U.S. DEPARTMENT of ENERGY | Federal Energy Management Program

Customizable Technical Specifications for Lithium-Ion Battery Storage Projects

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Tuesday, April 15, 2025

Webinar Overview

Agenda

I. Energy Storage Basics

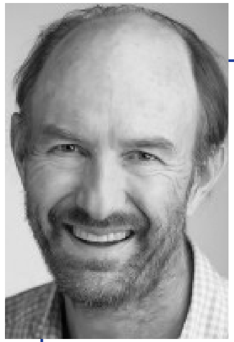
II. Tech Specs Overview

III. Li-Ion Battery Safety

Learning Objectives

- Identify key components of the **lithium-ion (li-ion) battery storage technical specifications** resource.
- Apply specifications to **develop project requirements** for energy storage projects.
- Analyze **case studies** to evaluate how the checklist can support project development.

Today's Presenters



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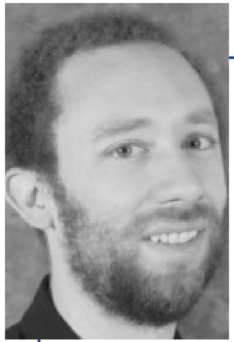

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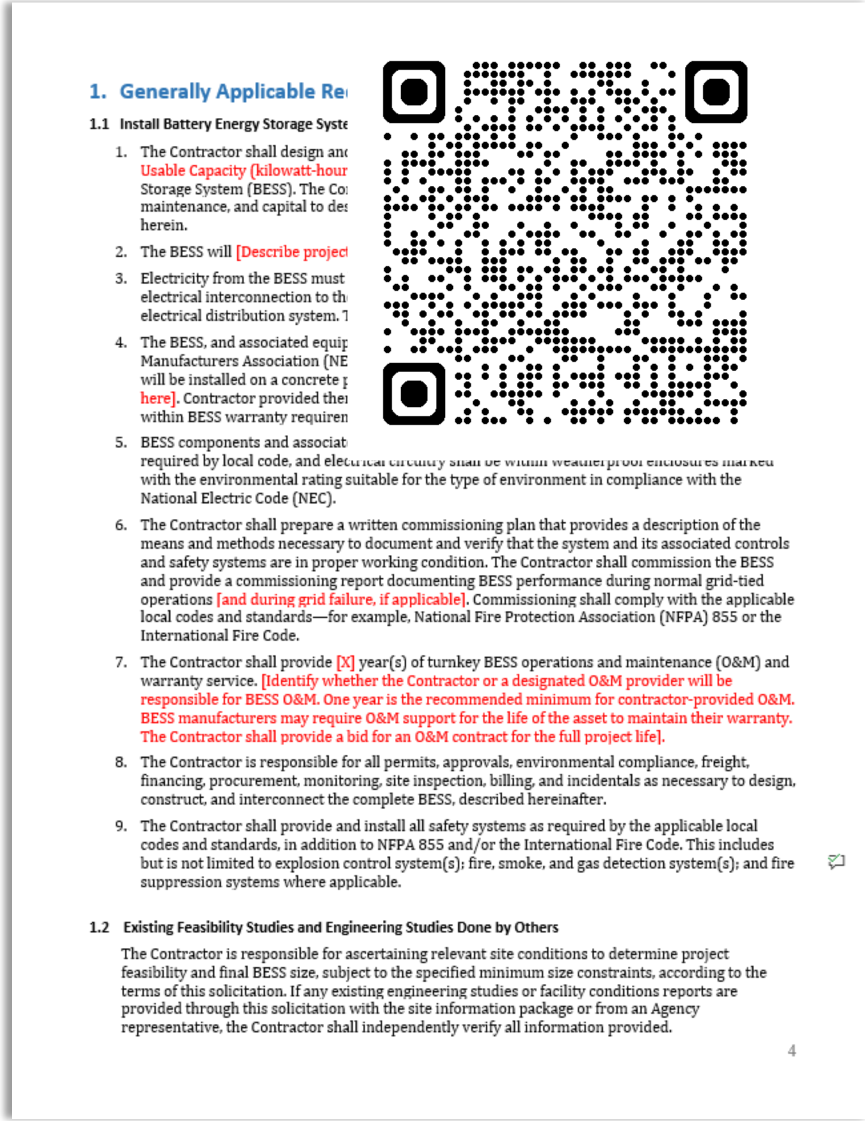
FEMP's Li-Ion Battery Storage Technical Specifications

- **Fully customizable template** for agencies to develop procurement and implementation plans for battery energy storage systems (BESS)
- **The document includes:**
  - BESS codes and standards
  - Use case requirements (demand control, photovoltaics [PV]-plus-storage, resilience)
  - Engineering and construction requirements
  - Severe weather considerations
  - Inspection, commissioning, and final acceptance process.
- It does not include specifics of battery manufacturer spec sheets or an evaluation of different battery chemistries.
- **Text that provides options** for the drafter are presented in **(blue parentheses)**. Fill-in-the-blank areas are indicated in **[red brackets]**.



