Lithium Battery Deployments

Staying Up To Date With Code Changes

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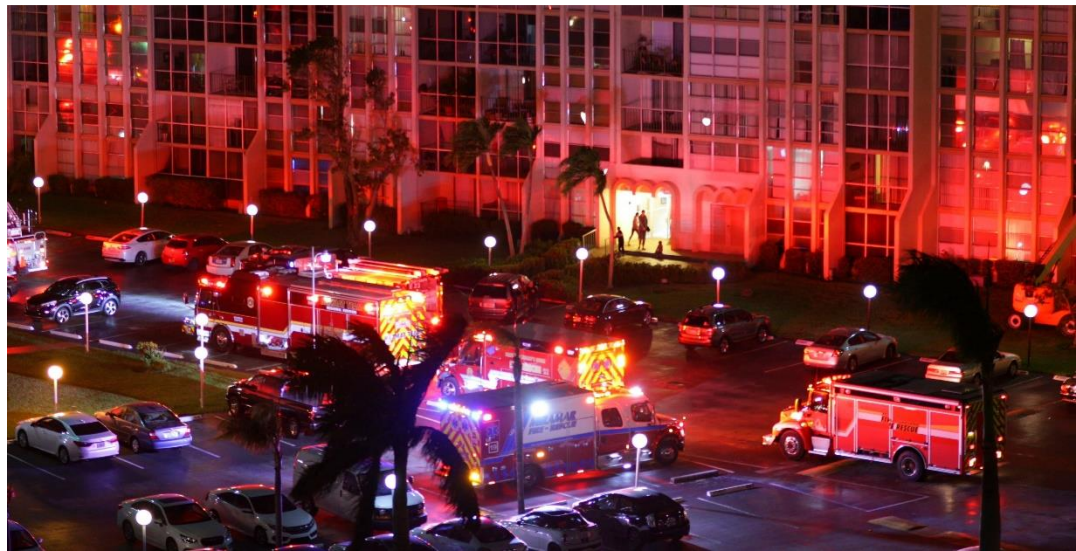
What should you expect in the next few years – technology changes, industrial standards, recycling, etc.

