Critical Metals
For a Sustainable World

Capitalight Research Inc.

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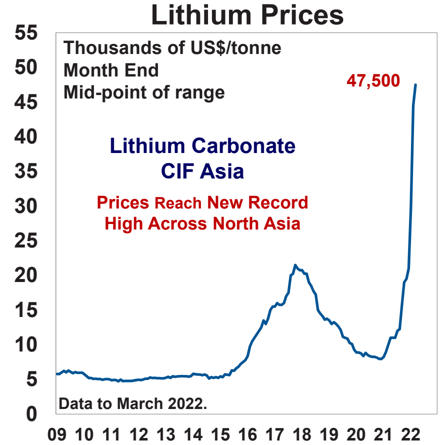
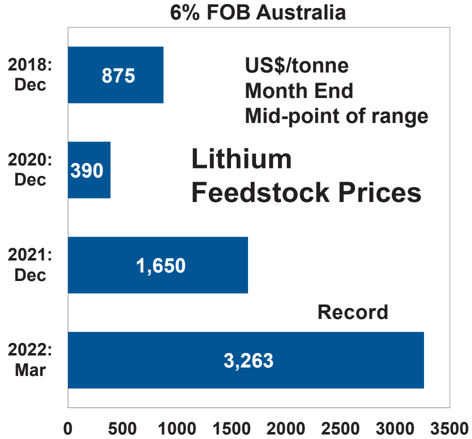
Patricia Mohr
Patricia.mohr@capitalightresearch.com
Dr. Tom Brady
Tom@capitalightresearch.com

Lithium Prices



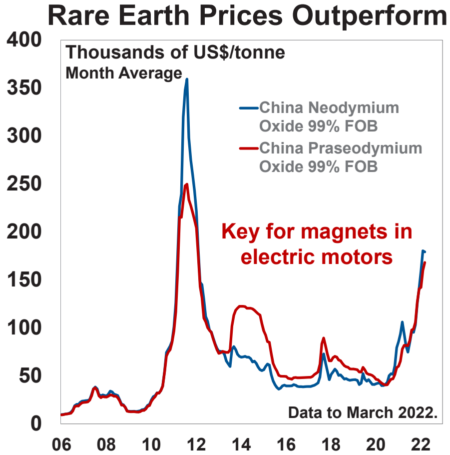
Source: BMI, Bloomberg, Capitalight Research.

Spodumene Concentrates
6% FOB Australia



Source: BMI, Bloomberg, Capitalight Research.

Rare Earth Prices Outperform



Source: Asian Metals Inc, Bloomberg, Capitalight Research.

- In-depth analysis on the lithium supply chain.
- Vale will supply Northvolt with Canadian nickel.
- Rare earth prices ease back in China.

This month we feature a special report by Dr. Tom Brady on the lithium supply chain. Patricia Mohr's comments start on page 7.

An Overview of the Lithium Supply Chain

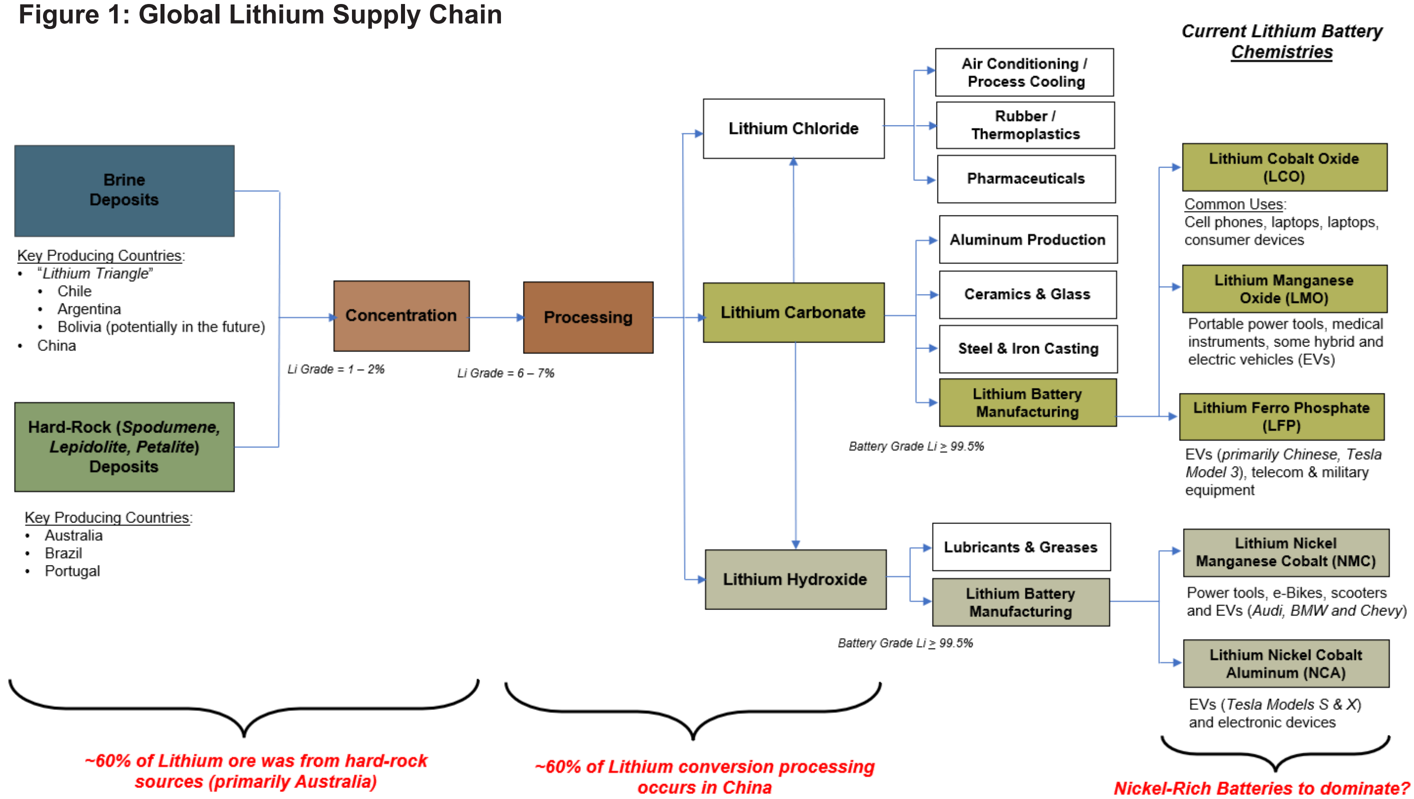
This month we provide an overview of the global lithium supply chain from the mining of ore through the processing of intermediate compounds, to the manufacture of lithium-ion batteries (Figure 1). Driven by increasing global demand for batteries, the search for new mine supply sources and processing techniques alongside the evolution of battery chemistries, this supply flow is guaranteed to change in the future.

