

Ziemba Insights

Critical Minerals Market Development

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How can liquid and transparent financial markets be created for lightly traded critical minerals?

From the 50+ minerals, 16 were selected

Commonality: Market size >= USD 1B, volatile prices, production not concentrated in countries where transparent global markets are not feasible		Trading volume		Market Depth		Geopolitical Factors		Applications: militarily and/or economically strategic	
METAL/MINERAL:	Existence on spot markets	Existence on derivatives markets	Annual trading volume	Annual market size >= USD 1B	Concentration of production by company	Concentration of production by country	Export/Import Restrictions		
Graphite	✓	✓							
Lithium	✓	✓							
Antimony	No	No	83,000 metric tons	USD 1.08 billion	Junan Nonferrous Metals Holding Group; Tongling Non-Ferrous Metals Group; Navitas Resources, United States Antimony Corporation	China accounted for 48% of global antimony mine production, while Tajikistan is the second largest producer; other world's leading antimony producing mine is in Russia.	China has placed export bans on antimony to the U.S. in retaliation for export controls put on Chinese zirconium oxide. The U.S. has threatened to impose 25% tariffs on China's antimony. China's threats of even more tariffs on China will only complicate things further.	Highly purified antimony is used in semiconductor technology to prepare the intermetallic compounds indium, aluminum, and gallium antimonide for diodes and infrared detectors. It is also a flame retardant and used in plastics, and is a key component of lead storage batteries for cars.	
Beryllium	No	No		USD 3.8 billion (but there are highly variant answers with some suggesting as low as USD 159.1 Million)		Junan Shukoushan Nonferrous Metals Group, Co. Ltd; Materion Beryllium Products Metallurgical Plant	The US produces 60% of global beryllium, followed by China, Mozambique and Brazil.	Exports are restricted and controlled by the US because of their strategic applications.	Used in military aircraft, nuclear weapons, missiles, semiconductors, and nuclear reactors.
Cobalt	Yes	Yes	200 metric tons	USD 16.96 billion	Glencore, CMOC Group, Freeport-McMoRan, BHP, Rio Tinto	The Democratic Republic of Congo produces 70% of global cobalt.	"Chinese firms had control over 62% of cobalt mining materials primarily used for cobalt chemical refining, 95% control of refined commercial-grade cobalt chemicals, 62% control of battery-grade cobalt hydroxide, 85% control of battery-grade cobalt sulfate, and 91% control of nickel-cobalt-manganese cathode materials."	Critical component in lithium-ion batteries needed for EVs and other green tech.	
Rhodium	Yes	No	NA	USD 2.44 billion	Lorain (South Africa), Ando American (U.K.), Russian Platinum (Russia), Alstria Resources (South Africa), Impala (South Africa)	South Africa (60% of the world supply) followed by Russia (19%)	No	Automotive Industry: The primary use of rhodium is in catalytic converters for automobiles, where it helps reduce nitrogen oxide emissions. This application is crucial for meeting stringent environmental standards.	
Vanadium	No	No	102,000 metric tons	USD 4.28 billion	EVRAZ KGOK (Russia), Bushveld Minerals (South Africa), Bango Resources (Brazil)	China is the largest producer of vanadium, accounting for about 68,000 metric tons in 2023, followed by Russia, South Africa, and Brazil.	No	Steel Industry and Military Applications: Over 85% of vanadium content is in steel products, where it is used to produce high-strength, low-alloy steels. It is also in construction, automotive, infrastructure, and military applications.	
Zirconium	No	No	1.4 million metric tons	USD 2.08 billion	Iuka Resources Limited (Australia), UAC Holdings plc, (UK) Eramet (France), Kenmare Resources PLC (Ireland), Rio Tinto (Australia, the UK)	Australia is the largest producer of zirconium, followed by South Africa and China.	Import and/or export controls by China, the US, and Canada	Nuclear reactors, structural material in naval systems, and thermal batteries	
Iridium	No	No	n/a		The iridium production market is relatively concentrated, with key players including: Lommin (U.K.), Anglo American (U.K.), Russian Platinum (Russia), Impala (South Africa)	South Africa is the leading producer of iridium, accounting for a significant portion of global production. Other notable producers include Russia, Canada, and the United States.	No	space exploration, hydrogen production (electrolysis), high-performance electronics, and medical implants.	
Praseodymium (Rare Earth)	Yes	Yes	n/a		https://www.businessresearchinsights.com/market-reports/iridium-market-100329	The praseodymium production market is	No	Praseodymium: smart phones, aircraft engines, nuclear reactors	
					https://www.businessresearchinsights.com/market-reports/praseodymium-market-100329	China is the dominant producer of praseodymium, accounting for a significant portion of global production.	No	https://strategicmetalsinvest.com/praseodymium-rare-earths/	

