Minerals for the Digital Future
Lithium and Batteries

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Welcome to the future, powered by lithium

- Where is the lithium in this device?
- How much lithium is there?
- Where did that lithium come from?
- How did lithium get into the battery?
- What about electric vehicles?
- What are the challenges?
Lithium Ion Batteries Enable Energy Mobility

An iPhone contains less than 1 gram of elemental lithium

It takes 6 grams of a lithium chemical compound to get that lithium to work

It takes even more to make the battery – excess lithium is lost to manufacturing process

The screen – which doesn’t need lithium to work – actually contains more than the battery
**The Lithium in a Battery Is (Mostly) In The Cathode**

A battery cell is made up of three principal components:
1. The anode (negatively charged)
2. The cathode (positively charged)
3. A liquid electrolyte

When the battery is in use, 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 moves the lithium ions back to the anode.

Except a very small amount in the electrolyte, the “lithium” in a battery is almost entirely in the cathode.

Cathode materials is manufactured as a powder, deposited on a substrate, and immersed in liquid electrolyte.

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*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.*
Most of a Battery is Not Made of Lithium

Sources: Nano One and Cairn Energy Research
Questions on Batteries?
What is Lithium?
The third element on the periodic table

- Lithium is the lightest – or least dense – metal that exists on earth
- Allows for high performance batteries that are smaller and last longer
- Lithium never occurs freely in nature, only in compounds
What do we mean by “Lithium”
Context of Lithium Carbonate Equivalent (LCE)

<table>
<thead>
<tr>
<th>Convert from ▼</th>
<th>Convert to →</th>
<th>Lithium Metal</th>
<th>Lithium Carbonate</th>
<th>Lithium Hydroxide</th>
<th>Lithium Chloride</th>
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<tbody>
<tr>
<td>Lithium Metal</td>
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<td>Lithium Carbonate</td>
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<tr>
<td>Lithium Chloride</td>
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<td>0.871</td>
<td>0.989</td>
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This table is for calculating physical contained lithium equivalencies.
Lithium chemical compounds are not priced based on contained lithium.
How does a lithium deposit look?
Easy to find, difficult and expensive to commercially extract

- Conventional Brine
- Volcanic Tuff
- Lepidolite
- Hard Rock (Spodumene)
- Clay
- Oilfield Brine
Not All Lithium Deposits Are Viable Projects

- Deposits on every continent
- New discoveries are made constantly – but new projects are few and far between
- Seawater contains 0.17 mg/l – not economic but a valuable illustration of lithium’s relative abundance
How does a lithium deposit look?  
Easy to find, difficult and expensive to commercially extract

There is a critical difference between:

- **Deposit:** I know it’s there
- **Resource:** I know how much there is
- **Reserve:** I know how to extract & commercialize

Mineral exploration is inherently risky and expensive. Results impossible to perfectly predict. The market can shift in the time it takes to bring a discovery through feasibility.
Questions on deposits?

- Conventional Brine
- Volcanic Tuff
- Lepidolite
- Hard Rock (Spodumene)
- Clay
- Oilfield Brine
For Lithium Producers, Batteries Are What Matters
Battery demand growing exponentially, others follow GDP Growth

*Demand for lithium in chemical compound form – does not include mineral use*
For Battery Producers, Transportation Is What Matters
Passenger EVs are by far the largest segment

Global lithium-ion demand by market segment

Annual GWh
1,400
1,200
1,000
800
600
400
200
0
2016
2018
2020
2022
2024
2026
2028
2030

Electric vehicles
Consumer goods
Stationary storage

3 hours of global power supply
7.5 minutes of global power supply

Source: Bloomberg New Energy Finance. Note: Assumes 100% of stationary is lithium-ion.
Within Transportation, Passenger EVs Dominate
Transportation Sector Forecast

- Majority of lithium ion batteries destined for use within transportation sector (515 thousand tons LCE)
- Majority of batteries in transportation sector will be in passenger EVs
- Non-EV markets like e-scooter, e-bus, and e-truck markets also demonstrate strong growth

Source: Cairn Energy Resource Advisors 2019
The Battery Market Needs More “Lithium Production”

That “production” must be of stable lithium chemical compounds that can be used to produce safe battery materials.
Batteries Fueling Exponential Lithium Market Growth

Relative Market Size in USD, Lithium

2015 2017 2019

Source: UN Comtrade & Trade Statistics

- The lithium market tripled from 2015 – 2017, but only reached US $1 billion for the first time in 2015
Market Growth in Context

**Relative Market Size in USD, Lithium vs. Gold**

- 2015
- 2017
- 2019

Gold

Lithium

Source: UN Comtrade & Trade Statistics
Exponential Lithium Growth vs. Relative Market Size

Relative Market Size in USD, Lithium vs. Gold and Oil

Source: UN Comtrade & Trade Statistics
Questions on the Market?