1. Generally Applicable Re

1.1 Install Battery Energy Storage Syste

1. The Contractor shall design an Usable Capacity (kilowatt-hour Storage System (BESS). The Co maintenance, and capital to de herein.
2. The BESS will [Describe project
3. Electricity from the BESS must electrical interconnection to th electrical distribution system.
4. The BESS, and associated equi Manufacturers Association (NE will be installed on a concrete here]. Contractor provided the within BESS warranty requiren
5. BESS components and associat required by local code, and electrical circuitry shall be within weatherproof enclosures marked with the environmental rating suitable for the type of environment in compliance with the National Electric Code (NEC).
6. The Contractor shall prepare a written commissioning plan that provides a description of the means and methods necessary to document and verify that the system and its associated controls and safety systems are in proper working condition. The Contractor shall commission the BESS and provide a commissioning report documenting BESS performance during normal grid-tied operations [and during grid failure, if applicable]. Commissioning shall comply with the applicable local codes and standards—for example, National Fire Protection Association (NFPA) 855 or the International Fire Code.
7. The Contractor shall provide [X] year(s) of turnkey BESS operations and maintenance (O&M) and warranty service. [Identify whether the Contractor or a designated O&M provider will be responsible for BESS O&M. One year is the recommended minimum for contractor-provided O&M. BESS manufacturers may require O&M support for the life of the asset to maintain their warranty. The Contractor shall provide a bid for an O&M contract for the full project life].
8. The Contractor is responsible for all permits, approvals, environmental compliance, freight, financing, procurement, monitoring, site inspection, billing, and incidentals as necessary to design, construct, and interconnect the complete BESS, described hereinafter.
9. The Contractor shall provide and install all safety systems as required by the applicable local codes and standards, in addition to NFPA 855 and/or the International Fire Code. This includes but is not limited to explosion control system(s); fire, smoke, and gas detection system(s); and fire suppression systems where applicable.

1.2 Existing Feasibility Studies and Engineering Studies Done by Others

The Contractor is responsible for ascertaining relevant site conditions to determine project feasibility and final BESS size, subject to the specified minimum size constraints, according to the terms of this solicitation. If any existing engineering studies or facility conditions reports are provided through this solicitation with the site information package or from an Agency representative, the Contractor shall independently verify all information provided.

4

Download the tech specs at:
https://www.energy.gov/femp/articles/lithium-ion-battery-storage-technical-specifications.

Energy Storage Basics

Key Battery Storage Terminology

Terminology	Definition
Battery storage	Technology that stores electrical energy in a reversible chemical reaction Lithium-ion (li-ion) batteries are the most common technology for energy storage applications due to their performance characteristics and cost.

The intended use case of the battery impacts the recommended system size and duration.

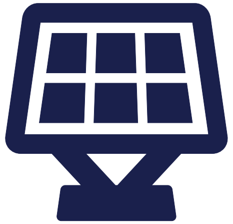
Common Battery Use Cases

Resilience

- Integrate a BESS with existing PV and backup generation.
- Consider critical power circuits.

Demand Control

- Install a battery energy storage system (BESS) to offset grid electricity usage and provide demand control/peak shaving to limit demand.

