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TOWNSHIP OF ARMOUR

06/05/2025

Third-Party Peer Review Comments and Resposes
Reviewer: Gary Chan, P. Eng., PLC Fire Safety Engineering

Document reviewed:
Hazard Mitigation Analysis – Project 903 BESS – EVLOFLEX Battery Technology – Township of Armour, Ontario, Canada

Comments Provided:
Third-Party Review Report – Battery Energy Storage System – Armour Township

Responder: Justin Williamson, Ph. D., FRA

Comments:

1. Prior to system operation, construction documents must be provided to the building owner, and a detailed operations and maintenance (O&M) manual must be delivered to both the ESS owner and system operator. The O&M manual must outline system specifications, maintenance procedures, contact information, operational narratives, and service logs. It must be finalized before approval and remain accessible to AHJs and emergency responders.

   Confirmation is required that project documentation will be provided to the AHJ as needed and will meet all the requirements of the applicable codes including NFPA 855.

   Reference: NFPA 855 Section 4.9,

2. Installation requirements such as electrical, loading and seismic were not addressed in the HMA report.

   Clarify if the project is compliant with NFPA 855 electrical, loading and seismic requirements of Chapter 4.

   Reference: NFPA 855 Section 4.7.1, 4.7.2 and 4.7.3

3. Section 4.1.6 of the HMA report states that the detection system will be connected to a fire alarm control panel (FACP).

   HMA Report to clarify the location of the FACP.

Reference: NFPA 855 Section 4.8

4. HMA Report Section 5.4.3 states that the requirements of NFPA 1142 apply.

   Clarify what are the relevant requirements, and whether they are met for this site.

   Reference: NFPA 855 Subsection 4.9.4

5. HMA Report Section 4.1.5 states that a dry hydrant is being proposed.

   Confirm the details regarding its location and what standard it is to comply with.

6. (1) Clarify specifically how the BMS is certified to UL 9540, and

   (2) Explain whether the TMS forms part of the thermal runaway protection.

   Reference: NFPA 855 Section 9.6.5.5

7. Section 5 (Page 27) of the HMA report states that the OFC references NFPA 855. Additionally, Section 7.1.3.1 (Page 39) notes that the "EVLO BESS has been tested to UL 9540A as required by the OFC".

   Clarify these statements with specific references to the OFC.

   Reference: Ontario Fire Code (O. Reg. 213/07)

8. The OFC is referenced throughout the HMA report, however the specific relevant OFC sections are not referenced where applicable.

   Clarify the applicable sections of the OFC, where mentioned in the HMA report.

9. Ontario Electrical Safety Code covers all electrical work and electrical equipment operating or intended to operate at all voltages in electrical installations for buildings, structures, and premises. Section 26 of Ontario Electrical Safety Code in particular outlines requirements for storage battery installations. Ontario Electrical Safety Code is not referenced in the HMA report.

   Provide further details on whether the installation will comply with CSA C22.1.

   Reference: Ontario Electrical Safety Code

Responses and Changes to the Report:

1. Added clarification in several key locations throughout the document that all required documentation will be provided to the AHJ and emergency response personnel as necessary for NFPA 855 SS 4.9 compliance.

2. This is discussed in Section 5.2 of the HMA. Electrical, Design loading and Seismic requirements are specifically outside of the scope of this HMA. Added a clarification that these must be addressed separately in design documents provided to the AHJ as necessary.

3. The control panel is shown in Figure 8 and the report has been revised to clarify the location.

4. Added the clarification to Section 4.1.6 that the water supply requirements can be relaxed with agreement between AHJ and site owner as listed in NFPA855 Section 9.5.2.5.

5. Added details to Section 4.1.5 for the location of the dry hydrant.

6. Added clarification to Section 2.0 that the BESS is compliant with UL 9540 and clarification to Section 5.2.4 that the ESMS complies with the relevant NFPA requirements. Additional commentary on why or how such systems are in compliance is not necessary here.

7. Language has been corrected to point to NFPA 855 as the industry best practice. The current version of OFC does not reference 855 and contains no specific guidance for BESS.

8. Most OFC references have been replaced with NFPA 855 as appropriate. Where possible, the report is updated to the appropriate section of OFC.

9. Added the OESC to Section 1.2 for Applicable Codes and Standards. Note that this HMA does not apply to electrical. As per response to comment 2, this limitation is discussed in Section 5.2 of the HMA. Electrical, Design loading and Seismic requirements are specifically outside of the scope of this HMA. This must be addressed separately in design documents provided to the AHJ as necessary.

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Hazard Mitigation Analysis

Project 903 BESS

EVLOFLEX Battery Technology

Township of Armour, Ontario, Canada

Final Report | Rev 1 | June 24, 2025

Prepared for:

Solarbank
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Date	Revision	Reason for Issue	Developed By	Checked By	Approved by

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 Solarbank Project 903 site located in the Township of Armour, Ontario, Canada (Project 903 BESS). The Ontario Codes & Standards (Ontario Fire Code) (OFC) is considered the code of record for the project, but it contains no specific guidance relative to BESS installations. The HMA was performed in accordance with the requirements of the NFPA 855 (2023) as the industry best practice code of record. The Project 903 BESS is anticipated to include 4.99 MW capacity manufactured by EVLO. This 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 Project 903 BESS.

Based on a review of the EVLO BESS and the site plan, the Project 903 BESS design can meet NFPA 855 requirements for an outdoor BESS when it is installed in accordance with the manufacturer's instructions, its listing, and the NFPA 855. Final Project 903 BESS site design code compliance will be confirmed upon completion of the design drawings.

Based on a review of the Project 903 BESS site plan, the EVLO BESS, its construction, design, fire safety features, listings, certifications, and UL 9540A fire test data, the EVLO BESS installation at the Project 903 BESS can meet the five HMA approval criteria outlined in NFPA 855 §4.4.3, as follows:

1. Fires or explosions will be contained within unoccupied battery storage rooms for the minimum duration of the fire-resistance rated walls.

    The Project 903 BESS meets this requirement. The EVLO BESS is installed outdoors, not within an unoccupied BESS room or area. However, it should be noted, the EVLO BESS design includes a series of passive fire protection schemes (barriers) to protect it from spreading a fire. As demonstrated in UL 9540A unit-level fire testing, thermal runaway propagated slowly through a maximum of 3 cells with 15 to 20 minutes delay between runaway events. Damage was minimal and no flaming debris or fire were reported.

2. Fires and explosions in battery cabinets occupied work centers will be detected in time to allow occupants within the room to evacuate safely.

    The Project 903 BESS meets this requirement. The EVLO BESS cabinet is installed outdoors, not within an occupied work center (or any other room). However, it should be noted, the EVLO BESS has a number of internal sensors within it that can detect an abnormal overheating event, such as a fire. These sensors are monitored by the BMS and are relayed to the LOC. The LOC can then inform O&M service personnel who, if necessary, can notify the fire department if there is a thermal event.

3. 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 occupants from that area.

   The Project 903 BESS meets this requirement. The EVLO BESS is installed outdoors, not within a building or adjacent to any means of egress. The nearest building/structure are adjacent existing houses which are located greater than 300 m from a EVLO BESS cabinet. This distance is greater than the clearance distance required by the NFPA 855 from the BESS to adjacent buildings and/or means of egress. However, it should be noted, toxic gas concentrations measured during UL 9540A module-level fire testing (where the products of combustion were collected within a hood) are well below the IDLH value for each gas. Given the Project 903 BESS is installed outdoors, where any gas release would be diluted by the entrainment of outside air, these gases, at the quantities measured during UL 9540A module level fire testing, 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 EVLO BESS). Nor would these gases, at the quantities measured during UL 9540A module level fire testing, be expected to have an adverse effect on emergency response personnel, who are wearing appropriate personal protective equipment (PPE) while responding to an EVLO BESS fire. Although this requirement applies to a building or to an installation that is immediately adjacent to a means of egress route, the Project 903 BESS still meets the intent of the requirement (i.e., do not produce toxic or highly toxic gases above the IDLH during an EVLO BESS fire event during the time deemed necessary to evacuate from the area).

4. Flammable gases released from ESS during charging, discharging, and normal operation shall not exceed 25 percent of their LFL.

   The Project 903 BESS meets this requirement. The EVLO BESS 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 Project 903 BESS during charging, discharging, and normal operation.

5. Flammable gases released from ESS during fire, overcharging, and other abnormal conditions shall not create an explosion hazard that will injure occupants or emergency responders.

   The Project 903 BESS meets this requirement. The EVLO BESS has an emergency gas ventilation system. The system is designed to maintain flammable gases below 25% LEL in a thermal runaway event before they accumulate within the enclosure. The effectiveness of the emergency ventilation system of the EVLO BESS was demonstrated through detailed modeling of the BESS systems performed by Jensen

Hughes, Inc. Additionally, it is noted from the three levels of UL 9540A testing, there were no observations of a deflagration, projectiles, flying debris, detonation, or other explosive discharge of gases.

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1.0 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 Solarbank Project 903 site located in the Township of Armour, Ontario, Canada (Project 903 BESS). The HMA was performed in accordance with the requirements of the Ontario Codes & Standards (OFC). The Project 903 BESS will have EVLOFLEX cabinets manufactured by EVLO and will have an approximate capacity of 4.99 megawatts (MW). This 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 Project 903 BESS.

1.1 Purpose and Scope

The OFC contains no specific guidance for BESS applications. The industry best practice is NFPA 855, which 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 (NFPA 855 §4.4.2):

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

The AHJ is then authorized to approve the HMA provided the analysis demonstrates all of the following (NFPA 855 §4.4.3):

1. Fires will be contained within unoccupied ESS rooms for the minimum duration of the fire resistance rating specified in NFPA 855 §9.6.4. (Not applicable to outdoor ESS as planned for Project 903 per NFPA 855 §9.6.4.2. Note that the Township of Armour does consider shipping containers to be buildings. While the EVLOFLEX enclosure is not specifically equivalent to a shipping container, it shares several similarities. This requirement can still be considered to be met since there is no significant hazard present for a fire to spread outside the initiating container provided all prescribed site restrictions and design components are followed.)
2. Fires and products of combustion will not prevent occupants from evacuating to a safe location. (Not applicable to outdoor unoccupiable ESS as planned for Project 903)

3. Deflagration hazards will be addressed by an explosion control system or other system. (Met based on analysis of the performance of the emergency ventilation system installed in each EVLOFLEX cabinet)

The framework for this analysis is as follows:

- **Review the EVLO BESS and UL9540A test data**: FRA reviewed the EVLO BESS, its construction, design, fire safety features, listings, and UL 9540A fire test data (see Section 2.0 and 3.0).
- **Review site specifications:** FRA reviewed the proposed Project 903 BESS site layout and installation including the area surrounding the BESS (see Section 4.0).
- **Prescriptive code compliance review:** The proposed site layout and site response plans / training procedures were reviewed for compliance with the NFPA 855 requirements. Where gaps were identified in the BESS installation and response plans / training procedures, recommendations are provided (see Section 5.0 and 6.0, respectively).
- **Hazard Mitigation Analysis:** The HMA evaluates the BESS failure modes as required by the 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. The NFPA 855 states 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 Applicable Codes and Standards

The following codes and standards are applicable to the Project 903 BESS installation in Ontario, Canada:

- Ontario Codes & Standards or National Fire Code of Canada, based on the 2021 International Fire Code, with local amendments (OFC).
- Ontario Electrical Safety Code – 2024 Edition (OESC).
- International Fire Code – 2021 Edition (IFC).
- NFPA 855, Standard for the Installation of Stationary Energy Storage Systems, 2023 Edition (NFPA 855).
- NFPA 68, Standard on Explosion Protection by Deflagration Venting, 2013 Edition (NFPA 68).
- NFPA 69, Standard on Explosion Prevention Systems, 2019 Edition (NFPA 69).
- IEC 60529, Degrees of Protection Provided by Enclosures, 2.2 Edition, January 2019 (IP Code).

