

Moss Landing BESS Fire

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**Electric Reliability
& Security for the West**

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January 16, 2025 – Moss Landing BESS Fire

- ML300 was built into an existing 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



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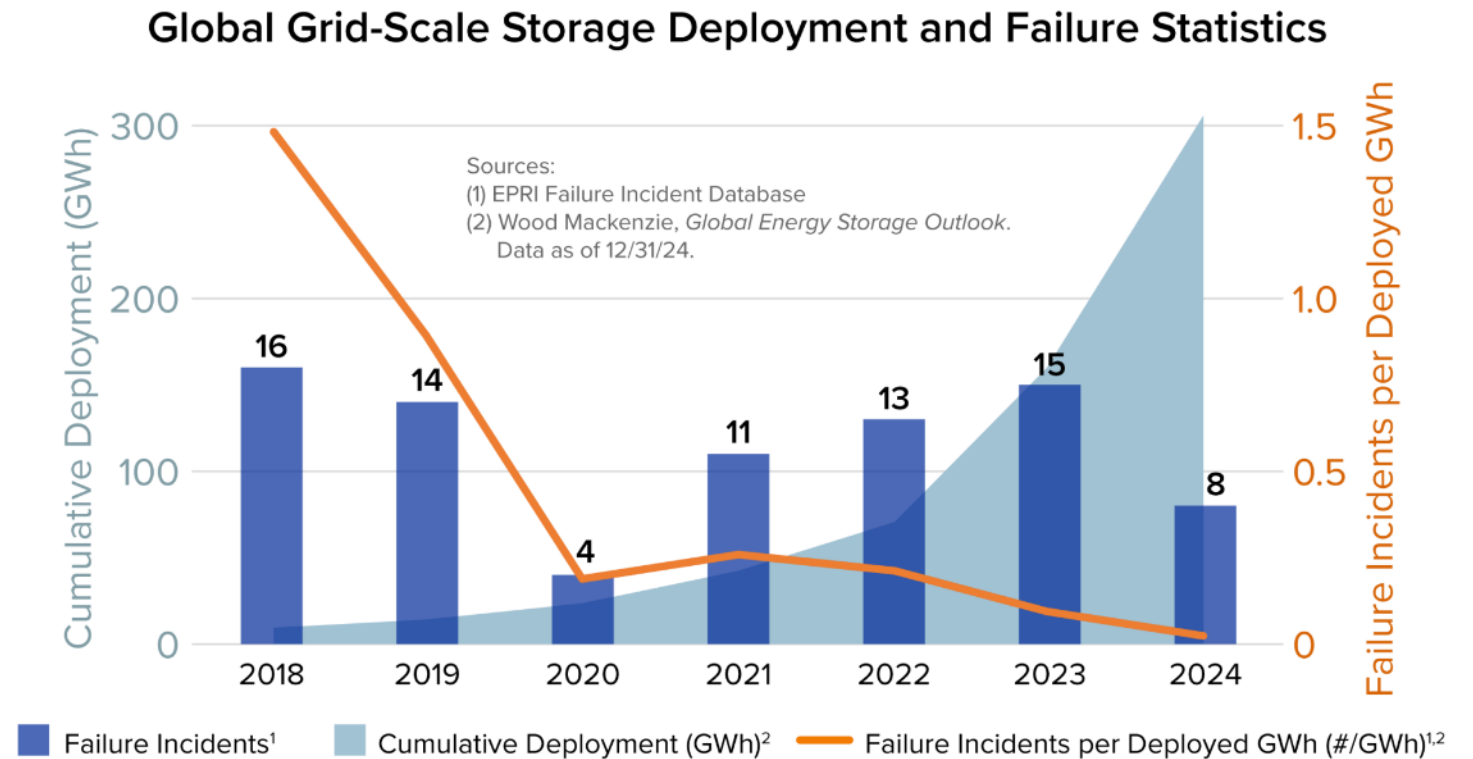
Milestones of Analysis Team

- Multiple interactions with Vistra team including on-site visit
- Conversations with multiple BESS OEMs
- Analyzed previous BESS fires looking for potential similarities
- Analyzing data from ML300 and other BESS fires
- Examined current fire standards and other publications on BESS installations
- Published report December 2025



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.



