

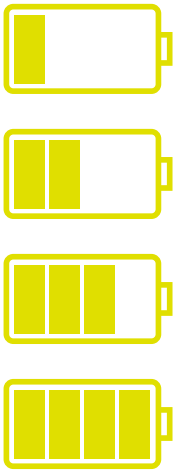
Battery Metals

HATCH

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Hatch: Providing engineering, construction management and business advisory to our clients in the metals, energy and infrastructure space.

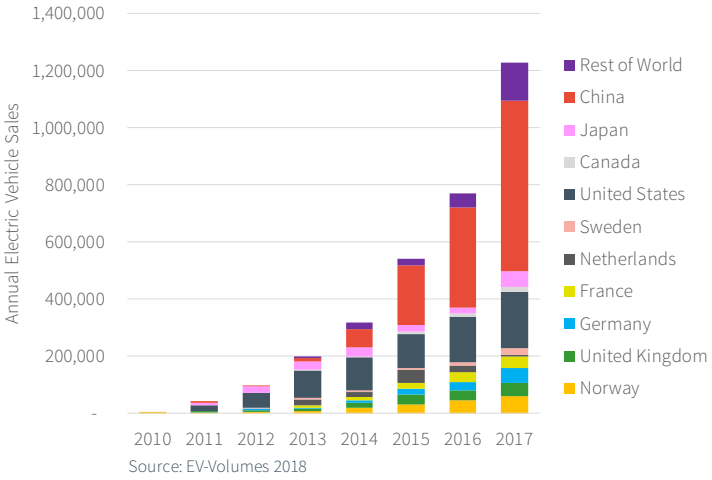


- Producers, new entrants and investors continue to have a growing interest in battery metals and the key commodities surrounding this trend:
  - Lithium
  - Cobalt
  - Nickel
- Hatch has been involved in numerous projects for these three metals, and our Advisory group is able to leverage our internal industry experts to assist our clients in transaction advisory services, including M&A, investing or lending.
- This discussion provides an overview of the battery metals trends and the key challenges of executing lithium, cobalt, and nickel projects

Battery Electric Vehicle Industry Trends

Global trends are pushing adoption and development of battery electric vehicle (BEV) technologies worldwide.

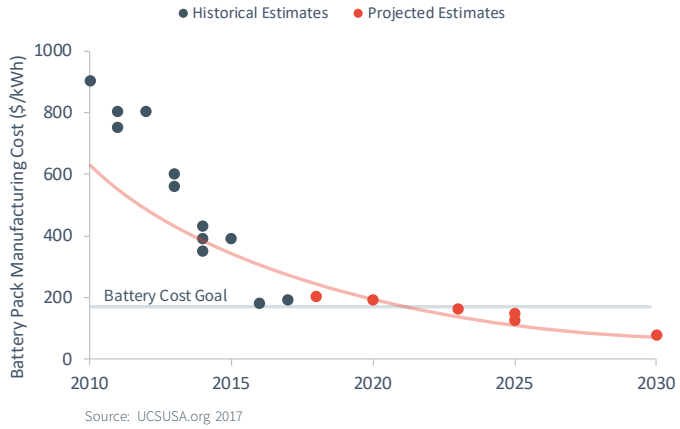
- Recent advances in battery technology have gradually improved performance and reduced cost, and BEVs are expected to be competitive with internal combustion engines (ICEs) in the near future
- Climate change and pollution concerns continue to push governments to reduce domestic fossil fuel consumption via subsidies and regulation for green energy
- China seeks to be a world leader in BEV production by aggressively incentivizing domestic EBV adoption and securing global battery metal supplies
- Energy storage is a growing industry as green energy and electric vehicle needs are increasing



Source: EV-Volumes 2018

Battery technologies are central to the BEV trend.

- Material costs account for about 60% of lithium ion battery (LIB) cost
- Battery manufacturers seek to secure raw material supplies of critical metals for battery cathodes:
  - Lithium
  - Cobalt
  - Nickel
- Research and development in battery technologies is driven by the desire to reduce cost and improve battery performance through substitution of cheaper cathode materials

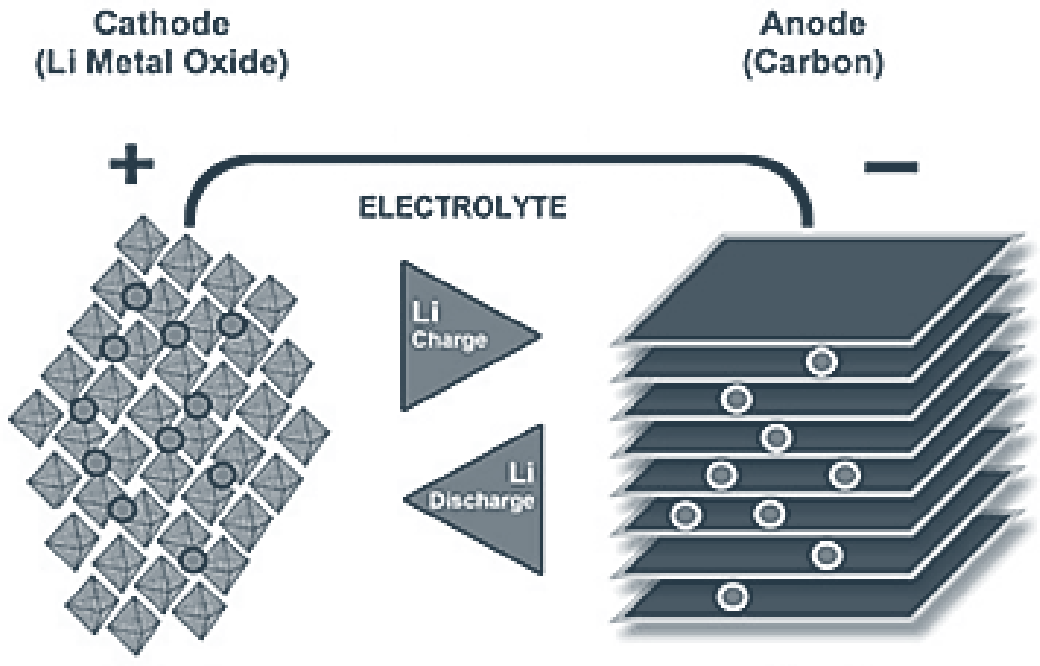


Source: UCSUSA.org 2017

Lithium Ion Battery Chemistries

For BEVs to be competitive, their batteries need to have long range, fast charging times, high safety and a low cost.