- IEC 62619, Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for secondary lithium cells and batteries, for use in industrial applications, Edition 1.0, 2017 (IEC 62619).
- UL 1642, Lithium Batteries, Edition 6, September 29, 2020 (UL1642).
- UL 1973, Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications, Edition 3, February 25, 2022 (UL1973).
- UL 9540, Standard for Safety of Energy Storage Systems and Equipment, Edition 2, February 27, 2020 (UL 9540).
- UL 9540A, Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems, Edition 4, November 12, 2019 (UL 9540A).

1.3 Reference Materials

The following reference materials were reviewed as part of this analysis:

- Project 903 BESS Project Preliminary Site Plan (the site plan) dated February 21, 2024
- EVLOFLEX CAB1000 Installation Manual, dated February 2023.
- EVLOFLEX Installation Manual, CXL2-DOC-INST-001, Rev. 01, dated May 8, 2024.
- EVLOFLEX BESS Preliminary Commissioning Plan – dated July 27 2024.
- EVLOFLEX BESS Operation and Maintenance Manual, CXL2-DOC-MMA-001, Rev. 1, dated May 10, 2024 (EVLO BESS O&MM).
- EVLOFLEX Intervention Plan, CXL2-DOC-SST-001, Rev 00, dated February 27, 2024.
- EVLOFLEX Based Solution Technical Specification, CXL2-SPEC-ING-002, Rev. 09, dated November 11, 2023
- EVLOFLEX BESS Fire Safety and UL 9540A Interpretation (EVLO BESS FPE Report).
- EVLO 2 Explosion Prevention Design Analysis, Rev 1, dated April 2024 (Jensen Hughes, Inc.)
- EVLO 2 Risk Assessment, Rev 0, dated May 13, 2024 (Jensen Hughes, Inc.)

1.4 Acronyms and Abbreviations

Alternating Current	AC
Authority Having Jurisdiction	AHJ
Battery Energy Storage System	BESS
Battery Management System	BMS
Controller Area Network	CAN
Customer Interface Bay	CIB
Direct Current	DC
Emergency Response Guide	ERG

Emergency Response Plan	ERP
Energy Storage System	ESS
Fire Alarm Control Panel	FACP
Fire Protection Engineering	FPE
Fire & Risk Alliance, LLC	FRA
Fire Code Official	FCO
Hazard Mitigation Analysis	HMA
Immediately Dangerous to Life or Health	IDLH
International Electrotechnical Commission	IEC
Inspection, Testing, and Maintenance	ITM
Local Operations Center	LOC
Lithium Iron Phosphate	LFP
Lower Explosive Limit	LEL
Lower Flammability Limit	LFL
Minimum Approach Distance	MAD
National Fire Protection Association	NFPA
National Institute for Occupational Safety & Health	NIOSH
Non-walk in	NWI
Operations and Maintenance	O&M
Personal Protective Equipment	PPE
Supervisory Control and Data Acquisition	SCADA
State of Charge	SOC
Thermal Management System	TMS
Underwriters Laboratory, LLC	UL

1.5 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

1.6 Limitations

At the request of Solarbank, FRA performed an HMA in accordance with the requirements of the OFC for the Project 903 BESS located in the Township of Armour, Ontario, Canada. 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.

2.0 EVLO BESS DESCRIPTION

The EVLOFLEX BESS is a fully integrated BESS consisting of battery modules, power electronics, control systems, a battery management system, a thermal management system, and an explosion control system all assembled within a single, non-occupiable cabinet. The EVLO BESS has a standardized, modular design that is not customizable or adjustable. EVLO BESS arrives at the site in four components (main cube, HVAC unit, HVAC curb, and gas evacuation grille) some onsite assembly, including alternating current (AC) connection and communications cables to be connected on the site. Meaning, every installation has the same EVLOFLEX BESS cabinets that are pre-assembled at the factory and delivered to the site. It is approximately 6.1m (20 ft) in length, 2.44 m (8 ft) wide, 2.9 m (9.5 ft) in height, and can weigh up to 29,500 kg (65,000 lb). Below is a brief description of the EVLO BESS, its components, design listing, and fire safety features. For a more detailed discussion of the EVLO BESS components, their location, functionality, and purpose, refer to the EVLO BESS DIM. The EVLO BESS is fully UL 9540 compliant.

2.1 Cabinet Layout

The EVLO BESS is intended for outdoor installations, ground-mounted to a foundation or base strong enough to support the weight of the equipment and anchor loads (including concrete pads, grade beams, etc.). The HVAC components sit above the battery module bays, as shown in Figure 1.

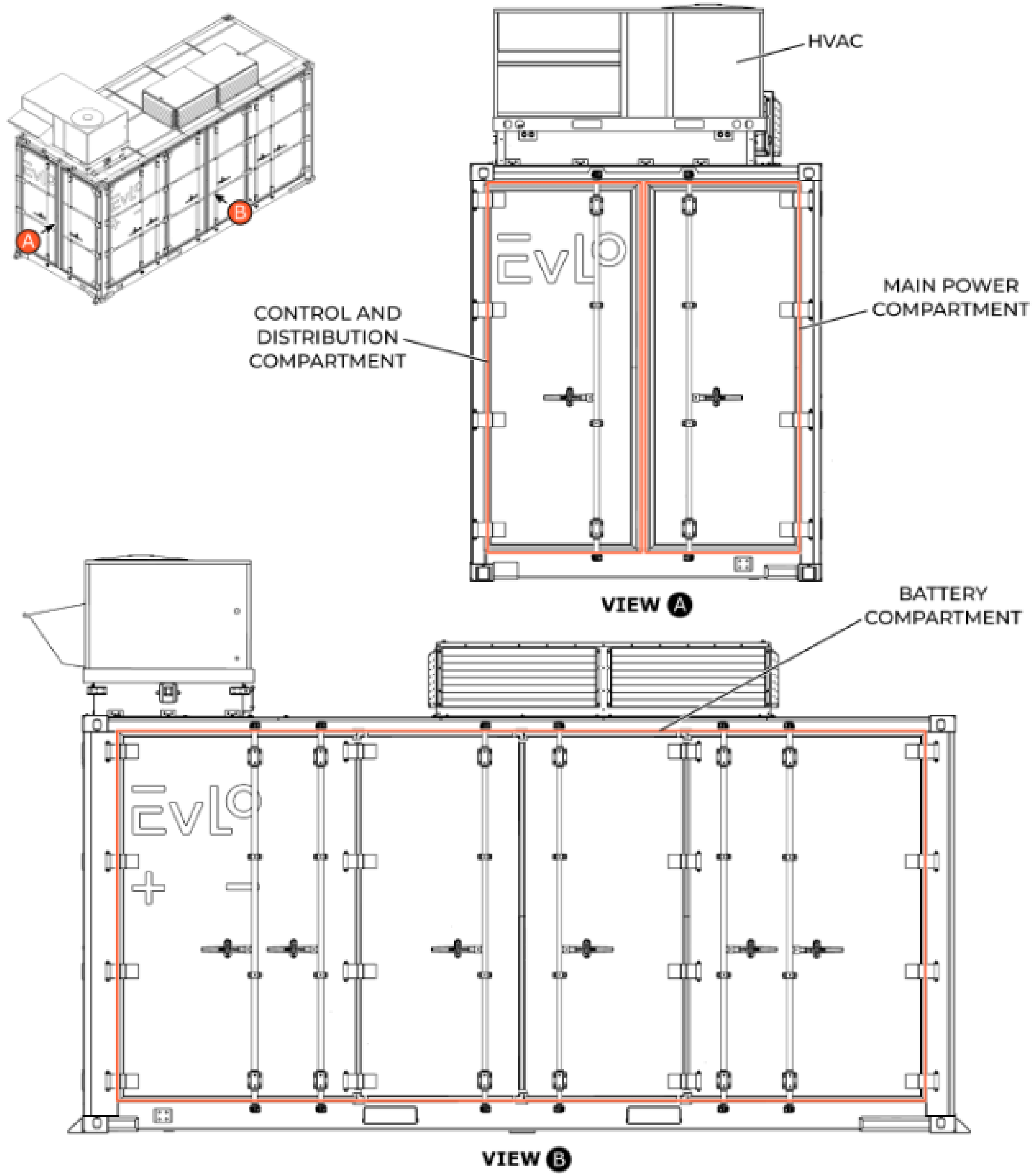


Figure 1. EVLOFLEX BESS internal components

The lithium-ion batteries are housed inside an NEMA 3R steel enclosure (battery module bay) that provides protection against particle and water ingress coming into contact with the battery modules and power electronics. The NEMA 3R enclosure is one continuous unit, with only a separation between the battery compartment and the control and distribution compartment. However, when the EVLO BESS cabinet is populated with battery modules, it cannot be entered. This modular, cabinet-style approach allows for the system to be easily maintained and serviced from outside the cabinets (i.e., the battery modules, thermal management system, and power electronics are serviced through doors located on the front of the cabinets), thus eliminating the need for personnel to enter an enclosure, structure, building or container to perform those activities. Since the BESS cabinets do not permit walk-in access, it is a non-walk-in style (NWI) BESS, they are not defined as occupied buildings or structures per the NFPA 855.

2.2 Cells and Battery Modules

The EVLO BESS can be populated with up to six battery strings with a maximum storage capacity of 2,506 kWh. Each battery string contains 51 battery modules connected in series, as shown in Figure 2, which are lithium iron phosphate (LFP) cells. The LFP cells (the cells) utilized in the EVLO BESS are 80-amp hour (Ah) with a nominal voltage of 3.65 volts (V) and are individually hermetically sealed and separated by alternating aluminum heat sinks and thermal insulation. They are pouches approximately 13 mm by 225 mm by 268 mm weighing 1430 g. Each battery module contains 32 cells and each unit (string) contains 51 modules.