Observations

- One of the most striking observations the teams experienced through this effort is the extraordinary pace of change in this field.
- A system designed in 2020 bears little resemblance to those being deployed today, even for projects of similar scale.
- This rapid evolution reflects the industry's steep learning curve, as manufacturers, operators, and engineers have gained valuable insights through accelerated growth and deployment.



BESS Design

Moss Landing 300, Warehouse Style BESS

- ML300 was constructed using 4,539 LG TR 1300 racks, a UL9540 tested design.
- Each metal rack is preassembled and approximately 41" wide, 47" deep, and 69" high.
- Each rack comes with 22 battery modules, cabling, and nozzle assembly and weighs a little over 5,000 lbs.
- Also mounted within the rack are the Battery Protection Unit and BMS.
- Each rack contains approximately 327 kWh of energy, and racks can be double-stacked to further boost the energy density at a facility, a feature which was used in the construction of ML300.



Warehouse Style Advantages

1. Warehouses allow for precise management of airflow, temperature, and humidity – critical factors for battery performance and longevity. Certain battery chemistries are especially sensitive to extreme temperatures, with sub-freezing or above 100° F conditions potentially degrading performance and voiding warranties. Controlled indoor environments help maintain optimal operating conditions and support long-term reliability.
2. Warehouse designs allow space efficiency. Indoor facilities can be vertically stacked and tightly configured, maximizing energy capacity within a limited footprint. This is particularly beneficial in space-constrained urban or industrial areas, where auxiliary cooling systems can support dense installations.
3. Warehouse installations allow for efficiencies in maintenance. Maintaining a single warehouse structure is generally more efficient than servicing dozens or hundreds of individual outdoor containers. Roof integrity and HVAC systems can be managed centrally, reducing labor and operational complexity.
4. Warehouses offer controlled access points and a secure perimeter, making it easier to monitor and protect sensitive infrastructure compared to sprawling outdoor setups.

Moss Landing 350, Containerized BESS



- The Phase III project is made up of 122 containers that together house more than 110,000 battery modules.
- The facility is rated at 350-megawatt/1,400-megawatt-hours.

Containerized Style Advantages

1. Containerized installations allow for simplified fire safety. Outdoor installations benefit from passive fire safety design, primarily through strategic spacing between containers. This reduces the risk of fire propagation and simplifies mitigation planning.
2. Containerized installations allow for flexible site deployment. Containerized systems can be installed on virtually any available land without the need for complex permitting or construction. This flexibility can significantly reduce project timelines and costs.
3. These sites allow for modular scalability. Containers can be easily added, removed, or replaced, allowing for straightforward system augmentation or asset rotation as needs evolve.
4. These installations provide the option to be redeployed to another location if desired with minimal disruption. This offers adaptability for changing grid demands or business strategies.

BESS Planning Recommendation

- Engage Early with Stakeholders:
 - Public Education: Build trust and transparency through proactive outreach and education.
 - Fire Services Collaboration: Involve local fire departments during the planning phase and conduct joint drills to ensure preparedness.



