

Market dynamics of lithium as a key element for modern energy

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Abstract. Oil has been and continues to be the "black gold" of the energy industry, and now the "white gold" of the energy industry has appeared - this is the alkali metal lithium. Lithium-ion batteries charge smartphones, laptops and electric vehicles. Some developed countries have committed to phasing out new gasoline and diesel vehicles by 2040. In 2021, global sales of electric vehicles, the main driver of the lithium market, grew 1.5 times. A further increase in demand in 2022 will mean a continued shortage of lithium this year, as consumption of the material outstrips production and depletes stocks. As the world's car manufacturers shift from internal combustion engines to electric vehicles, the need for new supplies of raw materials increases. The influence of environmental and political motives on the dynamics of supply and demand for lithium in the world is being discussed. Lithium deficiency can become a real limiting factor in achieving energy transition goals.

1 Introduction

Use Lithium is one of the most important minerals for the clean energy transition. The leading source of demand for lithium is the production of lithium-ion batteries, which has expanded at an unprecedented pace over the past decade thanks to the development of electric vehicles. While demand for nickel, cobalt and manganese may depend on the choice of cathode chemistry, lithium is the mainstay of all types of lithium-ion batteries, including lithium-ion phosphate (LFP) batteries. While technological innovation is accelerating progress in the commercialization of much more energy-intensive and thermally safe all-solid-state batteries (ASSB), they also come with lithium metal anodes [1].

Lithium supply is one of the most important elements in shaping the future decarbonization of energy transport and storage. Since 2021, prices have risen for mined feedstocks (spodumene or brines) and for high-purity lithium carbonate and hydroxide, that is, for every component of the lithium value chain. The previous boom in lithium prices was in 2017, following an unprecedented increase in demand for electric vehicle batteries as a result of China's EV subsidy scheme. This was followed by a period of overproduction and low prices between 2018 and 2020, when new mines were mothballed and expansion

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projects were shelved. This has left manufacturers unprepared for the growing momentum of electric vehicle adoption that has taken off around the world since the onset of the Covid-19 pandemic.

Worldwide car sales with lithium-ion batteries correlate with an exponential lithium usage curve. Electric vehicles consumed a record 270,000 tons of lithium carbonate equivalent (LCE) in 2021, double the 140,000 tons LCE in 2020 [2]. Lithium production increased by 30% in 2021, driven by Australia and Chile, despite this, prices continued to rise in 2022.

2 Historical trends

The industrial production of lithium began after the Second World War and reached the level of 5000 tons in 1955, where it had remained until the 1980s. The top three manufacturers were the US, Zimbabwe and Australia. After 1995, Chile became the leader in lithium production - the development of Salar de Atacama, a large saline deposit, began [3].

Lithium production increased from 9,500 tons to 28,000 tons between 1995 and 2010 driven by new demand for lithium-ion batteries and electric vehicles. From 2015 to 2019, the global lithium production showed an annual growth of 27%. Today, the top three producers, Australia, Chile and China, mine more than 86% of the world's lithium [4].

Lithium mining in Australia is mainly open pit, producing spodumene concentrate, that is processed then into lithium. Most of Chile's production comes from salt brines with high lithium concentrations [1]. Lithium is also found in seawater in low concentrations, but at the moment there is no economically viable technology for its extraction.

China, the third largest producer, leads the way in terms of primary raw material production growth. Since 2018, Chinese companies have invested more than \$5 billion in lithium mining projects around the world. In addition, the country also dominates the recycling and battery manufacturing stages of the lithium-ion battery supply chain. China accounts for more than 65% of global battery production and more than half of lithium chemical production [5].

The US produced 900 tons of lithium in 2020, which is only 1% of the global amount. The country has only a one underground lithium mine in Nevada, although the country has 750,000 tons of this metal. The top ten global lithium producers are presented in Table 1.

Table 1. World production of lithium, tons of pure lithium, 2021.

Country	Lithium output, tons	Worldmarketshare
Australia	40000	46,3%
Chile	20600	23,9%
China	14000	16,2%
Argentina	6200	7,2%
Brazil	1900	2,2%
Zimbabwe	1200	1,4%
USA	900	1,0%
Portugal	900	1,0%
Others	500	0,6%
Total	86300	100%

Source: Visual Capitalist [6].

Development of the industry has received recognition in the scientific world. The Nobel Prize in Chemistry for 2019 was awarded to the creators of lithium-ion batteries - laureates John Goodenow, Stanley Whittingham and Akira Yoshino solved the main problem of

lithium-ion batteries - materials and composition for efficient, durable electrodes. The idea of their creation appeared in 1973-74 after the first oil crisis. Now lithium batteries are used everywhere, they are necessary for IT devices, electric vehicles and renewable energy batteries, solar panels and wind generators [3].