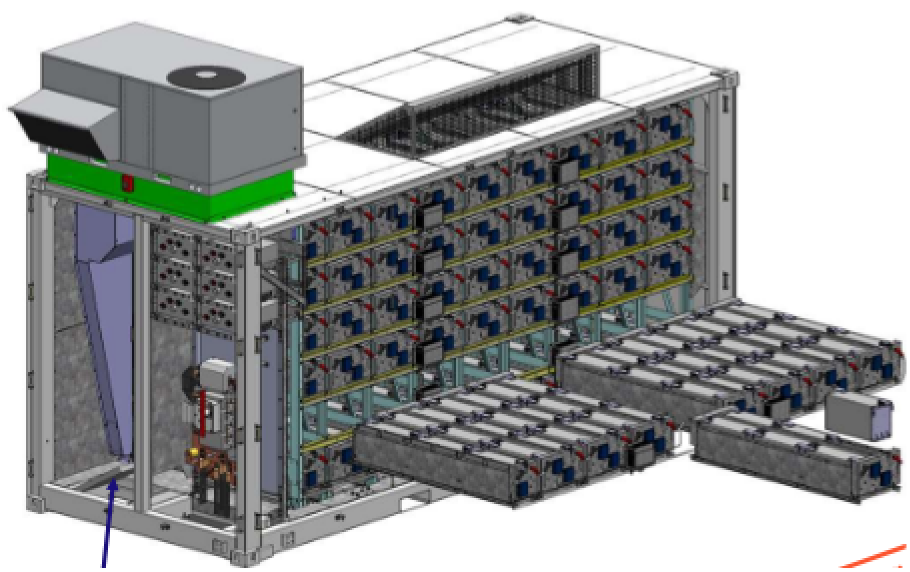


Figure 2. EVLOFLEX BESS unit and module

2.3 Communication and Control

The communication and control across the components of the BESS featuring EVLOFLEX is centered around the EMS control panel. This panel centralizes the inputs and outputs of multiple sources along with the communication between components. From this panel, fiber optic cables are routed to the Energy Management Panel (EMP) and from there, Ethernet cables are routed to each component of the BESS.

2.4 Thermal Management System

The thermal management system (TMS) provides a suitable operating temperature for EVLO BESS. The thermal bay and thermal roof house the components of the TMS. The TMS has three main options which are economizer closed (100% recirculated air), economizer open (25% fresh air, and 75% recirculated air) and a 100% fresh air supply mode to maintain an optimum battery operating temperature. The TMS works autonomously and does not require user feedback or controls to turn the system on when needed or to adjust temperature settings. The configuration uses a hot-aisle/cold-aisle arrangement to maintain efficiency. The primary operating equipment for the TMS are mounted on top of the BESS enclosure.

2.5 Battery Management System

The EVLO BESS has an integrated battery management system (BMS) that tracks the performance, voltage, current, and state of charge (SOC) of the cells (among many other datapoints). The BMS is included in each string of the BESS to allow for control and monitoring purposes. The BMS is engineered to react to fault conditions in an autonomous manner, with safeguards built into the firmware. These fault conditions include, but are not limited to, over-temperature, loss of communication, over-voltage, and isolation. For instance, to prevent a cell over-temperature the TMS is enabled by the BMS to cool the cells/module. This action by the BMS (which is just one example of many ways the BMS can respond to a fault condition) can either prevent thermal runaway from occurring in the cell or prohibit the propagation of thermal runaway to adjacent cells. Depending on the severity of the fault condition, the BMS can automatically isolate the affected battery module temporarily (less severe fault) or it can permanently disconnect the module.

2.6 Electrical Fault Protection Devices

The EVLO BESS has several passive and active safety control mechanisms installed within the battery module circuit and distribution circuit that would be available to interrupt a fault current. At a high level, these electrical fault protection features include:

- **Battery module overcurrent protection:** The battery modules contain direct current (DC) single-use fusible links mounted directly on the battery modules. These fuses are one-time only use safety devices that can interrupt the flow of an overcurrent in the battery module during an abnormal electrical event.
- **Inverter DC protection:** The inverter modules, which are installed at each of the battery modules, are equipped with their high-speed pyrotechnic fuse that can isolate the battery module passively or actively during an abnormal event.
- **Inverter AC protection:** In addition, each inverter module is equipped with its own AC contactor and AC fuses should an abnormal electrical event occur at the inverter module on the AC side of the circuit.

- **Ground fault protection**: Finally, the EVLO BESS is also provided with a DC ground fault detection system. It measures insulation resistance prior to operation and looks for excessive leakage current during operation. Additionally, the EVLO BESS also contains an AC circuit breaker, with ground-fault trip settings, which is installed within the CIB to provide distribution system protection.

2.7 Emergency Ventilation System

The EVLO BESS includes an emergency ventilation system to mitigate the risk of an uncontrolled deflagration. The system includes natural ventilation openings which open on gas detection and the TMS mechanical airflow to increase the efficiency of the battery offgas release. The system has been evaluated with computational fluid dynamics (CFD) to assure that the system maintains concentrations within the enclosure of less than 25% LEL of battery gas.

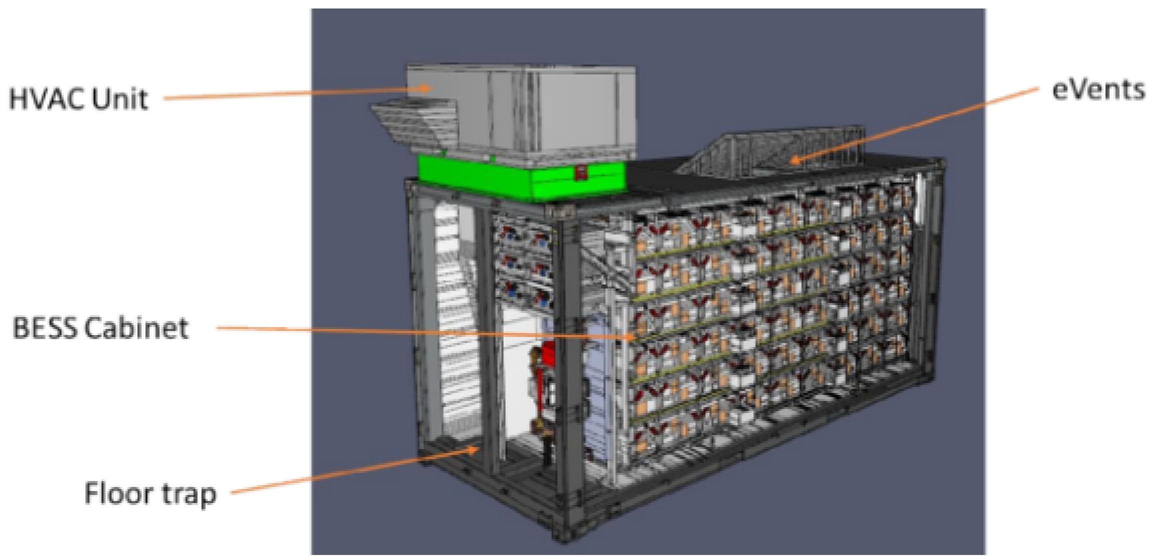


Figure 3. Location Emergency and TMS Equipment

2.8 Fire Detection and Suppression

The EVLOFLEX BESS has both gas and smoke detection. There is a hydrogen gas detector system (one XCL-H2, 0-1000ppm) and smoke detection system (two C4WTR-BA).

2.9 Clearances

The EVLO BESS is provided with a series of passive fire protection schemes (barriers) to reduce the likelihood of thermal runaway from spreading from cell-to-cell and reduce the likelihood of a fire from spreading unit-to-unit. These barriers consist of alternating cell-to-cell separations of aluminum heat sink and thermal shield insulation. The EVLO BESS can be installed side-to-side with a clearance distance of 3 m (10 ft) and end-to-end with a clearance distance of 1.22 m (4 ft).

These are minimum of clearance distances that must be provided to allow maintenance access to the containers, and any additional site-specific restrictions may require additional separation.

2.10 Emergency Response

EVLO has developed a BESS commissioning protocol, design and installation manual (DIM), an operations and maintenance manual (O&MM), and a lithium-ion battery intervention plan to provide guidance to anyone designing, installing, commissioning, operating, maintaining, servicing, decommissioning, or responding to an emergency involving an EVLO BESS. These manuals and guides can be utilized by site owners/operators to develop their own site-specific documents, such as commissioning plans, decommissioning plans, emergency operations plans (EOP), and/or emergency response plans (ERP). All appropriate documentation will be provided to the AHJ and emergency responders prior to system commissioning for approval per NFPA 855 §4.9.

2.11 EVLO BESS Product Listings

The EVLOFLEX BESS and its subcomponents are certified or listed to multiple national and international product design standards. These certifications and listings apply to the cells, battery modules, inverters, power electronics, control systems, integration between the BESS and the grid, as well as the BESS as a whole. The standards highlighted below pertain to the lithium-ion cells, the battery modules and the EVLO BESS at the unit level. For a full listing of all certifications and listings for all the EVLO BESS components, please refer to the EVLO BESS Compliance Packet.

Table 1. EVLO BESS Product Listings

Listing Standard		Description
Cell/ Module Level	UL 1642	This certification standard is applicable to secondary (rechargeable) lithium-ion cells and batteries used as a power source (such as BESS). The standard's requirements are intended to reduce the risk of fire or explosion when the battery is used in a product. For example, the standard subject's lithium-ion batteries to severe abuse conditions and evaluates if they can safely withstand them.
	UL 1973	This certification standard is applicable to batteries and battery systems utilized for energy storage. The standard evaluates the battery system's ability to safely withstand simulated abuse conditions. For example, the standard subjects module-level stationary batteries to an internal fire exposure test to force a thermal runaway in one cell to ensure it does not explode, propagate fire to neighboring cells, or propagate to the rest of the modular battery system. UL 1973 applies to stationary BESS applications, such as photovoltaic installations and wind turbine energy storage systems (ESS), as well as other specialized ESS, such as light electric rail (LER) operations.
	IEC 62619	This safety standard specifies requirements and tests to ensure the safe operation of secondary (rechargeable) lithium-ion cells and batteries used in ESS and in

Listing Standard		Description
		other industrial applications. Electrical safety is covered under Clause 8 of the standard, which requires the completion of a risk analysis to determine specific electrical safety issues associated with the intended use of a given battery system or device.
EVLO BESS Level	IEC 92933-5-2	This safety standard addresses various aspects of BESS, including the requirements for grid-integrated BESS.
	UL 9540	This standard covers ESS (including lithium-ion BESS) for stationary indoor and outdoor installations and establishes the system-level certification for ESS and their associated equipment
	UL 9540A	The test methodology evaluates the fire characteristics and thermal runaway fire propagation of a BESS (including lithium-ion BESS). The test method provides a means to evaluate thermal runaway and fire propagation at the cell level, module level, and unit level. The data generated from the test method can be used to determine the fire and explosion protection required for a BESS installation based on fire test data. This test is specifically referenced by the NFPA 855 to demonstrate the functionality of the BESS fire protection features during large-scale fire testing.

3.0 EVLO BESS UL 9540A TESTING

The UL 9540A test method 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 175 ºF (79.4 ºC) 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, and unit-level test results for the EVLO BESS are provided below.