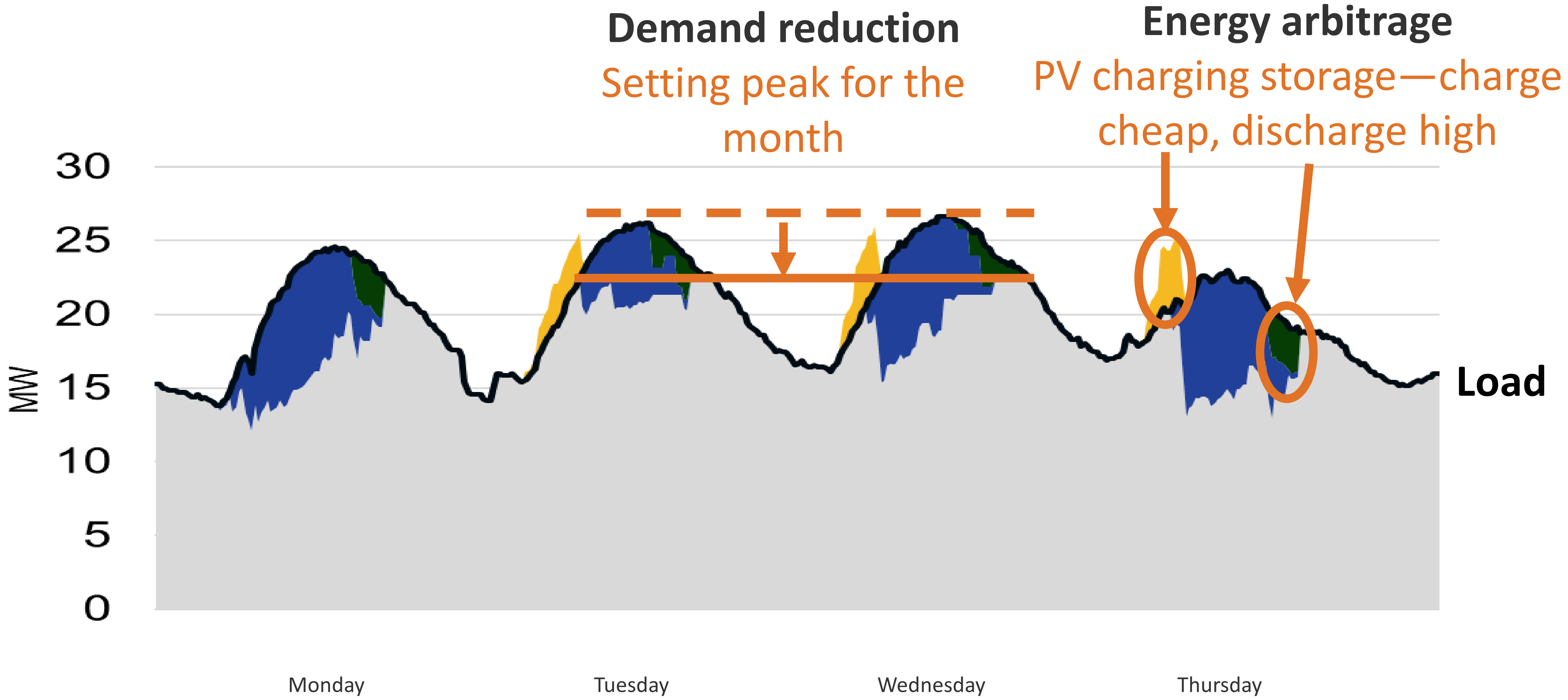


Solar Integration

- Integrate a BESS with solar photovoltaic (PV) to smooth power outputs.
- Store excess PV generation for use later during non-solar hours.

Other use cases include load shifting, grid forming/grid following, and arbitrage.

Battery Dispatch Example

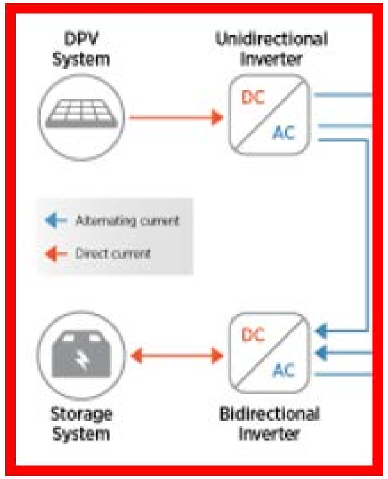


Illustrative example of optimal dispatch

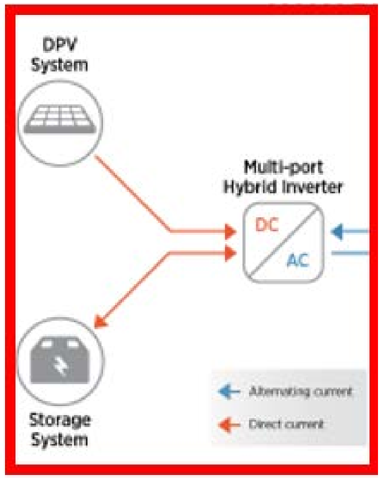
Grid Serving Load ■ PV Serving Load ■ Storage Discharging ■ PV Charging Storage — Electric Load

Battery Storage Configurations: Alternating Current (AC) vs. Direct Current (DC)

	AC-Connected	DC-Connected
Application	• More common for commercial and residential **behind-the-meter installations**	• Becoming more common; typically used for large **utility-scale systems**
Charging	• Battery can charge **from both PV and the grid**	• Battery **charged from PV**
Efficiency loss	• Slightly **higher losses**	• Slightly **lower losses**
Key trade-offs	• **Higher cost** but **greater flexibility**	• **Fewer components** required; **cheaper** but less flexible