- Traditionally, battery manufacturers achieve these characteristics by altering cathode chemistry in the battery
- All batteries have a cathode, anode, and electrolyte component
- Upon battery discharge, ions flow from the anode to the cathode via the electrolyte (conductor), while charging reverses this flow
- Cathodes are comprised of many metals, such as lithium, cobalt, nickel, manganese, and aluminum



Metals such as Co, Ni, Mn, Al, P, and Fe

Typically graphite

Source: batteryuniversity.com



There are five prevalent lithium ion battery cathode chemistries.

LCO – Lithium Cobalt Oxide	LMO – Lithium Manganese Oxide	LFP – Lithium Iron Phosphate	NCA - Lithium Nickel Cobalt Aluminum Oxide	NMC – Lithium Nickel Manganese Cobalt Oxide
(1991)	(1996)	(1996)	(1999)	(2008)
• High specific energy makes it popular for mobile devices • Limited specific power and high cobalt content (cost), and lower relative safety make it unsuitable for EVs	• Higher specific power than LCO, but lower specific energy • Pure LMO batteries now uncommon, superseded by lithium manganese batteries with other metals added (see NMC)	• Very high specific power, can be used in place of lead acid starter battery • High safety rating • Low specific energy makes it unsuitable for EVs on its own	• A good option for EVs • High specific energy, good specific power, good safety • Safety and cost are inferior to NMC batteries, but safety can be improved with proper battery design	• The preferred battery for EVs due to recent improvements in specific energy and cost • High specific energy, good specific power, good safety • Battery chemistry can be tailored to improve energy or power

Specific energy = how much energy a battery can store
Specific power = how fast energy can be taken from the battery

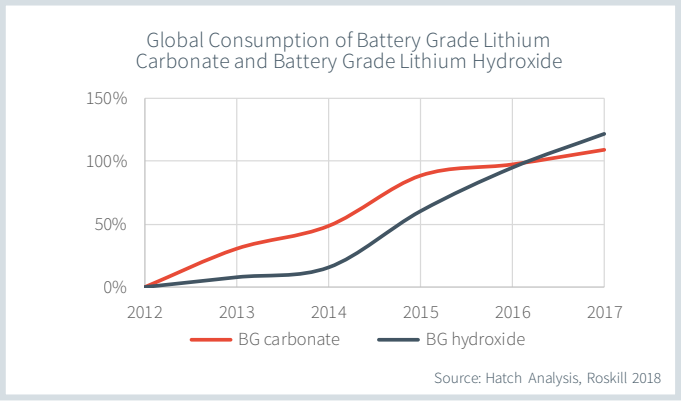
Source: Hatch

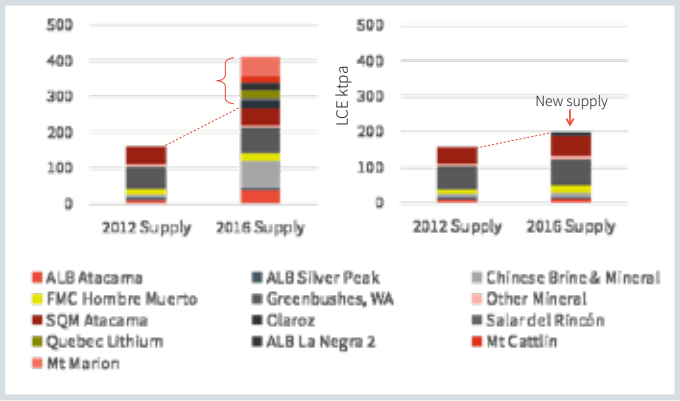
Raw Material Production for BEVs

Lithium

Lithium is a critical ingredient to lithium-ion batteries, and good alternatives are not yet available.

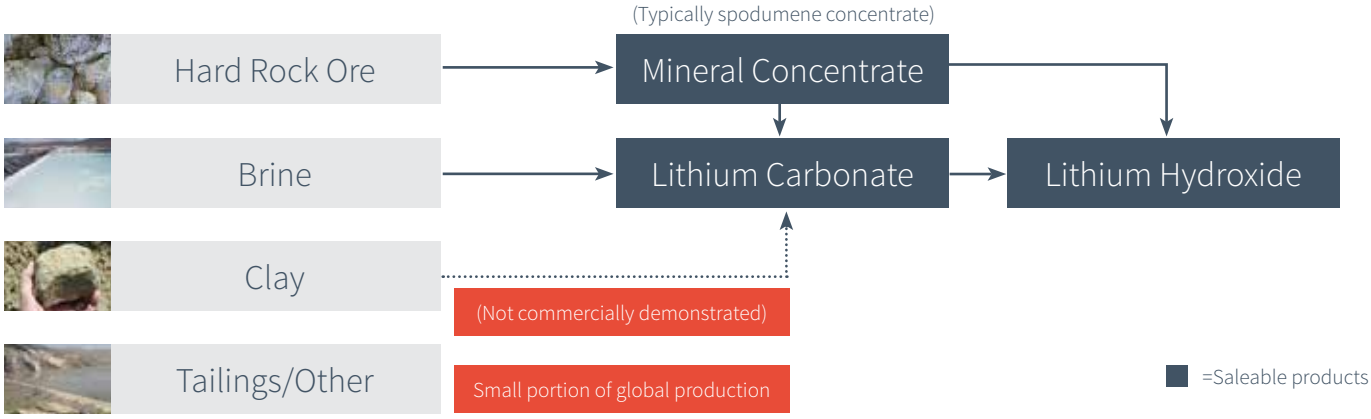
- Demand has increased significantly in recent years due to the forecast growth in EV adoption
- Other battery technologies that are free of lithium are still 10-20 years away from challenging lithium ion battery dominance in the market
- This growth has spurred on several projects for new and expanded capacity
- Lithium projects can take 5-10 years to begin production due to difficulty in raising funds as investors remain hesitant