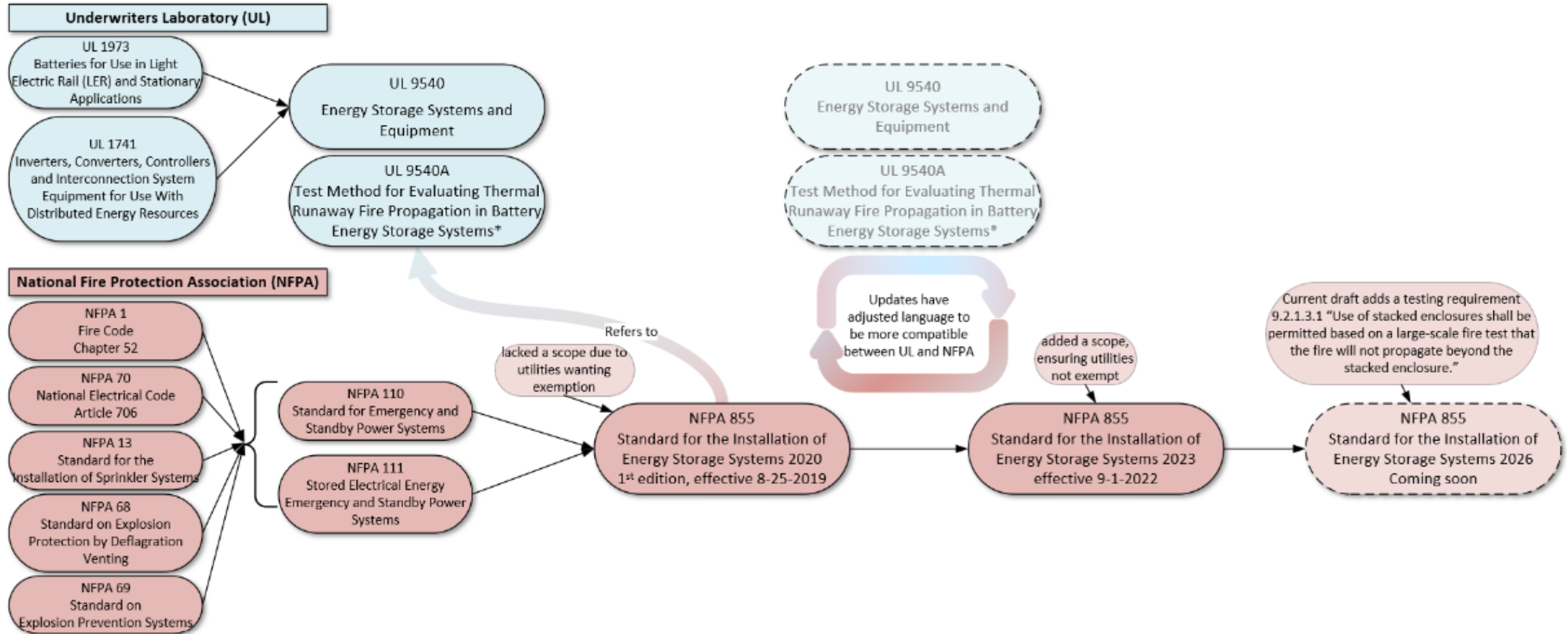
BESS Fire Codes

Moss Landing

- The design of ML 300 was complete and accepted prior to NFPA 855 2020 being issued.
- UL 9540 pre-existed (initially released in 2016) the design of Moss Landing and was applicable and the racks used for ML 300 were UL 9540a tested and certified.

