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Lithium-ion Battery Components and Cost

Inside the Lithium-ion Battery

Estimated Lithium-ion Battery Cost

Source: Argonne National Laboratory.
Credit: Mitch Jacoby/C&EN

Source: http://articles.sae.org/14195/
Gigafactories

NORTH AMERICAN GIGAFACTORIES

1. 400 MW plant in Detroit, Michigan, which expects to increase to 2 GW in 2023
2. Has two 150-MW sites in Ontario, Canada.
3. Owner-owned, which aims to scale up to a gigafactory by 2023.
4. Working on the development of its first pilot line in Bay Area (California) with the objective of scaling up in 2024.
5. Has launched a pilot line in 2021, which it expects to open up in 2023.
6. Two operational plants (Tennessee) with 58 GWh and Buffalo dedicated to solar cells of ±2 GWh. It expects to open to new gigafactory in Austin (Texas) with up to 100 GWh by the end of 2023 and has a pilot line in Fremont (California).

Windsor Essex

1. 5.6 GWh capacity plant in Indiana, Michigan.
2. Owner-owned, which aims to scale up to a gigafactory by 2023.

Solid Power

1. Since 2018, it has a pilot production line for solid electrolyte batteries that aims to scale up to a gigafactory by 2023.

QuantumScapes

SILA

1. Announced in March 2022 its intention to open in Quebec in 2023 plant with 8 GWh capacity.

Lion Electric

1. Announced in March 2022 its intention to open in Ontario in 2023 plant with 8 GWh capacity.

Solid Energy

IM3NY

1. Aiming to develop a plant by 2023 with a capacity of 11 GWh, expandable to more than 15 GWh.

SK Innovation

1. It is building two plants in Georgia planned for 2023 and 2024 with initial capacities of 40- and 42-GWh respectively (with the potential to increase beyond 25 GWh).

2. 1 GW plant in Jacksonville, Florida.

EUROPEAN GIGAFACTORIES

1. EV Battery Group: 1.4 GWh in 2023.
4. BASF/Volkswagen Nablat: 40 GWh in 2023 and 2024.

TSX.V: AMY | OTCQB: AMYZF | FSE: 2AM
Lithium-ion Battery Manufacturing

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 Scrap

TESLA Panasonic Cell Production

Percent of Apparent Capacity

- GF1 Battery Yield Rate
- GF1 Battery Yield Loss

Example of Cell Production Loss

39% Average Quarterly Cell Production Loss

Source: Panasonic Investor Presentation, Tesla Company Reports

Example of Cell Production Loss
Lithium-ion Battery Black Mass

Black mass produced by mechanical size reduction (pre-treatment) of end-of-life electric vehicle batteries
❖ Obtained from a variety of sources and pre-treatment processes
❖ Contain lithium, nickel, cobalt, manganese, graphite, carbon, aluminum, and copper
Current Options – Smelting

- **Harmful Emissions** - smelting oxides requires a fuel and generates about 2 tonnes of CO$_2$ 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 metal products
- **Further Refining** - individual metal products need to redissolved and crystallized into high purity salts before they can be processed into cathode precursors
Patents and Publications

US 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
- Korean Patent No. 10-2246670
- Japanese Patent No. 6906060
- National Phase Patent Applications for China, Europe, Australia, India, and Canada

US 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

A NOVEL CLOSED LOOP PROCESS FOR RECYCLING SPENT LI-ION BATTERY CATHODE MATERIALS
Joey Chung-Yen Jung1, Norman Chow2, Anca Nacu3, Mariam Melashvili4, Alex Cao1, Luka Khorbaladze1, Zarko Meseldzija2, Jay Pang-Chieh Sui3, and Jiujun Zhang1

Experimental Study on Recycling of Spent Lithium-Ion Battery Cathode Materials
Joey Chung-Yen Jung1,2, Norman Chow2, Douglas Dale Warkenin3, Ke Chen3, Mariam Melashvili4, Zarko Meseldzija2, Pang-Chieh Sui3, and Jiujun Zhang1,2
Closed-Loop Upcycling

The RecycLiCo™ process offers a closed-loop upcycling solution for lithium-ion battery waste into high-value cathode precursor material. With minimal processing steps and over 99% extraction of lithium, cobalt, nickel, and manganese the upcycling process creates valuable lithium-ion battery materials for direct integration into the re-manufacturing of new lithium-ion batteries.

- **Battery Manufacturing Waste (NMC/NCA Cathode Scrap)**
- **Pilot Plant Project (Pre-leach and Leach)**
- **Pregnant Leach Solution (PLS)**
- **Cathode Precipitation Reactor**
Closed-Loop Upcycling

SEM Scans of Cathode Precursor from Upcycled NMC and NCA Lithium-ion Battery Cathode Material

High Purity Cathode Precursor and Lithium Carbonate
Business Strategy

Close the loop by directly integrating the RecycLiCo™ process alongside Gigafactories and EV Manufacturers.

Intend to commercialize intellectual property via strategic partnerships and licencing agreements.

Battery Cathode Waste

Manufacturing Scrap

Upcycled Cathode Precursor Material

Cathode and Battery Manufacturers

Black Mass from Battery Pre-Treatment

Electric Vehicles
AMY and Italvolt Collaboration

Italvolt Battery Production Estimates:
• 45 GWh Full Capacity
• 76,725 tonnes of Cathode Active Material
• $1,220 Million Estimated Cathode Active Material Cost

Estimated Recoverable Value from 10% Production Scrap:
• 7,673 tonnes of Cathode Active Material Scrapped
• $122 Million Estimated Cathode Active Material Lost

Scarmagno, Italy
Planned Production Start – 2024
Full Capacity – 45 GWh
Road to Commercialization

Pilot Plant / R&D
❖ Approximately $10M raised to-date

Demonstration Plant
❖ $2.7M committed for construction & continuous operation testing
❖ Completed flowsheet modelling
❖ Equipment ordered

Commercial Plant
❖ In-House Estimate of $15-$20M
❖ Licensing / Joint Develop with Strategic Partners
Wenden Stockpile Project

Wenden Stockpile Material Reclamation and Advanced Material Processing Project was awarded to American Manganese by the U.S. Defence Logistics Agency (DLA) October 2020

Project consisted of lab-scale tests on Wenden Stockpile material to confirm the viability of American Manganese’s Patented Recovery Process (US Patent No. 8,460,631) to produce EMM

Manganese is listed by the U.S. Government as a critical mineral, one of 14 minerals or metals for which the U.S. is 100% import dependent.
$286M Market Cap

217M Shares Outstanding

34M Warrants and Options Outstanding

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