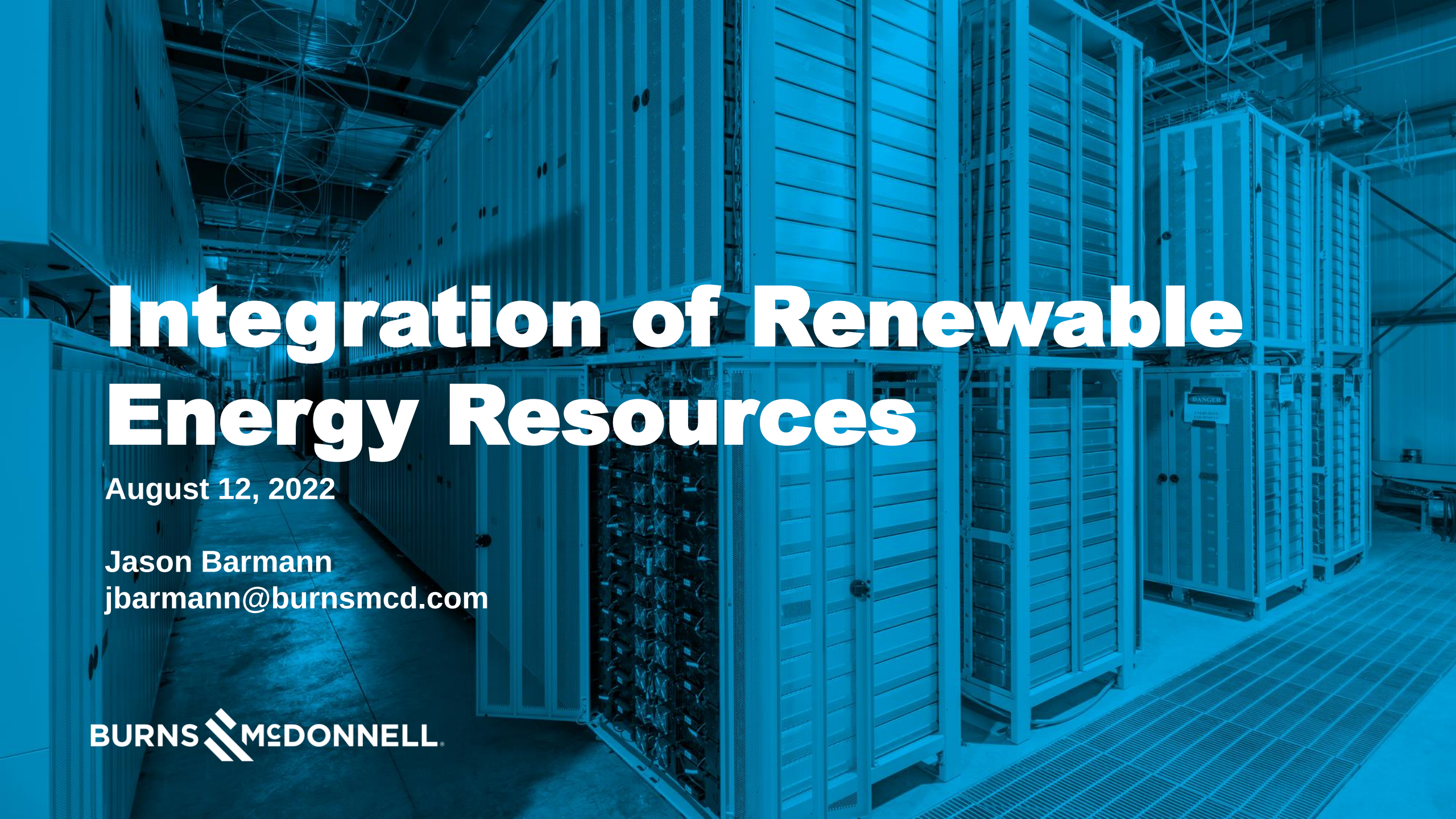


Integration of Renewable Energy Resources

August 12, 2022

Jason Barmann
jbarmann@burnsmcd.com

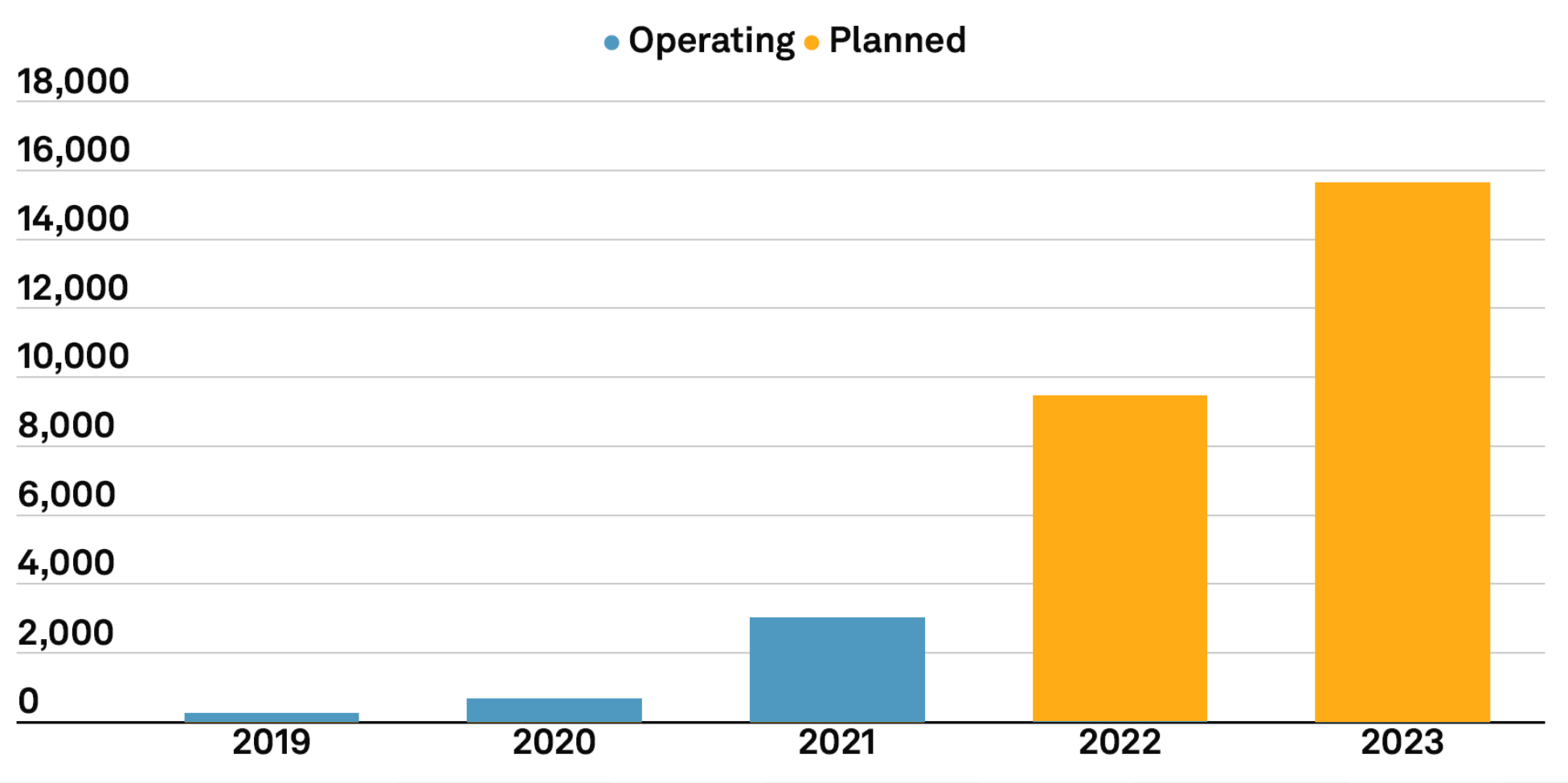
BURNS McDONNELL

Agenda

- BESS Market Overview
- Lithium-Ion Technology
- Use Cases
- Lithium-Ion Safety
- BESS Technology Trends