Currently, the majority of lithium mining occurs from either brine or hard-rock deposits[1]. Brine deposits are primarily mined from areas within the “Lithium Triangle” (which include Argentina, Chile and potentially, in the future, Bolivia) and are also mined in China. Actual mining from brine deposits involves the pumping of saline groundwater enriched with dissolved lithium from underground reservoirs to the surface for solar evaporation in successions of ponds. Hard-rock sources are dominated by spodumene deposits, primarily located in Australia. The Greenbushes operation, presently the world’s largest lithium mine is located in Western Australia.

Figure 2 summarizes annual global lithium mine production by deposit type since 2010. As shown, global supply has increased from ~28,000 tonnes in 2010 to ~105,000 tonnes last year, a nearly 3-fold increase. Lithium mine production from brine deposits dominated annual totals until 2017. Over the last five years however, production from hard-rock sources has averaged slightly under 60% of the annual global total.

[1] Traditionally, extracting lithium clay hosted sediments was considered too complex and uneconomic, however, a number of U.S. based projects are currently under evaluation, including Thacker Pass in Nevada, noted as having the largest resource in the U.S.

Figure 1: Global Lithium Supply Chain



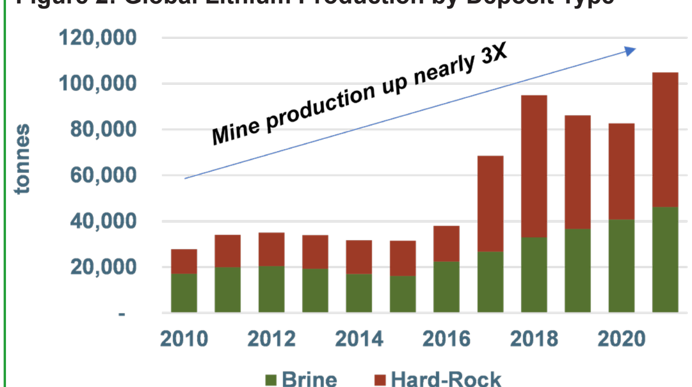
Source: Adopted from Peiro, et. al., "Lithium: Sources, Production, Uses, and Recovery Outlook", 2013 and Capitalight Research.

As noted on Figure 1, across deposit types, mining ore grades are generally low (1% to 2%), making these uneconomic for transport. As such, ore concentration activities typically occur at the mine site. Concentration of brined mined ore occurs through solar evaporation in successions of ponds to increase the grade. At hard-rock deposits, run of mine ore is initially processed through grinding and screening to separate lithium from surrounding materials in the ore. Following concentration, lithium grades are generally in the 6% to 7% range[2].

Lithium Processing/Conversion

Following ore concentration, the next step in the lithium supply chain is processing and conversion. As shown in Figure 1, lithium carbonate is a first intermediary chemical in the lithium supply chain, which is used in various manufacturing processes (including ceramics and glass, aluminum and steel castings) as well as some electric vehicle (EV) battery types. Lithium carbonate may also be further processed to obtain lithium chloride and lithium-hydroxide, the latter of which is used in the manufacture of nickel containing (often called "nickel rich") lithium-ion batteries.

