OCEAN WALL

The Case on Lithium

March 2024

CONTENTS

INTRODUCTION

Since our initial report in 2020, the lithium market has undergone several systemic changes impacting fundamental supply-demand dynamics, prices, and associated investments. We continue to believe that the lithium market presents one of the most compelling investments in the energy transition.

The long-term outlook remains positive, driven by the growth of electric vehicles, rising demand for renewable energy storage, and lithium's use in consumer electronics. Technological advancements in lithium extraction, delivering cleaner, faster, and far more efficient production solutions, combined with global regulatory commitment to reducing emissions serve as catalysts for these three drivers.

Lithium's criticality will continue to grow, driving the energy transition and disrupting the hydrocarbon sector. The commodity has been backed by significant investment from public and private entities, yet market sentiment has, of late, fallen behind. It is not a matter of if, but when, as the IEA estimate that lithium will experience the fastest growth rate amongst all critical minerals by 2040.

This report provides a summary analysis of the lithium market over the past four years, discussing the key themes surrounding the commodity including: An understanding of lithium's price movements; Demand for lithium - its uses and risks; The market balance and costs; Where lithium production is concentrated globally and its associated risks, as well as highlight key investments in the sector before concluding the report with our market outlook.

LITHIUM PRICES

Since our last report, issued on lithium in September 2020, lithium spot prices have experienced significant volatility. In 2022, lithium spot prices rallied to record levels, peaking at $82,993/t for lithium carbonate, ~1400% from its low in 2020. Between July 2021 and Jan 2022 lithium prices experienced a fivefold increase and overcorrection on the upside. This price movement followed robust Y/Y EV sales growth (+109%), positive market sentiment and a widening supply deficit.[1] Riding on lithium's momentum, supply additions from restarts, expansions and new projects started in 2022, increasing supply, particularly from China. This caused the market to swing from a supply deficit to an apparent surplus in 2023.

Lithium's sensitivity to changes in consumer trends give explanation to its volatile nature. A market surplus coupled with the expiration of the Chinese Government's subsidy program, weaker than expected EV sales and growth of the Chinese economy, and higher global interest rates, caused prices to decline drastically, culminating in an ~80% correction from November 2023 to January 2024. We believe that the market is now oversold and lithium prices will consolidate at current levels to form a bottom.

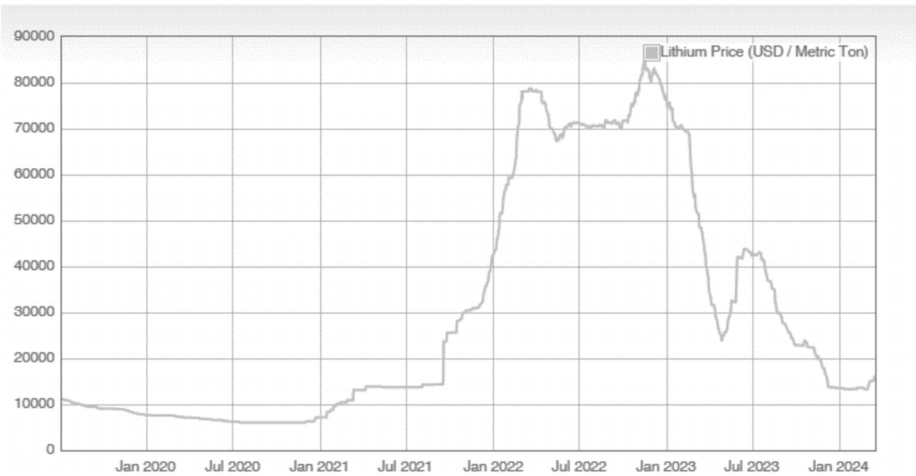


Figure 1: LCE (Lithium Carbonate Equivalent) Prices 2020- 2024

SHORT-TERM LITHIUM OVERSUPPLY

The market is estimated to have been in a minor surplus in 2023. Analysts at Canaccord Genuity and Fast Markets expect minor surpluses to continue over 2024-25.

Lithium supply/demand
Tonnes LCE

	2021	2022	2023f	2024f
Available production	568,400.00	719,600.00	937,700.00	1,510,000.00
Apparent demand*	566,500.00	764,100.00	923,900.00	1,477,000.00
Balance	1,900.00	-4,450.00	13,800.00	33,000.00

Source: Fastmarkets
*As downstream capacity expands it needs to build up working stock. Consumption + working stock build = Apparent demand

Figure 2: Market Balance (Source: Fastmarkets, Jan 2024)

The supply surplus has been driven primarily by China's accelerated lithium production expansion and increased battery capex. Additionally, Chinese imports of spodumene concentrate, particularly from Australia and Zimbabwe, grew sharply in 2023.

Excess supply, however, may push prices below the incentive levels for some producers, narrowing margins and reducing economic viability. For example, current market prices are hitting lower grade spodumene concentrate and lepidolite producers the hardest as they face comparatively higher production costs. There are already signs that producers are slowing output to relieve an oversupplied market. In Australia, Core Lithium Ltd. announced in January that it would halt mining operations at the Grants open pit and Greenbushes, a joint venture with Tianqi Lithium Corp. and Albemarle Corp has also stated that it intends to reduce production in the second half of the year. The mine produced 28% of global lithium production in 2022.

EXPIRATION OF THE CHINESE GOVERNMENT'S EV SUBSIDY PROGRAM

China uses exemptions on consumption tax to help lower production costs for EVs. Chinese consumers also benefitted from the EV scheme, taking advantage of purchase subsidies and relief from vehicle taxes.

Additionally, The Chinese government provided infrastructure support to optimise conditions for EV usage. The end of the purchase subsidy in 2022 likely influenced market sentiment, EV demand and subsequently, lithium prices.

Policy	End Date	Description
Purchase subsidy	End of 2022	Maximum subsidy of CNY 12,600 per vehicle for battery electric vehicle (BEV) passenger cars; and CNY 4,800 for plug-in hybrid (PHEV) passenger cars, including extended-range PHEVs. Maximum subsidy of CNY 50,400 per vehicle for non-fast-charging BEV buses; CNY

		36,400 for fast-charging BEV buses; and CNY 21,300 for PHEV (including extended-range) buses. Maximum subsidy of CNY 28,000 per vehicle for BEV trucks; and CNY 17,600 for PHEV (including extended range) trucks.
Purchase tax exemption	End of 2027	New EVs purchased by 31 December 2025 are exempted from vehicle purchase tax. New EVs bought between 1 January 2026 and 31 December 2027 have purchase tax reduced by half.

Table 1: Chinese EV Subsidies (Source: China Dialogue)

EV sales, however, remain strong. Rho Motion reported that global EV sales totalled 1.1 million units sold in January 2024, growing by 69% Y/Y. In the opening two months of 2024, the European EV market has grown by 21% Y/Y, in the US & Canada by 33%, and in China sales by 34%.

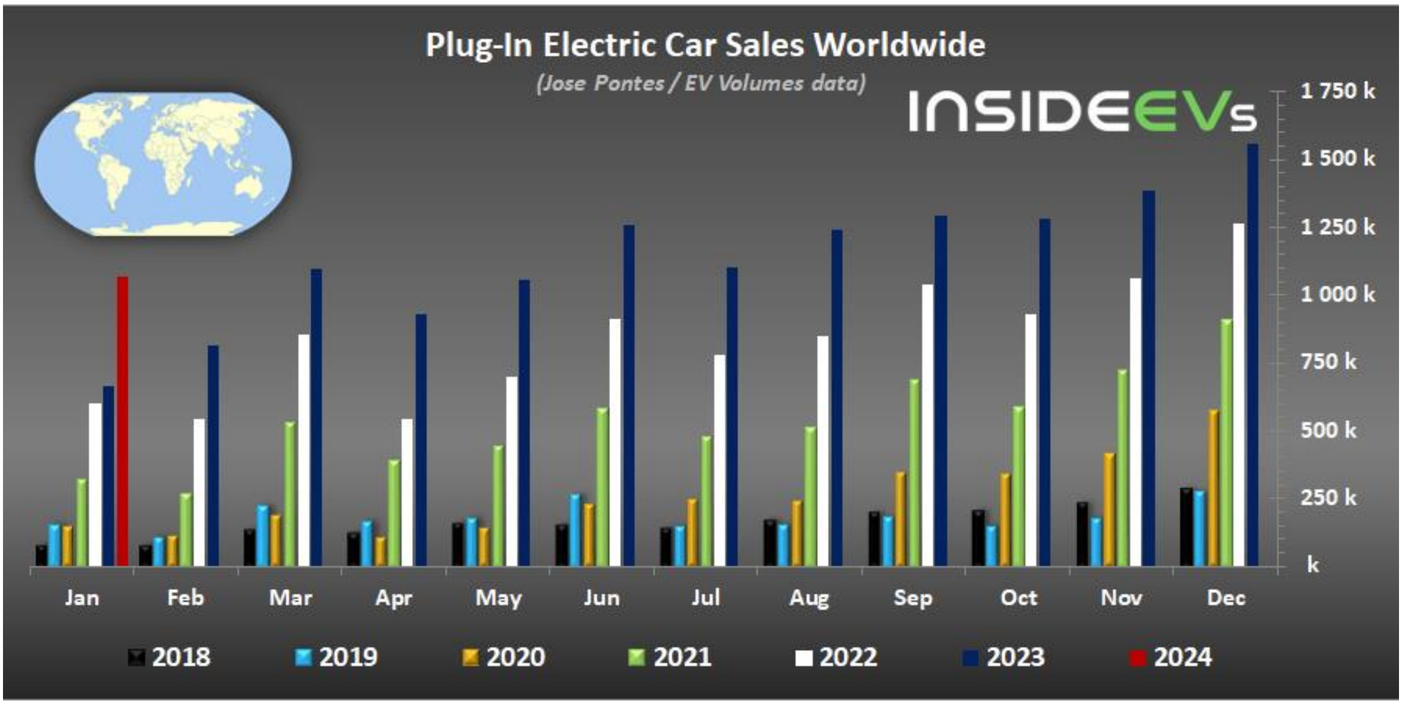


Figure 3: Global EV Sales (Source: Inside EVs)

