Lithium-ion UPS trends and installation considerations

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Purpose and Learning Objectives

- Purpose of this class is:
  - Overview lithium-ion batteries for UPS
  - Discuss applications for lithium outside the data center
  - Describe important considerations for successful lithium ion installations and code
- At the end of this presentation, you will be able to:
  - Be aware of lithium installation requirements
  - Understanding the basics of applying lithium in non-datacenter applications

Lithium-ion today

What’s new in battery technology?

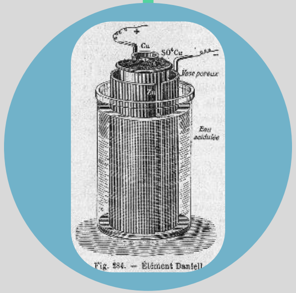
A slow evolution…

1800

Voltaic pile
“First battery”
Alessandro Volta

Porous pot cell
Dancer

1838



1859

“Original”
lead-acid cell
Gaston Plante

Flooded & VRLA
lead-acid batteries

2017

2018+

Modern lithium-ion

Source: https://en.wikipedia.org/wiki/History_of_the_battery

Benefits: comparing lithium-ion to VRLA

VRLA
Floor space

Lithium

- 58% smaller
- 75% less weight
- BMS included
- >8x # of cycles
- >2.4x life and warranty
- Higher operating temp (0 - 40°C)

example

example

	Lead acid VRLA	LMO Lithium
kW		200
kWh	33	33
Weight (lbs.)	4855	1213
In²	1436	624

Lithium-ion ideal when…

Size and weight are important

Battery monitoring/ management is required

High cycle count and long life are important

Lithium-ion batteries are safe in UPS applications:

1. Battery Management System (BMS) is included on every cabinet and every system
2. Using safest choice for lithium-ion chemistry for UPS application
3. Systems always designed to release heat faster than it can build up, limiting possibility of thermal runaway

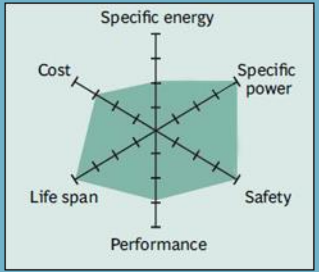
Most lithium-ion solutions comply with:

- **UL 1642** – Standard for lithium-ion batteries
- **UL 1973** – Batteries for use in stationary applications
- **UL 1998** – Standard for software in programmable components
- **UL 991** – Standard for tests for safety-related controls employing solid state devices
- **UL 9540A** – Test method for lithium battery systems — NOT a ‘listing’
- **UN 38.3** – Lithium battery transportation safety

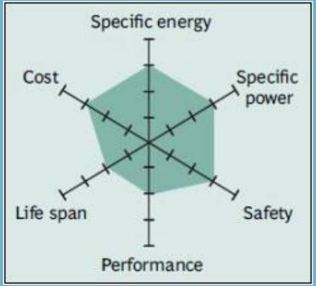
Lithium-ion ideal use cases:

1. Battery energy storage (BESS)
2. Outdoor UPS installations
3. Distributed Energy Resources (DERs)

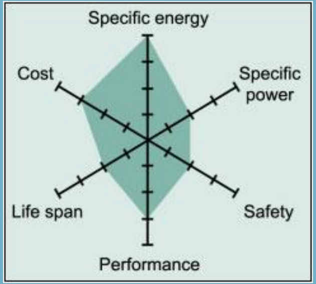
Lithium-ion chemistry
NMC vs. LFP



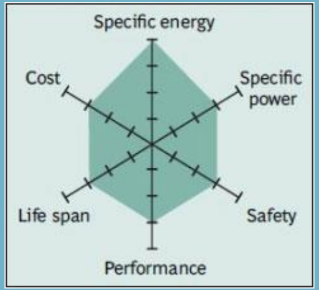
Lithium Iron Phosphate
- Acronym: LFP
- Thermal runaway: 270°C



Lithium Manganese Oxide
- Acronym: LMO
- Thermal runaway: 255°C



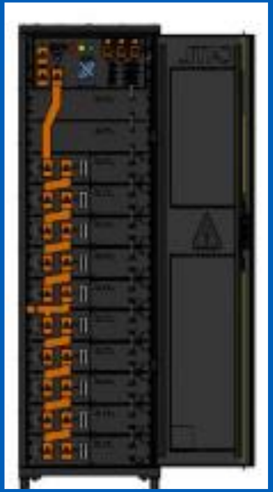
Lithium Cobalt Oxide
- Acronym: LCO
- Thermal runaway: 170°C



