WECC

Battery Energy Storage Systems (BESS) Observations

ML300 BESS Fire

James Hanson
Manager, Operations Analysis

Electric Reliability
& Security for the West

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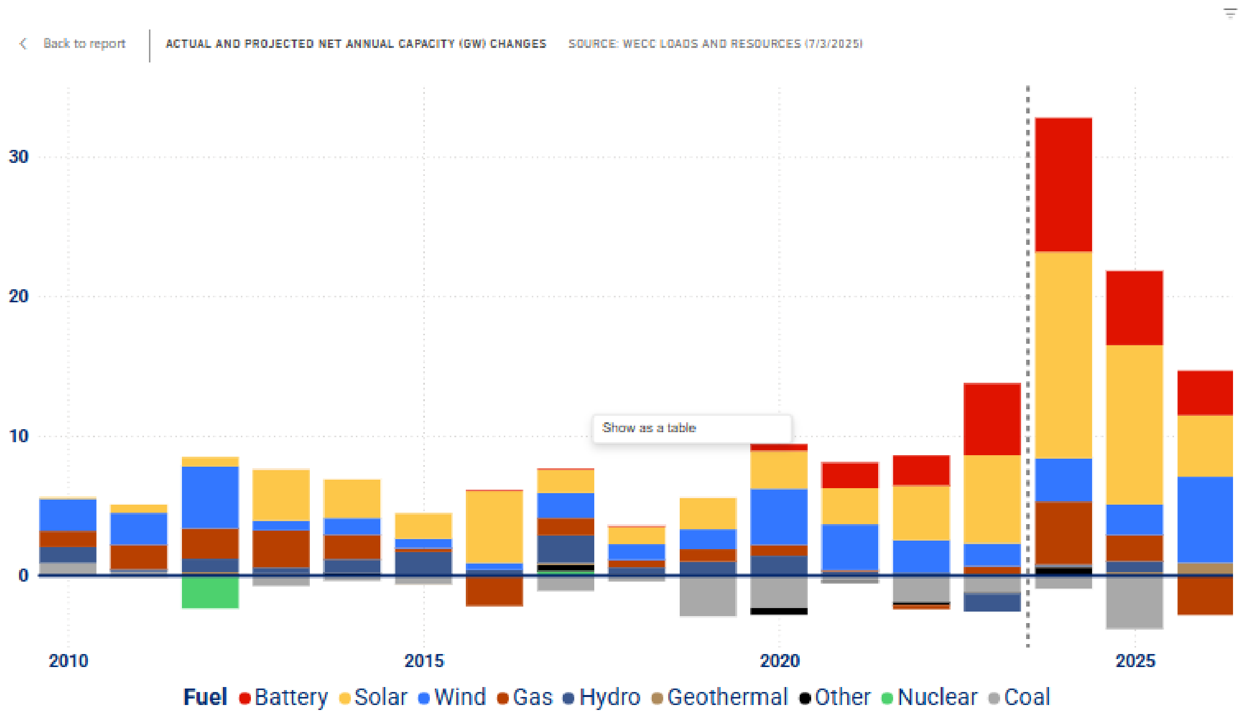
Battery Energy Storage Systems (BESS) Trends and Observations

- Rapidly growing resource in the Western Interconnection
- Provides needed energy after evening solar ramp but demand is still high
- Provides fast frequency response and other ancillary services

Annual Capacity Changes



BESS types and components

BESS facility types

Moss 300 - Phase 1

- 300-MW facility
- Located within refurbished 1950s turbine building
- Operational Dec. 2020