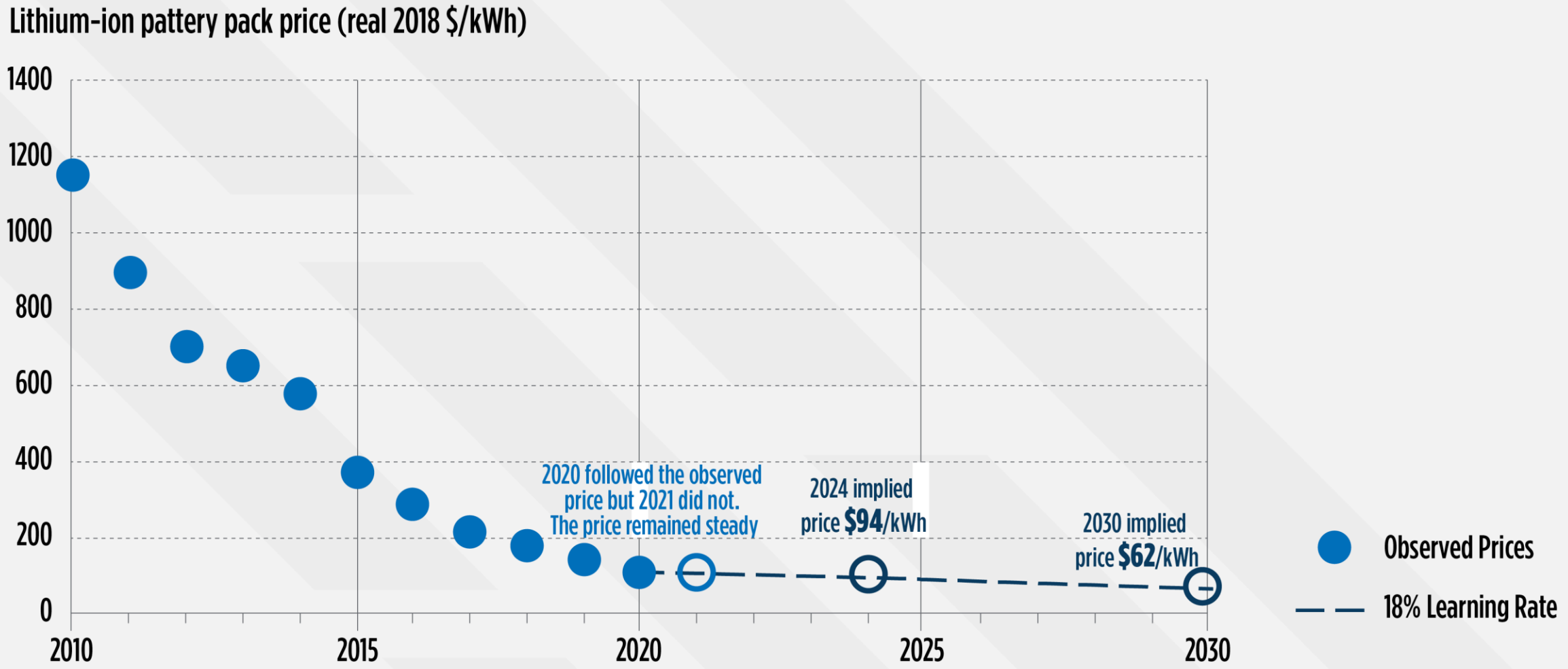
BESS Market Overview

US Utility-Scale BESS Deployments (MW)



Source: S&P Global Market Intelligence

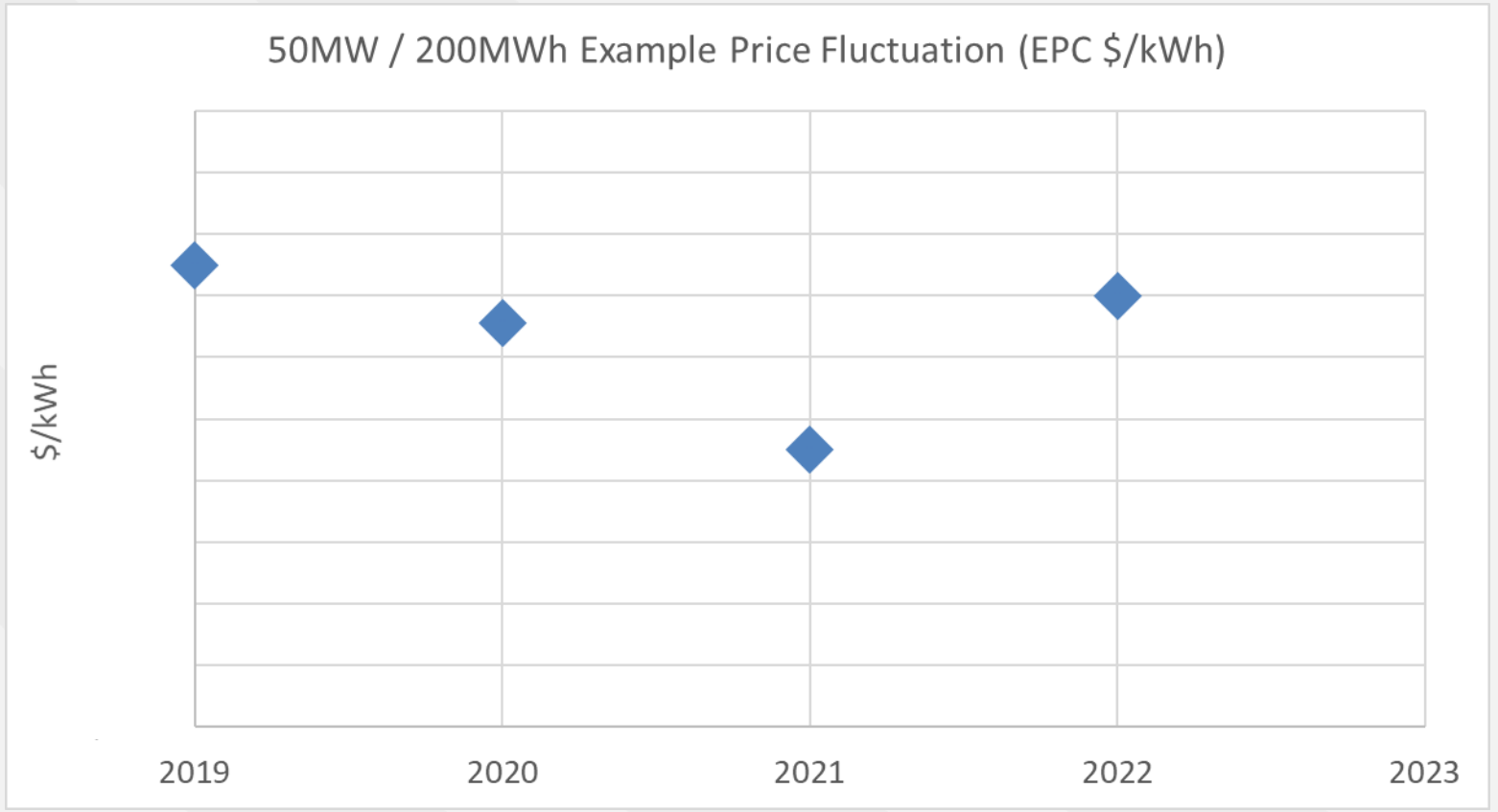
Li-Ion Battery Pricing Outlook



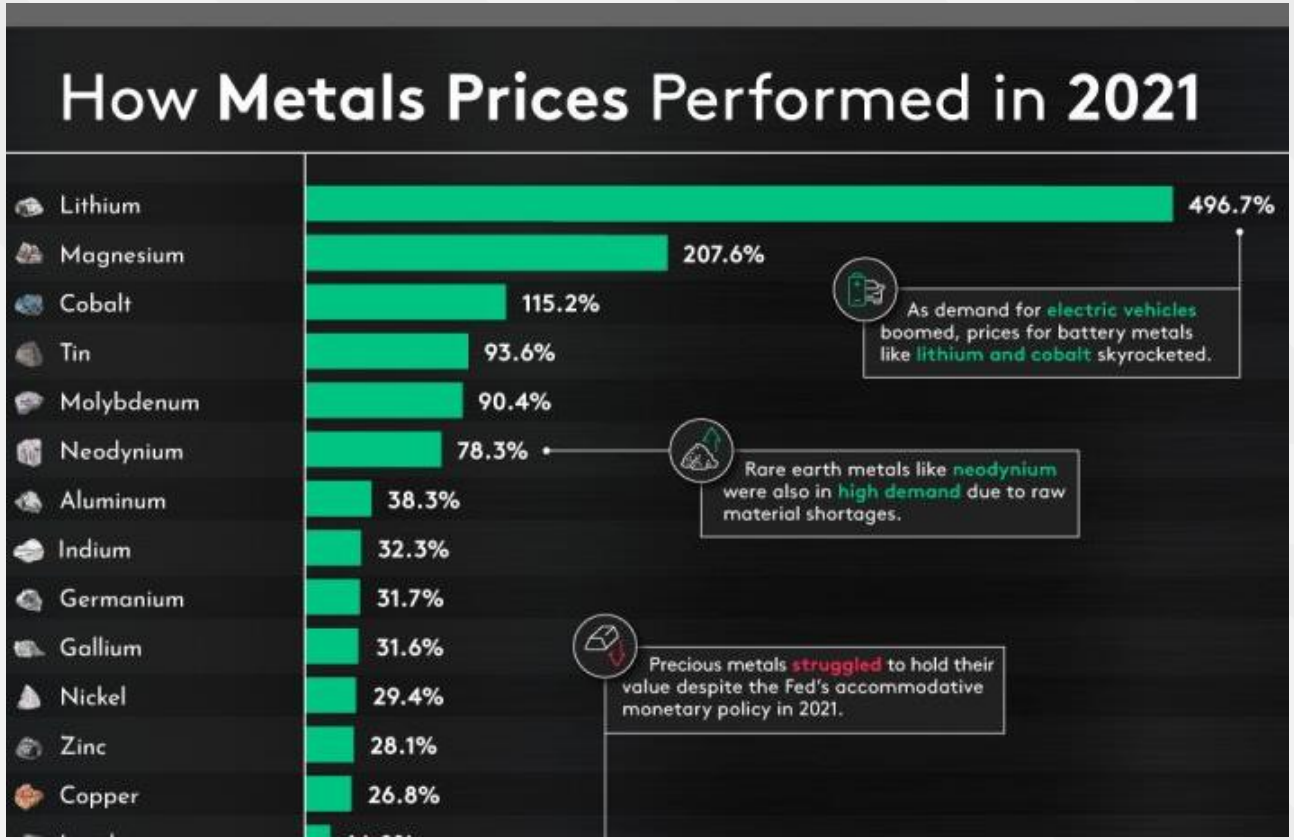
Source: BloombergNEF

Example Pricing for Lithium-ion BESS (50MW / 200 MWh)