- Market Size
- Existence on spot markets or Existence of a publicly available spot price
- Presence on Derivative Markets
- Concentration of supply and demand
- Trade restrictions
- Important applications

Graphical Summary of Findings

Degree of Readiness for Financialization

Not ready

Have potential

Ripe

Rhodium

Antimony

Graphite

Tantalum

Beryllium

Vanadium

Iridium

Zirconium

Rare Earth Minerals

Gallium

(Neodymium,

Germanium

Praseodymium, and

Gadolinium)

Heat map

Category	Minerals	Market Size	Physical production volume	Production concentration by company	Production concentration by country	Demand concentration by country	Trade Restrictions
Recently Financialized	Lithium	High	High	High	Medium	Medium	High
Ripe for Financialization	Graphite	Medium	Medium	High	High	High	High
	Vanadium	Medium	Medium	High	High	High	High
Potential for Financialization	Antimony	Medium	Medium	Medium	Medium	Medium	High
	Beryllium	Medium	Medium	High	High	High	High
	Zirconium	Medium	Medium	Medium	Medium	Medium	High
	Gallium	Medium	Medium	High	Medium	Medium	High
	Germanium	Medium	Medium	High	Medium	Medium	High
Not Ready for Financialization	Rhodium	Medium	Medium	High	Medium	Medium	Medium
	Tantalum	Medium	Medium	Medium	Medium	Medium	Medium
	Iridium	Medium	Medium	Medium	(N/A)	Medium	Medium
	Rare Earth Minerals (Neodymium)	Medium	Medium	High	High	Medium	Medium
	Rare Earth Minerals (Praseodymium)	Medium	Medium	High	High	Medium	Medium
	Rare Earth Minerals (Gadolinium)	Medium	Medium	High	Medium	Medium	Medium

Buckets:

1. Market size
 - a. Small Market (USD 1B – 5B)
 - b. Medium Market (USD 5B – 15B)
 - c. Large Market (USD 15B+)
2. Physical production volume (Metric Tons Annually)
 - a. Low Volume (<10,000 metric tons)
 - b. Medium Volume (10,000 – 500,000 metric tons)
 - c. High Volume (500,000+ metric tons)
3. Concentration of Production by Company
 - a. Low Concentration (No dominant producer, fragmented market, no company over 20%)
 - b. Moderately Concentrated (4–6 companies hold ~30–50% market share)
 - c. Highly Concentrated (1–3 major producers dominate production, >50% market share)
4. Concentration of Production by Country
 - a. Lower Concentration (No single country produces >50%)
 - b. Highly Concentrated (1 country produces >50%)
5. Concentration of Demand by Country
 - a. Lower Concentration (No single country demands >50%)
 - b. Highly Concentrated (1 country demands >50%)
6. Trade Restrictions
 - a. Yes (Subject to Export/Import Restrictions, Bans, or Controls)
 - b. No (No Major Trade Restrictions Noted)

Typical process
of commodity
financialization

Typical Process of Commodity Financialization

Bilateral contracts

Agreements between a buyer and a supplier.

Spot markets

Trading physically available commodities according to current supply and demand.

Derivative markets

- Forwards
- Futures
- Options
- Swaps

Case study of
commodity
financialization
-Lithium

Lithium's Early Rise to Financialization

- **EV Demand Surge** (mid-2010s): Lithium demand rose with EV popularity in mid-2010s.
- **Price Bubbles** (2016): Low liquidity and high demand led to price surges.
- **Emergence of Spot Markets** (2017-19): For immediate delivery → reflects market demand more accurately and increasing transaction frequency
- **Investor Influx** (late 2020): Increased investor interest, driving up demand.
- **Market Legitimization**: Spot prices boosted investor confidence, paving the way for derivatives.

