The Lithium in a Battery

By Emily Sarah Hersh
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Introduction

Many countries that possess lithium deposits are tempted to produce lithium ion batteries. While understandable, such plans do not often demonstrate understanding of the complexity of a battery and its associated manufacturing process.

Lithium in batteries is like the wheat that makes the flour for a cake: a fundamental and indispensable ingredient, but many steps away from the final product. This article sets out to explain what is inside a battery, and lithium’s necessary but insufficient role in powering the future of transportation.
Basic Battery Anatomy

Even though we call lithium-containing batteries “lithium ion”, there is quite a lot more going on—this brief provides a high-level look at some of these complex issues.

The battery packs that end up in our devices and electric vehicles contain multiple battery modules that in turn are made up of a series of battery cells. Figure 1 illustrates the components of a battery pack. Raw materials are not the only contributor to battery cost. Manufacturing and electronic management systems are also meaningful contributors to a battery cost. Lithium only represents between 5 and 15% of the total.¹

![Diagram of Battery Components](image)

Figure 1: Source: DCDB Group²

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¹ This number is based on lithium and battery prices at the time of paper writing, and the manufacturing costs of major producers including Panasonic, who makes the battery cells used by Tesla. This number can fluctuate within this range as lithium and other energy metal prices change, and may change as manufacturing or other battery component prices come down.

² DCDB Group is a multinational consulting firm with a specialization in the lithium industry. The author of this paper is a managing partner. [www.DCDBGroup.com](http://www.DCDBGroup.com)
Battery Cell Forms

Lithium ion battery cells are available in three basic forms: cylindrical, prismatic, and pouch. You encounter at least two of these forms every day. The batteries you put in your TV remote are cylindrical, whereas the battery in your smartphone or laptop is prismatic. Each form has pros and cons (Fig. 2).

Figure 2: Source: Cairn ERA

Inside the Battery Cell

Raw materials contribute to the cost of the battery cell. A battery cell is made up of three principal components (Fig. 3)—the anode (negatively charged), the cathode (positively charged), and a liquid electrolyte.

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3 Cairn Energy Research Advisors is a global research and consulting firm specializing in energy storage. http://cairnera.com/
When the battery is in use powering a device, the electrons flow through the circuit from the anode to the cathode, while the positively charged lithium ions (Li+) travel through the electrolyte to the cathode. Charging the battery causes the lithium ions to move back to the anode, allowing the battery to again provide power when connected (Fig. 4).

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4 Lux Research is a company based on science and engineering that provides technical expertise, advanced analytics, and primary research. https://www.luxresearchinc.com/
Today, except for a very small amount in the liquid electrolyte, the “lithium” in a lithium ion battery is almost entirely in the cathode. The cathode material is manufactured as a powder, which is then deposited on a substrate material and immersed in a liquid electrolyte.

**Cathode: Where the Lithium Is**

**Types of Cathode Materials**
Cathode materials differ between batteries (Table 1). In all cases they contain other minerals and metals in addition to lithium. Different cathode materials are used to make batteries with distinctive performance characteristics.

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5 https://www.luxresearchinc.com/
In the abbreviations, letters correspond to an element: N is for Nickel, C for Cobalt, A for Aluminum, etc. The L is for lithium, which is present even in the abbreviations with no L. When numbers follow the letters, it refers to the proportion of chemicals to each other. For example, NMC 1-1-1 contains equal parts nickel, manganese, and cobalt, whereas NMC 6-2-2 contains 6 parts nickel for every 2 parts manganese and cobalt.

There is no “best” cathode; rather, battery makers select which cathode to use based on the application needs and the material costs. Even within the transportation industry different cathode chemistries are preferred in different applications. High nickel cathodes like NMC are preferable for applications that prioritize range — or distance that an electric vehicle can travel before needing to be recharged, such as a personal automobile. Lithium iron phosphate (LFP) cathodes are less energy dense, and thus bigger and heavier, but are safer and can be charged and discharged more times, making them preferable for applications like buses.

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Table 1: Source: Cairn ERA

<table>
<thead>
<tr>
<th>Cathode</th>
<th>Chemistry Name</th>
<th>Formula</th>
<th>Applications</th>
<th>Strengths</th>
<th>Weaknesses</th>
<th>Gravimetric Energy Density (Wh/KG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCO</td>
<td>Lithium Cobalt Oxide</td>
<td>LiCoO₂</td>
<td>Consumer Electronics (phones, laptops, tablets)</td>
<td>Very high energy density</td>
<td>Thermal runaway is more common; poor low temperature performance; high cost</td>
<td>220-280</td>
</tr>
<tr>
<td>LFP</td>
<td>Lithium Iron Phosphate</td>
<td>LiFePO₄</td>
<td>Electric bus drivetrains; stationary storage</td>
<td>Excellent power capabilities; less prone to thermal runaway and fire</td>
<td>Very low energy density; no cost advantage over higher energy density cathodes</td>
<td>105-115</td>
</tr>
<tr>
<td>LMO</td>
<td>Lithium Manganese Spinel</td>
<td>LiMn₂O₄</td>
<td>Electric bus drivetrains; some power tools</td>
<td>Good temperature tolerance; high power capabilities; very low cost</td>
<td>Very low energy density</td>
<td>120-135</td>
</tr>
<tr>
<td>NCA</td>
<td>Lithium Nickel Cobalt Aluminum</td>
<td>LiNiCoAlO₃</td>
<td>Automotive drivetrains; power tools</td>
<td>Excellent power capabilities; high energy density; low cobalt usage</td>
<td>More prone to thermal runaway if heat builds up</td>
<td>180-240</td>
</tr>
<tr>
<td>NMC 1-1-1</td>
<td>Lithium Nickel Manganese Cobalt</td>
<td>LiNi₀.₃Mn₀.₃Co₀.₃O₂</td>
<td>Automotive drivetrains; stationary storage</td>
<td>Very stable compared to other cathodes with nickel; very good energy density; moderate cobalt usage</td>
<td>Cobalt cost is still high, making it relatively expensive</td>
<td>180-210</td>
</tr>
<tr>
<td>NMC 6-2-2</td>
<td>Lithium Nickel Manganese Cobalt</td>
<td>LiNi₀.₃Mn₀.₂Co₀.₂O₂</td>
<td>Automotive drivetrains; stationary storage</td>
<td>Sufficient stability so moderate susceptibility to thermal runaway; lower cobalt usage</td>
<td>Cobalt cost is still high enough to make it relatively expensive; tends to degrade more quickly</td>
<td>180-240</td>
</tr>
<tr>
<td>NMC 8-1-1</td>
<td>Lithium Nickel Manganese Cobalt</td>
<td>LiNi₀.₃Mn₀.₂Co₀.₁O₄</td>
<td>Automotive drivetrains</td>
<td>Very low cobalt usage and therefore eventually low-cost; extremely energy dense</td>
<td>Difficult and expensive to handle; manufacturing cost is more expensive; frequently unstable without extremely high-purity ingredients</td>
<td>200-260</td>
</tr>
</tbody>
</table>