- Impact of raw material prices and supply chain are being felt in pricing
- Today's estimates for EPC (including BESS procurement) are similar to 2020
- Note these are approximate examples and range of costs fluctuates for site conditions



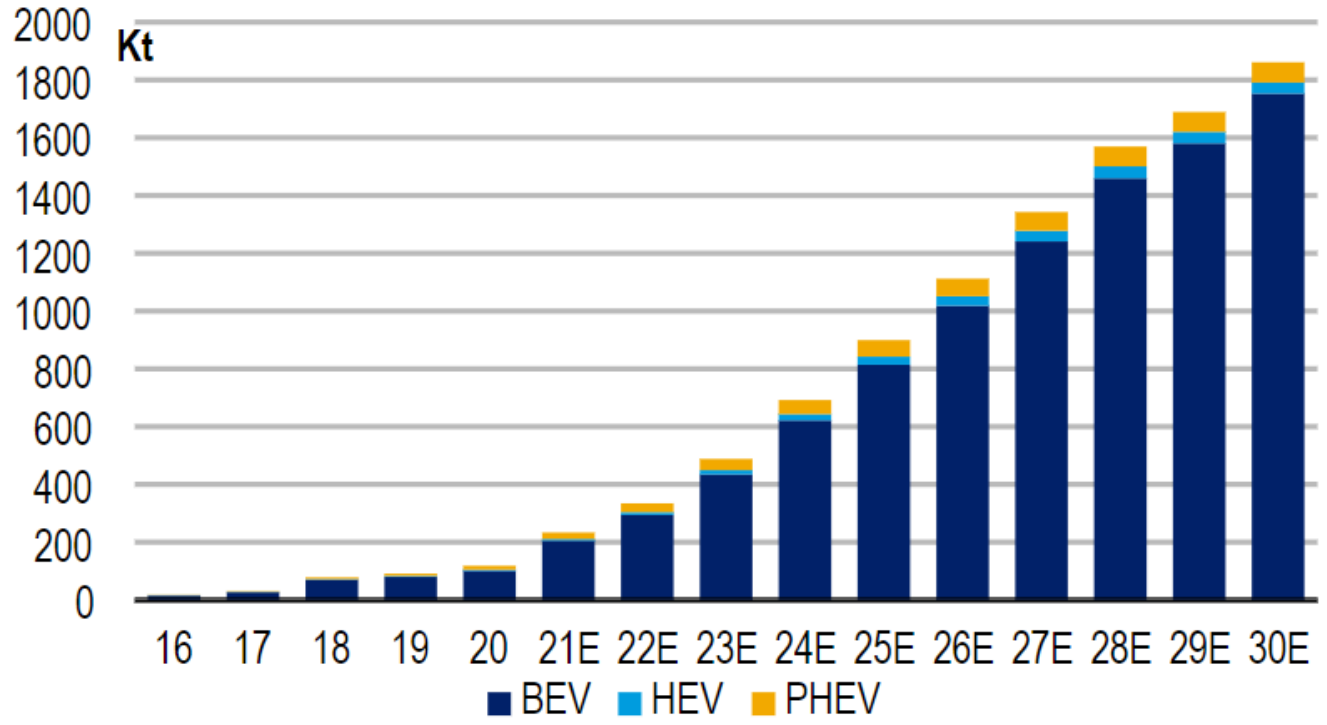
LITHIUM PRICE INFLATION



LITHIUM METAL DEMAND

Exhibit 5: Lithium demand growth

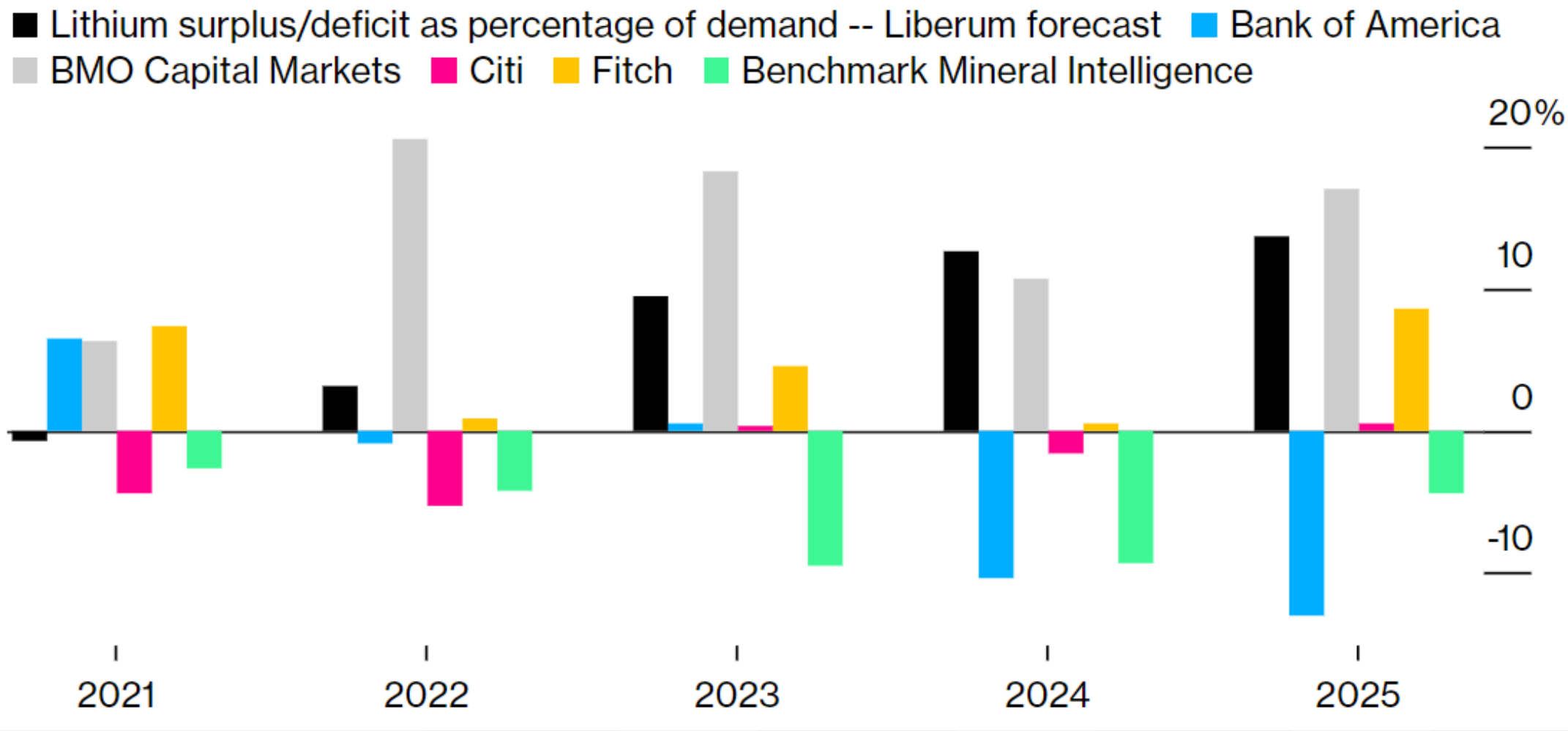
Lithium demand from EVs is set to grow steadily in the coming years



Source: BofA Global Research Estimates

BofA GLOBAL RESEARCH

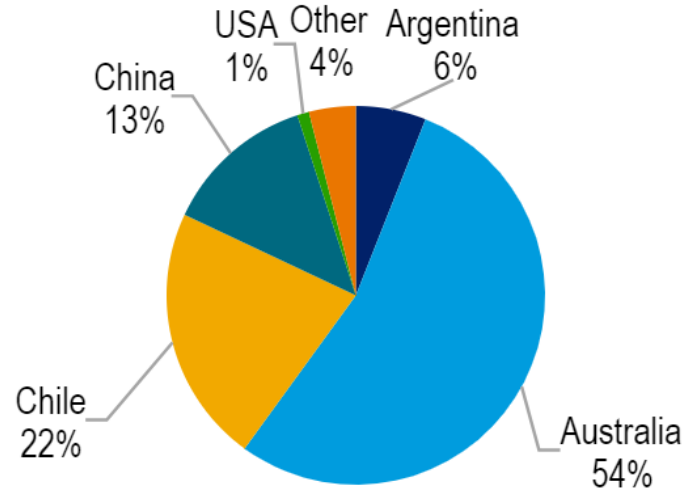
INDUSTRY IS SPLIT ON MINING FORECAST



Source: Bloomberg

LITHIUM MINING EXPANSION

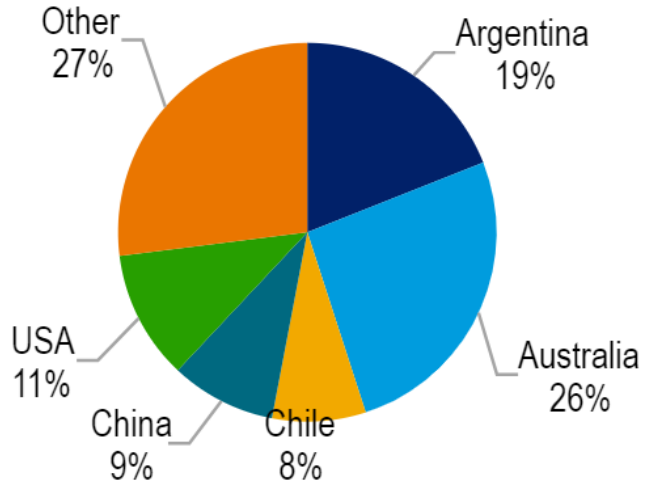
Exhibit 7: Breakdown of lithium mine supply, 2021
Australia and Chile are key to upstream supply