AC-connected configuration

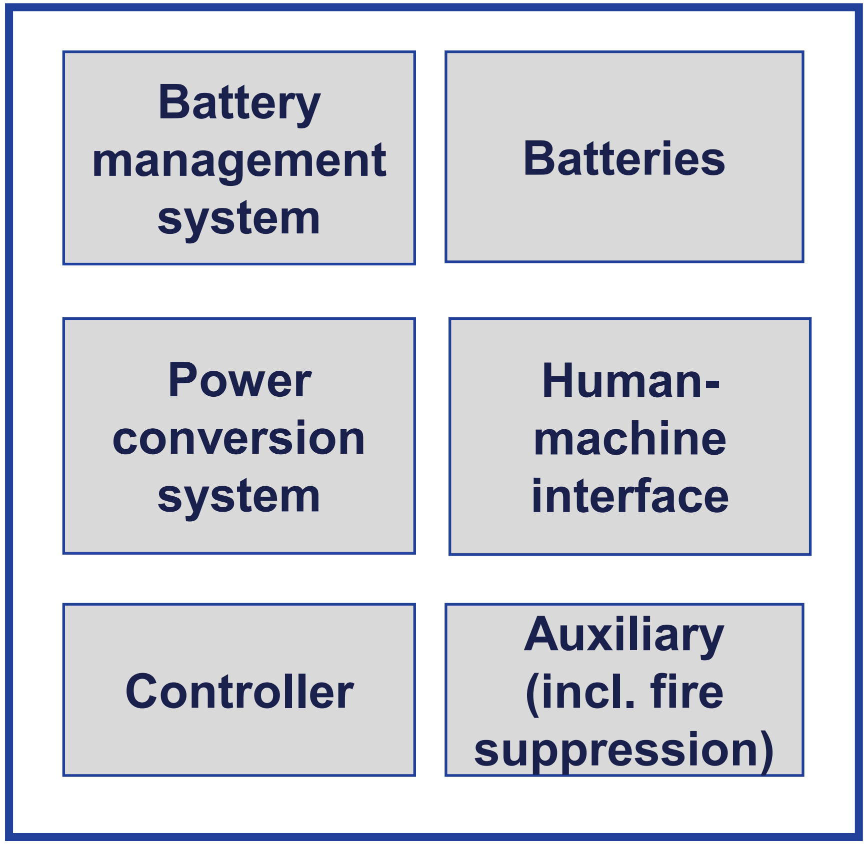


DC-connected configuration

Tech Specs Overview

Why the Tech Specs?

- A BESS—a battery energy storage *<u>system</u>*—is more than just a battery and an inverter.
- Procuring a BESS is complicated. Detailed requirements should be set early in the process and tracked, ensuring a functional, interoperable system at commercial operation.
- Hazards abound in the procurement process, any one of which can cause schedule slippage, cost overruns, and/or change orders.
- **Robust planning and execution are critical to ensure ultimate project success. The tech specs can help agencies with these steps.**



BESS container

The Tech Specs Are a Procurement Resource

<u>Use cases:</u>

- Identify requirements for the technology, project, and contractors / vendors in **request for proposal (RFP)** documents.
- Provide language that can be enshrined in **agreements/contracts** with the contractor and subcontractors.
- Support the development of **designs and other project documents**.
- Manage contractors, track deliverables, and support efforts to **maintain the schedule/budget** through construction, installation, testing, inspections, and commissioning.

<u>BESS Procurement Stages</u>

1. Sizing

2. Use case definition

3. RFP/contract award

4. Deployment

Generally Applicable Requirements

- Define the contractor scope of work and all responsibilities for the design, construction, installation and commissioning, including:
  - Labor, materials/equipment, and engineering
  - Interconnection
  - Capital and financing
  - Permits, approvals, compliance with prevailing codes, standards, and regulations.
  - Will the contractor also be responsible for operations, maintenance, and monitoring, or a third party?
- **Ensure that the scope is clearly articulated, and responsibilities are identified so contractors can accurately price their bids and schedule delivery.**

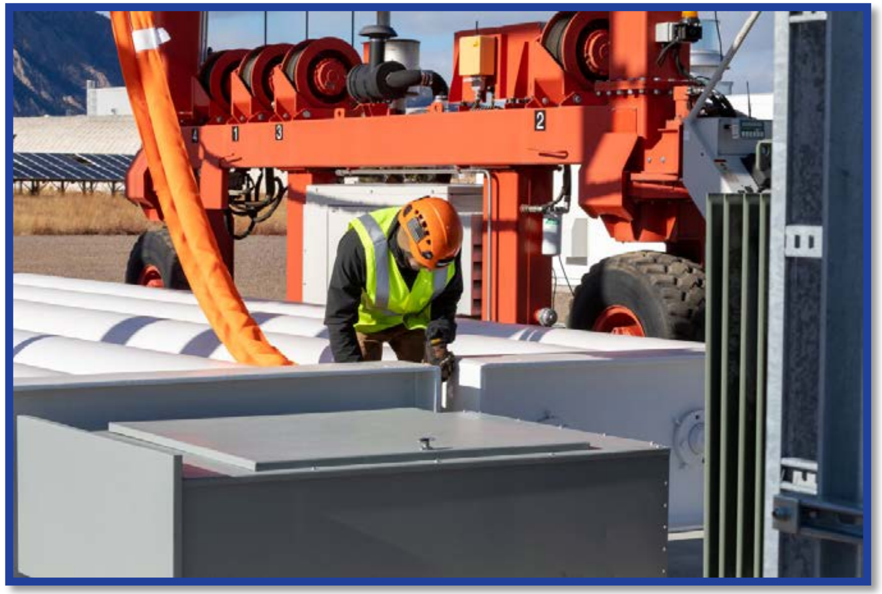


Photo by Werner Slocum, NREL 66418

Engineering and Construction

- Ensure bidders define and provide the appropriate system details in their proposals, including:
  - **Site plan or conceptual drawing**
  - **Single-line diagram**
  - **Key battery features**/characteristics, such as sizing (kWh/kW), round-trip efficiency, cycle life, degradation, manufacturer's specs, and safety details.
- Bidders should describe the battery's performance as it meets the site's particular needs and conditions. This could include:
  - **Grid outage scenarios**
  - **Demand control scenarios.**

