area, site personnel and first responders would provide physical separation between them and the potential deflagration and explosion hazard. This provides a second mitigation feature, physical separation of people from the SB3 cabinets, in addition to the CCR system. Note, these aspects provide mitigation only in the case in which multiple failures occur, including all of the battery system barriers identified in Section 7.1.2 and the CCR system. Accordingly, FRA recommends that first responders remain at an initial MAD of 100 ft from the distressed SB3 cabinet during a battery emergency.

7.1.3.3 Toxic Gas Hazard

The SB3 is not occupiable; therefore, toxic or highly toxic gas exposure is limited to individuals standing outside, in the open ambient air, in proximity to the SB3 cabinet during a failure/fire event. The toxic gases collected during the module level testing include typical fire byproducts, such as CO and CO_2. The fire alarm notification system is one mitigation feature installed at the cabinet level to address this hazard. This system can alert local site personnel and/or first responders, should any be in the area, of the hazard. Per the EOP/ERP and the training of site personnel/first responders, all personnel would be prompted to evacuate the area immediately upon activation of a fire alarm notification appliance. By immediately evacuating to a designated safe area, site personnel and first responders would provide physical separation between them and the potential toxic gas hazard. In addition, an ERP should direct first responders to wear proper Personal Protective Equipment (PPE), including a self-contained breathing apparatus (SCBA) and turnout gear, when responding to a battery emergency should they need to approach a distressed cabinet. Given the Worthington BESS is installed outdoors, any gas release would be diluted by the entrainment of outside air. At the quantities measured during UL 9540A module level fire testing, such gases would not be expected to have an adverse effect on individuals during the time deemed necessary to evacuate from the area (i.e., approximately 30 seconds to walk 100 ft away/evacuate from a burning SB3) nor expected to have an adverse effect on emergency response personnel wearing appropriate PPE including a SCBA while responding to an SB3 fire. Note, these aspects provide mitigation only in the case in which multiple failures occur, including all of the battery system barriers identified in Section 7.1.2. Accordingly, FRA recommends that first responders remain at an initial MAD of 100 ft from the distressed SB3 cabinet during a battery emergency.

Note, toxic gases sometimes associated with lithium-ion batteries, such as HF, HCl, and HCN, were not detected during the UL 9540A module level testing of the SB3. However, the internal components of the SB3 (plastics, printed circuit boards, wiring, coolants, refrigerants, and the lithium-ion cells) could experience thermal decay that contributes to the fuel load, heat release rate, and production of trace toxic components. These could include the release of HF gas upon thermal degradation/decomposition of the lithium-ion cells. Additionally, thermal decomposition of refrigerants included in the TMS and wire insulation can be other potential contributing sources of HF. Acid gases like HCN could also form from the incomplete combustion of nitrogen-containing materials (such as wool, silk, cotton, paper, and plastics) and HCl could be released from the pyrolysis of chlorinated plastics, particularly polyvinyl chloride (PVC), and other chlorine-containing materials/plastics. Note, these hazards are not exclusive to battery fires. As the modern built environment has expanded the use of plastic goods, materials, and electronics to a wide variety of household products, HF, HCl, HCN and other products of combustion are also found in modern day fires. As such, the gases mentioned above are similar to gases first responders would encounter in a typical Class A structure or vehicle fire and do not contain any unique, or atypical, gases beyond what you would find in the combustion of modern combustible materials, such as plastics and other electronics. Therefore, although these gases were not detected during the UL 9540A module level testing of the SB3, FRA recommends that monitoring of these gases in addition to CO and CO2 be conducted during a battery emergency.

7.2 Failure of the Energy Management System

7.2.1 Description

The SB3 is equipped with a BMS. The BMS tracks the performance, voltage, current, and SOC of the cells to ensure they are operating within manufacturer specifications. Per NFPA 855 §4.2.9.2 the BMS is required to disconnect electrical connections to the ESS if potentially hazardous conditions occur. Additionally, the BMS can initiate other controls based on the hazard detected as described in Section 2.6. Consequences due to BMS failure are evaluated in this section.

7.2.2 Barriers

The following barriers are provided to prevent BMS failure and minimize the consequences of BMS failure:

- The BMS is certified as part of the battery module to UL 1973.
- The BMS will be monitored as described in Section 2.6.
- Electrical fault protection is provided as described in Section 2.7.
- The BMS will be regularly maintained to ensure it is operating within its specific parameters, as described in Section 4.1.2.