CHINA'S ECONOMY AND WEAKER-THAN EXPECTED EV SALES

The correction began at the end of 2022. Market sentiment surrounding lithium was hurt by a fragile global economy and the slowdown in EV sales in China. A National Bureau of Statistics of China survey showed consumer confidence collapsed in 2022 and continued to stay at low levels in 2023.[2.]

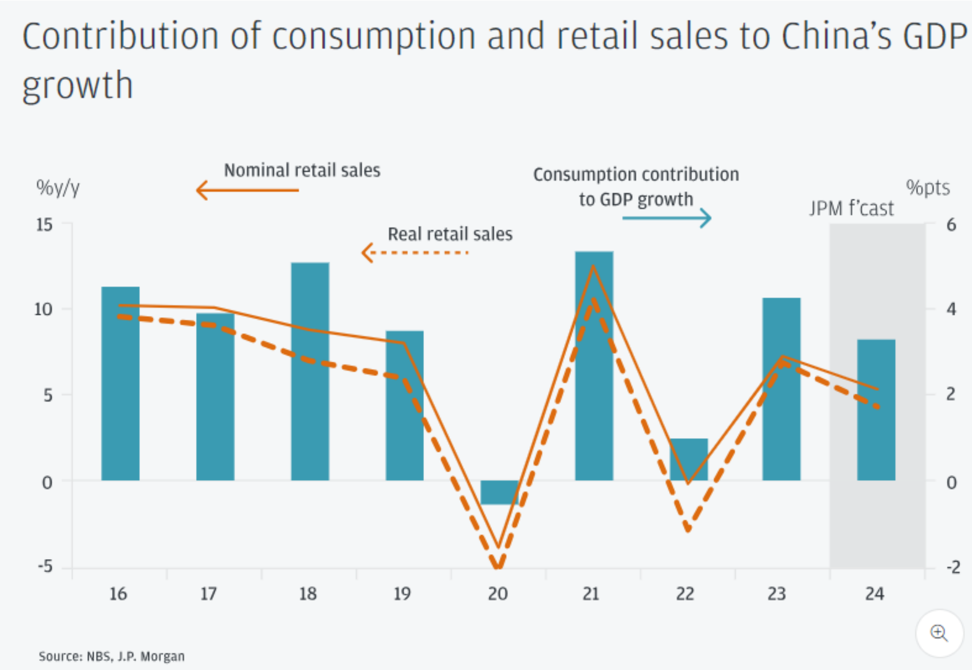


Figure 4: Chinese Consumer Confidence (Source J.P Morgan)

J.P. Morgan's baseline forecast looks for a 6% increase in consumption, of which 5% will come from income growth. China is targeting an ambitious 5% GDP growth target in 2024 and Premier Li Qiang, the country's No. 2 official, vowed to transform its growth model in the face of several significant challenges. Chinese EV sales from January 2024 would suggest another year of growth in the market - almost doubling for the equivalent month Y/Y.

China, however, represents only a portion of the market. At the end of 2022, inflation rates across the US and Europe ranged from 5-24%, where central banks have responded by increasing interest rates steadily since 2022. Comparatively, Chinese interest and inflation rates remain at 3.45% and 0.7% respectively.

The average EV cost in the US and China remains elevated at $55,353 and $41,100 in 2024, compared with $53,811 and $42,100 in 2020. Consequently, leasing and financing are the most popular options within the EV market. More than 90% of new cars are bought on finance whereas leasing is an attractive option for drivers that wish to explore the EV market without being locked into a commitment they do not want. Interest rates, however, play a significant role in determining both lease and financing costs.

When interest rates rise, the cost of borrowing money increases for leasing companies. As a result, the additional cost is passed to consumers in the form of higher lease rates. The same principle applies to those choosing to purchase a new car on finance; faced with higher costs for a loan, consumers may delay their purchase or opt for cheaper, conventional fuel alternative instead. This may explain why Europe, the EV sector's second largest market, experienced underwhelming growth in EV sales in 2022 compared to previous years.

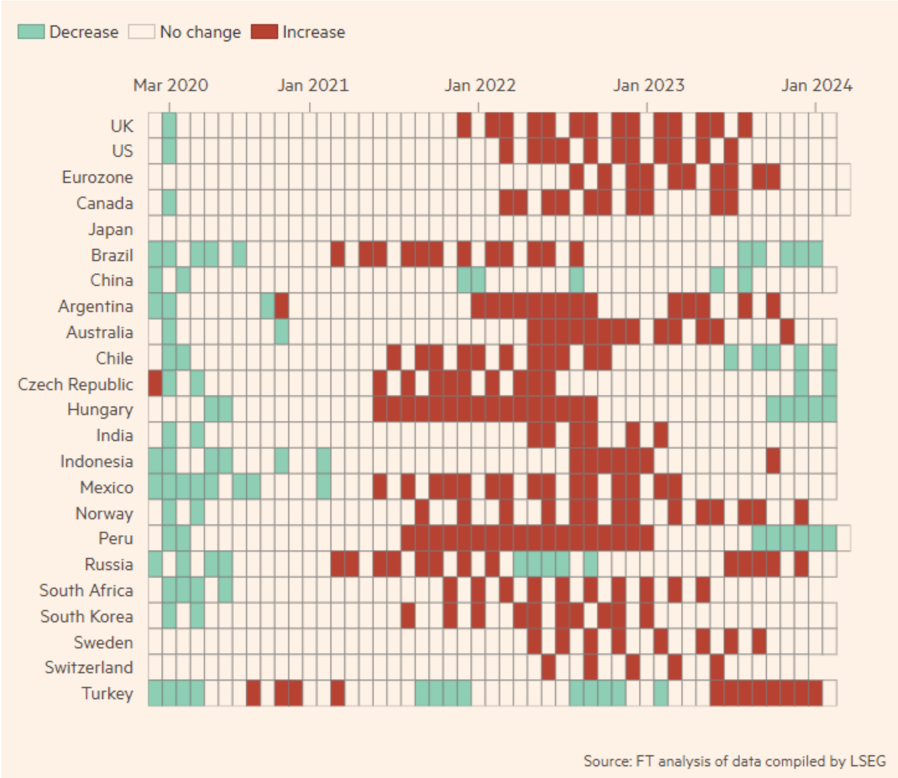


Figure 5: Changes in Interest Rates (source: FT)

In the US, EV grants featured in the Inflation Reduction Act (IRA) look to have curbed any potential effects of inflation on EV demand. Since Q3 2021, EV sales have increased in ten consecutive quarters. Starting in 2024, rather than being applied to the following year's tax return, the federal rebate will be offered directly at the point of sale. So, if the EV costs $50,000, customers will pay $42,500 immediately, rather than having to take a tax credit later. Government EV subsidies combined with anticipated rate cuts, an economic soft landing and subsequent increase in consumer confidence would facilitate growing demand for lithium end products such as EVs and consumer electronics.

HAVE PRICES BOTTOMED?

Despite a large correction from 2022, lithium prices remain 2-3 times greater than 2020 levels. However, there have been signs of a recovery as Chinese spot prices for carbonate, hydroxide and concentrate, are up 14%, 17% and 7%, respectively, since late January 2024.

In 2024, we expect prices to form a cyclical bottom, driven by inventory build-up relief (See Figure 6), mine closures and project deferrals. This is likely to support lithium prices as producers consider further production cuts to balance the market and stem further losses. According to Tribeca Investment Partners, the removal of this capacity signals that the commodity price is bottoming. Industry sources we have spoken to are optimistic about lithium prices recovering in the short-term. They expect lithium prices to consolidate at ~$20,000USD/t LCE, moving towards $30,000USD/t LCE in the longer-term. Concentrate prices, they asserted will not go lower than ~US$1,200/t, a figure which is in line with Canaccord Genuity estimates. Canaccord Genuity analysts forecast prices for lithium and related mining companies to continue to rally in 1H'24 to more sustainable levels at ~US$16k/t LCE. At these price levels they believe supply disruption and underinvestment is prevented and high-cost supply will remain unincentivised. With reference to their cost curve model, the investment bank add that they see longer-term prices at US$1,500/t for concentrate and US$22.5k/t for chemicals.