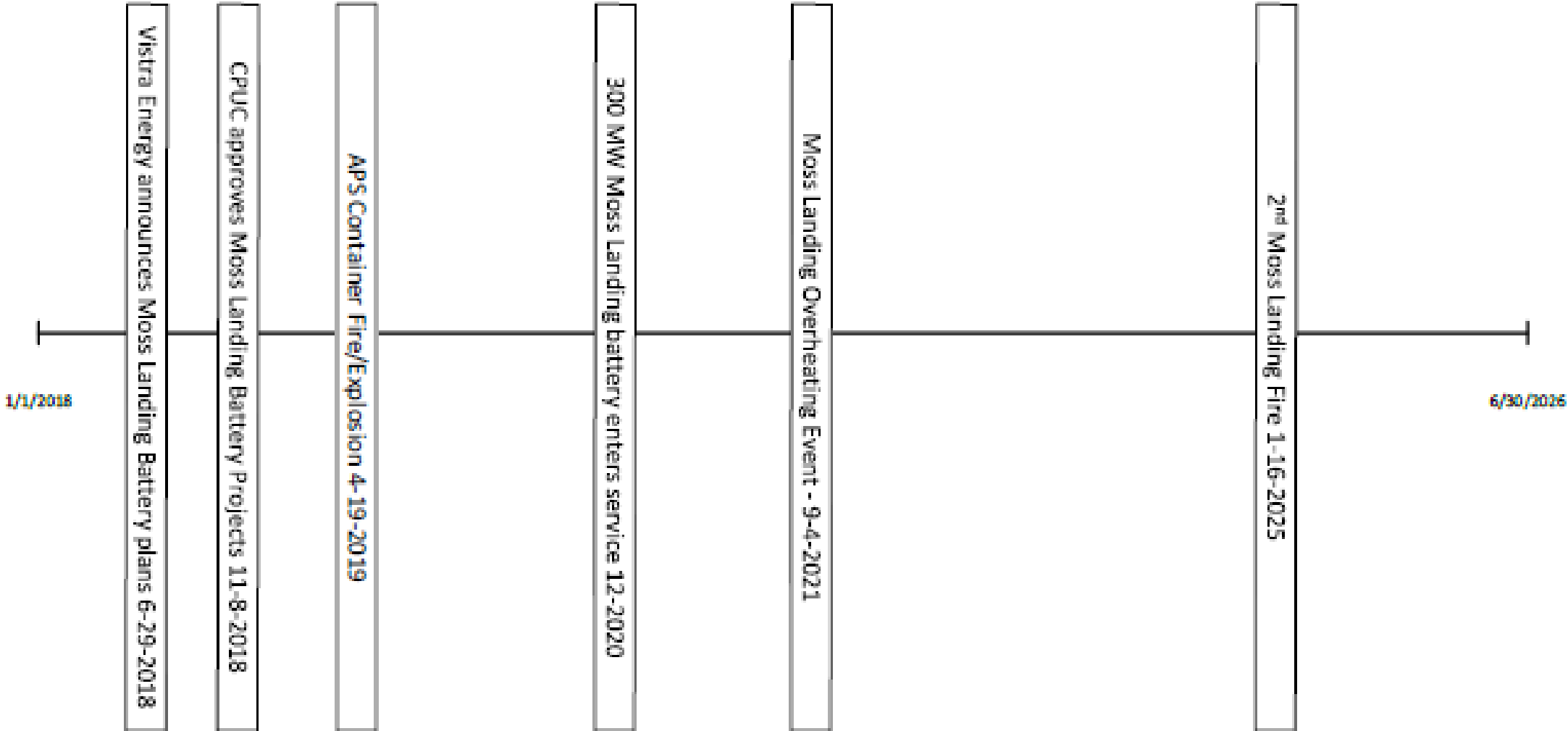


Fire Code Evolution



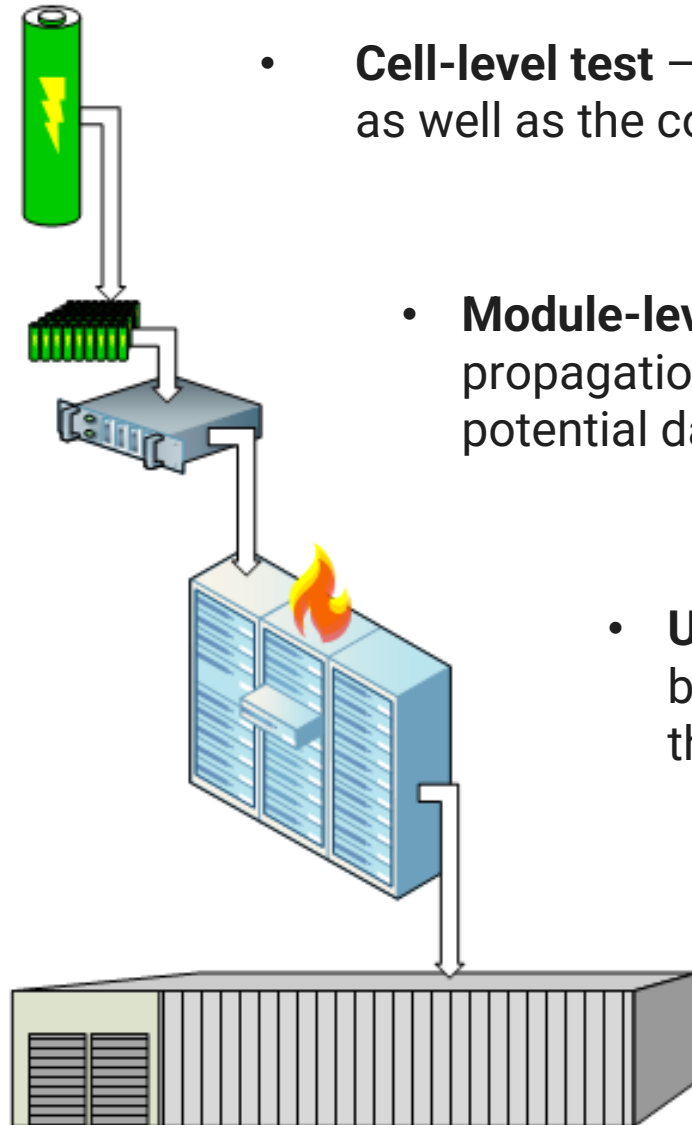


BESS Facility Timeline





UL 9540A Testing Levels for Thermal Runaway Propagation



- **Cell-level test** – evaluates the thermal runaway characteristics of the cell as well as the composition and flammability of the gases.

- **Module-level test** – evaluates the tendency of cell thermal runaway propagation, the heat and gas release rate of the module, and the potential danger of ignition or deflagration.

- **Unit-level test** – evaluates the likelihood of fire spread between modules, the unit’s heat and gas release rates, and the potential for deflagration or re-ignition.

- **Installation-level test** – evaluates the effectiveness of the fire protection system, as well as the heat and gas release rate of the system and the danger of deflagration or re-ignition.

Fire Code BESS Recommendations

- For legacy BESS installations, **several industry bodies and agencies recommend retroactive safety evaluations and upgrades for BESS installed before the current version of NFPA 855 to the extent possible.** These recommendations focus on hazard mitigation, emergency planning, and alignment with UL 9540A.

The team recommends:

- **Prioritize Standards Compliance:** Ensure all new BESS deployments strictly adhere to the latest NFPA and UL standards to mitigate safety risks and future-proof installations.
- For those facilities that do not meet the most current NFPA 855 requirements, owners and operators should review operational limits and other parameters with manufacturers to establish appropriate operating margins and limits to minimize the probability of thermal runaway.



Thermal Runaway

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

Can happen when a battery is physically compromised by either being dropped, crushed, or penetrated.

Thermal Abuse

Can occur when a battery is exposed to external heat sources.

Electrical Abuse

Can happen when the battery is overcharged, charged too rapidly or at high voltage, or discharged too rapidly.

Environmental Impacts

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.