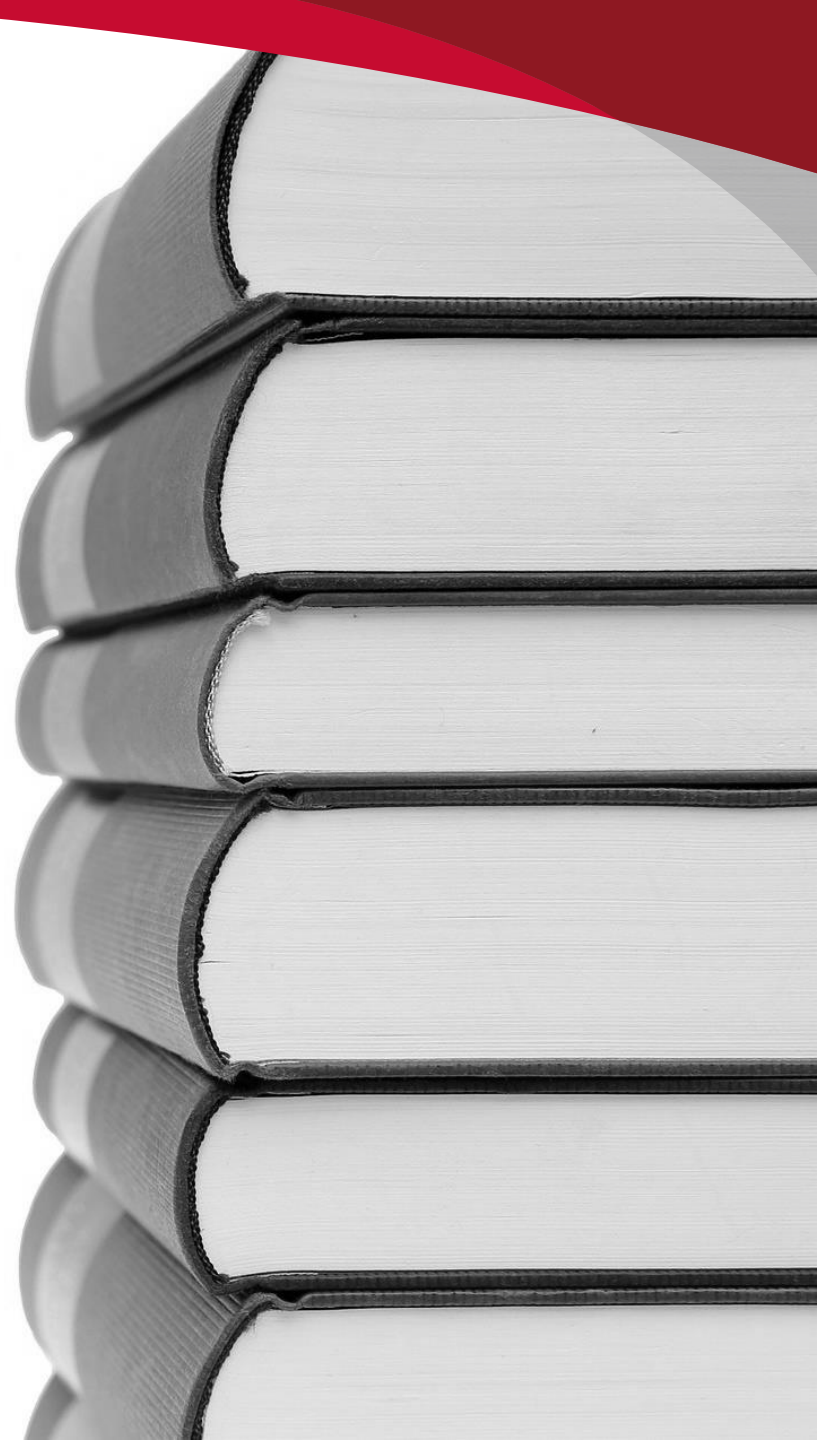
Drivers for New Codes

- Increasing Energy Storage – Microgrids in urban locations
- Energy storage in high rise / mixed use
- Perceived Fire Risk – Lithium/Electrolyte
- First Responder Safety - Unknown fire-fighting strategy – proper suppressing agents
  - Initial Suppression vs Longer Term Suppression
- Thermal Runaway



UL Regulations

- **UL 1973** – Batteries with Battery Management Electronics
- **UL 1989** – Replacement Lead Acid (UPS)
- **UL 1778** – UPS System *(includes batteries)*
- **UL 9540** – All Stationary Battery Applications
  (but intended for lithium)
- **UL 9540A** – A Full Fire Propagation Tests
- **UL 1741** – Chargers *(integrated as well)*
- **UL 1642** – Rechargeable Lithium Ion Cells