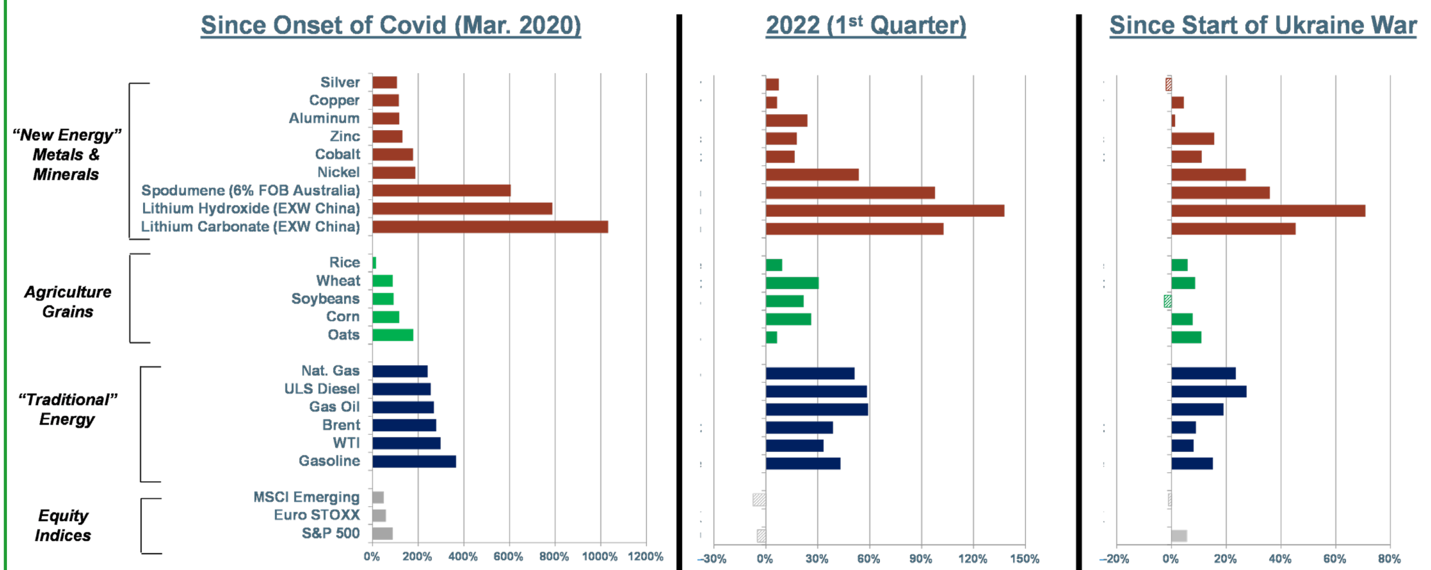
Figure 2: Global Lithium Production by Deposit Type



Source: U.S.G.S. Mineral Commodity Summaries, Capitalight Research.

[2] "Lithium", Bednarski, 2021.

Figure 3: Lithium Compounds & Select Commodities Price Performance



Source: BMI, LMBA, LME, COMEX, Bloomberg & Capitalight Research.

As depicted with the multiple arrows under the processing steps in Figure 1, the conversion of hard-rock (spodumene) lithium concentrate is more flexible in terms of production processes. It allows for a streamlined production of lithium-hydroxide while the processing of lithium from brine concentrates produces lithium carbonate which must then be further processed to obtain lithium hydroxide[3].

The processing of lithium ore is difficult and becomes more so as the mineral moves through the supply chain to the eventual material used in battery cathodes. Further, battery chemistries are fragile which infers that processing facilities must be able to produce consistent lithium intermediate products such as lithium-carbonate and lithium-hydroxide. Critical to this processing is the control of the many impurities that may coexist with lithium in concentrated ore such as magnesium, sodium and potassium that negatively impact battery cathode performance further down the supply chain[4].

Through the conversion steps, whether in the form of lithium carbonate or lithium hydroxide for eventual use in EVs or batteries for other electronic devices, the purity of lithium is increased to >99.5%. In terms of geopolitical risks within the lithium supply chain, currently over 60% of the facilities that convert lithium ore into the intermediate products of lithium carbonate and lithium hydroxide are located in China[5].

Figure 3 displays price returns for representative commodities and equity indices since the onset of the Covid-19 Pandemic, over the 1st quarter of 2022 and since Russia invaded Ukraine in late February. While not as widely reported as price increases in traditional energy (including WTI and Brent crude oil, natural gas and gasoline), metals and minerals associated with the energy transition (labeled "New Energy" on the figure) have experienced significant gains over the 3 identified periods. As shown, price increases in lithium hard-rock (spodumene) ore and the lithium carbonate and hydroxide intermediate compounds have each far exceeded traditional energy and agricultural grains. These sharp increases, along with the price climbs in cobalt and nickel are sure to drive higher battery prices (and overall EV prices) over the coming months.

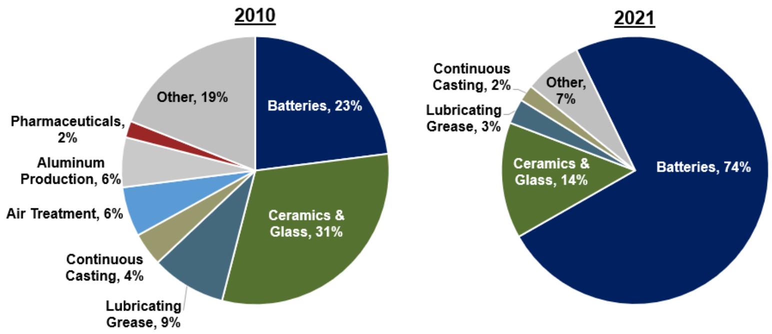
[3] "Building batteries: Why lithium and why lithium hydroxide?", Innovation Network, Feb. 2021.
[4] "Lithium", Bednarski, 2021.
[5] Source: "Supply Chain for Lithium and Critical Minerals Is ... Critical", ClearPath, June 2020.

Lithium Demand

Progressing further through the supply chain (back on Figure 1), following the conversion to the aforementioned intermediate products, are various manufacturing and end use applications. These include air conditioning and industrial process cooling, thermoplastics, pharmaceuticals (for bipolar and depression), as an alloy in aluminum production to add strength and corrosion resistance. In the manufacture of glass and ceramics, lithium carbonate allows for lower processing temperatures and thus lower energy input. Other uses include steel casting applications and finally in the manufacturing of lithium-ion batteries.