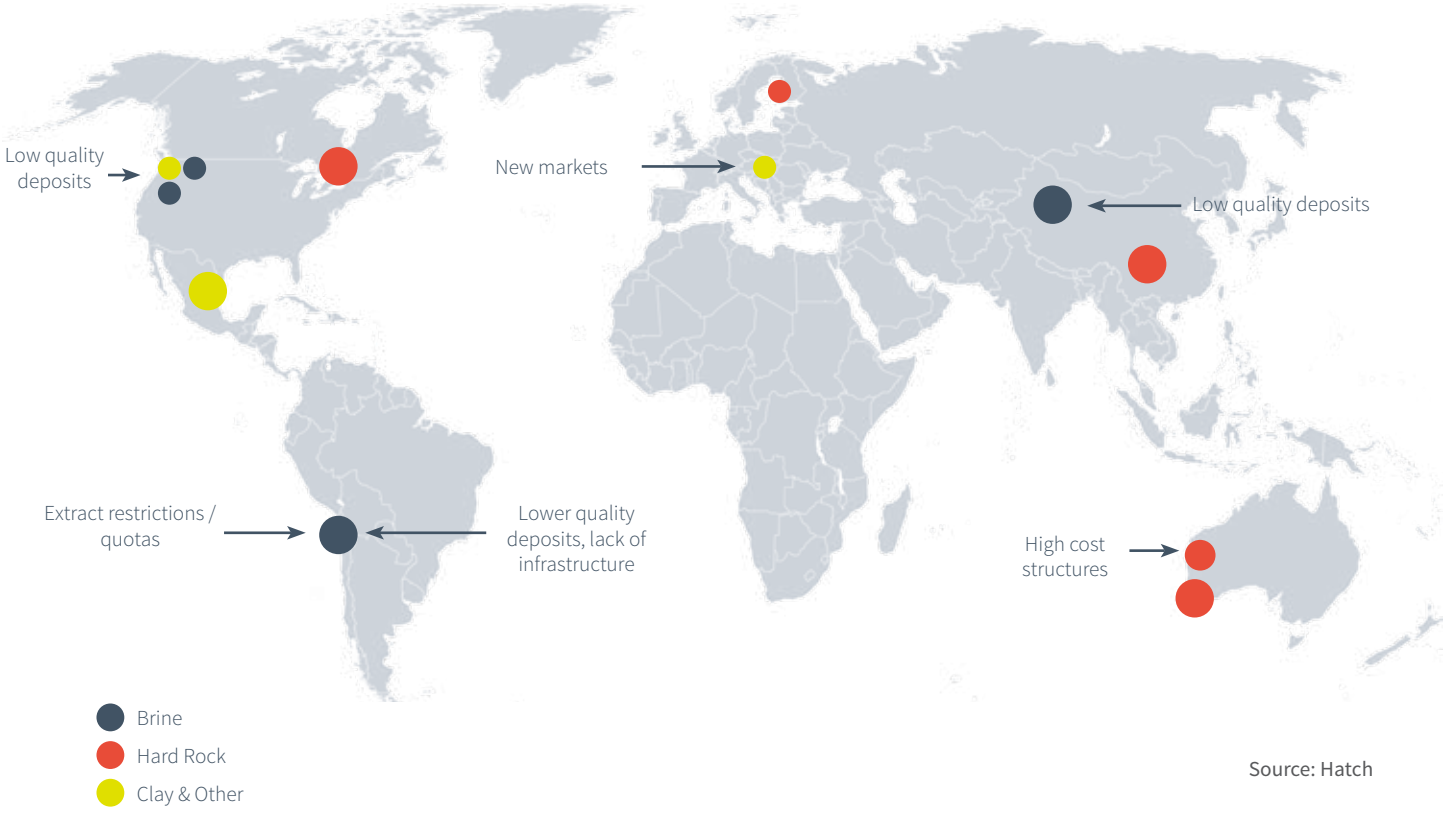
Source: Mining.com

The key lithium chemicals used in battery production are lithium carbonate (Li_2CO_3) and lithium hydroxide ($LiOH\text{-}H_2O$), which can be produced from various sources.



Source: Hatch

Each key lithium jurisdiction has challenges associated with the production and sale of lithium chemicals.



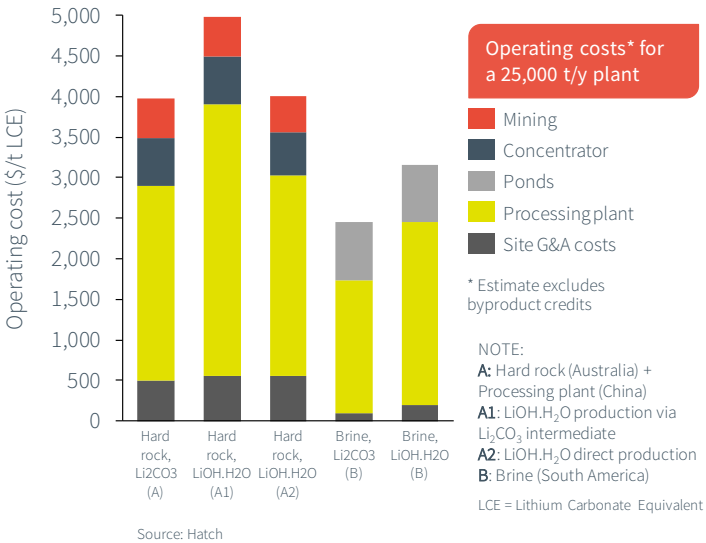
Source: Hatch

Most of the world's lithium carbonate and lithium hydroxide production currently comes from either mineral/hard rock or brine deposits.

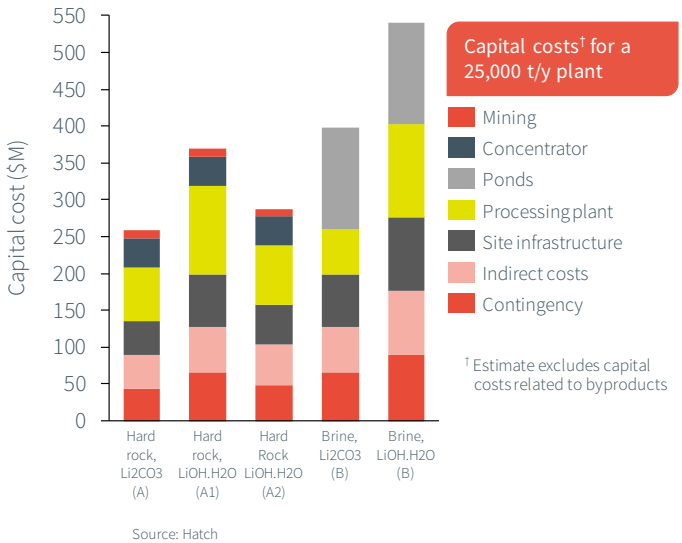
Current processing technologies:

Hard Rock	Brines	Clay/Other
High opex, fast ramp-up • Concentrator plant to produce mineral concentrate, followed by • Chemical plant to produce Li_2CO_3 from concentrate using acid roast leach process, or • Chemical plant to produce LiOH.H_2O directly from concentrate via the lime or causticization process	**Low opex, slow ramp-up** • Fresh brine to Li_2CO_3 using evaporation ponds and chemical purification, followed by • Li_2CO_3 to LiOH.H_2O using either the lime or causticization process	**No commercial plants currently exist, but projects plan to process clay to Li_2CO_3**

Operating costs are dominated by reagents and labour, while major capital cost contributors are the ponds (brine) and the purification / processing plant (hard rock and brine).