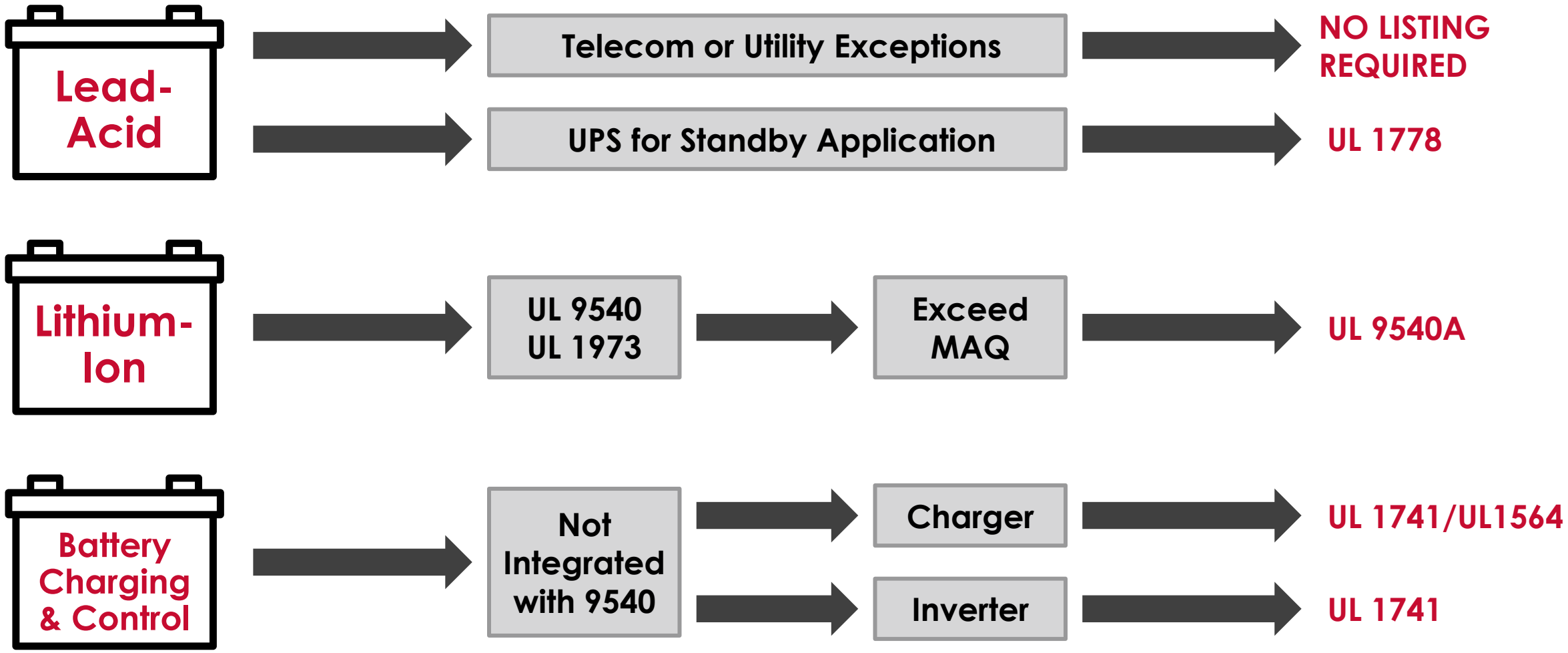
Safety – UL1642/UL2054

UL Standard for Lithium Batteries

- Electrical abuse – overcharge, over discharge, short circuit
- Mechanical abuse – crush, pierce, heat, +

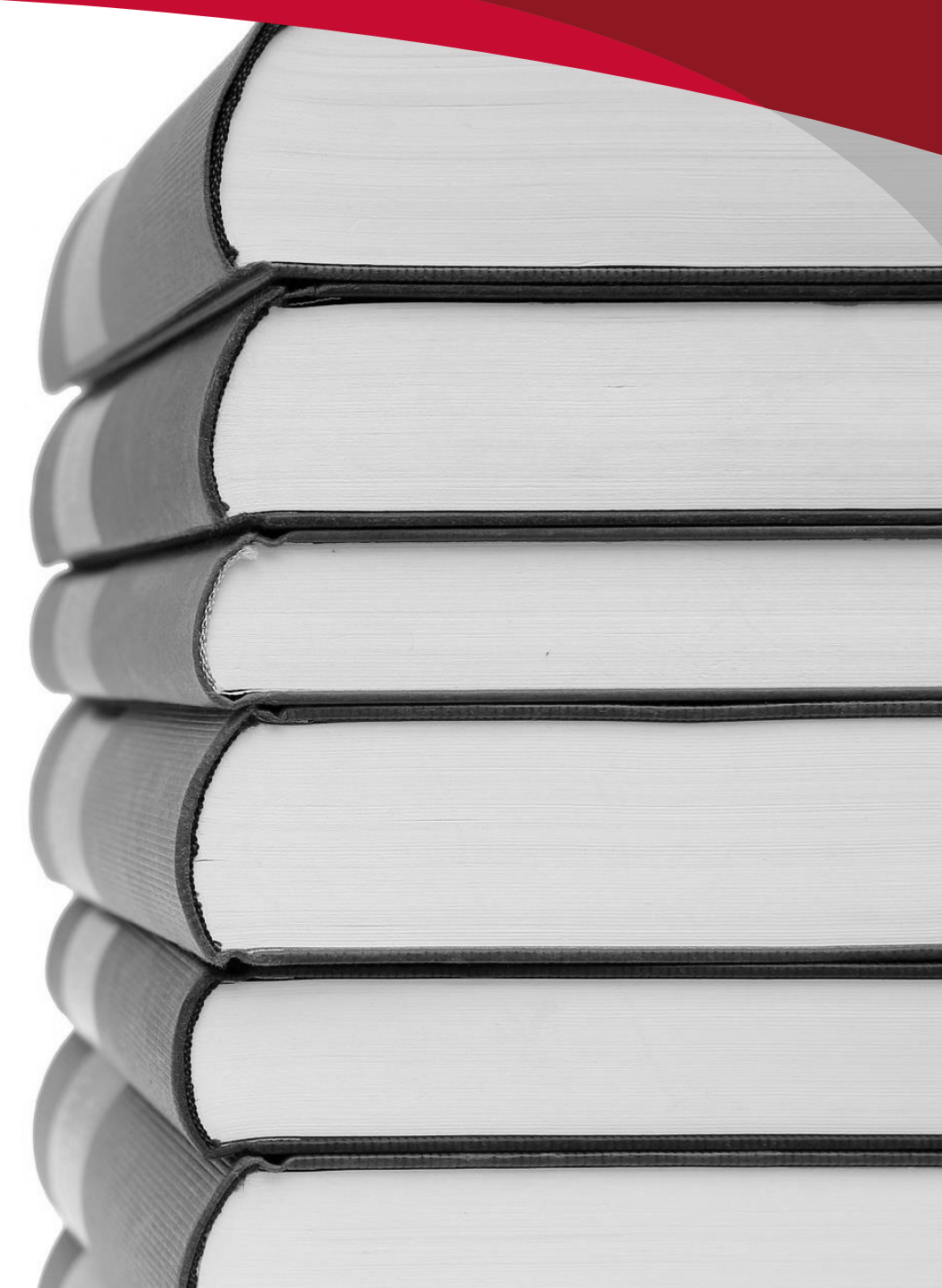
- Passed UL Testing
  - "The samples shall not explode or catch fire."
  - Proper and controlled venting may prevent flaming