Photo by Werner Slocum, NREL 65137

Key System Considerations

- **Data acquisition and monitoring:**
  - Consider how the BESS will be **controlled and monitored**. Who will have access? How will the **performance targets** be measured and verified?
- **Protection:**
  - The contractor should provide a **robust protection scheme** to ensure safe and reliable operation of the BESS. The contractor should also perform **arc flash and coordination studies** for both grid-paralleling and grid-islanding modes.
- **Thermal management:**
  - The **HVAC system** should keep the BESS operating within temperatures to maintain the **warranty,** hew to **codes/standards,** and prevent **fires and explosions**.
  - A **monitoring** and an **alarm system** should also be provided.
  - Who will supply, install, and monitor the system—e.g., the contractor, a third party?

Inspection and Commissioning

- The contractor should connect the system in the proper order and verify each connection.
- Predefined and agreed-upon **checklists** (e.g., installation, commissioning, verification) for startup and verification minimize troubleshooting and potential damage.
- The commissioning team should comprise *at least* the following personnel:
  - **Engineering, Procurement, & Construction**
  - **BESS commissioning staff**
  - **Agency facility manager and safety team member**
  - **Owner's engineer**
  - **Utility representative.**

Photo by Eliza Hotchkiss, NREL 90425

Commissioning Sequence

The ordering of commissioning steps is critical. Any steps that are **skipped**, **conducted out of order**, or **not verified** can result in project delivery and operational issues!

Electrical Infrastructure
Switchgear, transformer, cables, etc., installed and verified

BESS
Installed and verified

Interfacing
Electrical infrastructure wired to BESS and system tested

Verification
Ensure system and all connections match the detailed engineering drawings

Commissioning Process Summary

- The initial inspection is conducted for **substantial completion** of the construction.
- Pending the successful **initial inspection**, commissioning may begin.
- The **final inspection** may be scheduled following completion of the commissioning and approval of all documents:
  - Final as-built drawings (record drawings), meeting as-built requirements
  - Preventive maintenance work schedules and procedures
  - Operations and maintenance manuals (electronic and hard copy)
  - Training manuals (electronic and hard copy)
  - Equipment documentation and spare parts lists
  - Certificates of Authority Having Jurisdiction (AHJ) inspections.
- The contractor has the responsibility for **completing the rework** identified in the final inspection prior to scheduling system acceptance testing.

Site Acceptance Testing

- Site acceptance testing (SAT) specifications and checklists must be prepared, reviewed, and agreed upon by the agency before testing is conducted.
- To ensure complete functionality, the BESS testing must include (among others):
    - Power and energy capacity tests
    - All the operating modes, including grid-connected and islanding
    - Fault conditions: e.g., communication failure, HVAC failure, overcurrent.
- The agency's technical team should witness all tests, verify test conditions, and validate results.
- **The SAT report must be agreed upon by the contracting officer if all the tests are passed or passed with minor notes.**
- **Note: Factory acceptance testing can save time and costs—it is a best practice to leverage this service as much as possible.**

Final Acceptance Process Summary

- The system **acceptance testing** has been completed:
  - The system and all subsystems/components operated at the specified performance for one full charge/discharge cycle.
  - The power production levels are consistent with the proposed system's estimated production with 100% system availability.
- The system is approved for **interconnected operation** by the electric utility (signed interconnection agreement).
- Submission of **all documents** is required prior to the final inspection.
- **Training fulfillment** documentation
- The **commissioning report** is provided to the agency.

Lessons Learned From Real-World Projects

- **Be an informed buyer!** Agencies should understand what to expect in terms of deliverables, processes, testing, specifications, and other areas to minimize risks and successfully bring projects to completion.
- **Involve the utility early and often**. Consider engaging during the design phase to incorporate interconnection requirements and other considerations to ease permitting and approvals.
- **Develop checklists and follow them closely.** E.g., installation, commissioning, verification.

