Batteries 101- BESS Battery Safety Regulations, Standards, and Practice

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SAE Battery Standards Steering Committee
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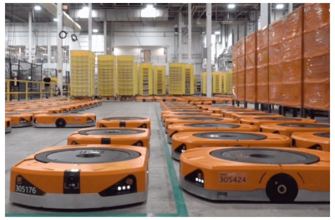
Global demand driving Energy Storage market

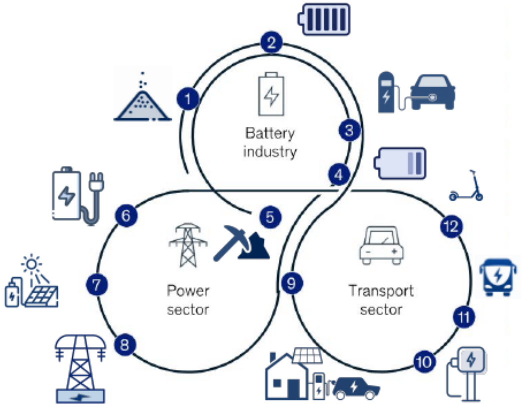
It's an entire ecosystem

- *Solar/wind farms*
- *Grid Energy Storage*
- *Extracting & Refining raw materials*
- *Battery cell manufacturing*
- *Battery Pack Assembly*
- *Battery Transport*
- *e-Vehicles & e-Machines*
- *Server Farms*
- *Power inverters*
- *Local Energy Storage*
- *Charging – (fast, bidirectional)*
- *Service*
- *Re-use/second life*
- *Decommissioning / Discharging*
- *Recycling*





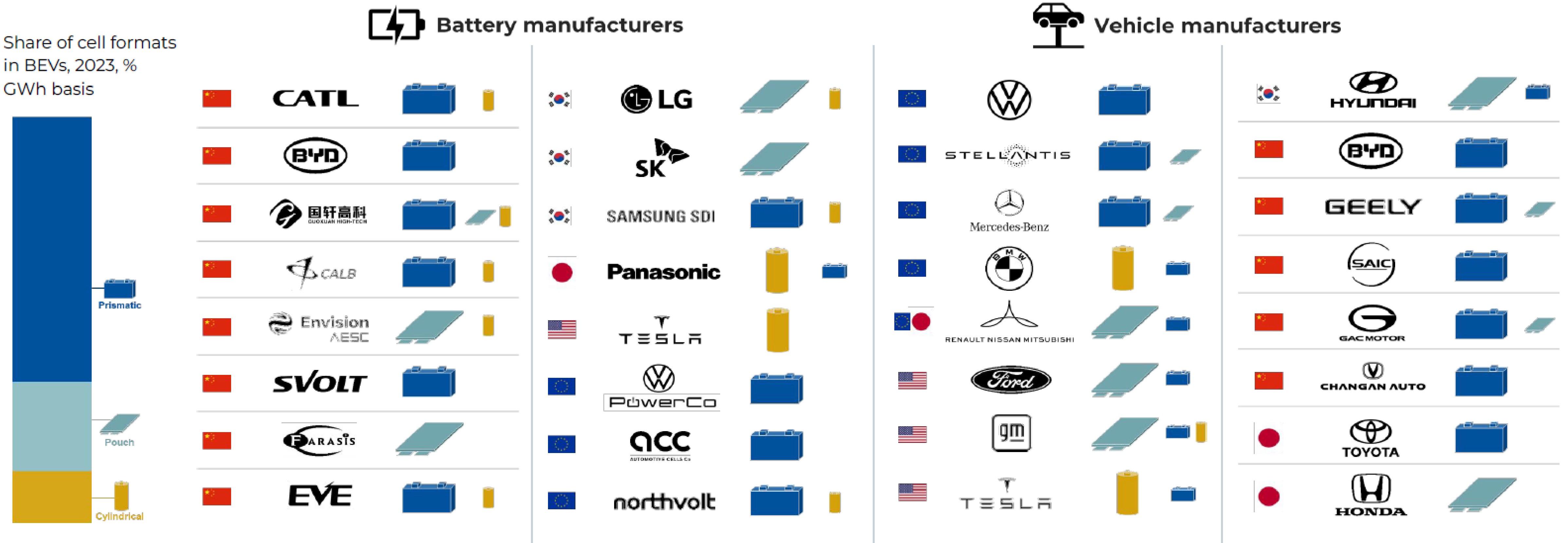



1. Active materials
2. Battery cell and pack
3. Battery application
4. Battery repair and refurbish
5. Mining and Battery recycling
6. Battery 2nd life
7. Decentralized battery energy storage
8. Centralized battery energy storage
9. Vehicle to grid
10. Smart charging
11. Urban EV
12. Shared E-mobility

Electrons are much easier to collect, transport and store than petroleum products

3 basic cell designs...