Code Compliance – Local Codes Rule



Applicable Codes

- **NFPA-855 Energy Storage (2020)**
- NFPA-1 Fire Code Chapter 52 (2018)
- NFPA-1 Fire Code Chapter 52 (2021)
- IFC (2018) Section 12
- **IFC (2021) Section 12**
- NFPA-111
- NFPA-70 (NEC) Article 480 / 706



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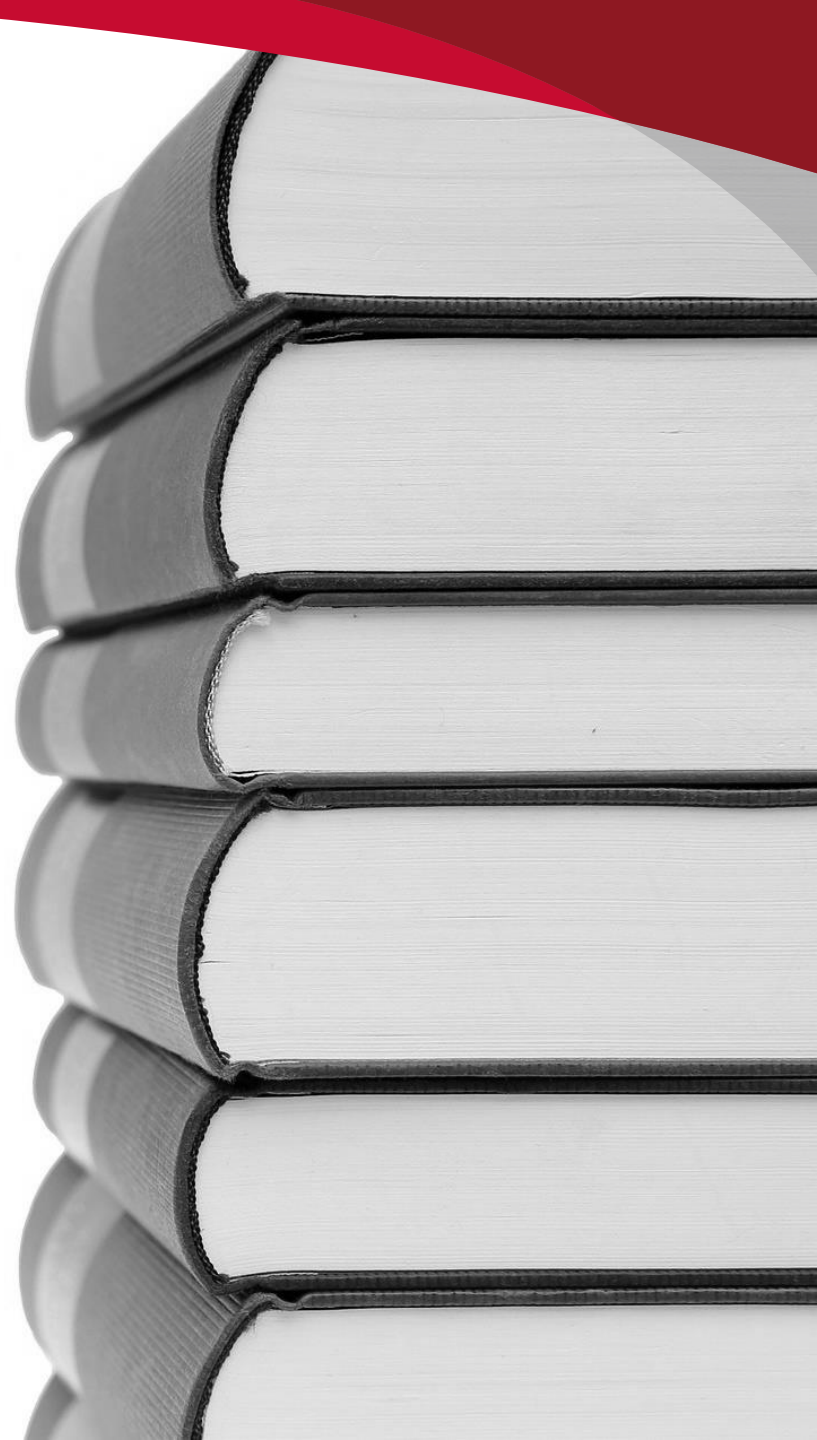


NEC/NFPA 70 - National Electrical Code

- Specific battery and DC systems sections – section 480 Storage Batteries (625 EV, 690 PV,+ etc)
- Canadian Electrical Code (CSA C22.1) similar
- IEC 60234 - International electrical code