Lithium-Ion Battery Safety

Why Are Codes/Standards Important? Incidents Can Happen

- 2019: McMicken, AZ—4 firefighters Injured (73 ft), explosion
- 2021: Australia—Tesla 1.5-MW Megapack, fire
- 2021: China—2 firefighters + 1 employee killed, 1 firefighter injured, explosion
- 2023: Idaho—fire
- 2024: Germany—2 firefighters injured, fire/explosion
- 2024: Fires in Otay Mesa and Escondido
- 2025: Moss Landing, CA

Source: RTO Insider

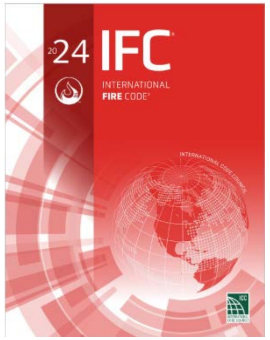
Source: YouTube

Key Takeaway

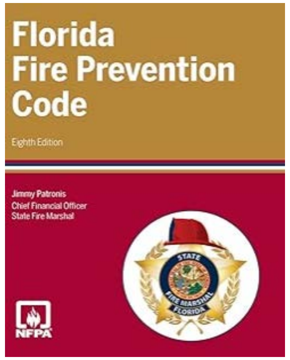
Compliance with safety codes and standards greatly reduces the probability of a fire or explosion.

U.S. Codes and Standards Framework

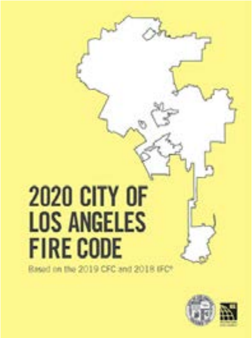
National Codes



State Codes
(examples)



Local Codes
(examples)



2022

DENVER BUILDING CODE

&

DENVER FIRE CODE

Installation Standard

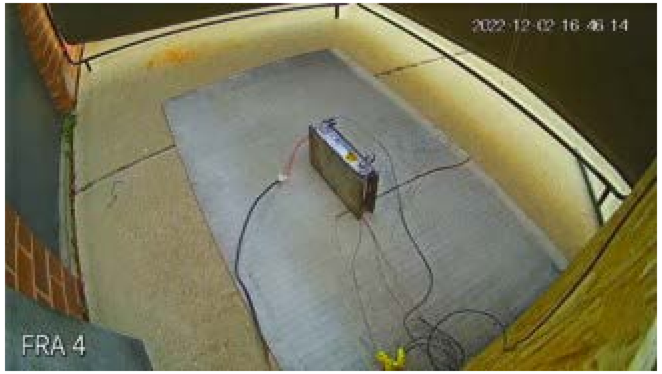
Edition is important - Standards change every 3 years to keep up with technologies!

Know what codes apply to ensure smooth permitting.

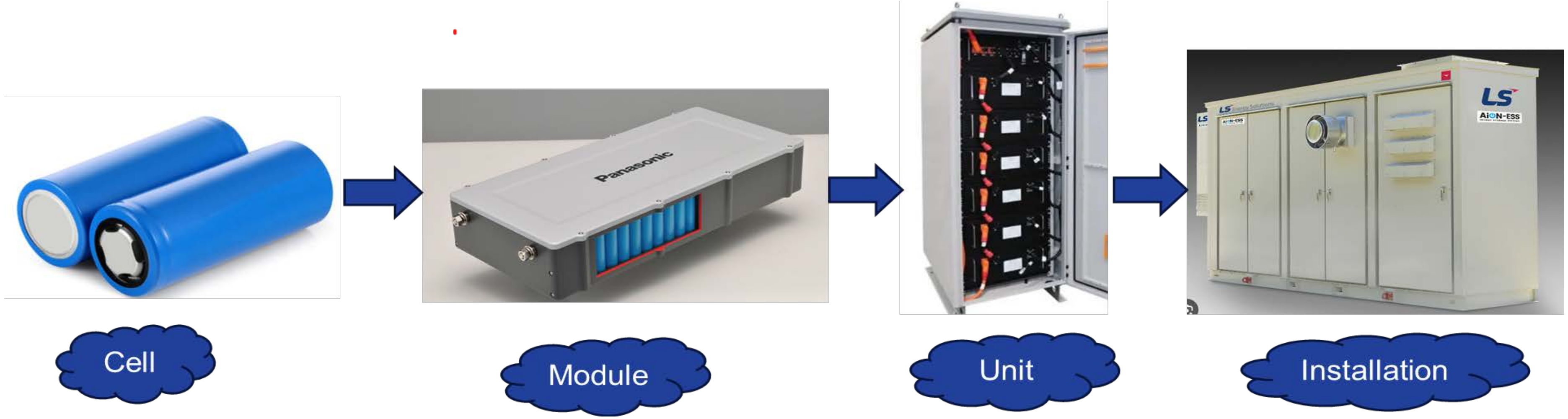
NFPA 855 provides the latest guidance on li-ion battery safety.

UL 9540A Test Method

- UL 9540A provides critical baseline data for energy storage system (ESS) safety design.
- It is a test method, not a standard.
- The test methodology forces the thermal runaway of a single cell.
- It informs the design of ESS explosion control systems, including in:
    - NFPA 68: Deflagration Venting
    - NFPA 69: Deflagration Prevention.



UL 9540A cell test video



LFP (Lithium Iron Phosphate—LiFePO4) Should Be Evaluated Within the Install Context

- Higher resistance to thermally induced thermal runaway:
  - TR temperature 220°C–270°C (approximate)
  - Others 175°C–210°C.
- Higher concentration of hydrogen
- Lower minimum ignition energy and mixture of LFL:
  - H2 MIE 0.19 MJ, CO MIE <0.3
  - H2 LFL 4%–75%, CO 12.5%–74%.