We consider the lithium market to be recovering following excessive overcorrection on the downside. Prices are now forming a support which will create short-term stability within the market and facilitate its long-term upward trajectory.

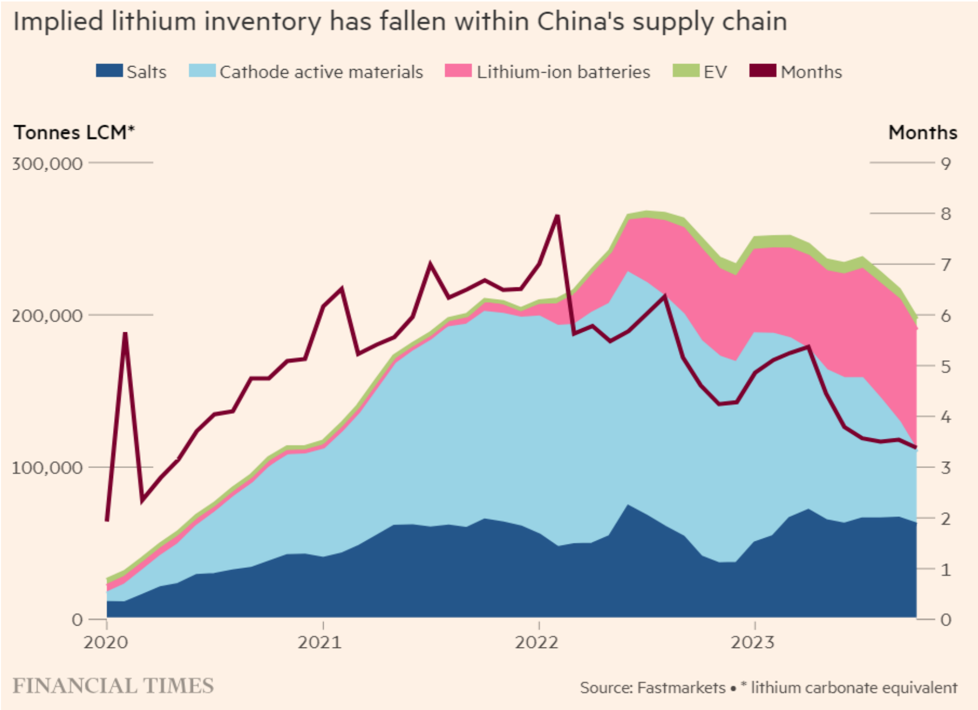


Figure 6: Implied Lithium Inventory (Source: FT)

Figure 7: Global Lithium Stock Prices (Source: Bloomberg)

DEMAND

Lithium’s high energy density makes it a very specialised and critical commodity. Its criticality is driven by demand, supply, and price perceptions as well as policies and narratives linked to achieving a sustainable and effective energy transition.

Countries are now stepping up their climate commitments and clean energy technologies are set to become the fastest-growing segment of demand for most minerals.[3] Despite its volatility, the thesis remains that lithium presents an asymmetric opportunity given future demand outweighs supply. In both of their scenario tests, the IEA estimate lithium to experience the fastest growth rate amongst all critical minerals necessary to meet demand by 2040, potentially growing by over forty times, and in one scenario, representing a 90% share of total demand for clean energy technologies.[3]

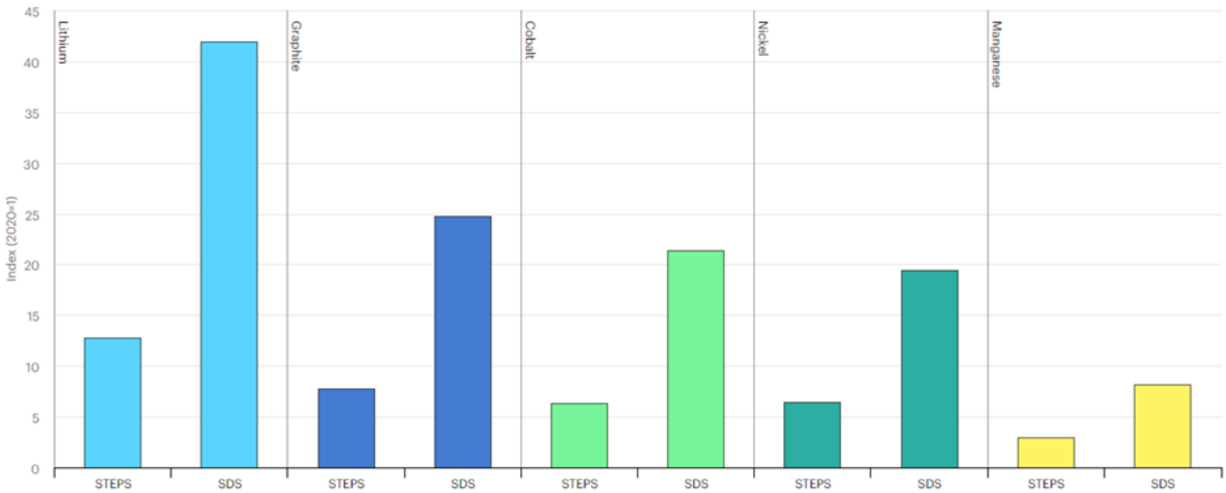


Figure 8: Growth in demand for selected battery-related minerals from clean energy technologies in 2040 relative to 2020 levels by scenario (Source: IEA)

The IEA stated in their September 2023 report ‘Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach’ that particular attention needs to be paid to bridging the looming supply-demand gap for critical minerals such as lithium. For context, global lithium production was estimated to be 862,967 t in 2023, an increase of 36% from 634,195 t in 2022. Albemarle anticipate demand to grow 28% Y/Y in 2024 and forecast demand for lithium to triple by 2030 to 3.3 million t from 2023 levels. The key demand drivers for lithium continue to be the growth of EVs, rising demand for renewable energy and its storage, and lithium’s use in consumer electronics.

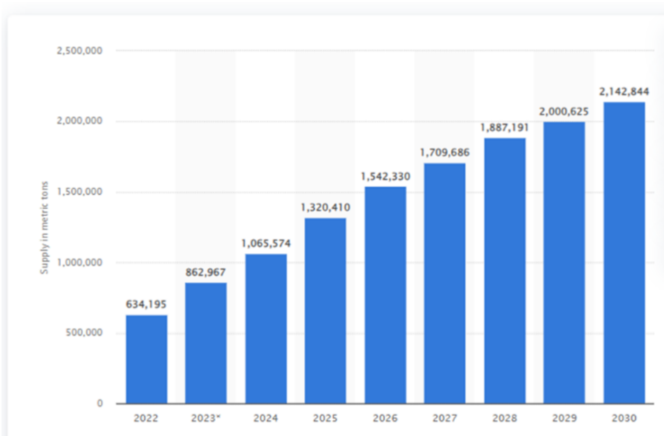
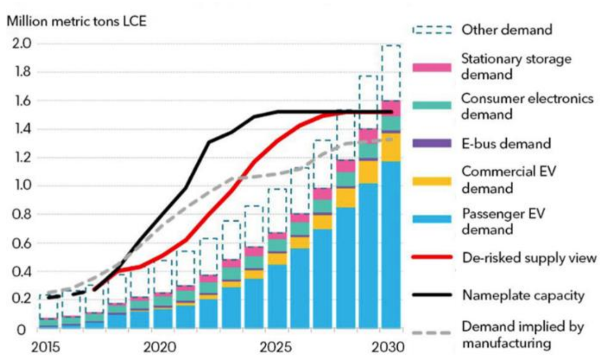


Figure 9: Actual and Forecasted Global Lithium Supply, (Source: Statista)

Analysis conducted by Global Data estimates lithium mining production will increase at a CAGR of 13.9% to reach 512,800 t in 2030. In their 'Net Zero Roadmap' report, the IEA estimates that 717,000 t of lithium will have to be produced per annum to achieve net zero emissions (NZE) by 2030. Moreover, by 2040 the future material demand for lithium is expected to exceed current raw material production, potentially by up to 8 times depending on the growth and technology scenario.[4] This would signal significant asymmetry in the market. Market analysts estimate a supply deficit by the 2030s, creating pressure to increase lithium production and processing. Benchmark Mineral Intelligence, estimates a 300,000 tLCE supply deficit by 2030 in its business-as-usual demand scenario. In an interview for CNBC, Corinne Blanchard, Deutsche Bank's director of lithium and clean tech equity research, sees a "modest deficit" of around 40,000 to 60,000 t of LCE, but forecasts a wider deficit amounting to 768,000 t by the end of 2030. Incentivising continued production growth to meet demand, however, requires prices to rise at or above production cost-curves.