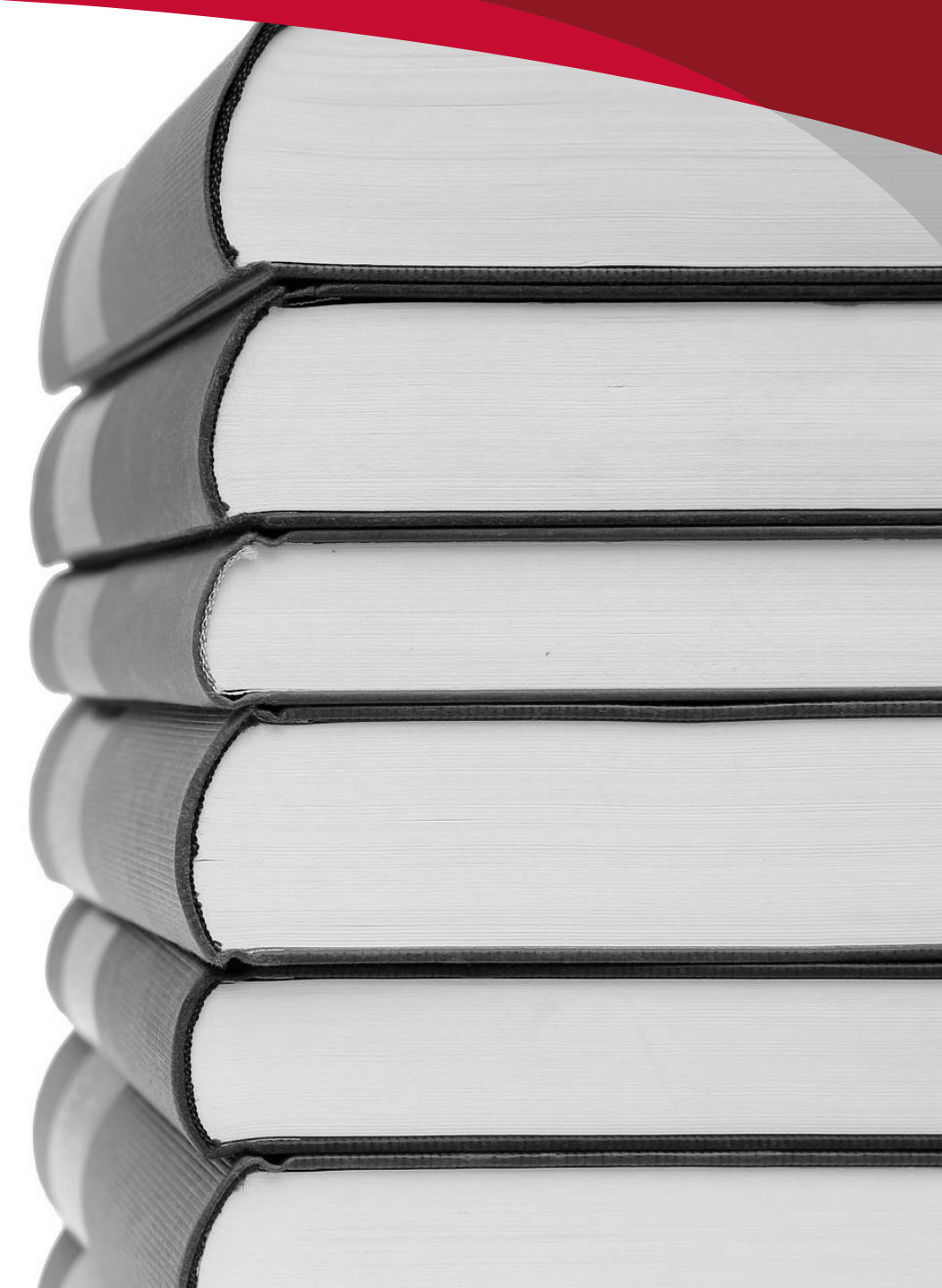
Fire Codes

- IFC – International Fire Code (IFC plans to match NFPA855)
- Section 608 (similar to NFPA 1)
- Max quantities, signage, fire suppression, +

… and the list is growing (NFPA 855)

New Requirements

- Maximum Allowable Quantity (MAQ)
- Maximum Array, Group, String Size
- Location Restrictions (within building)
- Separation Criteria (walls or other obstructions)
- Listing criteria (UL)
- Operational Requirements (permits, commissioning, decommissioning)
- Hazard Mitigation Criteria
- Ventilation



Maximum Allowable Quantity (MAQ)

