SAiT UYSAL

Critical Raw Materials Bulletin

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Content

Critical Raw Materials

Common and most important Critical Raw Materials

Critical Raw Materials		
1	Indium	Common on all lists
2	Cobalt	
3	Lithium	
4	REE	
5	Titanium	
6	Vanadium	
7	Antimony	Found on at least 7 out of 8 lists
8	Gallium	
9	Germanium	
10	Graphite	
11	Chrome	
12	Magnesium	
13	Manganese	
14	Niobium	
15	PGM	
16	Tantalum	
17	Tungsten	

Different studies have been undertaken by different names as Critical, Strategic, Technologic, etc for some of the raw materials. Common parts of these studies are; those raw materials are important for that country's economy, technology, or defense industry. Published lists related to critical materials are;

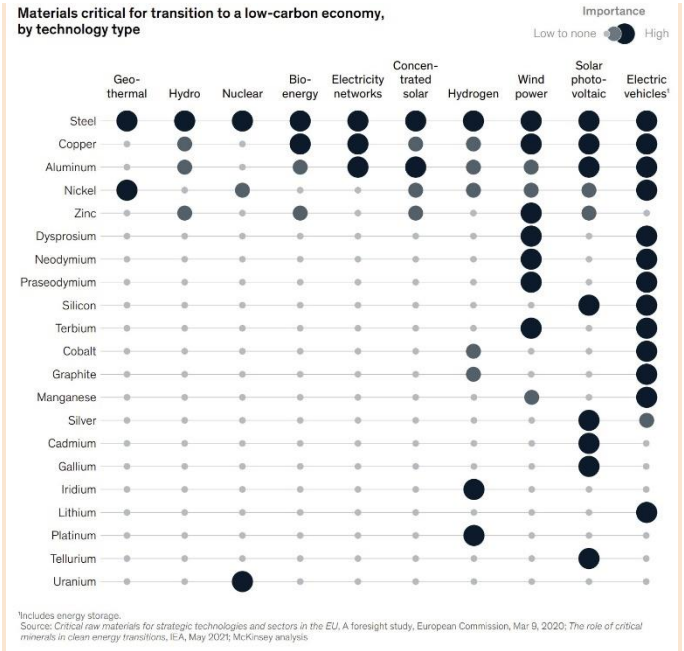
- Australian List
- USA (USGS) List
- European Union List
- Japan List
- Canadian List
- Korean List
- BGS Risk List
- World Bank "Minerals for climate action" Report

Each list consists of different raw materials but indium, cobalt, lithium, rare earth elements, titanium, and vanadium are the common ones that exist on all lists. Besides these 6 raw materials, antimony, gallium, germanium, graphite, chrome, magnesium, manganese, niobium, platinum group metals, tantalum and tungsten are listed at list 7 out of 8 lists.

The raw-materials challenge[1]

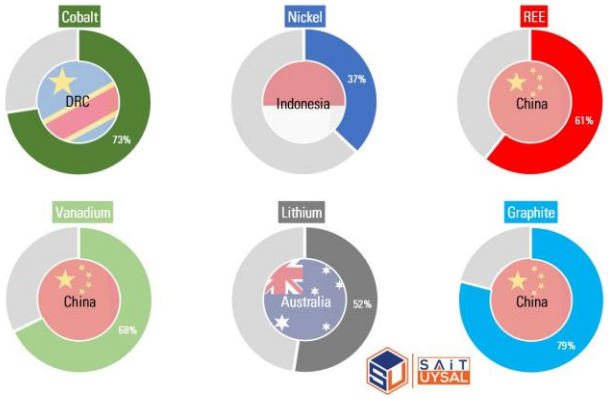
The transition to a net-zero economy will be metal-intensive. As the move toward cleaner technologies progresses, the metals and mining sector will be put to the test: it will need to provide the vast quantities of raw materials required for the energy transition. Raw materials will be at the center of decarbonization efforts and electrification of the economy as we move from fossil fuels to wind and solar power generation, battery- and fuel-cell-based electric vehicles (EVs), and hydrogen production.

Requirements for additional supply will come not only from relatively large-volume raw materials—for example, copper for electrification and nickel for battery EVs,—but also from relatively niche commodities, such as lithium and cobalt for batteries, tellurium for solar panels, and neodymium for the permanent magnets used both in wind power generation and EVs.