Lithium Nickel Manganese Cobalt Oxide
- Acronym: NMC
- Thermal runaway: 215°C

Definitions
- ✓ ***Specific energy:*** Capacity that relates to runtime
- ✓ ***Specific power:*** The ability to deliver high current
- ✓ ***Performance**:* *At hot and cold temperatures*
- ✓ ***Lifespan**:* Reflecting cycle life and longevity

Source http://batteryuniversity.com/learn/article/types_of_lithium_ion



example

Lithium chemistry LMO+NMC
- Origins in automotive use drove high physical density
- Enhancements for thermal performance
- Best price/performance for short-backup UPS

Lithium Iron Phosphate LiFe04
- Slightly larger footprint
- Easier path to UL9540A
- Works for UPS and for BESS
- Narrowing price gap vs NMC

Lithium adoption continues to grow

60%

Customers continue to adopt lithium for UPS and energy storage applications. In 2022, 60% of customers requesting lithium for systems ≥200kW

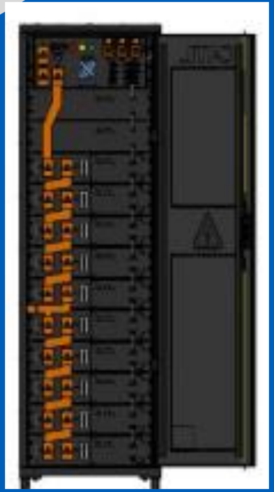
UL 9540A testing requirement adds further fire protection to lithium cabinet designs

Deployment easier than ever

- Fully assembled cabinets from factory
- Internal BMS control power from the DC bus
- New designs allow for outdoor deployment

Advancements in outdoor installations make lithium a viable “green” option to replace traditional generators

Testing to UL 9540A means 3-ft. gap between cabinets, 50kWh max block, and 600kWh per room limitations may <u>not</u> be required.



example

Lithium-ion trends

- ✓ Energy storage systems
- ✓ Demand management programs

Data center customers have large battery banks that often sit unused

- The UPS is a vital piece of technology for any data center, providing critical backup power to ensure business continuity in the event of an outage
- Outages, however, are infrequent, which often renders the UPS/battery an underutilized asset

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UPS as an energy asset

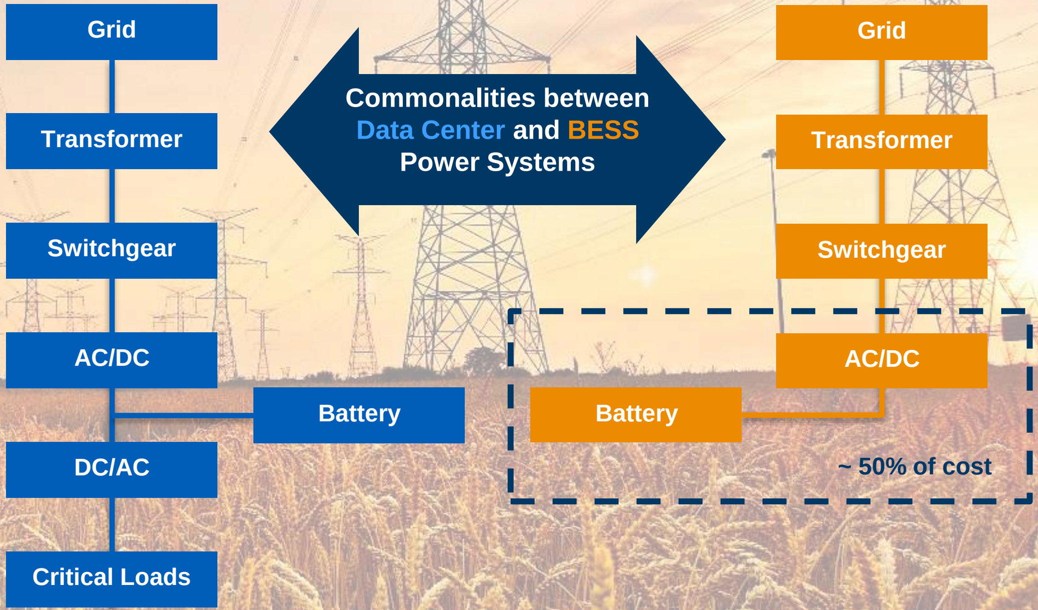
1. The UPS has inherent flexibility to reduce and modify your site’s electricity consumption from the power grid
2. With intelligent controls, customers can participate in electricity markets to generate revenue, save money, and improve grid resiliency
3. Customer defined parameters ensure UPS system supports critical load functionality and site resiliency when participating in markets