3.1 UL 9540A Cell Level Summary

Cell-level testing was conducted by the CSA Group in January 2023. The CSA group lab is an OSHA-approved testing lab which routinely performs UL 9540A testing. Testing was performed on five model WX12I3280, 3.65 V, 80 Ah, LFP pouch cells manufactured by Wanxiang A123 Systems Co., Ltd. for use in the EVLO BESS. Each cell was charged to 100% state of charge

(SOC) prior to testing. Thermal runaway was initiated via film strip heaters installed on both of the wide side surfaces of each cell, as shown in Figure 4. Meaning two heaters were installed on each cell. The heaters were programmed to increase the temperature of the cell's surface by approximately 5.4°C per minute until the cell vented and went into thermal runaway. The cell was placed within a testing enclosure and the products released during testing were collected and analyzed.

Figure 4. Individual cell tested to UL 9540A (left) and installed film strip heater (right)

3.1.1 Key takeaways & Results

Key takeaways from the tests include:

- The average cell vent and thermal runaway temperature was determined to be 144°C (291°F) and 215°C (419°F), respectively, as listed Table 2.
- 24.3 liters of cell vent gases were released.
- The cell vent gas mixture is flammable and has an LFL of 5.75% at ambient temperature.
- The cell vent gases were predominantly Carbon Monoxide (CO), Carbon Dioxide (CO2), Hydrogen (H2), and Methane (CH4), as listed in Table 3.
- Toxic gases sometimes associated with lithium-ion batteries, such as Hydrogen Fluoride (HF), Hydrogen Chloride (HCL), and Hydrogen Cyanide (HCN) were not vented from the cell.

Table 2. UL 9540A cell level testing: key flammability characteristics

Flammability Property	Value
Average cell surface temperature at gas venting	174°C
Average cell surface temperature at thermal runaway	215°C
Cell vent gas volume released	24.3 L
LFL, % volume in air at the ambient temperature	5.75%
LFL, % volume in air at the venting temperature	5.05%
Burning Velocity (Su)	71.8 cm/s
Maximum pressure (Pmax)	739.1 kPa

Table 3. UL 9540A cell level testing: cell vent gas composition

Gas Name	Chemical Structure	% Measured
Carbon Monoxide	CO	4.69
Carbon Dioxide	CO2	15.27
Hydrogen	H2	54.47
Methane	CH4	5.42
Propene	C3H6	2.32
Methanol	CH3OH	1.19
Ethanol	C2H6O	0.027
Ethane	C2 (Total)	1.26
Propane	C3 (Total)	0.42
n-Butane	C4 (Total)	1.47
n-Pentane-	C5 (Total)	0.70
n-Hexane	C6 (Total)	0.38
n-Hexane	C6+ (Total)	1.78
Benzene	C6H6	0.018
Toluene	C7H8	0.0051
Total	-	100

3.1.2 Performance Criteria

UL 9540A, Section 7.7 outlines the performance criteria for the cell level test. If all these conditions are met, further testing (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.

2. The cell vent gas does not present a flammability hazard when mixed with any volume of air, at both ambient and vent temperatures.

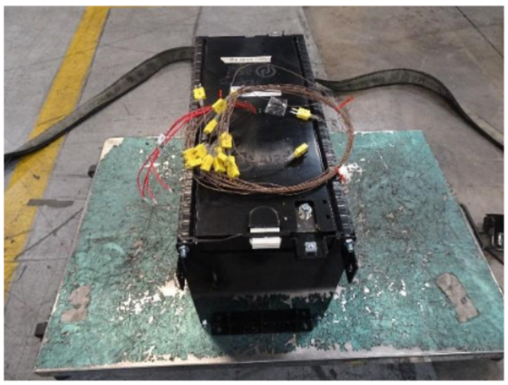
Given the cell went into thermal runaway and vented flammable gases, UL 9540A module level testing was required.

3.2 UL 9540A Module Level Summary

Module level testing was conducted at a TÜV SÜD Canada (TÜV) laboratory in February 2023. TÜV is an OSHA-approved NRTL and offers the TÜV mark, which is equivalent to other NRTL marks such as UL, ETL or CSA. Testing was performed on a 25.6 V, 320 Ah, EVLO BESS module (model WXL12S026320A / 4P8S Module), manufactured by A123 Systems, as shown in Figure 5. Each module consists of 32 model WX12I3280 LFP pouch cells that were charged to 100% SOC prior to testing. During the test, the EVLO BESS module is not connected to the BMS or TMS; meaning, 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 two cells, similar to the cell level test (see Figure 4). This resulted in between two and four cells undergoing thermal runaway over the duration of the test. The heaters were programmed to increase the temperature of the cell's surface by approximately 4.7 to 7.0 °C per minute 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.

Photograph 1. Mod 1, Initial

Photograph 2. Mod 1, Initial



Photograph 3. Mod 1, Initial

Photograph 4. Mod 1, Initial

Photograph 5. Mod 1, Initial

Photograph 6. Mod 1, Initial

Figure 5. Module (1) tested to UL 9540A module level testing

3.2.1 Key Takeaways and Results

The test heating of cells forced multiple cells to go into thermal runaway that propagated from the initiating cell to the adjacent cells across the module. One test produced a flaming event, while six other tests only resulted in thermal runaway without a fire or sparks. Products of combustion were collected in the hood and flammable gases were identified. Key takeaways from the UL 9540A module level test include:

- Thermal runaway propagated from the initiating cells to the adjacent cells in the EVLO BESS module with significant thermal runaway limited to approximately 4 cells (6 of 7 test modules).
- The one test module fire was rapidly extinguished by flooding the test chamber, though significant damage occurred to the test module in this case.
- Sparks and flying debris were not observed in the thermal runaway cases.
- Products of combustion were collected, but not provided in detail in the test report.

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) are not required. The acceptable performance criteria during the UL 9540A module level test are as follows:

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

Given the cell vent gases are flammable (as summarized previously) and thermal runaway was not contained by the module design, UL 9540A unit level testing was required.

3.3 UL 9540A Unit Level Summary

The unit level fire test was conducted at ESRG on July 12, 2023, and was witnessed by TÜV SÜD Canada. TÜV SÜD Canada is an OSHA-approved NRTL and offers the TÜV mark, which is equivalent to other NRTL marks such as UL, ETL or CSA. 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 unit test was performed on a fully populated string of an EVLO2 Subassembly (4P408S) of which 6 are installed in each EVLOFLEX enclosure. The unit is a component of the larger BESS lacking construction of cabinet itself, enclosure strength, and fire safety features, such as the ventilation and detection systems. TÜV witnessed and reported on one UL 9540A unit level fire test for the EVLO unit.

The EVLO test unit consisted of 54 battery modules, with a capacity of 417.8 kWh, tested at 100% SOC. During the test, the BMS and TMS are disabled; meaning, they are 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 test can be considered a worst-case scenario fire scenario, where: (1) the unit tested was the largest variation in terms of energy capacity; (2) the unit tested was at the highest energy density possible (100% SOC); and (3) 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 central to the unit, in the middle battery tray, as shown in Figure 6. This location was deemed to be the worst-case, given there are battery trays directly above it, below it, and on all adjacent sides. In addition, by initiating in the bottom battery module, there are two additional battery modules installed directly above the initiation location. Within the battery tray itself, cells were heated via four film heaters (as shown previously in Figure 4). The heaters were programed to provide a heating rate of 4 to 7°C per minute, as specified by UL 9540A. 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.

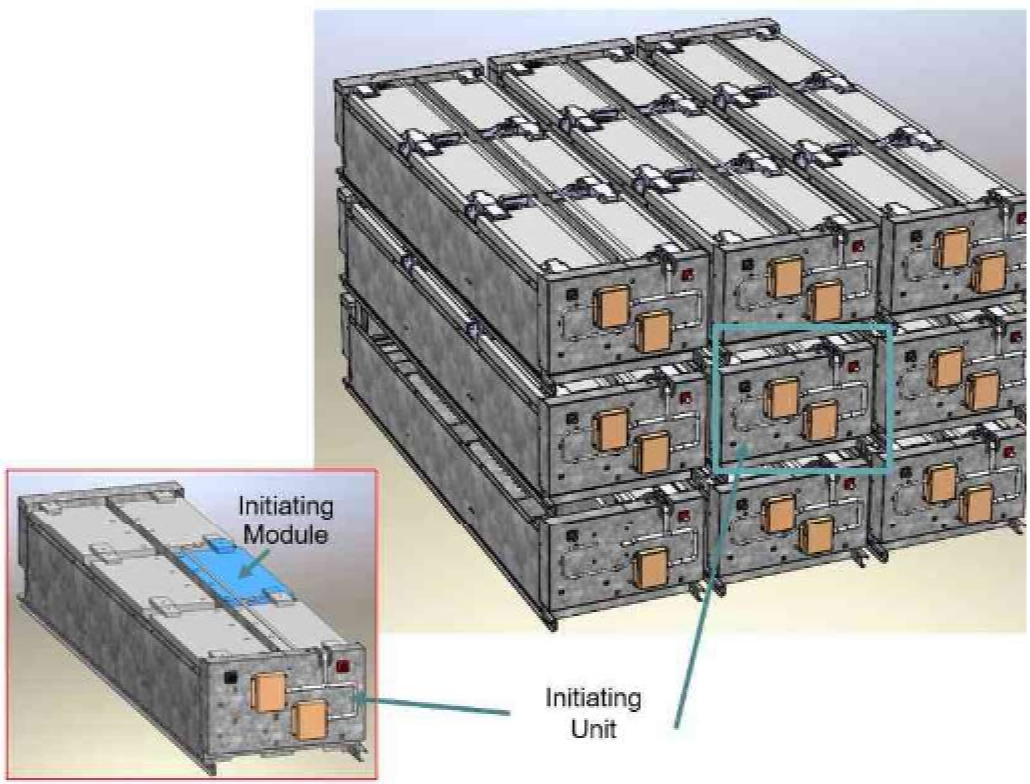


Figure 6. Unit Test initiation location: central module

3.3.2 Test Results

The cameras, instrumentation and the heaters within the initiating Unit were turned on at or around time 0:00:00 (hours: minutes: seconds). They heated the internal cells 36 minutes 21 seconds until the first initiation cell reached thermal runaway. Fourteen minutes later, the second group of initiating cells reached their thermal runaway temperature. Thermal runaway propagated sequentially through several cells/modules until the test was terminated at approximately 4 hours duration. Table 4 provides a summary of key events from the UL 9540A unit level fire test of the EVLOFLEX. No flaming, deflagration or flying debris were observed during the test.

Table 4. UL 9540A unit level testing: timeline of key events

Timeline of thermal runaway		
Time (hh:mm:ss)	**Event**	**Description**
0:00:00	Test Start	Primary Heaters ON
0:36:21	Thermal Runaway Event	Gas production visible outside of module. Cell venting observed
0:50:48	Thermal Runaway Event	Thermal runaway and gas release.
1:07:19	Thermal Runaway Event	Thermal runaway and gas release.
1:40:15	Thermal Runaway Event	Thermal runaway and gas release.
2:09:18	Thermal Runaway Event	Thermal runaway and gas release.
2:14:54	Thermal Runaway Event	Thermal runaway and gas release.
2:17:28	Thermal Runaway Event	Thermal runaway and gas release.
2:25:14	Thermal Runaway Event	Thermal runaway and gas release.
2:42:49	Thermal Runaway Event	Thermal runaway and gas release.
2:54:24	Thermal Runaway Event	Thermal runaway and gas release.
3:03:55	Thermal Runaway Event	Thermal runaway and gas release.
4:00:48	Test End	Gas collection stopped

3.3.3 Key Takeaways

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

- Over the duration of the test, eleven cells went into thermal runaway. This demonstrated that cell to cell propagation had occurred during the test, as is required by UL 9540A.
- No other signs beyond melting of plastic covers were observed in the initiating battery module. Thermal runaway did not propagate beyond the eleven cells.