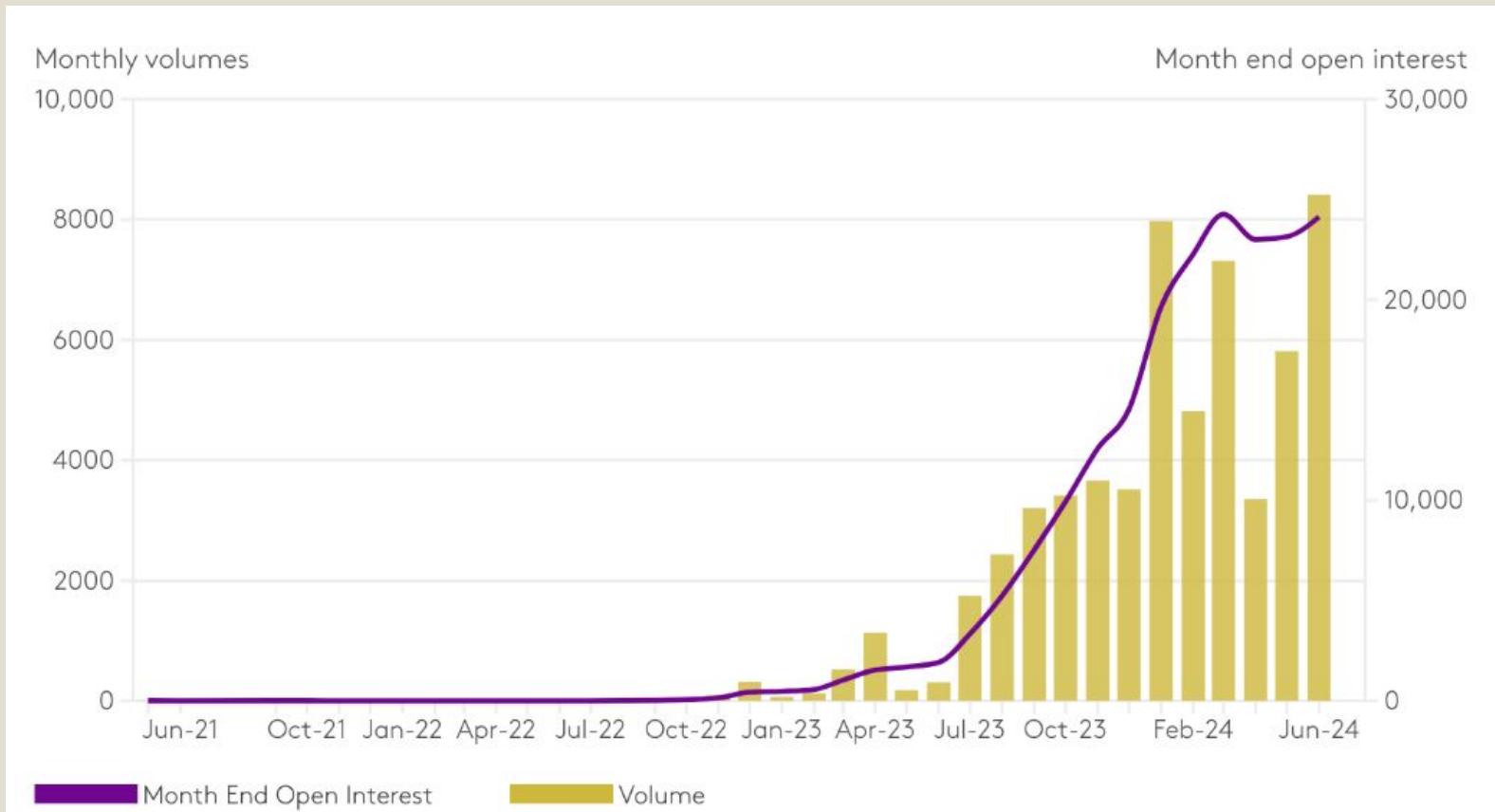
Creation of derivative markets

Steps in the Chicago Metals Exchange (CME)'s launch of the lithium derivatives market