Source: Cairn ERA

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http://cairnera.com/
The “spiderweb” in Figure 5 illustrates tradeoffs between operating parameters in NMC and LFP cathodes.

![Figure 5](source: Targray)

In the case of a lithium ion battery for a bus, energy density and range are sacrificed to achieve higher safety and an increased number of cycles.

**Battery Costs**

**Raw Materials**

The cost of cathode production is driven by costs of all the raw materials, as well as the technology and manufacturing processes. Cathodes are manufactured using predominantly:

- Lithium
- Nickel
- Cobalt
- Manganese

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7 Targray is a supplier of lithium ion battery materials for battery and energy storage technologies. [https://www.targray.com/li-ion-battery](https://www.targray.com/li-ion-battery)
Of these materials, cobalt exhibits volatile price movement and presents supply chain concerns due to geographic concentration in politically volatile jurisdictions. A desire to reduce exposure to this market has influenced battery makers to favor and develop chemistries with lower proportions of cobalt.

**Battery Prices vs. Material Costs**

Falling lithium ion battery prices are a major enabler of the EV revolution, and battery prices have continued to fall despite the fact that raw material prices have risen and fallen (Fig. 6). This is due both to technological innovation and the economies of scale gains as mega and giga factories drastically increase battery production worldwide. Because of the complexity and global nature of the battery supply chain, raw material price movements do not necessarily imply a direct pass through to battery prices.

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**Figure 6: Source: Benchmark Mineral Intelligence**

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**The Lithium in a Battery**

As noted, lithium is only one of the components required to make a battery and is not the most significant cost contribution. Figure 7 illustrates a standard Tesla battery and shows the relative importance of lithium to the cathode, and the cathode to the battery.

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8 Benchmark Mineral Intelligence provides price, supply, and demand information and forecasting on battery raw materials such as graphite, lithium, cobalt, and nickel [https://www.benchmarkminerals.com/](https://www.benchmarkminerals.com/)
In Figure 7, the column of minerals on the left side represent the minerals used in making the NCA cell that Tesla puts in its cars, with lithium represented in red. Those raw materials are used to manufacture the cathode, represented by the pie chart. The lithium is represented as lithium carbonate equivalent (LCE) by the red slice. The cathode is then shown in the battery, represented by the cylinder. In this example, the cathode represents only 22% of the total cost of the battery.

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9 This graphic was created by the hosts of the Global Lithium Podcast (http://lithiumpodcast.com/) using information from Nano One Materials Corp (https://nanoone.ca/) and Cairn Energy Research Advisors (http://cairnera.com/)
**Key Takeaways**

You need lithium to make a battery – but you need a whole lot more. In order for countries with lithium resources to maximize their value in the battery supply chain, they must work to develop expertise and understanding of how to integrate in areas with the highest competitive advantage.

Making lithium ion batteries simply because there is a lithium deposit is not economic, and will result in uncompetitive projects that fail to deliver return to countries. Countries that possess lithium deposits should take steps to understand and support the growth of robust supply chains based on competitive advantage and cooperation between actors.
Emily Sarah Hersh is based in Buenos Aires, Argentina where she serves as Managing Partner of DCDB Research. Emily is a well-known lithium industry expert and is the co-host of the popular Global Lithium Podcast (www.lithiumpodcast.com). Emily manages projects in South America for companies in the mining, energy, oil and gas industries. Her specialization in lithium includes project due diligence, country risk assessment and emerging battery technologies. She manages a private family office fund dedicated to raw materials in the battery supply chain.

Emily has given keynote speeches on lithium, energy storage, renewable energy in Latin America, and emerging battery technology at events hosted by The Institute of the Americas, Metal Bulletin, Fastmarkets, Benchmark Mineral Intelligence, Euromoney, GFC Media, Greenpower Conferences, SolarPlaza, and many others.

In 2013, Emily co-founded The Bubble News. She appears on CNN and Al-Jazeera America in relation to Argentina’s economy, and her work is frequently featured in Business Insider, The Bubble, Wolf Street, and InfoBAE. She is regularly quoted in The Financial Times, Bloomberg, and Reuters related to lithium and battery materials.

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