Form Factors: mass market trending towards large-format cells, especially prismatic

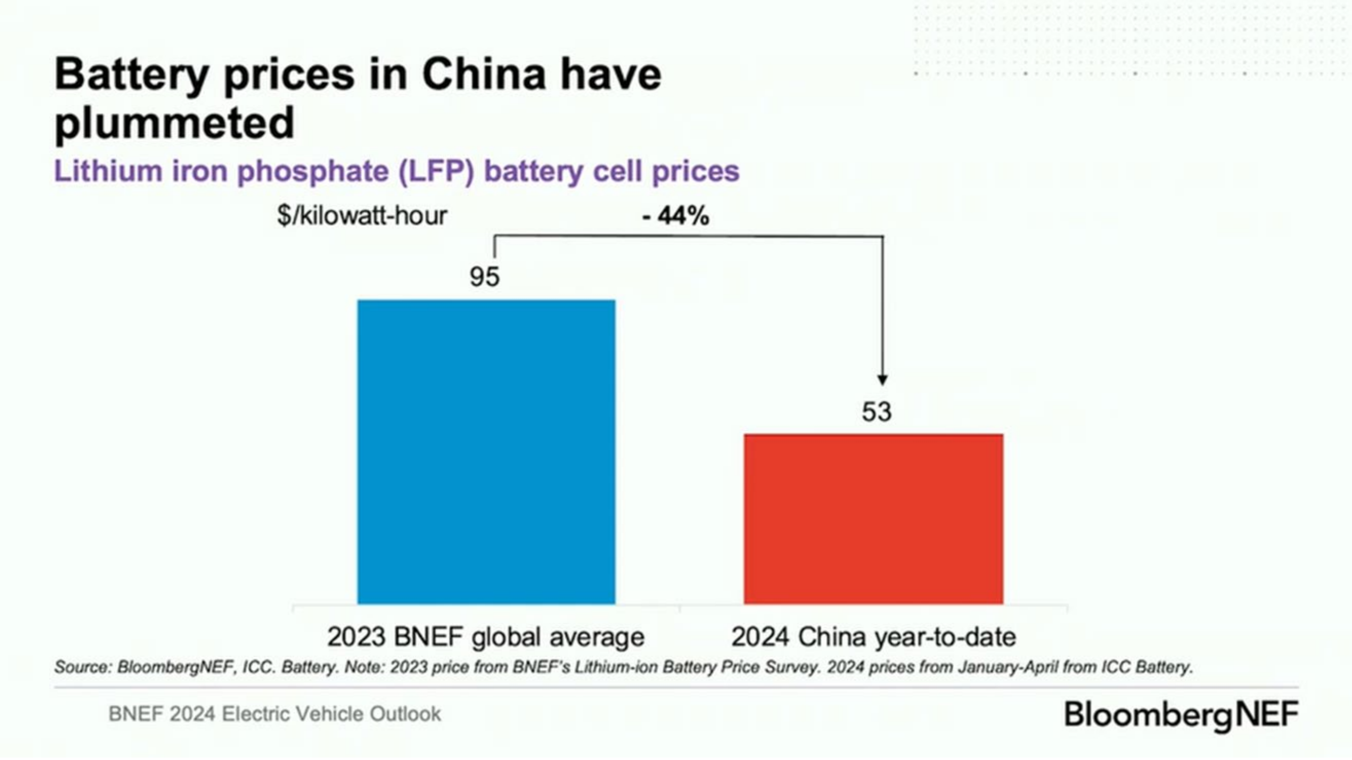


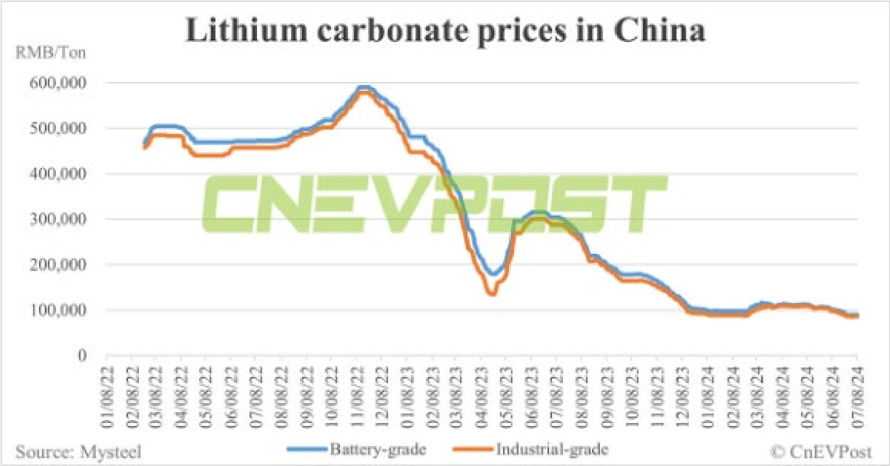
Large and small icons denote primary and secondary form factors respectively.

Larger format, prismatic cells trending, along with increasing energy density

Volta Foundation, 2023

LFP cell costs reduced by ~50% in less than 1 year





Over the last year, the price for lithium iron phosphate, or LFP, battery cells in China has dropped 51% to an average of **$53 per** kilowatt-hour. The average global price of these batteries last year was $95/kWh.