UPS as Battery Energy Storage System (BESS)

Commonality between battery energy storage systems and data center power infrastructure are creating new opportunities and business models

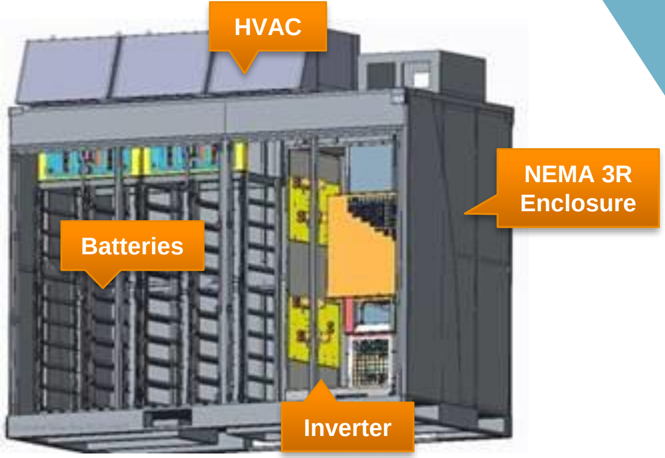
≈ 1500 kW

≈ 200 kWh



Energy storage applications

examples



Certifications:

- ✓ UL 9540, 9540a
- ✓ UL1741, 1741SA
- ✓ UL 50, 50E
- ✓ NFPA 855
- ✓ NEMA 3R

- ✓ Battery is optimized for peak shaving or long duration backup
- ✓ Enables outdoor deployment to save space in datacenters
- ✓ Ideal for C&I applications

Typical Example

System Stats:

400kW / 228kWh rating

- 480V 60hz 3-wire + ground
- 200kWh available through year 10
- 1 cycle/day (3650 lifetime)
- 100kW charging power limit
- -30°C to 50°C external temperature

Construction:

NEMA 3R outdoor enclosure with HVAC

- 6ft deep x 12ft wide x 10ft high
- Size of a parking spot

Lithium-ion:
“Energy” vs “Power”

Energy vs. power batteries

Power, energy and C-rate

Power (kW or MW)

Is the peak energy that can be used at any point in time.

Energy (kWh or MWh)

Is the storage capacity.

Common terminology but both have the same meaning:

- 100kW / 200kWh
- 100kW 2-hour

VS.

C-rate

Is a measure of the **rate** a battery is discharged (or charged). Examples include:

- 2C = entire battery discharged in 30 minutes
- 1C = entire battery discharged in 1 hour
- 0.5C = entire battery discharged in 2 hours

Think of C-rate as an operating limit:

- Ok to discharge more slowly, not ok to discharge fast
- Pay a premium for high C-rate batteries

Example:

400kW / 200kWh (or 400kW ½-hour) product

- 400kW - peak power at any point in time
- 200kWh - total amount of energy available
- 30 minutes - run time at peak power

1) What C-rate batteries are needed? **2C**
2) Can it run for 1 hour when the load is only 200kW? **Yes, this is below the 2C operating limit.**
3) What if the customer wants it to run for 2 hours? They're asking for 100kW / 200kWh (or 100kW 2-hour).

   It can do that, but 2C batteries are more costly. 2C may be too expensive for that application, where 0.5C would be sufficient.

Battery life for energy storage purposes

Most customers expect 10 to 15-year life.
Control degradation factors:

- Specify number of cycles
- Limit charging rate
- Stay within temperature band

Degradation controls are trade-offs:

- Multiple ways to achieve desired lifetime
- Need to understand customer's application