Top Critical Minerals Producing Countries[2]

USGS published 2022 Mineral Commodity Summaries. Based on the USGS report, 73% of the Cobalt is mined in the DR of Congo, 37% of Nickel in Indonesia, 52% of Lithium in Australia, 61% of REE, 68% of Vanadium, and 79% of graphite mined in China.



Russia's invasion of Ukraine to impact raw materials[3]

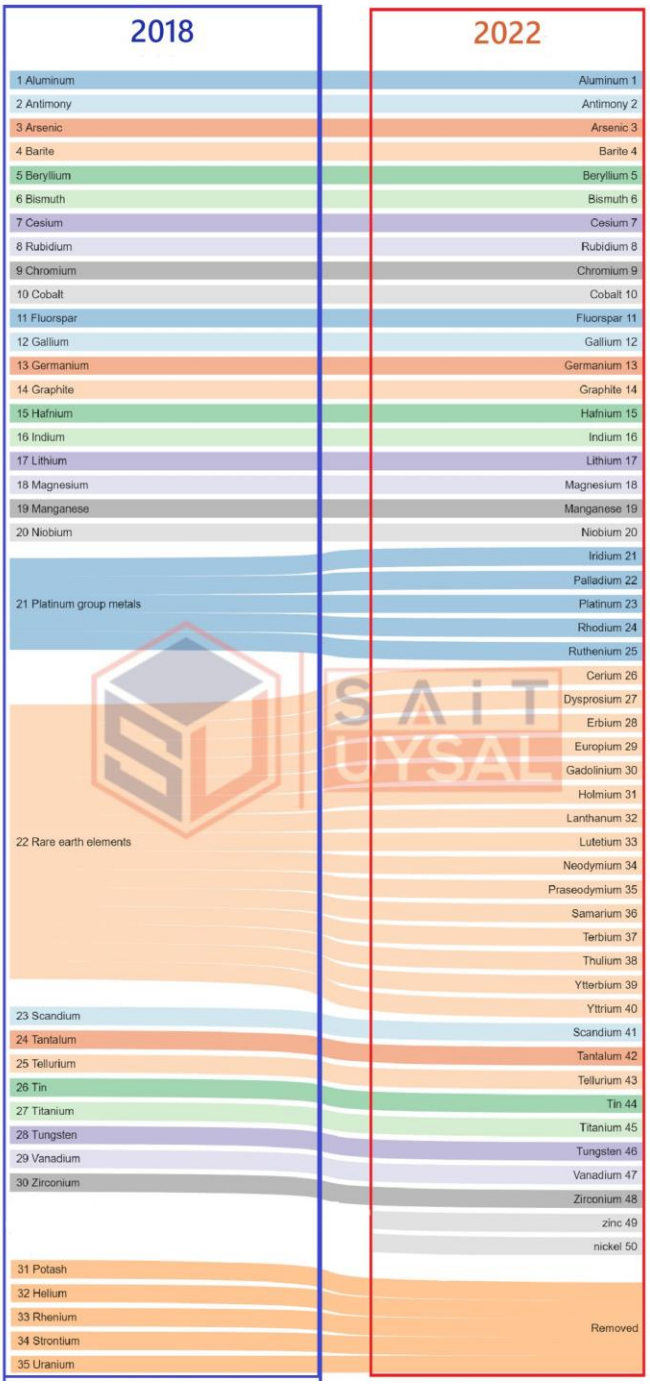
Russia's invasion of Ukraine is expected to have a significant impact on global aluminum supply and prices, as well as nickel and copper. Russia-based Rusal is one of the largest aluminum producers across the world and plays a vital role in global supplies. Russia's primary nickel output of 146,000 mt in 2021 accounted for 5% of the world's total, and if the conflict worsens, this could weigh on the global nickel supply.

The biggest impact from the Russia-Ukraine crisis, however, could be worsening energy shortage, which other than impacting Russia's metal capacity may also hit nonferrous metals output capacity in Europe. This could hit both Russian and European metal output capacity, as higher natural gas prices would hike power costs and negatively impact production.

USGS 2022 Critical Mineral Lists[4]

USGS has released a new list of 50 mineral commodities critical to the U.S. economy and national security. The new list contains 15 more commodities compared to the 2018 list. Much of the increase in the new list is the result of splitting the rare earth elements and platinum group elements into individual entries. The 2022 list of critical minerals adds nickel and zinc to the list while removing helium, potash, rhenium, uranium, and strontium.