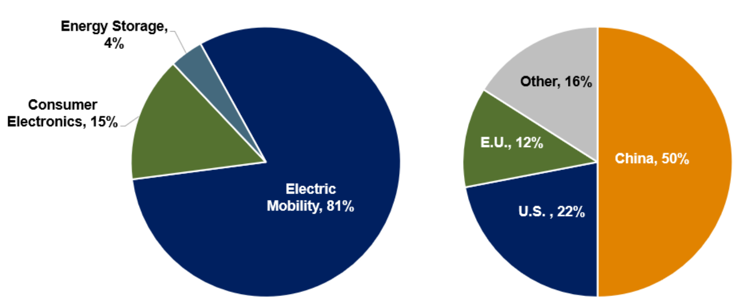
Figure 4, displays how the demand for lithium has evolved over the last ~10 years. In 2010, ceramics and glass demand dominated global demand, accounting for nearly 1/3rd of the total, followed by battery applications requiring nearly 25% of the total[6]. Spring forward to 2021, reflecting the huge increase in demand needs for EVs and other consumer electronics, batteries now require ~75% of annual global demand.

Figure 4: Global Lithium Demand



Source: U.S.G.S. Mineral Commodity Summaries, Capitalight Research.

Figure 5: Lithium-Ion Battery Demand by Use and Country (2020)



Source: Energy Reports, Capitalight Research[7].

Lithium-Ion Battery Manufacturing and Demand

Continuing down the lithium supply chain, Figure 1 also displays the major types of current lithium-ion batteries that have come to dominate the portable electronics, energy storage and EV markets. Key to lithium batteries are the relatively higher energy densities (higher power and lower weight) compared to non-lithium ion battery types. For EVs higher energy density translates into more power and higher mileage ranges. As shown on Figure 1, at present there are 5 general types of lithium-ion battery chemistries including lithium cobalt oxide (LCO), lithium manganese oxide (LMO), lithium ferro (or iron) phosphate (LFP), lithium nickel manganese cobalt (NMC) and lithium nickel cobalt aluminum (NCA)[7]. While some of these common battery types may or may not include cobalt (a topic for a future article), all contain lithium. Actual manufacturing of lithium-ion batteries occurs primarily in China (CATL, BYD, …), Japan (Panasonic, Samsung, NEC, Sanyo, Sony, …) and South Korea (LG Chem, …)[8].

Figure 5 displays demand for lithium-ion batteries by end use and by country for 2020. As shown, electronic mobility (primarily EVs but also includes e-bikes, scooters, etc.) dominates demand at over 80%. Consumer electronics (laptops, medical devices, cell phones to name a few) accounts for 15%, followed by

[6] Note, in the mid-1990s only ~7% of global lithium demand was allocated to batteries. Remember the hand-held Sony Camcorder?
[7] Another common battery chemistry uses lithium titanate (LTO) which replaces graphite used in the anode of the battery with lithium titanate, for use in the LMO or NMC as the cathode chemistries. Source: "A Guide To The 6 Main Types Of Lithium Batteries" (https://dragonflyenergy.com/types-of-lithium-batteries-guide/), Sep. 2021.
[8] The companies listed are not comprehensive. Among others outside of Asia, include SAFT (France), Valence Tech (U.S.), Source: "Battery management for electric vehicles", Energy Reports, Nov. 2021.

energy storage (4%). China by far leads in the global demand for lithium-ion batteries with over half, followed by the U.S. (22%) and the E.U. at 12%.

Lithium-Ion Battery Types & Pros and Cons

Specifically, the following summarizes the benefits and challenges associated with the current 5 general chemistries utilized in the cathode of lithium-ion batteries[9].

Lithium-Cobalt Oxide (LCO)

These batteries are most commonly used in smaller, portable electronics including mobile phones, tablets, laptops, and cameras. A key attribute of this battery type is the ability to deliver power over long periods for low power-requirement applications. Negatively, these batteries suffer from relatively short lifespans, losing effectiveness after 500 to 1,000 life cycles (or charging periods). These batteries also have poor thermal stability (there are many reported incidents of batteries overheating due to overcharging and/or poor performance in extremely hot or cold environments).

Lithium-Manganese Oxide (LMO)

In comparison with LCO batteries, this chemistry offers improved thermal stability. LMO batteries are commonly used in power tools and medical instruments. Early EVs such as the Nissan Leaf used LMO batteries which suffer from relatively short driving ranges of 80 to 100 miles. LMO batteries have shorter life cycles, in the 300 – 700 charging cycles range.

Lithium-Iron-Phosphate (LFP)

Along with LMO batteries, LFP chemistries have the benefit that these do not contain cobalt (another mineral critical to the “New Energy Future”, whose prices have also climbed as shown in Figure 3). In addition, cobalt brings significant geopolitical risk as >80% of world supply is from the Democratic Republic of the Congo. LFP batteries offer a relatively longer life span (1,000 to 2,000 charge cycles). These batteries are known to be relatively safe, however performance can suffer in low temperatures. In addition to not using cobalt, LFP batteries use iron rather than more costly nickel. Average costs are currently lower than nickel-rich chemistries. At present, the current trend appears to be heading toward LFP batteries. Nearly 60% of EVs produced in China during 2021 use LFP batteries[10]. Also, Tesla recently migrated its entry-level Model 3 to use LFP.

Lithium-Nickel-Cobalt-Manganese (NCM)

Within the cathodes of NCM batteries, manganese is added to nickel to provide additional thermal stability. These batteries are known for having relatively long life spans (similar to LFPs). NMC batteries are widely used in power tools, in e-bikes and scooters. Higher end Chinese EVs such as the BYD Qin Pro use NCMs as does the VW ID.4 and Chevy Bolt.