Source: Company Reports, CRU, Woodmac, BofA Global Research

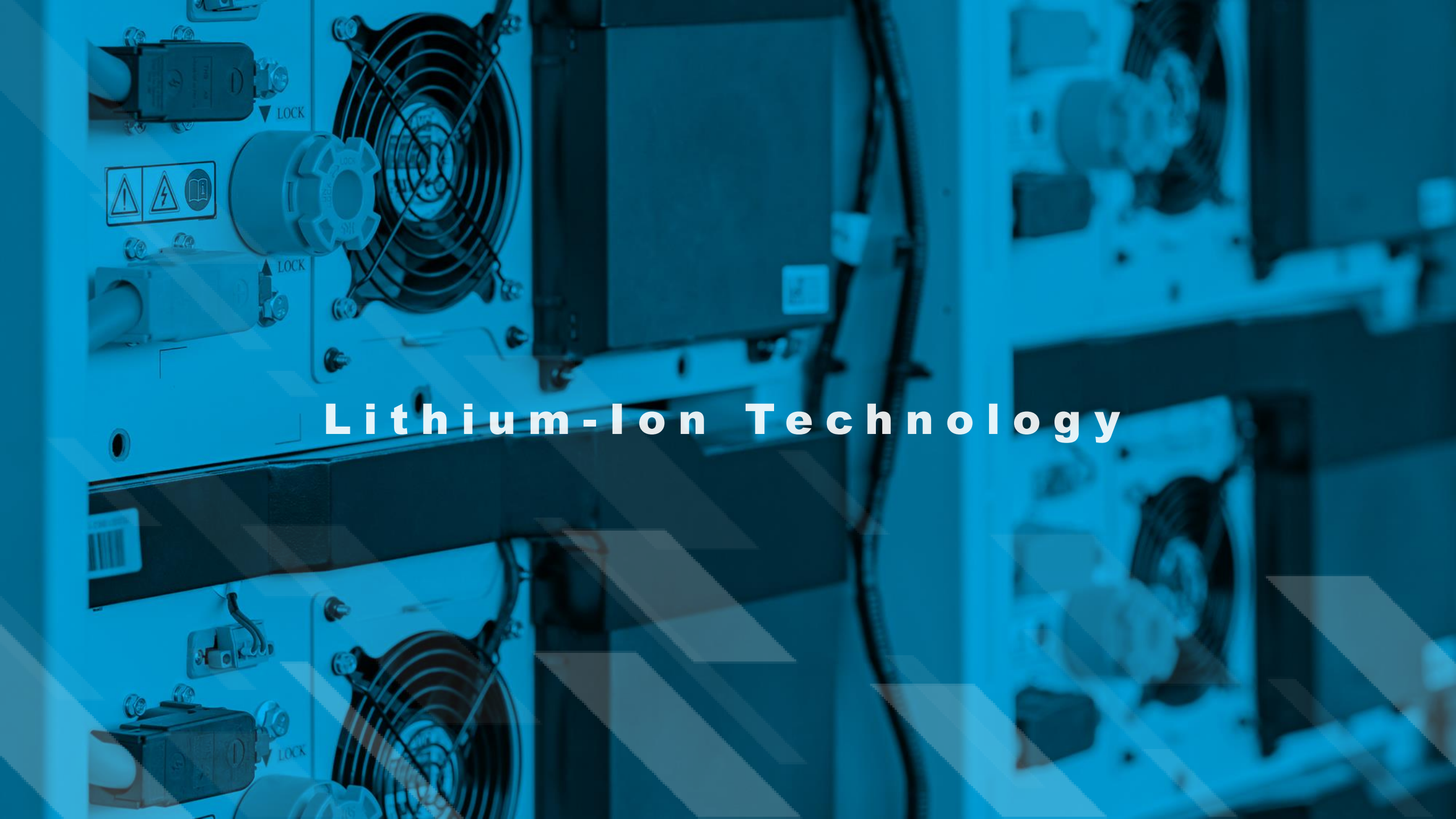
BofA GLOBAL RESEARCH

Exhibit 8: Breakdown of lithium project pipeline, 2030
The project pipeline is geographically diverse