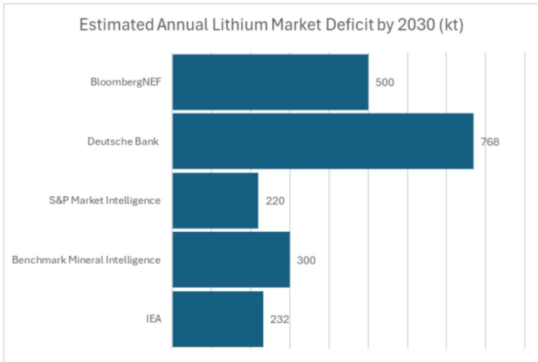


Figure 10 : Global lithium supply and demand forecast, (Source: Bloomberg NEF); Figure 11:Estimated Annual Market Deficit by 2030

LITHIUM USES

Lithium uses are diversified across sectors, including alloys, materials for glass and ceramics production, greases, lubricants, and medical intervention.[5] Today, batteries make up 87% of lithium's end-usage distribution.[6] Lithium-ion batteries have proven to be an effective and affordable alternative energy storage solution. Lithium carbonate (Li2CO3) and lithium hydroxide (LiOH) are the two primary lithium compounds used in Lithium-ion Batteries (LIBs).

Lithium hydroxide trades at a premium to lithium carbonate due to its larger share of global demand as well as its direct role in battery manufacturing. Lithium carbonate has industrial uses other than batteries including ceramic glazes, tile adhesives and cement densifiers. These products benefit from lithium carbonate's ability to join with silica and other materials. [7]

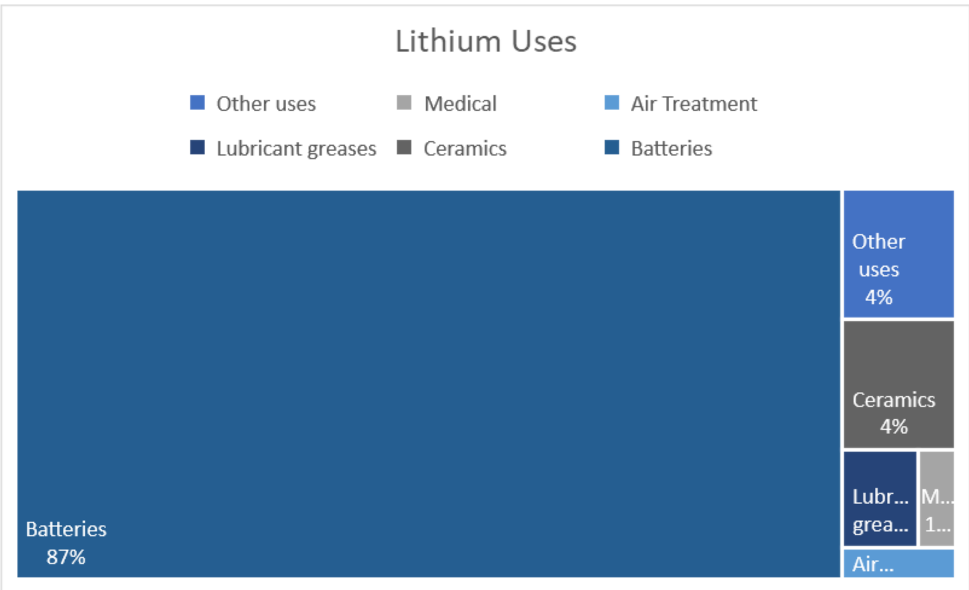


Figure 12: Distribution of lithium end-usage worldwide in 2023 (Source: Statista)

BATTERY STORAGE TECHNOLOGIES

Battery storage technologies play a crucial role in accelerating the transition from fossil fuels to renewable energy sources. These energy storage systems are becoming increasingly pivotal in bridging the gap between green energy production and meeting electricity demands. Battery storage, also known as battery energy storage systems (BESS), are devices that enable energy from renewables, like solar and wind to be stored. This stored energy can then be released precisely when demand is highest.

Lithium-ion batteries currently dominate the field of large-scale energy storage. They contribute significantly to ensuring a reliable supply of renewable energy for national electricity grids and private organisations. In 2019, Tesla provided their lithium-ion Megapack batteries for use at the South Australian, Hornsdale Power Reserve. In its first year, the facility saved nearly $40 million alone and helped stabilise and balance the region’s unreliable grid. Capacity at Hornsdale Power Reserve is 194MWh following a 50MWh expansion in 2020.

Demand for energy storage is increasing. In 2023, the total installed capacity of BESS stood at 45.4GW with approximately 6.8 GW of new large-scale battery capacity added, a 59% increase from 2022. It is expected to grow to 650GW/1877GWh by 2030. Completed in 2024, Edwards & Sanborn Solar-Plus-Storage project in California is currently the world’s largest BESS facility, with 3,287MWh of BESS capacity.

BESS Project	Capacity (GWh)	Description	Location
Edwards & Sanborn Solar and Energy Storage	3287	Completed in January 2024, the project consists of 863 megawatts of solar and 3,287 megawatt-hours of energy storage. It is currently the largest single solar and battery energy storage project to reach this milestone.	California, US
Moss Landing Energy Storage Facility	1200	The Moss Landing Energy Storage Facility, located in Monterey County, California, is the world’s largest battery energy storage system. It comprises 1,200 MWh/300 MW of energy storage.	California, US
Manatee Energy Storage Center Project	900	The Manatee Energy Storage Center, situated in Parrish, Florida, is the world’s largest solar-powered battery. It can power approximately 329,000 households for more than two hours.	Florida, US
Victorian Big Battery	450	The site provides grid support services. It is owned and operated by Neoen and uses Tesla Megapacks	Victoria, Australia
Elkhorn Battery	730	The Elkhorn Battery, part of PG&E’s Moss Landing facility in Monterey County, California, consists of 256 Tesla Megapacks. It enhances grid reliability, integrates renewable energy, and prevents blackouts during network instability	California, US
McCoy Solar Energy Project	679	The McCoy Solar Energy Project, covering 2,300 acres in Riverside County, California, generates clean energy using solar technology. Energy is stored in BESS and supplies electricity for provider Southern California Edison.	California, US

Table 2: Largest BESS Projects Globally

According to BloombergNEF, Global energy storage’s record additions in 2023 will be followed by a 27% CAGR to 2030, with annual additions reaching 110GW/372GWh.[8] In 2022, $5bn was invested in BESS globally and the figure is set to grow to $120-$150bn by 2030.

SOLID-STATE BATTERIES

The Li-ion batteries that we rely on currently have a liquid electrolyte through which ions flow in one direction to charge the battery and the other direction when it is being drained. Solid-state batteries replace this liquid with a solid material. The solid electrolyte is expected to enable safer, larger-capacity and higher-output batteries than lithium-ion. Lithium-based solid-state technology is on track to transform the energy storage industry, displacing Li-ion batteries.

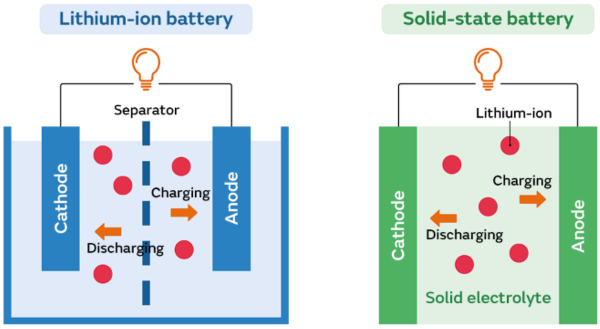


Figure 13: How lithium-ion batteries and solid-state batteries work (Source: Murata)

If EVs are to compete with ICEVs (internal combustion engine vehicles) and become the leader in the industry, they must demonstrate a similar level of mileage or 'range' as current ICEV models. To accomplish this, the capacity of an EV battery will need to increase. There are two ways to increase capacity: First, is increasing the number of batteries. With Li-ion batteries this would mean the EV battery occupying a greater space in the vehicle's chassis and the cost of the battery rising relative to the increase in the number of batteries. A solid-state battery, however, has higher energy density than a Li-ion battery. Moreover, it does not carry the safety risks associated with Li-ion batteries of fires or blasts. Therefore, the space previously allocated to safety components can now accommodate greater capacity, safer solid-state batteries. A solid-state battery can increase energy density per unit area since only a small number of batteries are needed. For that reason, it is perfect for the high capacity requirements of EVs and BESS.

Solid-State Battery Advantage	Description
Can withstand low to high temperatures	Since the electrolytes in lithium-ion batteries are made of flammable organic solvents, there is concern about their use in high-temperature environments. On the other hand, since the electrolytes in solid-state batteries are not made of flammable materials, they can be used at higher temperatures. Further, in the case of liquids, the movement of ions slows at low temperatures, causing battery performance to drop, and the voltage may decrease. In the case of solids, the internal resistance does not increase so much and battery performance does not drop much because the solid does not freeze like a liquid even at low temperatures.
Fast charging is possible	The benefit of being resistant to high heat is also advantageous for fast charging. The faster batteries charge, the more they heat up. Because of this, it is believed that it will be possible to charge high-temperature-resistant solid-state batteries even faster than current lithium-ion batteries.
Long lifespan	The lifespan of a battery depends on the properties of the electrolyte. Since lithium-ion batteries do not use a battery reaction like other secondary batteries, the electrode deteriorates little and lasts a long time, but when used for a long time, electrolyte deterioration can be seen. In that respect, since the electrolytes in solid-state batteries deteriorate less than liquids, it will be possible to extend battery lifespan even further.
High degree of freedom in shape	Liquid electrolytes have structural restrictions to prevent liquid leakage. In the case of solid-state batteries, however, there is no such limitation. Solid-state batteries can be used in various shapes because it is easy to make them smaller and thinner, and because they can be used while overlapped or bending.