- 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.
- Internal cell components were observed inside the initiating unit; however, no free-flowing liquid or runoff was observed.

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 induced thermal runaway within the unit did not lead to flaming combustion nor to a propagating thermal runaway event throughout the unit.

4.0 PROJECT 903 BESS SITE

The Project 903 BESS is being proposed for installation in the Township of Armour, Ontario, Canada. It is bounded by open land on all sides with access to the property by Peggs Mountain Road to the north of the site and will service an existing solar photovoltaic generation site, as shown in Figure 7. As such, the Project 903 BESS will be located in a rural area in surrounded by farmland, woodland, and a few single-family residences.

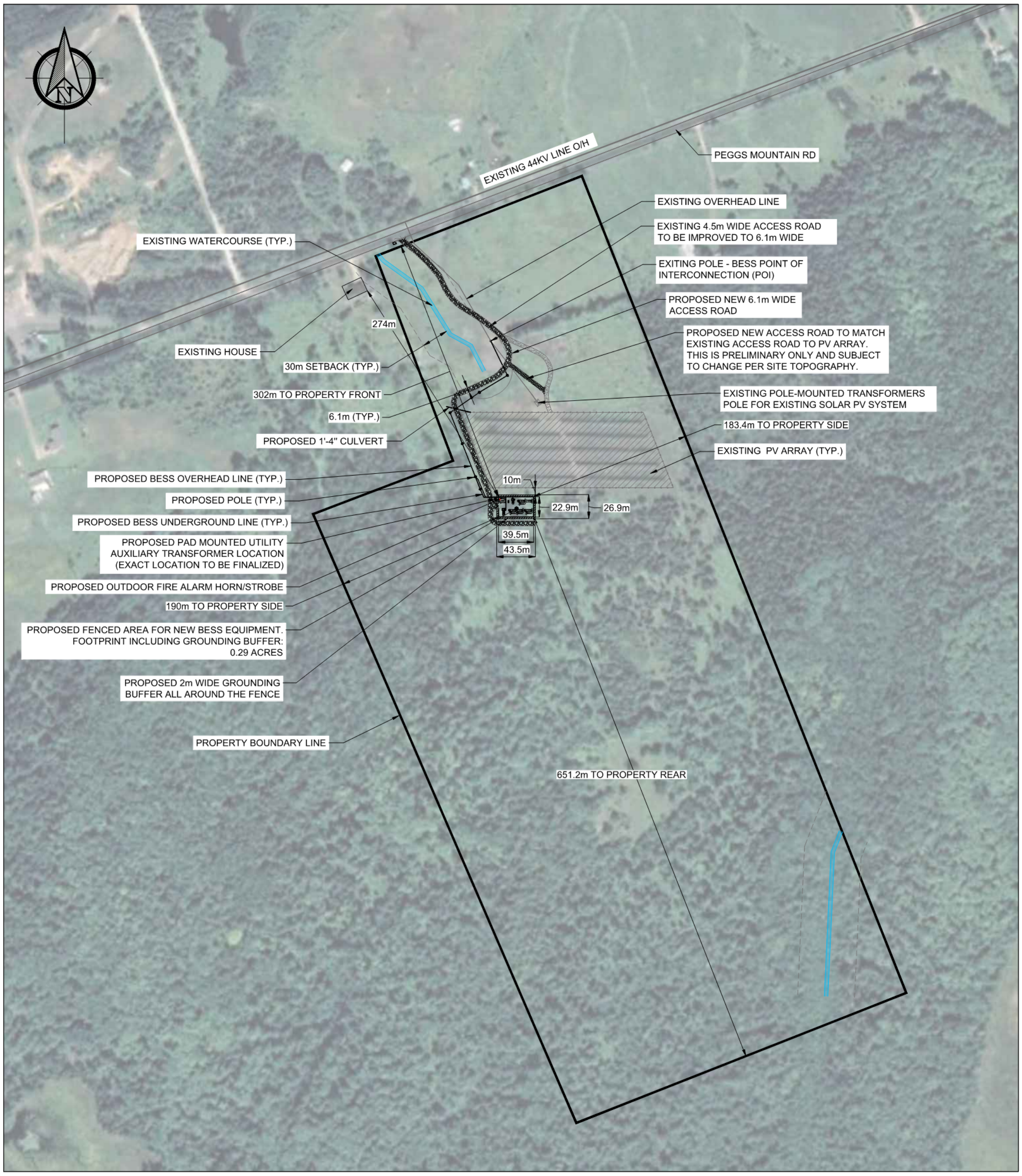


Figure 7. Aerial map

4.1 Site Level Fire Safety Features

Based on a review of the Project 903 BESS Preliminary Site Plan (the site plan) dated June 24, 2024, the Project 903 BESS includes 9 EVLOFLEX BESS enclosures with a capacity of 4.99 MWh, as shown in Figure 10. It will also contain power conversion, transformers, and an electrical control house to support grid connection. As shown in the site plan and the EVLO BESS product documentation, the Project 903 BESS will have a number of site-level fire safety systems and features as described in the following sections.

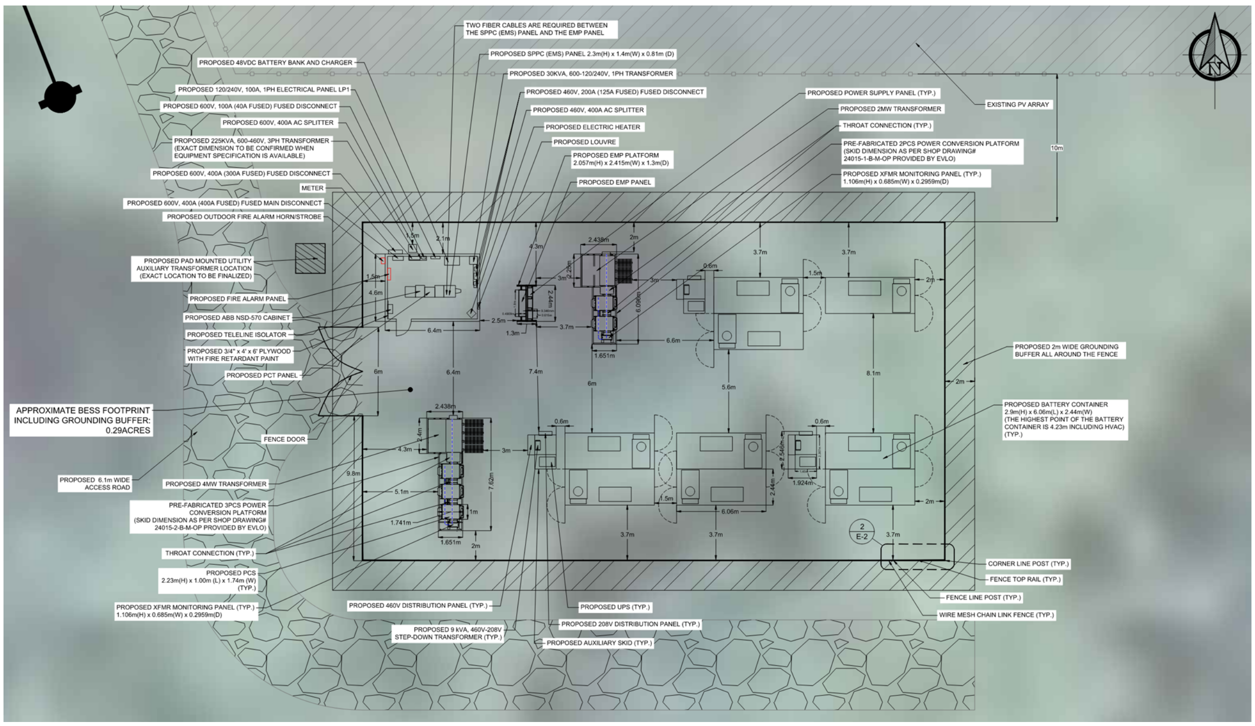


Figure 8. Site plan

4.1.1 BESS Monitoring and Emergency Notification

The Project 903 BESS will be remotely monitored. If an abnormal signal is received, they will contact the operation and maintenance (O&M) management organization and the responsible service personnel (O&M service personnel). If necessary, such as the abnormal condition leading to a thermal event, the O&M service personnel responding to the signal will then notify first responders.

4.1.2 Periodic Maintenance

The Project 903 BESS will be periodically inspected and serviced by trained O&M service personnel from the O&M management organization, as required by EVLO BESS O&MM.

4.1.3 BESS Security

A security fence will be installed around the perimeter of the Project 903 BESS to prohibit access to the EVLO BESS cabinets. The secured area around the Project 903 BESS will include a vehicular access gate on the west side and a visual screen on the north side.

4.1.4 Fire Department Access

Burks Falls District Fire Department is the closest fire department to the Project 903 BESS and is approximately 4 km away from the BESS installation. The closest access road to the Project 903 BESS is Peggs Mountain Road. The apparatus access roads have the following design features:

- Extends to within 5 feet of the Project 903 BESS.
- Have a minimum unobstructed width of 6 m with a minimum turning radius of 25 ft and an unobstructed vertical clearance.
- Constructed of asphalt to provide all-weather driving capabilities.
- Does not have any dead ends.

4.1.5 Emergency Water

The Project 903 BESS site will use a nearby dry hydrant for emergency water. The dry hydrant is across the road from Katrine Beach located at 1014 Ferguson Rd. This location gives good line of sight in either direction for firefighter safety, allows multiple routes guaranteeing access and has unlimited water.

4.1.6 Fire Alarm and Notification System

The Project 903 BESS site will be equipped with a detection system that is connected to a fire alarm control panel and monitored remotely. The fire alarm control panel will be installed in the Northwest Corner of the site as shown in Figure 8.

4.1.7 Emergency Stop

The Project 903 BESS site will be provided with an emergency stop.

4.2 Permanent BESS or Electrical Grid Exposures

The Project 903 BESS and its associated equipment mentioned below, are intended to operate year-round, 24 hours a day, 365 days a year. Installed within the Project 903 BESS are 9 EVLOFLEX BESS cabinets. The specific supporting electrical equipment installation locations are still in initial design phases and information in this section will be updated upon receipt of the full drawing set. Transformers, inverters and an enclosed E-house serves the BESS installations and is located within the fence of the proposed site. The equipment is connected directly to an existing 44 kV distribution line to the north of the site parallel to Peggs Mountain Road approximately 175 m away.

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 EVLO BESS cabinet.