Source: Company Reports, CRU, Woodmac, BofA Global Research

BofA GLOBAL RESEARCH

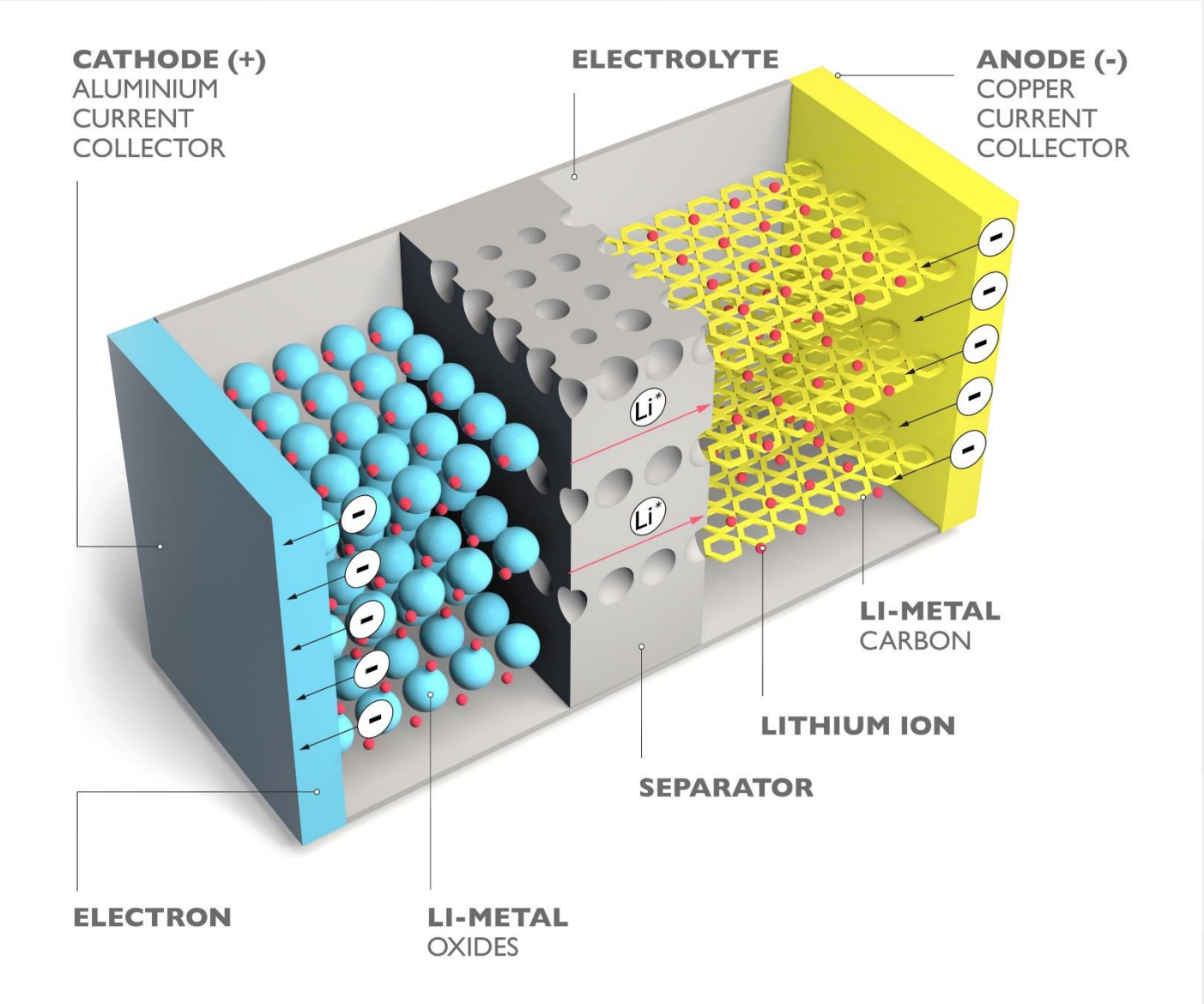


Lithium-Ion Technology

Battery Basics

During **charging**, lithium ions move from the cathode to the anode

Li*



During **discharging**, lithium ions move from the anode to the cathode

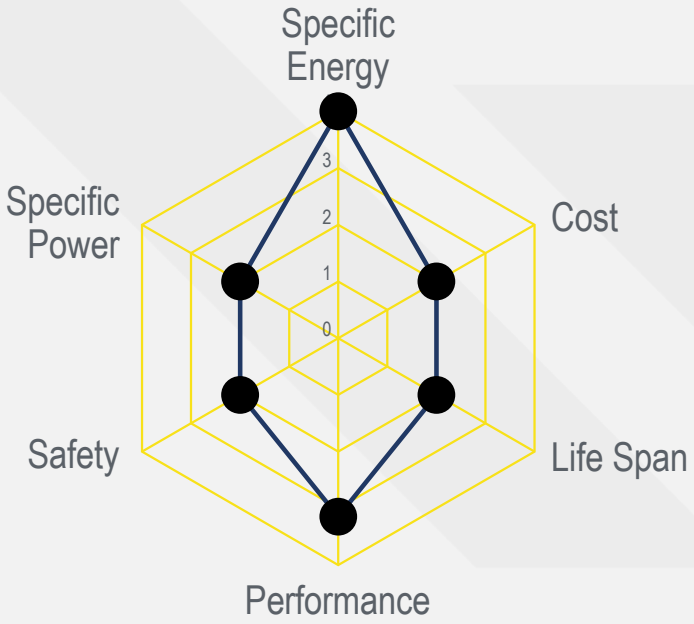
Li*

Lithium-Ion Chemistries

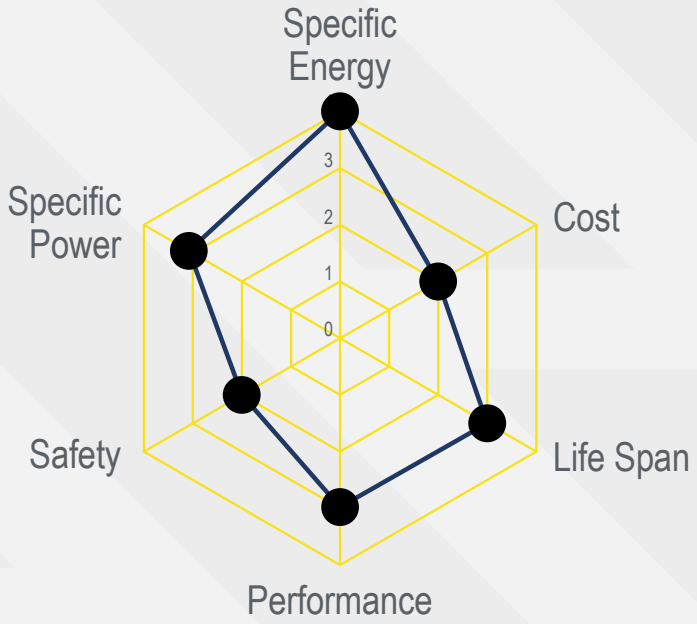
- LCO – Lithium Cobalt Oxide
- LMO – Lithium Manganese Oxide
- NMC – Lithium Nickel Manganese Cobalt Oxide
- NCA – Lithium Nickel Cobalt Aluminum Oxide
- LFP – Lithium Iron Phosphate
- LTO – Lithium Titanate

Most Common Li-ion Chemistries

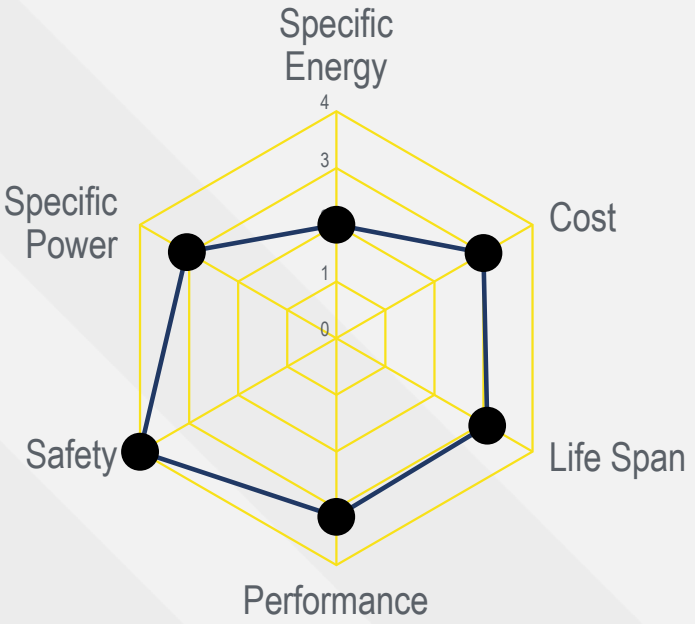
NMC
Lithium Nickel Manganese Cobalt



NCA
Lithium Nickel Cobalt Aluminum

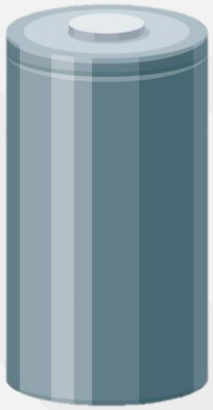


LFP ($LiFePO_4$)
Lithium Iron Phosphate

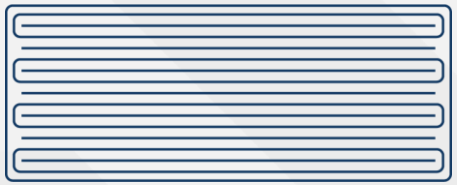


Li-Ion Form Factors

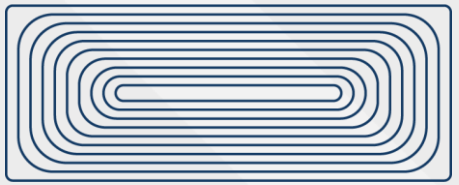
Cylindrical Cell
(Panasonic)



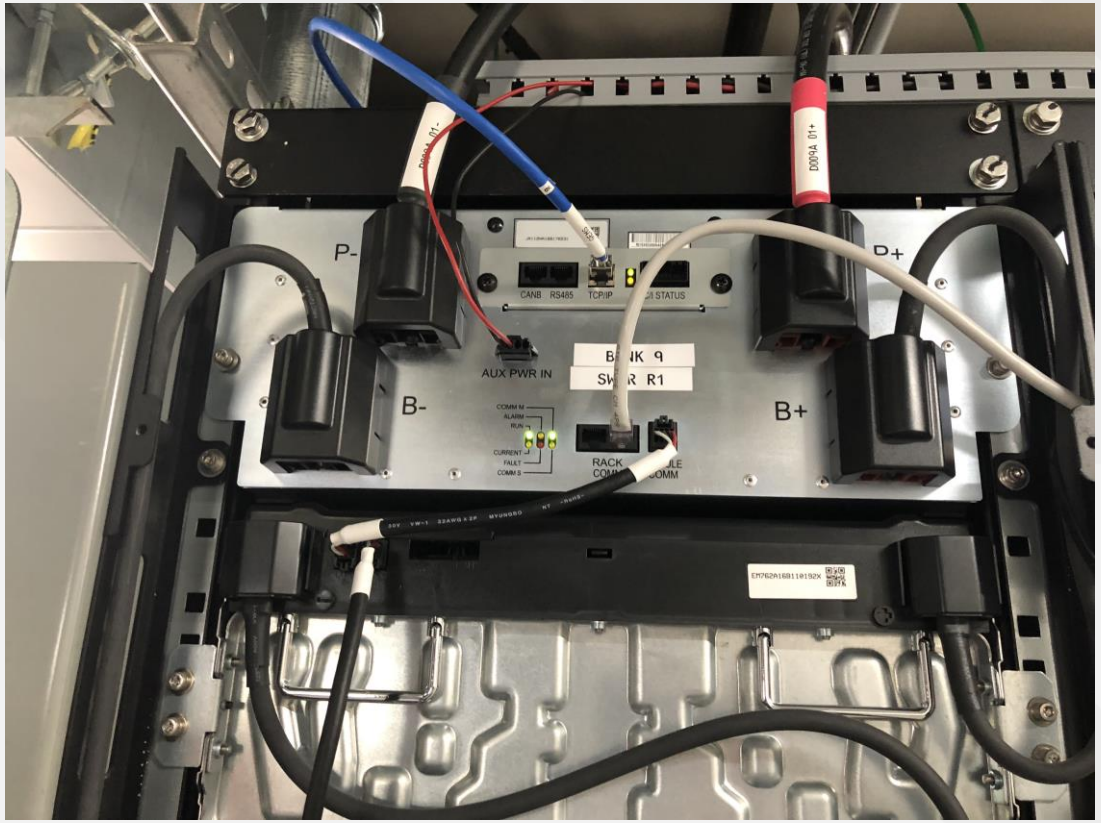
Pouch Cell
(LG Chem)