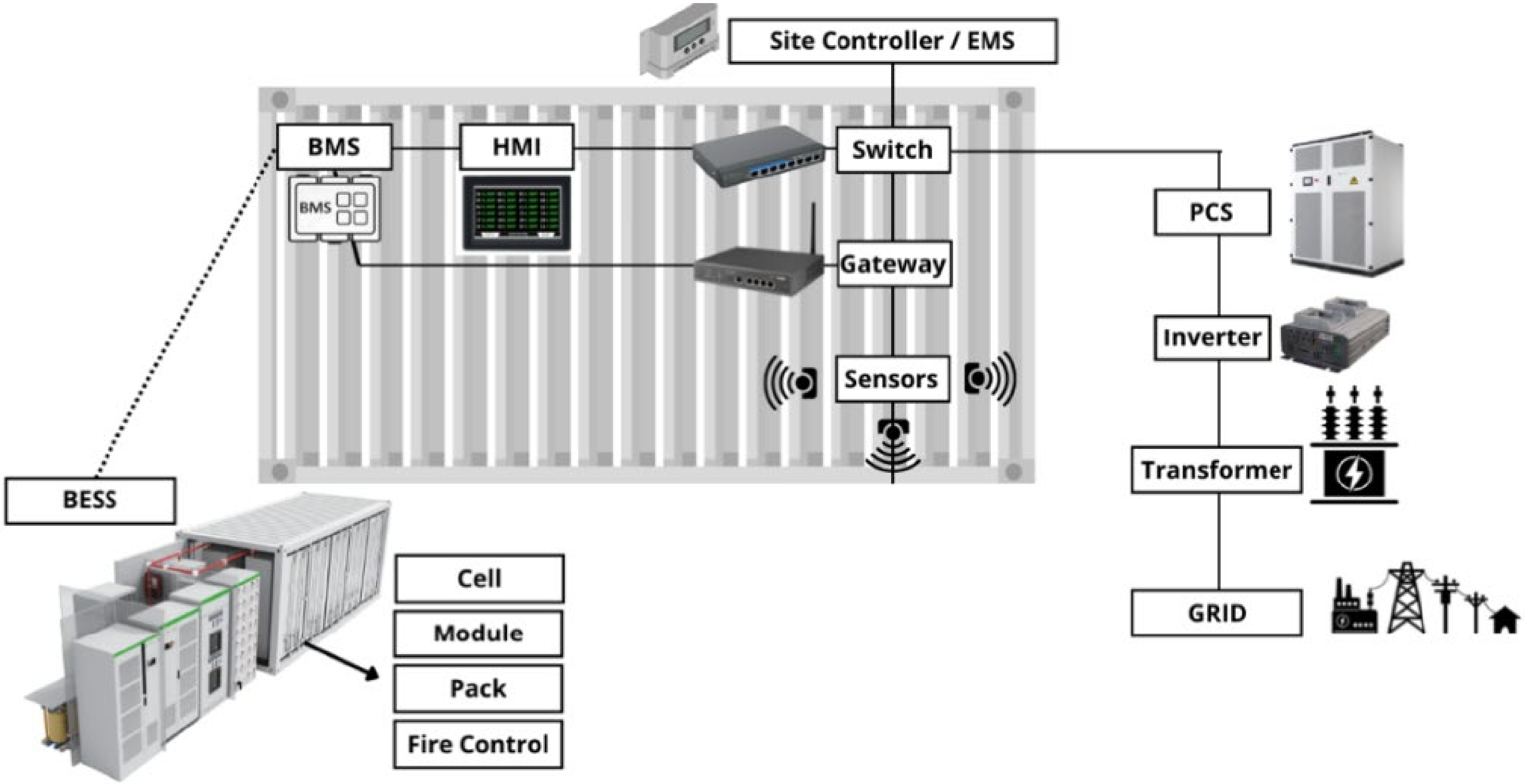
Moss 100 - Phase 2 Expansion

- 100-MW facility
- Located within newly constructed warehouse
- Operational July 2021

Moss 350 - Phase 3 Expansion

- 350-MW facility
- Configured in multiple containers
- Operational June 2023

Containerized BESS system architecture



Battery Chemistry

Lithium Nickel Manganese Cobalt Oxide ($LiNiMnCoO_2$)—NMC

- Pros
  - **High Energy Density**: NMC batteries can store a lot of energy in a compact size, making them ideal for EVs where space and weight matter.
  - **Fast Charging Capability**: NMC cells typically support faster charging than some alternatives like LFP (lithium iron phosphate).
- Cons
  - **Thermal Instability**: Compared to LFP batteries, NMCs are more prone to overheating and thermal runaway if damaged or improperly managed.
  - **Sensitive to Charging Habits**: Regularly charging to 100% or discharging to 0% can accelerate degradation.
  - **Shorter Lifespan**: Typically offer fewer charge cycles than LFP batteries—around 1,000–2,000 full cycles before noticeable degradation.