7.2.3 Consequences

Failure of the BMS will prevent active monitoring of battery cell conditions. The BMS will be monitored such that a failure will be quickly detected and remediated reducing the duration a SB3 is operating with deficient safety features. Additionally, remote capabilities will be provided to discharge batteries from an affected SB3 cabinet or shut down modules/entire cabinets, depending on the severity of the issue and the operational capabilities of the system at the time. Discharging the batteries reduces the consequences of a potential thermal event while the BMS is offline because the fire and explosion hazard is a direct correlation to battery SOC. It should be noted, BMS failure alone will not cause battery failure. In a worst-case scenario, a BMS failure in conjunction with a secondary failure condition (such as over voltage, excess temperature, etc.) may result in a thermal runaway event. Barriers and consequences of thermal runaway are provided in Sections 7.1.2 and 7.1.3 of this report.

7.3 Failure of Any Required Ventilation System

7.3.1 Description

A failure scenario involving any required ventilation or exhaust may expose the batteries to elevated operating temperatures. Depending on the resulting ambient temperature, ventilation failure may cause batteries to be exposed to temperatures outside of the manufacturer recommended operating conditions or temperatures at which the cell fails. The SB3 is not provided with any required ventilation or exhaust system beyond that utilized for explosion prevention. However, the SB3 is provided with a closed loop liquid cooling TMS for the battery modules, as described in Section 2.5. The cooling system performs a similar function to ventilation such that it is provided to cool battery cells and maintain battery operating temperatures within the manufacturer's recommended range. This failure scenario evaluates the consequences associated with a failure of the liquid cooling system.

7.3.2 Barriers

The SB3 is equipped with the following barriers to prevent ventilation system failure and reduce the consequences of a failure event:

- The TMS is monitored as described in Section 2.5.
- The TMS will be regularly maintained to ensure it is operating within its specific parameters, as described in Section 4.1.2.

7.3.3 Consequences

Failure of the cooling system may expose batteries to ambient temperatures. The average peak ambient temperature in Worthington, MA is 82ºF (28ºC) and occurs in July. The peak temperature is less than the cell venting temperature 399ºF (203.7°C); therefore, failure of the cooling system is not anticipated to lead to a thermal runaway event. The TMS is monitored such that a failure will be quickly detected and remediated reducing the duration a SB3 is operating with deficient safety features. Additionally, remote capabilities will be provided to discharge batteries from an affected SB3 cabinet or shut down modules/entire cabinets, depending on the severity of the issue and the operational capabilities of the system at the time. Discharging the batteries reduces the consequences of a potential thermal event while the TMS is offline because the fire and explosion hazard is a direct correlation to battery SOC. In a worst-case scenario, batteries operating at elevated temperatures for extended periods of time may degrade and have a higher likelihood of failure over time, possibly leading to thermal runaway. Barriers and consequences of thermal runaway are provided in Sections 7.1.2 and 7.1.3 of this report.

7.4 Failure of a Fire Protection System

7.4.1 Description

The SB3 is equipped with a fire and gas detection system and a CCRS, as described in Sections 2.8 and 2.10. The fire and gas detection system includes three photoelectric smoke detectors (two in the battery compartment and one in the electrical compartment), three heat detectors (two in the battery compartment and one in the electrical compartment), two hydrogen gas detectors in the battery compartment, and an addressable FACP. For local notification, an alarm bell and an audible/visible appliance are installed on the exterior of the SB3 cabinet. Failure of the fire and gas detection system may result in a delay in fire/gas detection, a delay in the activation of the CCRS, and a delay in on-site and off-site notification of the thermal event. This failure scenario evaluates the consequences associated with failure of the fire and gas detection system and the CCRS.

7.4.2 Barriers

The following barriers are provided to prevent fire and gas detection system and CCRS failure and minimize the associated consequences:

- The fire and gas detection system will be designed in accordance with NFPA 72.
- Three smoke detectors are installed throughout the cabinet providing coverage throughout.
- Three heat detectors are installed throughout the cabinet providing coverage throughout.
- Two gas detectors are installed throughout the cabinet providing coverage throughout.
- The smoke and gas detectors are continuously monitored by the FACP.
- Integral backup power supply will be provided in case of a loss of auxiliary power, as required by NFPA 72.
- Remote monitoring will be provided; if power is lost, O&M service personnel will be notified to remediate the issue.
- Regular inspection, testing, and maintenance (IT&M) performed on the fire and gas detection system through its lifespan, as required by NFPA 72.
- The CCRS is designed in accordance with NFPA 69.
- Regular inspection, testing, and maintenance should be performed on the CCRS throughout its lifespan, as required by NFPA 69.