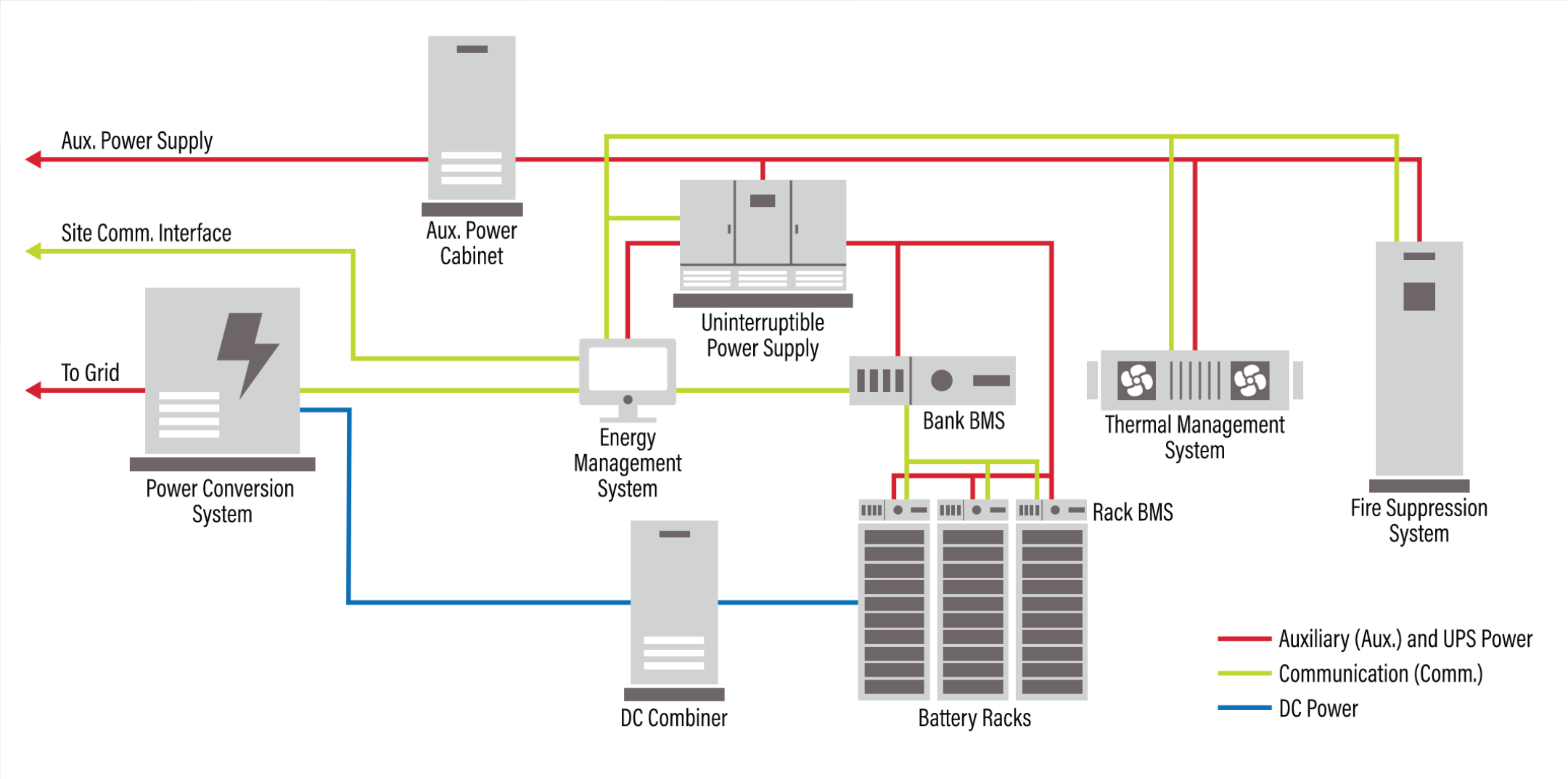
Prismatic Cell
(BYD, CATL, Samsung)



Li-Ion Racks



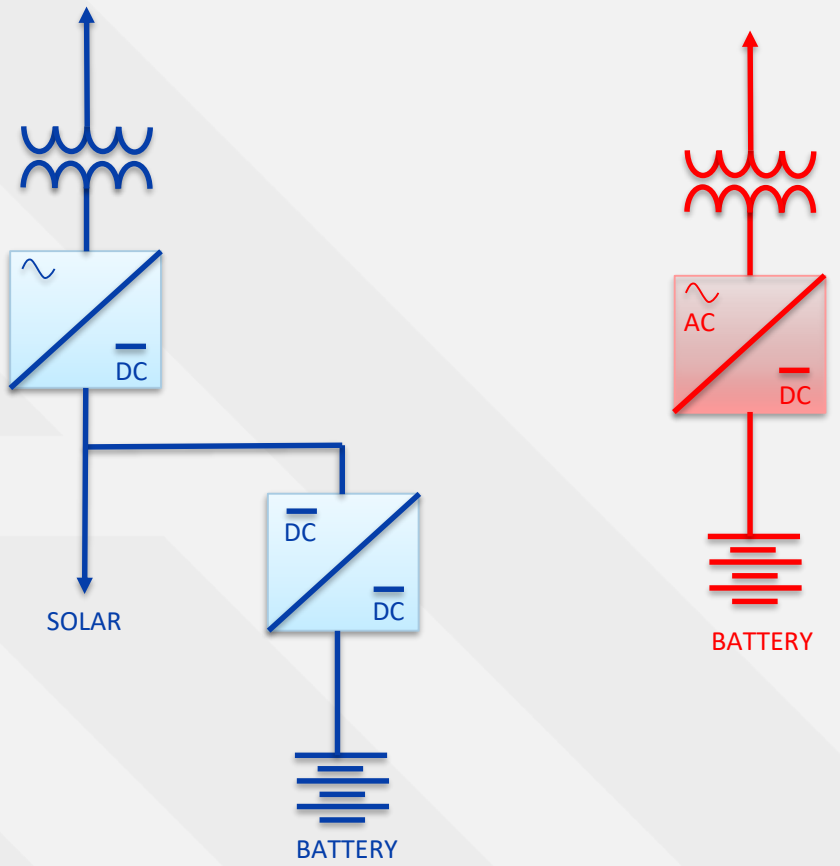
Li-Ion Battery System Components



Use Cases

SOLAR + STORAGE

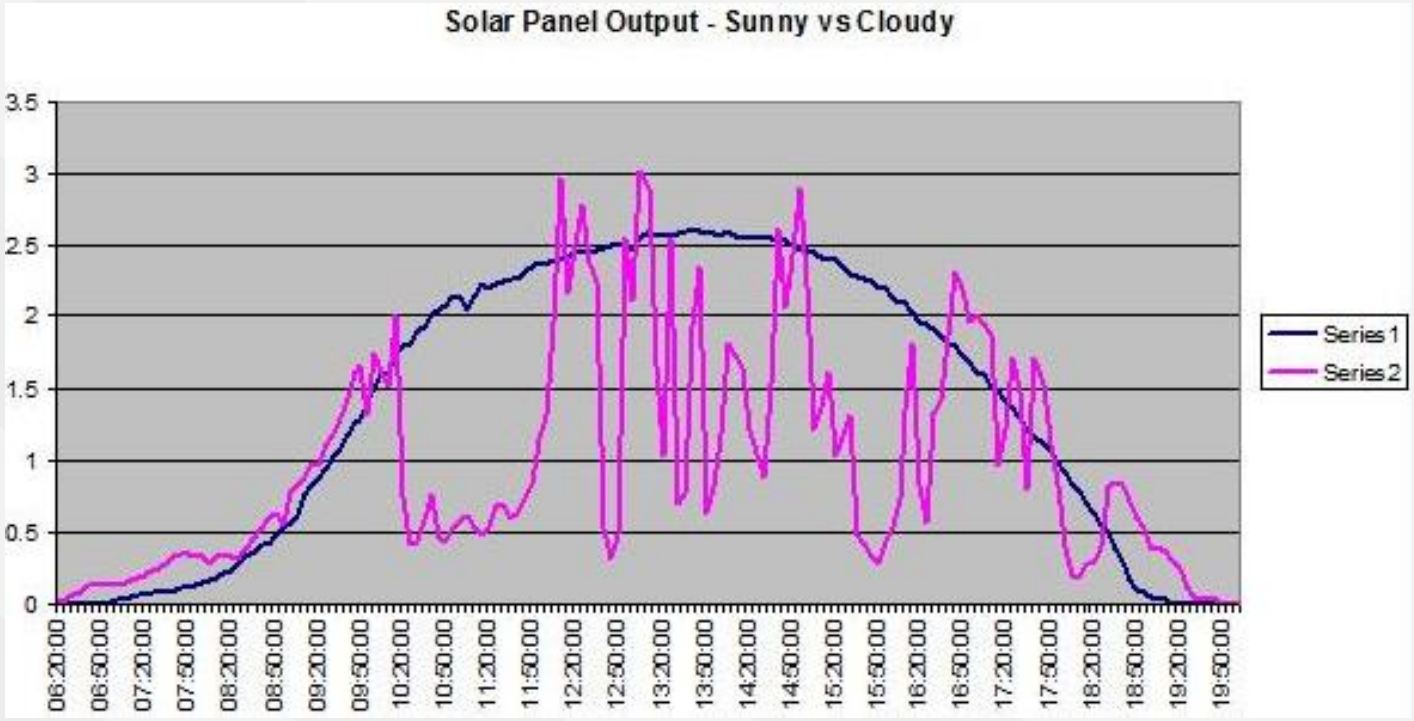
- AC-coupled vs. DC-coupled
- Optimization opportunities
- Coordination between resources
- Use cases will vary



PUERTO RICO MTR

- Frequency Response/Regulation
- Ramp Rate Control
- Voltage Regulation
- Black Start