Lithium Iron Phosphate (LiFePO4) – LFP

- Pros
  - **Long Cycle Life**: Typically lasts **2,500–9,000+ charge cycles**, depending on usage
  - **High Safety**: Very stable chemistry—resistant to overheating and thermal runaway
  - **Wide Temperature Range**: Performs well in **hot climates** and is less prone to degradation
- Cons
  - **Lower Energy Density**: Offers **less energy per kilogram** than NMC or NCA batteries—meaning **larger or heavier packs** for the same capacity
  - **Cold Weather Performance**: Can struggle in **low temperatures**, with reduced charging and discharging efficiency

Thermal Runaway Mitigation (TRM)

Thermal Runaway

- *Thermal runaway* is a term used for the rapid uncontrolled release of heat energy from a battery cell.
- It is a condition when a battery creates more heat than it can effectively dissipate.
- Thermal runaway in a single cell can result in a chain reaction that heats up neighboring cells. As this process continues, it can result in a battery fire or explosion.
- This can often be the ignition source for larger battery fires.

Failure Modes

Mechanical Abuse	Thermal Abuse	Electrical Abuse	Environmental Impacts
Can happen when a battery is physically compromised by either being dropped, crushed, or penetrated.	Can occur when a battery is exposed to external heat sources.	Can happen when the battery is overcharged, charged too rapidly or at high voltage, or discharged too rapidly.	Can lead to battery failure include seismic activity, rodent damage to wiring, extreme heat, and floods.

Mitigation Actions

Battery Management System

Monitors battery modules and can disconnect in the event of abnormal conditions

Fire Suppression System

Water has been shown to be the most effective medium for cooling an ESS

Spacing

Units should be grouped into small segments of limited capacity and spaced apart to prevent horizontal propagation.

Explosion Protection/Prevention

Explosion prevention systems or deflagration venting

Cooling systems

Air Cooling

Air cooling is the most common method used in BESS, primarily because of its simplicity and cost-effectiveness. This method involves using fans or blowers to circulate air around the batteries, dissipating the heat generated during operation.

Advantages:

Cost-Effective	Simplicity	Low Maintenance

Disadvantages:

Limited Cooling Capacity	Noisy	Space requirements for circulation

Liquid Cooling

Liquid cooling uses a coolant fluid to absorb and dissipate heat from the batteries.

Advantages:

Superior cooling efficiency	Compact design	Quieter Operation

Disadvantages

Higher Costs	Potential for Leaks	Complexity

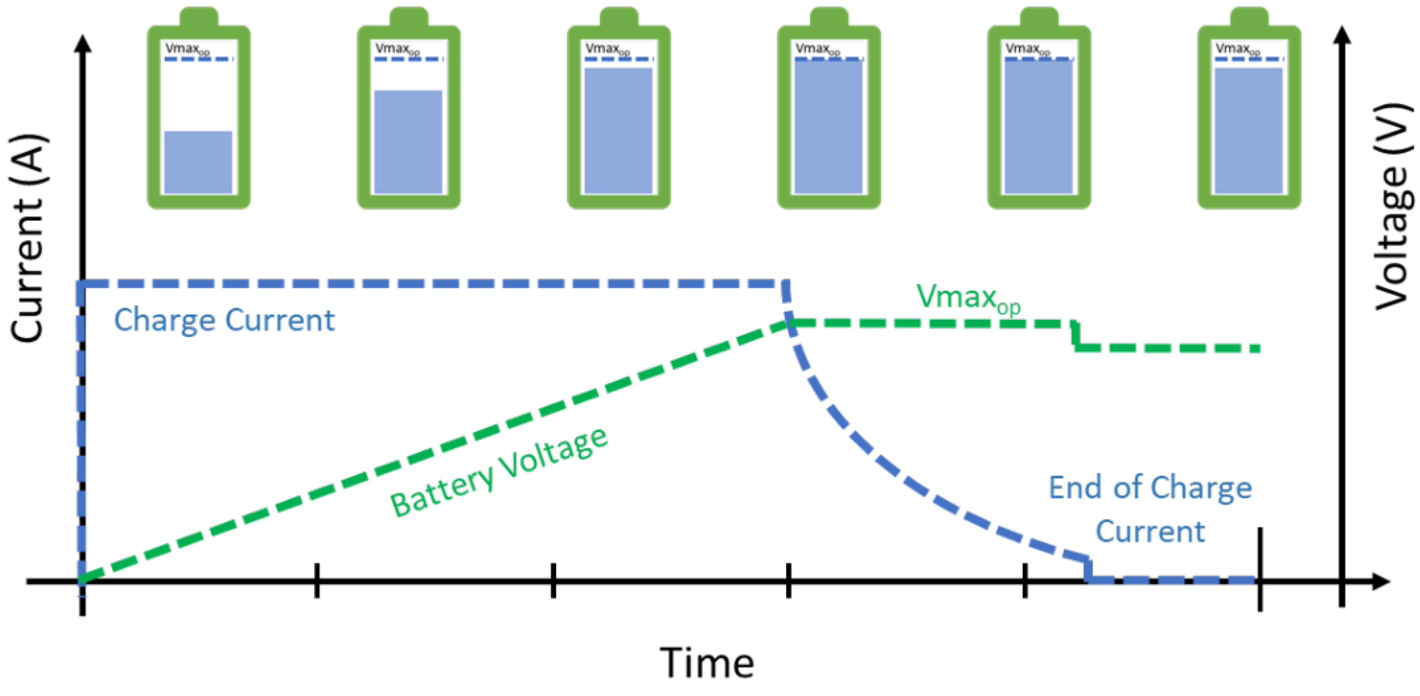
Operations and Testing

Operations

- Operators perform real-time monitoring of project performance and all monitored equipment including inverters, combiners, re-combiners, weather stations, trackers, interconnection, and meters including:
  - Respond to alarm and alert conditions and dispatch service personnel
  - Curtailment monitoring, tracking and execution
  - Generation and outage management
  - Manage and operate the communications and metering hardware and software applications for telemetry, voice and data communications

Capacity Test

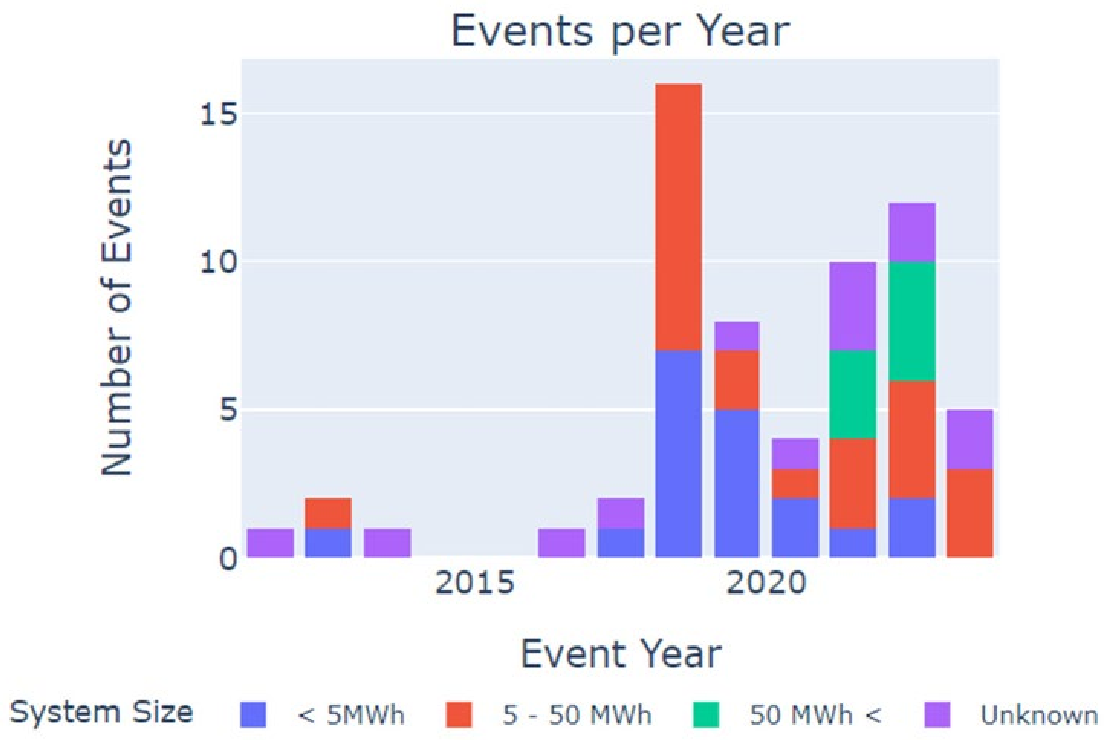
- A battery's capacity is related to the energy that it can supply in a given application
- Capacity testing is performed to understand how much charge/energy a battery can store and how efficient it is



Fire Codes

ESS Incidents as a Driver for Codes and Standards Development

- The codes and standards landscape started to change after a series of 23 fires, mostly occurring in the period of June 2018 to January 2019, at South Korean energy storage facilities
- One prominent event involving a Li ion battery was an explosion at the McMicken BESS in Surprise, Arizona, in which four firefighters were injured. There was ongoing propagation of thermal runaway in the absence of flame, allowing flammable gases to build up in the container above the upper flammable limit (UFL)