USGS 2022 Critical Minerals List vs 2018



$10tn of critical raw material needs[5]

KoBold Metals, a start-up backed by a coalition of billionaires including Bill Gates and Jeff Bezos, has raised $192.5 million in its latest financing round. The Silicon Valley-based firm, founded in November 2018, plans to use artificial intelligence to create a "Google Maps" of the Earth's crust, with a special focus on finding cobalt deposits. It collects and analyzes multiple streams of data

— from old drilling results to satellite imagery — to better understand where new deposits might be found.

KoBold Metals estimates the world needs to mine more than $10 trillion of key metals to meet the expected demand for electric vehicles (EVs), adding that traditional mining companies are likely to turn to artificial intelligence (AI) tools to help them along their quest.

Pentagon to boost critical minerals stockpiles[6]

The Pentagon plans to boost the stockpile of rare earth minerals, cobalt and lithium it manages for the U.S. government to reduce its long-term dependence on China. An agreement between the Departments of State, Energy, and Defense was signed in early February and covers the select materials as well as large batteries used in the electrical grid.

The memo also directs inter-agency coordination of an unclassified stockpile for relevant non-fuel minerals necessary for a transition to using more clean technologies. The agreement enables other U.S. agencies, like the Department of Energy, to coordinate on and draw from these stockpiles.

From fossil fuel waste to the rare materials for tech[7]

A new initiative spearheaded by the US Department of Energy is looking for ways to extract critical minerals and rare earth elements from fossil fuel waste. The Energy Department plans to build the nation's first large facility to extract critical minerals like nickel and cobalt from waste like coal ash. Those metals could then be used in components for renewable-energy batteries, cell phones, and electric vehicles, among other technologies.

The project will primarily focus on extracting minerals from coal waste. However, byproducts from oil and gas drilling -- such as the water used to extract the fuel -- can also be good sources of minerals like lithium.

Turkey Coal Ashes for Critical Mineral Potential

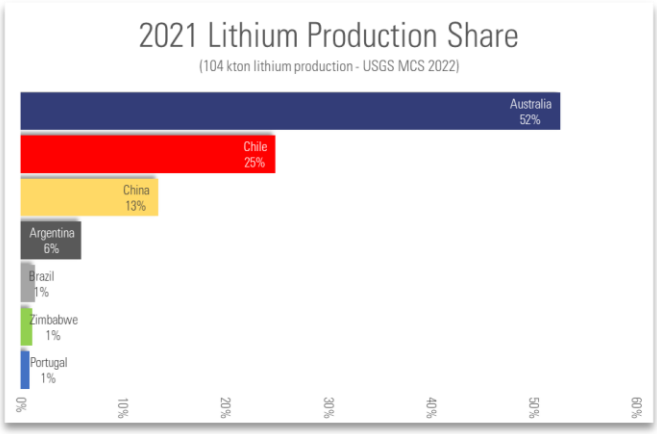
Asphaltite coals are the most important resources for vanadium, molybdenum, and nickel. Overall deposits in Southeast Anatolia have more than 80 million tonnes of the reserve. Vanadium content is quite high in coal as high as % 0,5 V, when it is burned and turned into the ashes V2O5 content would increase over %1. It is obvious that coal ashes from asphaltites are a serious critical minerals source and sustainable critical mineral production could be established from this source.

Trace element contents of Asphaltite in Southeast Anatolian Region[8]

Deposit Name	Reserve (Million Tonnes)	Ni %	Mo %	V %
Avgamasya	22,3	0,32	0,18	0,30
Milli	6,5	0,30	0,23	0,27
Karatepe	6	0,49	0,27	0,53
Nivekara	2	0,22	0,19	0,37
Segürük	1,1	0,34	0,28	0,21
Harbul	28,8	0,25	0,15	0,12
Üçkardeşler	20,3	0,28	0,33	0,46

Lithium

2021 Lithium Production



Based on USGS - 2022 Mineral Commodity Summaries, 104 ktons of lithium were produced in 2021. Australia produced more than half of the lithium in the world. (It converts to more than 530 kton Lithium Carbonate)

Risks in Lithium Mining and Supply[9]

Chip shortages were a factor in last year's supply chain crisis in auto manufacturing. Shortages in lithium could mean that EV batteries are next. Currently, more than 80% of the raw materials needed EV batteries come from China, which also controls nearly all of the worldwide processing facilities for key critical minerals, including lithium.