7.4.3 Consequences

Potential fire and gas detection system failure could produce two primary consequences: (1) a delay or complete failure to operate the explosion prevention system and/or (2) a delay in detection/notification of a thermal event to on-/off-site personnel. The primary potential causes for this failure would be a fault in a listed fire alarm initiating device, an initial installation error, or degradation of a fire alarm device/wiring over time. The likelihood of these occurring with a properly designed, installed, commissioned, monitored, inspected, tested, and maintained fire alarm system is historically low based on data from the National Fire Protection Association (NFPA). Also, the fire alarm system is an addressable system where the status of each device is monitored by the FACP and BMS; therefore, failure of a system component would be reported and can be remediated. Lastly, IT&M would be periodically performed to inspect the fire alarm system for damage/degradation and to test the devices for proper performance. Each of these fire alarm system mitigation aspects would be in place to minimize the likelihood of system failure over the life span of the SB3.

Failure of the CCRS may result in the accumulation of flammable gases in the cabinet and subsequent deflagration. However, the CCRS is expected to be properly designed, installed, commissioned, monitored, inspected, tested, and maintained to minimize likelihood of failure. In the case that the CCRS malfunctions, notification by the fire and gas detection system would alert local site personnel and/or first responders, should any be in the area, of the hazard. Per the EOP/ERP and the training of site personnel/first responders, all personnel would be prompted to evacuate the area immediately upon activation of a fire alarm notification appliance. By immediately evacuating to a designated safe area, site personnel and first responders would provide physical separation between them and the potential toxic gas hazard. In addition, an ERP should direct first responders to wear proper PPE, including a SCBA and turnout gear, when responding to a battery emergency should they need to approach a distressed cabinet.

7.5 HMA Analysis Approval

Based on the analysis above, the Worthington BESS meets all of the HMA approval criteria for FCO or AHJ approval per NFPA 855 §4.1.4.3, as it has demonstrated that:

1. Fires will be contained within unoccupied ESS rooms for the minimum duration of the fire resistance rating specified in NFPA 855 §4.3.6.

   The Worthington BESS meets this approval criteria. The SB3 is a non-occupiable cabinet that is installed outdoors, not within unoccupied ESS rooms. However, it should be noted that the SB3 has a number of protection schemes in place to prohibit fire from spreading from one SB3 cabinet to another. As demonstrated in UL 9540A unit level testing, thermal runaway was contained to a single module within a SB3 cabinet. As discussed in 7.1.3.1, a LSFT and/or fire modeling has not been performed to explicitly evaluate the potential for thermal runaway to propagate from one SB3 cabinet to adjacent SB3 cabinets. Therefore, site level emergency response procedures (such as exposure protection) could be utilized during a fire event, based on real time fire conditions and observations (i.e., wind direction/speed, fire intensity, proximity of flames to adjacent cabinets), to minimize the potential for fire to spread to adjacent cabinets.

2. Suitable deflagration protection is provided where required.

   The Worthington BESS meets this approval criteria. The SB3 is equipped with a CCR system which activates upon receiving signals from the gas detection sensors contained within the cabinet. Upon gas detection of 10% of the LFL, the ventilation system activates, pulling in outside air and exhausting internal air, to reduce the concentrations of flammable gases to under 25% of the LFL. In addition, the activation of the CCRS would also trigger the sounding of local fire notification appliances installed on the exterior of the SB3. These appliances can alert local site personnel and/or first responders, should any be in the area, of the hazard. Per the EOP/ERP and the training of site personnel/first responders, all personnel would be prompted to evacuate the area immediately upon activation of a fire alarm notification appliance. By immediately evacuating to a designated safe area, site personnel and first responders would provide physical separation between them and the potential deflagration and explosion hazard. This provides a second mitigation feature, physical separation of people from the SB3 cabinets, in addition to the CCRS.

3. ESS cabinets in occupied work centers allow occupants to safely evacuate in fire conditions.

   The Worthington BESS meets this approval criteria. The SB3 is a non-occupiable cabinet that is installed outdoors, not within occupied work centers (or any other room). However, it should be noted that the SB3 has numerous internal sensors that are monitored by the BMS that can detect abnormal events and/or failures of the unit. The SB3 also includes smoke, heat, and gas detection systems with an alarm bell and audible/visible appliance installed on the exterior of the cabinet to provide local notification. These systems are also monitored remotely, providing off-site notification in the unlikely event of a fire. Although this applies to occupied work centers (and not an outdoor installation), the Worthington BESS still meets the intent of the approval criteria through the internal sensors, fire and gas detection system, the remote monitoring provided, and the local notification appliances installed in each SB3 cabinet.