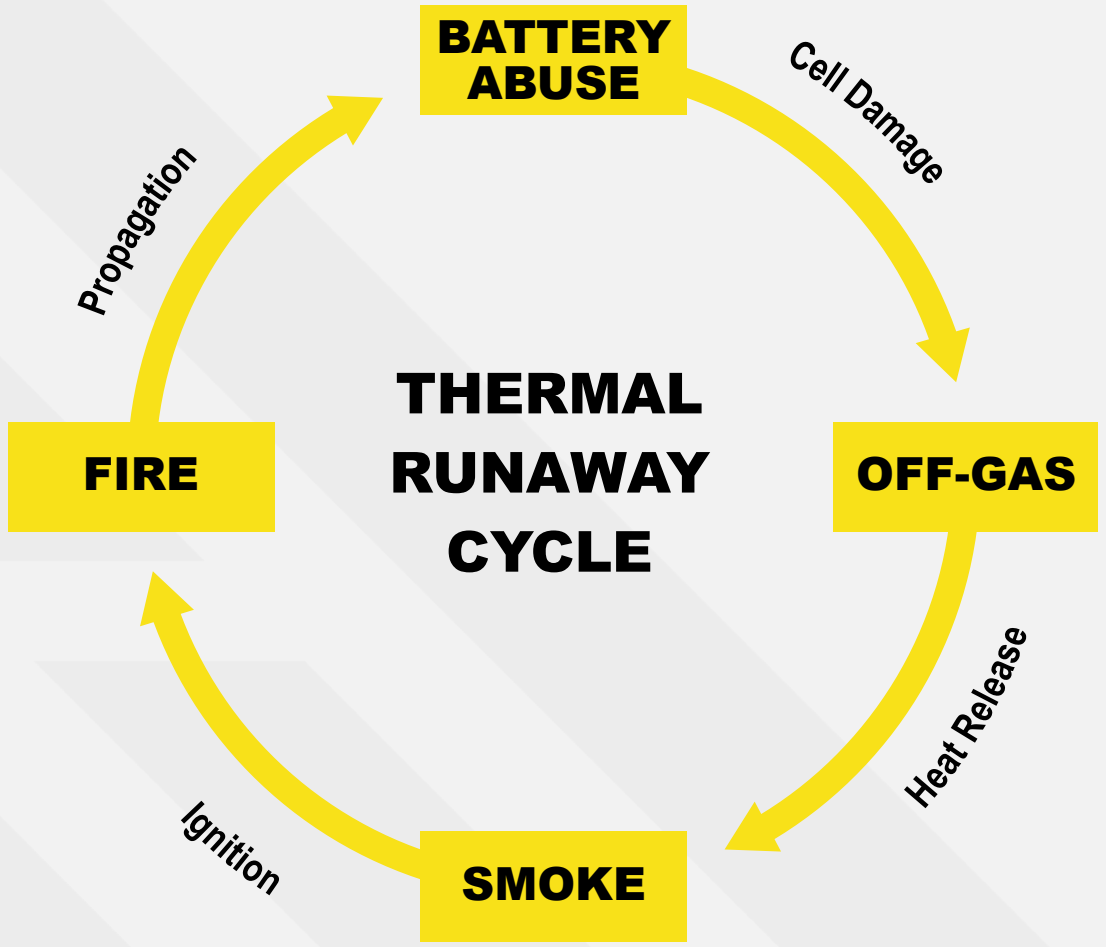
- Controls?
- Planning for cycling?
- Lessons learned



Lithium-Ion Safety

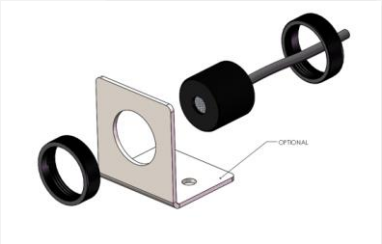
Li-Ion Battery System Components

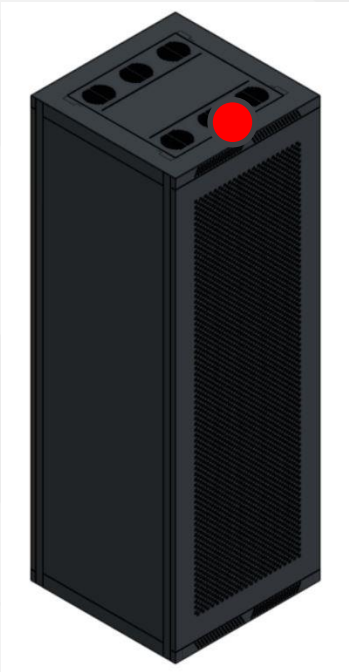
- Thermal runaway cycle
  - Thermal abuse
  - Electrical abuse
  - Mechanical abuse

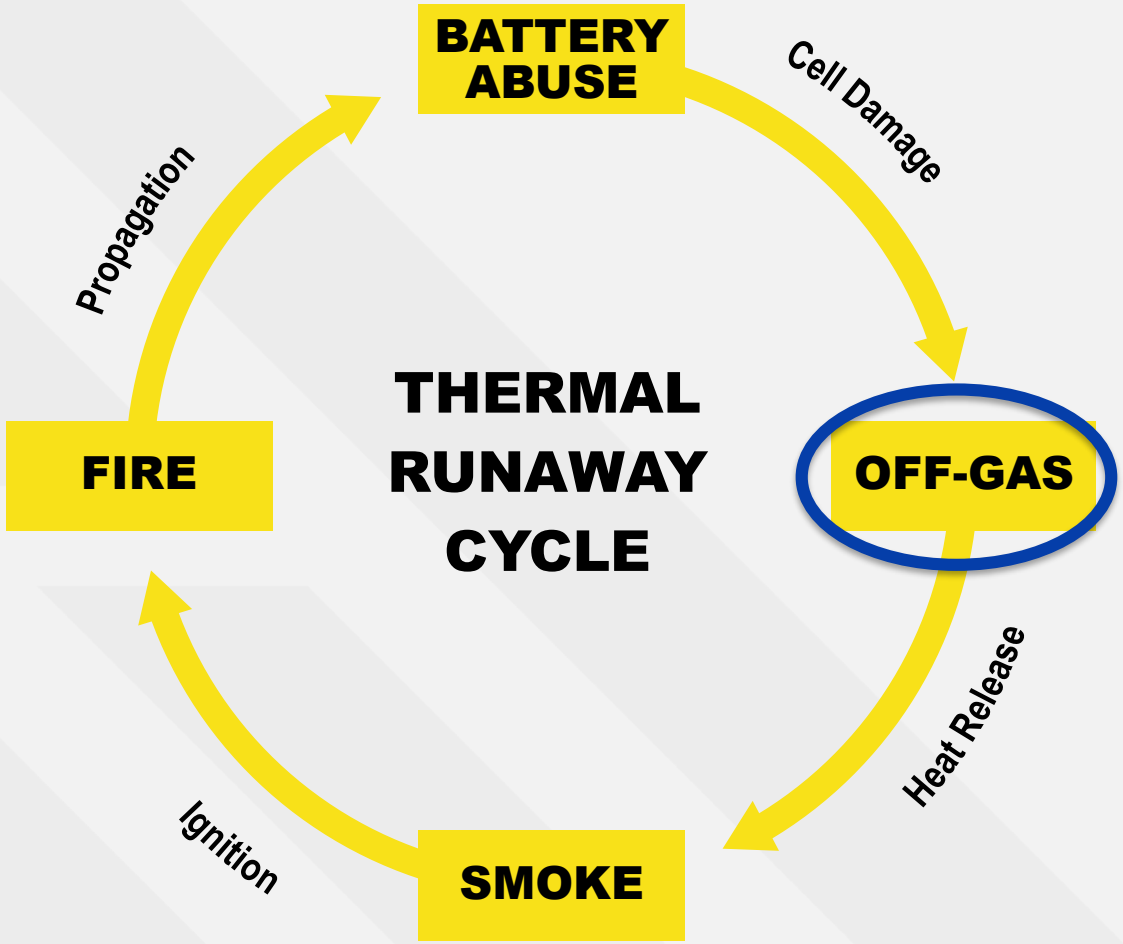


Li-Ion Battery System Components

- Off-gas detection
  - Detects released VOCs
  - Li-ion tamer
  - TR prevention







BESS Safety

Gaseous/clean agent/aerosol have not been shown to be effective

- Little to no cooling effect
- Usually require both heat and smoke to operate
- May take several cells reaching TR to trigger heat sensor
- Single-shot design
- If used, must be tested to NFPA 2001

BESS Safety

Traditional sprinklers may not be effective

- Traditional systems provide coverage across top of racks
- Can’t effectively spray water onto lower modules
- May need to spray both top and bottom of each module