1. **Market research and demand assessment:** CME and industry experts analyzed the growing need for a lithium futures market.
2. **Collaboration with industry actors:** CME worked with battery manufacturers, miners, traders, and analysts to design a contract that meets industry needs.
3. **Benchmark price selection:** Fastmarkets' lithium hydroxide price assessments
4. **Regulatory approval:** by regulatory bodies like the U.S. Commodity Futures Trading Commission (CFTC).
5. **Contract design and specifications:** Including contract size, pricing mechanism, expiration dates, and cash settlement method.
6. **Implementation and promotion:** CME launched lithium futures trading and promoted it to industry, traders, and investors.

Current state of the lithium futures market

Chart 1. CME lithium hydroxide volumes and open interest (Koralewski 2024; originally source: CME Group)



Similarities with the financialization of iron ore

- **Similar Transition:** Lithium's financialization mirrors iron ore's shift to spot-based, index-linked pricing.
 - Iron Ore Milestone: 2010 launch of futures trading on SGX boosted spot market growth with risk management tools.
 - Lithium Development: Financial instruments are increasingly integrated into lithium's supply chain.
- **Market Interaction:** High interaction between Chinese futures markets (DCE for iron ore, Guangzhou Futures Exchange for lithium) provide have **boosted liquidity** in global exchanges for both commodities.

Projections

Market Growth: Similar to iron ore, reaching 0.33x and 0.71x the physical market by 2025 and 2026. There is potential to exceed physical volumes due to increasing demand from EVs and energy storage (Koralewski, 2024).

Market Challenges: Low demand growth in Western markets, price volatility, storage limitations, and stringent ESG requirements, (Ouerghi, Stibbs, & Perry, 2024).

Future Opportunities: Emerging exchanges like Abaxx's lithium carbonate futures (March 2025) signal increasing liquidity and financialization, amid rising demand for battery metals (Reuters, 2025).



Minerals Ready for
financialization

Graphite – A Compound primed for Financialization

What is Graphite?

- An allotrope of carbon used in **electronics, automobiles, aerospace products, batteries, steelmaking, and lubricants.**
- **Rising strategic importance** – Growing demand for graphite in **various decarbonization technologies**, such as fuel cells and nuclear reactors. **LEDs, semiconductors, batteries, and military applications** are also of note.
 - a. This demand will be better served by a lower risk, high information trading through a financialized market.
- Extracted in natural form and manufactured synthetically from other allotropes of carbon.

Production & Market Dynamics

- **China dominates production and processing** of natural graphite (~75%), followed by **Madagascar, Mozambique, and Brazil.**
- **Estimated market size** of **\$7-17 billion (2024)**, with various estimates of **5-15% CAGR** until **2030-2035.**
- **Export restrictions** introduced by **China** to limit international supply.

Graphite – A compound primed for Financialization

Challenges to Financialization

- **Supply chain concentration** – Extraction of natural graphite is highly **concentrated in China**.
 - **Processing** of natural graphite is **highly centralized in China**.
 - Creation of **synthetic graphite** is also **highly centralized in China**.
- **Lack of open trading market** – Sales occur through **private offtake agreements** between miners and buyers to purchase graphite at an agreed price for a period of time.
- **Lack of market liquidity** – No major financial products (futures, options...), reducing liquidity, market security, mechanisms of reducing risk, or mechanisms for third parties buying and selling solely for the purpose of financial investment.

Graphite – A compound primed for Financialization

Suitability for Financialization

- Increasing investment in **domestic production and processing** is a key **geopolitical goal** for governments:
 - Aiming to reduce dependence on China
 - Support domestic manufacturing of advanced technology systems
 - Strengthen domestic supply chains.
- Graphite market is massive and possesses high growth projections, meaning there is **likely sufficient capital and political/regulatory will** to financialize the market.
- **Natural graphite price** already appears to show **high variability**, akin to iron ore pre-financialization.

Minerals with
potential for future
financialization:

Antimony – A Mineral with Emerging Financialization Potential

What is Antimony?