Lithium-Nickel-Cobalt-Aluminum (NCA)

NCA batteries are widely used in the EV marketplace as they perform well under high-load applications and offer long battery life. NCA batteries can offer ~30% more energy density (more energy per unit of weight) compared to LFPs. Tesla’s higher-end models (the S, X and Y) use NCA battery types.

Currently the “nickel rich” batteries appear the preferred battery type in the U.S. and Europe.

Outlook

In an attempt to shore up domestic supply chains, on March 31 the Biden administration announced plans to use the Defense Production Act to ramp up the mining and processing of key minerals used in batteries for renewable

[9] This section relies heavily upon: “A Guide To The 6 Main Types Of Lithium Batteries and Overview of batteries”; (https://dragonflyenergy.com/types-of-lithium-batteries-guide/), Sep 2021, and “battery management for electric vehicles”, Energy Reports, Nov. 2021.
[10] Tesla & Chinese EV Makers Putting Lot Of Weight On These Low-Cost EV Batteries, CleanTechnica, Jan. 2022.

energy and electric vehicles[11]. Under the order, companies "could" receive funding for feasibility studies to extract lithium, nickel, cobalt, graphite, and manganese. Two initial concerns arise with this announcement. First, while companies may obtain assistance for the study of potential domestic projects, it does not appear that the U.S. government will help with actual capital expenses associated with building mining operations. Second, as highlighted in this article, the significant risks associated with the lithium supply chain lie in the processing of lithium carbonate and hydroxide intermediate compounds necessary for EV battery manufacture. 60% of this processing occurs in China. The Chinese have been working 10+ years on refining processes to transform lithium containing ores into the exacting and precise materials required by battery manufacturers for eventual use in EVs and other critical electrical equipment used in industry and by consumers.

In our view, many in the Western Countries of the world have unrealistic expectations for the "Energy Transition". As a representative example, global automobile sales are expected to approach 125M units by 2030 (a nearly 45% increase from 2021)[12]. If the world is to build toward a "Net Zero Carbon by 2050" scenario, this will require nearly 60% of these 2030 sales to be for EVs. However, rolling back through the lithium supply chain, this would require mine supplies to be ~5-times higher than the 100,000 tonnes mined last year. When one contemplates the actual time required for companies to explore, study and model potential resources, the negotiation and finalization of national, state and local permits, the extensive efforts to solidify buy-in from local communities and stakeholders, the raising of capital funds and then to the actual construction of a mine, this level of expansion (all within <8 years) is extremely unlikely[13]. As the world operates today and Congress will discover, it is much easier to state proclamations such as, "the U.S. Government will end gas-powered vehicle purchases by 2035" than to fulfil that proclamation.

[11] The U.S. Defense Production Act allows the president to respond to a national emergency by requiring that companies prioritize federal contracts for whatever goods or materials it deems necessary.
[12] "Global Automotive Market: COVID-19, Growth & Forecast 2020-2030 – ResearchAndMarkets.com", Business Wire, Oct. 2021.
[13] Further, this quick calculation ignores the requirements in electronic and medical devices as well as the building requirements for the lithium to be needed in actual EV charging stations.

Copper Prices Remain Lucrative

LME official cash settlement prices climbed to an average of US$4.64 per lb. in March, up from US$4.51 in February and remain at a profitable US$4.73 on April 5. Prices averaged US$4.40 in the fourth quarter of 2021 and US$4.23 for 2021 as a whole.

Copper prices are holding up at high levels in the aftermath of the February 24th Russian invasion of Ukraine, which boosted commodity prices across a wide swathe (linked to banking sanctions and transportation disruptions affecting Russian supplies). Copper concentrate supply to Aurubis' Bulgarian smelter has been disrupted, as shipping lines have avoided entering the Black Sea south of Crimea. The Pirdop site in Bulgaria produced one-fifth of Aurubis' 2021 copper cathode output. Aurubis is Europe's largest copper cathode & products producer.

Traders are also taking a positive view on the outlook for copper, despite the recent COVID-related lockdown of economic activity in Shanghai. While industrial production rebounded strongly in China in January and February (+7.5% yr/yr), COVID-19 restrictions contributed to a significant drop in the Caixin Purchasing Manager Index in March. Visible exchange inventories on the LME, COMEX and SHFE remain low at only 7.9 days' supply, but have edged up from a mere 5.4 days at the end of January.

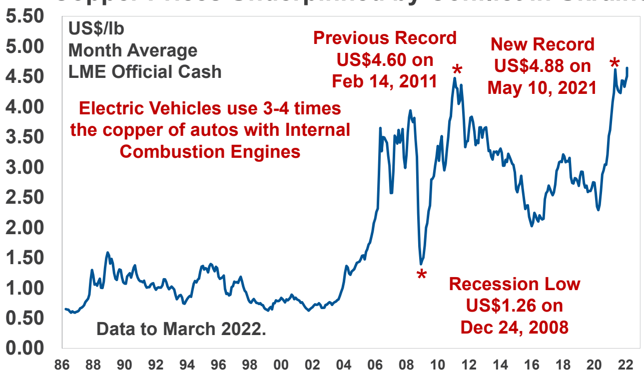
Robert Friedland's bullish comments at the CRU World Copper Conference in Santiago in late March have probably lifted sentiment. Mr. Friedland, Founder and Executive Co-Chairman of Ivanhoe Mines, expects that soaring world copper consumption points to a copper supply & demand 'deficit' of 5-9 million tpa later this decade.