Battery degradation factors

Major

- Number of cycles
- Charge rate
- Temperature

Minor

- Time at min/max state of charge
- Min/max state of charge
- Age

Example charging limitations

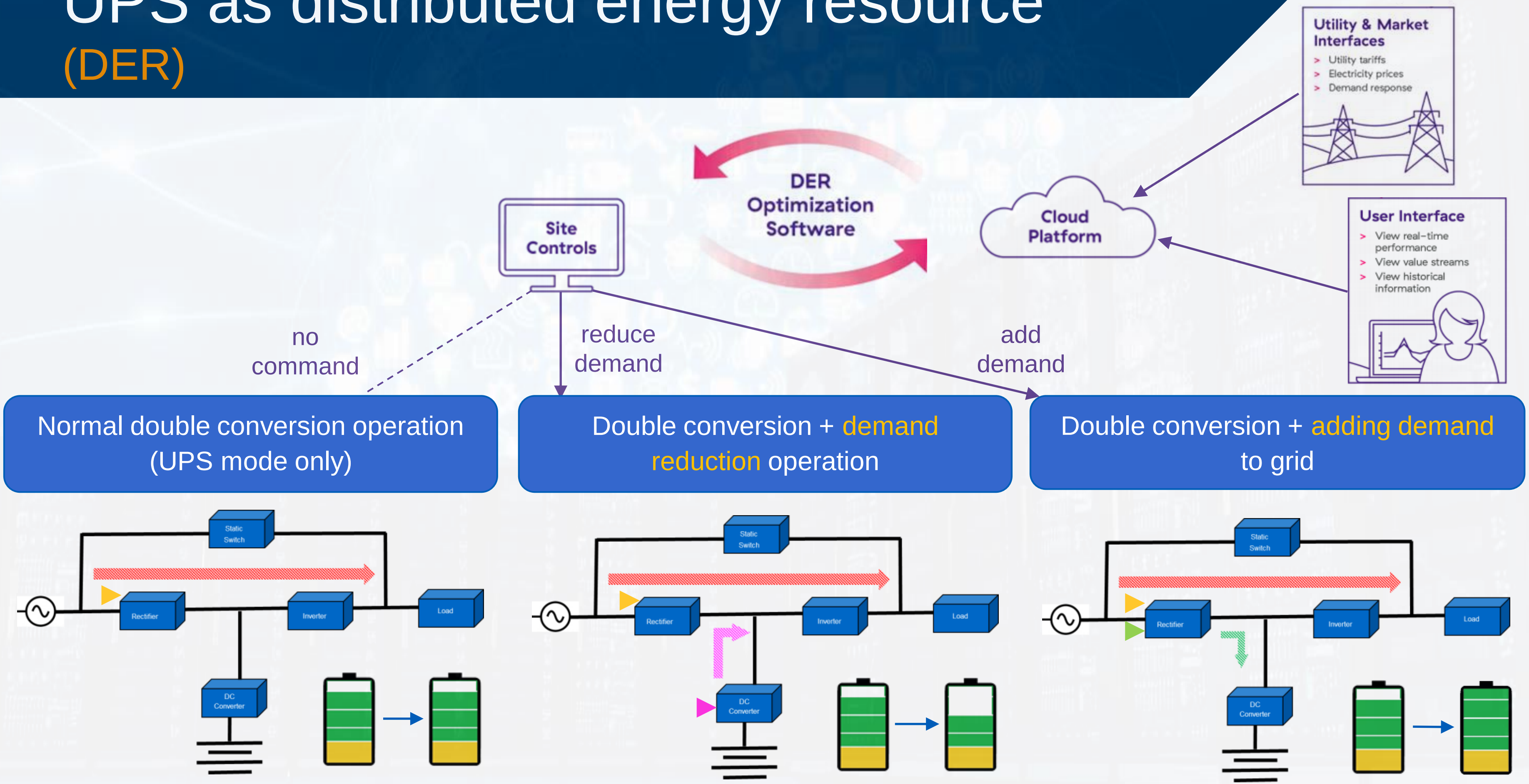
Theory

- C-rate also applies to charging

Reality

- That's accurate up to 80% charge, but the last 20% takes a little longer
- Charging at the maximum rate affects battery life
- Slower charging is appropriate in most applications

UPS as distributed energy resource (DER)



Peak shaving for C&I
(Commercial & Industrial)

Generate revenue through utility programs

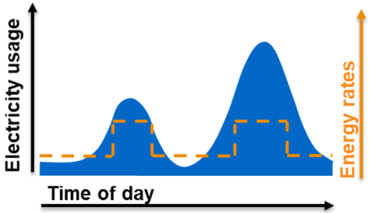
Reduce OpEx through cost avoidance

Coincident peak programs:

Curtail energy usage a few times per year to earn extra revenue from the utility. With EnergyAware, there's no effect on day-to-day operations.