The mass introduction of lithium-ion batteries began in 1991. Japanese and American manufacturers of portable power storage devices pushed the new type of device into the computer science and communications (ICT) sector, and since then, lithium-ion batteries have been in all laptops and phones.

3 Demand and price dynamics for lithium

It should be noted that commodities in general, and metals in particular, were an asset class with positive capital inflows in 2021 and early 2022. In particular, in 2021, the US Commodity Index (Bloomberg Commodity Index) rose by 30%, overtaking the US stock index S&P 500, not to mention the declining debt index, and it continued to grow this year.

Lithium, a critical component for battery production, stands out among the commodity assets: buyers around the world are facing a shortage of supply of this metal, while demand is growing rapidly, primarily due to the growth in sales of electric vehicles, especially in China, the world's largest market.

In the period between 2015 and 2020, lithium prices dropped from over \$17,000/t in 2015 to some \$8,000/t in 2018, and then prices fluctuated until the end of 2020. Lithium in a commercial form of carbonate is now the world standard lithium (LCE) in Chinese yuan per ton. Commodity prices on the Shanghai exchange began to rise from Q1 2021 and increased from 100,000 yuan/t (12,000 USD/t) lithium carbonate (LCE) to 400,000 yuan/t (63,000 USD/t) carbonate lithium (LCE) at the end of Q1 2022 [7]. Due to a significant increase in consumption, the lithium balance has changed from a surplus of 69,000 tons LCE in 2020 to a deficit of 7,000 tons LCE in 2021 [2].

In 2021, against the background of strong demand for raw materials, the prices for batteries reached a record, especially in the domestic market of China. Battery material prices rose by 459% for lithium carbonate and by 479% for lithium hydroxide in 2021, while prices for cobalt and cobalt sulphate rose by 82% over the same period (Table 2). For comparison, prices for nickel rose by 15% and for copper – by 23% [8].

Table 2. Price dynamics for batteries, 2021

Metalcommodity	Price index in 2021
Nickel	15%
Cobalt	82%
Lithiumhydroxide	459%
Lithium carbonate	479%

Source: S&P Global Market Intelligence [8].

Another metal used in cathodes is cobalt, which has risen in price to \$70,000/t in the year since the beginning of 2021, while nickel has risen to \$20,000/t. The rapid rise in cobalt prices caused disruptions to transportation due to the pandemic and the closure of borders in Africa for quarantine. Further, lithium prices continued to rise from the beginning of 2022, while the main driver was the growth in the production of electric vehicles [9].

Environmental and political motives affect the dynamics of lithium supply and demand in the world. In early 2021, Serbia blocked Rio Tinto Plc's plans to develop Europe's largest lithium mine amid widespread environmental protests. While lithium may be of paramount

importance for combating climate change on a global scale, but at the same time, local environmental problems associated with mining cannot be ignored.

In the US and Europe, they are trying to reduce the environmental footprint of battery technologies by working to optimize the extraction and processing of metals. Environmentalists in developed countries demand that batteries be made from recycled materials.

Sometimes there are also political risks. Chile is the second largest supplier of lithium in the world, but in the structure of its economy, lithium mining occupies a small part. Chile elected a new, left-leaning president in 2021, and the country's plans to set up a national lithium mining company are now on hold, with licenses and lengthy project development periods delaying new capacity by years. The new government of Chile is concerned that the use of artesian water for the industrial production of lithium salts in the Atacama Desert is not acceptable on environmental and social criteria.

The analytical agency S&P Global Market Intelligence [8] estimates the demand for lithium at 2 million tons by 2030, its production/supply should be increased by 23 times compared to 2020.

4 Sales of electric vehicles

Demand for lithium is rising, so are battery prices - lithium shortage is a critical factor for the adoption of electric vehicles. Automakers have to compete for raw materials in a global competition to produce cheaper electric vehicles. Finding raw materials for batteries is becoming as much of a problem as semiconductor supply was in 2021, and there is a real risk that EV production will be suspended in planned quantities due to material shortages.

Global sales of electric vehicles reached 5.6 million (to which 1.6 million hybrid cars can be added) in 2021, compared to 3.1 million in 2020 due to strong sales levels in China [10]. A further increase in demand in 2022 will mean a continued shortage of lithium this year, as consumption of the material outstrips production and depletes stocks.