Sample Gas Composition by Chemistry

Chemistry	H_2	CO	CH_4	C_2H_4	CO_2	LFL
NMC	24.7	28.3	6.1	7.4	30.2	9.21
NCA	32.7	40.9	15.4	0.5	9.2	9.04
LFP	48.7	9.9	4.6	4.8	28.8	6.1

Key Takeaways

- LFP is not decidedly “safer,” but it should be evaluated within its installation context.
- There is potential for thermal runaway in li-ion batteries for fire and explosion risks if not properly managed.
- Not all batteries fail due to external overheating—it depends on the form factor, the end use application, and mitigating measures.

Explosion Control Is Required for All Li-on Chemistries

- Injuries and fatalities have occurred at sites that did not plan for or provide explosion control.
- **Relevant codes:**
  - NFPA 68: Deflagration Venting
  - NFPA 69: Deflagration Prevention
  - Engineered Systems Allowed.

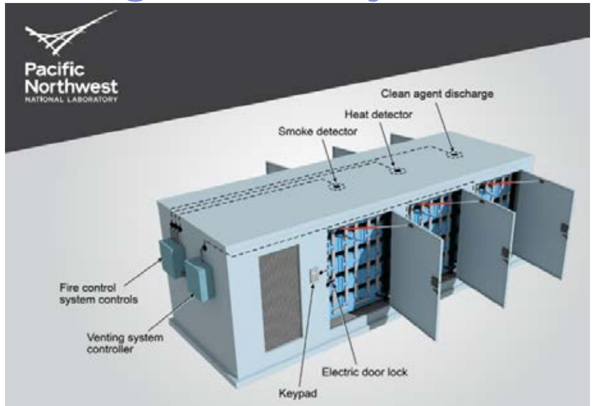
Source: Courtesy of Baker Risk

NFPA 68

Source: Courtesy of Fike Corp

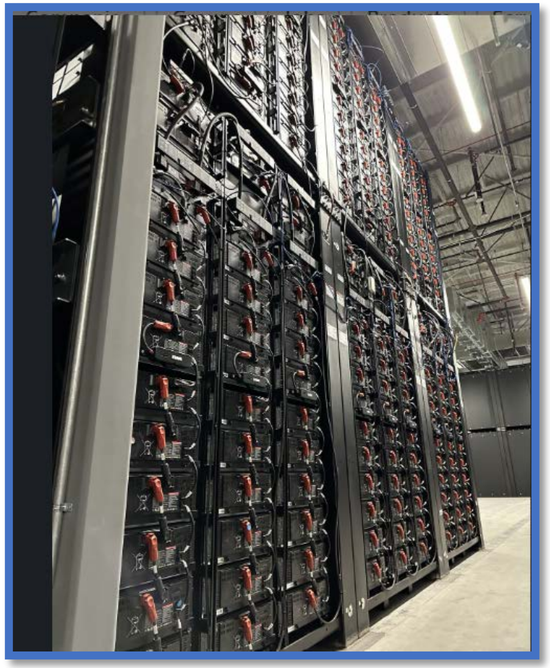
NFPA 69

Engineered Systems



Location and Separation

- Individual containers spaced appropriately (and validated by testing and engineering) will limit the incident size.
- There are different approaches for indoor versus outdoor configurations.
- **NFPA 855 provides requirements for:**
  - Indoor
  - Outdoor—remote (>100 ft to exposures)
  - Outdoor—near exposure (<100 ft to exposures).



Indoor installation
Source: Chief Berlant, CAL FIRE (LinkedIn)

Outdoor installation
Source: Enel North America

Key Takeaway

Outdoor containerized ESS spaced properly greatly reduces risk.

Suppression Does Not Stop Thermal Runaway

- Traditional/standard suppression and extinguishing methods are not effective.
- New technology is under development to minimize cell-cell propagation.

> UL FSRI report from McMicken incident:
> *"It is unlikely the concentration of NOVEC 1230 remaining in the ESS at the time the door was opened provided meaningful protection against the ignition of flammable gases and vapors that had accumulated in the ESS."*
> *"The clean agent suppression system prevented flaming during the early phase of the incident, but was not designed for and did not provide explosion protection."*