But the lion's share of this lithium is mined elsewhere, and much of the world's resources are concentrated in Latin America. Bolivia, Chile, Argentina, Peru, and Mexico together make up about two-thirds of global lithium reserves, with most of it concentrated in Chile, Argentina, and Bolivia. But the mix of rising resource-based nationalism and inadequate infrastructure in many of these

countries may make it tougher to move quickly on the lithium projects in these countries than once believed.

China already controls substantial lithium assets in South America, and its businesses have made roughly $4.5 billion in lithium investments over the last three years in South America and Mexico.

Possible Lithium deficit[10]

A lack of investment in a new supply of lithium could generate a structural deficit throughout the coming decade, at a time when demand is soaring, according to supply and demand data running to 2030. EV sales accounted for almost 20% of new car sales in China and over 25% in the EU in recent months, forcing lithium suppliers to try accelerating expansion and new projects.

"Unfortunately, battery capacity can be built much faster than lithium projects," said Joe Lowry, president of consulting firm Global Lithium. And added, "The lack of investment in lithium capacity over the past five years will extend the supply shortage." Platts 2030 supply and demand estimates also show that supply is unlikely to meet the projected 2 million mt level of demand by the end of the decade.

The record price surge in Lithium[11]

Surging electric vehicle sales have sent lithium prices skyrocketing to record levels amid "panic buying" by the world's battery manufacturers. Prices for lithium salts, lithium carbonate, and lithium hydroxide, rose by between 400-500 percent last year, and show no signs of slowing down as supplies struggle to keep up with demand.

Battery-grade lithium carbonate was trading at $US9600 per tonne in January 2021, according to S&P Global Platts, but by the beginning of February 2022 spot prices were US$59,600.

Lithium-rich spodumene concentrate, an unrefined ore mined in Australia, is up roughly 480 percent since the start of last year. Spodumene typically contains about 6 percent lithium and is shipped overseas for processing, usually in China. Australian spodumene concentrate was fetching US$2400 per tonne in January, up from US$1650 per tonne in December

Lithium Chemicals Plant in Kingdom of Saudi Arabia[12]

EV Metals Arabia has signed a Front-End Engineering Design Agreement (FEED) with Mustang and Faisal Jameel Al Hejailan Consulting Engineering Company, a subsidiary of Wood Plc, for the development of the first two processing trains for the production of lithium hydroxide monohydrate (LHM) in the Lithium Chemicals Plant of the Battery Chemicals Complex in the Kingdom of Saudi Arabia.

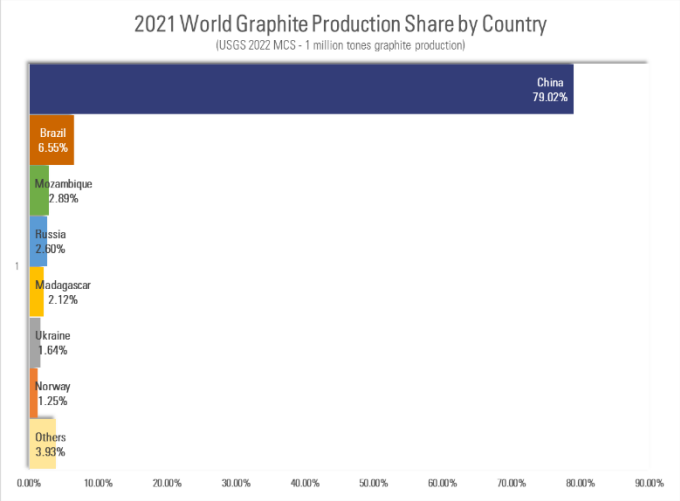
The first two trains of LHM will bring in an initial investment of US$800 million. They will produce 50,000 tpa of LHM for Original Equipment Manufacturers, principally electric vehicle manufacturers and battery cell manufacturers. The Lithium Chemicals Plant is designed to process spodumene concentrate containing 6% lithium oxide (SC6) imported from upstream spodumene concentrators in Western Australia.

EVM has identified a critical gap in supply chains for electric vehicles manufacturers and battery cell manufacturers which EVM is addressing through the development of a Lithium Chemicals Plant, a Nickel Chemicals Plant and a Cathode Active Materials Plant based on the upstream integration and development of supply chains for long term supplies of lithium, nickel, cobalt and other metals from Western Australia while the Saudi supply chain is being developed.