Time-of-use optimization:

Shift energy consumption to avoid times of high energy prices



Generator alternative:

Ride through longer outages without starting a backup generator (and reduce carbon emissions)

Enable facilities to transition from energy consumers to energy assets on the grid

Regional example

1MW UPS deployment

35 minutes CAPEX	35 minutes financing	2 hours CAPEX	2 hours financing
• ~$38k net revenue in 2021 from Demand Response programs	• ~$? net revenue in 2021 from Demand Response programs	• ~$69k net revenue in 2021 from Demand Response programs	• ~$? net revenue in 2021 from Demand Response programs
• Expected incremental CAPEX is $100k	• Incremental CAPEX is $0	• Expected incremental CAPEX is $430k	• Incremental CAPEX is $0
• 2.5 year simple payback	• No risk	• 6-year simple payback	• No risk
		• No emissions	• No emissions

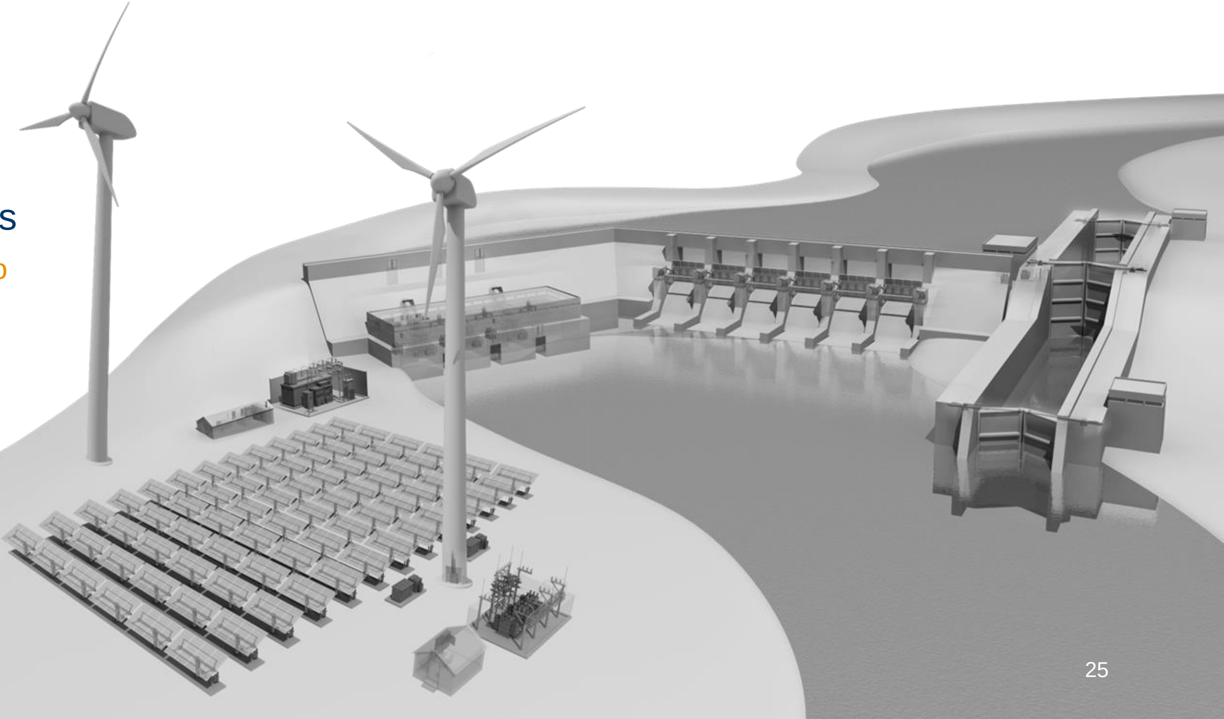
Regional example (different RTO)

1MW UPS deployment

35 minutes CAPEX	35 minutes financing	2 hours CAPEX	2 hours financing
• ~$20k net revenue in 2021 from Demand Response programs	• ~$? net revenue in 2021 from Demand Response programs	• ~$67k net revenue in 2021 from Demand Response programs	• ~$? net revenue in 2021 from Demand Response programs
• Expected incremental CAPEX is $100k	• Incremental CAPEX is $0	• Expected incremental CAPEX is $250k	• Incremental CAPEX is $0
• 5-year simple payback	• No risk	• 6.5-year simple payback	• No risk
		• No emissions	• No emissions

Is my facility a candidate for
Energy Storage?

1. Does the utility rate structure include high demand charges (peak penalties or tariffs)?
2. Does the utility rate structure include Time-of-Use rates (varying rates based on time of day)?
3. Is the facility integrating solar infrastructure? (optimize self consumption)
4. Does the customer participate in Demand Response programs today? (load shedding or offloading to gensets)
5. Are there other energy management challenges to address?