Table 3: Solid-state battery features (Source: Murata)

Car manufacturer Toyota announced in 2023 that it had made a breakthrough in its goal to improve the durability of this technology. Toyota's recent advances have overcome previous challenges of battery life and now the company has moved its focus to bringing solid-state batteries into mass production. According to its technology roadmap, mass-production of its solid-state batteries is estimated by 2027/2028. Toyota's stated goal is for their solid-state batteries to ultimately have a range of >1,200km, and to go from 10 – 80% charge in 10 minutes or less. This compares to the Tesla Model Y, which currently has a range of 542 km, and fast-charges in 27 minutes.

The battery storage market is growing in tandem with the EV market and has attracted significant interest from private equity. Investment deals for battery storage companies reached a combined $11.2 billion in 2022, with a total of 80 deals announced. In 2023, SK On, a South Korean rechargeable battery maker received a $909 million investment from an investor group including BlackRock, MBK Partners and Qatar Investment Authority. The company has reportedly raised about $5.3 billion in total since the beginning of 2022.[9]

EV MANUFACTURING

EV manufacturers are adopting a local-for-local strategy. This involves positioning production facilities and sourcing components and raw materials closer to key markets. The goal is to reduce lead times, lower transportation costs, and mitigate supply chain risks.[10]

Lithium-supply security has prompted car manufacturers to integrate lithium directly into their own supply-chains. General Motors (GM) for example, have invested $650mn in lithium mining company Lithium Americas, a record investment by a carmaker to secure the raw materials used in electric vehicle batteries.[11] In addition to GM, EV manufacturers, Ford, Hyundai and Tesla have signed long-term lithium supply agreements with major lithium producers including: Albemarle, SQM, Nemaska Lithium, Ganfeng Lithium and Liontown to support their expanding EV production.[12][13]

OIL AND GAS

Lithium also provides an opportunity for traditionally hydrocarbon focused producers to transition towards cleaner energy. For example, American multinational oil and gas corporation, ExxonMobil have expanded their venture into sustainable energy. The company has begun drilling at their recently acquired lithium well in Arkansas. The energy provider has stated that it aims to be a leading supplier for electric vehicles by 2030.[14]

Following suit, Saudi Aramco and Abu Dhabi National Oil Company (ADNOC), Saudi Arabia and the United Arab Emirates' respective national oil companies, plan to extract lithium from brine in their oilfields. The petrostates are looking to diversify their economies and profit from the shift to renewables.

RISKS TO DEMAND

SODIUM-ION

Alternatives to lithium-ion batteries, such as sodium-ion batteries, remain one of the key risks associated with lithium demand. Alternative battery sources may increase price pressures to the downside for lithium companies. However, there is the potential for these alternatives to be complementary rather than substitutes given their different respective traits.

Interest in sodium-ion batteries stems from their two key advantages: sustainability and cost. Sodium is far more naturally abundant and easily mined than lithium. Subsequently, it is a fraction of the cost per kilogram and much less susceptible to price fluctuations or supply chain disruptions.[15] Further benefits include sodium-ions superior energy density, charging capability at below freezing temperatures and its predominant use of globally abundant elements, iron, and manganese. [15]

One of its major limitations, however, is its weight. Sodium metal is about three times heavier than lithium, increasing the battery weight and thus impacting the EV driving range. This, so far, has prevented the sodium-ion battery from making any meaningful ground in terms of commercialisation in the EV market.

Sodium-ion cells have a lower energy density (140-160 Wh/Kg) in comparison to lithium-ion (180-250 Wh/Kg. Therefore, it may be more likely that the lithium alternative plays a larger role in stationary storage and smaller vehicles, where capacity requirements are lower. Chinese EV manufacturer, BYD, stated that batteries from its upcoming sodium plant will go into "microcars". Sodium's wider application within the market is limited by differences in consumer preferences across regions. For example, in comparison to China, those in Europe and the US are more likely to drive longer distances and have larger cars.

To date, both public and private sectors have invested billions towards localised lithium-ion battery production, diverting investment away from a sodium-ion alternatives and in favour of the commercially viable, lithium. Sodium-ion technology made the news when lithium prices were rallying in 2022. Discourse surrounding battery costs and availability of metals such as nickel at the time, provided the perfect conditions for sodium projects to attract interest. Lithium prices have since experienced a significant correction and sodium's cost competitiveness is becoming less and less advantageous. As lithium-ion batteries become increasingly affordable, the case for sodium-ion becomes less appealing. In summary, lithium-ion technology will likely continue to be favoured within the industry.[16] We will, however, continue to monitor any advancements carefully.

REGULATORY RISK

Demand for lithium has stemmed largely from increased global regulation surrounding climate goals. For example, the UK last year set out its zero-emission vehicle (ZEV) mandate. The mandate sets minimum annual targets, starting with a requirement for 22% of new cars sold in 2024 to be zero emission, rising each year up to 100% by 2035. The UK's ambition has already triggered investments in gigafactories and EV manufacturing.[17] The US, EU, Canada, UK and UAE have set a goal of net-zero emissions by no later than 2050. China, Nigeria and Saudi Arabia have targeted 2060 to achieve the same.

All forecasted models of demand for clean energy storage and EVs are contingent on the long-term commitment of governments to these regulatory frameworks. In the US particularly, climate change and its related policies have been subject to increased scrutiny and scepticism despite its scientific merit. This has largely been driven by the increasingly polarised nature of US politics. Myron Ebell, the Head of the Environmental Protection Agency (EPA) transition team for Trump's first term, believes a Trump re-election poses significant risks to current and future climate objectives and legislation. Ebell suggests that Trump would look to reverse everything the Biden administration has done, going further, and moving more quickly than he did before. If successful, Trump's Republican allies would likely target Biden's Inflation Reduction Act. The legislation includes $370 billion in funding and features significant support for clean energy projects and EVs. Carla Sands, a key environment adviser to the pro-Trump America First Policy Institute who has criticised Biden's "*apocalyptic green fantasies*", said:

> *"Our nation needs a level regulatory playing field for all forms of energy to compete. Achieving this level playing field will require the repeal of the energy and environment provisions within the Inflation Reduction Act."* [18]

Should the US step away from its climate commitments including subsidies and legislation surrounding clean energy technologies, it is likely that lithium demand will be negatively impacted as incentives for companies and consumers are reduced or cancelled completely. The wider effect this scenario would have remains unclear, though it can be argued that the actions may prompt other countries to follow suit, abandoning their respective policies. Alternatively, the decision may potentially encourage key global powers to increase their own efforts. From a corporate perspective, regulatory risk could delay the adoption of sustainable business practices for US based SMEs. Multinationals, on the other hand, would likely continue to adhere to ESG standards and targets, driven by their internal strategies, vision beyond presidential terms, and sensitivity to consumer perceptions of their business.

SUPPLY

LITHIUM RESOURCES TODAY AND TOMORROW

70% of the estimated global lithium resources are in Bolivia, Chile, and Argentina. The countries contain a region known as the "Lithium Triangle". Bolivia's lithium resources are the largest, however, access is currently unviable due to socio-political conditions. Chile and Argentina ranked first and third, respectively, for proven reserves, and have been comparatively much more attractive regions for investors.

Table 4: Global Lithium Reserves

Country	Lithium Content (Tonnes)	Percentage of Total	Type
Chile	9,300,000	35.7%	Brine
Australia	6,200,000	23.8%	Minerals
Argentina	2,700,000	10.4%	Brine
China	2,000,000	7.7%	Brine & Minerals
United States	1,000,000	3.8%	Brine, Minerals & Clay
Canada	930,000	3.6%	Brine & Minerals
Zimbabwe	310,000	1.2%	Minerals
Brazil	250,000	1.0%	Minerals
Portugal	60,000	0.2%	Minerals
Other	3,300,000	12.7%	
Total	26,050,000	100.0%	