Graphite

2021 World Graphite Production

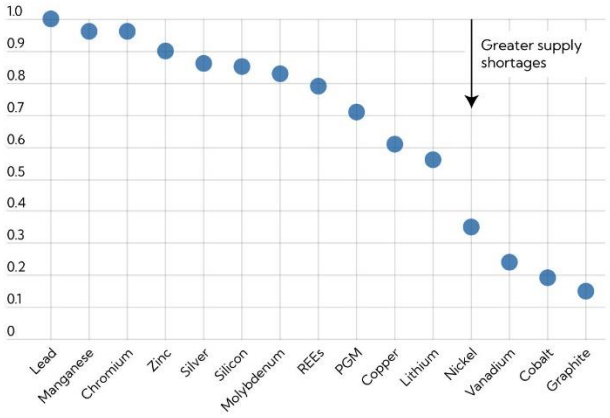
USGS has reported 2021 world graphite production of a bit over 1 million tonnes. With roughly 800 thousand tones production China is by far the biggest natural graphite producer.



Graphite will face the greatest supply shortages[13]

The clean energy transition needed to avoid the worst effects of climate change could unleash unprecedented metals demand in coming decades, requiring as much as 3 billion tons. Replacing fossil fuels with low-carbon technologies would require an eightfold increase in renewable energy investments and cause a strong increase in demand for metals. Increasing demand and supply constraints will create supply shortages and the greatest supply shortages will be seen on graphite.

Metals in a net-zero scenario
Current production rates of some important metals, including copper, are likely to be inadequate to satisfy future demand.
(supply/demand ratio, energy and non-energy demand coverage)



Source: International Energy Agency, US Geological Survey 2021, and IMF staff calculations.
Note: PGM = Platinum-group metals. REEs = Rare-earth elements. Supply-demand ratio is the ratio of supply to demand. Supply = cumulative production volume for 2021-2050, fixed at 2020 output level. Demand = total metal demand 2021-2050 for renewable energy and other uses.

IMF

Graphite supply concern[14]

By 2030, graphite demand is expected to be triple the current global production of material, Tirupati CEO Shishir Poddar told S&P Global Platts. He added "Globally, we produce 1.3-1.4 million mt/year, but most of that goes to applications other than energy storage (10-15%). By 2030, it is estimated that another 4-5 million mt/year of graphite will be needed. Conservatively, around 3.5 million mt/year."

Most production is currently concentrated in China, although several companies are exploring, developing, and producing in eastern Africa, as well as Scandinavia and the Americas. The issue with graphite supply is not a shortage of resources, but rather of mining projects.

Mined graphite is usually processed to 95-96% carbon purity on-site, but must be processed further elsewhere into a spherical, coated 99.95% purity product to be used in battery cells. Almost all these facilities are concentrated in China, even with the development of mines elsewhere. To ensure enough supply meets demand, more investment is needed in graphite mining and processing.

8.5% CAGR estimated for the Graphite market[15]

The global graphite market is forecast to register continuing growth through 2025, boosted by the growth of the electric vehicle (EV) sector. According to a research report by Researchandmarket.com, the global graphite market is expected to be worth US$26.8B by 2025, up from US$16.4B in 2017, registering a CAGR of 8.5% during the forecast years. S&P Global recently suggested that the world's reliance on China for graphite has emerged as a major obstacle to EV makers' production schedules amid trade disputes and soaring demand.

Comment: There are different estimations on graphite and its market size. The estimated US$26.8 Billion market size should be understood as the total market including natural and synthetic graphite. The synthetic graphite market has the lion's share on this, as the materials like Graphite Electrodes are covered under the synthetic graphite.

Graphite demand to rising [16]

Fastmarkets' graphite supply-demand balance has been updated based on its upwardly revised expectations for growth from the electric vehicle (EV) battery sector. Its forecasts for EV battery production indicate demand for graphite from the battery sector will rise by 36% to approximately 594,000 tonnes in 2022 from around 437,000 tonnes in 2021. It is also expected to see shipping issues impact graphite availability, prompting supply shortfalls and higher prices well into the first half of 2022.

Nickel

How high can the nickel price go?[17]

Nickel is a key component of ternary cells that are lithium-ion cells that utilize a cathode made out of three major metals. Nickel is always one of these metals, and it may be joined by various weightings of cobalt, high purity manganese, and aluminum. Tesla's NCA (Nickel-Cobalt-Aluminium) cell was an early-mover in this space, but the focus in recent years has shifted more to NCM (Nickel-Cobalt-Manganese) formulations.