2017:
- Lithium Ion Battery: 51%
- Glass/Frit/Glaze: 19%
- Grease: 10%
- Air treatment: 4%
- Polymer: 3%
- Pharma: 4%
- Metal: 3%
- Other: 4%

2018*:
- Lithium Ion Battery: 59%
- Glass/Frit/Glaze: 17%
- Grease: 7%
- Air treatment: 2%
- Polymer: 2%
- Pharma: 4%
- Metal: 4%
- Other: 3%

GLOBAL LITHIUM

217,121 Tons LCE

225,948 Tons LCE
Lithium Chemical Compounds ≠ Commodities

Battery “Grade” is Nonexistent
• Battery “Quality” is not one specification
• Impurities define ability to use lithium chemical in a battery
• Future price reporting will require more nuance
Lithium Production Doesn’t Tell Full Story

![Annual Lithium Exports Graph](image)

Annual Lithium Exports
Tons Lithium Carbonate Equivalent (LCE)

- 2015
- 2016
- 2017
- 2018

- Green bars represent Chile
- Blue bars represent Argentina
- Red bars represent Bolivia
Not All Lithium is “Battery Ready”

As battery share of the market increases, producers must improve
Lithium Chemical Compounds – Quality Affects Price

Joe Lowry, Global Lithium 2019

<table>
<thead>
<tr>
<th>Destination</th>
<th>Volume</th>
<th>Ave Price</th>
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<tbody>
<tr>
<td>ANTWERP</td>
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<tr>
<td>BALTIMORE</td>
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<td>BUENOS AIRES</td>
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<td>DURBAN</td>
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<td>SHANGHAI</td>
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</tbody>
</table>

SQM’s May Export Prices from Chile – Mostly “New Normal”


BRISBANE, Australia, July 23, 2019 (GLOBE NEWSWIRE) -- JUNE QUARTER 2019 KEY HIGHLIGHTS*1

OLAROZ LITHIUM FACILITY (ORE 66.5%)*2

- Q4 FY19 production was 3,455 tonnes, down 4% on the previous corresponding period (PCP) following a strategy of managing brine quality, now pond preparation and slightly lower than average evaporation rates. Production for the year was up marginally from FY18 to a new record of 12,605 tonnes.
- Quarterly sales revenue was US$27.8 million, down 17% QoQ with a realised average price achieved of US$8,220/tonne on a free on board basis (FOB)*3.
- June quarter product pricing was below that of the March quarter due to current market softness. Sales volume for the quarter was down 4% QoQ to 3,387 tonnes.
- Gross cash margins (excluding export tax) of US$3,727/tonne were down 29% QoQ mainly due to the lower average price received, however the gross cash margin remains at a very strong 45% of revenue.
- Cash costs for the quarter (on cost of goods sold basis)*4 were US$4,493/tonne, up 7% on QoQ excluding the recently announced export tax of US$0.7/tonne.
Chemical Pricing:
Different Products Have Different Prices

- The commodity vs. specialty chemical debate continues – I am firmly in camp B
- Price obsession distracts and oversimplifies the underlying fundamentals of the market
Lithium Chemical Compound Supply and Demand to 2025

Battery Quality Likely to be Undersupplied

Supply
Lithium Supply and Demand Long Term Forecast

Source: Benchmark Minerals 2019
Questions on Price?
The Lithium Supply Chain Overview

LI-ION BATTERY VALUE CHAIN
From mining to OEM level

Mineral Extraction → Chemical Production → Cathode Production → Cell Production → Module Assembly → Electric Vehicle

Source: VW modified by DCDB Group
The Lithium Supply Chain Overview

LI-ION BATTERY VALUE CHAIN
From mining to OEM level

Mineral Extraction  Chemical Production  Cathode Production  Cell Production  Module Assembly  Electric Vehicle

Source: VW modified by DCDB Group

Map indicating production and supply locations around the world with a focus on China and South America.
Lithium price does not determine final battery costs

Lithium demand driven by battery market size

**Battery prices fall while lithium prices rise due to:**
- Economies of scale
- Increases in efficiency
- Technology advances

As batteries become cheaper and more efficient, more batteries are demanded for an increasing number of applications.
The Laptop Supply Chain
Mindset: “South America Exports Raw Materials”
Battery Quality Lithium Chemicals Are **Not Raw Materials**

Lithium Chemicals Are Value Added Products
Lithium Chemical Compound Production is Complex

Capital investments and technological development today for future production

Capital, Technology, and Infrastructure are needed today to achieve future production
Who is next Latin American Lithium Chemical Producer?

Chile: Commercial production
- High quality brine
- Concentrated assets

Argentina: Commercial production
- Diverse brines
- Too many players

Peru: Exploration
- Volcanic Tuff
- One deposit

Brazil: Advanced exploration
- Spodumene
- Few Players

Bolivia: Exploration
- Low quality brine
- Low government support

Mexico: Exploration
- Clay deposit
- Few Projects
Who is Next Latin American Lithium Chemical Producer?

Peru, Mexico, or Bolivia could become third country in Latin America to make lithium chemicals for the battery market

This depends on:
- Policy Supporting Long Term Investment
- Understanding of Value Chain
- Attracting Capable Investment Partners
- Setting Realistic Expectations Among Society

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- High quality brine
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