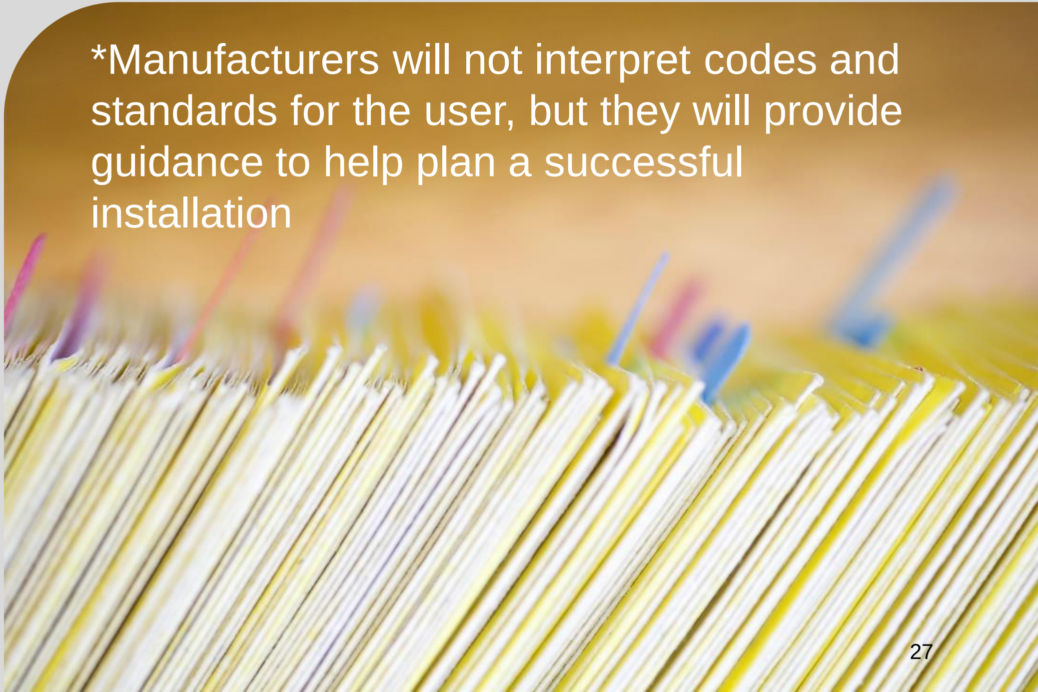


Lithium-ion deployments

Review of codes and standards for installations

Navigating the codes & requirements*

- UL 1778
- IFC 1206 or 1207
- UN38.3
- UL 9540A
- NFPA 855
- UL 1973
- FMEA MIL-STD 1629A



*Manufacturers will not interpret codes and standards for the user, but they will provide guidance to help plan a successful installation

NFPA 855, IFC 1206 or 1207

IFC 1206/7

NFPA 855

Lithium-ion installations may be required to comply with any or all the below, plus local codes!

NFPA 855 (2020)

- Aligns with international fire code IFC 1206 or 7, but the language is not identical

IFC 1206 or 1207

- Replaces the former IFC 608 for stationary battery installations

NFPA 855 also

- Consolidates the requirement cross references between the International Fire Code and International Building Code.

2021 IFC Requirements

What size battery systems comply with the fire code?

TABLE 1206.2
BATTERY STORAGE SYSTEM THRESHOLD QUANTITIES.

BATTERY TECHNOLOGY	CAPACITY[a]
Flow batteries[b]	20 kWh
Lead acid, all types	70 kWh
Lithium, all types	20 kWh
Nickel cadmium (Ni-Cd)	70 kWh
Sodium, all types	20 kWh[c]
Other battery technologies	10 kWh

examples

Lithium-ion cabinets could have a range of 15 to 34 kWh capacity, and thus exceed the threshold quantity.
So they are required to meet Section 1206 and 1207 guidelines

2021 IFC Requirements

Section 1206 and 1207 – Special requirements for lithium

Most requirements affecting VRLA will be the same for lithium-ion battery systems i.e., seismic, smoke/gas detection, ventilation, fire suppression, etc.

Capacity threshold for code compliance

<20kWh → Code compliance NOT required

>20kWh →

Room location	Max qty in room	UL listings required	Battery Management System (BMS)	Electrolyte quantity
75’ above or 30’ below street level (fire dept. access)	600kWh affects building hazardous occupancy class—H2 Cabinet Spacing—3 ft. all sides, unless waived by AHJ using UL 9540A test	UL 1973 which includes UL 1998 for BMS	REQUIRED!!	>1000 lbs. for lithium (vs. 50 gal. for VRLA), require ‘incidental use’ classification for the battery room. A typical lithium cabinet contains 100-120 lbs. of electrolyte

2021 IFC Requirements

Section 1206 and 1207 – Seismic requirements for lithium

Must comply with IBC (building code) Section 16

Section 16 describes how strong to make the building. It does **<u>not</u>** define battery cabinet performance. That is done elsewhere in the IBC.