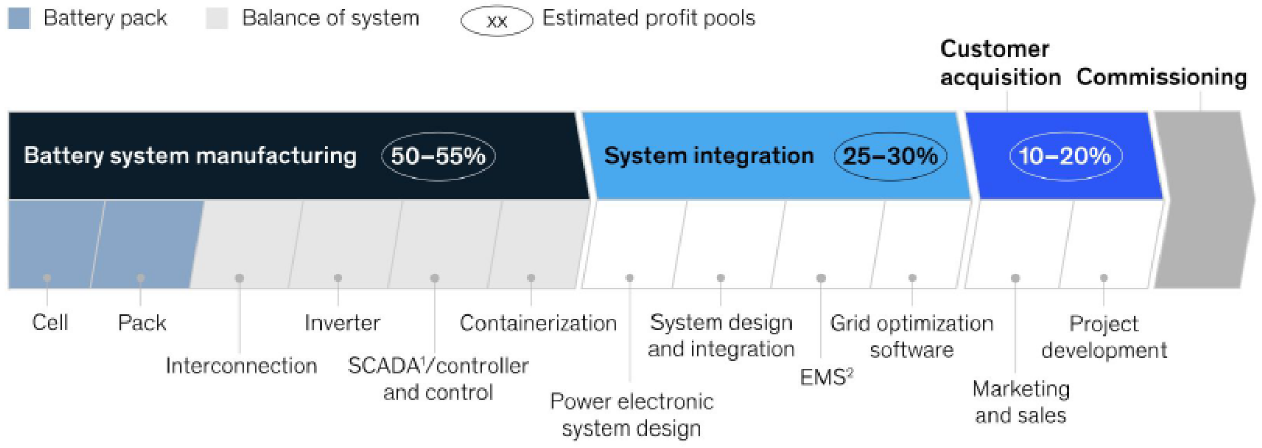
Typical Cathode chemistries include NMC, NCA, and LFP
LFP dominating chemistry, overcapacity driving historically low prices

Battery Energy Storage System (BESS) market growth

BESS is a nascent yet rapidly growing market

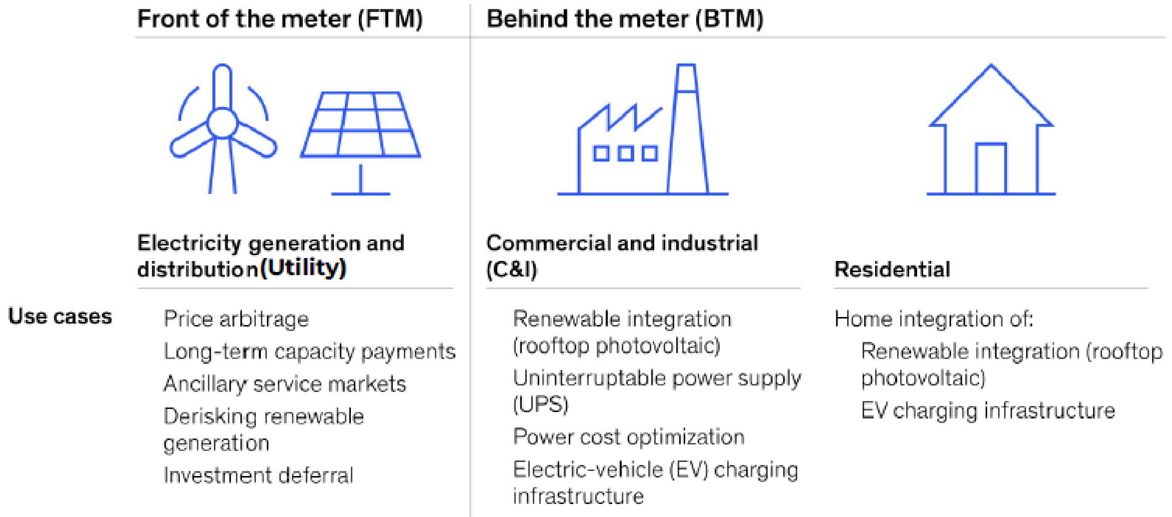
Investment into battery energy stationary storage (BESS) has tripled to $5 billion in 2022 compared to 2021 with the global BESS market expected to reach ~**$120-$150 billion by 2030.** However, there is risk and uncertainty around financiers, integrators, and battery chemistries. From cell to commission, the ecosystem is complex, with 50%+ of the BESS value chain profit pool dominated by battery system manufacturing.

Value chain breakdown of battery energy storage systems (hardware only)



[1]Supervisory control and data acquisition.
[2]Energy management system.

Battery energy storage systems are used across the entire energy landscape.