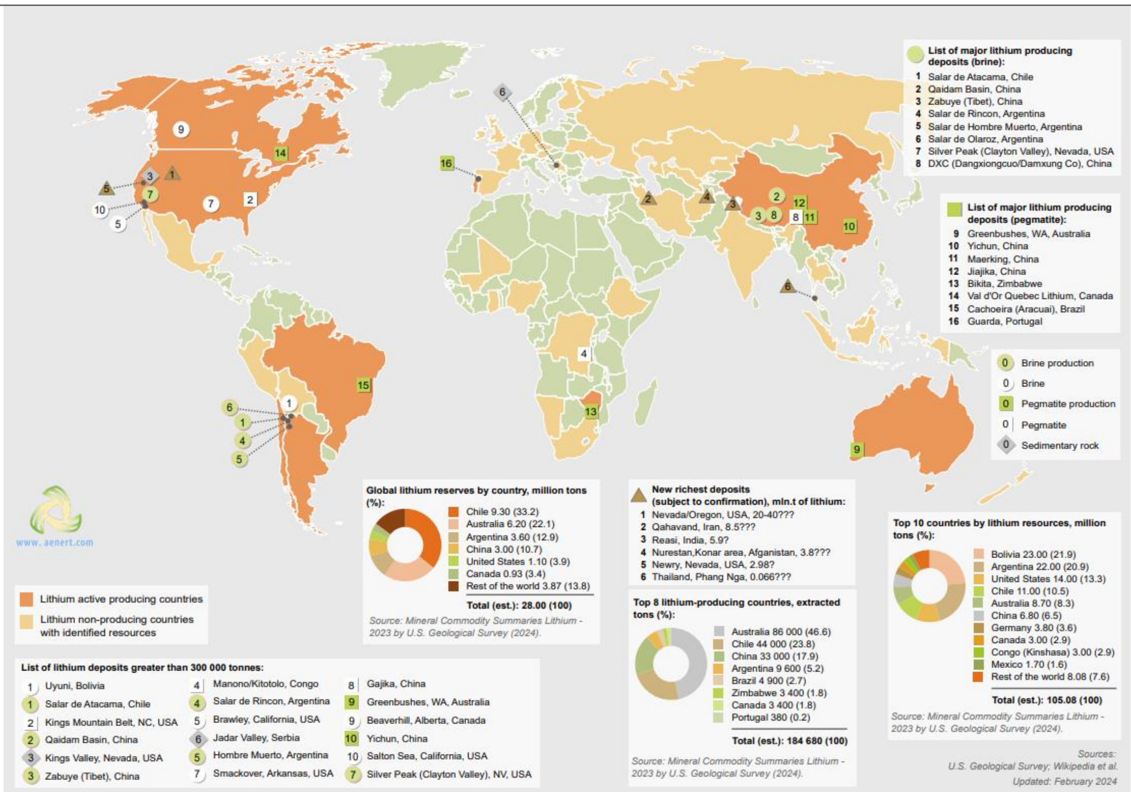


Figure 14: Global Lithium Reserves, (Source: Aenert)

Australia is the global leader in lithium production, with five mines accounting for nearly half of global lithium production in 2022. Together, Australia, Chile, and China account for over 90% of today's global lithium production market.

Rank	Country	Mine production 2022E (Tonnes)	Share
1	Australia	61,000	47%
2	Chile	39,000	30%
3	China	19,000	15%
4	Argentina	6,200	5%
5	Brazil	2,200	2%
6	Zimbabwe	800	1%
7	Portugal	600	0%
8	Canada	500	0%
	Other countries'	700	1%
	World Total	130,000	100%

Table 5: Global Lithium Mine Production

China dominates the lithium processing industry globally. Lithium processing is the refining of ores taken from mines and processed into lithium carbonate or lithium hydroxide for use in batteries. According to UBS AG, China could account for almost a third of the world's lithium supply by 2025.[19] The country is home to most the world's facilities for processing lithium and produces around 75% of all lithium-ion batteries used worldwide.

In response, one can expect the West to mobilise its resources to secure and expand its own supply chain as geopolitical tensions continue to simmer. Thacker Pass lithium mine, one of the largest known lithium deposits in the US and one of the largest and only lithium claystone mines in the world, is planning to start production in 2H 2026. It is estimated that production from Thacker Pass will meet most of the projected demand for lithium in the US, reducing the country's dependency on foreign suppliers.[20] Lithium extraction from clay deposits, however, remains unproven at a commercial scale.

Future supply of lithium will dictate the commodity's price. UBS Group AG and Goldman Sachs Group Inc. have trimmed their 2024 supply estimates by 33% and 26%, respectively, while Morgan Stanley suggests there may be a growing risk of lower inventories in China.[21] On this basis, Canaccord Genuity analysts see potential for surpluses to swing to deficits, providing pricing upside risk. Longer term, Canaccord continues to forecast material deficits emerging from 2027.

LITHIUM EXTRACTION

Lithium is an alkali metal; the lightest of all metals and the least dense of any elements that are solids at room temperature. Because of its inherent instability and reactivity, it naturally occurs as a compound. Lithium salts can be found in underground brine deposits, mineral ore, and clay, as well as in seawater and geothermal well brines/water. The method of extracting and isolating the lithium requires chemical processing; This process transforms lithium from its natural state to a commercially more practical form.

Lithium resources can primarily be categorised into brines, hard rock mining and clay. Brines offer a cost-effective, efficient, and sustainable method for extracting lithium compared to traditional mining methods, which present lower profit margins and higher emissions (15 t CO2/t LCE for spodumene versus 5 t CO2/t LCE for brines). However, project development and processing times for brine are considerably longer. As demand for the metal has ramped up, however, technological innovations such as Direct Lithium Extraction ("DLE") offer a cleaner, faster, and far more efficient extraction solution.[22]

Brines make up 66% of the world's lithium resources whereas ores represent 25%. Currently, however, hard rock sources of lithium account for 60% of the global supply of mined lithium compared to brine at 39%. Despite its economic advantages, brine focused projects are often limited due to geography and geological conditions.[23]

DLE

Direct Lithium Extraction (DLE) is a single-stage chemical process which has potential to transform the extraction of lithium from brine projects. The technology looks to accelerate the supply of lithium, reducing operating costs and the production timeline from months to potentially hours as well as improving project efficiency. It is estimated that DLE could increase lithium yield from 40-60% to 70-90%+.[24.]

DLE is more sustainable and less environmentally invasive than traditional brine projects. It can recycle both water and brine, limiting land area requirements. Another key advantage to the technology is that production can continue despite adverse weather conditions unlike traditional brine and hard-rock extraction.

The six key chemical technologies highlighting the potential of DLE include: Adsorption, ion exchange, solvent extraction, membrane separation, precipitants, and electrochemical separation/refining.[22] Since 2020, DLE focused technology has received more than US$979 million in investment, demonstrating public and private sector investors' interest in the sector and technology. For example, Lilac Solutions, a California-based DLE start-up, announced in February 2024 that it had secured $145 million in funding from investors such as Gates's Breakthrough Energy Ventures and Japanese industrial conglomerate Mitsubishi. The company hope to extract lithium from the Great Salt Lake in Utah using its ion-exchange technology. DLE, however, continues to be an emerging technology. Many of the projects continue to exist in conceptual, prototype and demonstration forms.

Technique	Description	Inferred Technology Readiness Level	Process Efficiency	Lithium Recovery Rate	Number of Innovators or Vendors	Number of DLE Projects	Select Challenges
Adsorption	Adsorbent materials bind with and capture lithium ions from brine	9 — commercial	*75 %	95%-99%	16 of 38	27 of 57	Higher operating temperature (>40°C) and additional processing to extract lithium from sorbent
Ion exchange	Resins exchange lithium ions from brine with hydrogen ions. Washing resins with acid recovers lithium and restores hydrogen.	7 — demonstration	-	90%-99%	6 of38	8 of 57	Large quantities of acid to lithium from resin
Membrane separation	Mixture of brine and other fluids is pumped through membranes that allow only ithium ions to pass	7 — demonstration	*90%	80%-99%	7 of38	30 of 57	Mainly suits brine low in sodium or potassium and is relatively waterintensive (though more water efficient technology is in development)
Solvent extraction	Solvent chemicals react with brine to form lithium compounds that deliver lithium with further processing	6 — prototype	60%.90%	85%-97%	4 of 38	3 of 57	Solvent poses environmental and equipment corrosion challenges
Precipitants	Reagents added to brine make lithium precipitate in crystals	3 — conceptual	*90 %	90%-99%	-	-	Can precipitate unwanted minerals creating reagent loss and waste disposal challenges
Electrochemical separation	Electricity passed through lithium solution makes lithium ions migrate to an electrode	3 — conceptual	-	-	-	-	Energy-intensive poor durability of materials used, and suits lithium refining than extraction

Table 6: DLE Technology overview (Source: Deloitte)

Company	CleanTech Lithium	Livent (Producers)	Chaidaimu Xinghua Lithium (Producers)	Zangge Lithium (Producers)	Jintai Lithium (Producers)	China Minmetals Corp (Producers)	Compass Minerals	Controlled Thermal Resources	Anson Resources
Asset Name/s	L.Verde & Francisco Basin	Hombre de Muerto	Dachaidan Qinghai	Golmud, Qinghai	Haixi Qinghai	Qaidam Basin	Great Salt Lake, Utah	Hell's Kitchen	Paradox, Utah
Country of Project									
DLE Provider	SUNRESIN	Proprietary	SUNRESIN	SUNRESIN	SUNRESIN	SUNRESIN	ENERGY SOURCE	Aquatech	SUNRESIN
Stage	Pilot	Prod.	Installed	Prod.	Prod.	Prod.	PFS	Construct.	DFS
Resource (MT LCE)	2.7	2.2	N/A	N/A	N/A	N/A	2.4	N/A	0.8
Lithium Grade (mg/L)	200-220	218-523	N/A	N/A	N/A	N/A	N/A	N/A	123-125
Geothermal	✓	✗	✗	✗	✗	✗	✗	✓	✗
Prod. Start Date	2026	1998	2023/2024	2017	2018	2018	2025	2025	2025
Capacity (KTPA/LCE)	40	>40	5	10	7	6	>11 >35	>25>300	13
Opex costs per tonne (US$)	$3,875	$6,346	N/A	N/A	N/A	N/A	$4,200	N/A	$4,368
Country of Company									
Valuation (US$'m)*	US$69m	US$3,810m	N/A	N/A	N/A	N/A	US$1.23bn	Private	US$118m