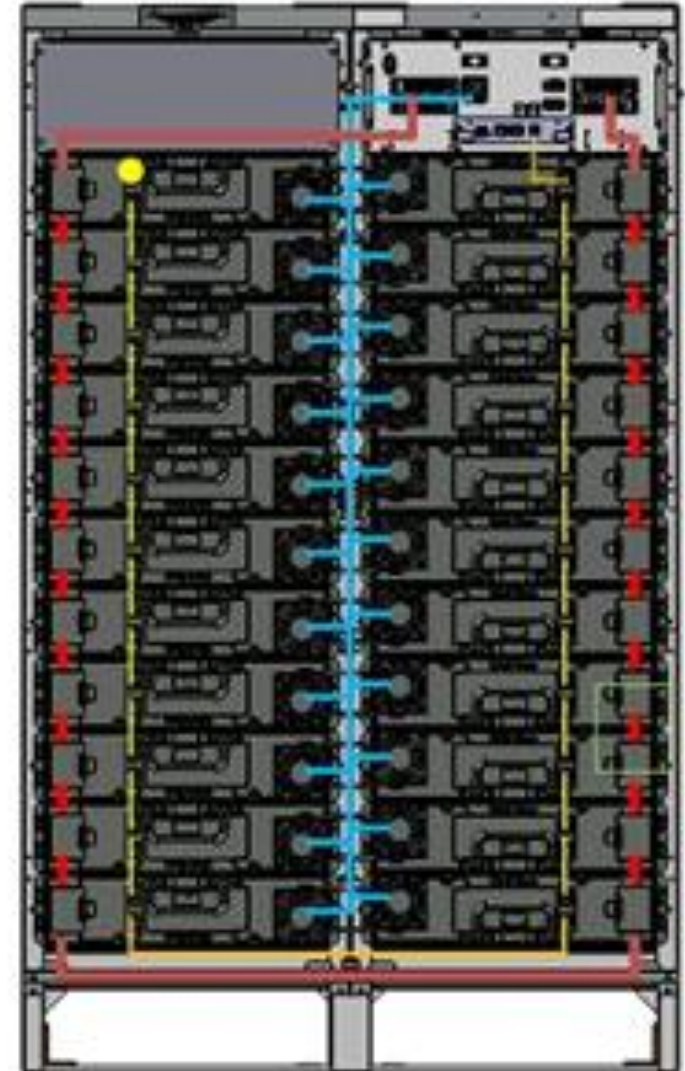


Explosion Protection/Prevention

Explosion prevention systems or deflagration venting

Thermal Runaway Mitigation

- The ML300 design features a water-based TRM system engineered to prevent thermal runaway within individual battery modules. This system is organized into 25 pre-action zones distributed across the facility, each zone covering three to four battery cores.
- Each zone comprises carbon steel header pipes connected via flexible hoses to rack-mounted piping. Integrated into this piping are sprinkler nozzles, strategically positioned within each battery module. Activation of the system begins with smoke detection where water is released into the header pipes of the affected zone.
- Subsequently, if the temperature within a specific module rises to the nozzle's activation threshold, water is directly injected into that module – providing targeted suppression and mitigating the risk of thermal escalation. Parts of the TRM system are owned by Vistra and other parts are owned by the OEM.





Fire Suppression Recommendation

- **The team recommends:**
 - Rethink Fire Suppression Strategies: Avoid defaulting to overhead sprinkler systems; explore alternatives better suited to BESS environments.



Lithium-Ion Batteries

Lithium-Ion Batteries (Li-ion)

Pros

- **High Energy Density:** Stores more energy in a compact form, making it ideal for space-constrained applications.
- **Long Cycle Life:** Can last thousands of charge-discharge cycles, reducing replacement costs over time.
- **High Efficiency:** Round-trip efficiency often exceeds 90%, meaning minimal energy is lost during charge and discharge.
- **Fast Charging & Discharging:** Suitable for applications that require rapid energy deployment, such as frequency regulation and grid balancing.
- **Low Maintenance:** Unlike lead-acid batteries, Li-ion systems require minimal maintenance and have no memory effect.

Cons

- **Fire Risk and Thermal Runaway:** If improperly managed, Li-ion batteries can overheat and experience thermal runaway, leading to safety concerns. Advanced cooling and battery management systems (BMS) are necessary for safe operation.
- **Higher Cost:** While prices have declined, Li-ion batteries remain more expensive than lead-acid alternatives.
- **Raw Material Constraints:** Uses materials like lithium, cobalt, and nickel, which are subject to supply chain risks and geopolitical concerns.
- **Degradation Over Time:** Capacity gradually declines with repeated charge-discharge cycles, especially in high-temperature environments.
- **End-of-Life Challenges:** Recycling and disposal remain complex due to the battery's chemistry and the need for specialized recycling processes.