BESS Safety Conclusion

Failures are not common

Li-ion failures present unique hazards

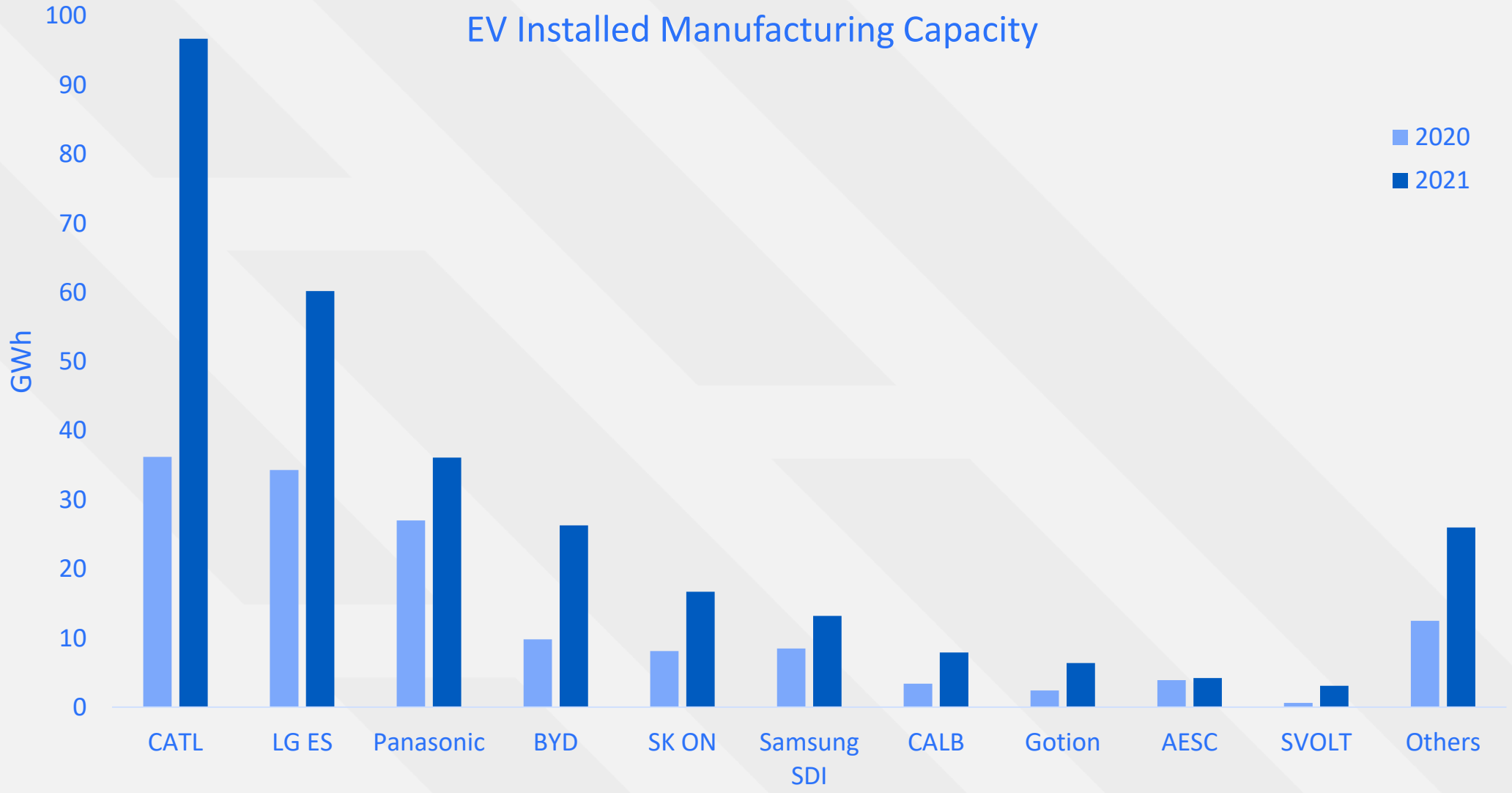
Regulations are evolving

Failures must be detected early

Careful planning can control risk

BESS Technology Trends

Li-Ion Battery OEMs

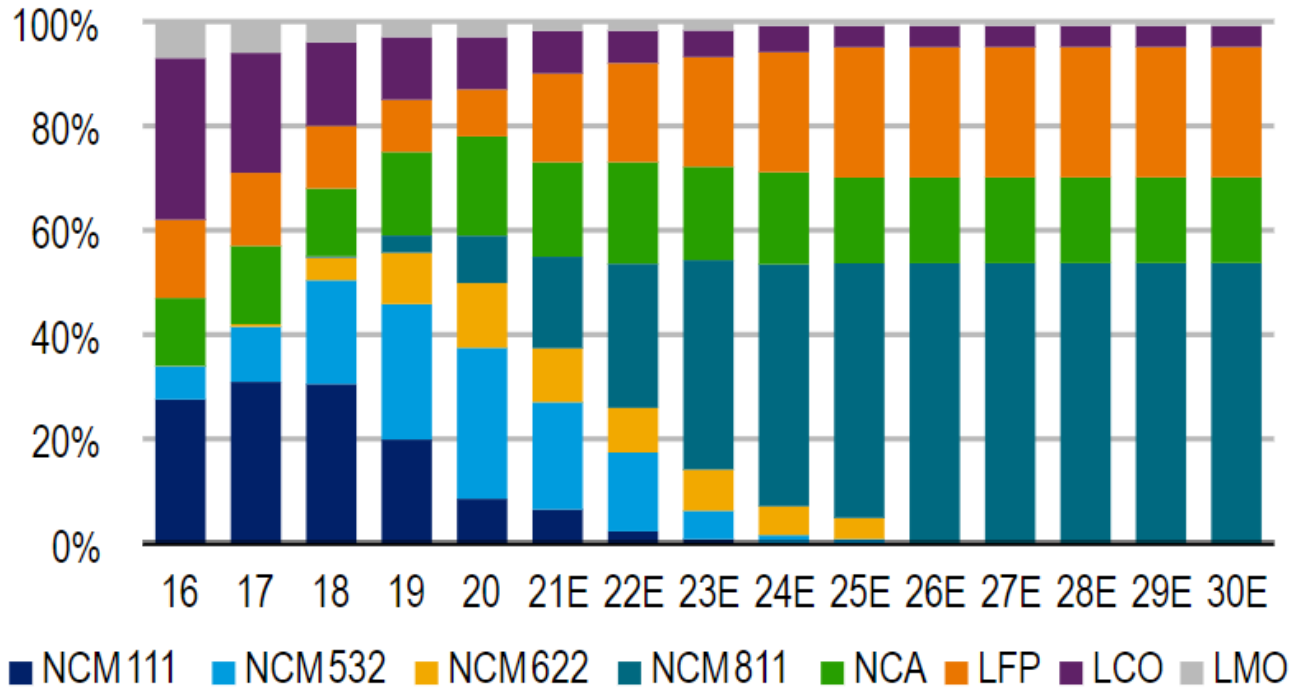


Form Factors

Lithium-ion Chemistry Shift

Exhibit 4: Breakdown of EV battery cathode

While EV manufacturers shift between battery cathodes, batteries remain lithium-intensive



Source: BofA Global Research Estimates

BofA GLOBAL RESEARCH

Non-Lithium Alternatives

Aiming to Scale

Non-Lithium Alternatives

NEWS

Eight-hour lithium-ion project wins in California long-duration energy storage procurement

By Andy Colthorpe

January 27, 2022

Americas, US & Canada Grid Scale Business, Market Watch, Technology

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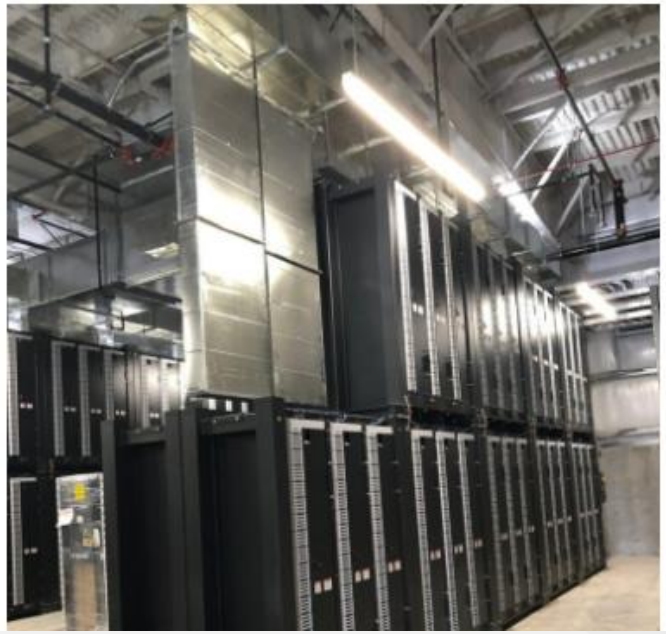

NEWS

Second eight-hour lithium-ion battery system picked in California long-duration storage procurement

By Andy Colthorpe

March 8, 2022

Americas, US & Canada Grid Scale Policy, Technology

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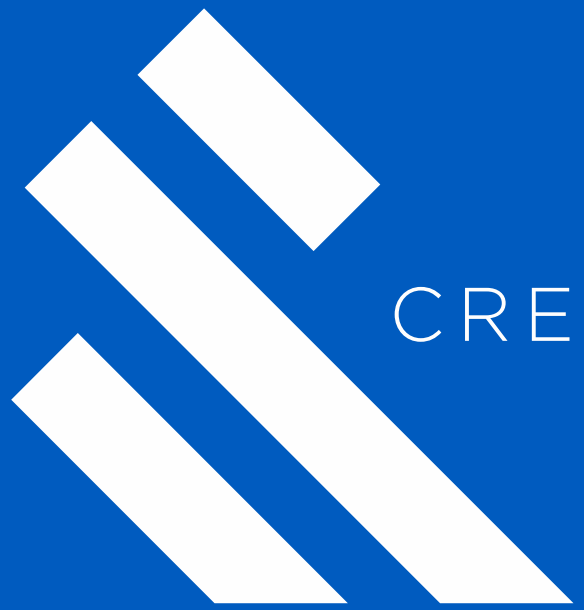
Many had expected an emerging technology like flow batteries to be selected. Pictured is California's largest flow battery installation. Image: SDG&E / Ted Walton.



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