Fire Codes and NFPA 855

- The two model fire codes are the International Fire Code (IFC), published by the International Code Council, and NFPA 1, Fire Code
  - For these model codes to be enforceable, they must be adopted, in whole or in part, by states or local jurisdictions.
- The IFC includes ESS-related content in Section 1207
- Chapter 52 of NFPA 1 provides high-level requirements for ESS but mostly refers to NFPA 855, Standard for the Installation of Stationary Energy Storage Systems
  - A key focus of NFPA 855 is explosion control

Fire and Explosion Testing

- Fire and explosion testing to UL 9540A is mandated by the fire codes
  - UL 9540A is a test method with no stated pass/fail criteria, so it is not a qualification standard
  - Favorable test results under this standard are important for securing approval by the authority having jurisdiction (AHJ) for the proposed ESS layout

Firefighting Philosophy

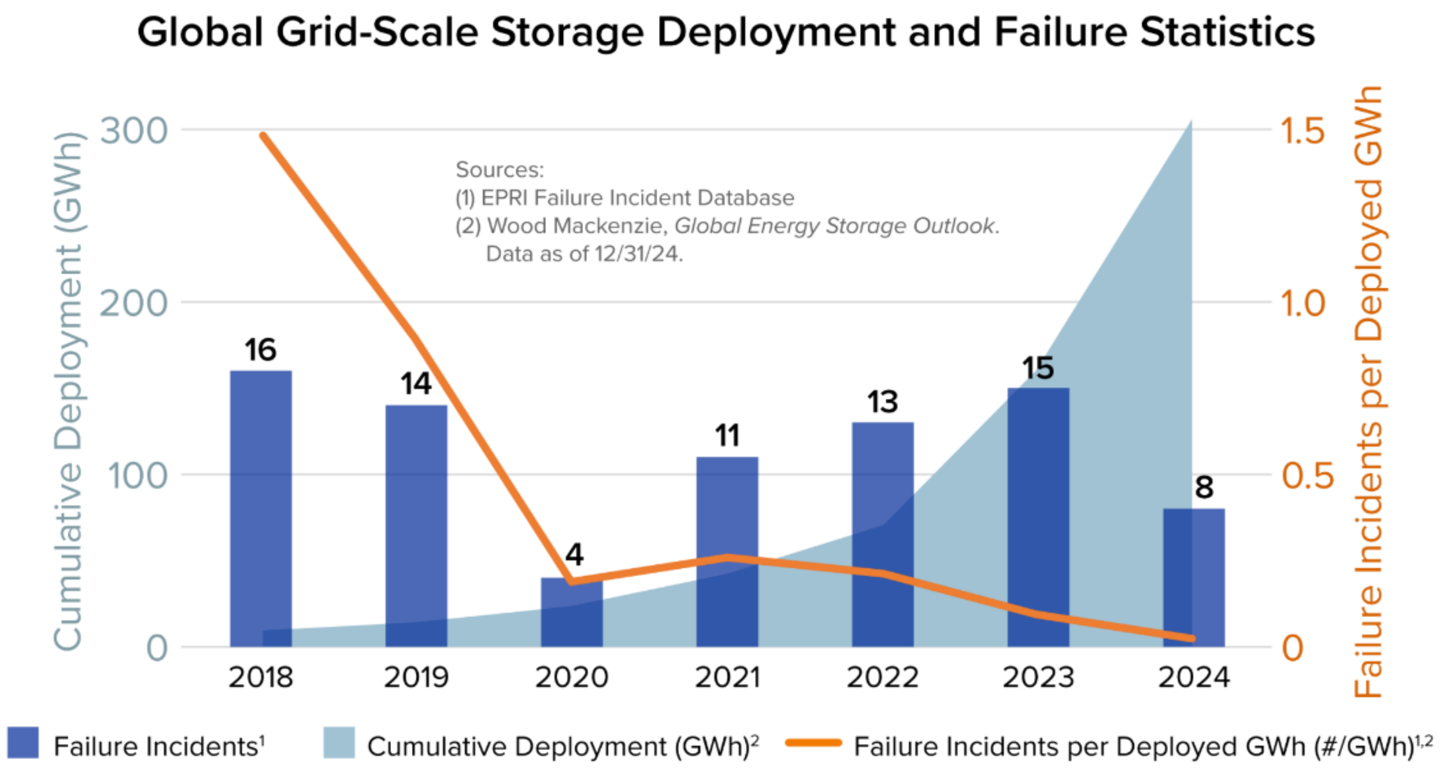
- In the early days of Li ion deployments, all ESS Li ion battery systems were equipped with FSS. Over the years, it became more widely recognized that extinguishing a fire without being sure to stop ongoing exothermic reactions and potential propagation could create an explosion risk
- This realization has driven a new ‘let it burn’ philosophy, in which an ESS battery fire is allowed to burn out in a controlled manner while protecting adjacent exposures