- Lithium cabinets have been evaluated to UBC Zone 3 or 4
- OSHPD may be available for some cabinet systems

…so the IFC/IBC seismic requirements for lithium are not different from those requirements used for VRLA cabinets

2021 IFC Requirements

Section 1206 and 1207– Fire rating for the battery room

- IBC table 509
- Depends on the system electrolyte weight. Greater than 1000 lbs. of lithium electrolyte will require ‘incidental use’ classification
- Stricter code requirements depend on “Maximum Allowable Quantity” or MAQ. AHJ can waive this, based on UL9540A test and FMEA analysis of the site.
  - MAQ for lithium is 600kWh. Above that requires H-2 (high hazard) occupancy classification for the room, and various stricter codes apply
  - Typical UPS lithium battery cabinet are 25-35 kWh each, so installations of >18 cabinets may exceed the 600kWh limit

2021 IFC Requirements

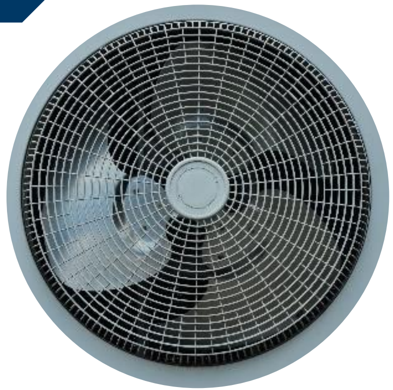
Section 1206 and 1207 – Fire detection and suppression

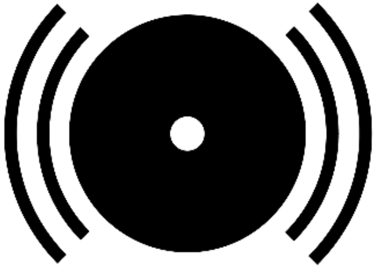
- Hot batteries may produce gasses from melting plastic like those from VRLA batteries.
- Gas detectors like those used in VRLA installations, are required.
- Sprinkler systems (water), 0.3 gpm/ft^2, are required as in NFPA 13 and IFC Sec.903.3.1.1. Water (and lots of it) is the required suppressant for lithium batteries per code.
- Use Safety Data Sheet (SDS) from the manufacturer to provide instructions for fire suppression.
- Clean, gaseous systems i.e., Novec1230, FM200, and CO2 extinguishing systems are allowed, but used mostly to extinguish fires for non-water-resistant equipment in the room with the battery. See NFPA 855.
- ABC type fire extinguishers are OK if the fire has not originated in, or spread to, the battery. Note: Class D extinguisher is not required.
- Water may also be used to cool the battery, and other systems in the same room.

2021 IFC Requirements

Section 1206 and 1207 – Ventilation

- Convection cooling, is acceptable in the battery cabinet, providing:
- Max. gassing is limited to <25% of the lower flammability limit
  - May require room ventilation or fans which must be remotely monitored
  - Smoke detectors are required
  - Gas detectors that can automatically start the room fans and/or stop charging are required
  - *The above are not different than that which is required for VRLA installations of similar size*





2021 IFC Requirements

Section 1206 and 1207 – Battery cabinet placement and spacing

Cabinet placement

- Must be within 10’ of UPS in “occupied workspaces” but not applicable in equipment rooms or basements.

Cabinet spacing

- IFC 1206,1207and NFPA 855 requires 3’ spacing on all sides and does apply to UPS battery installations. Exception: if the battery cabinet is tested to 9540A, the 3’ spacing may not be required. The AHJ makes this call based on his/her evaluation of UL9540A test results and a site based FMEA analysis!
- UL 9540A is a ‘flame propagation test.’ This test proves that a thermal runaway in a single battery module will not propagate to adjacent cabinets or structures.