BESS systems address a number of needs in grid management and energy demand

Public charging, server farms, grid level arbitrage competing for resources

Volta Foundation, 2023

Battery Energy Storage System (BESS) Global Suppliers

Applications | BESS | Players: Cell Suppliers & Integrators

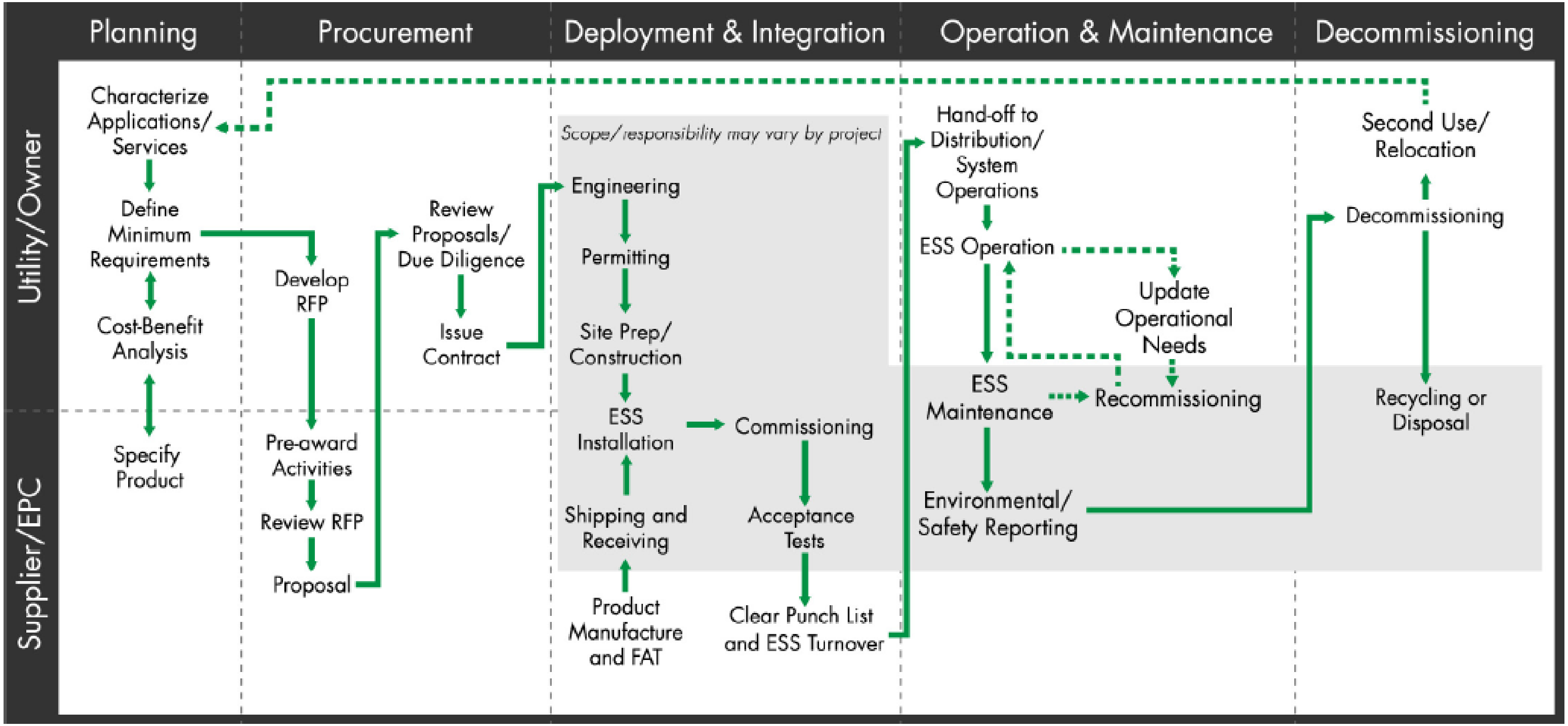
TESLA ENERGY, ENPHASE, Alpha-ESS, RIMAC ENERGY, WÄRTSILÄ, Nidec, HITHIUM, POWERVAULT, BYD, ENERGY STORAGE E3/DC, ABB, Panasonic, Trinasolar, ESS INC, VARTA, SENEC, SAMSUNG SDI, Form energy, ENERGY VAULT, CATL, LG Energy Solution, CATL, Envision AESC, NEXTera ENERGY, POWIN, Gotion, FLUENCE A Siemens and AES Company, northvolt, EVE, PYLONTECH, noon ENERGY, SIEMENS, sunrun, SUNWODA, SK innovation, sonnen, SUNGROW Clean power for all, Bloomenergy, VISTRA ENERGY, Highview Power, HYPERSTRONG

This supply chain can provide battery products to many application spaces

Volta Foundation, 2023

Battery Energy Storage System (BESS) Lifecycle Process

EPRI BESS deployment model

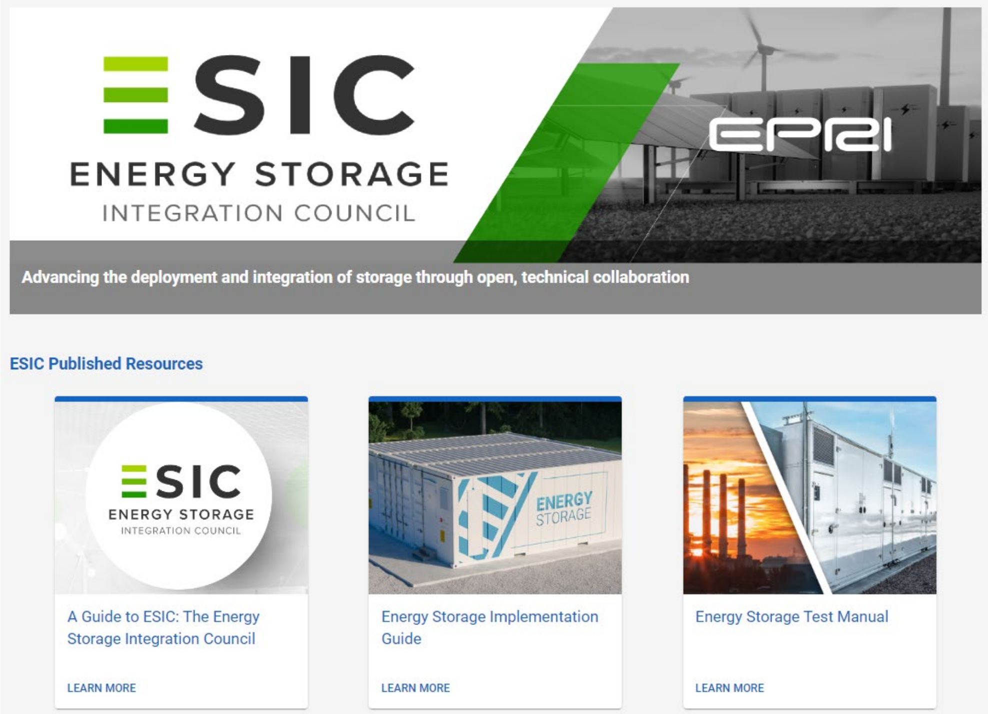


Electric Power Research Institute – Energy Storage Integration Council

A resource for energy storage : www.epri.com/esic

Energy Storage Implementation Guide:

- To serve as an evolving reference guideline for utility project managers, the suppliers they work with, and users investigating energy storage solutions
- To support the development of a practical, short-term industry research agenda to deploy safe, reliable, cost-effective energy storage projects with a one- to three-year time horizon
- To identify common problems and risks that are encountered in the implementation of energy storage projects and provide a path toward resolution
- To provide ongoing updates on the publicly available tools of ESIC



Energy Storage Test Manual:

- Tests should include “metrics of merit” that are important for understanding the value of storage in utility applications.
- Terminology and scope should be consistent with the technical specification template terms/definitions
- Tests should be practical to implement, considering commonly available equipment and analysis needs, with clear acceptance criteria

Additional Resources:

- A Guide to ESIC: The Energy Storage Integration Council
- ESIC Energy Storage Implementation Guide
- Summary of Energy Storage Control Performance Metrics
- ESIC Energy Storage Operation and Maintenance Tracking Tool
- ESIC Energy Storage Reference Fire Hazard Mitigation Analysis
- ESIC Energy Storage Safety Incident Gathering and Reporting List
- ESIC Energy Storage Test Manual
- Electrical Energy Storage Data Submission Guidelines
- ESIC Energy Storage Commissioning Guide
- Storage VET & DER-VET sup porting documentation
- Energy Storage System Taxonomy of Operating Behaviors
- ESIC Energy Storage Request for Proposal Guide
- ESIC Energy Storage Technical Specification Template
- ESIC Energy Storage Cost Template and Tool

Battery incidents catch headlines. Data shows that incident frequency is rare, but outcome of individual events can be have significant impact. New regulations, standards, tools, and training are rapidly evolving to substantially improve outcomes

Firefighters extinguish ‘unpredictable’ blaze at battery storage facility in Otay Mesa

Ohio firefighters battle burning truck carrying li-ion batteries

Officials evacuated an area west of downtown Columbus fearing a possible explosion

April 18, 2024 08:19 AM

When firefighters opened the building's doors after checking the temperature, they found it was filled with smoke. When they tried to use a smoke exhaust system outside the building, an explosion occurred, injuring four male firefighters in their 20s to 40s.

All of them are conscious, but one of them suffered severe burns to his face and hands and is hospitalized.

4 firefighters injured in Japan BESS incident

2 Firefighters injured in Neermoor, Germany incident

Battery Hazards & First Responders

Lithium ion Battery Fire Hazards:

- Flammable gas release
- Hazardous gas release
- High temperatures
- Self sustaining reaction, cell supplies O2 to support combustion
- Difficult to access cells
- Stranded energy can cause reignition
- Potential for arcflash
- Thermite reactions
- Inhalation, ingestion, absorption hazards

First Responder Needs & Considerations:

- Easy, clear Emergency Rescue/Response Guides
- Consistent training across electrified applications
- Consistent SOP
- Consistent and inexpensive tools
- “Let it burn” philosophy can help with stranded energy issues but increase exposure risks
- Water works, but use requires understanding of cell designs
- Workable procedure needed for de-energizing / preventing reignition

PPE, Defensive planning, lots of water, and patience required -
Work with your local First Responders on Response planning!

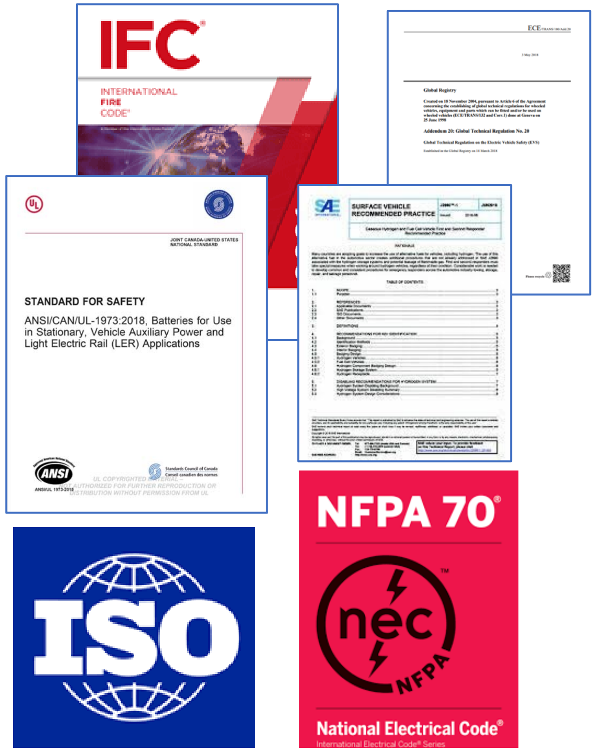
Regulations and practice

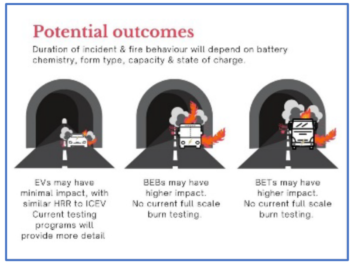
Evolving EV & Battery Safety Regulations & Standards:

- CFR-49 Part 173: Lithium cells & Batteries: https://www.ecfr.gov/current/title-49/section-173.185
- UN 3090, Lithium metal batteries (shipped by themselves)
- UN 3480, Lithium ion batteries (shipped by themselves)
- UN 3091, Lithium metal batteries contained in equipment or packed with equipment
- UN 3481, Lithium ion batteries contained in equipment or packed with equipment Code of Federal Regulations 40: Protection of the Environment Part 273
- UN38.3: Certification for Lithium-ion batteries
- IFC: 2024; Chapter 3: Section 321 Rechargeable Battery Storage
- UL 1973: Batteries for use in Stationary, Vehicle Aux Power and light rail apps
- UL9540: Safety for Energy Storage Systems
- NFPA 70: Electrical Safety
- ISO-17840: Road vehicles — Information for first and second responders
- SAE J2990: Hybrid and EV First and Second Responder Recommended Practice
- SAE J3235: BEST- PRACTICES FOR THE STORAGE OF LITHIUM-ION BATTERIES
- UL TC 1487: Battery Containment Enclosures

Code of Federal Regulations

A point in time eCFR system





Courtesy EVFiresafe

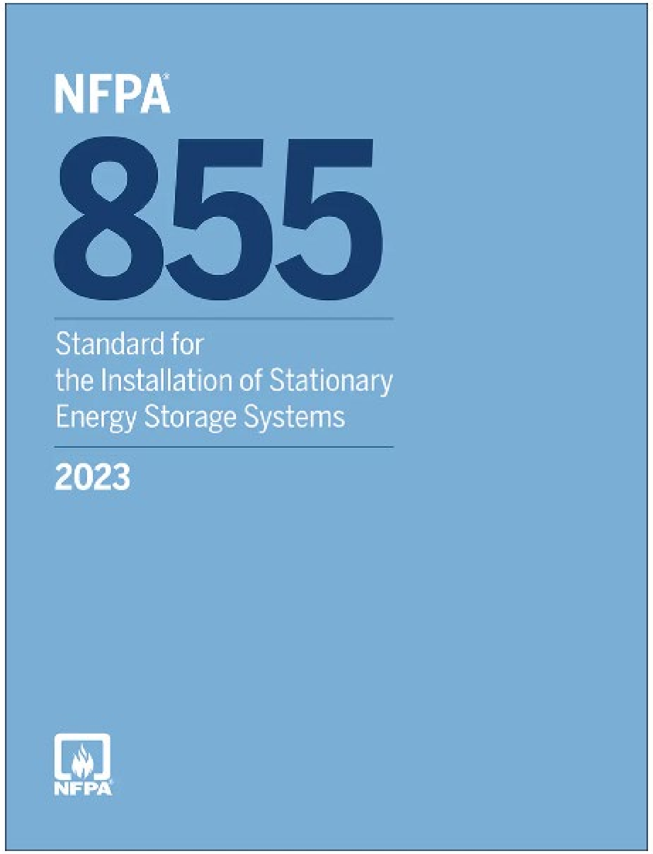
UL Standards & Engagement

Regs & Standards challenged to keep up with technology changes in the field

NFPA 855

<u>Standard for Installation of Energy Storage Systems</u>

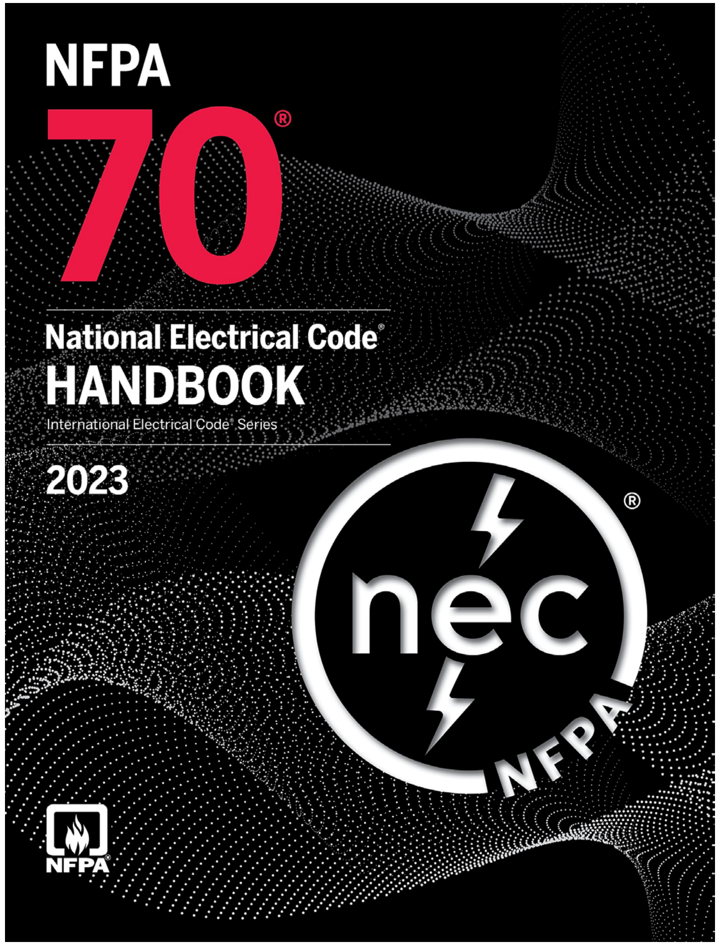
- ***Defines the design, construction, installation, commissioning, operation, maintenance, and decommissioning of stationary energy storage systems (ESS),*** including traditional battery systems used by utilities. The standard aims to help ensure that installations are performed appropriately and mitigate risks while considering life safety.
- NFPA 855 includes ***requirements for monitoring and managing ESS*** to reduce the risk of thermal runaway. It also defines an Energy Storage Management System (ESMS) that can ***monitor, control, and optimize ESS performance, and disconnect the ESS in the event of abnormal conditions***. For example, the ESMS can electrically isolate ESS components or place them in a safe condition if hazardous temperatures or other conditions are detected.
- NFPA 855 also sets rules for residential settings, including ***spacing requirements, the number of kWh per unit, and the energy rating of individual units.*** For example, the standard states that multiple storage units must be at least three feet apart, and that individual ESS units can have a maximum stored energy of 20 kWh.
- https://www.nfpa.org/codes-and-standards/nfpa-855-standard-development/855