The major problem in the nickel world in recent years is that the world is running out of high-quality nickel sulfide discoveries, and the largest chunk of new nickel projects is based on laterite orebodies, which either require HPAL or are not high enough grade to produce Class 1 nickel which is required for lithium battery cathode.

There has been a pretty clear price/inventory relationship for nickel over time. Because of increasing demand, supply, and quality problems nickel exchange inventories could continue to fall. If nickel exchange inventories continue to fall then prices should

move materially higher, and fast. It's not unrealistic that battery-grade nickel prices could double from current levels.

> *It's not unrealistic that battery-grade nickel prices could double from current levels.*

Nickel price hits decade high[18]

Nickel rose to $25,000 a ton for the first time since 2011, extending a rally driven by dwindling global inventories and concerns that Ukraine tensions could disrupt supplies from key producer Russia.

Nickel is "one of the main commodities linked to Russia given their importance to supply," said Ryan McKay, commodity strategist at TD Securities. "So the latest events keep supply risk for the metal particularly high, especially as inventories are already at very low levels." Nickel inventories on the LME have fallen to the lowest since 2019 with a steep backwardation — when cash prices are much higher than futures — pointing to very tight fundamentals. Stockpiles continued to fall

Jump in the deployment of high nickel battery[19]

2021 saw a record 286.2 GWh deployed onto roads in the batteries of new passenger EVs globally, a massive 113% leap over 2020 as global EV sales jumped 83% over the same period, according to Adamas Intelligence. Over 98% of all watt-hours deployed in 2021 went into plug-in electric vehicles (i.e., BEVs and PHEVs) alone.

In 2021, 54% of battery capacity deployed onto roads globally in new plug-in electric vehicles was powered by "high nickel" cathode chemistries (i.e., NCM 6-, 7-, 8-series, NCA, NCMA), 26% by "low nickel" cathodes (i.e., NCM 5-series and lower) and 20% by "no nickel" cathodes (i.e., primarily LFP).

Regionally, deployment of high nickel chemistries was most prevalent in the Americas on the back of Tesla, VW, Ford, Hyundai, and others, while the deployment of no nickel cells was most prevalent in the Asia Pacific, and particularly China, on the back of Tesla, BYD, SGMW, Great Wall and a long list of others.

> *" I'd just like to re-emphasize, any mining companies out there, please mine more nickel. Wherever you are in the world, please mine more nickel and...go for efficiency, obviously environmentally-friendly nickel mining at high volume. Tesla will give you a giant contract for a long period if you mine nickel efficiently and in an environmentally sensitive way."*[20]
>
> *Elon Musk*

$4.3 billion in capital expenditure for Nickel[21]

Sumitomo Metal Mining Co Ltd (SMM) will triple its capital expenditure over the next three years to boost its output capacity of nickel and cathode materials used in batteries. The Japanese miner and smelter plan to spend 494 billion yen ($4.3 billion) in capital expenditure, excluding investment and lending, in the next three years, up from 164 billion yen spent last three years.

SMM plans to boost its monthly output capacity of cathode materials for rechargeable batteries used in electric vehicles to 10,000 tonnes by end-March 2028 and 15,000 tonnes by end-March 2031 from nearly 5,000 tonnes now to meet burgeoning demand. SMM supplies the nickel-cobalt-aluminum (NCA) cathode materials used in Panasonic Corp's lithium-ion battery that powers Tesla Inc's Model 3 and Model X cars.

Boehmite & Alumina

Uses of high purity alumina[22]

There are two significant consumers of high purity alumina, lithium-ion batteries, and synthetic sapphire. Batteries require a purity of 99.99, whilst sapphire manufacturers require solid pucks of 99.999% (5N).

In batteries, the HPA is used to coat the separator between the anode and cathode to improve its thermal capacity, thereby reducing the risk of thermal runaway and the well-publicized, but rare, fires in mobile phones and electric vehicles. There is also research into using HPA to coat the anode and/or cathode to provide stability to the battery, reduce the use of cobalt in the battery chemistry and decrease the losses of capacity commonly encountered in the initial charge-discharge cycle.

The main markets for synthetic sapphire are for LED and semiconductor substrates. The unique properties of sapphire make it ideal for scratchproof windows and lenses on high-end electronic devices and optical components.