5.0 BESS SITE DESIGN CODE ANALYSIS

The Township of Armour, Ontario, Canada adopts the OFC, which contains no language applicable to BESS sites. This analysis refers to the 2023 Edition of NFPA 855 as the industry best practice where necessary. The 2023 Edition of NFPA 855 was used in the development of this HMA. As part of this analysis, FRA evaluated the proposed site design for compliance with NFPA 855. 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 Project 903 BESS has an energy capacity of 4.99 MWh, NFPA 855 site design requirements apply. Below is a review of the Project 903 BESS for installation level compliance with NFPA 855 based upon a review of the site plan and the EVLOFLEX BESS. Note, this code analysis applies only to site design elements of the Project 903 BESS pertaining to fire and life safety. Other aspects of the site design, including the electrical or structural design/installation, 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, as well as all fire protection systems, will be designed, 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 Classification and Requirements

The Project 903 BESS includes 9 EVLOFLEX BESS installed outdoors. The EVLOFLEX 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 §9.3.2]. The two 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 a review of the site plan, there is greater than 100 ft separation distance between the BESS and the nearest exposures not associated with the electrical grid infrastructure. Based on the site plan, the Project 903 BESS is classified as a remote, outdoor BESS in accordance with NFPA 855. NFPA 855 Table 9.5.2 and 9.6.5 list the code requirements pertaining to a remote, outdoor lithium-ion BESS installation. These requirements are summarized below in Table 5 and discussed in detail within the following sections.

Table 5. NFPA 855 Remote Outdoor BESS Installation Requirements

Requirement	Compliance Required	NFPA 855 Code Reference
General	Yes	§4.1-4.7
Maximum size	Yes	§9.5.2.4
Clearance to exposures	Not Applicable	§9.5.2.6.1
Means of egress separation	Not Applicable	§9.5.2.6.1.7
Walk-in units	Yes	§9.5.2.3
Vegetation control	Yes	§9.5.2.2
Size and separation	No	§9.4.2
Maximum stored energy	No	§9.4.1
Smoke and fire detection	Yes	§9.6.1
Fire control and suppression	Yes	§9.6.2
Occupied work centers	Not Allowed	§9.5.1.2.1
Technology Specific Protection – Lithium-Ion Batteries		
Explosion control	Yes	§9.6.5.6
Thermal runaway	Yes	§9.6.5.5
Fire protection water supply	Yes	§9.6.3

5.2 All ESS Installations

NFPA 855 Table 9.5.2 and §4.1 requires compliance with the general requirements outlined in §4.1 through §4.7. Note, these sections have been written for all ESS installations: indoors, outdoors, stationary, or mobile. Only the fire and life safety general installation requirements applicable to 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, but are not limited to, electrical installations [NFPA 855 §4.7.1], seismic protection [NFPA 855 §4.7.2], design loads [NFPA 855 §4.7.3] and means of egress [NFPA 855 §4.7.8]. It is assumed that design compliance with these requirements will be discussed in separate design documents and provided to the AHJ as necessary. In addition, requirements related to plans, such as commissioning or emergency response, are not discussed, as those items are not related to the site design. See Section 5 for a discussion on plans and emergency response.

5.2.1 Combustible Storage

NFPA 855 §4.5 does not permit combustible materials to be stored in dedicated rooms, cabinets, or enclosures containing ESS. In addition, combustible materials cannot be stored within 3 ft of the ESS. The EVLOFLEX 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 container to store additional combustible materials. In addition, based on a review of the site plan, no combustible storage will be stored within 3 ft of the EVLOFLEX. As such, the Project 903 BESS site design complies with the NFPA 855 combustible storage requirement.

5.2.2 Equipment

NFPA 855 §4.6.1 requires ESS to be listed in accordance with UL 9540. The EVLOFLEX is listed to UL 9540. As such, the Project 903 BESS site design complies with the NFPA 855 equipment requirement.

5.2.3 Environment

NFPA 855 §4.6.7 requires the temperature, humidity, and other environmental conditions in which the ESS is located to be maintained in accordance with the listing and the manufacturer's specifications. The EVLOFLEX is provided with a TMS that maintains suitable environmental conditions for the ESS (see Section 2.4.3). As such, the Project 903 BESS site design complies with the NFPA 855 environment requirement.

5.2.4 Energy Storage Management System (ESMS)

NFPA 855 §4.6.10 and §9.6.5.5 requires ESS to be provided with an ESMS or a BMS and a TMS. The EVLOFLEX is provided with a BMS and TMS that monitors battery cell temperatures, voltages, currents, and dry contact switching in real-time (see Section 2.4.4). As such, the Project 903 BESS site design complies with the NFPA 855 §9.6.5.5 ESMS requirement.

5.2.5 ESS Toxic and Highly Toxic Gases Release During Normal Use

NFPA 855 §4.6.11 does not permit ESS to release toxic and highly toxic gas during normal charging, discharging and use. The EVLOFLEX utilizes listed lithium-ion cells that do not vent toxic or highly toxic gases (or any gases) during normal charging, discharging, or use. As such, the Project 903 BESS site design complies with the NFPA 855 toxic and highly toxic gas release requirement.

5.2.6 Enclosures

NFPA 855 §4.6.12 requires enclosures to be noncombustible and weatherproof. The EVLOFLEX is a noncombustible container with an IPX4/NEMA 3R rating. As such, the Project 903 BESS site design complies with the NFPA 855 enclosure requirements.

5.2.7 Signage

NFPA 855 §4.7.4 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 containers.
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, as shown in Figure 9:

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 or directory 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.

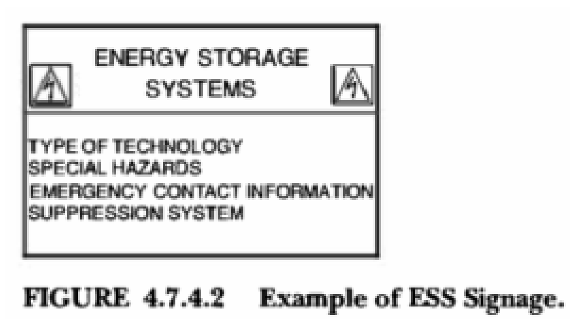


Figure 9. Example of ESS signage

Code compliant signage was not shown in the provided drawing set; however, FRA understands signage in accordance with NFPA 855 §4.7.4.3 will be provided for the Project 903 BESS installation.

5.2.8 Impact Protection

NFPA 855 §4.7.5 requires ESS to be located or protected to prevent physical damage from impact where such risks are identified. Based on a review of the site plan, impact protection is not being provided at the Project 903 BESS. However, impact protection is not necessary as the Project 903 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 (re. there are no public roads/ways on the site). As such, the Project 903 BESS site design complies with the NFPA 855 impact protection requirement.

5.2.9 Security of Installations

NFPA 855 §4.7.6 requires ESS to be secured against unauthorized entry and safeguarded in an approved manner and that security barriers, fences, landscaping, and other enclosures shall not inhibit the required airflow to or exhaust from the ESS and its components. Based on a review of the site plan, a security fence is provided around the perimeter of the Project 903 BESS (see Section

3.3). As such, the Project 903 BESS site design complies with the NFPA 855 security of installation requirement.

5.2.10 Access Roads

NFPA 855 §4.7.11 requires fire department access roads to be provided to outdoor ESS installations in accordance with the local fire code. Based on the site plan, 20 ft wide fire department access roads are provided, as required by the local jurisdiction (see Section 3.4). As such, the Project 903 BESS site design complies with the fire department access road requirements.

5.3 Remote Outdoor ESS Installations

5.3.1 Maximum Size

NFPA 855 §9.5.2.4 does not permit outdoor ESS walk-in units or ESS cabinets to exceed 53 ft × 8.5 ft × 9.5 ft, not including HVAC and other equipment. The EVLOFLEX is a NWI style container with dimensions of 9.5 ft tall, 8 ft wide, and 20 ft long, which is smaller than the maximum permitted size for outdoor walk-in units per NFPA 855. As such, the EVLOFLEX installation at the Project 903 BESS complies with the maximum size requirements.

5.3.2 Clearance to Exposures

NFPA 855 Table 9.5.2 states that the clearance to exposures requirements are not applicable to remote outdoor BESS installations. Although not required to meet the clearance to exposures requirements, based on a review of the site plan, lot lines, public ways, buildings, stored combustible materials, hazardous materials, high-piled stock, and other exposure hazards not associated with the electrical grid infrastructure are all greater than 10 ft away from the EVLOFLEXs. As such, the Project 903 BESS site design complies with the NFPA 855 clearance to exposure requirements.

5.3.3 Means of Egress Separation

NFPA 855 Table 9.5.2 states that the means of egress separation requirements are not applicable to remote outdoor BESS installations. Although not required to meet the clearance to exposures requirements, based on a review of the site plan, there are no buildings within 10 ft of the EVLOFLEXs. As such, the Project 903 BESS site design complies with the NFPA 855 means of egress separation requirements.

5.3.4 Walk-in Units

NFPA 855 §9.5.2.3 requires walk-in units to comply with NFPA 855 and the local building code. The EVLOFLEX is a NWI style BESS. Therefore, the walk-in unit requirements of NFPA 855 do not apply. As such, the Project 903 BESS site design complies with the NFPA 855 walk-in unit requirements.

5.3.5 Vegetation Control

NFPA 855 §9.5.2.2 requires areas within 10 ft on each side of outdoor ESS to be cleared of combustible vegetation and other combustible growth. FRA understands the entire area inside of the perimeter fence will be clear of vegetation, which provides greater than 10 ft clearance around each BESS. As such, the Project 903 BESS site design complies with NFPA 855 §9.5.2.2 vegetation control requirements.

5.3.6 Size and Separation

NFPA 855 Table 9.5.2 does not require remote outdoor BESS to be segregated into groups not exceeding 50 kWh nor does it require each group to be separated by minimum 3 ft from other groups. As such, the Project 903 BESS site design complies with the NFPA 855 size and separation requirement.

It should be noted, the Project 903 BESS will have larger capacities and smaller separation distances than what is specified in NFPA 855 §9.4.2. However, NFPA 855 also permits the size and separation utilized at the Project 903 BESS based on the UL 9540A large-scale fire testing results [NFPA 855 §9.4.2.3]. The EVLOFLEX large-scale fire testing performed in accordance with UL 9540A (see Section 6.3) demonstrated that a fire will not propagate from module-to-module within the EVLOFLEX or to adjacent EVLOFLEXs. As such, although not required for a remote outdoor BESS, the UL9540A testing also supports the current design configuration (size and separation) for the site.

5.3.7 Maximum Stored Energy

NFPA 855 Table 9.5.2 does not require remote outdoor BESS installations to meet the maximum allowable quantities threshold of 600 kWh. As such, the Project 903 BESS site design complies with the NFPA 855 maximum allowable quantities requirement.