IFC, NFPA-855 and NFPA-1 MAXIMUM ALLOWABLE QUANTITIES (MAQ)		
BATTERY TECHNOLOGY	**MAXIMUM ALLOWABLE Quantities [a]**	**GROUP H OCCUPANCY**
Lead acid, all types	unlimited	Not Applicable
Nickel cadmium (Ni-Cd)	unlimited	Not Applicable
Lithium, all types	600 KW-h	Group H-2
Sodium, all types	600 KW-h	Group H-2
Flow batteries [b]	600 KW-h	Group H-2
Other battery technologies	200 KW-h	Group H-2 [c]
a. For batteries rated in Amp-Hours, Watt-hours (KWh) shall equal rated battery voltage times the Amp-hour rating divided by 1000		
b. Shall include vanadium, zinc-bromine, polysulfide-bromide, and other flowing electrolyte type technologies		
c. Shall be a Group H-4 occupancy if the fire code official determines that a fire or thermal runaway involving the battery technology does not represent a significant fire hazard		

- Maximum Allowable Quantities for different types of batteries are **defined in IFC chapter 12 and NFPA-1 chapter 52 and NFPA-855**
- 2018 and 2021 editions of IFC and 2020 NFPA-855 will be harmonized with the values shown in the table
- If a user or site **exceeds or is planned to exceed** these maximum allowable quantities, the facility will need to be **classified as a high hazard occupancy and be subjected to increased physical and operational criteria** as described in the occupancy sections of the IFC/IBC or NFPA-1
- The **high hazard designation has consequences in allowed uses** for the building, fire protection measures, and construction

Chemical Specific Criteria – NFPA-855

NFPA-855 Table 9.2 Technology Specific Requirements

Compliance Required	Lead-Acid (VLA)	Lead-Acid (VRLA)	Lithium Ion (Li-Ion)	Reference Section
Exhaust ventilation	Yes	Yes	No	Section 4.9
Spill control	Yes	No	No	Section 4.14
Neutralization	Yes	No	No	Section 4.15
Safety caps	Yes	Yes	No	Section 9.4
Thermal runaway	No	Yes	Yes**	Section 9.3
Explosion Control	Yes*	Yes*	Yes	Section 4.12
Size and separation	Yes	Yes***	Yes	Section 4.6

*Explosion control is not needed for:

- Lead-acid systems less than 50V ac or 60V dc for dedicated telecom installations in compliance with NFPA-76
- Electrical utility systems in accordance with IEEE C2 under exclusive control of utility
- UPS systems listed per UL 1778 housed in racks or cabinets in equipment area of a building***

**Thermal runaway protection permitted to be part of BMS system evaluated to UL 1973 or UL 9540

Location Example – Building Elevation Criteria

Electrochemical ESS shall not be located in the following areas:

1. Where the floor is located more than 75 feet (22 860 mm) above the lowest level of fire department vehicle access, or
2. Where the floor is located below the lowest level of exit discharge

Exceptions to elevation criteria:

- Lead-acid telecom
- Lead-acid utility
- Lead-acid UPS
- Lithium / Lead-acid underground vaults complying with NFPA 70, Article 450, Part III.
- Where approved by the fire code official, installations shall be permitted on higher and lower floors

IFC & NFPA Separation Criteria

- Electrochemical ESS shall be segregated into groups not exceeding **50 KWh** (180 Mega joules)
- Each group shall be **separated a minimum three feet (914 mm)** from other groups and from walls in the storage room or area. The storage arrangements shall comply with Chapter 10.

Exceptions to maximum group/string size and separation:

- Lead-acid telecom
- Lead-acid utility
- Lead-acid UPS
  - Comply with UL1989 & UL1778

Separation Criteria

Indoor: 3 ft. from walls, equipment, other obstructions

Exception: Lead acid and nickel cadmium storage battery arrays. The fire code official is authorized to approve listed pre-engineered and prepackaged battery arrays with larger capacities or smaller battery array spacing if large scale fire and fault condition testing conducted or witnessed and reported by an approved testing laboratory is provided showing that a fire involving one array will not propagate to an adjacent array, and be contained within the room for a duration equal to the fire resistance rating of the room separation specified in Table 509 of the International Building Code.

Outdoor: 10 ft. from lot lines, public ways, buildings, stored combustible materials, hazardous materials, high-piled stock, and other exposure hazards.

EXCEPTIONS APPLY!