NFPA 70

<u>**National Electrical Code:**</u>

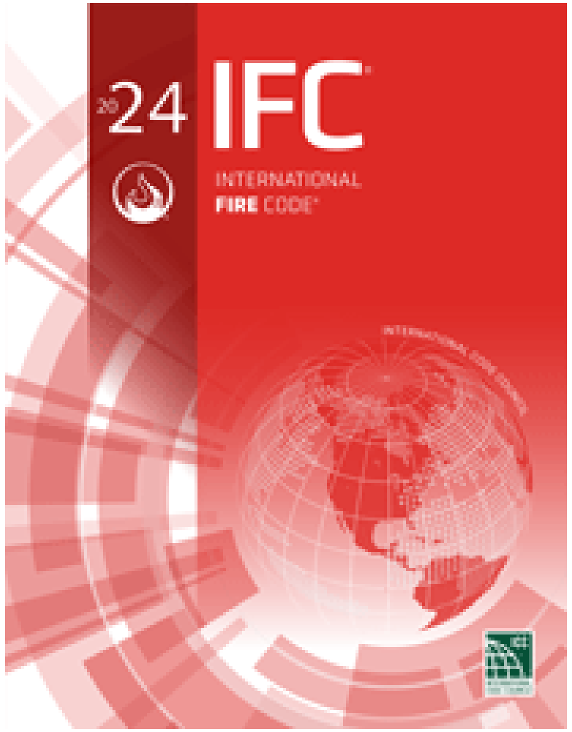
- NFPA 70, also known as the National Electrical Code (NEC), is a standard that establishes ***guidelines for the safe design, installation, and inspection of electrical systems***. It's intended to protect people and property from electrical hazards by providing practical safeguarding practices. NFPA 70 is written for high-level electricians and engineers and is enforced in all 50 states
- NFPA 70 covers the electrical installation that supplies power to equipment, but does not apply to the equipment's internal wiring, controls, or components. Instead, it covers the materials and methods used outside of the equipment. For example, NFPA 70 ***provides guidance on how to install equipment, run conduit and cable, and mount boxes***.
- NFPA 70E is another NFPA standard that provides guidance on safe electrical work practices. It defines terms such as ***arc flash, arc flash boundary, shock hazard, and arc rating***
- ***https://www.nfpa.org/codes-and-standards/nfpa-70-standard-development/70***



International Fire Code

<u>2024 Updates:</u>

- Energy Storage Systems (ESS). Continued focus on ESS. Now referencing NFPA 855 along with IFC Section 1207 to regulate Energy Storage system. The provisions continue to evolve with technologies.
- Lithium-ion batteries. Research, storage, and manufacturing of such technologies are being regulated through active systems including automatic sprinkler systems and detection requirements along with proper overall building design and construction. The IFC contains a specific section to provide tools to manage the collection of lithium-ion batteries.
- Powered micromobility devices. A section dedicated to the hazards associated with charging such devices are addressed in the IFC. This includes a number of requirements focusing on issues such as product listings, separation requirements, and use of detection systems.
- https://codes.iccsafe.org/content/IFC2024P1



Standard – UL 9540 and UL9540a

UL 9540

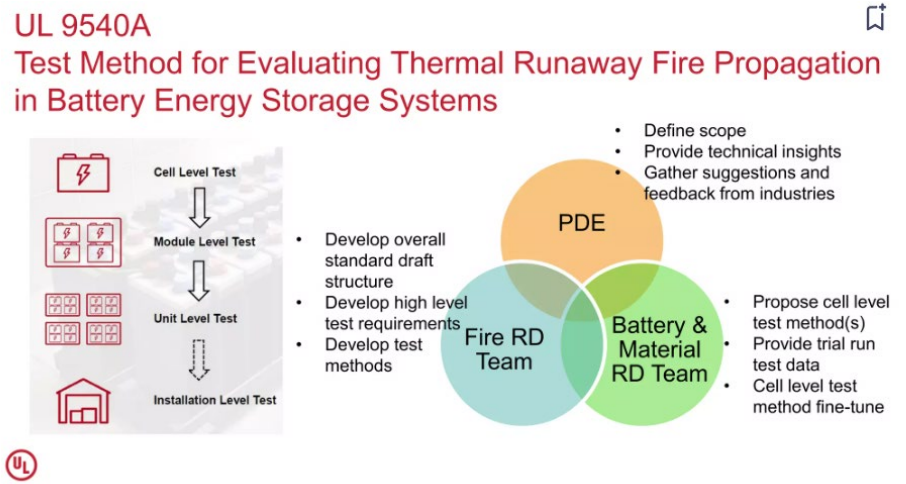
UL 9540A

UL9540:

- UL 9540 provides a ***basis for safety of energy storage systems that includes reference to critical technology safety standards and codes***, such as UL 1973, the Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications; UL 1741, the Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources; IEEE 1547 and 1547.1; CSA FC1; NFPA 70; NFPA 2; ASME Boiler and Pressure Vessel Code; and ASME B31 piping codes. It includes additional criteria to ***address materials, enclosures, including walk-in enclosures, controls, piping, utility grid interaction, including special purpose interactive systems, hazardous moving parts, signage and instructions.***

UL9540A:

- UL 9540A is a ***test method to evaluate the fire safety hazards*** associated with propagating thermal runaway within battery systems. The tests establish that a storage technology is capable of reaching thermal runaway and then assess the fire and explosion hazards of that technology
- [***https://www.ul.com/services/ul-9540a-test-method***](https://www.ul.com/services/ul-9540a-test-method)



Transport: CFR49

Code of Federal Regulations
A point in time eCFR system

CFR49 173.185 Lithium cells and batteries:

As used in this section, consignment means one or more packages of hazardous materials accepted by an operator from one shipper at one time and at one address, receipted for in one lot and moving to one consignee at one destination address. Equipment means the device or apparatus for which the lithium cells or batteries will provide electrical power for its operation. Lithium cell(s) or battery(ies) includes both lithium metal and lithium ion chemistries. Medical device means an instrument, apparatus, implement, machine, contrivance, implant, or in vitro reagent, including any component, part, or accessory thereof, which is intended for use in the diagnosis of disease or other conditions, or in the cure, mitigation, treatment, or prevention of disease, of a person.

https://www.ecfr.gov/current/title-49/subtitle-B/chapter-I/subchapter-C/part-173/subpart-E/section-173.185

Transport: UN3480 and UN 38.3:

- **UN3480:**
- UN3480 is the UN ID for lithium ion batteries that are ***not packed with or installed in equipment***. There is one entry in the DOT Hazardous Materials Table for UN3480. UN3480 - Hazard Class 9, Lithium ion batteries [including lithium ion polymer batteries]

UN38.3:

- UN 38.3 is a United Nations (UN) standard that ***regulates the transportation of lithium batteries and cells. It applies to all stages of transportation, including when batteries are in or out of products, being returned, or in non-original packaging***. The standard also covers the design, manufacturing, and distribution of lithium batteries and products that use them
- https://unece.org/fileadmin/DAM/trans/danger/ST_SG_AC.10_11_Rev6_E_WEB_-With_corrections_from_Corr.1.pdf

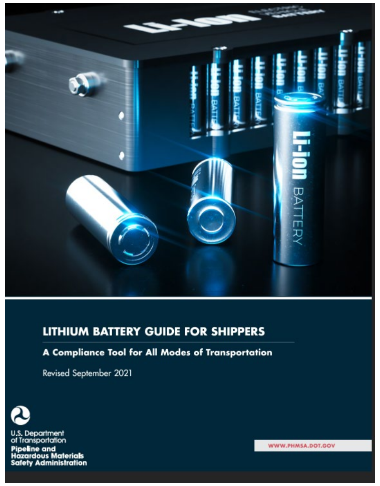
Resources:

U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration

DOT PHMSA - Transporting Lithium Batteries:

- https://www.phmsa.dot.gov/lithiumbatteries
- https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/2021-09/Lithium-Battery-Guide.pdf

- Resources for Recycling Batteries
- Resources for Shippers
- Lithium Battery Test Summaries
- Resources on Lithium Batteries by Air
- Resources for Airline Passengers
- Public Safety Resources
- Hazardous Materials Information Center



Sandia National Lab – Energy Storage Safety:

Sandia National Laboratories
Energy Storage Safety

- Informs updates and enhancements to codes and standards
- Facilitates the use of the provisions of adopted codes and standards
- Helps educate the public and relevant stakeholders in the application of ESSs and how to best respond to any safety-related ESS incidents
- https://www.sandia.gov/energystoragesafety/

Resources:

NFPA Battery Safety

- https://www.nfpa.org/education-and-research/home-fire-safety/lithium-ion-batteries
- https://www.nfpa.org/forms/energy-storage-systems-safety-fact-sheet

UL Electrochemical Safety Research Institute:

- https://ul.org/research/electrochemical-safety
- In recent years, renewable energy technologies have emerged as one of the highest priority solutions to climate change. But they also present very real risks; for example, key chemicals inside lithium-ion batteries pose life-threatening harm if they aren't manufactured, stored, and recycled correctly. Our scientists explore the safety and performance limits of storage batteries and other renewable energy technologies and investigate how we can overcome those limits safely

Research Institutes

News
February 29, 2024

ULRI Scientist Calls for Building Fire Suppression Aid Into Lithium-Ion Battery Design