Nickel Prices Steady, But LME Market Barely Trades

LME official cash settlement prices averaged US$14.45 per lb. in March (using the monthly average calculated by the LME) – up from US$10.97 in February and US$10.13 in January. Prices are fairly steady at US$15.31 on April 5, though LME trading volumes remain exceptionally low. The illiquidity of the Exchange is a source of concern for industrial producers and consumers, who use the LME to price their contracts and hedge risk.

The relatively modest average price increase in March disguises extreme volatility through the 'short-covering squeeze' – from US$19.50 on March 7 (closing at US$21.81 for 3-month futures) before trading was suspended on March 8 through the 15th – ending the month at US$15.15. (In early trading on March 8, the 3-month price rose to a record US$101,365 per tonne (US$45.98 per lb.) as a major Chinese market participant (Tsingshan Holdings) and others struggled to cover large short positions

Copper Prices Underpinned by Conflict in Ukraine



*May 10, 2021 record was intra-day;
April 5, 2022: US$4.73/lb.
Source: LME, Bloomberg, Capitalight Research.

Slow Nickel Trading Volumes on LME, After 'Squeeze'

April 5, 2022: US$15.31/lb.
LME monthly average settlement price for March 2022: US$14.45/lb.
Source: LME, Bloomberg, Capitalight Research.

and escalating margin calls in a tight and illiquid market; one 'long' reportedly held 50-80% of LME inventories. Three-month futures subsequently dropped back to US$80,000 as of 08:15 GMT on March 8, at which point the LME suspended trading. In a very controversial move, the LME cancelled all nickel trades executed on or after 00:00 hours on March 8 in the inter-office market and on LME Select – worth about US$3.9 bn.)

Since trading resumed on March 16, the LME has set daily upper and lower price limits (initially only 5%, rising to the current 15%) and has imposed reporting requirements on OTC positions.

The Financial Conduct Authority (FCA), which regulates the financial services sector in the United Kingdom, will launch a review of how the LME handled the nickel squeeze, while the Bank of England will look into the conduct of the Clearing House. The LME will launch its own regulatory review in a bid to prevent similar volatility in future.

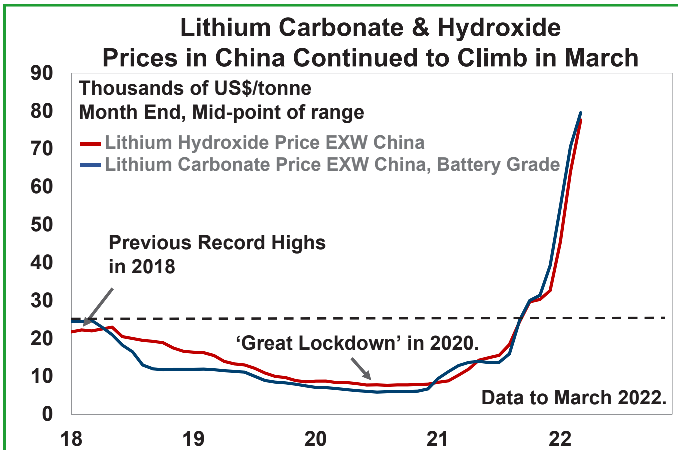
In a positive development for Canada, Vale has announced that it will supply nickel to Northvolt from its Long Harbour Newfoundland processing plant – a geopolitically secure source of supply with one of the lowest carbon footprints in the world (almost half the level of Russia's Norilsk Nickel and roughly 7 times lower than Indonesia's nickel matte).

Lithium Price Gains Slow in China, As Buyers Hesitate

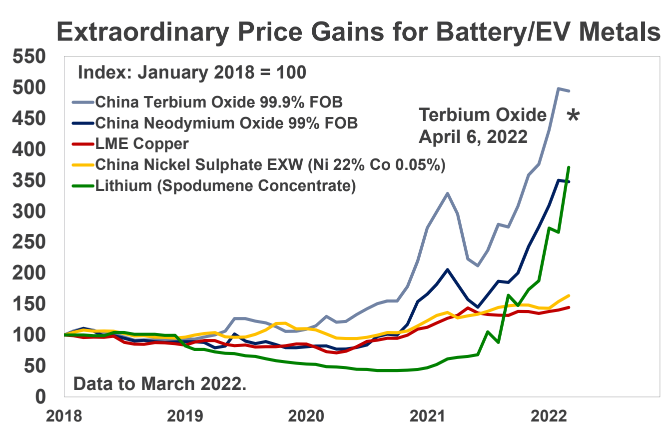
Lithium remained in a physical supply-side squeeze in late March and prices continued to move higher. However, gains slowed in the Chinese domestic carbonate market, as buyers hesitated to move significantly above the RMB 500,000 per tonne level (US$79,000). In other markets, Chinese hydroxide price momentum continued and international pricing for small spot volumes neared parity with China.

Lithium carbonate EXW China (battery grade) – the price which sets the tone of international lithium prices – climbed to a new record high of US$79,550 per tonne at the end of March – up an extraordinary 519% yr/yr. Lithium hydroxide prices EXW China advanced at a slightly faster pace to US$77,650, but stayed below carbonate, given China's interest in LFP batteries (BMI price assessments).

Average spodumene concentrate prices (6% Li_2O) FOB Australia bounced back in late March to a new record high of US$3,263 per tonne – after retreating slightly to US$2,340 in February. Formula-driven spodumene prices are expected to move even higher in the second quarter due to rising demand from China.



