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American Manganese is Recycling Lithium-ion Battery Manufacturing Waste with its...
Lithium-ion Battery Components and Cost

Inside the Lithium-ion Battery

Battery Pack: 31%
Cathode: 22%
Anode: 17%
Electrolyte solution: 15%
Separator plastics: 3%
Carbon black and binder: 4%
Copper: 17%
Aluminum: 8%

Estimated Lithium-ion Battery Cost

Cathode: 25%
Pack Thermal System: 8%
Battery Pack Management System: 16%
Cell Labor: 8%
Depreciation of Equipment: 8%
Anode Materials: 8%
Cell Fixed Cost: 6%
Land Cost for Cell Manufacturing: 6%
Pack Labor: 5%
Current Collectors: 3%
Electrolyte: 1%
Other: 3%

Source: http://articles.sae.org/14195/
Lithium-ion Battery Material Supply Chain

Raw materials make up the majority of costs during the production of lithium-ion cells

Cost breakdown of cell NCM811 \(^1\) [EUR/kWh; %; 2020]

**Note**
- No cell margin included
- No costs included to manage supply chain risks
- Reflecting traded raw material prices without contracted discount and price fluctuations
- No further cost reductions during contract period included

![Diagram showing cost breakdown of lithium-ion cell production](source: https://www.rolandberger.com/en/Point-of-View/Battery-recycling-is-a-key-market-of-the-future-is-it-also-an-opportunity-for.html)

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1. Prismatic cell and production in China; material prices forecasted for 2020
2. Lithium Spodumene Concentrate 6%
3. Euro per kg of CAM material
4. Markup of 6.3% that accounts for efficiency losses between theoretical vs. nominal voltage level

Source: https://www.rolandberger.com/en/Point-of-View/Battery-recycling-is-a-key-market-of-the-future-is-it-also-an-opportunity-for.html
SIMON MOORES, MD, BENCHMARK MINERALS:

“Taking an average lithium ion battery scrap rate of 10% means we could have as much as 80GWh of scrap lithium ion batteries to recycle by 2025. This is the same size as the world’s entire lithium ion battery market in 2017.

That equates to:

64,000 tonnes lithium chemical
96,000 tonnes graphite anode
45,000 tonnes nickel
18,000 tonnes cobalt
22,000 tonnes manganese...”
Lithium-ion Battery Manufacturing and Scrap

39% Average Quarterly Cell Production Loss
RecycLiCo™ Cathode Scrap Recycling

The RecycLiCo™ patented process was designed with the goal to produce recycled and high purity cathode materials that could be directly integrated into the re-manufacturing of battery cathodes using minimal processing steps.

Battery Manufacturing Waste (NMC/NCA Cathode Scrap) → Pilot Plant Project (Closed Loop Process) → Recycled Cathode Material (Up to 99.7% Extraction and 99.9% Purity)
RecycLi/Co™ Making Lithium-ion Last Forever™

An Innovation of

AMERICAN MANGANESE INC.

CATHODE SCRAP

RECYCLED ALUMINUM FOIL

RECYCLED HIGH PURITY NICKEL-COBALT HYDROXIDE

RECYCLED HIGH PURITY LITHIUM CARBONATE
Patents

Patent No. 10,246,343

United States Patent and Trademark Office granted patent for lithium-ion battery recycling process and recovery of cathode materials on April 2, 2019

Patent No. 10,308,523

United States Patent and Trademark Office granted patent on June 4, 2019 for:

- Recovery of graphite and carbon from ground battery concentrates
- Treatment of fluoride originating from electrolyte solution
- Separation of aluminum from cathode active material
Current Options – Shredding and Smelting

- **Harmful Emissions** - smelting oxides requires a fuel and generates about 2 tonnes of CO₂ per tonne of metal

- **Low Recovery** - 40%-60% of the nickel and cobalt and no lithium recovery

- **Additional Steps** - the portion of base metals recovered require further processing such as conversion, leaching, solvent extraction, and electrorefining to produce individual LME value metals products

- **Further Refining** - individual metal products need to redissolved and crystallized into high purity salts before they can be processed into cathode precursors
Competitive Analysis

99.7%
Cathode material extraction efficiency

99.9%
Recycled product purity

4-10x
More valuable than equivalent amount of pure metals

RecycLiCo™

Pyrometallurgy

Hydrometallurgy

High Value Product

Low Extraction

High Extraction

Low Value Product
Conceptual Commercial Recycling Plant

- Planned cathode scrap process capacity – 1,000 tonnes/year

- Potential annual material extraction:
  - 382 tonnes lithium chemical
  - 119 tonnes cobalt
  - 384 tonnes nickel
  - 90 tonnes manganese

- Estimated capital cost – US$12 Million

- Estimated reagent consumption cost – US$1,000/tonne of cathode scrap
Business Strategy

Create a safe, sustainable, and circular supply chain for the lithium-ion battery industry

Intend to commercialize intellectual property via joint development partnerships or licencing agreements
- American Manganese’s research and development contractor
- Privately-owned contract research and development company with over 350 clients worldwide
- Specialize in extractive metallurgy, chemical and environmental processing, cleantech and specialty chemical analysis
- Over 30 technical, scientific, engineering, and support staff with diverse specialties
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