4. Toxic and highly toxic gases released during normal charging, discharging, and operation will not exceed the PEL in the area where the ESS is contained.

   The Worthington BESS meets this approval criteria. The SB3 utilizes listed lithium-ion cells that are hermetically sealed and do not vent during charging, discharging or normal operation. Unlike other battery types, no toxic gases are released during normal operation of the lithium-ion batteries. As such, no toxic gases will be released from the Worthington BESS during charging, discharging, and normal operation.

5. Toxic and highly toxic gases released during fires and other fault conditions 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 from that area.

   The Worthington BESS meets this approval criteria. The SB3 is installed outdoors, not within a building or adjacent to any means of egress. The nearest building/structure is an individual residence, which is approximately 500 ft from a SB3 cabinet. This distance is greater than the 10-ft clearance distance required by NFPA 855 from the BESS to adjacent buildings and/or means of egress. The fire alarm notification system is one mitigation feature installed at the cabinet level to address this hazard. This system can alert local site personnel and/or first responders, should any be in the area, of the hazard. Per the EOP/ERP and the training of site personnel/first responders, all personnel would be prompted to evacuate the area immediately upon activation of a fire alarm notification appliance. By immediately evacuating to a designated safe area, site personnel and first responders would provide physical separation between them and the potential toxic gas hazard. In addition, an ERP should direct first responders to wear proper PPE, including a SCBA and turnout gear, when responding to a battery emergency should they need to approach a distressed cabinet. Given the Worthington BESS is installed outdoors, any gas release would be diluted by the entrainment of outside air. At the quantities measured during UL 9540A module level fire testing, such gases would not be expected to have an adverse effect on individuals during the time deemed necessary to evacuate from the area (i.e., approximately 30 seconds to walk 100 ft away/evacuate from a burning SB3) nor expected to have an adverse effect on emergency response personnel wearing appropriate PPE including a SCBA while responding to an SB3 fire. Although this applies to a building or to an installation that is immediately adjacent to a means of egress route, the Worthington BESS still meets the intent of the approval criteria.

6. Flammable gases released during charging, discharging, and normal operation will not exceed 25 percent of the LFL.

   The Worthington BESS meets this approval criteria. The SB3 utilizes listed lithium-ion cells that are hermetically sealed and do not vent during charging, discharging or normal operation. Unlike other battery types, no flammable gases are released during normal operation of the lithium-ion batteries. As such, no flammable gases exceeding 25% of their LFL will be released from the Worthington BESS during charging, discharging, and normal operation.

8. RECOMMENDATIONS

Throughout the report, FRA provided several recommendations related to the Worthington BESS installation and emergency response to mitigate the hazards of a fire event. These recommendations are based on our review of the available materials, our background, experience and training, the analyses performed to date described above, common industry best practices for responding to a thermal event involving lithium-ion BESS, as well as from FRA's experience with lithium-ion battery hazards, lithium-ion battery BESS hazards, and previous BESS fires. These recommendations do not provide opinions or conclusions meant to address specific circumstances or all possible scenarios of an emergency. As with all emergency events, emergency response actions should be evaluated and performed based on real time fire conditions and observations (i.e., wind direction/speed, fire intensity, proximity of flames to adjacent electrical equipment and structures) during the actual emergency. Below is a summarized list of the recommendations provided throughout the report:

1. **Site Design Elements:** As the design of the site is finalized, FRA recommends the following:
    a. Approved signage must be provided at the site per NFPA 855 §4.3.5.
    b. Increase minimum unobstructed fire apparatus access roadway width from 16 ft to 20 ft.
    c. Obtain FCO approval for having no fire protection water supply at the site per NFPA 855 §4.13.
2. **BESS Plans:** FRA recommends that prior to energizing the Worthington BESS, develop commissioning, operations and maintenance, decommissioning and EOP/ERP plans, as required by NFPA 855.
3. **Emergency Response Training:** FRA recommends that all site personnel and emergency response personnel, who could be responsible for responding to a Worthington BESS emergency, be trained on the EOP/ERP prior to energizing the Worthington BESS. Refresher training should be provided as appropriate, typically annually, as required by NFPA 855.
4. **Fire Protection Systems:** FRA recommends that all fire protection systems be designed, installed, commissioned, and periodically inspected, tested, and maintained as required by each respective NFPA standard.
5. **Minimum Approach Distance (MAD):** When responding to a battery emergency, FRA recommends that all site personnel and first responders remain at a safe distance, upwind from a distressed SB3 cabinet, as should be designated in an ERP, to ensure they are not momentarily exposed to dangerous conditions. Initially, this MAD should be a minimum of 100 feet. In addition, site personnel and first responders should not approach the front of distressed SB3 cabinets, and all first responders should wear proper PPE when approaching a distressed SB3 cabinet during a battery emergency.