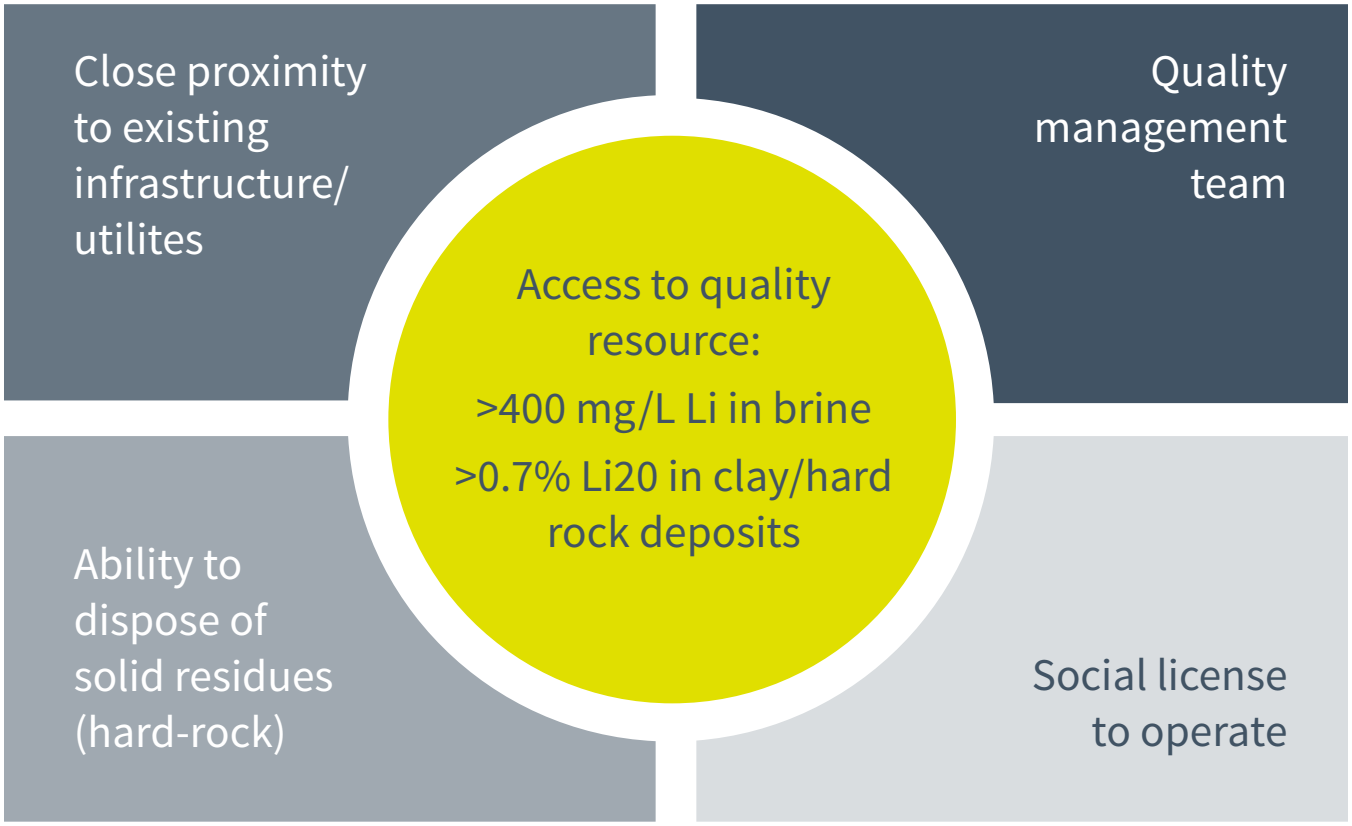
Source: Hatch



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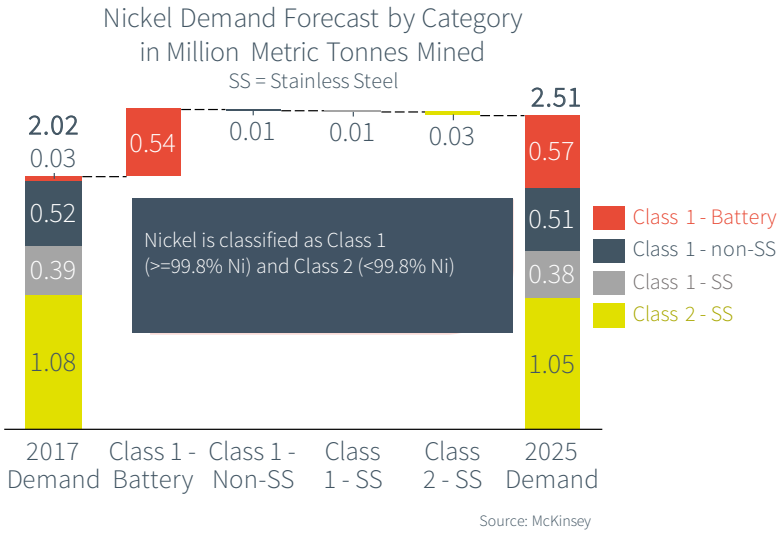
Key success factors for Lithium Projects:



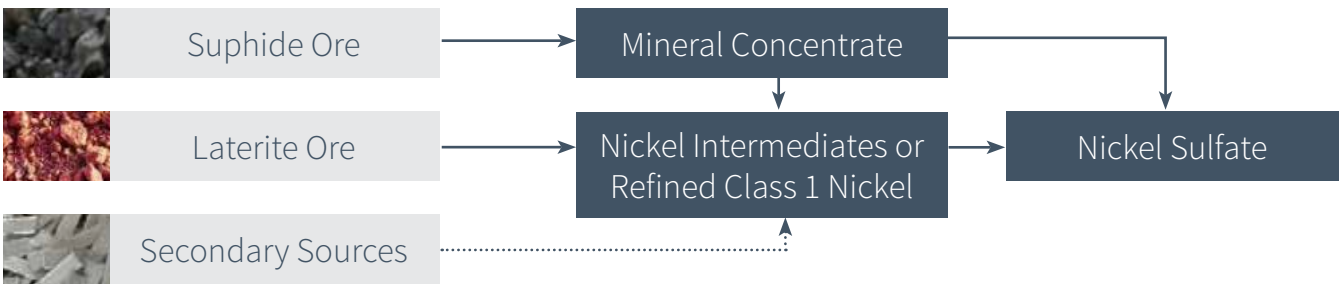
Nickel

Nickel is used in lithium-ion batteries to improve battery performance, and battery production requires Class 1 nickel.