Comparison of Code Application

	Containerized	Dedicated-Use Building (indoor)
How's are the installations classified?	NFPA 855 (2023) Section 3.3.9.2 Energy Storage System Cabinet. An enclosure containing components of the energy storage system where personnel cannot enter the enclosure other than reaching into access components for maintenance purposes.	NFPA 855 (2023) Section 3.3.9.3 Energy Storage System (ESS) Dedicated-Use Building. A building that is only used for energy storage, or energy storage in conjunction with energy generation, electrical grid-related operations, or communications utility equipment.
Location	Outside	Indoor
Fire area (area that is enclosed and bounded by fire resistant construction)	Limited to one container – fire tested to avoid propagation (validated by fire testing and UL9540a testing)	Appears to be entire building – fire barriers not required in dedicated-use buildings
Maximum stored energy	600 kWh or determined on fire testing, HMA, or additional supporting documentation	No limit for dedicated-use buildings
Maximum size	NFPA 855 Section 9.5.2.4.1: Outdoor ESS walk-in units or ESS cabinets shall not exceed 53 ft × 8.5 ft × 9.5 ft (16.2 m × 2.6 m × 2.9 m), not including HVAC and other equipment. The container is 28.9 ft x 5.4 ft x 9.2 ft (8.8 m x 1.65 m 2.785 m)	Maximum size is per local building codes, which are dependent on use classification and building materials.
Fire testing	UL9540A, explosion control (validate sparker/vent system), full destructive test for propagation from container to container	Unknown. Any testing performed was likely not large-scale testing.
Suppression	N/A: Container is considered an outdoor, non-walk-in unit thus suppression is not required per NFPA 855 (2023) section 9.6.2. Containers are designed to safely consume themselves in the event of a propagating thermal event	Suppression is required for ESS systems within buildings per NFPA 855 (2023) Section 9.6.2.
Smoke Detection	N/A: Container is considered an outdoor, non-walk-in unit not required.	Detection is required for ESS systems within a building per NFPA 855 (2023) Section 9.6.1. Vistra utilized an Air aspirating smoke detection

BESS Failure Rate

- The failure rate dropped by 98% from 2018 to 2024 as lessons learned from early failures have been incorporated into the latest designs and best practices.



Moss Landing BESS Fire

January 16, 2025

January 16, 2025—Moss Landing BESS Fire

- ML300 was built into an old turbine building
- In service date–late 2020
- Largest BESS in the world at the time of installation
- Batteries were installed on both floors of the building
- Built with LG JH4 cells (nickel manganese cobalt (NMC) chemistry)
- Air cooled
- Intricate Thermal Runaway Mitigation System
- Fire resulted in complete loss of ML300

Multi-Organization Team

- WECC
  - James Hanson
  - Curtis Holland
- FERC
  - Eddy Lim
- NERC
  - Rich Bauer
  - Rick Hackman
- CAISO
  - Ali Miremadi
  - Drew Thompson

Milestones of Analysis Team

- Multiple interactions with Vistra team including onsite visit
- Conversations with multiple BESS OEM’s
- Analyzed previous BESS fires looking for potential similarities
- Analyzing data from ML300 and other BESS fires
- Drafting report—targeting publication in September 2025

Observations/Takeaways/ Considerations

- This installation was in service before most fire codes address ESS
  - Fire codes are quickly adding and updating ESS requirements
- Consider needs when selecting battery chemistry—pros and cons to each
- Warehouse vs. containerized
- Thermal Mitigation Approaches vary greatly by OEM
  - Operator's ability to intervene varies
- Cooling approaches vary by OEM
- Maintenance programs—tailor-made for many locations
- Batteries in high state of charge are more vulnerable to thermal runaway

WECC

WWW.WECC.ORG | (801) 582-0353

155 N 400 W, Salt Lake City, UT 84103, USA