Table 3. Sales growth of electric vehicles, million per year. (* - 2022 – estimate)

Year	2015	2016	2017	2018	2019	2020	2021	2022*
Electric	0.3	0.5	0.9	1.6	2.2	3.1	5.6	7.8
Hybrid	0.1	0.1	0.2	0.3	0.4	0.8	1.6	2.6

Source: BloombergNEF [10]

As the world's car manufacturers shift from internal combustion engines to electric vehicles, the need for new supplies of raw materials increases. Volkswagen and BMW have said that more than 50% of sales in 2030 will come from electric vehicles. Ford Motor expects to electrify 40% of its sales worldwide by 2030. At the end of 2021, Toyota announced plans to sell 3.5 million electric vehicles in 2030 [11].

In China, EV sales growth is outpacing the US or Europe. The country is trying to avoid resource scarcity by using lithium iron phosphate compounds for some parts instead of the expensive nickel and cobalt compounds that are expanding supply in developed countries. The expansion of the market for electric vehicles must occur in tandem with the growth of mineral extraction and the construction of supply chains.

The cost of EV batteries will rise in 2022 after falling sharply in the 2010s as the supply of lithium and other components can't keep up with rising demand. According to Bloomberg NEF [10], lithium-ion battery prices in 2010 exceeded \$1,200 per kilowatt-hour, but by 2021 have fallen to \$132. However, in 2022, average prices could rise to \$135 per kilowatt-hour. Cathode materials typically account for about 30% of the total cost of batteries.

5 Building supply chains and increasing them

Now the demand for lithium is growing, and the supply has not yet kept pace with it. The lithium shortage should end as supply companies will soon increase their upstream investment in response to price signals. Also, exploration should play a key role in discovering new resources, especially in countries such as the United States, which by now have lost their position in the industry.

China accounts for more than 65% of global battery production and more than a half of lithium chemical production. This dominance worries many in the automotive industry, given geopolitical tensions. No country can match China in terms of price competitive advantage, but the Chinese producers are also experiencing a shortage of raw materials and dependent on imports of ore from Australia and salts from Chile.

Several projects ~~will~~ started production in 2022, including Cauchari-Olaroz (Argentina, 40,000 LCE), Sal de Vida (Argentina, 11,000 LCE) and Finnis (Australia, 25,000 LCE). Other major projects slated to begin production in 2023 or 2024 include Thacker Pass (USA), Mt Holland Lithium (Australia), James Bay (Canada), Authier (Canada) and Keliber (Finland). The announced expansion of the Silver Peak project in Nevada, the only active lithium facility in the United States, will double production by 2025 to 10,000 tons of LCE per year [12]. While prices may come down in 2023 as new supplies come in, the security of lithium supply will remain important given the fast pace of demand growth and limited refining capacity for battery products.

The corporate sector is actively responding to changes in the lithium market. In 2020, Tesla acquired licenses to mine lithium from alumina deposits in Nevada, USA - this reflects the automaker's decision to gain direct access to primary resources without intermediaries. BMW signed a \$113 million five-year cobalt supply deal with Moroccan manufacturer Managem [13]. In 2022, Volkswagen signed an agreement with the Vulcan Group to supply "zero carbon" lithium to battery factories. In the same month, the German company announced the creation of a joint venture with the Belgian company Umicore to increase the production capacity for source and cathode materials in Europe. Toyota has said it has secured sufficient supplies of battery raw materials, including lithium, to meet demand through up to 2030 [14].

The shortage situation in the lithium market is driven by rising demand amid regulations and increased consumption in Europe, the US and China, as well as supply constraints due to insufficient investment in recent years. There is no physical shortage of lithium resources - this is a matter of economic and political incentives for development of the industry. Research into the battery feedstock market shows that lithium prices will not fall, unlike previous industry cycles [15], and the new technologies, such as solid-state batteries, will require even more lithium

6 Conclusions

- From 2015 to 2019, global lithium production showed an annual growth of 27%. Today, the top three producers, Australia, Chile and China, mine more than 86% of the world's lithium.

- China accounts for over 65% of global battery production and over half of lithium chemical production.

- In 2021, global sales of electric vehicles, the main driver of the lithium market, increased by 1.5 times with 7.2 million new hybrid and electric vehicles registered, increasing the global electric vehicle market share to 8.6%.

- With the achievement of the decarbonization goals set at the COP26 climate conference in 2021, the demand for lithium will grow to 2 million tons by 2030, its

production/supply should be increased by 23 times compared to 2020. Lithium shortage could become a real limiting factor for the energy transition.

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