Lithium Nickel Manganese Cobalt Oxide (LiNiMnCoO₂) – 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

Battery Chemistry Recommendation

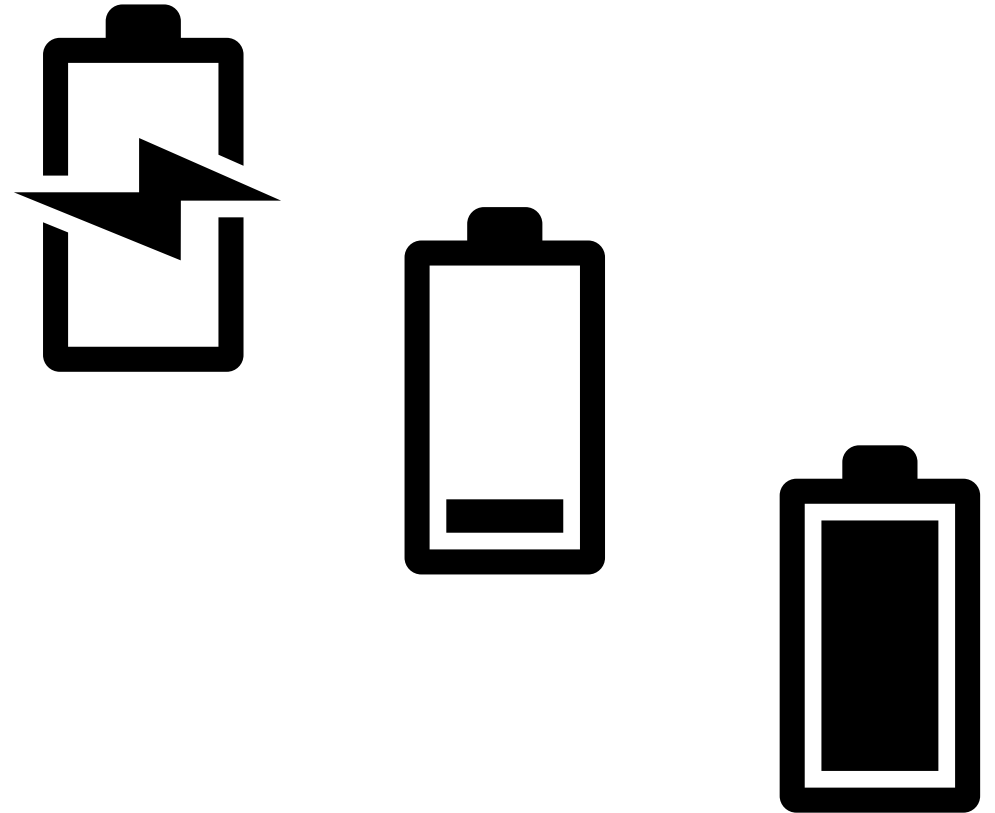
- **The team recommends:**
 - Evaluate battery chemistries carefully: Select chemistries that balance performance with safety and are supported by robust TRM systems.



State of Charge (SOC)

State of Charge

- The state of charge (SOC) represents the percentage of energy stored in a battery or energy storage system relative to its full capacity.
- State of charge in a BESS cannot be directly measured; it must be estimated.
- It is calculated using algorithms within a battery management system (BMS) that monitor and combine data from measurable variables like voltage, current, and temperature.



High State of Charge Operations

- Operating a BESS at a higher state of charge is known to make the system more susceptible to thermal runaway.
 - There have been several known BESS fires occurring when operating in a high SOC.
 - One of the largest fires in the WI occurred during capacity testing.
- In our limited discussions with manufacturers and other experts in the industry, we walked away with the understanding that the probability of cell failure does not change with the high state of charge. But the amount of energy released in case of failure directly correlates with the state of charge.

State of Charge recommendation

- **The team recommends:**
 - Conduct capacity tests with caution: Treat these tests as high-risk operations requiring special protocols and heightened awareness.



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