Company	Standard Lithium	E3 Lithium	Cornish Lithium	Vulcan Energy	Tibet National Energy	Zijin Mining	Lake Resources	Rio Tinto	Alpha Lithium
Asset Name/s	Smackover, Arkansas	Clearwater Lithium	Twelveheads	Upper Rhine Valey	Tibet	Tres QueBradas	Kachi	Rincon	Tolillar
Country of Project									
DLE Provider	KOCH	Proprietary	GEL	Proprietary	SUNRESIN	SUNRESIN	Lilac	Initial Testing	Initial Testing
Stage	PFS	PEA	Pilot	Pilot & DFS	Construct.	Construct.	PFS	Construct.	PEA, NI-43-101
Resource (MT LCE)	1.8	16.9	N/A	26.6	N/A	7.6	8.1	12.0	5.0
Lithium Grade (mg/L)	437	75	N/A	N/A	N/A	400-786	219-283	325	270
Geothermal	✗	✗	✓	✓	✗	✗	✗	✗	✗
Prod. Start Date	2025	2026	N/A	2026	2024	2023	2027/2028	2024	2027
Capacity (KTPA/LCE)	30	20	> 1.5 >3.0	24	10	20	>25, >50	>3 >30	>25
Opex costs per tonne (US$)	$4,073	$3,656	N/A	$4,359	N/A	N/A	$6,266	N/A	$5,266
Country of Company									
Valuation (US$'m)*	US$613m	US$158m	Private Co.	US$357m	N/A	US$737m	US$196m	US$825m	US$169m

Company	Lithium Chile	Summit Tibet	Posco	Eramet Lithium
Asset Name/s	Arizaro	Salar Arizaro	Sal de Oro	Centenario Ratones
Country of Project				
DLE Provider	SUMMIT NANOTECH	SUNRESIN	Proprietary	Proprietary
Stage	PEA, NI-43-101	Construct.	Construct.	Construct.
Resource (MT LCE)	3.3	2.1	13.5	10.0
Lithium Grade (mg/L)	278-360	502	N/A	N/A
Geothermal	✗	✗	✗	✗
Prod. Start Date	N/A	2024	2024	2024
Capacity (KTPA/LCE)	>25	>50>100	>25 >50	24
Opex costs per tonne (US$)	$5,197	N/A		N/A
Country of Company				
Valuation (US$'m)*	US$111m	N/A	US$34.59bn	US$2.34bn

*Valuations as at 18.08.23

Figure 15: DLE developers and producers worldwide (Source: CleanTech Lithium)

PRODUCTION COSTS

The total cost of producing battery grade lithium carbonate by 2025 is expected to amount to approximately $4,165 and $5,500 per ton of lithium carbonate equivalent (LCE) from brine and spodumene, respectively.[25]

Margins may, however, be tighter than the available data suggests. Albemarle Corp, the world's largest lithium producer and major Canadian miner, North American Lithium, have reported that they would cut costs following challenging market conditions. Slowed capex spending, as well as planned projects being delayed, indicate additional future supply cuts remain a possibility should LCE prices fall further.

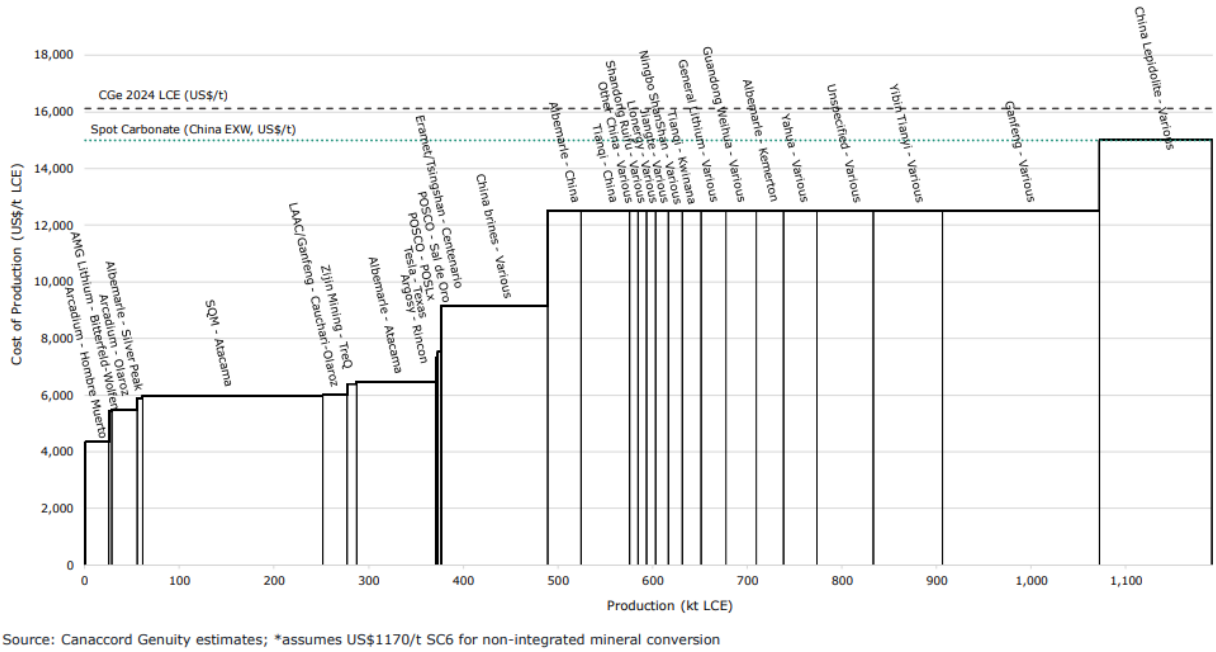


Figure 16: Estimated 2024 LCE Cost Curve, (Source: Canaccord Genuity)

The Largest Lithium Miners	Market Cap (Billions)	%	Main Resources
Albemarle	33.9	23%	Australia (Greenbushes), Chile
SQM (Sociedad Quimica y Minera de Chile)	29.6	20%	Chiile, Argentina
Tianqi Lithium	25	17%	Australia (Greenbushes), China
Ganfeng Lithium	22.9	15%	Australia, Argentina, China, Ireland, Mali Mexico
Mineral Resources Ltd	9.4	6%	Australia
Pilbara Minerals	8.6	6%	Australia
Allkem	5.9	4%	Australia, Canada
Sichuan Yahua Industrial	4.8	3%	China, Australia, Zimbabwe, Namibia
Lithium Americas	4.2	3%	US
Livent	3.9	3%	Argentina, US
Total	148.2		

Table 6: Largest Lithium Mining Companies

RISKS TO SUPPLY

ENVIRONMENTAL

Negative environmental externalities from lithium production risks delaying projects, disrupting production, and potentially damaging the perception of lithium's centrality to achieving an environmentally sustainable global economy. Key environmental issues include loss of natural habitats and biodiversity, water depletion, toxic contamination and the threat to indigenous communities.

In 2009, the Ganzizhou Rongda Lithium mine in China was accused of leaking toxic waste into the Liqi River which flows through Tibet. Local villagers claimed that the facility's pollution resulted in the death of many fish, the destruction of sacred grassland, and the loss of hundreds of yaks that drank from the river.[26]

Lithium resources are largely found in remote, fragile ecosystems, where fresh water is in scarce supply. Indigenous communities have historically been disproportionately affected by the mineral's extraction. For example, water critical to centuries of farming and survival is now being diverted to necessitate lithium production. Over 80% of lithium reserves are in regions that have cultural significance to native populations. [27] Indigenous people in Australia, South America and the US have collectively raised their concerns about lithium. In Argentina, there continues to be considerable political tension between locals and government bodies regarding new lithium developments. Last year the indigenous Argentine population marched to the capital, Buenos Aires, in a protest they call "Malón de la Paz" (Raid for Peace). This is the third protest of its kind, calling on similar indigenous protests held in 1946 and 2006. Protestors were standing against extensive lithium extraction in Northern Argentina and legislation introduced to the region which will declare that anyone without land titles can be displaced for violating property rights. This reform also makes it easier for mining companies to secure land rights disputes and prohibits future protest. The indigenous people have lived on the land for thousands of years and could now face eviction.[28]

Technological innovations within mining and extraction, such as DLE, will be key to helping reduce the environmental footprint of lithium and address concerns surrounding its sustainability and impact on communities.