The application of Boehmite as a coating material is increasing

Inorganic coating with boehmite and alumina has become the mainstream coating for Lithium battery separators. Alumina has been widely used in the coating of lithium-ion battery separators in the early stage. But the proportion of boehmite in the application of inorganic coating materials is increasing. Compared with alumina, the hardness of boehmite is low, the particle size distribution is narrower, the specific surface area is controllable, the specific gravity is low, which reduces the coating cost; the water absorption is weaker, the coating flatness of boehmite is

high, the internal resistance is small, the energy consumption is low, and the production process is more environmentally friendly[23].

Global demand for boehmite by 2025 will be 220,000 tonnes, the unit price will be US$2,428 per tonne, the market space will be US$528 million, and the CAGR over the past five years reached 55%[24].

(Credit to Brendan Jephcott)

Rare Earths

Demand for scandium is set to increase more than 2.5 times[25]

Key raw materials needed for most types of clean hydrogen production could become scarce and much more expensive, Germany's Federal Institute for Geosciences and Natural Resources (BGR), has warned. The greatest supply risks are expected in **iridium** and **scandium** – due to the very high demand on the raw material markets from water electrolysis.

> *It is expected that by 2040, demand for scandium is set to increase more than two and a half times and demand for iridium will even soar five-fold compared to 2018 production.*

More than 75% of today's scandium is produced in China, followed by Russia as far-off second, totaling up to an estimated 14-16 tonnes of annual production. For 2040 demand in electrolyzers, 24 tonnes of annual demand are predicted.

Rare Earth Elements Becoming Increasingly Expensive[26]

The Chinese government announced on Feb. 16 that the Chinese price index of 21 rare-earth elements (REE) oxides and products are at an all-time high of 426.75 this week. The figure was about 213 a year ago and 340 on Feb. 4.

According to market sources, the average spot price of neodymium praseodymium oxides reached 1.1 million yuan (US$174,000) per ton on Feb. 16. The price of the oxide for use in electric vehicle batteries and so on surged 135 percent in just one year. China's use of REEs is increasing rapidly, led by wind turbine suppliers and new energy vehicle manufacturers.

NdPr oxide would be in short supply[27]

The first batch of rare earth mining and smelting separation quotas for 2022 will increase by 20% year-on-year compared with 2021. Of which, LREE mining quotas are 89,310 tonnes, an increase of 23.2% year-on-year, and the HREE mining quotas are 11,490 tonnes, which is flat year-on-year. It is estimated that the overall domestic rare earth mining quotas in 2022 will be about 200,000 tonnes or more, an increase of about 20% year on year.

The global supply of NdPr oxide is expected to be in short supply of 12,000 tonnes and 19,000 tonnes respectively in 2022-2023. The rapid development of global new energy vehicles, wind power, and other fields has driven the demand for NdFeB permanent magnets to increase.

Vanadium

Why vanadium redox flow batteries will be the future of grid-scale energy storage[28]

To get the target of net zero by 2050 renewable energy sources will play a crucial role. The demand for renewable energy continues to grow, the need for solutions that can regulate the flow and frequency of electricity across the grid intensifies and Vanadium Redox Flow Batteries is one of the solutions for this.

The vanadium redox flow battery (VRFB) was invented at University New South Wales (UNSW) in the late 1980s and has recently emerged as an excellent candidate for utility-scale energy storage.

Energy is stored in a liquid vanadium electrolyte and pumped through a membrane to generate electricity. Vanadium ions are simply moved between oxidation states as batteries are charged and discharged, with no degradation over tens of thousands of charging cycles.