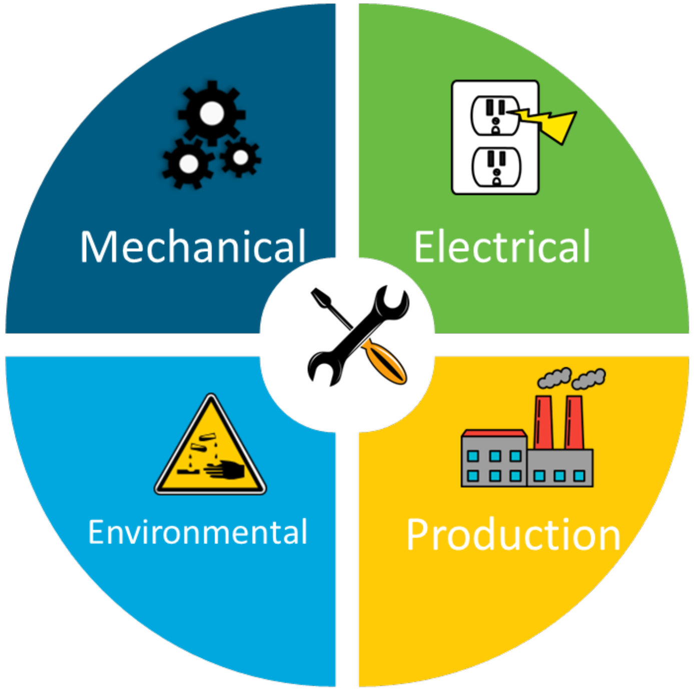
> FM 5-33:
> *Section 3.3.A: "As of 2019, there is no evidence that gaseous protection is effective in extinguishing or controlling a fire involving energy storage systems…the hold time is generally 10 minutes, not long enough to fully extinguish a LIB-ESS fire or prevent thermal runaway from propagating…"*

Listings Are Required by Code and Are Critical for Installation Safety

- UL 9540 (system level)
- UL 1973 (battery/module level)

Containment of Moving Parts
Leakage Tests
Strength Tests
Wall Mount Fixture Test

Normal Operations Test
Dielectric Voltage
Impulse Test
Grounding/Bonding
Insulation Resistance
Electromagnetic Immunity



Moisture Exposure
Marine Environments
Seismic

Electrical Production
Mechanical Production
Production Quality Control

Hazard Mitigation Analysis

- Failure modes, mitigation measures, and consequences
- Product and site specific
- Developed by qualified individual
- Required by codes and standards:
  - 2023 NFPA 855 ➔ Greater than 600 kWh
  - **2026 NFPA 855 ➔ All installations**

Key Takeaway

Hazard mitigation analysis evaluates failure modes and mitigation measures, and it is critical to establishing the safety basis of installation.

Failure modes

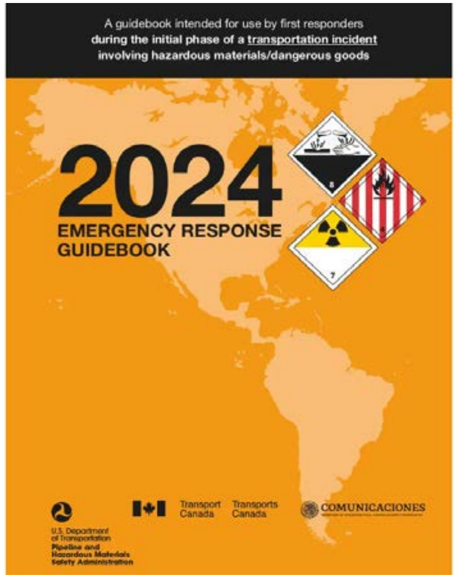
Thermal runaway/mechanical failure

Failure of ESMS/BMS

Failure of required systems (e.g., fire detection, HVAC, exhaust, gas detection, etc.)

Emergency Response—A Key Component!

- Responder safety is critical to avoid serious injuries.
- Current approach: “**Let it burn**.”
- *2024 Emergency Response Guide* by the U.S. Department of Transportation:
  - Guide 147: Li-ion and sodium-ion batteries:
    - *“Allow battery fire to burn itself out and protect surroundings.”*
    - *“Apply water spray to neighboring batteries to reduce the spread.”*
- NFPA 855:
  - Emergency response plan required
  - Training required (e.g., fire department, facility staff, etc.).



Additional FEMP Resources

Checklists and Other Resources

- Battery Energy Storage Procurement Checklist
    - Provides federal agencies with a standard set of tasks, questions, and reference points to assist in the early stages of BESS project development.
- Battery Energy Storage System Evaluation Method
    - Report describes a proposed method for evaluating the performance of a deployed BESS or solar PV-plus-BESS system.
- Distributed Energy Interconnection Checklist
    - Provides federal site managers with a series of tasks and questions to ask their utility, broken out by each interconnection process step.
- Microgrid System Procurement Checklist
    - Provides federal agencies with a standard set of tasks, questions, and reference points to assist in microgrid project development.

This Training Is Accredited

How to obtain your CEUs:

1. Take the assessment and evaluation.
   - The link will be posted in the Webex chat and emailed to all attendees after the training.
2. Complete the assessment with a score of 80% or above.
3. Upon passing the assessment, provide your name and email address to continue to the evaluation.
4. Complete the evaluation.
5. The WBDG Support Team will email you a Certificate of Completion within 2 business days.
6. Questions or issues? Contact WBDG Support at wbdg@nibs.org.

What's an IACET CEU?

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Thank you!

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