Integration of Renewable Energy Resources

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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

Lithium-ion battery pack price (real 2018 $/kWh)

2020 followed the observed price but 2021 did not. The price remained steady.

2024 implied price $94/kWh

2030 implied price $62/kWh

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

## How Metals Prices Performed in 2021

<table>
<thead>
<tr>
<th>Metal</th>
<th>Percentage Increase</th>
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<tbody>
<tr>
<td>Lithium</td>
<td>496.7%</td>
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<tr>
<td>Magnesium</td>
<td>207.6%</td>
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<tr>
<td>Cobalt</td>
<td>115.2%</td>
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<tr>
<td>Tin</td>
<td>93.6%</td>
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<tr>
<td>Molybdenum</td>
<td>90.4%</td>
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<tr>
<td>Neodymium</td>
<td>78.3%</td>
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<td>Aluminum</td>
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<tr>
<td>Indium</td>
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<td>Zinc</td>
<td>28.1%</td>
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<tr>
<td>Copper</td>
<td>26.8%</td>
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- As demand for electric vehicles boomed, prices for battery metals like lithium and cobalt skyrocketed.
- Rare earth metals like neodymium were also in high demand due to raw material shortages.
- Precious metals struggled to hold their value despite the Fed’s accommodative monetary policy in 2021.

## Exhibit 2: Carbonate prices, USD/mt

Chinese carbonate prices have broken out to the upside.

### Source:
Asian Metals, Benchmark, Bloomberg

BofA GLOBAL RESEARCH
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
INDUSTRY IS SPLIT ON MINING FORECAST

Lithium surplus/deficit as percentage of demand -- Libereum forecast

Source: Bloomberg
**LITHIUM MINING EXPANSION**

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

- Australia: 54%
- Chile: 22%
- China: 13%
- USA: 1%
- Other: 4%
- Argentina: 6%

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

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

- Australia: 26%
- Chile: 8%
- China: 9%
- USA: 11%
- Other: 27%
- Argentina: 19%

*Source: Company Reports, CRU, Woodmac, BofA Global Research*
Lithium-Ion Technology
Battery Basics

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

During discharging, lithium ions move from the anode to the cathode.
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 (LiFePO₄)**
  - Lithium Iron Phosphate

<table>
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<tr>
<th>Specific Energy</th>
<th>Specific Power</th>
<th>Safety</th>
<th>Performance</th>
<th>Cost</th>
<th>Life Span</th>
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Li-Ion Form Factors

Cylindrical Cell
(Panasonic)

Pouch Cell
(LG Chem)

Prismatic Cell
(BYD, CATL, Samsung)
Li-Ion Racks
Li-Ion Battery System Components
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
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
Li-Ion Battery OEMs

EV Installed Manufacturing Capacity

GWh

CATL | LG ES | Panasonic | BYD | SK ON | Samsung SDI | CALB | Gotion | AESC | SVOLT | Others

2020 | 2021

0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100
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
Non-Lithium Alternatives
Aiming to Scale
Non-Lithium Alternatives

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

By Andy Colthorpe
January 27, 2022

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

By Andy Colthorpe
March 8, 2022
CREATE AMAZING.