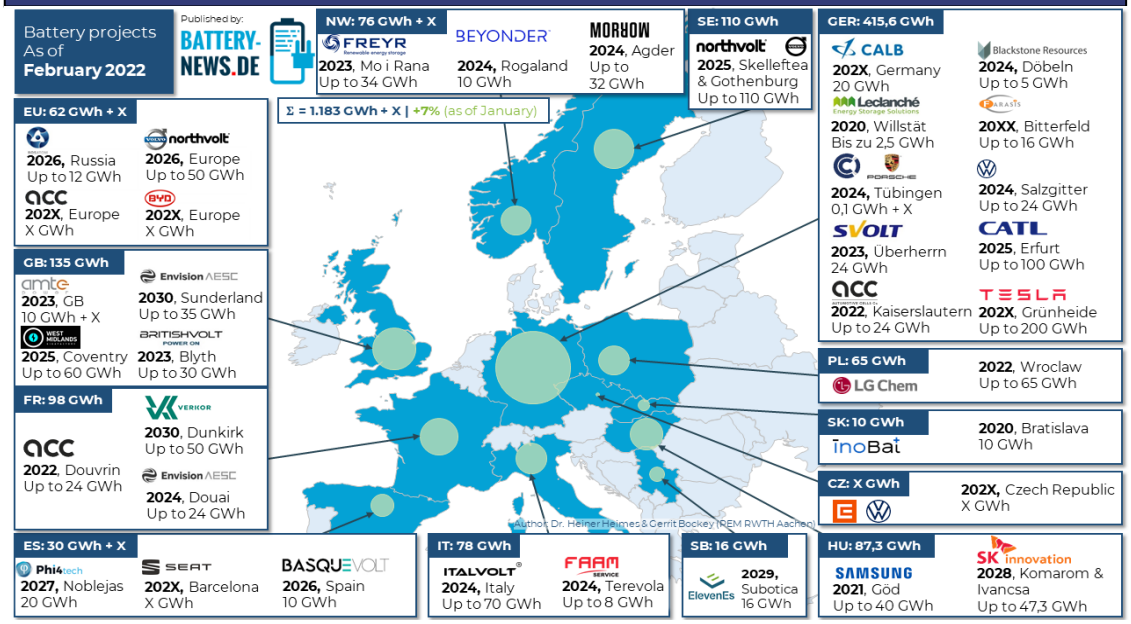
Vanadium redox flow batteries are a safe and effective choice for longer duration storage over 4 hours where energy is discharged every day, whilst li-ion batteries are more suited to store up to 4 hours of energy 50 times per year.

VRFBs are cost-effective, recyclable, and non-flammable, eliminating the risk of dangerous events like the Tesla lithium-ion battery fire. As demand for renewable energy grows, demand for VRFBs will grow so the demand for vanadium will grow.

Vanadium demand could almost triple in 2022[29]

Forecasts from Argus Media, the global vanadium redox flow battery (VRFB) sector could rise to at least 9,100t of vanadium pentoxide (V^2O^5) in 2022 from 3,640t last year. And the independent providers of energy and commodity price benchmarks are not alone in their predictions, commodity researcher Roskill says vanadium use in batteries is set to grow at an average of 20.7% per year from 2020 to 2029.

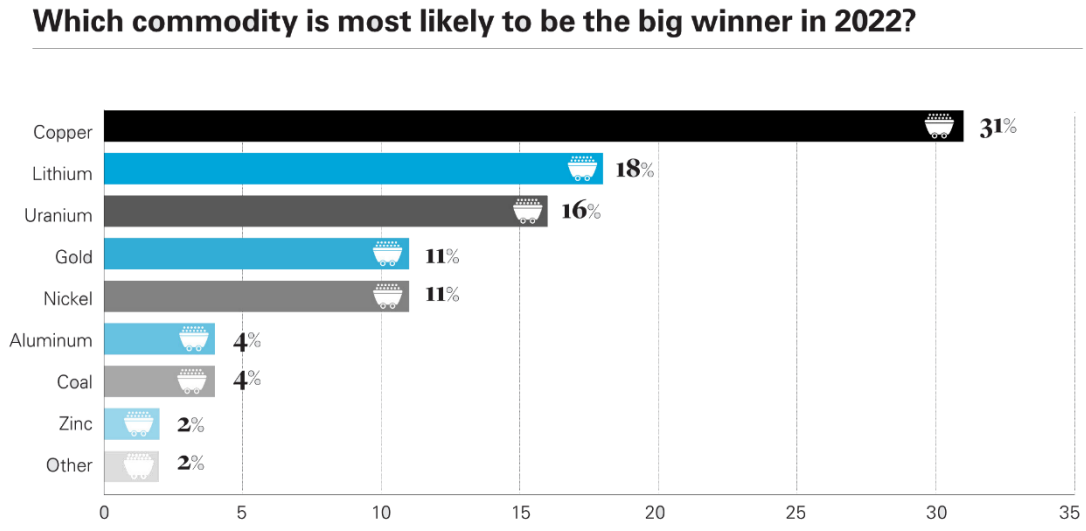
Lithium Battery investments in Europe



Source : battery-news.de

Above graphic shows the lithium battery investments in Europe. Planned capacity for Europe only is 1183 GWh and would probably increase. To look this capacity in critical materials perspective, just graphite

Chart of the Month



Source: White & Case 2022 Mining & Metals market sentiment survey

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