- The majority of global nickel consumption is in the steel industry, which uses both Class 1 and Class 2 nickel
- Class 1 nickel consumption is expected to grow significantly, and nickel pricing may be split into two products
- Nickel sulphide deposits may offer the best economics for production of nickel sulphate, but few major new high grade discoveries have been made
- Future demand will likely have to be met by increased nickel sulphate production from lateritic deposits

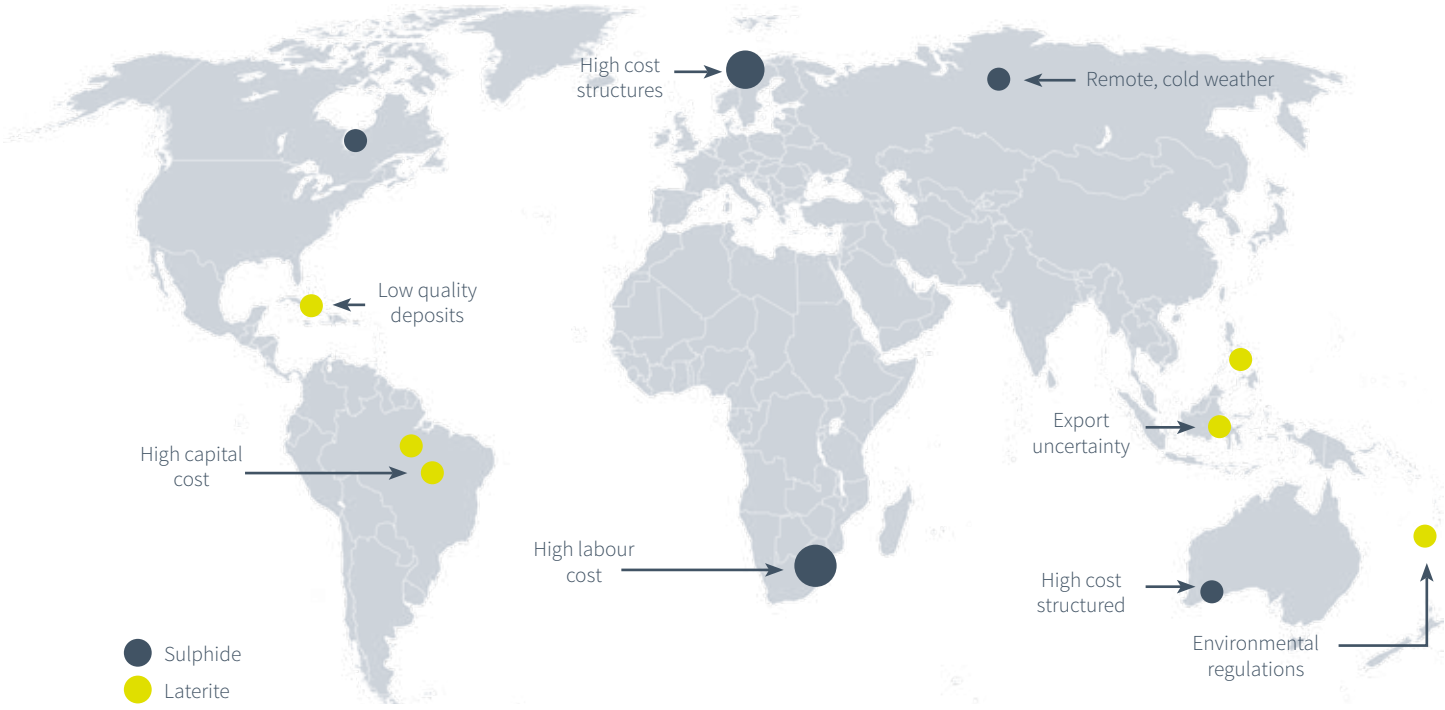


The main nickel chemical for battery production is nickel sulphate ($NiSO_4$-xH_2O), which can be produced in multiple ways.



Source: Hatch

Each key nickel jurisdiction has challenges associated with the production and sale of nickel chemicals.



Source: Hatch

Most of the world's current nickel sulphate production comes from either nickel sulphide or laterite ores, both of which may be processed via multiple different technologies.

Current processing technologies:

Laterite Ores	Sulphide Ores
High opex	**Low opex, few new discoveries**
• Upgrading to produce higher grade ore, followed by	• Concentrator plant to produce mineral concentrate, followed by
• High pressure acid leach (HPAL) to produce nickel intermediates, or	• Smelter to produce nickel intermediates, or
• Smelter with Sulphur addition to produce nickel matte, followed by	• Acid leach to produce nickel intermediates, followed by
• Refinery to produce nickel sulphate	• Refinery to produce nickel sulphate

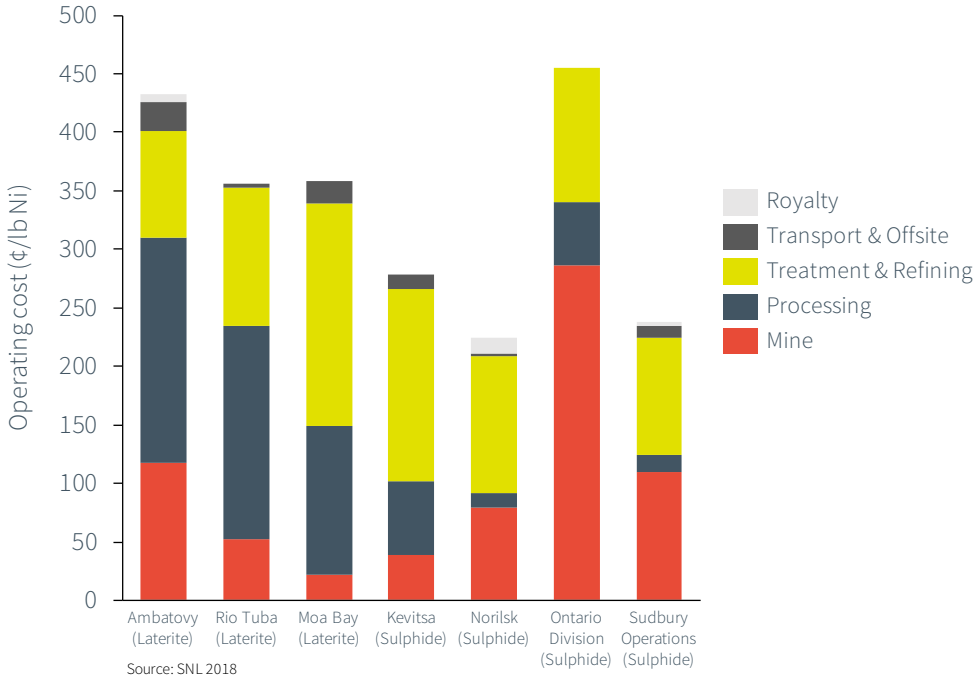
Nickel sulphate production can be done with many different feedstocks, including but not limited to nickel hydroxide, nickel or mixed sulphide, nickel matte, nickel metal, and nickel carbonate