- A silver-grey metalloid used in **semiconductors, infrared detectors, batteries, flame retardants, and ceramics**
- Growing importance in **military, electronics, and energy storage applications**

Production & Market Dynamics

- **China dominates production (~48%)**, followed by **Tajikistan and Russia**
- Estimated market size: **\$1.08 billion (2024)**, projected to grow at **6.5% CAGR until 2032**
- Used in **semiconductor manufacturing**, leading to **export restrictions from China** to limit international supply

Antimony – A Mineral with Emerging Financialization Potential

Challenges to Financialization

- **Supply chain concentration** – Production is highly **dependent on China**,
- **Lack of liquidity** – No major financial products
- **No standardized pricing** – Market operates on **private contracts** rather than open exchanges

Potential for Financialization

- **Rising strategic importance** – Growing demand for antimony in **semiconductors, batteries, and military applications**
- **Government policies** – Increasing investment in **domestic supply chains** to reduce dependence on China
- **Industry innovation** – Research into **new battery chemistries and alternative applications** could boost demand
- **Pathway to market development** – If production is diversified and **pricing becomes standardized**, antimony could become more investable

Minerals not ready
for financialization

Rhodium – A Strategic Metal with Financialization Potential

What is Rhodium?

- A rare and valuable **Platinum Group Metal (PGM)**
- **Primary use (85%)** – Automobile catalytic converters for emissions reduction
- Also used in **electronics, chemical processing, and hydrogen fuel cells**

Production & Market Dynamics

- **80% of global supply comes from South Africa**, followed by Russia, Zimbabwe, Canada, and the U.S.
- **Extracted as a byproduct of platinum and palladium mining**, limiting direct production scalability
- Global market valued at **\$2B–\$4B USD**

Rhodium – A Strategic Metal with Financialization Potential

Challenges to Financialization

- Extreme price volatility
- Lack of transparent pricing
- Supply chain risks
- Low liquidity

Why Financialization is Unlikely

- No exchange-traded instruments (ETFs, futures) due to lack of transparency and liquidity
- Supply disruptions and geopolitical concentration discourage institutional investment
- Market remains **small, volatile, and opaque**, making it unsuitable for large-scale financialization

Recommendations

Ready for financialization

Financial Actors Recommendations

Strategic partnerships to foster market development within **Sectoral Hubs**

Establishment of trading infrastructure and financial derivatives on key commodity exchanges

1. Supply-side incentivization

Government Recommendations

2. Demand-side incentivization

3. Supply chain strengthening via data collection

4. Supply chain strengthening via stockpiling

Recommendations - Ready for financialization

Analytical basis for recommendations

- Graphite and Vanadium markets are similar to iron ore market pre-financialization.
 - Iron ore had rapidly rising demand, causing investment in supply development.
 - Caused high volatility in price.
 - Graphite and Vanadium are in a similar position as iron ore in the 2000s.
- Volatility is key to incentivizing financialization of graphite and vanadium.
 - Mainly bilateral agreements

Recommendations - Ready for financialization

Supply-side interventions

- Government-led Resource Discovery and Mine Development.
- Government-led Grant Funding and Concessional Loan Incentivization Schemes to incentivize private sector engagement.

Demand-side interventions

- Government-led basic scientific research in technologies likely to use graphite and vanadium.
- Commercialization of technologies using graphite and vanadium through Government, Business, Research, and Financial Actor collaboration within Sectoral Hubs.
- Government-led procurement with a focus on creating economic spillovers.
- Regulatory Changes by Government to spur financialization of graphite and vanadium.

Potential for future financialization

Government Recommendations:

Reducing Geopolitical Risk through Trade Policy and Diplomatic Engagement

Diversify Supply Chains and Increase Domestic Production

Build Regulatory & Legal Frameworks for Financialization

Financial Actors Recommendations:

Creation of spot market in partnership with price reporting agencies

Balancing Long-Term Stability with Market Flexibility

Conduct a Pilot & Test Derivative Markets

Not ready for financialization

**Government
Recommendations**

Government
Investment

Institutional and
Government
Support

Strengthening
Supply Chains &
Infrastructure

**Financial Actors
Recommendations**

Investor Confidence
& Market
Transparency

Strategic
Partnerships &
Market Development

Infrastructure &
Market Readiness