GEOPOLITICAL RISKS TO THE LITHIUM SUPPLY CHAIN

The geographic concentrations of lithium raise high political, security, and reputational risks. The dominance of China in lithium refining poses a significant geopolitical challenge to the US and its allies. More than 96% of spodumene exports from Australia, an ally of the US, are sent to China. Here they are converted into lithium carbonate and hydroxide, primarily for domestic use, although China is also the leading exporter of lithium hydroxide. Almost all of the remaining processed lithium compounds are exported to South Korea and Japan. Chinese lithium producers are increasingly integrating extraction and processing, having either acquired or partnered with assets in Australia and Latin America.[29]

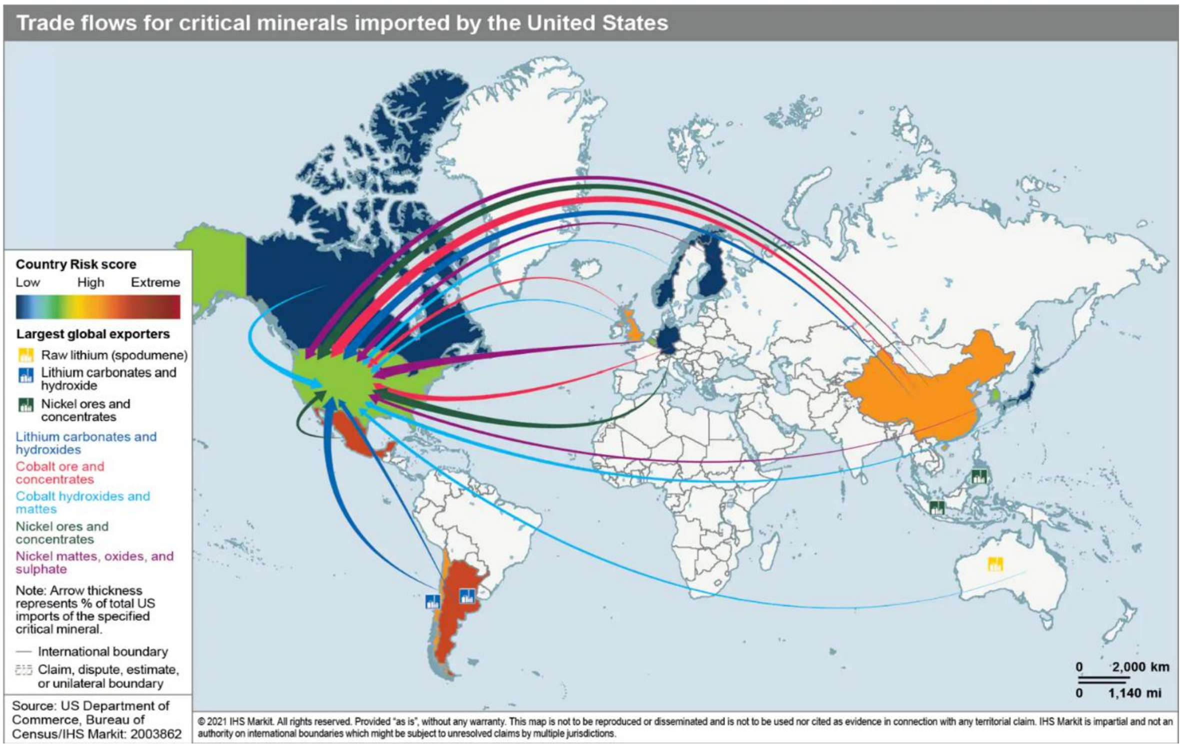


Figure 17: Trade flows for Critical Minerals Imported by the US, (Source: S&P Global Market Intelligence).

Cobalt, particularly when combined with nickel, contributes to higher energy density in lithium-ion batteries. This translates to longer driving ranges and improved performance for electric vehicles. Historically, lithium has faced controversy for its connection to cobalt, due to the unethical working conditions associated with the extraction of the metal. The world is dependent on the Democratic Republic of Congo (DRC) for supply of the rare mineral, which makes it unpredictable and highly susceptible to political risks. There have been reports of child labour, serious health risks and deaths at DRC operated mines.

Consequently, EV manufacturers are considering lithium-iron-phosphate (LFP) cathodes in their battery production. LFP cathodes are less energy-dense and less recyclable than nickel-manganese-cobalt oxide (NMC) cathodes, but they are cheaper to produce, and the manufacturers are less exposed to country risk driven supply chain disruption. LFP supply chains are relatively resilient as they rely on two diversely sourced inputs, phosphate and iron, that are supplied by lower risk countries. [29]

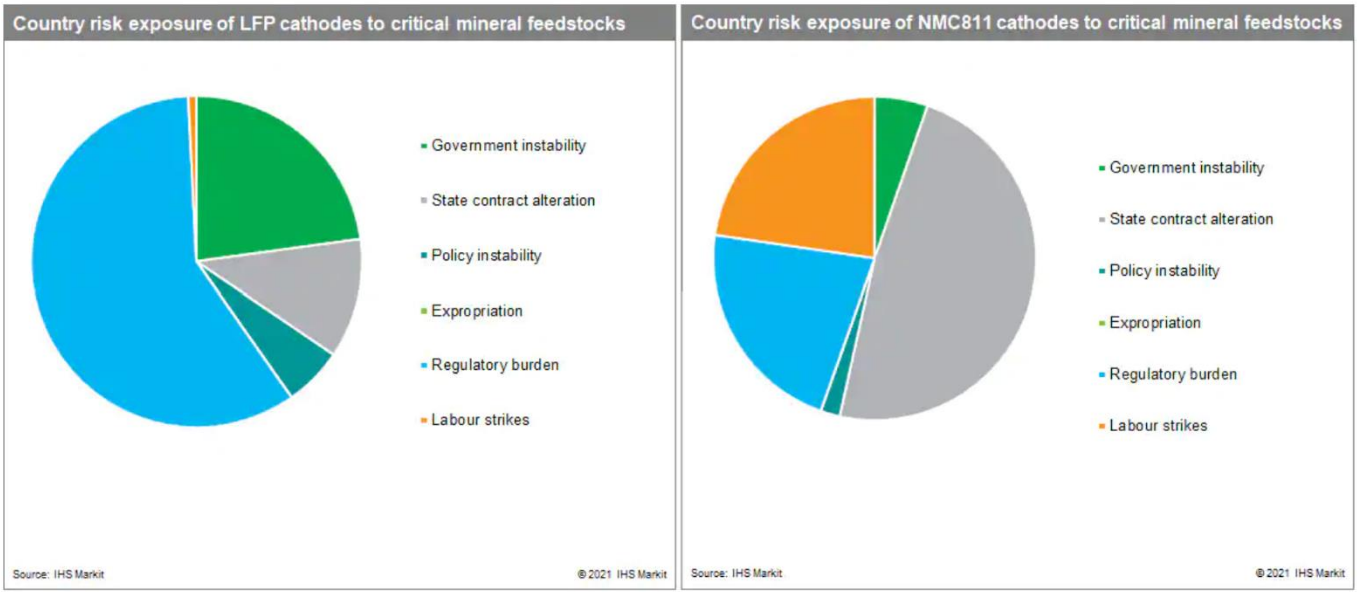


Figure 18: Country risk and reliability in EV battery cathodes supply chain, (Source: S&P Global Market Intelligence).

In Chile and Argentina, lithium concentrates are extracted from brines and processed into lithium carbonates, after which they are processed into the higher-grade lithium hydroxide.

Chilean authorities have reiterated that the door remains open to private companies to invest in the region, and insisted that relations with the two incumbents, Albemarle and SQM, are productive. Industry sources operating in Chile that we have interviewed, emphasise that the Government values all of its regional lithium projects and enjoys working collaboratively with them. They remain very optimistic about the lithium industry in Chile, and its regulatory landscape.

In Argentina, recently elected president, Javier Milei, has said that he is bringing a free-market revolution to the country's long-troubled economy. With reference to the country's rich lithium and copper reserves he said:

> *"Mining is another area with great potential in the country that is notably underdeveloped...to that end, we must eliminate costs."*

MARKET OUTLOOK AND CONCLUSION

The increasing demand for electric vehicles, renewable energy storage, and consumer electronics is inevitable and is expected to drive lithium demand significantly in the medium to long-term. The mineral is critical to achieving a successful energy transition and its inherent volatility does not change that. Record investment from public and private sectors globally reiterate this sentiment.

Technological advancements in lithium extraction are set to transform the industry, making the extraction process more efficient and environmentally friendly. Much like shale extraction did for oil, DLE can potentially revolutionise the lithium industry, unlocking new sources of lithium and increasingly efficient and sustainable extraction. We will continue to follow the leaders in this space as well as their technology and commercial viability.

A market surplus in 2023 has resulted in production cuts, slowed capex, project delays and uncertainty over future supply, key indicators that prices might have bottomed. Lithium prices will need to consolidate at a level above producers' cost curves to incentivise additional capacity and the long-term supply of lithium. The recent uptick in lithium spot prices and equities reflect a recovery in market sentiment from the volatility of the past year. A return to 2022 prices may be ambitious and unlikely, however, the underlying economics outlined in this report suggest significant future asymmetries driven by fundamental market imbalances. It is for this reason that we remain bullish on lithium prices and the sector's long-term trajectory.

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