Operating costs for laterites are dominated by processing and refining, while mining represents a high portion of operating cost for some sulphide producers.

The processing costs of laterite ore projects are often higher than those for sulphide ore projects

Many of the first quartile producers on the nickel cost curve are sulphide ores



Source: Hatch Analysis, SNL 2018

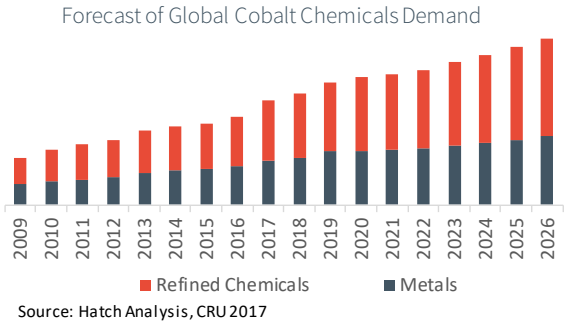
Cobalt

Cobalt is a critical ingredient for EV batteries, where it is used in the form of cobalt chemicals.

- Battery manufacturers continue to push for lower cobalt to reduce battery cost, but eliminating cobalt entirely is not likely in the short to mid-term future
- Approximately 97% of the world's cobalt is produced as a by-product of nickel or copper, and supply of cobalt is strongly governed by Cu and Ni prices
- China has been making significant moves to secure a dominant position in the cobalt market
  - Ability to invest in cobalt projects on western-based exchanges are therefore limited
  - The majority of Chinese-owned cobalt assets are in the Democratic Republic of the Congo

The majority of world cobalt reserves and resources are located in the Democratic Republic of the Congo (63%), followed by Australia (10%), Tonga (9%), and Canada (5%)

Refined chemicals are expected to represent over two thirds of total cobalt demand by 2026



The key cobalt chemicals used in battery production are cobalt oxide and cobalt sulphate, which can be produced from various sources.

Current common processing technologies for cobalt-containing ores:

Cobalt-Copper Ores	Cobalt-Copper-Nickel Ores
• Cobalt-copper ores in DRC and Zambia are typically processed to produce a mineral concentrate • This is treated to produce a separate cobalt-rich concentrate for treatment in the cobalt circuit • Cobalt concentrates are then treated further via pyrometallurgical or hydrometallurgical processes, followed by electrolysis to recover cobalt	• In pyrometallurgical processes, cobalt is oxidized to smelting furnace slag along with iron. The slag is typically treated in a furnace to recover the cobalt to a metal alloy • In hydrometallurgical processes with pressure leaching of nickel, cobalt is recovered from solution by reduction with hydrogen under pressure • Cobalt is refined from crude processing by-products via electrowinning

Cobalt found in laterite ores that are processed to Class 2 nickel products such as ferronickel and nickel pig iron is typically not recovered.

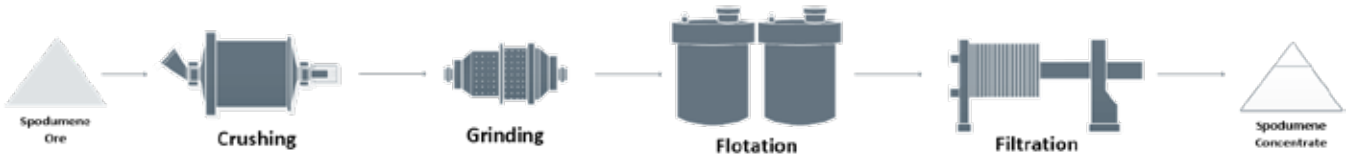
Conclusions

Demand for electric vehicles and battery energy storage is expected to continue growing in the short and mid-term.

- While development of new supply is attracting investor attention for lithium, investors are still hesitant how expansion projects of existing producers will affect supply and how long new projects will take to bring online
- Battery production is a growing source of Class 1 nickel consumption, bringing opportunity to Class 1 nickel producers. Some existing nickel producers are also developing nickel sulphate plants to take advantage of the growing demand for this material
- Cobalt supply is closely tied to copper and nickel, resulting in a recent surge in cobalt pricing. Investors and buyers are hesitant about the social impact of supply from the world's largest producer, the DRC, in which some small producers use manual labour with low safety standards
- Hatch has extensive experience in engineering and execution of mining and metals processing projects in the lithium, nickel, and cobalt industries. We have worked with many major lithium and nickel producers over the past few decades supporting both greenfield and brownfield projects, including supply of our Hatch technologies. We are excited to leverage this experience to assist your pursuits in the battery metals space