It should be noted, the Project 903 BESS will have a capacity of 4.99 MWh, which is greater than the 600-kWh threshold specified in NFPA 855 Table 9.4.1. However, NFPA 855 also permits the maximum allowable quantity utilized at the Project 903 BESS based on the development of an HMA and performing UL 9540A large-scale fire testing [NFPA 855 §9.4.1.1]. The EVLOFLEX large-scale fire testing performed in accordance with UL 9540A (see Section 6.3) demonstrated that a fire will not propagate from module-to-module within the EVLOFLEX or to adjacent EVLOFLEXs. In addition, this HMA has been developed for the Project 903 BESS. As such, although not required for a remote outdoor BESS, this HMA and the UL9540A testing also supports the current design configuration (maximum allowable quantities) for the site.

5.3.8 Smoke and Fire Detection

NFPA 855 §9.6.1 requires areas containing ESS located within buildings or structures to be provided with a smoke detection or radiant energy-sensing system in accordance with §4.8. NFPA 855 §4.8.1 requires such systems to be installed in accordance with NFPA 72. Each EVLOFLEX is equipped with a multi-criteria photoelectric smoke detector that provides fire detection inside each EVLOFLEX (see Section 2.4.5), as required by NFPA 855.

NFPA 855 §4.8.2 requires annunciation to be located as required by the AHJ and that multiple FACPs must be aggregated to a master annunciator panel that is also installed in a location approved by the AHJ. Visual and audible notification is provided on the exterior of each EVLOFLEX via a horn/strobe, as required by NFPA 855. The fire alarm devices for each cube are connected to a Core FACP to be installed adjacent to the OCTE.. FACPs associated with cores 1-8 and 16-23 are aggregated to MFPP-1 and FACPs associated with cores 9-15 and 24-30 are aggregated to MFPP-2.

NFPA 855 §4.8.3 requires that smoke and fire detection systems protecting an ESS with lithium-ion batteries shall be required to provide a secondary power supply in accordance with NFPA 72 capable of 24 hours in standby and 2 hours in alarm. Battery back-up power is provided for EVLOFLEX detectors, Core FACPs, and the MFPP in accordance with NFPA 72.

Note, backup power to the fire alarm system will provide uninterrupted power during power outages and also during the initial moments of a fire event, even if auxiliary power to the EVLOFLEX has been severed. Maintaining power during this time is critical for the detection and notification (both locally and remotely) of the fire event to provide site personnel, should anyone be in the area, time to evacuate.

NFPA 855 §4.8.4 requires alarm signals from the detection systems to be transmitted to a supervising station in accordance with NFPA 72. FRA understands MFPP signals will be transmitted to a supervised central station and will automatically notify the local fire department upon alarm.

5.3.9 Fire Control and Suppression

NFPA 855 §9.6.2 requires an automatic fire suppression system to be installed in rooms and areas within buildings and walk-in units containing BESS. The EVLOFLEX 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 EVLOFLEX installation at the Project 903 BESS do not require fire suppression systems. As such, the Project 903 BESS site design complies with the NFPA 855 fire suppression system requirements.

5.4 Technology Specific Protection – Lithium-ion Batteries

NFPA 855 §9.6.5 requires electrochemical ESS to comply with the requirements as outlined in NFPA 855 Table 9.6.5. For lithium-ion BESS, this requires compliance with the explosion control requirements of §9.6.5.6 and the thermal runaway requirements of §9.6.5.5. Note, lithium-ion batteries do not need to meet the exhaust ventilation requirements of §9.6.5.1, the spill control requirements of §9.6.5.2, neutralization requirements of §9.6.5.3, or the safety cap requirements of §9.6.5.4.

5.4.1 Explosion Control

NFPA §9.6.5.6 requires ESS installed within a room, building, ESS cabinet, ESS walk-in unit, or otherwise nonoccupiable enclosures to be provided with one of the following:

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

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

The EVLO BESS includes an emergency ventilation system to mitigate the risk of an uncontrolled deflagration. The system includes natural ventilation openings which open on gas detection and the TMS mechanical airflow to increase the efficiency of the battery offgas release. The system has been evaluated with computational fluid dynamics (CFD) by Jensen Hughes, Inc. to assure that the system maintains concentrations within the enclosure of less than 25% LEL of battery gas. As such the Project 903 BESS site design complies with the explosion control requirements.

5.4.2 Thermal Runaway Protection

NFPA 855 §9.6.5.5 requires thermal runaway protection to be provided for lithium-ion technologies with a listed device or other approved method to prevent, detect, and minimize the impact of thermal runaway. 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 EVLOFLEX is equipped with a BMS that was tested and verified to UL 9540. As such, the Project 903 BESS site design complies with the thermal runaway requirements.

5.4.3 Water Supply

NFPA 855 §9.6.3 requires sites where nonmechanical ESS are installed to be provided with a permanent source of water for fire protection in accordance with §4.9.4. Where no permanent and reliable water supply exists for firefighting purposes, the requirements of NFPA 1142 apply; however, NFPA 855 §9.5.2.5 allows for relaxation of the water supply requirements when agreed by the AHJ and site owner. The Project 903 BESS site is remote installation without access to an adequate and reliable water supply and cold weather would prevent on site storage tanks. Therefore, the site will rely on fire department apparatus if water is needed, but the ERP recommends alternate methods of suppression that do not rely on water. As such, the Project 903 BESS site design complies with the NFPA 855 water supply requirements.

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 6.3) demonstrated that a fire will not spread from module-to-module within the EVLOFLEX or to adjacent EVLOFLEXs. This result was without a fire suppression system installed inside the EVLOFLEX and without manual fire suppression via hose lines. 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 (CO2, Halon), dry chemical suppressants, or foams, are unlikely to be effective.

5.5 Project 903 BESS Site Design Code Analysis Summary

Based on a review of the EVLOFLEX and the site plan, the Project 903 BESS site design meets NFPA 855 installation level requirements for a remote, outdoor, NWI style BESS when it is installed in accordance with the manufacturer's instructions, its listing, the approved drawings, and NFPA 855. Note, signage documentation in accordance with NFPA 855 §4.7.4.3 was not provided in the drawing set; however, it is understood that signage and a permanent plaque directory will be installed for the Project 903 BESS installation in compliance with NFPA 855.

6.0 PROJECT 903 BESS PLANS AND TRAINING

NFPA 855 requires a number of plans to be developed for a BESS facility. 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. NFPA 855 states that the operation, inspection, testing, and maintenance must follow the manufacturer's instructions.

A commissioning plan is to 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 will 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 is 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 installed/commissioned, inspected, tested, and maintained as required by the IFC and their respective NFPA standard [IFC Chapter 9].

Commissioning, operation/maintenance, and decommissioning plans must be developed for the Project 903 BESS facility. A commissioning guide, operations and maintenance, and a decommissioning guide have been prepared by EVLO. These documents can be used as a guide for the development of site-specific plans. Once developed, the Project 903 BESS will comply with NFPA 855 requirements for commissioning, operations and maintenance, and decommissioning. All appropriate documentation will be provided to the AHJ and emergency responders prior to system commissioning for approval per NFPA 855 §4.9.

6.2 Emergency Response Plan

NFPA 855 §4.3.2.1 requires an Emergency Operations Plan (EOP) to be readily available at the Project 903 BESS 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 procedure changes. 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, AHJ operations and response procedures [NFPA 855 §4.3.2.1.4].

An EOP has been developed by FRA for the Project 903 BESS facility that complies with NFPA 855 requirements for an emergency operations plan. All appropriate documentation will be provided to the AHJ and emergency responders prior to system commissioning for approval per NFPA 855 §4.9.

6.3 Emergency Response Training

NFPA 855 §4.3.1 requires the owner of the BESS or their authorized representative to engage in emergency planning and training of emergency responders such that any foreseeable hazards associated with the outdoor BESS units can be effectively addressed. Additionally, NFPA 855 §4.3.2.2 requires annual refresher training to be provided. FRA recommends that all site personnel and emergency response personnel, who could be responsible for responding to a Project 903 BESS emergency, be trained on the EOP prior to energizing the Project 903 BESS. Refresher training should be provided as appropriate, typically annually, as required by NFPA 855.

7.0 HAZARD MITIGATION ANALYSIS

This HMA is being prepared following the guidance by NFPA 855 §4.4. The HMA evaluates the fire safety features of the EVLOFLEX, the findings of the UL 9540A cell, module, and unit level tests as summarized in the EVLOFLEX FPE report, and the site level fire safety features of the Treasure Valley 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.

Per NFPA 855 §4.4.2 the consequences of the following failure modes must be evaluated:

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

Only single failure-modes must be evaluated. The consequences of each failure mode are evaluated in Sections 7.1 through 7.6 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 (battery gas release event in the absence of ignition source) event and convective heating is the primary mode of heat transfer to adjacent cells for a flaming event (battery gas release event in the presence of an ignition source).

Based on the cell level and module level testing, the EVLO BESS 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 container. 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 EVLO BESS:

- The cells and modules utilized in the EVLO BESS are certified to UL 1973, as described in Section 2.11. The standard evaluates the battery system's ability to safely withstand simulated abuse conditions. For example, the standard subjects module-level stationary batteries to an internal fire exposure test to force a thermal runaway in one cell to ensure it does not explode, propagate fire to neighboring cells, or propagate to the rest of the modular battery system.
- The EVLO BESS 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 2.5.
- The EVLO BESS 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 2.4. Additionally, the TMS cools adjacent batteries in a thermal runaway scenario to prevent thermal runaway propagation.
- The EVLO BESS modules are equipped with passive barriers to minimize the likelihood of thermal runaway propagation from cell to cell and module to module. In addition, the
- The EVLO BESS is equipped with a series of electrical fault protection devices, as described in Section 2.6.
- The EVLO BESS 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.
- The EVLO BESSs are remotely located greater than 150 ft from any public exposures in an rural area, as described in Section 4.3.

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 categories:

7.1.3.1 Deflagration & Explosion Hazard

The EVLO BESS has been tested to UL 9540A as required by the NFPA 855. The module level test results shown in Section 3.0 indicate flammable gases, predominately hydrogen and hydrocarbons, are released from the battery modules. The EVLO BESS is equipped with an emergency ventilation system that actively maintains the concentration of gasses below 25% LEL as demonstrated by CFD analysis performed by Jensen Hughes, Inc. The system utilizes a combination of mechanical and natural ventilation to achieve a safe environment inside the enclosure.

7.1.3.2 Toxic Gas Hazard

The EVLO BESS 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 EVLO BESS cabinet during a failure/fire event. The non-flammable gases collected during the module level testing are listed in Table 6 and provide guidance on the types of gases individuals and first responders may encounter when evacuating from or responding to an outdoor EVLO BESS fire. In addition to flammable gases discussed above, typical fire byproducts, such as CO2 were the only non-flammable gases detected during the full combustion of a EVLO BESS cells. The nonflammable gases detected are similar to gases first responders would encounter in a typical Class A structure 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. Note that toxic gases sometimes associated with lithium-ion batteries, such as HF, HCL, and HCN, were not detected during the combustion of the EVLO BESS during UL 9540A module level testing.