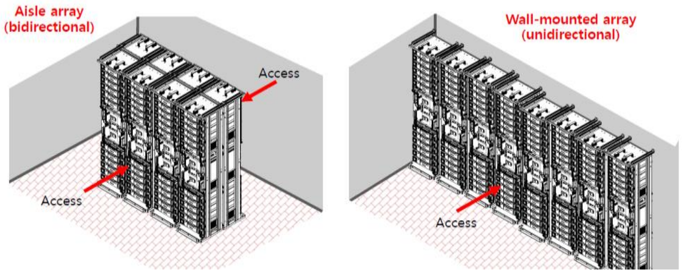


Image courtesy of LG Chem UR22G512F _P300AF1C3 V2 Rack installation manual; used with permission

examples

2021 IFC Requirements

Section 1206 or 1207 – What fire code officials will look for

As with VRLA systems, FMEA analysis by user may be required to verify the below points:

1

Waiver of the 600kWh max allowable qty or 3’ spacing based on UL9540A test results

2

No toxic gas production above IDLH (immediate danger to life or health)

3

Flammable gas emitted in normal operation not to exceed 25% of LFL (lower flammability limit)

4

Flammable gas emitted in abnormal conditions (overcharge or over discharge) must not explode

2021 IFC Requirements

What's a FMEA analysis?

Failure **M**odes and **E**ffects **A**nalysis (FEMA)

FMEA is the process of reviewing as many components, assemblies, and subsystems as possible to identify potential failure modes in a system and their causes and effects. For each component, the failure modes and their resulting effects on the rest of the system are recorded in a specific FMEA worksheet.

Who performs the FMEA analysis?

- FMEA must be conducted by the user or their designate, as it depends on site-specific conditions. The format is described in IEC 60812, 61025, and MIL-STD-1629A.
- While the battery vendor cannot create this analysis, they can format their data to comply with FMEA format.

UL 9540 listing vs. UL 9540A testing

UL9540 listing

Provides a listing mark on the product nameplate and is intended for long- backup Energy Storage Systems, or ESS.

UL9540A testing

This is not a listing. It is a test method that shows how a given battery cabinet performs during a large-scale fire event.

- Verifies no flame spread, no excessive gas emission, and measures heat release.

UL 9540A Fire Propagation Testing of Battery Energy Storage Systems
Codes and Standards Considerations

Key takeaways for installation planning

The AHJ has the final say

Contact your local AHJ during the site design phase

Getting their input early will ensure their acceptance as they have the ability to waive or accept certain requirements.

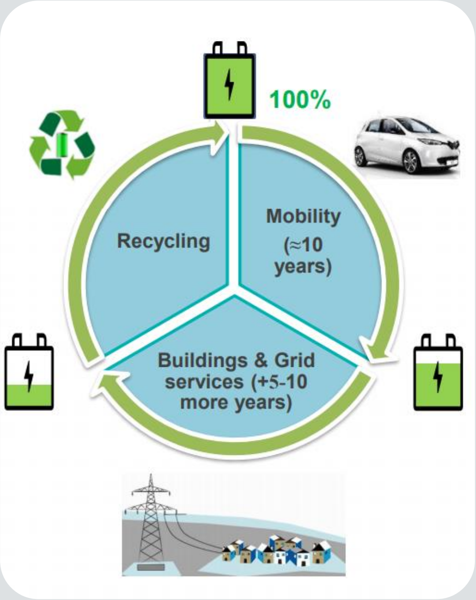
Verify your battery vendor can supply UL9540A test results for the FMEA and AHJ analysis

Contact your UPS vendor with any questions

They have access to the OEM battery manufacturer, and the experience of many lithium installations.

Lithium recycling:

“The lithium itself is not currently recycled. When it gets to the smelter, it rises to the top in the form of foam and is sheared off and disposed of. The other elements of the battery fall to the bottom and are recycled in the traditional fashion. There is only about 1-2% of lithium actually in a Li-ion battery.”



Elsa
ENERGY LOCAL STORAGE ADVANCED SYSTEM

Amsterdam ArenA success story (eaton.com)

Amsterdam ArenA

2nd life application example

Nissan and technology company The Mobility House sign a 10-year deal with Amsterdam Arena – home of the Ajax Football Club. The deal will provide backup power from a system combining UPS's with second-life batteries from Nissan's LEAF electric vehicles.

Second-life lithium-ion battery systems efficiently store and distribute energy when needed, ensuring the lights never go out. Using 280 repurposed Nissan LEAF batteries and bidirectional inverters, the system designed for the Amsterdam ArenA will be the largest energy storage system powered by second-life batteries in use by a commercial business in Europe.

Backup power from diesel generators will become unnecessary. The system enables Amsterdam ArenA to power the surrounding neighborhood when necessary and protect the grid, in addition to providing vital back-up power to the stadium.

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