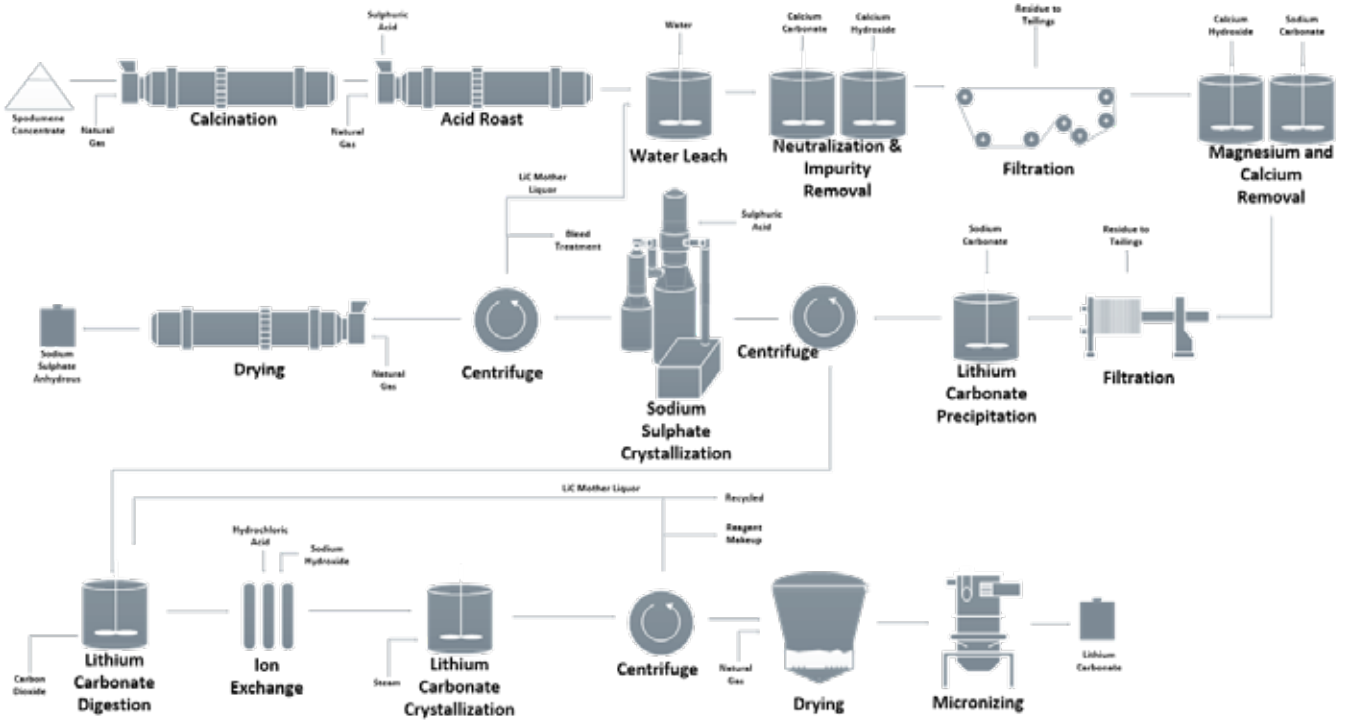
Appendix A: Lithium Process Flow Diagrams

Hard rock deposit owners can focus on concentrate production, for sale to China (or other low cost country) where it can be processed at lower cost.



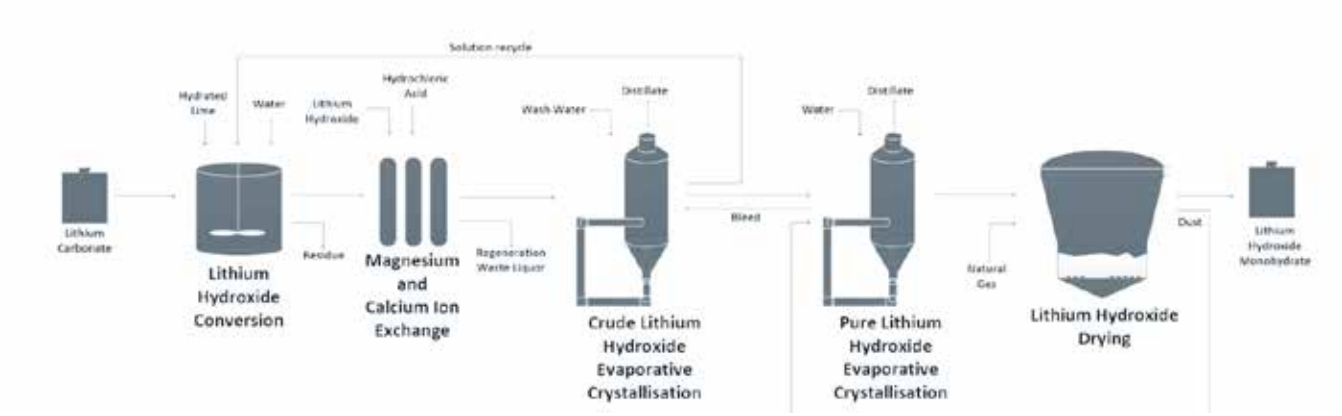
Source: Hatch

Spodumene concentrate is calcined, roasted, and leached prior to chemical purification and Li_2CO_3 production.