Shipping of Lithium-Ion Batteries

Numerous regulations – must know what you have:
lithium battery type, size of battery, in equipment, condition of battery, + more

- UN Manual of Tests and Criteria Part III Subsection 38.3 [B6]
- US DOT, HMR 49 CFR, Section 171-180: 172 (shipping), 173 (packaging)
- ICAO, IATA – Air Transport
- IMDG – Int'l Maritime Dangerous Goods code
- IEC 62281 (B2)
- +others

… ship at 30% SOC or less, cargo-only aircraft (maybe), Class 9 Dangerous Goods

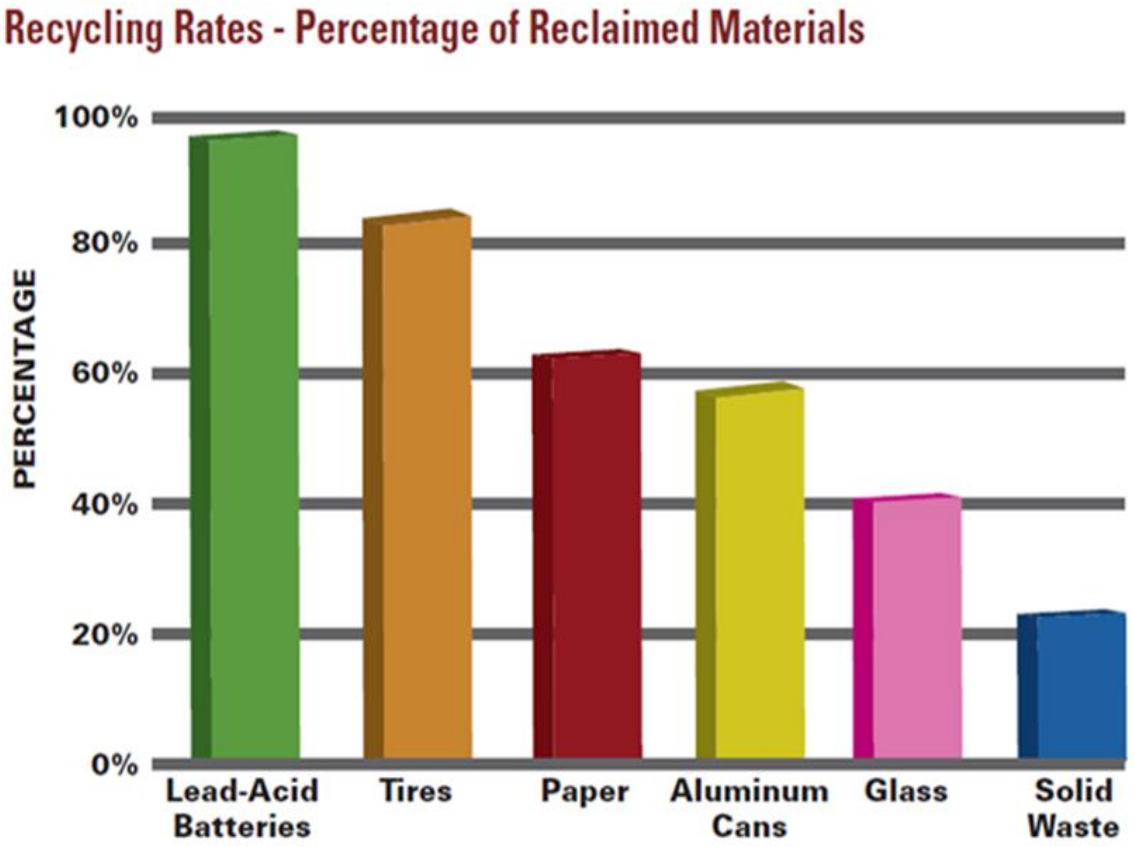
Li-Ion Battery Disposal

Currently

- Batteries in general are covered as hazardous waste under 40 CFR (Code of Federal Regulations), Part 273
- May be hazardous depending on metals and electrolyte formulas
- Personnel protection always required; disposal often not specifically regulated (much ends up at lead smelters which causes issues)
- Required collection in some areas – supplier should take back depleted batteries
- Lithium is not in short supply in the world, other metals may be

Lead-Acid Recycling Success Story

- More than **99%** of lead batteries are recycled
- Most recycled product in the U.S.
- Lead can be recycled infinitely without loss of performance
- Modern, close-looped recycling keeps more than **122 million** lead batteries from landfills each year