Lithium Hydroxide EXW China, Mar 31, 2022: US$77,650/t.
Lithium Carbonate Battery Grade EXW China, Mar 31, 2022: US$79,550/t.
Source: BMI, Capitalight Research.



Based on Monthly U.S. dollar prices; yuan prices converted to U.S. dollars.
Source: Capitalight Research, Asian Metal Inc. & Bloomberg.

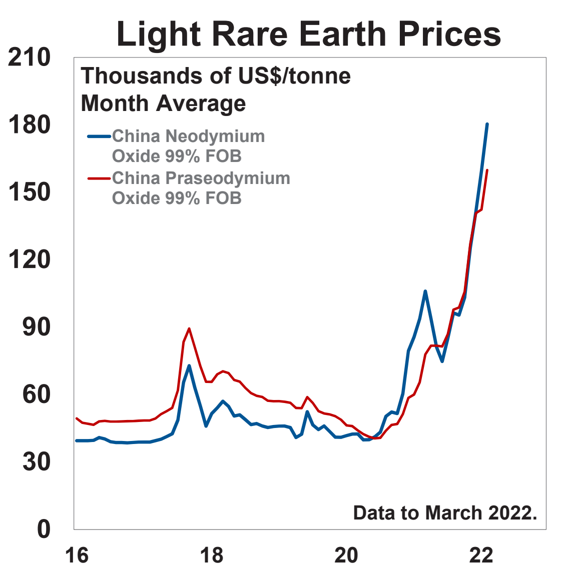
The extraordinary price advance for lithium has become a growing source of concern for Beijing as well as battery manufacturers worldwide. Given China's goal of leading world development of 'new energy vehicles', the Ministry of Industry and Information Technology has recently held talks with industry players, hoping to reign in prices – likely difficult to achieve.

China Pressures Domestic REE Producers To Bring Down Prices

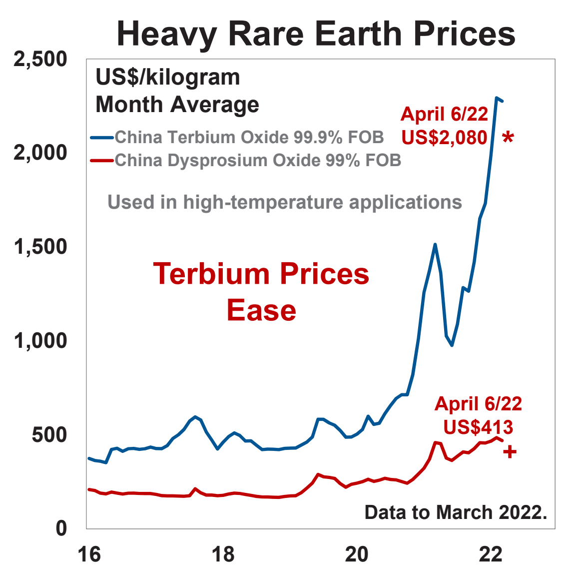
After skyrocketing through February 2022, key rare earth element (REE) prices – vital for the production of magnets driving EVs and generators for wind turbines – eased back in mid-March. While underlying demand and longer-term orders at Chinese magnet manufacturers remain strong, China neodymium oxide has edged down from an average of US$180,363 per tonne (FOB China) in February to US$179,239 in March and is US$159,500 in early April. Praseodymium oxide has held up better – advancing to US$168,130 per tonne in March – but has slipped to US$156,000 in early April. Even terbium oxide – a heavy rare earth and the top performing critical metal within our universe since 2018 – eased to US$2,080 per kilogram on April 1 from an average of US$2,293 in February.

Buyers may be using up inventories on hand, having restocked REEs over the past year. In addition – as with lithium – China's Ministry of Industry and Information Technology has been pressing the three main State Owned Enterprises, who control REE mining and processing in China, to regulate their operations to prevent hoarding and speculation. The three players include: China Rare Earth Group (the recent consolidation of China Minmetals Rare Earth Co., Chinalco Rare Earth & Metal Co. and China Southern Rare Earth Group plus several others, with about 70% of China's heavy REE mine output), China Northern Rare Earth Group (dominating China's light REE mining) and Shenghe Resources.

Turning to Russian supplies, Solikamsk Magnesium Works mines REEs in Russia, accounting for less than 10% of global production. Solikamsk provides about 70% of REE feedstock for Neo Performance Materials' Estonia separation plant – important for EU supplies of separated rare earths.



* Neodymium Oxide, April 6, 2022: US$156,500/t.
+ Praseodymium Oxide, April 6, 2022: US$156,000/t.
Source: Asian Metals Inc., Bloomberg, Capitalight Research.



* Terbium Oxide, April 6, 2022: US$2,080/kg.
+ Dysprosium Oxide, April 6, 2022: US$413/kg.
Source: Asian Metals Inc., Bloomberg, Capitalight Research.