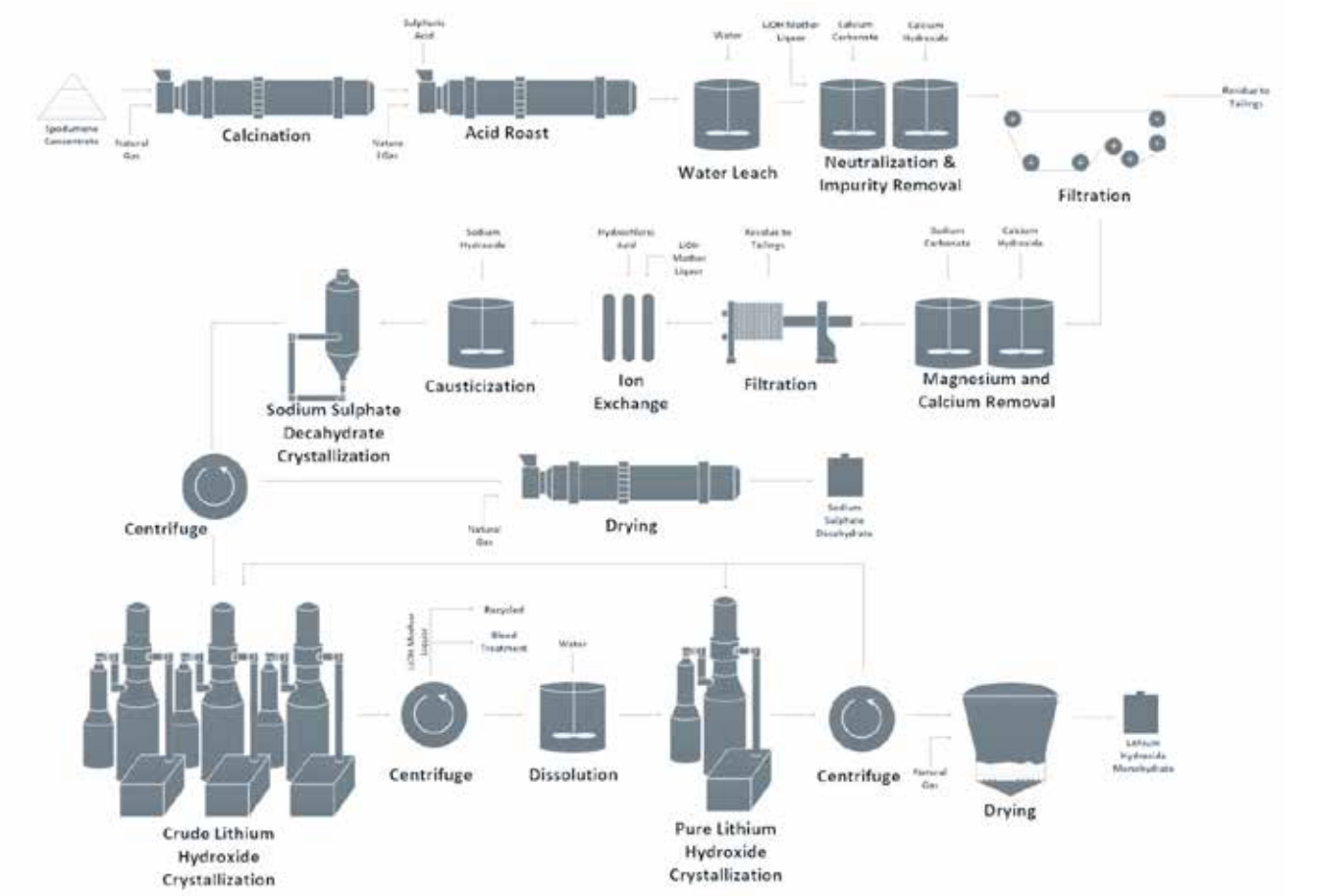
Source: Hatch

Li_2CO_3 is reacted in solution with hydrated lime followed by ion exchange before crystallizing and drying the $LiOH.H_2O$.



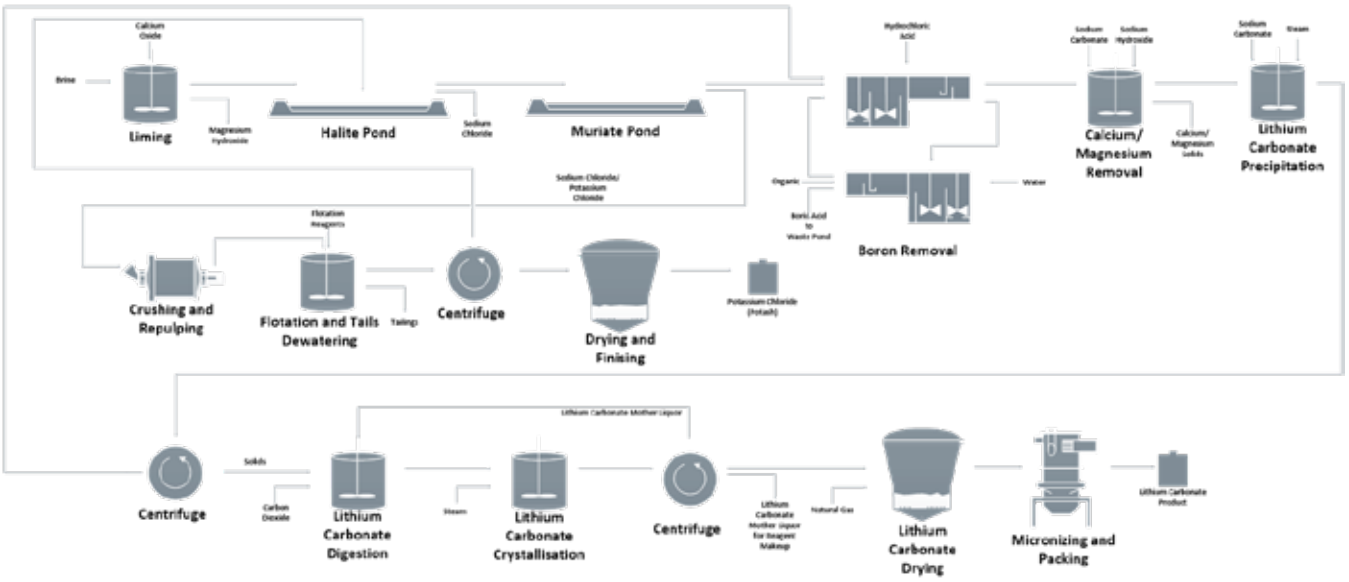
Source: Hatch

$LiOH.H_2O$ can be produced directly from spodumene concentrate via a causticization process.



Source: Hatch

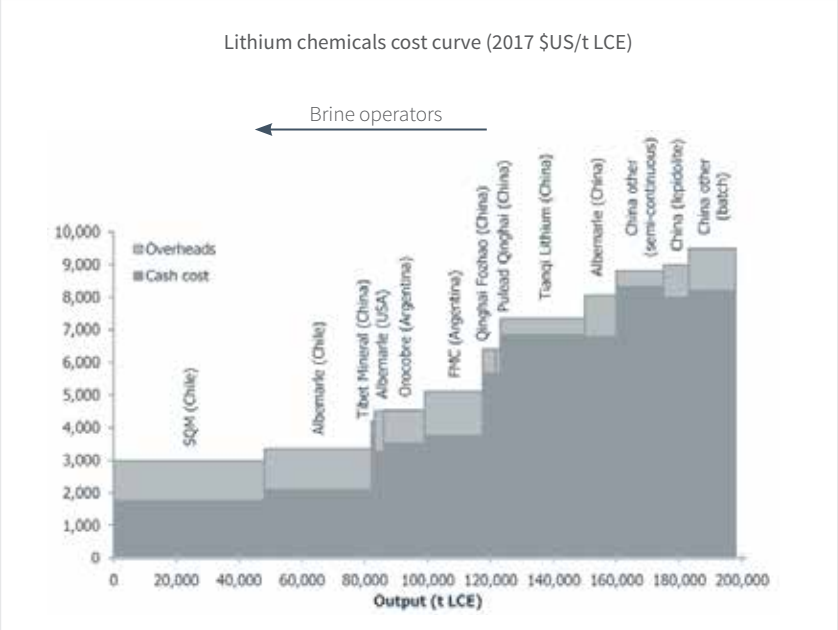
Lithium rich brines utilize large solar evaporation ponds, prior to on-site chemical purification and conversion to Li_2CO_3.



Source: Hatch

Appendix B: Lithium Cost Curve

The bottom half of the lithium carbonate cost curve is dominated by brine production facilities.



SOURCE: Roskill

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