Recycling Example – EPRI

Estimated Disposal Costs of a 1MWh Li-Ion NMC Energy Storage System

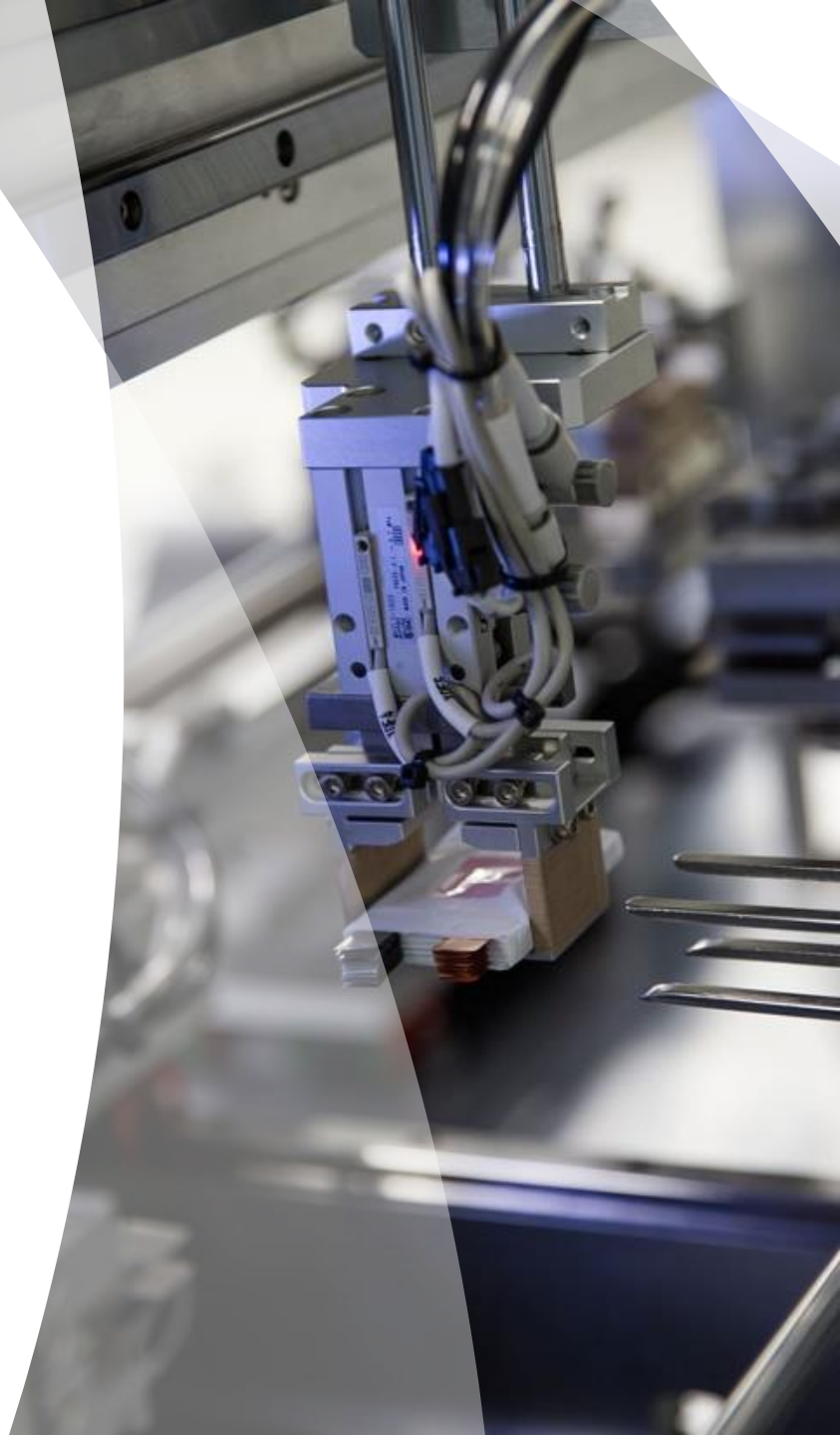
Description	Cost
Preparation and Post-Site Work	$2,800
Container Housing	$1,400
Battery Components	$75,350
Power Conversion System (PCS)	$6,100
System Controls and Communications	$350
HVAC Thermal Management System	$2,100
Fire Suppression System	$1,700
Additional Equipment	$1,700
Total Disposal and Recycling Costs	**$91,500**

Electric Power Research Institute (EPRI), Dec. 2017

Summary – Advantages

Compared to the most lead-acid batteries, **lithium has advantages in performance**:

- Half the weight
- Half the volume
- Higher cycle life
- Large temperature window
- Higher round trip efficiency



Summary – Disadvantages

Lithium also has disadvantages to consider when deploying in industrial settings:

- Operation windows are strict and inflexible
  - LVD is built in and can't be bypassed
  - High temp will disable battery
  - High rates cannot be accommodated
- Existing charger may not be compatible
- BMS introduces electronic failure modes (MTBF)
  - Single points of failure per module
- New Codes for deployment increase installation and site prep costs
- Most insurance carriers have increased coverage premiums

Summary

- Installations defined by local regulations – Fire/electrical/building
- No IEEE or industry standards (yet) on sizing, installation, testing or maintenance – full reliance on manufacturers' recommendations
- Safety aspects must be considered
  - Ambient temp
  - Ventilation
  - Fire suppression
  - Personnel safety
- Cost – initial cost vs. life-cycle costs must be evaluated

Is Lithium-Ion the Battery Technology of the Future – *for You*?

Thank you.

Questions Welcome