Table 1

Critical Metals - Price Trends

	2018 Annual	2019 Annual	2020 Annual	2021 Q1	2021 Q2	2021 Q3	2021 Q4	2022 February	2022 March	Latest April 6
Copper										
LME Copper Official Cash Settlement[1] (US$/lb)	2.96	2.72	2.80	3.85	4.40	4.25	4.40	4.51	4.64	4.70
Nickel										
LME Nickel Official Cash Settlement[2] (US$/lb)	5.95	6.31	6.25	7.99	7.87	8.68	8.99	10.97	14.45	15.24
SHFE Nickel, Generic First Contract[2] (CNY/tonne)	102,916	110,746	109,054	131,120	128,570	143,708	147,198	176,134	218,527	221,200
China Nickel Sulphate EXW > 22% Ni, 0.05% Co[2] (CNY/tonne)	28,411	30,487	29,874	35,766	35,714	39,276	39,720	41,313	43,924	50,250
Lithium										
Lithium Carbonate, CIF Asia ≥ 99.2% Li_2CO_3[3] (US$/tonne)	17,063	11,675	8,421	9,083	11,000	13,333	19,833	44,500	47,500	47,500 *(Data to March 31)*
Lithium Carbonate, CIF North America ≥ 99.0% Li_2CO_3[3] (US$/tonne)	14,833	11,215	7,746	8,083	9,750	12,375	17,000	40,000	45,000	45,000 *(to March 31)*
Lithium Hydroxide, FOB North America ≥ 55.0% LiOH[3] (US$/tonne)	16,771	13,521	10,629	10,458	11,750	14,333	19,333	38,875	44,875	44,875 *(to March 31)*
Spodumene Concentrate, FOB Australia 6% Li_2O, Lithium Feedstock[3] (US$/tonne)	886	595	406	472	579	1,048	1,492	2,340	3,263	3,263 *(to March 31)*
Rare Earth Elements										
China Neodymium Oxide 99%, FOB[4] (US$/tonne)	49,918	44,655	48,757	95,147	83,222	92,267	123,356	180,363	179,239	156,500
China Neodymium Metal 99% FOB[4] (US$/kilogram)	64	57	62	116	102	115	153	219	216	187
China Praseodymium Oxide 99%, FOB[4] (US$/tonne)	63,627	54,024	45,725	67,818	81,665	94,484	124,540	159,875	168,130	156,000
China Praseodymium Metal 99% FOB[4] (US$/kilogram)	114	103	91	96	104	110	139	180	193	193
China Dysprosium Oxide 99%, FOB[4] (US$/kilogram)	177	234	259	384	398	400	447	485	470	413
China Dysprosium Metal 99% FOB[4] (US$/kilogram)	262	307	341	497	516	516	554	592	579	561
China Terbium Oxide 99.9% FOB[4] (US$/kilogram)	455	503	664	1,382	1,121	1,213	1,600	2,293	2,275	2,080
China Terbium Metal 99% FOB[4] (US$/kilogram)	604	655	849	1753	1,430	1,534	2,038	2,876	2,890	2,613

Sources:
1) LME, Bloomberg. 2) LME, SHFE, Asian Metal Inc., Bloomberg. 3) BMI, Bloomberg. 4) Asian Metal Inc., Bloomberg.

Table 2

Copper Price Outlook - Annual Averages

	pre-pandemic 2018	2019	2020	2021A	2022F	2023F	…	Long Term (2025+)
	2.96	2.72	2.80	4.23	4.52	4.25		5.50+

Copper Quarterly Averages

		20-1	20-2	20-3	20-4	21-1	21-2	21-3	21-4	22-1	22-2	22-3	22-4	23-1	23-2	23-3
		Actual														
		2.56	2.42	2.96	3.25	3.85	4.40	4.25	4.40	4.53						
Sensitivities	High										4.90	4.80	4.70	4.70	4.70	4.60
	Base										**4.70**	**4.51**	**4.35**	**4.25**	**4.25**	4.20
	Low										4.40	4.10	4.00	3.80	3.80	3.80
Probability	High										0.15	0.15	0.20	0.20	0.20	0.20
	Base										0.75	0.75	0.60	0.60	0.60	0.60
	Low										0.10	0.10	0.20	0.20	0.20	0.20
Probability-Weighted Forecast											**4.70**	**4.51**	**4.35**	**4.25**	**4.25**	**4.20**

LME official cash settlement, US$/lb., quarterly averages.

Source: LME official cash settlement, US$/lb., quarterly averages.

Nickel Price Outlook - Annual Averages

	pre-pandemic 2018	2019	2020	2021A	2022F	2023F
	5.95	6.31	6.25	8.38	13.59	9.50

Nickel Quarterly Averages

		20-1	20-2	20-3	20-4	21-1	21-2	21-3	21-4	22-1	22-2	22-3	22-4	23-1	23-2	23-3
		Actual														
		5.77	5.53	6.46	7.23	7.99	7.87	8.68	8.99	11.85						
Sensitivities	High										21.00	17.00	15.00	12.00	11.50	11.50
	Base										**16.50**	**14.00**	**12.00**	**10.00**	**9.50**	9.50
	Low										12.00	11.00	9.00	8.00	7.50	7.50
Probability	High										0.20	0.20	0.20	0.20	0.20	0.20
	Base										0.60	0.60	0.60	0.60	0.60	0.60
	Low										0.20	0.20	0.20	0.20	0.20	0.20
Probability-Weighted Forecast											**16.50**	**14.00**	**12.00**	**10.00**	**9.50**	**9.50**

LME official cash settlement, US$/lb., quarterly averages.

Source: LME official cash settlement, US$/lb., quarterly averages.

Note: The LME nickel price forecast has been revised up significantly due to the logistical challenges facing Russian supplies and the recent short-covering ‘squeeze’ on the LME. Nickel prices are intrinsically volatile. The outlook over the balance of 2022 will depend upon the length of the conflict in Ukraine, the performance of the world economy (affecting stainless steel and EV demand) and the timing & extent of new supply from Indonesia. Prices have steadied on the LME, but trading volume is low.

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