Table 6 also indicates the Immediately Dangerous to Life or Health (IDLH) values for each of the gases based on data published by National Institute for Occupational Safety & Health (NIOSH). The IDLH is an atmospheric concentration of any toxic, corrosive or asphyxiant substance that: poses an immediate threat to life; would cause irreversible or delayed adverse health effects; or would interfere with an individual's ability to escape from a dangerous atmosphere. The values measured from UL 9540A module level fire testing (where the products of combustion were collected within a hood) are well below the IDLH value for each gas.

Table 6. Products of combustion: nonflammable gases and IDLH values

Gas Name	Chemical Structure	Quantity Measured	IDLH Value
Carbon Monoxide	CO	205 ppm	1,200 ppm
Carbon Dioxide	CO_2	6,721 ppm	40,000 ppm

Given the Project 903 BESS is installed outdoors, where any gas release would be diluted by the entrainment of outside air, these gases, at the quantities measured during UL 9540A module level fire testing, 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 EVLO BESS). Nor would these gases, at the quantities measured during UL 9540A module level fire testing, be expected to have an adverse effect on emergency response personnel, who are wearing appropriate personal protective equipment (PPE) while responding to an EVLO BESS fire.

7.2 Failure of any Emergency Management System

7.2.1 Description

The EVLO BESS is equipped with a BMS. The BMS tracks the performance, voltage, current, and state of charge (SOC) of the cells to ensure they are operating within manufacturer specifications. The BMS disconnects electrical connections to the ESS if potentially hazardous conditions occur. Additionally, the BMS sends an alarm to the monitoring station and can initiate other controls based on the hazard detected as described in Section 2.5. 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, as described in Section 2.11.
- The BMS is monitored, as described in Section 2.3.
- Electrical fault protection is provided as described in Section 2.6.
- 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 is monitored such that a failure will be quickly detected and remediated reducing the duration a EVLO BESS is operating with deficient safety features. 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 Section 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 EVLO BESS utilizes ventilation for both normal operations and emergency ventilation to prevent explosible gas accumulation inside the enclosure. This failure scenario evaluates the consequences associated with a failure of the ventilation thermal management system (TMS).

7.3.2 Barriers

The EVLO BESS 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 2.3.
- 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 temperatures in Ontario, Canada is typically 93 ºF (33ºC) and occurs in July or early August. The peak temperature is less than the cell venting temperature; 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 EVLO BESS is operating with deficient safety features. Additionally, the LOC has remote capabilities to discharge batteries from affected EVLO BESS cabinets 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 Section 7.1.2 and 7.1.3 of this report.

7.4 Voltage Surges on the Primary Electric Supply

7.4.1 Description

A voltage surge on the primary electric supply to the BESS may expose batteries to excessive voltage. This failure scenario evaluates the consequences due to a voltage surge on the primary electric supply.

7.4.2 Barriers

The following barriers are provided to minimize the consequences of a voltage surge on the primary electric supply:

- Electrical fault protection is provided as described in Section 2.6.
- Battery health is monitored by the BMS and automatically shuts down power upon over voltage conditions.
- The electrical components of the EVLO BESS are monitored, as described in Section 2.3.

7.4.3 Consequences

In the event of a voltage surge, the electrical fault protection will automatically stop electricity flow in the affected electrical circuit. The BMS provides redundancy and will also cut power to the affected cells and send a signal to the monitors such that a failure will be quickly detected and remediated, reducing the duration a EVLO BESS is operating with a damaged electrical component/equipment. In a worst-case scenario, a voltage surge may lead to a thermal runaway event, the barriers and consequences of thermal runaway are provided in Section 7.1.2 and 7.1.3 of this report.

7.5 Short circuits on the Load Side of the BESS

7.5.1 Description

A short circuit on the load side of the BESS may result in an increased current traveling through the battery circuit. Electrical currents outside of the recommended operating range may damage batteries and lead to a thermal runaway event.

7.5.2 Barriers

The following barriers are provided to minimize the consequences of a short circuit event:

- Electrical fault protection is provided as described in Section 2.6.
- Battery health is monitored by the BMS and automatically shuts down power upon over voltage conditions.
- The electrical components of the EVLO BESS are monitored, as described in Section 2.3.

7.5.3 Consequences

In a short circuit condition, the electrical fault protection will automatically stop current in the affected electrical circuit. The BMS provides redundancy and will also cut power to the affected cells and send a signal to the monitors such that a failure will be quickly detected and remediated, reducing the duration a EVLO BESS is operating with a damaged electrical component/equipment. In a worst-case scenario, short circuits may lead to a thermal runaway event, the barriers and consequences of thermal runaway are provided in Section 7.1.2 and 7.1.3 of this report.

7.6 Failure of a Fire Protection System

7.6.1 Description

A failure of a fire protection system can include a smoke detection, fire detection, fire suppression, gas detection system or explosion control system failure. The EVLO BESS has internal smoke detection, and gas (H2) detection system that is integral to its design/construction. It has an emergency ventilation system system which is credited with limiting deflagrations and explosions. Therefore, this failure scenario evaluates the consequences associated with failure of the fire protection systems.

7.6.2 Barriers

The fire protection systems are provided with the following features to prevent failure and minimize consequences associated with failure:

- Multiple forms of detection are installed (smoke and gas) with multiple detectors inside the enclosure.
- The detection systems are continuously monitored by the FACP and offsite monitoring.
- The system is provided with redundant power supply.
- The emergency ventilation system uses passive ventilation in addition to mechanical ventilation in order to release combustible gas and does not fully rely on power operation of any component.
- Regular IT&M performed on all systems.

7.6.3 Consequences

Independent failure of a fire protection system will have no effect on the battery container and will not induce a thermal runaway event. The fire protection systems are continuously monitored by the FACP and offsite monitoring which will produce a trouble alarm upon any degraded operation.

In the unlikely event of fire protection system in conjunction with a thermal runaway event, delayed detection may occur resulting in increased damage to onsite equipment. Since Project 903 BESS is in a remote rural area, no significant hazard exists for life safety.

7.7 HMA Analysis Approval

Based on the analysis above, the Project 903 BESS meets all of the HMA approval criteria for FCO or AHJ approval per NFPA 855 §4.4.3, as it has demonstrated that:

1. Fires will be contained within unoccupied ESS rooms for the minimum duration of the fire resistance rating specified.

   The Project 903 BESS meets this requirement. The EVLO BESS is installed outdoors, not within an unoccupied BESS room or area. However, it should be noted, the EVLO BESS design includes a series of passive fire protection schemes (internal barriers) to protect it from spreading a fire from one EVLO BESS cabinet to another. As demonstrated in UL 9540A unit-level fire testing, an initial thermal runaway event spread to 11 cells, but did not result in thermal runaway propagating throughout the battery module or to adjacent EVLO BESS cabinets. In addition, large-scale fire testing demonstrated a fire will not propagate from one EVLO BESS to adjacent EVLO BESS cabinets under the tested conditions. Although this requirement applies to BESS rooms or areas (and not an outdoor installation), the Project 903 BESS still meets the intent of the requirement by containing a fire event to a single EVLO BESS cabinet.

2. Fires and products of combustion will not prevent occupants from evacuating to a safe location.

   The Project 903 BESS meets this requirement. The EVLO BESS cabinet is installed outdoors, not within an occupied work center (or any other room). First responders have adequate safeguards and clearance distances to limit their exposure as well.

3. 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 occupants from that area.

   The Project 903 BESS meets this requirement. The EVLO BESS is installed outdoors, not within a building or adjacent to any means of egress. The nearest building/structure are adjacent existing houses which are located greater than 300 ft from a EVLO BESS cabinet. This distance is greater than the 10-foot clearance distance required by the NFPA 855 from the BESS to adjacent buildings and/or means of egress. However, it should be noted, toxic gas concentrations measured during UL 9540A module-level fire testing (where the products of combustion were collected within a hood) are well below the IDLH value for each gas. Given the Project 903 BESS is installed outdoors, where any gas release would be diluted by the entrainment of outside air, these gases, at the quantities measured during UL 9540A module level fire testing, 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 EVLO BESS). Nor would these gases, at the quantities measured during UL 9540A module level fire testing, be expected to have an adverse effect on emergency response personnel, who are wearing appropriate personal protective equipment (PPE) while responding to an EVLO BESS fire. Although this requirement applies to a building or to an installation that is immediately adjacent to a means of egress route, the Project 903 BESS still meets the intent of the requirement (i.e., do not produce toxic or highly toxic gases above the IDLH during an EVLO BESS fire event during the time deemed necessary to evacuate from the area).

4. Flammable gases released from ESS during charging, discharging, and normal operation shall not exceed 25 percent of their LFL.

   The Project 903 BESS meets this requirement. The EVLO BESS 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 Project 903 BESS during charging, discharging, and normal operation.

5. Flammable gases released from ESS during fire, overcharging, and other abnormal conditions shall not create an explosion hazard that will injure occupants or emergency responders.

   The Project 903 BESS meets this requirement. The EVLO BESS has an emergency ventilation system installed inside the cabinet that has been demonstrated to maintain levels below 25% LEL through CFD analysis performed by Jensen Hughes, Inc. The system uses the existing mechanical ventilation and natural ventilation openings.

8.0 RECOMMENDATIONS

Throughout the report, FRA provided several recommendations related to the Project 903 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. **Emergency Response Training:** FRA recommends that all site personnel and emergency response personnel, who could be responsible for responding to a Project 903 BESS emergency, be trained on the ERP prior to energizing the Project 903 BESS. Refresher training should be provided as appropriate, typically annually.
2. **Site code compliance:** the following items must be confirmed upon receipt of initial drawing package to demonstrate code compliance.
    a. Signage must be provided at the site per NFPA 855.
    b. Disconnecting means or placards must be provided at the site per NFPA 855

9.0 CONCULSIONS

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:

1. The EVLO BESS and the Project 903 BESS site design can meet the NFPA 855 requirements for an outdoor BESS installation when it is installed in accordance with the EVLO BESS DIM, its listing, and the NFPA 855. Once the design of the site is finalized, full compliance with the NFPA 855 can be determined.
2. The HMA demonstrates the Project 903 BESS meets all the HMA performance criteria for approval outlined in NFPA 855 §4.4.3, as follows:
    a. Fires will be contained to a single EVLO BESS as demonstrated through UL 9540A unit level testing and destructive installation level fire testing and fire modeling.
    b. Fires will be detected in time to allow personnel to safely evacuate via the internal sensors of the EVLO BESS and external flame detection/notification system.
    c. Toxic and highly toxic gases released during fires will not reach concentrations in excess of IDLH levels in the area during the time deemed necessary to evacuate from the Project 903 BESS area, as demonstrated by UL 9540A module level fire testing.
    d. Flammable gases released from a EVLO BESS during charging, discharging and normal operation do not exceed 25% of their LFL given the listed lithium-ion cells utilized in the EVLO BESS are hermetically sealed and do not vent during charging, discharging or normal operation.
    e. Flammable gases released from the EVLO BESS during a fire, overcharging and other abnormal conditions will be controlled through the use of emergency ventilation of the gases preventing accumulation as demonstrated by CFD analysis performed by Jensen Hughes, Inc.
3. Based on this analysis, the Project 903 BESS can be approved by the FCO or AHJ following completion of the site design in order to demonstrate full compliance with the NFPA 855.