9. CONCLUSIONS

Based on our review of the available materials, our background, experience and training, and the analysis performed to date described above, the following conclusions are submitted with a reasonable degree of scientific and engineering certainty:

- The SB3 and the Worthington BESS site design can meet NFPA 855 requirements for an outdoor BESS installation when it is installed in accordance with the SB3 instructions, its listing, the approved drawings, and NFPA 855. Several aspects were identified in this analysis that require modification/confirmation to ensure compliance as identified in Section 5.5.
- As described in detail in Section 7.5, the HMA demonstrates the Worthington BESS meets all the HMA performance criteria for approval outlined in NFPA 855 §4.1.4.3, as follows:
  - Fires will be contained to a single SB3 as demonstrated through UL 9540A unit level testing and should a fully developed fire event occur, site level emergency response procedures (such as exposure protection) could be utilized during a fire event, based on real time fire conditions and observations (i.e., wind direction/speed, fire intensity, proximity of flames to adjacent cabinets), to minimize the potential for fire to spread to adjacent cabinets.
  - Suitable deflagration protection is provided for the SB3 cabinet via the NFPA 69 CCR explosion control system.
  - Fires will be detected in time to allow personnel to safely evacuate via the fire alarm system and internal sensors of the SB3.
  - Toxic and highly toxic gases will not be released during normal charging, discharging, and operation of the SB3 given the listed lithium-ion cells utilized in the SB3 are hermetically sealed and do not vent during charging, discharging or normal operation.
  - Toxic and highly toxic gases released during fires and other fault conditions will not reach concentrations in excess of IDLH levels within a building or an adjacent means of egress given the nearest building is approximately 500 feet away.
  - Flammable gases will not be released during charging, discharging and normal operation of the SB3 given the listed lithium-ion cells utilized in the SB3 are hermetically sealed and do not vent during charging, discharging or normal operation.

10. LIMITATIONS

At the request of BlueWave Energy, FRA performed an HMA in accordance with the requirements of NFPA 855 2020 Edition for the Worthington BESS located at 190 Ridge Road, Worthington, MA. The scope of services performed during this analysis may not adequately address the needs of other users of this report, and any re-use of this report or its conclusions presented herein are at the sole risk of the user. The opinions and comments formulated during this assessment are based on observations and information available at the time of the analysis, which has been provided to FRA by others. No guarantee or warranty as to future performance of any reviewed condition is expressed or implied.

As the Worthington BESS site is still under development, this analysis assumed that the BESS and its associated equipment, as well as all fire protection systems, will be installed, commissioned, inspected, tested, and maintained as required by the manufacturer(s), NFPA 855, and/or other applicable codes and standards throughout the lifetime of the BESS. The accuracy and applicability of this report's findings are subject to change based on changes to the site. FRA assumes no liability for performance, errors, omissions, or failures that may arise during construction or operation, and no warranty of fitness for a particular purpose is implied.

11. REVISIONS

Date	Revision	Reason for Issue	Developed By	Reviewed By	Approved By
04/16/2026	B	Client Comments	KL	AB	AB

Warning, this document is a preliminary draft.

Significant changes will occur once site design and equipment decisions are finalized.

APPENDIX 1: ACRONYMS AND NOMENCLATURE

Acronyms and Abbreviations

Authority Having Jurisdiction	AHJ
Battery Energy Storage System	BESS
Battery Management System	BMS
Emergency Response Plan	ERP
Energy Storage System	ESS
Fire & Risk Alliance, LLC	FRA
Fire Code Official	FCO
Hazard Mitigation Analysis	HMA
Lithium Iron Phosphate	LFP
Lower Flammability Limit	LFL
National Fire Protection Association	NFPA
Non-Walk-In	NWI
Operations and Maintenance	O&M
Personal Protective Equipment	PPE
State of Charge	SOC
Thermal Management System	TMS
Underwriters Laboratory, LLC	UL

Nomenclature

Ampere-hour	Ah
Degree Celsius	°C
Degree Fahrenheit	°F
feet	ft
inch	in
kilopascal	kPa
kilowatt-hour	kWh
Megawatt	MW
Megawatt-hour	MWh

Millimeter	mm
Liter	L
Pounds per square inch absolute	psia
Parts per million	ppm
Volt	V